MANUAL No. 3

ELECTRICAL INSTRUMENTS AND TELEPHONES

OF THE

U. S. SIGNAL CORPS

1905

MANUAL No. 3.

ELECTRICAL INSTRUMENTS AND TELEPHONES

OF THE

U. S. SIGNAL CORPS.

PREPARED UNDER THE DIRECTION OF

BRIGADIER-GENERAL A. W. GREELY,

Chief Signal Officer of the Army.

Revised 1905.

WASHINGTON:
GOVERNMENT PRINTING OFFICE
1905.

WAR DEPARTMENT
DOCUMENT No. 257.
OFFICE OF THE CHIEF SIGNAL OFFICER OF THE ARMY.

WAR DEPARTMENT, SIGNAL OFFICE,
Washington, May 27, 1905.

The following instructions for the installation, operation, and maintenance of the electrical instruments and telephones of the Signal Corps will replace all others heretofore issued by this office.

In view of the rapidly increasing application of electricity to warfare, the importance of a thorough practical knowledge of electrical and telephonic instruments and equipment can not well be overestimated.

In order to keep abreast with modern developments along these lines, officers and men of the Signal Corps may, and are expected to, acquire promptly a good working basis by familiarizing themselves with the general information contained herein.

Apart from the indispensability of a thorough knowledge of technical data regarding electrical instruments in time of war, it is to be borne in mind that it is also essential for efficient and economic administration in time of peace.

As regards telephones, there should not only be a thorough familiarity with the ordinary methods of operating telephone lines, whether the instruments are bridged or in series, but also a knowledge of the construction of the various types of telephones herein described, so that faults may be readily located and remedied, whether in the instrument, in the battery, or on the line.

Not only should officers and men be able to install and operate all instruments and equipments described in this manual, but they should also be familiar with so much of the theory of electricity as bears directly or indirectly on their work.

With such practical and theoretical knowledge, economical principles of prevention and preservation may reasonably be anticipated in Signal Corps operations, instead of conditions of reparation and replacement so costly in time and labor.

A. W. GREELY,
Brigadier-General,
Chief Signal Officer of the Army.

Approved, May 27, 1905.
ROBERT SHAW OLIVER,
Acting Secretary of War.

TABLE OF CONTENTS.

INTRODUCTION.

The first technical manual of the Signal Corps, Manual No. 1, 1901, a valuable memoir of telephones, was written by Maj. Samuel Reber, Signal Corps. It was followed later by Manual No. 3, 1902, on Electrical Instruments and Equipments of the Signal Corps, by Maj. Edgar Russel, Signal Corps.

Marked advancements and improvements have been made in electrical devices since these manuals appeared, while modified types of telephones have been introduced in large numbers in the fire-control work of the Signal Corps. As the supply of the original manuals is exhausted, it has become necessary to modify the subject-matter so as to be in harmony with the latest advance.

In view of the changed condition of affairs it is in the interests of economy and efficiency to consolidate the two manuals. In so doing the greater part of the valuable publications of Majors Reber and Russel have remained unchanged. Major Russel, in his revision of the work along lines designated by the Chief Signal Officer of the Army, has been assisted by Mr. R. A. Klock and other members of the electrical staff of the Signal Corps.

The data regarding electrical instruments of the Signal Corps have heretofore been widely scattered, some in technical publications, where it was associated with much not immediately useful to the Signal Corps electricians and operators, and some in separate publications, drawings, and documents filed in the office of the Chief Signal Officer of the Army.

Practical experience with telegraph apparatus under the severe tests imposed by tropical field conditions, supplemented by over a year's observations in the central telegraph office at Manila, P. I., emphasized the necessity of eliminating some old appliances and the adoption of modern improvements suitable for military telegraphy.

Many of the details of the storage battery switchboard connections were worked out by the Signal Corps in the Manila office.

The voltmeter-milliammeter method of testing, while not new, was, it is believed, given an unusually prolonged and constant use in the Philippines to determine its fitness for tropical as well as ordinary service conditions.

Much of the other matter in the chapter on "Testing and location of faults" is new, and includes the application of the ohmmeter to line-testing by methods suggested and put into practice by Mr. Robert C. Lord. The importance of regular tests, and full records thereof, at offices is so great that this practice can not be too strongly enjoined, not only as insuring uniformly excellent working conditions, but also as a means of training men in the intelligent use of their instruments.

Part of the chapter on "Repeaters" and all of the chapter on "Duplex" methods are taken, by courtesy of the author, Mr. William Maver, jr., from that excellent work, American Telegraphy. A number of descriptions of batteries and instruments are taken from manufacturers' circulars.

A republication of some of the valuable articles of Mr. Willis H. Jones, originally published in the Telegraph Age, on adjusting office instruments will be useful to operators.

An interesting extract from the Western Union publication on "Construction of permanent lines" is inserted by the kind permission of Col. R. C. Clowry, the president of the Western Union Telegraph Company.

The chapters on telephones describe in simple and nontechnical language the construction and operation of the various types of telephones and switchboards supplied by the Signal Corps for the use of the Army; consequently no reference to the engineering principles involved is made.

Many of the apparatus described have been designed by officers of the Signal Corps to meet the special necessities of military service, where the requirements are quite different from those of commercial life. In the field apparatus strength and portability are the predominating features of design, while the efficiency of talking and ringing circuits is maintained. A part of the field apparatus utilizes the principles of simultaneous telegraphy and telephony over the same circuit.

A. W. Greely,
Brigadier-General, Chief Signal Officer of the Army.

LIST OF ILLUSTRATIONS.

Chapter I.

ELECTRICAL DEFINITIONS AND TERMS.

Theories as to the nature of electricity, demonstrations of the assertions made regarding many of its manifestations, and complete statements of the laws governing electrical phenomena cited are not within the province of this manual. For analytical investigation and a thorough exposition of the subjects, reference is made to some of the standard books, a list of which is appended on page 215.

Certain names are given the practical electrical units, such as those of current, electro-motive force, resistance, capacity, power, and quantity. The unit of current strength is called the "ampere," and a measure of this strength is stated in its power to produce a certain magnetic or chemical effect. For example, the current necessary to operate a 4-ohm sounder is about a quarter of an ampere, and the chemical effect produced by a current in a given time is shown by the amount of copper deposited or zinc dissolved in the cells. With current strength as stated (one-fourth ampere), in one hour there would be deposited in each cell in the sounder circuit from the copper sulphat solution $4\frac{1}{2}$ grains of copper, and $4\frac{3}{4}$ grains of zinc would be dissolved.

The unit of electro-motive force is called the "volt," and is the measure of the effect tending to cause a flow of electricity between two points. Thus a certain form of cell has a certain electro-motive force tending to cause a current between its terminals; or, as it is otherwise stated, has a certain difference of potential between these terminals. Thus the E M F (as it is usually abbreviated) of the ordinary bluestone cell when freshly set up is slightly above 1 volt; of two cells in series, 2 volts; of three cells, 3 volts, and so on.

The unit of resistance is called the "ohm," and expresses a certain amount of obstruction which exists to a flow of current. No substance is so perfect a conductor that it does not oppose a certain resistance to the flow of current. Silver is the best conductor, and coming closely after it is copper. The practical way of measuring resistance is by comparison with standard coils. An idea of the dimensions of this unit (the ohm) is given when it is stated that the resistance of 330 feet of No. 9 B. W. G. (Birmingham wire gauge) galvanized telegraph wire is 1 ohm.

The practical unit of capacity is the "microfarad." The capacity of a metal plate or other conductor is determined by the quantity of electricity which it takes to raise its potential to a certain point. And, other conditions remaining constant, its capacity depends upon its distance from other conductors and its position with respect to them. This capacity is increased if the metal plate be brought near another. The condenser is a piece of apparatus which embodies this principle, and consists of a large number of sheets of tinfoil in one group interleaved with, yet insulated from, a large number of sheets in another group. The capacity of the ordinary small condensers used in telegraphy and telephony is from one-third to 3 microfarads.

The practical unit of electrical power is the "watt." As electrical power is the rate at which electrical work is done, it follows that a certain current, if driven in one case by twice the E M F that it is in another, will do twice the amount of work in a given time in driving a motor, heating resistances, or producing chemical changes. So the unit of power, the watt, is equal to 1 ampere driven by 1 volt, and in the commercial rating of dynamos 1,000 watts is taken as the unit and called the "kilowatt" (abbreviated K W). Thus a dynamo giving a current of 10 amperes at 100 volts, or one giving 1 ampere at 1,000 volts would have a power of 1 kilowatt.

The so-called practical unit of quantity of electricity, the "coulomb," is seldom commercially used. This is the quantity of electricity conveyed by a current of 1 ampere flowing for one second. It may be called the "ampere second." In its place the "ampere hour," which is 3,600 times larger, is commonly used commercially. Thus if a certain cell has sufficient zinc and solution to give a current of 1 ampere for two hundred hours, or 2 amperes for one hundred hours, the quantity of electricity it is capable of giving out is defined by saying it is a 200-ampere-hour cell.

The foregoing are the units which are commonly used in telegraph or telephone work. There are many other units which will be found fully defined in some of the works cited. The relations between these units may be expressed in various ways. A certain difference of potential between two points on a conductor will cause a current to flow between them, the strength of this current being determined by the resistance between these points. If we represent the current by C, the electro-motive force tending to cause the current to flow by E, and the resistance by R, the relation between them may be expressed as follows: $C=\frac{E}{R}$. This is the algebraic expression of Ohm's law, and, stated in practical units, it is that the current in amperes is equal to the electro-motive force in volts divided by the resistance in ohms. Another way of stating it is that the current flowing in a conductor is directly proportional to the driving (electromotive) force and inversely proportional to the resistance opposing the current. The other expressions of Ohm's law are $E=R\ C$ and

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

The habitual use of currents much smaller than 1 ampere in telegraphy has caused the adoption of a name expressing a thousandth of an ampere—the "milliampere."

The use of the above expressions in some practical calculations is given below.

If we have a line of No. 9 galvanized wire 50 miles long on which there are five stations, each with a 150-ohm relay, and it is desired to know how much current will flow with 30 bluestone cells at each end of the line, each cell having an E M F of 1.1 volt and 3 ohms resistance, we proceed as follows:

E M F given by batteries, $60\times1.1=66$ volts.

	Ohms.
Resistance of 50 miles wire at 16 ohms per mile	800
Resistance of 5 relays at 150 ohms each	750
Resistance of 60 cells at 3 ohms each	180
Total	1,730

Then $C=\frac{66}{1730}=.038$ amperes or 38 milliamperes.

Suppose it is desired to use polarized relays on this circuit which require but 25 milliamperes to operate properly, how many Edison-Lalande cells, each giving 0.7 volt and having 0.08 ohm internal resistance, would be required to give the current stated? This is easily solved algebraically, as follows:

Represent the number of cells in series by X, then in the expression $E=R\ C$, $E=.7\ X$, the number of cells in series being X and the E M F of each being 0.7 volt. The resistance R is made up of line and relay resistance, $800+750$, and battery resistance $0.08\ X$ (the resistance of each cell being 0.08 ohm and X of them in series). The current required is 0.025 amperes. Hence the expression $E=R\ C$ becomes $.7\ X=(800+750+.08X)\ .025$.

Solving:

$$.7\ X=20+18.75+.002\ X.$$
$$.698\ X=38.75.$$
$$X=56 \text{ cells.}$$

The following empirical rule is an amplification of one proposed by Mr. Willis H. Jones for determining the number of cells to be used on lines operated with ordinary 150-ohm relays and may prove useful:

Divide the entire resistance of the line, including that of the relays, by one of the following numbers, depending upon the kind of cells used:

Gravity (bluestone)	23
Edison-Lalande	17
Fuller	45
Storage	50
Leclanche, Gonda, Samson, or dry cell	35

These last-named cells are used on the "open-circuit" Morse system subsequently described.

Chapter II.

BATTERIES.

PRIMARY BATTERIES USED BY THE SIGNAL CORPS.

THE GRAVITY CELL.

This is the most extensively used form of primary cell in telegraphy. The usual form is shown in fig. 1, consisting of a glass cell about 8 inches high and 6 inches in diameter. In the bottom is placed two strips of sheet copper, riveted together, as shown, with a rubber-insulated wire attached to one of the strips. There are many forms of zincs, but the most popular is the familiar "crowfoot" form, now almost universally used.

Perhaps the most convenient way to set up the cell is to put about 3 pounds of "bluestone" (sulphate of copper) in the cell after putting in the copper, then hanging the zinc and filling up with water. The cell or cells are then "short circuited" (zinc and copper connected together) and allowed to stand several days. By that time part of the bluestone will have dissolved, the blue line being well defined. Above this will be a clear solution of sulphate of zinc, formed by the action of the battery, which, being of less specific gravity than the copper-sulphate solution, will remain on top if the cell is not shaken or stirred up. The battery may now be put into service.

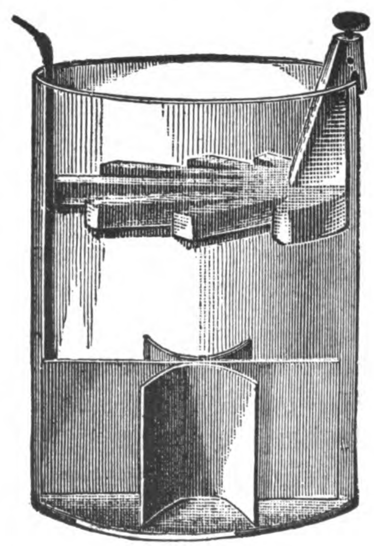


Fig. 1.

If in a hurry for the cell, it may be started off at once by stirring up about a tablespoonful of salt with the water before pouring it into the cell; but this method is apt to make a battery dirty and considerably shorten its period of usefulness. Any long, dark masses forming on the lower part of the zinc should be removed with a stick. The zinc-sulphate solution will grow stronger and stronger, until finally the white salts will begin to creep or "climb" up the sides of the jar and the zinc. As they will corrode the connections and cause dirt and loss of insulation around the cells, they should be looked after. Much of the trouble will be obviated if, as soon as they appear, part of the zinc-sulphate solution is drawn off with a battery syringe or a siphon made of a bent glass tube, and water put in its place. If the upper part of the cells are warmed and smeared with paraffin, it will help matters. But the best plan of preventing evaporation and creeping of salts is to use a good quality of paraffin or lubricating oil, pouring on a layer about one-fourth inch thick as soon as the cells are set up. In cleaning cells after that wet cotton waste dipped in sand will clean the zincs, etc., of the adhering oil. The local battery, being much harder worked, requires renewing about every six weeks; a main-line battery will usually stand from four to six months. As soon as the blue solution goes down below the level of the copper, more bluestone should be added. Corrosion of the connections of the zincs with their wires should be carefully looked after. It is better to have routine inspections of batteries made, and, if possible, instrumental tests, made with the Weston voltmeters (figs. 92 to 96) or voltammeters (fig. 110) furnished for that purpose, should be carefully recorded. By this means deterioration may be accurately noted and many annoying breakdowns and delays which are frequently due to neglect and lack of regular inspection of the batteries may be avoided.

EDISON BATTERY.

This battery is being quite extensively introduced for Signal Corps use. A modification of the " type V " cell made for the Signal Corps is issued (fig. 2). This has the same capacity as the " type V," but its enameled-steel jar is slightly conical, enabling the cells to be nested together for transportation. The caustic soda and oil for each cell are in tin cans, so there is nothing that will not stand transportation. This cell has very low internal resistance (not exceeding one-eighth ohm) and will remain set up for a long time without injury. It will bear considerable transportation ready set up if kept " right side up." It has a capacity of about 150 ampere hours, which means it will furnish about two hundred and ten days' continuous service on a main line where the current is 30 milliamperes and forty days' service as a local when the current is about 0.16 ampere.

It gives but 0.7 volt E M F in steady work, so for main-line use about 14 cells Edison battery are needed to replace 10 bluestone, but owing to its low internal resistance one cell of Edison will give more current as a local with the 4-ohm sounder than a bluestone cell.

The following complete directions for setting up, management, and renewal of these cells are furnished by the company manufacturing them:

Directions for setting up and using Edison Primary Batteries, formerly known as Edison-Lalande. (Liquid-tight Cell Type V.)

TO CHARGE AND CONNECT BATTERIES.

To make solution.—Fill the cells with water to 1½ inches of the top on the inside. Then open the can of granulated caustic soda by cutting out the bottom (which is made of very thin tin) with a penknife.

Add the caustic soda gradually to the water, stirring the solution constantly until the soda is entirely dissolved, which will take about three minutes.

When the solution cools, it may be found necessary to add a little more water to bring it up to 1½ inches of the top again. Then pour contents of bottle of heavy paraffin oil from bottle furnished on the solution in each jar.

Note 1.—The caustic soda will burn the skin and clothes. In stirring the liquid avoid splashing it.

To set up cells.—Unscrew the nut *N* and the jamb nut *M* from the screw on the brass neck of the double zinc plate and remove the leather washer. Pass the screw from below through the central hole in the cover *C*. Replace the leather washer and the jamb nut *M* on the screw and tighten down the jamb nut until the zinc plate is rigid to the cover. The thumb nut *N* can then be screwed on.

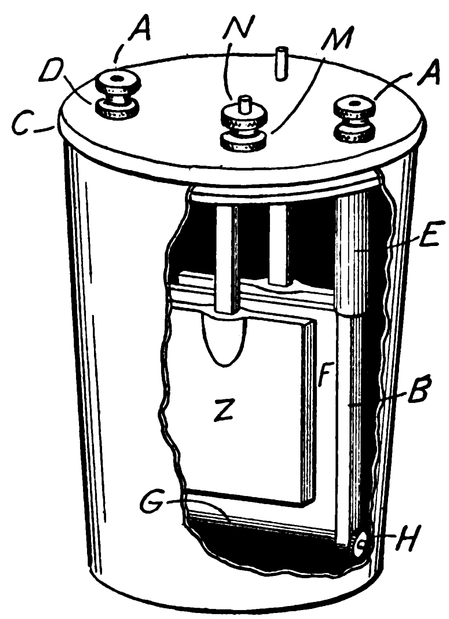


Fig. 2.

Unscrew the nuts *A A* and jamb nut *D* from the screws on the two side pieces *B B* of the copper frame, leaving the flat leather washers in position on the screws, and pass the screws from below through the two round holes in the cover *C*. Replace the jamb nut on one of the screws and one of the thumb nuts on the other screw, and tighten both down until the frame sides are rigidly clamped to the cover. Replace the other thumb nut on the screw holding jamb nut. Then slip the hard-rubber insulating tubes *E E* over the sides of the frame, one on each side.

To fill copper frames.—(In this cell only one oxide plate is used. See fig. 2.) Slide the oxide plate *F* sufficiently far into the frame to enable the copper bolt *G* to be passed underneath it through the slots in the bottom of the frame sides and the copper nut *H* tightened up on same.

Be careful that the zinc plates do not touch the copper oxide plates, or the cell will be short-circuited.

The copper connection is made between the thumb nut *A* and the jamb nut *D* on one end of the copper frame and the zinc connection between the thumb nut *N* and the jamb nut *M* on the brass bolts suspending the zincs.

After the oxide and zinc plates are properly connected to the cover, as above, soak them in water (in a bucket or under the faucet) and while still wet insert in jar previously filled with caustic solution.

(Wetting the plates prevents the oil in jar from adhering to them.)

Important.—In order to allow the cover on the jar to fit easily, it is advisable to wet the rubber gasket ring fitting into the grooved edge of the cover by placing it in water. This will cause the cover to slip on easily and will make the cell liquid tight.

It is absolutely necessary that the upper edge of the oxide plates should be submerged at least 1 inch below the surface of the caustic-soda solution in the jar; also on no account can the layer of oil on top of the solution be omitted, as without it creeping salts are formed and the life of the battery is reduced fully two-thirds.

MANAGEMENT OF BATTERY.

Unless a short circuit should occur, the battery requires no attention until it is exhausted. A short circuit between the plates in the cell will destroy the cell; a short circuit outside will destroy the whole battery.

RENEWING.

When the cell becomes exhausted, the solution and the remains of the zinc and oxide plates must be thrown away. All the remaining parts can be used over again.

TO TAKE THE CELLS APART.

Lift the lids, unscrew the bolts, and remove the zincs and oxide plates. Wash off (with water) the copper frames, bolts, and rubber insulators, brightening up the metal, where corroded, with emery paper, especially the inside grooves of the copper frame sides. Pour away the solution carefully and set up cells with new caustic soda, oxide plates, and zincs according to directions.

NOTE.—In taking the cells apart, the parts that have been immersed in the caustic soda must be washed before they are handled.

TO ASCERTAIN IF THE OXIDE PLATES ARE EXHAUSTED.

Pick into the body of the oxide plates with a sharp-pointed knife. If they are red throughout the entire mass, they are completely exhausted and need renewing. If, on the contrary, there is a layer of black in the interior of the plate, there is still some life left, the amount being dependent entirely upon the thickness of the layer of black oxide still remaining.

Too great stress can not be laid on the necessity of observing (when setting up the cells) that the top of the oxide plate is fully 1 inch below the surface of the caustic-soda solution, and consequently about 1½ inches below the top of the oil.

The difference of 1 inch in the height of the solution in the jars determines the success or failure of these batteries.

COPPER FRAMES.

When renewing the battery it is desirable to clean the inside grooves of the copper frames, where the copper-oxide plates make contact, so as to insure a good electrical connection. This is especially important where the batteries are required to give a heavy current for cautery or motor purposes. These frames can be easily cleaned by wrapping a small piece of emery paper round a stick which will just fit into the groove, or by immersing them in a dilute solution of 1 part of sulphuric acid and 4 parts water, and then carefully rinsing them in clean water to remove all traces of the acid.

COPPER-OXIDE PLATES.

These plates are made of compressed copper oxide, the surfaces of which are reduced, by special process, to metallic copper.

The amount of copper oxide used in each cell is so calculated that it will be entirely reduced to metallic copper when the zincs are consumed and the solution is exhausted.

It is very poor economy to use exhausted oxide plates over again, as the battery will then polarize on account of there being no oxide of copper left to act as a depolarizer. To explain this more fully, it should be remembered that the action of the cell is as follows:

ELECTRO-CHEMICAL ACTION OF BATTERY.

When the circuit is closed the water of the solution is decomposed into nascent oxygen and hydrogen. The oxygen goes to the zinc plate (the negative pole) and unites with it, forming oxide of zinc. This in its turn is dissolved by the caustic-soda solution, forming zincate of soda. The hydrogen goes to the oxide of copper plate (the positive pole) and unites with the oxygen in the oxide of copper, forming water (H_2O), leaving behind metallic copper. As the oxide plate is porous, this action goes on, when the battery is in service, until the oxide plate is reduced throughout its entire mass of metallic copper in a finely divided state, and there being no more oxide of copper left the hydrogen will then collect in bubbles on the surface and in the interior of the plate and polarization will ensue.

When the cells are only used over extended intervals of time (remaining idle during the balance of the time) it is advisable to keep them always on closed circuit through a high resistance, as there is a tendency of the solution to reoxidize the reduced copper surface of the oxide plates, and consequently just enough current should be taken from the battery to overcome this action. In practice it is found that a current of 15 milliamperes is sufficient to accomplish this result.

Caution.—The oxide plates should never be removed from the caustic-soda solution and allowed to dry in the air, as, if this is done, the surface of the plates becomes reoxidized by absorbing the oxygen from the air, and the oxide thus formed is much more difficult of reduction than the original oxide of which the plates are formed. The internal resistance is consequently very greatly increased and the current materially diminished.

NOTE.—Where batteries are placed in warm places, they should be examined every two or three months to see that the solution has not evaporated, as this will gradually take place, in spite of the oil, if they are in a hot room. If the solution is found to have evaporated, add more water to bring it again to the proper height.

The importance of keeping the cells filled to the proper height will be seen from the following explanation: The reduced surface of the copper-oxide plate is covered with a fine dust of copper, particles of which become detached when the plate is put into the solution. These particles rise to the surface of the solution and float underneath the layer of oil. If, therefore, the surface of the solution is only on a line with the top of the copper-oxide plates, these particles will in time form a bridge from the zincs to the oxide plate, and a short circuit will be established in the cell itself, which will destroy it and cause the zincs to eat off at the line of the solution.

One other point yet remains to be noted. It is of the first importance that all binding posts and connection wires should be kept clean and bright at the points of connection.

FULLER BATTERY.

This belongs to the class popularly called "acid batteries." The cell has a high electro-motive force (nearly 2 volts), a comparatively low internal resistance (one-half ohm), and is much used in this country as a telephone transmitter battery on long-distance or heavily worked telephones. Its only disadvantage is that it uses a corrosive solution containing sulphuric acid, necessarily transported in liquid form. As ordinarily set up for telephone use, it consists of a glass jar about 8 inches high and 6 inches in diameter, with a wooden cover painted with asphaltum (fig. 3). This supports a carbon plate about 4 inches wide and 7 inches long, with the top coated with paraffin to prevent the corrosion of the connection by the acid. In the jar stands an earthenware porous cup, in the bottom of which is placed about 2 ounces of mercury. In this stands a conical zinc, into which is cast a copper wire extending out at the top. In the glass jar is placed the "electropoion" solution, made by slowly adding 1 pound of strong sulphuric acid to 9 pounds of water, and then stirring in 3 pounds pulverized bichromate of potash or $2\frac{1}{2}$ pounds bichromate of sodium. This last is preferable, as the crystals formed in the action of the cell are not so hard and insoluble as those produced by the potash. In the porous cell with the zinc and mercury is placed water, in which about a tablespoonful of salt has been dissolved. This cell will usually require little attention for three or four months. When the solution assumes a muddy bluish tint, it is about exhausted.

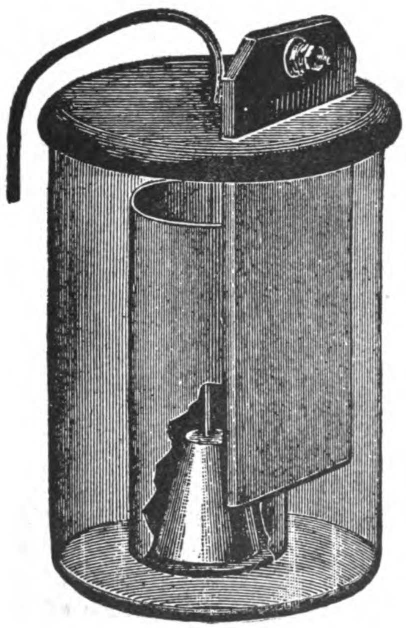


Fig. 3.

If the copper wire at its junction with the zinc is covered with paraffin or ozite and warmed to melt it in, or if the copper wire is well amalgamated by rubbing with mercury after dipping into acid, the wire will not tend to eat off at the junction, as it otherwise does under heavy service.

Of late years various salts are on the market which, when dissolved, form a good substitute for the electropoion fluid. These have been given various names, such as "voltak," "chromite salts," etc.

The carbon of this cell, of course, lasts indefinitely, but should be soaked in warm water when renewals are made. The zinc may last through several renewals of the electropoion fluid. The mercury should be saved and used repeatedly.

The following table, quoted from Abbott's Telephony, indicates the effect of age on efficiency of transmission with the Fuller cell.

TWO-CELL FULLER BATTERY.

Age in days.	Volume of transmission.
	Per cent.
20	92
30	88
40	84
50	80
60	76
70	70
80	62
90	54

From this it would appear that the cells must be renewed at least once in three months when used on a telephone transmitter.

SALAMMONIAC BATTERIES.

There are two general classes of these in use, popularly known as the "wet" and the "dry." Of the former, the Leclanche, the Gonda, and the "Samson" are the forms usually adopted. All are alike in having a sal ammoniac solution, zinc and carbon elements, and "black manganese" (manganese peroxide) as a depolarizing material.

The Leclanche is the oldest form (fig. 4). In this the solution is contained in a glass jar, in which is a pencil of amalgamated zinc, a porous earthenware cup, in which is placed a carbon plate, around which is packed a mixture of broken carbon and manganese peroxide.

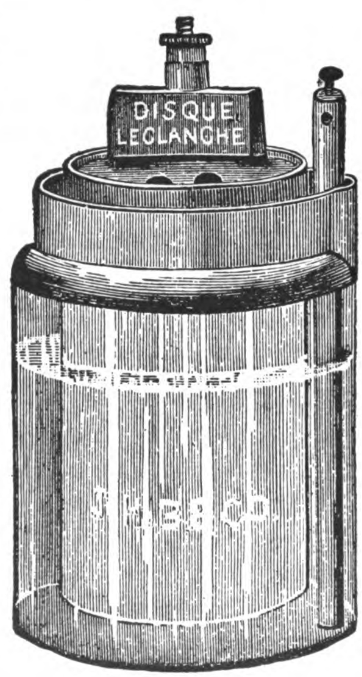


Fig. 4.

In the "Gonda" (fig. 5) the solution and elements are the same, but the mixture of carbon and manganese is compressed into briquettes or prisms that are attached to the carbon by rubber bands. A cover is provided to prevent evaporation and creeping of salts. This form of cell is very efficient and popular.

The "Samson" battery (fig. 6) has the carbon in the form of a corrugated porous cup, in which is put the broken carbon and manganese mixture. The zinc is in the form of a curved plate, giving large surface and low internal resistance, making it a useful cell for some special purposes.

In the three foregoing forms the top of the jar is coated with paraffin to prevent creeping salts from forming around the top.

The commonest faults occurring in the wet salammoniac batteries are: (1) Zincs eaten off; (2) porous cell or depolarizing prisms exhausted; (3) solution exhausted, evaporated, or leaked out; (4) corrosion of contacts.

(1) and (4) and absence of solution can be seen at once. Exhaustion of sal-ammoniac solution is indicated by its being milky. With renewal of zincs and solution and cleaning, if battery is still weak, the porous cells or prisms need renewing.

In all cases in cleaning the hard crystals should be scraped off

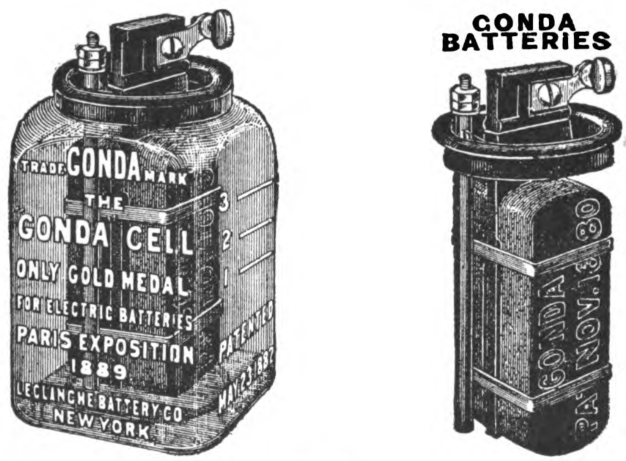


Fig. 5.

the zincs, porous cups, and carbons, and they should be soaked in hot water.

The dry battery is being very extensively used in connection with Signal Corps field and fire-control telephone work. While all makes of this type of cell conform in general to the following description, it is found that different brands vary widely in efficiency. In order to demonstrate the comparative merits of each make, a careful life test is undertaken annually in the Signal Corps laboratories, the results of which determine approved makes of cells for the coming year.

The dry battery is a form of sal-ammoniac battery in which the zinc constitutes both the containing vessel and negative element, doing away with the breakable and expensive glass cell. Some absorbent porous material fills the space between the carbon in the center, with its depolarizing mixture around it, and the zinc vessel. This porous material is saturated with a solution containing chloride of zinc and sal ammoniac, and a top of asphalt or similar material is put on. Binding posts for zinc and carbon and a pasteboard cover to prevent short circuiting of adjacent cells complete this convenient form of battery. When these cells are of reasonable size (say not less than 20 cubic inches in volume), are carefully made, kept at moderate temperatures, and right side up, they are fairly reliable. They can not, like the wet batteries, be renewed, but their cheapness offsets this. A short run of usefulness, after they are exhausted, when they can not be replaced, may be obtained from them in this way: Punch a number of holes through them and use them as elements in a wet cell by placing them in jars with a solution of sal ammoniac. A salt solution may be used, but is not so good.

Fig. 6

The results of field work, supplemented by the regular battery tests, have demonstrated that the round type of dry cell is more efficient than the rectangular type. This is due to the uniform distribution of the active surfaces of both elements in the former type of cell. The round cell has therefore been made standard in Signal Corps work, and is regularly furnished in sizes shown in fig. 7.

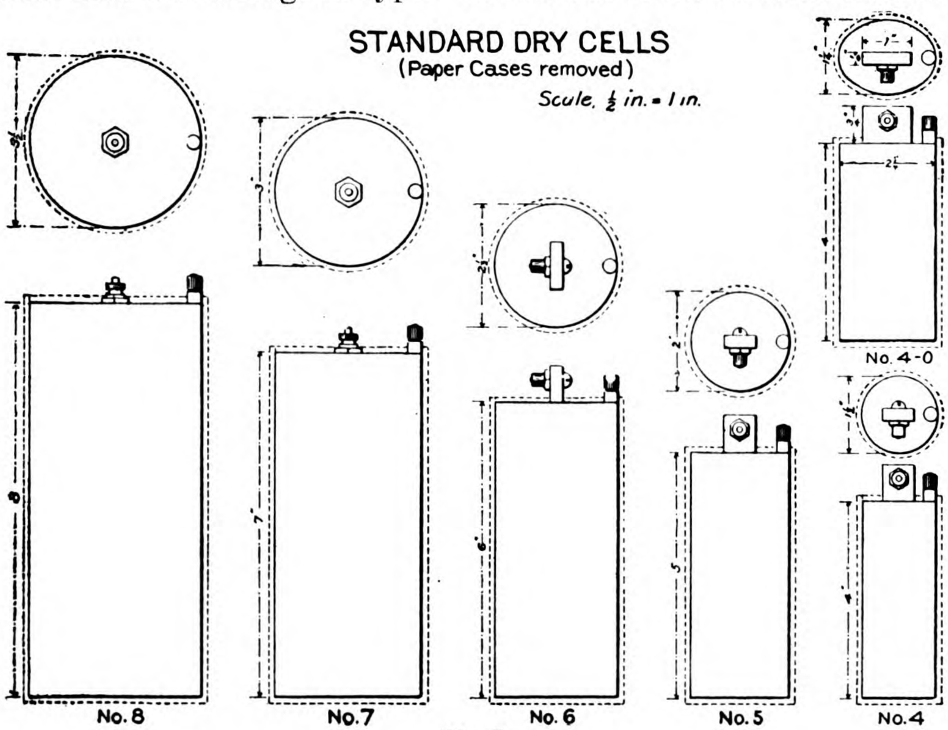


Fig. 7.

These cells are used as indicated in the following list:

Size 4-0:
- 5 in field buzzer.
- 4 in cut-in telephone.
- 2 in each composite artillery type battery commander's telephone.

Size 6:
- 2 in each field telephone.
- 2 in each service telephone.
- 2 in each composite artillery type wall telephone.

The other sizes are used for special work.

The wet or dry salammoniac batteries will not stand on closed circuit and can not be used in the ordinary American Morse system of telegraphy, but can be used on the "open-circuit" system. (See p. 16.)

GROUPING OF CELLS.

When it is necessary to cause a certain current to flow through a considerable resistance, as a long telegraph line, for instance, the necessary E M F is obtained by connecting cells in series—that is, the copper of one cell to the zinc of the next, and so on until the requisite E M F is obtained, the relatively small increase of the total resistance due to the internal resistance of the cells being of little effect. But when it is desired to get a certain current through a low resistance, another grouping must be made. The internal resistance of the ordinary gravity cell is about 3 ohms. And with its 1 volt E M F the current through a short thick wire of no appreciable resistance connecting its poles will be one-third ampere. And if we have 100 cells in series and connect the terminals of the entire battery, we would get $\frac{100}{300}$ ampere, or one-third, as before. For any number of these cells in series, to obtain an increased current through low external resistance, we must cut down the internal resistance of our battery. This, with a given type of cell, may be done by linking them in parallel—that is, by connecting all the zincs together and all the coppers together and then connecting the multiple zinc and multiple copper thus obtained to the low external resistance. The E M F of the battery remains the same as that of one cell. The two diagrams (figs. 8 and 9) illustrate, first, four cells connected in series; the second, four cells in parallel.

In the first case we should get a current of $\frac{4}{12}=\frac{1}{3}$ ampere through our short circuit; and in the second case, $C = 1 \div \frac{3}{4} = \frac{4}{3}$ ampere through the short circuit.

STORAGE BATTERIES.

Storage batteries are used by the Signal Corps in connection with telephony, the supply of power for the telautograph, and in telegraphy.

The batteries supplied in telephone work consist of either 15 cells E–5 chloride accumulator, having a normal charge rate of 10 amperes and designated as type A, or 15 cells of E–7 chloride accumulator, having a normal charge rate of 15 amperes and designated as type B. Each of these batteries is supplied complete with electrolyte ready for setting up.

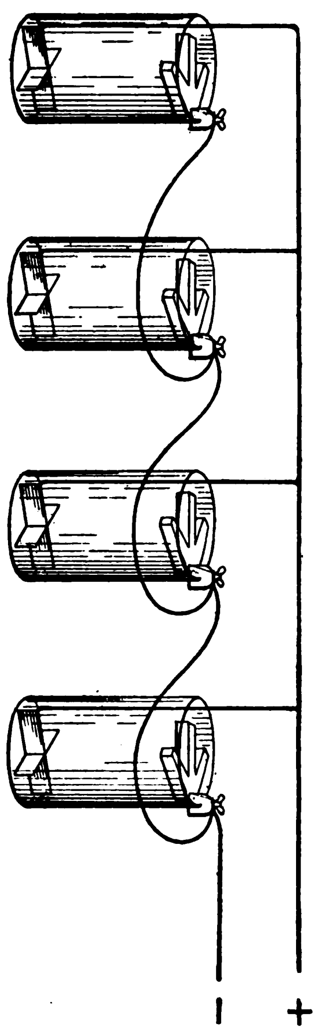


Fig. 9.

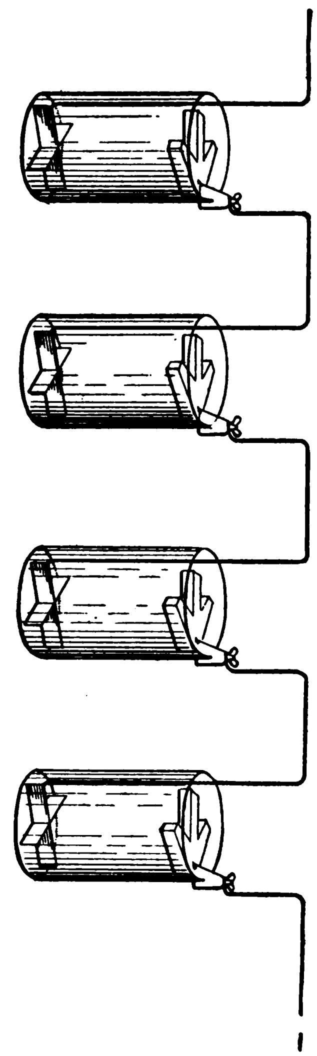


Fig. 8.

In telautograph work the batteries are supplied in varying sizes to suit the installation for which they are required. The P. T. type has given satisfactory service for small installations and requires very little attention. Larger types are usually supplied with a form of end cell switch in order to keep the line voltage uniform.

The storage cells used for telegraphy vary widely in types, and are in all cases ordered to fit the installation in question. The following general description and directions are applicable to all types of storage battery in use by the Signal Corps.

The great compactness of storage cells, high E M F (2 volts per cell), and very low internal resistance, combined with qualities of cleanliness and certainty of action, make them most desirable for both main and local use. The elementary form of storage cell is made by immersing two lead plates in dilute sulphuric acid. The principle involved in the storage cell is the chemical action produced by a current which causes such changes of the lead plates in the acid that upon cessation of the current, if the two plates are connected together by a wire, a current will flow in the opposite direction from the original one and the plates will tend to return to their original condition.

The action of the current is to coat the plate that is connected with the positive pole of the charging dynamo with peroxide of lead, and to reduce to spongy metallic condition the surface of the plate connected with the negative pole. When the plates are connected by a wire, the peroxide coating tends to be reduced back to lead and the spongy lead on the other plate to become oxidized. The plates thus becoming alike the current will cease and the cell is said to be discharged. Various methods of manufacture are intended to give the plates more capacity—that is, to prepare more reducible peroxide on one and more spongy lead on the other. The means adopted are to make the plates up in the form of fine strips or grids of lead and fill in these interstices with the oxides of lead by various processes. These plates, being made up in sets, are then immersed in acid and given what is called a "forming charge," after which they may be used.

The plates as received from the manufacturer are seen to be of two kinds. The sets of plates of one kind are of a chocolate brown, while the other sets are of a grayish leaden color. When these are placed in the jars, the sets of plates represent the zinc and copper, respectively, the gray plates acting as zincs and the brown as copper. In connecting cells in series the brown set of one cell should be connected with the gray set of another, and so on. Care should be taken that no plates of different kinds touch on the inside of cells, and that the perforated separators are properly placed, if these are furnished with the kind of cell used. The connecting lugs should all be brightened before they are bolted together, and after all connections are made it is well to go over them with a coating of cosmoline or asphaltum varnish. The cells should always be set up in a dry place, preferably where there is a good means of lighting and where there may be ample ventilation.

As telegraph batteries are frequently quite high in voltage, the insulation of the battery should be looked to. If the small porcelain insulators for each cell are furnished, so much the better; if not, the shelves should be as well insulated as possible, or strips of glass or small strips of paraffined wood under each cell may be used in an emergency. Before putting the acid in the jars be sure that everything is ready, that the dynamo, etc., are in condition for a prolonged run. Enough voltage should be given by the dynamo so that it will equal at least that of the number of cells in series multiplied by 2.8—that is, if we had 40 cells in series, the dynamo should give at least 112 volts. The current required depends on the size of the cells being charged and the number of rows of them in multiple. For example, the small type of cell sometimes used in telegraphy requires a current of 10 amperes to charge it properly. So each row of 40 cells would require 10 amperes, and for each additional row of 40 cells being charged at the same time a current of 10 more amperes would be required. The maker usually furnishes a statement of the proper current for each type of cell.

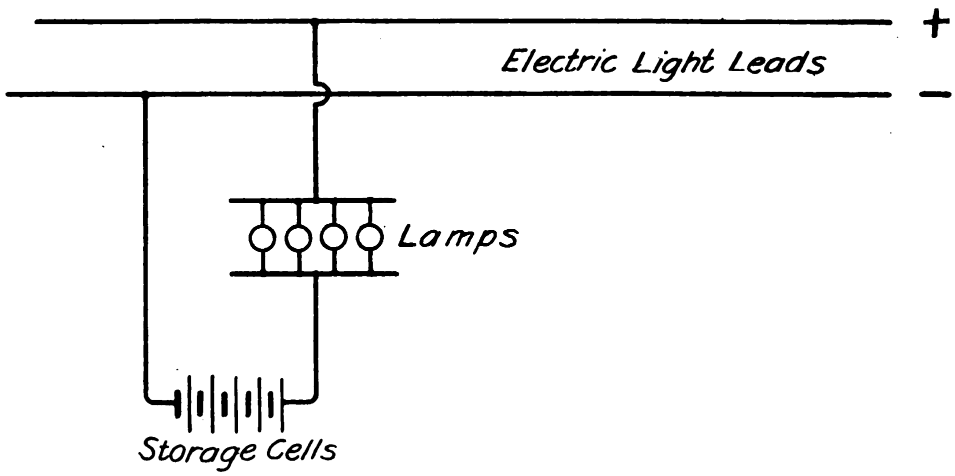


Fig. 10.

Having all ready, see that connections are so arranged that the brown end of the battery is connected with the positive pole of the dynamo, and the gray end of the battery with the negative pole. This should be ascertained with certainty before starting, as it would ruin the battery if it were reversed. Lastly, pour in the dilute acid and begin charging at once, adjusting voltage and resistance so the proper current passes. The preliminary charging is continued for twenty-four to thirty hours, at which time, during charging at normal rate, the voltage of each cell should be at least 2.6, and cells should be gassing very freely.

In charging some of the smaller types of cells a convenient arrangement is represented in fig. 10. In this the electric-light mains are connected with the storage cells with some incandescent lamps in parallel, as shown. If 32-candle-power lamps be used, each lets about 1 ampere of current pass. So with a type of cell requiring 6 amperes six lamps in parallel would permit the required current to pass. Of course the source of supply must be a direct, not an alternating, current.

The diagram (fig. 11) shows the arrangement for an office where a constant-current lighting circuit is available as a supply.

The lamps may be used to illuminate the office, as the opposing E M F of the one storage cell will not perceptibly diminish their light. As will be noted, the storage cell is constantly in use even while charging.

On account of its low internal resistance, as many sounder circuits in parallel can be fed from one of these storage cells as the capacity of the battery will permit without interference. Each sounder requires one-fourth ampere, so in twenty-four hours it would require at most 6 ampere hours to supply it. And if the storage cell had a capacity of 50 ampere hours it could supply four sounder circuits and still have a reserve for another day in case of accident to the charging circuit.

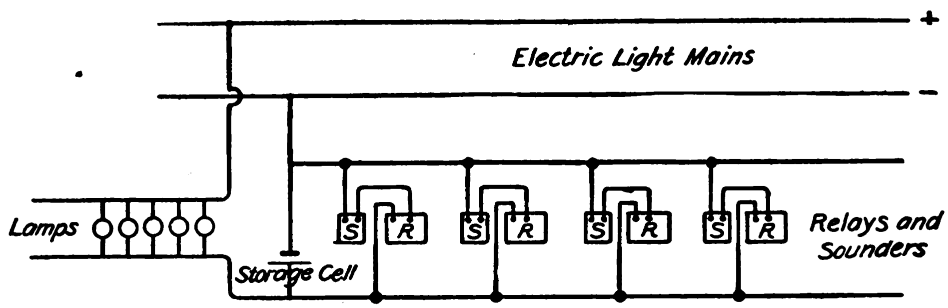


Fig. 11.

The method of tapping off various voltages from a number of storage cells in series for the different lines is shown under the heading of switchboard diagrams.

In connection with the maintenance, it is important to remember that a storage battery must have work to do if it is to be kept in perfect condition, and that a charge should not be continued after the voltage and specific-gravity readings indicate that the cells are fully charged.

The telephone storage batteries supplied by the Signal Corps in common battery work are not usually required to give out much current, but must be low in internal resistance. They should, therefore, be discharged occasionally through artificial resistance in order to keep them in good condition.

The directions appended for subsequent care of the battery issued by the Electric Storage Battery Company, although applying particularly to the larger types of cells, indicate the precautions to be taken with any storage battery. It should be remembered that while a storage battery is very little trouble to care for after it is once fairly started, it can easily be ruined by a failure to give it the small routine attention required.

General Instructions for the Operation and Care of the "Chloride Accumulator."

[Written for the United States Signal Corps by the Electric Storage Battery Company.]

To obtain the best possible results from the battery it is absolutely essential that proper, careful, and methodical attention be given to all the details of its operation and care, the same as is necessary with the generating machinery; and for this reason the following information and rules should be most carefully noted and followed. If this is done, the total work in connection with the operation and care of the battery will be reduced to a minimum.

It will be noted that the subject-matter has been divided into two parts.

The first part deals with the daily handling of the battery in regard to the work it has to perform, and for this reason it is given the general heading "Operation." The second part contains information in regard to maintaining the battery in good condition, and is given the general heading "Care of the battery." It also includes miscellaneous information of a general nature, which should also be carefully noted.

Operation.

CHARGING.

General.—The battery should preferably be charged at the normal rate. (See under "Normal rating," p. 40.) *It is important that it should be sufficiently charged, but the charge should not be repeatedly continued beyond that point,* as not only will an unnecessarily rapid accumulation of sediment and excessive evaporation of the electrolyte result, but, what is more important, the life of the plates will be very much shortened.

Both from the standpoint of efficiency and life of the plates the best practice is a method which embraces what may be called a regular charge, to be given when the battery is from one-half to two-thirds discharged, and an overcharge, to be given weekly if it is necessary to charge the battery daily, or once every two weeks if the regular charge is not given so often.

The reading of the specific gravity of a pilot cell (see p. 37), or of the voltage across a fixed number of cells, can be used as a guide in following the above. The pilot-cell method is to be preferred, owing to its being independent of the rate of charge, the voltage method being used as a check on the gravity, or in cases where, due to the character or inaccessibility of the cells, the pilot-cell method is not practicable.

Regular charge.—As soon as practicable after a discharge the battery should be charged at or as near the normal rate as possible until the following conditions are fulfilled:

(*a*) The gravity of the pilot cell having risen to a point which is 3 points below the maximum reached on the preceding weekly overcharge.

(*b*) The voltage across the main battery having risen to a point which is 0.05 volt per cell below what it was on the preceding overcharge, the charging rate being the same in both cases. If a recording voltmeter (see p. 38) is installed, the record on the chart can be used in the same manner.

(*c*) The cells all gassing moderately.

Overcharge.—If the battery is charged daily, then once a week, and on the same day of the week, the regular charge should be prolonged until the following conditions are fulfilled:

(*a*) The gravity of the pilot cell having reached a maximum, five successive 15-minute readings of this cell showing no further rise.

(*b*) The voltage across the main battery having reached a maximum, five successive 15-minute readings showing no further rise, the charging rate being kept constant. If a recording voltmeter is installed, the record on the chart should have risen to a maximum and run flat for an hour.

(*c*) The cells all gassing freely.

If the battery is not charged daily, then the overcharge should be given once every two weeks.

DISCHARGING.

The voltage should not be allowed to fall below 1.75 volts per cell at the normal rate of discharge. If the current is less than normal, the voltage should not be allowed to go so low.

The specific gravity of the pilot cell is an excellent indication of the state of charge or discharge, the gravity falling on discharge and rising on the charge. When the cells are equipped with the full number of plates, the maximum limit beyond which the discharge should not be carried is 30 points below what it read on the preceding overcharge. For instance, if the maximum gravity attained on the preceding overcharge is 1.207, the extreme limit beyond which the discharge should not be carried is 1.177. If the cells have less than the full number of plates, this range in gravity is proportionately reduced.

Never allow the battery to stand completely discharged, as serious injury will result.

CELL READINGS.

As a guide in following the battery, and also as a record of what is taking place, *it is highly important that readings be regularly taken and recorded, as follows:* The gravity of the pilot cell and the voltage across the main battery should be read and recorded at the end of every charge and discharge, all readings being taken while current is still flowing, both on charge and discharge.

The day before the overcharge a gravity reading should be taken of each cell and recorded. At the end of the overcharge, while the current is flowing, a voltage reading of each cell should be taken and recorded.

The above cell readings should be carefully examined and any cell showing a falling off in specific gravity or voltage relative to the surrounding cells should be noted, *and as soon as possible inspected and the cause removed.* (See below, under "Inspection.")

In addition to the above readings, the temperature of the pilot cell should be read and recorded at least once each day.

Care of the battery.

INSPECTION.

A careful inspection of each cell should be made periodically. This is very important, it being bad practice to wait till trouble comes and then hunt for the cause. The best time to make an inspection is just before the overcharge, so that if any trouble is discovered it can be removed in time for the cell to get the benefit of the overcharge.

If the elements have wood separators or are in glass jars, an ordinary incandescent light on an extension cord can be used to advantage in making the inspection, and a careful examination should be made between the hanging lugs to see that they are not touching, and also anything unusual in the color or appearance of the plates should be carefully noted. If the cells are in glass jars without wood separators, the lamp should be held at the bottom of the jar, so that by looking down between the plates any material that may have lodged across can be discovered and removed. If the elements are in wooden or alloy tanks without wood separators, a submerged lamp should be used for inspection between the plates.

Special attention should be paid to cells that read low at the time the cell readings were taken. If any trouble is discovered *it should be remedied as soon as possible, and not later than the beginning of the overcharge.* Short circuits should be removed with a thin strip of wood or rubber; *never use metal.*

Near the end of the overcharge all cells should be looked over to see that they are *gassing freely.*

INDICATIONS OF TROUBLE.

The following are the chief indications of trouble in a cell:

Falling off in specific gravity or voltage relative to the surrounding cells.

Lack or deficiency of gassing on overcharge, as compared with surrounding cells.

Color of plates markedly lighter or darker than in surrounding cells.

In case of any of the above symptoms being found in a cell, examine carefully for cause and *remove at once.*

TREATMENT OF LOW CELLS.

The above symptoms in a cell indicate that it has fallen below the rest in its state of charge. If the cause is discovered and removed immediately, it will generally be restored to normal condition on the following overcharge. If only partially restored in this way, it must be carefully watched during the ensuing week. If the next overcharge does not completely restore it, or if the original deficiency was excessive, it may be necessary to give it a separate overcharge.

SEPARATE CHARGING.

The first and simplest method of separate charging is to overcharge the whole battery, but care should be taken not to carry this to excess, and it should only be resorted to when the deficiency of the low cell or cells is slight.

The second is by cutting the low cell out of circuit for one or two discharges and in on charges. This method can be used to advantage when the elements are bolted together.

The third method is by giving an individual charge while the battery is either on discharge or standing idle. This charge can be given either from the charging generator or booster through a water rheostat or from a special small dynamo, usually motor driven.

Before putting a cell that has been in trouble into service again, *care should be taken that all the signs of complete charge are present,* viz, the rise in potential and specific gravity to a maximum, free gassing from the plates, and normal color.

SEDIMENT.

The accumulation of sediment in the bottom of the cells must be watched carefully and removed when the clearance has been reduced to one-half inch below the bottom of the plates; *under no circumstances must it be allowed to* *get up to the plates*, as, if this occurs, unnecessarily rapid depreciation will result. Very often it will be found that the depth is greatest under the middle plates, and if the sediment is leveled over the bottom of the cell, its removal will not be necessary for some time longer. This can be done by using an L-shaped device, using no metal in its construction.

To remove the sediment, the simplest method, if the cells are small and bolted together, is to lift out the elements, after the battery has been fully charged, draw or pour off the electrolyte carefully, dump the sediment, clean the jar with water, then replace the elements and cover quickly with electrolyte. The plates must not be exposed to the air except for the very shortest possible time, and must not be allowed to dry out in the least.

If the elements are larger and burned together, the sediment can be removed by using a special form of scoop for drawing it from beneath the plates and then removing it from the jar. Detailed information concerning these scoops will be furnished upon application to the Electric Storage Battery Company. The wood separators, if the battery is thus equipped, should be temporarily drawn up, so that the dowels will not interfere with the manipulation of the scoop. The separators should be handled carefully to avoid breakage.

A third method is to draw off the electrolyte and flush the cell with water (using the local supply) in such a way that the sediment will be continually agitated; at the same time a siphon, inserted at the bottom of the cell, and with such capacity as will keep up with the water supply, should be started. This operation should be continued until the cell is entirely free of sediment. The water should then be withdrawn and the cell immediately refilled with electrolyte. Do not allow the plates to dry out in the least. This method is usually only to be preferred when the cells are very large and where there is a strong head of water for stirring up the sediment.

In connection with the removal of sediment it will be necessary to provide some new electrolyte, to be added to the old to make good that displaced by the sediment. In order to reduce the bulk of the new supply, 1.400 specific gravity acid is a suitable strength to use. (See under "Electrolyte," below.)

Immediately after the battery is cleaned and the stronger acid added it should be given a long charge, *continuing until every cell is fully charged*, when the gravity of each cell should be read and, if necessary, adjusted to standard—that is, from 1.200 to 1.210.

ELECTROLYTE.

General.—Electrolyte is dilute sulphuric acid, and can be prepared by mixing *suitable* commercial sulphuric acid, or "oil of vitriol," as it is more commonly called, with *pure* water. It is essential that both acid and water should *be absolutely free from impurities*, such as iron, arsenic, nitric or hydrochloric acid, and for this reason it is recommended that all electrolyte or acid, as noted above, be purchased through the Electric Storage Battery Company.

If, however, a user mixes his own electrolyte, samples of both the acid and water should be forwarded for test. (See below.)

The proportions of acid (of 1.840 specific gravity, or 66° Beaumé) and water are one part acid to five parts water, by volume. Care must be taken to pour the acid into the water and not the water into the acid. The acid must be added to the water slowly and with great caution, on account of the heat generated. The final gravity of the solution must be read when the solution has cooled. The vessel used for mixing must be a lead-lined tank, one of glazed earthenware, or of wood which has not been used for any other purpose, such as a new washtub or spirits barrel.

Specific gravity.—The specific gravity of the electrolyte of a cell in good condition when fully charged and at normal temperature (70° F.) should be between *1.200 and 1.210.* Due to loss through spraying at the end of charge and to absorption by the sediment, there is a gradual lowering of the gravity, its rapidity depending on the work and care the battery is receiving.

Unless a compensating hydrometer is used, allowance must be made for temperature variation on the basis of an increase of three points in gravity for each 10° Fahrenheit decrease in the temperature, and vice versa; for instance, acid that is 1.207 at 70° F. will be 1.210 at 60° F., and 1.204 at 80° F.

Restoring lowered specific gravity.—When, due to the above causes, the gravity at the end of charge and at normal temperature has fallen to 1.190, it should be restored to normal by the addition of 1.400 acid instead of water when replacing evaporation.

Acid of 1.400 specific gravity is recommended because the proper density of the electrolyte will be more quickly and easily attained by the use of this heavier solution, it containing double the amount of pure acid in comparison with that at 1.210; so that, for instance, if 4 carboys holding 10 gallons each of 1.210 specific gravity electrolyte will be required in any particular case the same result would be gotten by using 2 carboys holding 10 gallons each of 1.400 specific gravity.

Never, under any circumstances, add acid to a cell in which short-circuits, high temperature, or partial charge may account for the low gravity.

Replacing evaporation.—Only pure water, preferably distilled, should be used to replace evaporation, and it should be added often enough to keep the level of the electrolyte from one-half to three-fourths inch (no higher) above the top of the plates. The proper time to add the water is just before the overcharge. If the water used is natural water, a sample should be submitted for test from time to time. (See below.)

Impurities.—Should it be known that any impurity has gotten into a cell, *steps should be taken to remove it at once.* In case removal is delayed and a considerable amount of impurity becomes dissolved in the electrolyte it should be entirely replaced with new, flushing the cell with water before putting in the new electrolyte. The change should be made when the battery is discharged and just before charging. Do not allow the plates to dry. If in doubt as to whether the electrolyte contains impurities, a sample, taken at the end of discharge, should be submitted for test. (See below.)

Samples for test.—For analysis of acid an 8-ounce sample is required, and of water 1 quart. These samples should be forwarded in clean bottles, *carefully packed and tagged, by express, prepaid,* to the Electric Storage Battery Company, Nineteenth street and Allegheny avenue, Philadelphia, Pa., which will gladly analyze and report upon them free of charge.

PILOT CELL.

This cell, as its name implies, is to be used as a guide in the operation of the battery. For this purpose a readily accessible cell, and one which will be representative of the whole batery (not an end cell), is to be selected and known as the "pilot cell." Readings are to be taken on this cell with sufficient frequency to indicate its state of charge and discharge, which will thus serve as a guide in the operation of the battery as a whole. *The pilot cell, when once selected, should not be changed,* unless the cell has to undergo special treatment or repairs. The height of the electrolyte in this cell *should be kept at a fixed point,* three-fourths inch above the top of the plates, by adding a small quantity of water at least once each day. This will prevent the sudden drop in the gravity of the electrolyte consequent upon the addition of a considerable quantity of water and the following increase in gravity as it slowly evaporates. The fixed point should be marked in a convenient manner; for instance, by a painted line on the outside of a glass jar or an S-shaped strip of lead hung over the edge of a lead-lined tank.

RECORDING VOLTMETER.

This instrument, besides furnishing a valuable record of the operation of the battery, is of great assistance in enabling the attendants to easily and accurately note the progress of charge and overcharge and to determine the time when each should be cut off.

It should be connected across those cells which are always in circuit on both charge and discharge, and should not include any end cells or C. E. M. F. cells.

This voltmeter should be *calibrated at least once a week* with a standard voltmeter known to be correct, using the variable resistance for adjustment. The charts should be kept flat in the box until ready for use, as a buckled chart will make a great change in the character of the curve. The pen should be kept clean, and only the special recording voltmeter ink should be used. Care should also be taken that the pen does not press too tightly on the paper, as otherwise a true record can not be obtained.

THE BATTERY ROOM.

The battery room should be so laid out or arranged that all the cells will be convenient of access, and, if possible, *they should all be on one tier.*

The ventilation should be very carefully considered, with a view to keeping the temperature moderate and the air dry. Usually suitable outlets in the ceiling or roof, with inlets of double the area near the floor, will suffice, though in some cases forced draft may be necessary.

The windows should be so arranged as to allow of plenty of light, but care should be taken that direct sunlight is not allowed to fall on the cells; painted or ground glass should be used if this occurs.

To obtain the best results the temperature should be between 50° and 80° F. If the room temperature is very high—that is, over 80° F., for any great length of time, the wear on the plates is excessive. If the temperature is low, no harm results, but the available capacity is reduced during the period of low temperature.

Almost equally important with the temperature is the question of dryness, and the circulation of air should be sufficient to keep the stands, insulators, and cells free from dampness, which is very liable to cause grounding of the battery itself or its connecting circuits.

If the floor, stands, or any part of the battery should become saturated with acid-laden moisture, the parts affected should be washed with a saturated solution of bicarbonate of soda in water, which will neutralize the acid, and they should then be rinsed with water and all the windows thrown open, to allow of complete drying. In doing the above work care should be taken not to get the washing solution into the cells.

END CELLS.

If there are any end cells in the battery—i. e., if some of the cells are so connected with the switchboard that by either cutting them in or out the pressure can be regulated, those that may have been successively cut into circuit on the discharge should be cut out again on the following charge as soon as they are charged, as shown by their gassing moderately. Those that have been on discharge the shortest time will, of course, have to be cut out sooner than those which were on discharge longer.

All the end cells, whether used regularly or not, should be cut into circuit with the main battery on the overcharge, and each cell kept in circuit until it gases freely.

REPAIRS TO JARS OR TANKS.

If a tank is leaking or a jar broken or cracked so that it has to be removed for repairs, the negatives should be lifted out and immediately placed in a vessel containing clean water. The positives can be allowed to dry. The wood separators, if the battery is equipped with them, should first be removed and stored in the free space of surrounding cells; this should be carefully done, to avoid breakage. The utmost care should be taken that neither the negative plates nor the wood separators be allowed to dry out in the least.

The plates and wood separators should be placed in the new tank or jar just before the charge is started and immediately covered with electrolyte; the plates will then have the benefit of the following charge.

BATTERY USED BUT OCCASIONALLY.

If the battery is used but occasionally or is standing idle, it should be given a freshening charge once every two weeks; this also applies to any cells that are temporarily out of circuit for any cause.

PUTTING BATTERY OUT OF COMMISSION.

If the use of the battery is to be discontinued for some considerable time—say, six months—it is generally advisable to take it entirely out of service, which should be done as follows: After thoroughly charging and determining that there are no low cells, siphon off the acid (which may be used again) into convenient receptacles, preferably carboys which have been previously cleaned and have never been used for other kinds of acid, and as each cell becomes empty immediately fill it with fresh, pure water; when water is in all the cells, allow the battery to stand twelve or fifteen hours, when the water should be drawn off and the plates allowed to dry. The battery will then be in a condition to stand indefinitely.

If equipped with wood separators, these should be removed just before drawing off the water, and if they are in good condition and it is desired to use them again they should be kept submerged in water. In general, however, it will be found the better plan to throw them away and use new separators when the battery is put into service again.

If there is any considerable amount of sediment in the cells, advantage should be taken of the out-of-service period to clean them thoroughly. The carboys in which the acid is stored should be tightly corked, to keep out impurities.

PUTTING THE BATTERY INTO COMMISSION AGAIN.

The cells should be filled with the stored electrolyte one after another as quickly as possible and after all are filled (which will probably require a little new electrolyte to replace that lost) the charge should be started.

This charge is in all respects similar to the initial charge and should be at the normal rate and should last until the specific gravity and voltage have ceased rising for a period of four to five hours. *From thirty-five to forty-five hours will be required to complete this charge.*

If wood separators are used, these should be put into place before the acid is poured in, each cell, however, being filled as soon as its separators are in position, so that the separators will have no chance to dry. If part new and part old separators are used, these should not be mixed together, but kept together in cells by themselves, putting all of the new ones in one end of the battery and all of the old ones in the other end.

GENERAL PRECAUTIONS.

The battery must not be repeatedly overcharged, undercharged, overdischarged, or allowed to stand completely discharged. (See under "Operation.")

Be careful to have the room *freely ventilated* at all times, and especially while charging.

Never bring *an exposed flame* into the battery room during or shortly after the gassing period of a charge, as the gases form an explosive mixture if closely confined, as in case of poor ventilation.

Keep all iron, copper, and other metal work about the battery or room *free from corrosion*, either by frequent painting or coating with vaseline.

All connections should be kept tight so that there will be no trouble from heating.

The daily and weekly readings should all be *regularly and accurately taken and recorded.*

The above general instructions, as well as the condensed routine instructions, *should be read and followed closely* in order that no harm from careless or ignorant handling may follow.

NORMAL RATING.

To obtain the normal charge and discharge rate of a battery, multiply the rate given in the table below by the number of positive plates per cell. Thus for a type E battery of 13 plates per cell (6 positives and 7 negatives) the normal rate is 30 amperes.

Type.	Amperes per positive plate.	Type.	Amperes per positive plate.
C	1¼	F	10
D	2½	G	20
E	5		

Elements of the two-plate type have the following normal rating:

Type.	Normal rate, in amperes.	Type.	Normal rate, in amperes.
BT	¾	PT	3
CT	1½	ET	4½

Different types of plates can be identified from the following table, giving dimensions, not including lugs:

Type.	Size.	Type.	Size.
	Inches.		*Inches.*
BT	3 x 4	D	6 x 6
CT	5 x 5	E	$7\frac{3}{4}$ x $7\frac{3}{4}$
PT	$8\frac{1}{4}$ x 5	F	11 x $10\frac{1}{4}$
ET	$7\frac{1}{4}$ x $7\frac{7}{8}$	G	$15\frac{5}{16}$ x $15\frac{5}{16}$
C	$4\frac{5}{8}$ x 4		

The normal rating of cells of the "portable type" can be obtained from the name plate on the cases.

RECORDS.

For conveniently recording the daily and weekly readings, the following form is recommended. In the sheet provision has been made for 22 cells, and in case the battery contains more than that number the sheet should be enlarged accordingly.

The paper should be of such texture as to permit of legible carbon copies being obtained.

It will be found that a valuable aid in following the condition of the cells will be to transcribe the gravity and voltage readings of all cells to a parallel column record book, so that consecutive readings can be easily compared. The following form is recommended, it being a sample double page:

Storage battery weekly report.

[*Directions.*—Daily readings: The daily readings of the pilot cell for the week should begin on the day before the overcharge.

In case battery is not charged daily write in the words "Not charged" across the space for the "End of charge" readings for that day, but record the specific gravity and temperature of the pilot cell on such day at usual time of charging under the heading "Start of charge."

Weekly readings: Cell specific gravity readings to be taken at end of charge on day before overcharge. Cell voltage readings to be taken at end of overcharge with charging current flowing at normal rate. Cell specific gravity readings to be taken weekly whether battery is overcharged weekly or not. Pilot cell readings end of overcharge are to be taken at 15-minute intervals after gassing starts.]

Battery No. ———. Week beginning ———, ——, 190—. Type of cell ——— "chloride accumulator." No. of plates per cell ———.

DAILY READINGS OF PILOT CELL NO. ——.

Day of week.	Start of charge or end of discharge.		End of charge (immediately before charge is stopped).		
	Time.	Specific gravity.	Time.	Specific gravity.	Temperature of acid.

WEEKLY CELL READINGS.

Specific gravity readings: Day, ——; time, —{a. m. / p. m.
Voltage readings: Day, ——; time, —{a. m. / p. m.
Chg. current while taking voltage readings: — amperes.

Cell No.	Specific gravity.	Voltage.	Cell No.	Specific gravity.	Voltage.
1.			12		
2.			13		
3.			14		
4.			15		
5.			16		
6.			17		
7.			18		
8.			19		
9.			20		
10.			21		
11.			22		

PILOT CELL READINGS, 15-MINUTE INTERVALS, END OF OVERCHARGE.

Time.	Specific gravity.	Time.	Specific gravity.

Pilot cell maximum specific gravity on preceding overcharge, ——. Water added: Date, ——, —; quantity per cell, ——. Cells inspected during week, ——. Cells given special attention during week (state attention given), —— ——.
Remarks: —— ——.
Readings taken by —— ——.
Approved by —— ——.

PUTTING THE BATTERY INTO COMMISSION AGAIN.

To do this, proceed in the same manner as when the battery was first put into commission. After first determining that the polarity of the charging source has not been altered, so that its positive pole will still be connected to the positive end of the battery, put in the electrolye and start charging at once at the normal rate, continuing until the charge is complete; from twenty-five to thirty hours at this rate will be required. The completion of this charge is determined in the same manner as are these when the battery is in regular service as noted above.

TESTS FOR PURITY OF ELECTROLYTE.

The necessity for using pure electrolyte in storage batteries is something which is seldom recognized. Its importance in maintaining a battery in its highest efficiency for any length of time is a matter which should receive attention, not only at the time the battery is set up, but subsequently in the addition of water or fresh electrolyte.

The most frequent impurities in water are sodium or magnesium chloride, and some of the salts of lime and iron. The presence of lime will of course be objectionable, but its presence in very small quantities is less objectionable than that of the other impurities.

In general, it may be stated that the only suitable water for safety is distilled water, and no amount of trouble necessary to get this kind of water should be considered as too great when making up the electrolyte if strong acid be furnished, or for subsequent additions to replace loss by evaporation.

If strong acid is furnished, the method of mixing this with the requisite amount of water to bring the specific gravity of the solution to 1,200 has already been stated. It is again urged that no acid be used which is made from iron pyrites; the only suitable electrolyte is made from acid which is manufactured from pure sulphur.

The impurities which may be in the acid, and for which tests should be made, are: Chlorides or free chlorine, the salts of iron, copper, mercury, and the nitrates. Small cases of reagents will be furnished by the Signal Corps for storage-battery installations where there are 15 cells and upward, and tests should invariably be made before setting up the battery and in subsequent additions of electrolyte.

It must be noted that after running some time the electrolyte may become contaminated with chlorides or nitrates from the plates, formed during manufacture.

The small reagent case will contain the following chemicals:

Nitrate of silver.
Red prussiate of potassium.
Yellow prussiate of potassium.
Strong ammonia.
Iodide of potassium.
Concentrated sulphuric acid.
Diphenylamine.

If distilled water is used, of course no tests of it will be necessary, but any natural water should be open to suspicion.

Tests for chlorine or chlorides.—A few drops of solution of nitrate of silver in a test tube partly filled with electrolyte will give a curdy, white precipitate of silver chloride if chlorine or its salts are present. This chloride turns to a violet tint on exposure to light. If the clear liquid be poured off this white precipitate and strong ammonia be poured on it, it will dissolve.

Test for iron.—The presence of ferrous salts in the electrolyte is shown if a dark-blue precipitate is given upon the addition of a solution of the red prussiate of potassium. If ferric salts are present in the electrolyte, a solution of yellow prussiate of potassium will give a blue tint. Consequently, if into two test tubes, one of which contains a few drops of yellow prussiate and the other a few drops of red prussiate, a little electrolyte be poured, the two tests can be made at once. If the impurities be present in small quantities there will not be a precipitate formed, but a bluish-green coloration will result.

Test for copper.—Place a small quantity of electrolyte in a test tube and add an excess of strong ammonia. If copper be present there will be a bright bluish tint given to the mixture. If present in large quantities, a chocolate-colored preparation will be formed upon the addition of a solution of the yellow prussiate of potassium.

Test for mercury.—The mercurous salts will give an olive-green precipitate with iodide of potassium; the mercuric salts, a scarlet precipitate with the same reagent.

The use of hydrometers having mercury in the lower bulb will frequently give a mercury impurity in the electrolyte through breakage of this bulb. Consequently it is better to use only a shot-filled hydrometer.

Test for nitrates.—Some diphenylamine should be dissolved in a small quantity of concentrated, chemically pure, sulphuric acid and put in a test tube. A small quantity of electrolyte is then carefully dropped in the same tube. If a blue color results, nitrates or nitrites are present. Traces of nitrates are very objectionable. They cause a surprisingly rapid deterioration of the plates.

Chapter III.

TELEGRAPH INSTALLATION.

MORSE TELEGRAPH CIRCUITS.

The two methods of arranging the ordinary Morse circuits are called the " open " and " closed " circuit systems.

The latter is frequently called the American system, the diagram of which is given in fig. 12. In this only one line battery is necessary, although in practice it is found better to divide the battery between the terminal stations as shown, care being taken not to connect the batteries in opposition. Each key is furnished with a circuit-closer

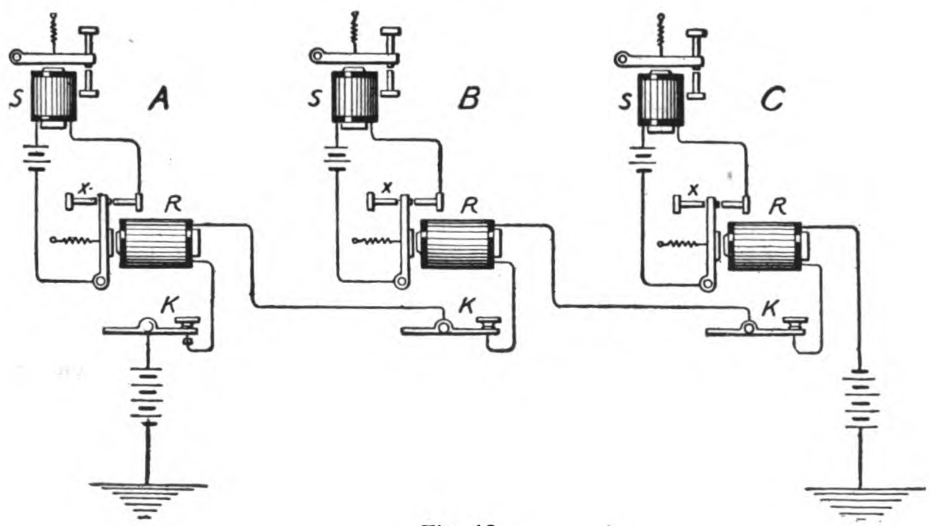


Fig. 12.

lever, and when the line is quiet the current is constantly running, keeping the relays and sounders closed. When any station opens his circuit by means of the lever he controls it entirely with the key. This system is in universal use in the United States and Canada.

The diagram of the open-circuit system is given in fig. 13. In this system each station must have sufficient main-line battery to work the line. The keys have a front and a back contact. (See fig. 16.) When the line is quiet there is no current running, and when any station depresses his key he breaks the back contact and introduces his main-line battery through the front contact, operating the relays on the line. The relay is frequently put in the back-contact circuit, in which case the operator does not work his own relay, thus cutting its resistance out of the circuit, but the American operator prefers to hear his own instrument work.

This system has been used exclusively on the short Signal Corps

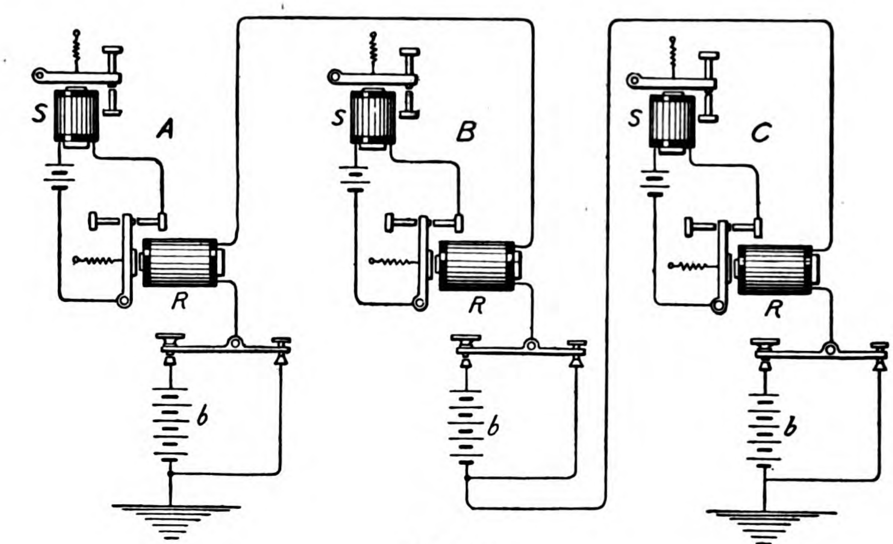


Fig. 13.

submarine cables. It obviates the constant application of battery to the cable, as would result from use of the closed-circuit system.

TELEGRAPH OFFICE EQUIPMENTS.

The familiar essential instruments of the ordinary Morse telegraph office need but brief mention, as it is assumed that the reader is already familiar with the first principles of telegraphy.

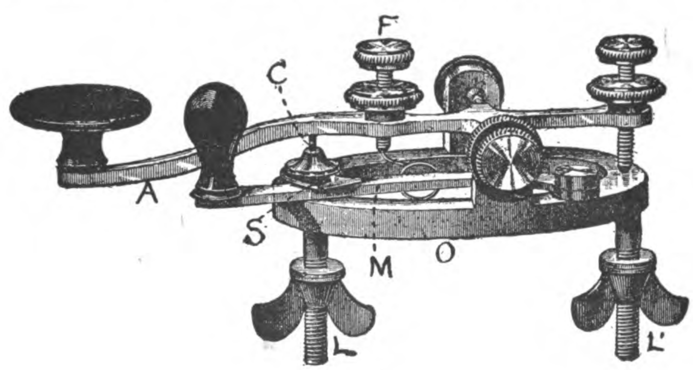


Fig. 14.

THE KEY.

The ordinary American Morse or closed-circuit key is shown in fig. 14. The lever A is ordinarily of steel nickel plated; the milled-head screw F adjusts the tension of the spring below it. O is the base which supports the trunnion bearings of the key. M is the circuit-closer lever, which is pivoted at the rear and slips under a curved metal piece, S, which is insulated from the base but in connection with the front leg L. This front leg is connected with the relay and the back leg L to the battery or other line if it is a " way " office. C represents the upper and lower contact points of platinum, this metal

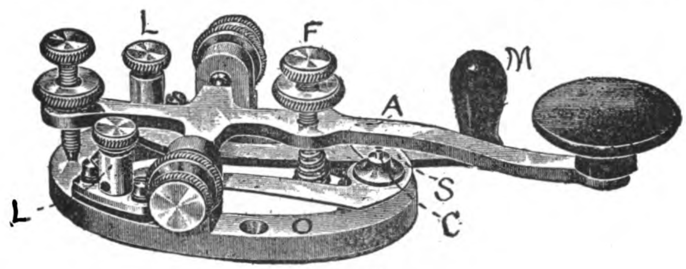


Fig. 15.

resisting the corroding action of the spark produced on opening the key.

The legless key is shown in fig. 15. The binding posts instead of the legs are connected to line and battery, respectively. The parts corresponding to the leg key are similarly lettered.

The "open-circuit" key has an insulated front and an insulated back contact, and the circuit-closing lever is dispensed with. As shown in fig. 16, the screw C on the base of the key is connected with the relay,

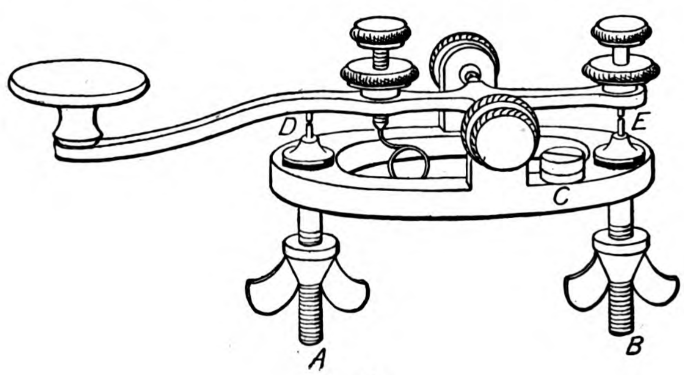


Fig. 16.

the insulated lower front contact, D, with the battery, and the insulated back contact, E, with the ground at a terminal station or with the outgoing wire at a " way " station.

THE RELAY.

The function of the relay is, briefly, to cause a comparatively powerful local current through a sounder to be controlled by the much feebler one in the main-line circuit. The relay coils are included in the main-line circuit, the two binding posts on the right (fig. 17) being connected with the key and line, respectively, the binding posts on the left being connected with the sounder and local battery, respectively. The main and local circuits are indicated by the broken lines. The resistance of the relay coils is now almost universally 150 ohms, although on some short lines a "pony" relay of 20 ohms is used.

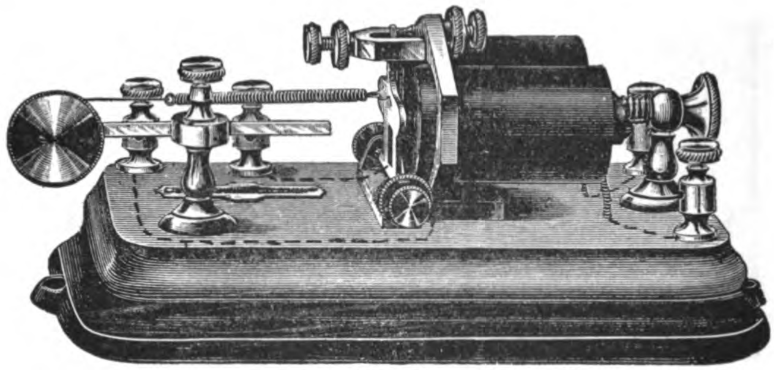


Fig. 17.

The familiar box relay with the key on the base is shown in fig. 18. This relay has a heavier lever for giving a louder sound than that of the ordinary relay, resonance of the box assisting. As it may be used at temporary field offices, when local batteries are not obtainable, and is of great strength and simplicity, it is a most useful instrument for military lines.

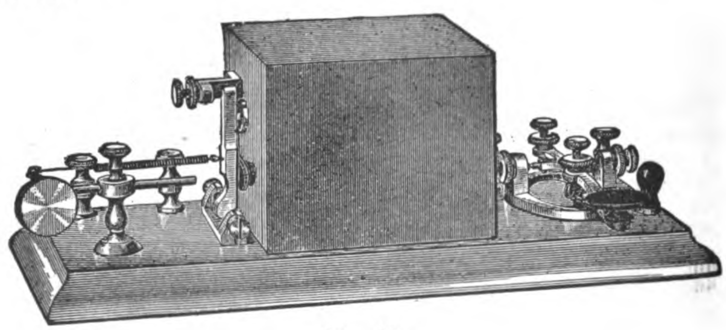


Fig. 18.

The "main-line sounder" (fig. 19) is somewhat of an improvement on the box relay. The coils are usually wound to 150 ohms, the same as other main-line instruments.

The "pocket relay" is a compact form of main-line sounder for testing purposes. About 40 milliamperes current is required to operate the 150-ohm instruments to best advantage.

THE SOUNDER.

This well-known instrument is shown in fig. 20, this being one of the most common forms now in use. Its connection with the relay and local battery circuit has already been indicated. The coils are usually wound to a resistance of 4 ohms, and it requires about one-fourth ampere to operate the sounder as vigorously as is required for ordinary offices. Hence two bluestone cells, each having about 1 volt

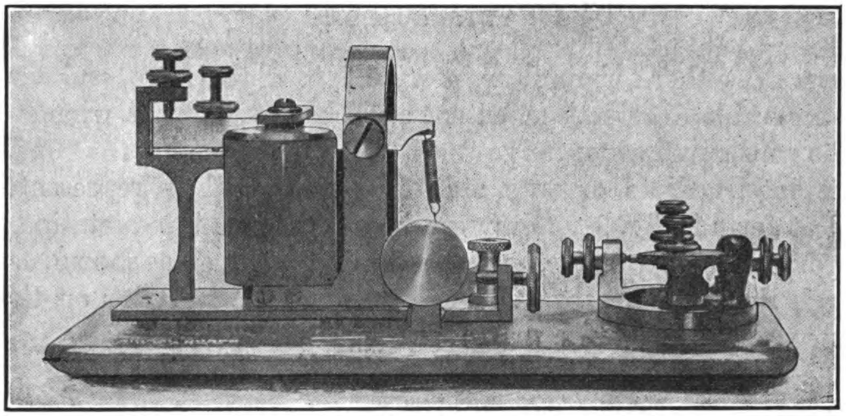


Fig. 19.

E M F and 2 ohms internal resistance, will give the required current. $(C=\frac{E}{R};\ .25=\frac{2}{2\times2+4}.)$

If the sounder is put in circuit with a cell of higher E M F and lower resistance, some resistance wire should be put in to keep the

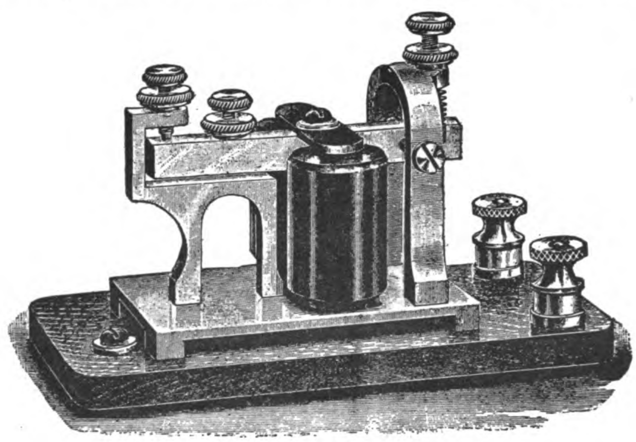


Fig. 20.

current down to one-fourth ampere; otherwise the battery will be used up wastefully. For example, with a Fuller cell of 1.8 volts E M F and one-fourth ohm internal resistance, $C=\frac{1.8}{\frac{1}{4}+4}=.42$ ampere, which is considerably more current than necessary. The necessary added resistance, X, can be found as follows: Required current is .25 ampere, so $.25=\frac{1.8}{4+\frac{1}{4}+X}$; $1.06+.25\,X=1.8$; $X=3$ ohms, the "dead resistance" to be introduced in circuit.

In cases when a number of sounders are fed from one storage cell (see fig. 11) a "dead resistance" of 4 ohms should be inserted in each sounder circuit, as the storage cell has virtually no internal resistance and an E M F of 2 volts.

SWITCHBOARDS.

These are either terminal or intermediate in their use, and as there is considerable difference in extent and character of the wiring, they will be considered separately.

The intermediate or way station switchboard is represented in simplest form in fig. 21. Suppose two lines come into a station, they are brought to the tops of the vertical strips of brass, as shown, usually through lightning arresters. These are frequently strips or disks of brass connected with the ground and placed close to the strips con-

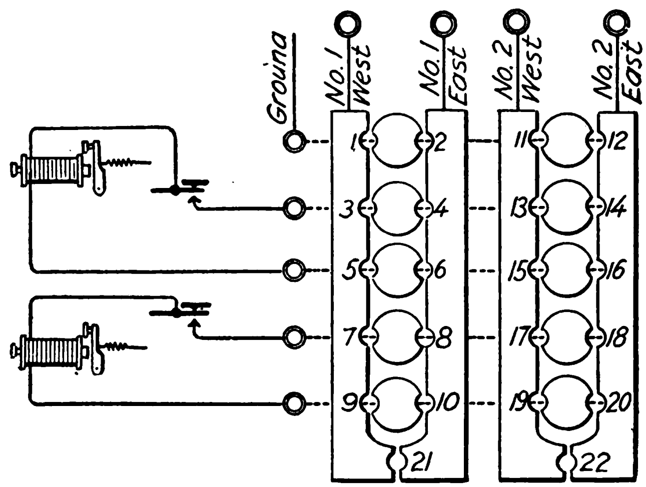


Fig. 21.

nected with the line. Between these vertical strips of brass connected to the lines are vertical rows of brass disks, all the disks in any horizontal row being connected together by a metal strip on the back of the board. Semicircular spaces are cut adjoining each other in the strips and disks, so connections may be made at any of these points between the disks and strips by the insertion of conical metal plugs with hard-rubber heads. By means of these, sets of instruments may be connected up with each other, the different lines, or the ground, as shown. To cut out a set of instruments, insert plugs at 21 or 22. To cut in the upper set on line No. 1, take plug out of 21 and insert plugs at 4 and 5 or 3 and 6. To cut upper set in on line No. 2, remove plugs from 3, 4, 5, 6, and 22 and insert them at 13 and 16 or at 14 and 15. In a similar manner the lower set of office instruments may be cut in on either line.

Suppose either of the sets is cut in on No. 1. If to test we wish to ground No. 1 east, we insert a plug at 2. The closing of the circuit, if open before, will show at once that the line is open east of us. In like manner test by grounding west may be made on either wire. The foregoing illustrates the use of the ground wire.

Due to defects in one of the lines, the main office may desire a "patch" made. This means that it is desired to cross-connect lines 1 and 2. Suppose the chief operator directs that line No. 1 west be connected with line No. 2 east. Of course it is desired to keep one of the sets cut in at this office on this patched line.

Plugs are inserted at 3 and 16 and all other plugs are removed.

To patch No. 1 east with No. 2 west, put plugs at 4 and 15.

To loop No. 1 west with No. 2 west, put plugs at 3 and 15, if desired to leave instruments in. If desired to leave them out, insert plug at 13 instead of at 15.

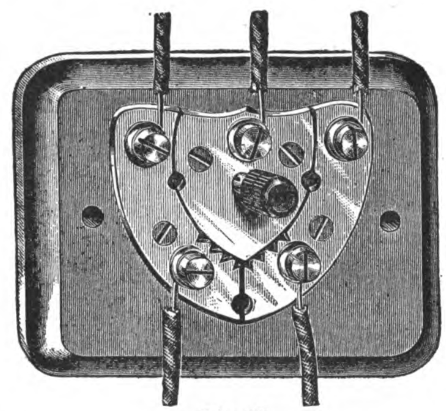


Fig. 22.

If directed to ground this loop, as may be needed sometimes in testing, insert a plug at either 1 or 11.

The simplest form of office switch, called a plug cut-out, is shown in fig. 22. The line wires come in from above, the wires to instruments come out below, and the upper central wire leads to ground. The insertion of the plug in the upper holes grounds "east" or "west," and when in the lower hole cuts out the station. The central ground plate near the line strips acts as a lightning arrester.

LIGHTNING ARRESTERS.

The principle in general upon which these are made is to bring the line or some of the first metal parts to which it is connected in the office close to a conductor connected directly to the ground. The lightning jumps to this ground connection instead of going through the instruments. These arresters are frequently parts of the switchboard, consisting of a metal plate connected to the ground, extending across the vertical line straps and not quite touching them, or of a series of brass disks extending very closely over the straps, the disks being all connected to the ground wire. A simple form of arrester is shown in fig. 22, being part of the plug cut-out. Sometimes small blocks of carbon, with a piece of thin perforated mica separating them, are used. These are slipped into a metal clip, one of the jaws of which is connected with the line and the other with the ground. The advantage of the carbon is that it is not fused by the lightning, which causes grounds or short-circuits in the all-metal ones.

The Argus lightning arrester (fig. 23) is now much used. It consists of a porcelain block upon which the line terminal *A* and the switchboard terminal *B* are secured. A wire spiral *C* connects these. Above the spiral, and not quite touching it, is the metal plate *D* con-

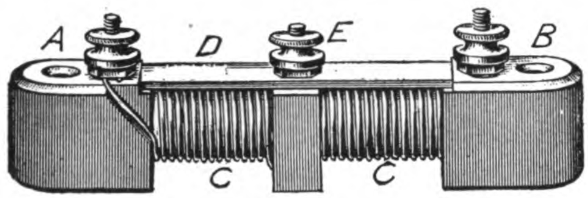


Fig. 23.

nected to ground by the binding post *E*. The theory of its action is that lightning, being an oscillatory discharge, is choked back by the coil *C* and jumps to the ground plate *D* more readily than it would from a straight wire or plate. Its action seems to bear out the theory.

The Mason arrester (fig. 24) operates on the same principle as the Argus but provides more paths for the discharge to take. Its grounded section is made of carbon.

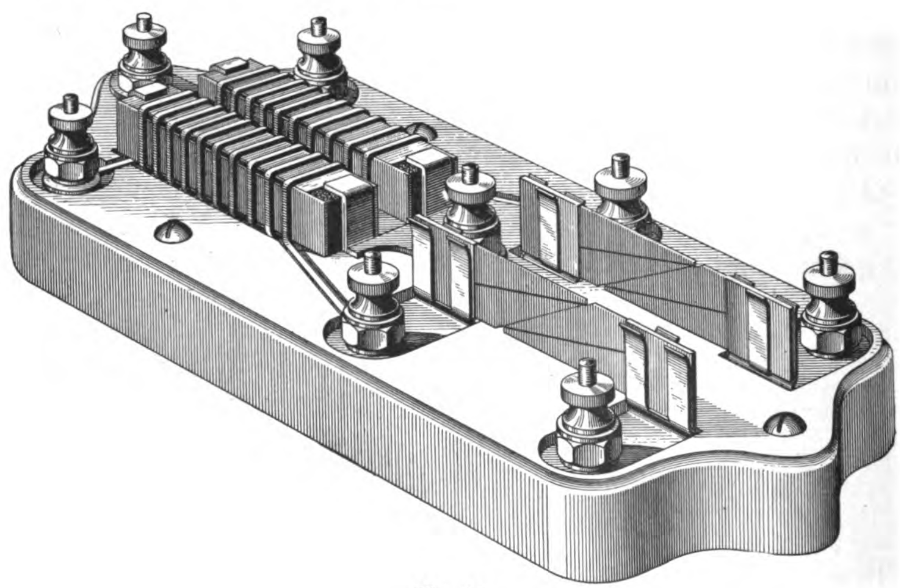


Fig. 24.

In connection with all the "jump" arresters previously described it is customary to place a fuse, this usually being the first connection made to the line coming into the office. A convenient form of fuse and mounting is shown in fig. 25. Of course the action of the lightning or other dangerous current is to burn off the fine wire *A*, mounted on the mica strip, and spare mica fuses should be on hand. Care should be taken that the copper terminals on the mica fuse make good connection with the spring clips *B B*.

Both arresters are installed with or without fuses. The purpose of the fuse is to protect apparatus beyond the arrester from the disruptive effect of the lightning discharge, as the line will be opened by this device the instant the spark jumps to the ground connection. In case arresters are installed to protect a cable line, the fuse should invariably be provided and should be connected on the line side of the arrester. This is very important, since if it were located on the

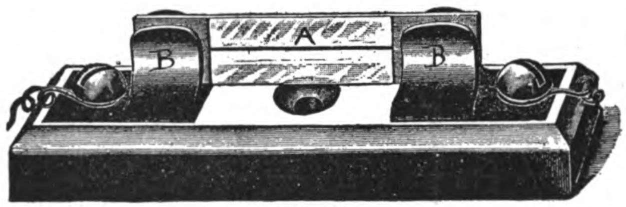


Fig. 25.

cable side of the arrester it could only act when the discharge had found its way to ground through the insulation of the cable.

When an arrester is installed to protect a telephone line on a system not regularly inspected by an expert the fuse should be omitted. In this case the only advantage attained would be had in the clearing of the telephone instrument from the momentary high tension of the lightning charge. There is no reason why the small charge which might exist beyond the arrester should do any damage to the instrument itself, and the opening of the fuse might result in line trouble which would not be readily located by an inexperienced repair man.

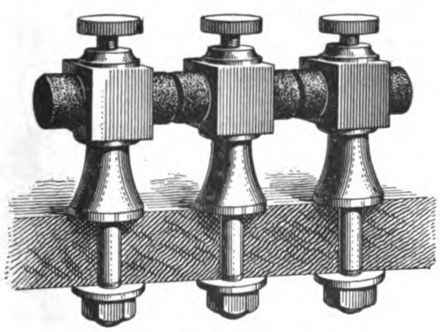


Fig. 26*a*.

Fig. 26*b*.

In connection with these arresters a peculiar style of fuse has been developed, known as the Z link. This fuse is so arranged that the arc, which the blowing of the fuse naturally forms, is not carried entirely across either face of the mica link. The advantage of this device is at once evident.

Besides these two forms of arrester, which are supplied for usual conditions, the service telephone is equipped with one of the two types of carbon arrester shown in figs. 26*a* and 26*b*. In both these arresters a very narrow gap is provided across which the lightning may jump in case the line becomes dangerously charged. This type of arrester is considered to be of sufficient value to protect a telephone on average lines. On long lines in regions where thunderstorms are common an arrester of one of the foregoing types should be provided.

In general, whenever the line comes open or is grounded, careful examination of the jump arresters and fuses should be made. This trouble is, of course, liable to appear during a thunderstorm.

TERMINAL OFFICE SWITCHBOARD AND BATTERY ARRANGEMENTS.

The general plan of the terminal switchboard is shown in fig. 27, introducing a row of spring jacks at the bottom of the board. The

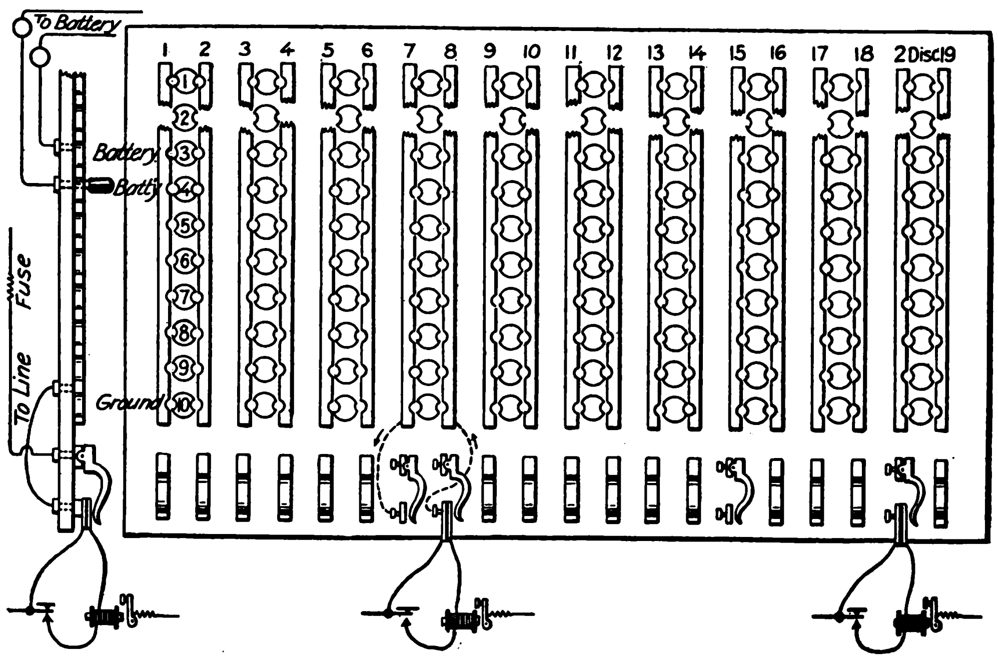


Fig. 27.

method of utilizing these in cutting in sets of instruments by insertion of the double flat plugs is shown. These flat plugs, with hard-rubber insulation between the metal strips composing them, are connected with flexible insulated double-conducting cords leading to the sets of instruments. It will be seen that each line comes in through a fuse wire to the top spring contact of the jack, and, if no plug is inserted, passes through the back contact and up to one of the vertical straps of the board. The insertion of a round conical plug at the appropriate disk connects it to the battery and ground. The insertion of a flat plug and cord leading to a set will introduce that instrument into the circuit. The various arrangements for interconnecting, the provision for duplex and repeater sets, and the connections for loop switches can be studied out, especially if the reader will consult Mavers's American Telegraphy and Jones's Pocket Edition of Diagrams, etc., both of which have been consulted in preparing the diagrams and above descriptions.

As most modern terminal and repeating offices are now provided with storage battery and dynamo sources of current, the method of supplying the terminal switchboard and its connecting lines in the United States Signal Corps Central Office, military telegraph, at Manila, P. I., will be described. In this the storage battery was used, the general diagram (fig. 28) showing the scheme of connections. The storage battery consisted of two groups, of 30 cells each. One

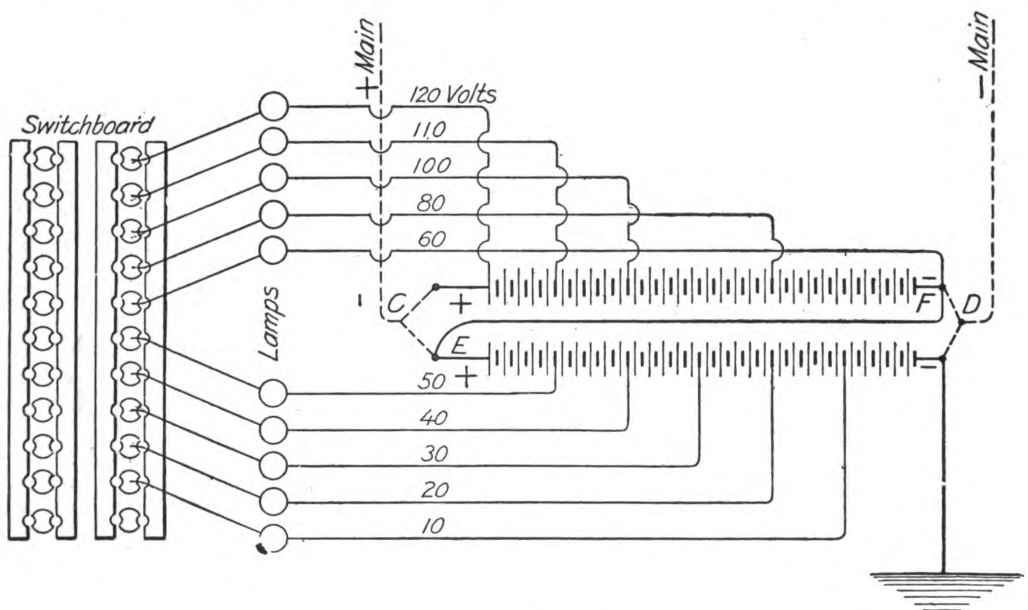


Fig. 28.

of these groups and its scheme of connections to charging mains and terminal switchboard is shown. With the wire *E F* disconnected and the + and — mains connected, as shown in the dotted lines, the cells were connected to the dynamo in two rows in parallel for charging. When completely charged they were disconnected at *C* and *D* and reconnected by *E F*. This puts the 60 cells in series again with the negative end to ground. At various points (10, 20, 30, etc.) taps are taken off, through incandescent lamps introduced as safety resistances, to various horizontal rows of disks on the switchboard. Thus beginning at the top, this row of disks is at the highest potential (120), and a conical plug inserted, connecting any disk of this row with the line leading to the vertical strap through the jack at the bottom, will give the strongest current, and so on down the rows to 10, which brings into the circuit only the last 5 cells next to the grounded end of the battery. The low internal resistance of the storage battery permits feeding almost any number of lines out of the same row of cells without interference. The introduction of lamp resistances is necessary because of this low internal resistance of the cells, as a grounding of the line close to the terminal office would otherwise cause a current dangerous to the instruments. The amount of lamp

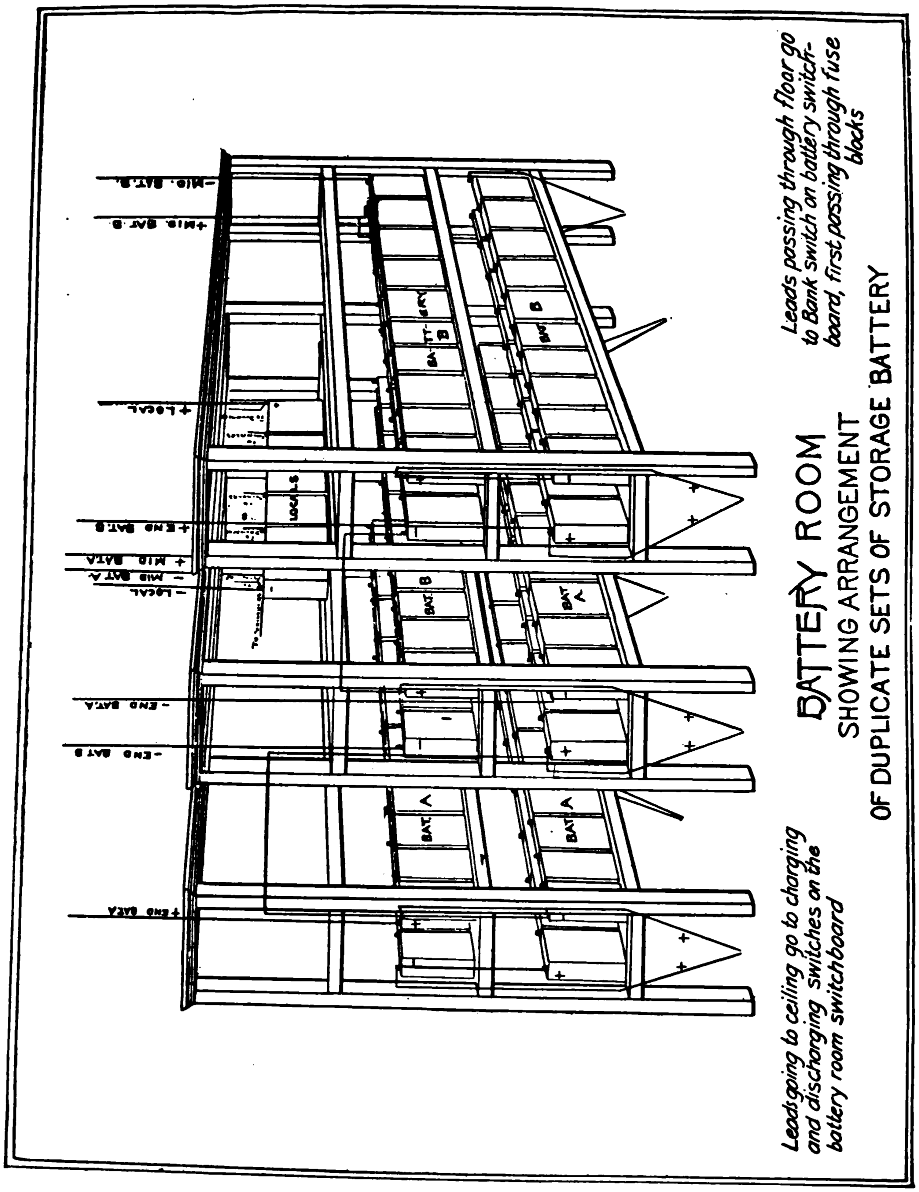
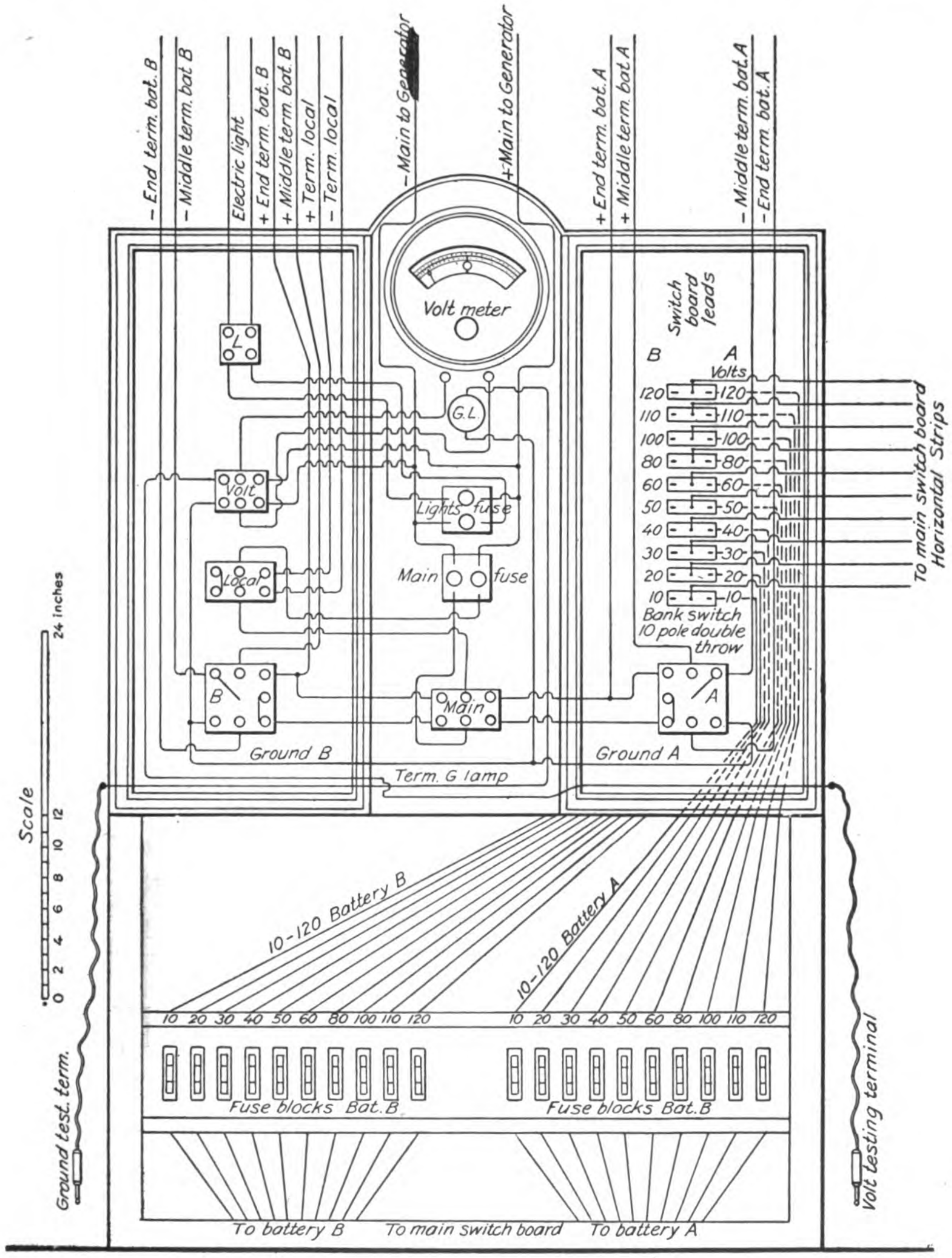


Fig. 29.

resistance to be inserted at each potential is, according to Jones, in his Pocket Edition of Diagrams, etc., 2 ohms for each volt. One ordinary 16-candlepower lamp would be about right for the 110-volt potential, and two of these in parallel for the 50-volt potential.

The arrangement of the duplicate sets of batteries on the racks in the battery room is shown in fig. 29. One of these sets was in use on the lines while the other could be charged. On the top shelves were some larger cells that could be charged in series with the double row of smaller cells below being charged. These large cells were used



WIRING PLAN OF
STORAGE BATTERY
SWITCHBOARD

Fig. 30.

for the local circuits, each of the large cells being connected to four sounders in parallel. (See fig. 11.) The wires from the racks were carried to the storage-battery switchboard shown in fig. 30. The potential tap wires come up from below, pass through fuses and up to the 10-pole double-throw bank switch on the right. The various potentials go from there by the horizontal wires to the rows of disks on the terminal switchboard as described. The other set of potentials from battery *B* lead up to left side of bank switch. These wires are not shown. By throwing bank switch to right, battery *A* is brought into use; by throwing it to left, battery *B*. By throwing triple-pole switch *A* in lower right-hand corner to right, the — end terminal of battery *A* is put to ground. Likewise with battery *B* connected to lines, triple-pole switch *B* thrown to left will put battery *B* to ground.

Suppose it is desired to charge battery *B* while lines are being run by battery *A*. The double-pole double-throw switch marked "*main*" is thrown to the left and large switch *B* to the right. The current then comes down the + main, through the main fuse passing through switch marked "*local*." If this is to the right, the current must pass out through the large local cells before described, then down back to switch, to "*main*" over to *B*, dividing to pass through the two sections of battery *B* through wires marked "+ *end term. battery B*" and "+ *middle term. battery B*" coming back on "— *end term. battery B*" and "— *middle term. battery B*," to large switch *B*, there uniting going out through "*main*" and "*main fuse*" to — main back to generator. If "*local*" is turned to the left, the current cuts across the switch and does not go through local batteries. Precisely the same manner of circuit tracing may be noted for charging battery *A*, except that *A* is turned to the left and "*main*" to the right. By turning the switch marked "*volt*" to the right the voltage during charge may be read. By turning "*volt*" to left and touching "*volt* testing terminal" plug (hung by a flexible cord on the right) to various points on the bank switch, the voltage of various parts of battery may be tested. To test if insulation of the battery is bad, if the "*ground test term.*" plug on the left is touched to the 120-volt potential point of battery not in service on the bank switch, the ground lamp (*G L*) will show it by lighting up more or less. This ground lamp will also serve as a rough indicator of potentials of the line in use and, of course, grounded at the — terminal. The mains are connected to the office electric light circuit by closing switch *L*.

Chapter IV.

TELEGRAPH REPEATERS.[a]

THE MILLIKEN REPEATER.

This was one of the earliest repeaters introduced into the telegraph service, and it is still a standard repeater of the principal telegraph companies of this country.

This repeater may perhaps be termed an automatic electro-mechanical repeater, for, while electricity is the controlling force in the performance of its automatic functions, the ultimate action is mechanical, as will be seen.

Fig. 31 is a theoretic diagram of the connections of the Milliken repeater. R and R' are the main line relays. EM and EM' are extra magnets, which, in practice, are supported on metal standards that hold them rigidly in their respective positions relative to the main line relays. The armature levers of the extra relays are pivoted at the top as shown. T and T' are transmitters. The levers $L\ L'$ of the transmitters are insulated from the tongues $x\ x'$ at points $i\ i'$ and from screw posts $F\ F'$ by small pieces of hard rubber.

The working of this repeater may perhaps be best described by assuming that the east is about to send. To that end he opens his key; that opens relay R' and its lever l' falls back, as in the figure, and opens the local circuit controlling the transmitter T'. As the latter instrument opens, it first breaks the local circuit of EM at a'; the retractile spring S of extra magnet EM at once pulls its lever against the lever l of relay R as in figure; presently the transmitter T' opens the western circuit at x'; this demagnetizes relay R, and its spring would withdraw its lever l from its front stop f, thereby opening the transmitter T, and consequently the eastern circuit at x, but that, as already said, the lever of EM is against lever l, holding it on its front stop and thus keeping the local circuit of T closed. When the east again closes his key, relay R' also closes; consequently so does T'. This action closes EM, and the lever of that instrument is withdrawn from its position against the lever R. This releases R's lever, but,

[a] The descriptions and diagrams of the Milliken and Weiny-Phillips repeaters are taken by permission from Maver's American Telegraphy.

as now the western circuit is closed at x', the lever l is held forward by its armature.

In this way the function of the repeater in keeping closed the opposite transmitter, and virtually also the circuit which is being "repeated" into, is performed.

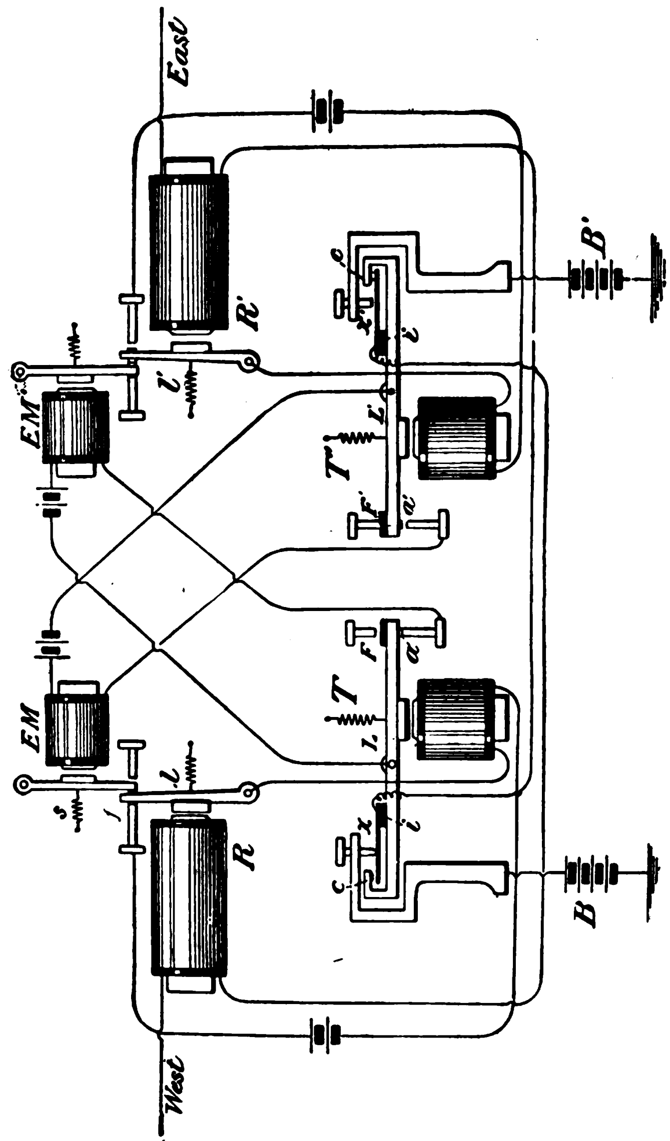


Fig. 31.

Should the west now desire to "break" or send to the east he opens his key, which action, by opening the local circuit of transmitter T at F, opens the eastern circuit at x. The east, finding his circuit now open, closes his key to await the remarks of the west, when the "repeating" actions just described are reversed.

THE WEINY-PHILLIPS REPEATER.

This repeater, which is in operation on the lines of the United Press, the Postal Telegraph Company, and elsewhere, is shown in fig. 32. The opposite transmitter is kept closed at the repeating station by the action of an extra magnet added to the main line relays, the construction and operation of which is, briefly, as follows: The

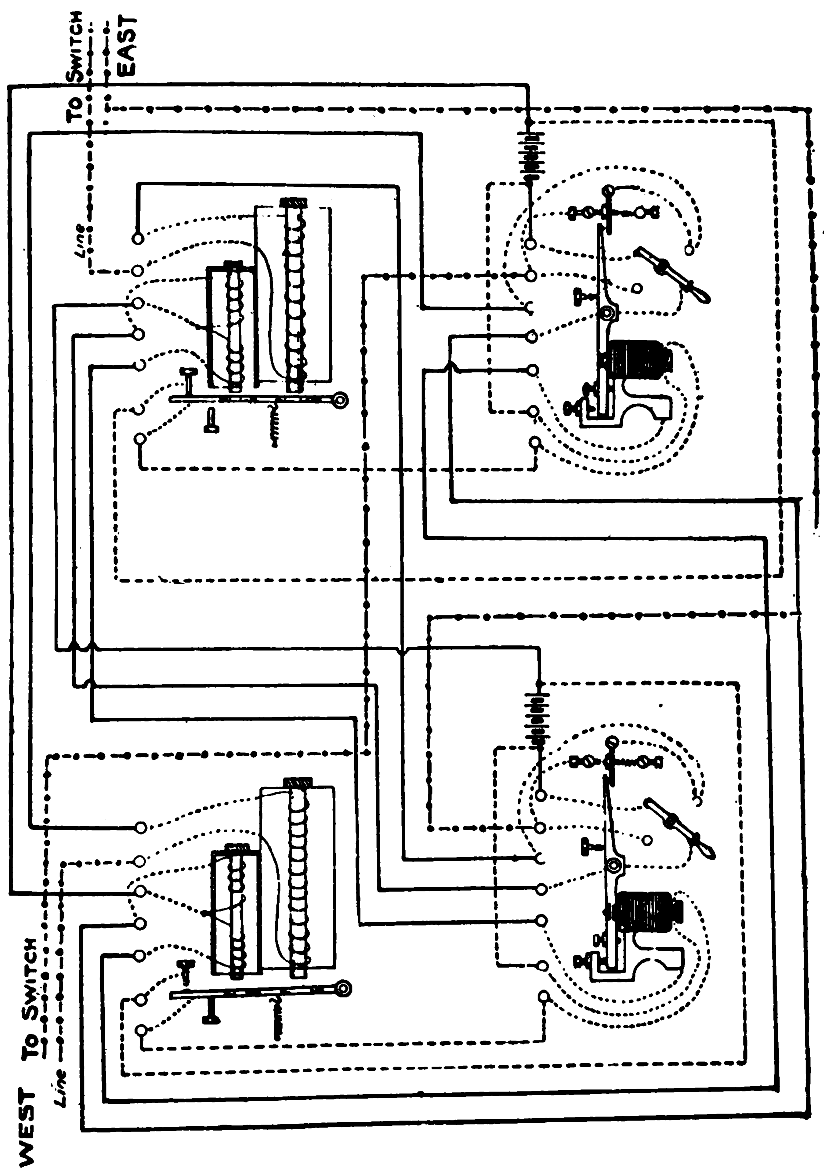


Fig. 32.

extra magnet is wound, as shown, with two coils, through which a current flows from a local battery in opposite directions around the core, so that the latter is, normally, not magnetized. When, however, one of these extra coils is opened the current in the other coil magnetizes the core. The wire which is joined to both coils of the extra magnet goes directly to the right-hand end of the opposite local battery. The other end of each coil passes to the other pole of the same battery, one coil by way of the left-hand post and the other by way of the lever of the opposite transmitter, as shown. This lever is insulated from the left-hand post when the transmitter is open. Consequently, when the left-hand transmitter is open, as in figure, the circuit of the left-hand coil of the extra magnet of the eastern relay is open at the left-hand post of the western transmitter, and as a result thereof that extra magnet is magnetized by the current passing through the right-hand coil, and hence the armature lever of that relay is held against its front stop. Thus, for example, when, as in the figure, the west sends to the east, and thereby opens his key, the western relay in the repeating office opens and its armature lever falls back, opening the local circuit of the western transmitter. As this transmitter opens it first breaks, at its left-hand post, the circuit of the left-hand coil of the extra magnet of the eastern relay, and next opens the eastern main line circuit at the right-hand post. As, however, the armature of the eastern relay is kept closed in the manner stated by its extra magnet, the eastern circuit remains unbroken in the repeating station.

The local battery, it will be seen, is also utilized to operate its respective transmitter. A button switch is placed on the base of each transmitter for the purpose of short-circuiting the main line contact points on the transmitter when it is desired to use the transmitter simply as a sounder for the relay.

THE GHEGAN AUTOMATIC REPEATER.

[From Manufacturer's Circular.]

Two ordinary relays, and two Ghegan transmitters, constitute a complete set of automatic repeaters.

PRINCIPLES INVOLVED.

The fact that an armature, on being drawn toward a magnet becomes itself magnetic by induction, and that the closer it approaches the magnet cores, the stronger the magnetism becomes, are the novel principles utilized in this repeater.

DESCRIPTION.

It will be noticed (fig. 33) that, besides its ordinary armature with spring contact, the transmitter is provided with a second armature mounted above the regular one. The lever of this second or superposed armature also carries a spring contact so arranged that it makes contact with its back stop the instant that the armature begins its upward movement, and does not break contact therefrom until its downward stroke is almost completed, so that with two circuits connected to the contacts of the transmitter armatures, one of the circuits so connected is always closed before the other is opened, by the movements of the armatures.

The second armature is adjusted so that, on closing the local circuit of the transmitter, the regular armature must reach its front stop before the magnetism induced in it is sufficiently strong to draw the second armature from its back stop. The object of this is to allow a sufficient margin of time between the closing of the main circuit by

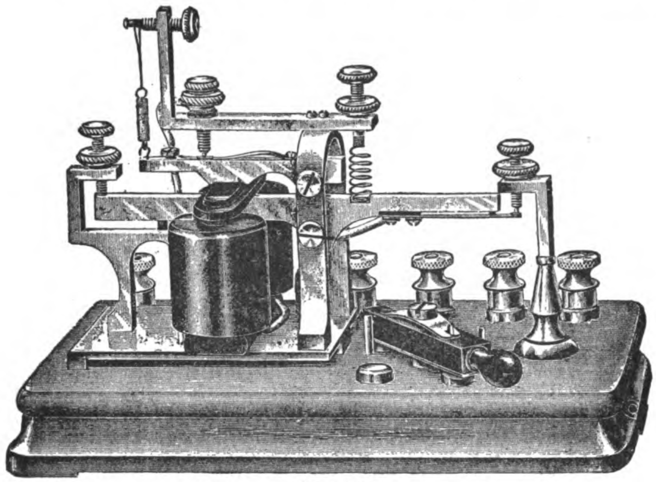


Fig. 33.

the downward movement of the first armature and the opening of a shunt circuit by the subsequent downward movement of the second armature, to permit a relay in the main circuit to close its local contacts before the shunt circuit around them is opened.

This margin of time between the closing of the main and the opening of the shunt circuit enables these repeaters to work well even on leaky lines where the relays act sluggishly.

MODE OF OPERATION.

Fig. 34 shows how the main, local, and shunt circuits are to be connected.

The operation of the repeater is as follows:

When a key on the western circuit is opened, the instruments assume the positions shown in the diagram. The armature of relay R' first falls back and opens the local circuit of transmitter T', which, in turn, opens the eastern circuit at s' r', thus causing the armature of relay R to fall back. This falling back of the armature of relay R, however, does not affect the local circuit of transmitter T, because before the eastern circuit was broken at s' r' the shunt around the local contacts of relay R was closed at M' O'.

On closing the western key, the armature of relay *R′* closes the local circuit of transmitter *T′*, which, in turn, first closes the eastern circuit at *s′ r′*, and, as already explained, after sufficient time has elapsed to permit the armature of relay *R* to reach its front stop, opens the shunt circuit of transmitter *T* at *M′ O′*.

Should east "break" when west is sending, the armature of relay *R* would remain on its back stop, thus breaking the local circuit of transmitter *T* on the first downward stroke of the superposed armature of transmitter *T′*, and so break the western circuit at *s r*.

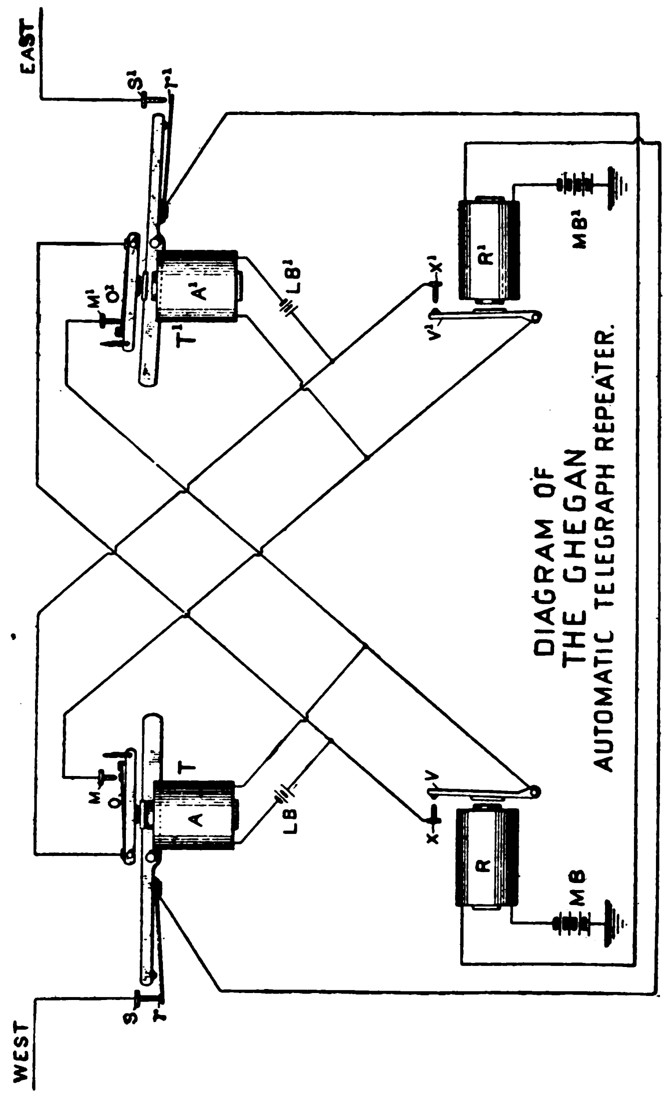


Fig. 34.

The transmitters when once set need practically no attention, the only adjustment necessary being that of the ordinary relay.

The transmitters are provided with switches for working the lines independently or putting them together at will.

Fig. 35 shows the binding-post connections of the Ghegan automatic telegraph repeater.

In running shunt wires from transmitters to local posts of opposite relays, be sure either to connect at the local posts of relay or between them and the local battery.

If either transmitter "kicks" when relays are properly adjusted, a slight increase of tension of the spring of superposed armature of the other transmitter will stop it.

If either side can not break freely, decrease the tension of the superposed armature spring of opposite transmitter. The switches

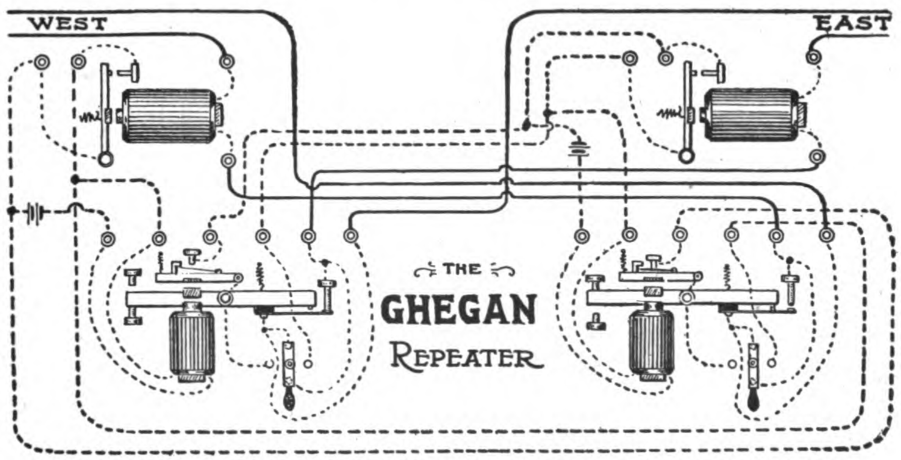


Fig. 35.

when turned to the right connect lines for repeating. When turned to the left the lines work separately.

NOTE.—Where gravity cells are used for locals and the business is mostly in one direction, it will equalize the work of the batteries to reverse the repeater sides daily.

Glass shades or other suitable covers are recommended for keeping the transmitters clean.

30222—05 M——5

Chapter V.

DUPLEX TELEGRAPH CIRCUITS.[a]

THE STEARNS DUPLEX.

The Stearns duplex is, broadly speaking, operated in practically the same way as is the ordinary Morse telegraph system, namely, by the placing of a battery in the line to actuate or magnetize the home relay, thereby attracting the armature, and by removing such battery from the line, thereby permitting the retractile spring of the armature lever to withdraw it from the core of the relay.

The home battery is prevented from affecting the home relay when the home key is opened and closed in the manner described as the "differential," namely, by winding the relays "differentially." This duplex is sometimes termed the differential duplex.

In actual duplex working in which the differential or bridge plan is utilized it is necessary that the resistance of the wires attached to the respective coils of the relays, or to the arms of the "bridge," should be equal, that an equal strength of current from the home battery should tend to flow in each coil or wire.

In the arrangement of a "differential" duplex, as the main-line wire is connected to one of the coils of the relay at each terminal station, it is clear that considerable "resistance" must be connected up with the other coil to insure that the current flowing in the latter coil shall be equal in strength to that in the former coil. It is clear also that if in duplex telegraphy it were necessary to provide a wire, similar in size and length to the main-line wire, wherewith to bring about this equality of current in both coils, the main advantage of duplex telegraphy, namely, its ability to provide additional facilities for telegraphing without increased expenditure for wires, would be lost.

But such, fortunately, is not the case, for it is well known that, with a given electromotive force and a circuit of a given resistance, the strength of current will be the same, whether the conductor composing the circuit be 1 mile or 100 miles in length, 1 inch or 1 foot in diameter.

Availing of this fact, the resistance necessary to insure the equality of currents referred to is made up of "resistance-coils," composed of

[a] From Maver's American Telegraphy, by permission.

small wire of high resistance, termed a "rheostat," or "resistance box," which is constructed in such a manner that the resistance may be varied until it is found to equal the resistance of the main line. When this result is obtained the duplex is said to be "balanced." The method of obtaining this balance will be fully described.

In fig. 36 the connections and apparatus of a Stearns duplex system are shown, theoretically. Two stations, *X* and *Y*, are represented and the instruments and apparatus at one station are duplicates of those at the other.

R and *R′* represent the resistance coils just referred to. In practice these coils are generally termed the "artificial" line; sometimes the compensating line.

The coil of the relay at either end which is connected to the main line is termed the "main-line" coil; the coil connected to the resistance coils, the "artificial-line" coil.

B and *B′* are the main batteries. *T* and *T′* are instruments known as "continuity-preserving" transmitters, but ordinarily termed simply transmitters. These transmitters are operated by a local battery and Morse key, as indicated in the figure. Differential relays *r* and *r′* are placed at each terminal.

CONTINUITY-PRESERVING TRANSMITTER.

The transmitter in the Stearns duplex takes the place of the key in the simple Morse system. It has, as may be seen (*T T′* in fig. 36), a

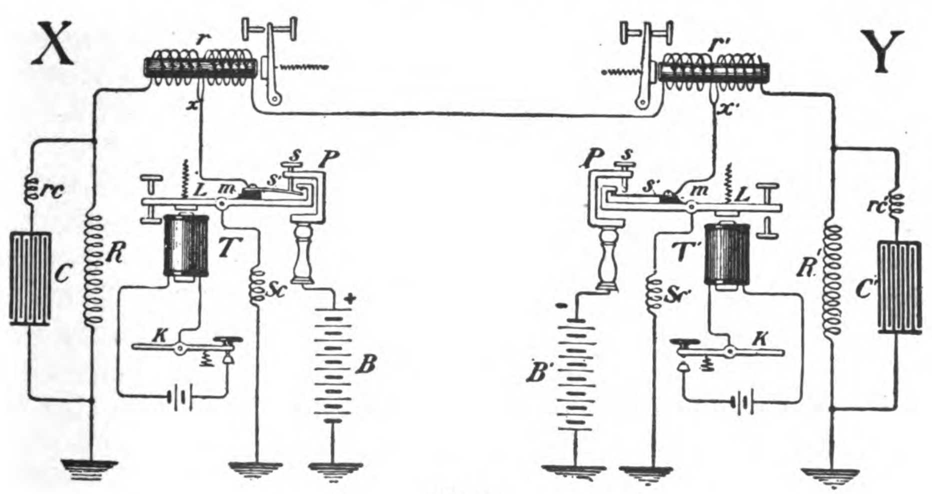


Fig. 36.

lever *L*, which is bent at one end. The lever carries a piece of insulating material *M*, on which is fastened a strip of metal *s′*, generally of steel, called the "tongue," which extends under the bent end of the lever *L*. A metal post or standard *P*, is equipped with a screw s, the lower end of which is near to and in certain positions of L touches the tongue s', making contact therewith, as at transmitter T.

A wire leading to the line is generally connected, as shown, to the tongue, the battery wire to the post P, and the "ground" wire to the lever L. Hence, when so connected, if the transmitter be "open" the line is placed to the ground, as at T'; and if it be "closed," battery is placed to the line, as at T.

The transmitter derives its name, "continuity preserving," from the fact that by the arrangement of the tongue s', the screw s, and the bent end of the lever L the line wire, which is attached to s', as shown, is transferred from the battery to the earth without any "break" in the "continuity" of the circuit.

This will be apparent from an examination of the diagram. In the figure the transmitter at X is closed. When it opens, the right end of the lever will descend, and as it does so the tongue s' will come into contact with the bent end of L, which will withdraw s' from s and leave it in the position shown at station Y, where the key controlling T' is open.

OPERATION OF DIFFERENTIAL DUPLEX.

In fig. 36, as just stated, the transmitter T is closed and T' is open.

This places the positive pole of battery B to the line and leaves battery B' open, but places the line wire to the ground at Y.

The current from X divides in equal parts at x, one part passing to the main line and ground at Y, the other to the artificial line R and ground. The result is that since the current from battery B passes around the coils of r in equal and opposite directions, no effect is produced upon that relay. At the distant end Y, however, the current only passes through line coil of relay r' to the ground, and consequently that relay is magnetized and its armature is attracted.

The statement that the current only passes through the line coil of the relay at Y might be slightly qualified, since, while it is true that in the position of the transmitters in the figure the bulk of the current will pass through that coil to the ground via transmitter T', it is the case, also, that a smaller portion of the current will pass through the artificial-line coil of r' to the ground via R'; but, as in doing so it passes around the core of the relay in a direction similar to that in which the current traversing the line coil passes around the same core, it only assists in the further magnetization of the relay. The amount of current which will flow through the artificial coil at this time depends upon the respective resistances of Sc' and R'. The greater the resistance of Sc', the resistance of R' remaining the same, the greater will be the strength of current traversing the artificial line R'. If there were no appreciable resistance at Sc', virtually no current would pass through the artificial coil.

When the conditions are reversed and transmitter T' is closed and T is open, the relay at Y will not be affected by battery B, while the relay at X will be operated.

When both transmitters are closed simultaneously, thus placing a positive pole to the line at X and a negative pole to the line at Y, the effect will be that practically twice the amount of current will pass through the main-line coils of the relays as will pass through the artificial-line coils.

This is due to the fact that the placing of both batteries to the line has doubled the electromotive force on the main-line current, while practically only the electromotive force of one battery is placed to the artificial line at each station. This gives a preponderance of current in each main-line coil, owing to which the cores of the relays are magnetized and their armatures are attracted.

Hence, since, as we have seen, with the distant key open and the home key closed or open, the home relay remains open, it is obvious that it is practically immaterial whether battery is to the line or not at the home station so far as regards signals sent from the distant end. In other words, owing to the differential arrangement of the coils of the relays and the fact that each coil is part of a circuit of equal resistance, the home relay is only responsive to changes in the current strength due to the operation of the distant transmitter.

SPARK COIL.

In fig. 36 *Sc* is a small resistance coil (often termed the spark coil) employed to compensate for the internal resistance of the main-line battery when the transmitter is open. The object in using this coil is to maintain a uniform resistance on the line in either position of the transmitter. For instance, assuming the internal of a battery to be 300 ohms, when the battery is to the "line" this 300 ohms is added to the resistance of the line, whereas when the transmitter is "open" it would not be, normally. Thus, without the resistance referred to, placed at *Sc* it would likely occur that an unevenness of the signals would follow.

STATIC COMPENSATING CONDENSERS.

C C' are condensers which are employed in duplex telegraphy to impart to the "artificial" line a "static" capacity equal to that of the main line.

The necessity for the employment of condensers in this respect may be explained as follows:

Conductors, besides possessing "resistance," also possess the property of electrostatic capacity. The electrostatic capacity of overhead telegraph conductors is very much less than that of underground or submarine conductors, about as 1 to 23. This is mainly due to the proximity of the latter to the earth, and also to the specific inductive capacity of the insulating material of the cable.

The effect of charging a conductor which has a measurable electrostatic capacity is that at the moment of charge a greater rush of current takes place into the wire than would be the case if the conductor were devoid of this quality. When the battery is removed and a route to the earth provided, the accumulated "charge" rushes out in a direction opposite to that of the charging current.

The German-silver wire of which the rheostats employed as the artificial line are generally composed has, normally, no appreciable "static" capacity. The consequence is that (unless capacity is furnished to the rheostat) at the moment when the home battery is placed to the main and artificial lines, and also when the battery is cut off, a greater quantity of current for an instant flows through the line-wire coil of the relay than flows through the artificial line coil, and when the line wire is of sufficient length this excess of current is ample to cause a momentary magnetization of the core of the relay, which tends to attract the armature; or it might be that the excess of "charge" and "discharge" currents, due to the static capacity of the line, would tend to momentarily demagnetize the core, and thus permit it to be withdrawn from its contact point.

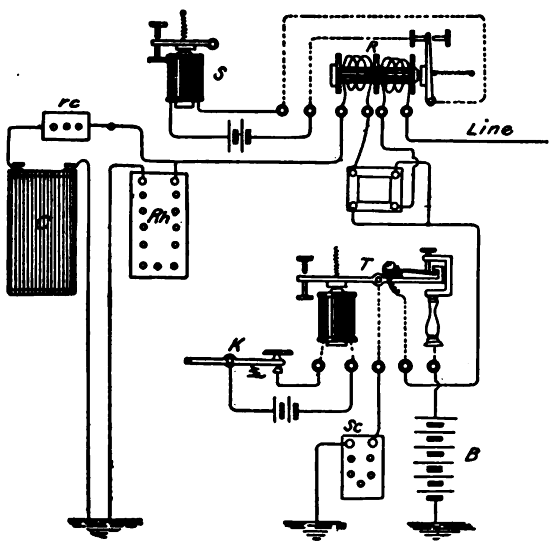


Fig. 37.

The effect of these momentary currents of static charge and discharge of the line upon the home relays are, on long lines, of such an injurious nature as to entirely prevent the successful reception of signals in duplex telegraphy when both stations are simultaneously transmitting signals, and were it not possible to compensate for this effect, not only duplex, but also quadruplex telegraphy, and especially the latter, would be impracticable. It is especially true of quadruplex telegraphy because of the much greater electromotive force used in that system than in duplex telegraphy, the static charge and discharge increasing in direct proportion with the electromotive force of the terminal batteries.

The instruments used to impart to the artificial line the quality of electrostatic capacity are the condensers referred to, C, C' (fig. 36). One terminal of the condenser at each end of the line is connected to the artificial line R, R', the other to the earth. The condenser is provided with an adjusting arrangement by means of which its capacity is increased or decreased until it is found to furnish current which exactly offsets that due to the static capacity of the line. When such is the case the line is said to be balanced for "static." In order to bring about this balance more accurately it is sometimes essential to use two or even three condensers, arranged in multiple and with a

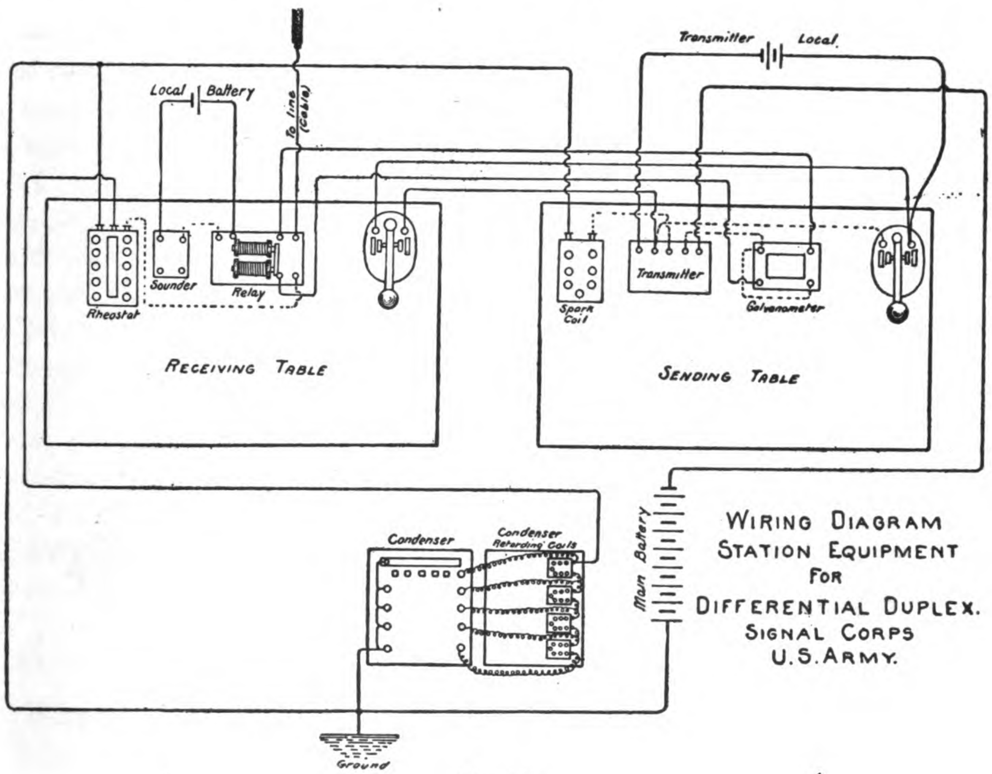


Fig. 38.

resistance coil inserted before each of them. In fig. 36 such resistance coils rc and rc' are shown placed between condensers C and C' and the artificial lines.

The effect of the resistance coil is to retard and diminish the condenser charge and discharge to conform more closely to the actual conditions of the main line.

NOTES ON DUPLEX BALANCING.

[Signal Corps note.]

Lack of rheostat or resistance balance is shown on galvanometer or relay by steady deflection or action as long as key is depressed.

Whether too much or too little is unplugged in rheostat is shown by the direction of galvanometer deflection.

Lack of static balance is shown by a "kick" of galvanometer or relay tongue at the instant key is opened or closed. The center metal strip on rheostat being connected by plugs to the resistance buttons, balance is obtained by throwing off more or less of the microfarad divisions on the condenser. A whole division is thrown off by disconnecting the wire from one of the binding posts on the left. Balance is completed by the plugs across the top division. The connections to retarding coils are shown in diagram (fig. 38). The amount unplugged in each depends on the resistance of the cable. In a cable, for example, where the resistance is about 2,000 ohms, 400 to 500 ohms out of each box may be found about right—some changes may have to

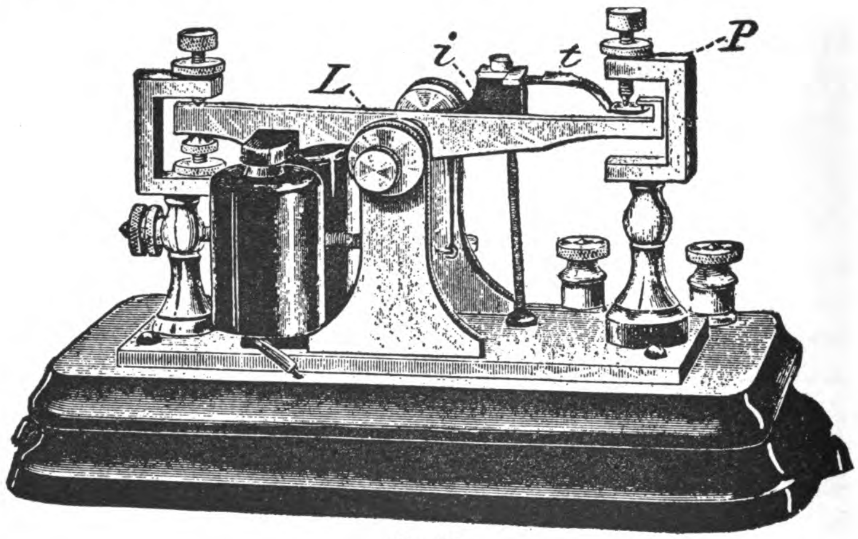


Fig. 39

be made to suit local conditions of cable. The spark coil is supposed to compensate for internal resistance of main battery. Gonda cells or other good open-circuit batteries are best suited for use in differential duplex sets.

As the resistance of each Gonda cell is about 1 ohm, stations where, say, 70 Gonda cells are used, would require about 70 ohms unplugged in spark coils.

THE POLAR DUPLEX.

POLARIZED RELAY.

The instrument corresponding to *PR* in fig. 43 and which is designed to respond at a distant station to the movements of a pole-changer at a home station, is termed a "polarized" relay or, for short, a "polar" relay.

One form of this instrument, very generally used in duplex and quadruplex telegraphy, is shown in fig. 40. It is known as the Western Union polarized relay.

The polarized relay is a combination of a permanent magnet and an electro-magnet. The electro-magnet consists of short cores made of the best Norway soft iron, surrounded (when intended for differential duplex working) by "differentially wound" coils, each having a resistance of about 400 ohms. In some forms of polarized relays the core of the electro-magnet is extended beyond the edge of the coils so as to bring the poles face to face. These extensions, which are also of soft iron, are termed pole pieces.

A permanent magnet, *PM*, fig. 43, bent to the shape shown, rests on the baseboard of the instrument. These permanent magnets are formed of steel and are very retentive of magnetism. On the lower end *SP* of the permanent magnet the crosspiece of the electro-magnet rests. The crosspiece of the electro-magnet is a strip of soft iron connecting the two cores of the electro-magnet in the usual way. To the upper end *NP* of the permanent magnet is pivoted, at *X*, a soft iron tnbe, *A*, which extends between, and somewhat beyond, the poles of the electro-magnet. This is the armature of the polarized relay. This armature is constantly magnetized by its nearness to the permanent magnet *PM*. Assuming the end *NP* of the permanent magnet to be its north pole and *SP* its south pole, the armature *A* will be magnetized so that its end between the poles of the electro-magnet will be a north pole, and the ends of the cores of the electro-magnet, which are also magnetized by contact with the permanent magnet, will be south poles, that is, during the time that no "magnetizing" current is flowing through its coils. The term magnetizing current is used here advisedly, because of the fact that, in a "differential" relay, the current does not magnetize the core until an excess of current flows through one of the coils.

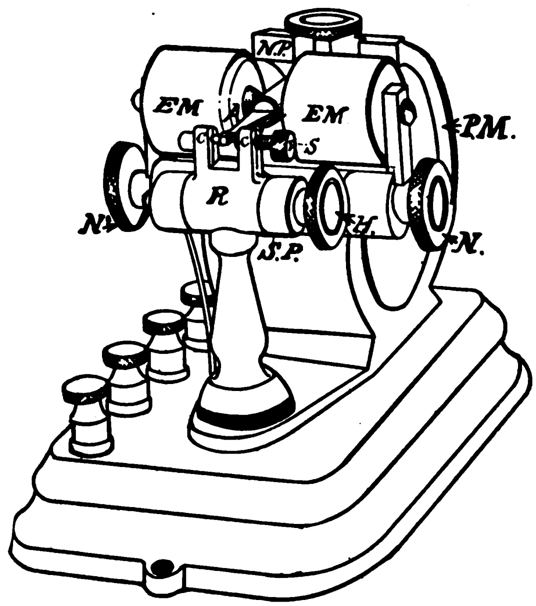


Fig. 40.

When, therefore, there is no magnetizing current in the coils of *EM*, the armature *A*, which, having no retractile spring, when placed exactly in the "center" between the two ends of *EM*, will be attracted equally by both ends, since a south pole on each side is "pulling" with equal strength at a north pole.

But, if the armature be placed nearer one pole face of *EM* than the other, it will be held toward that face or end. Consequently, under the conditions stated, the armature will stay on whichever side it is last placed. When, however, a magnetizing current passes through the coils of the electro-magnet, the magnetism in its core (due to the permanent magnet) is either increased or overcome, and its ends become north or south poles according to the direction of the magnetizing current, and the armature *A* is attracted by the south pole of the electro-magnet and repelled by the north pole.

The magnetism of the electro-magnet of the polarized relay changes in response to the reversal of the distant battery, and the armature vibrates to and fro between its front and back stops in accordance with those changes.

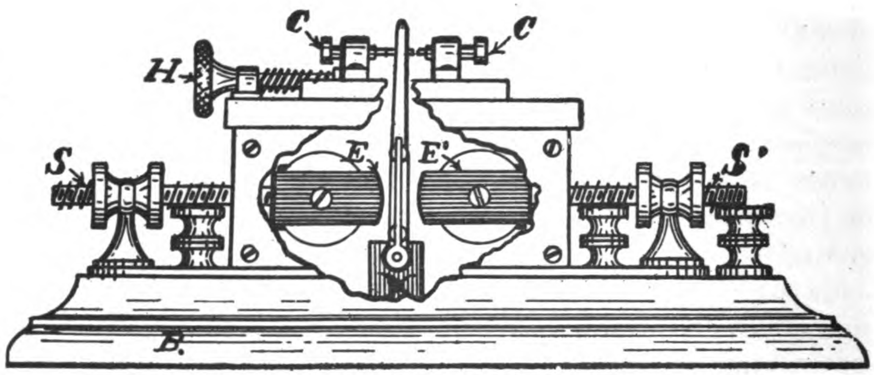


Fig. 41.

It is obviously essential that the magnetism of the permanent magnet should not be reversed by the reversals of magnetism of the electro-magnet, otherwise the magnetism of the armature *A* would be reversed also, and would fail in that case to respond properly to the reversals of the distant battery. Since the armature does respond properly, it is evident that the permanent magnet is not materially affected by the magnetic reversals of the electro-magnet. There may be a slight tendency to so change on the part, as it were, of the electro-magnetism of the electro-magnet, but, owing to the point at which the permanent magnet is connected to the cores or crosspiece of the electro-magnet—that is, at its "neutral" point, namely, at the middle of the cores, any such effect is not perceived in practice.

The play of armature of the Western Union polarized relay is adjusted by means of the small screw *S*. Its position between the cores of the electro-magent is regulated by the position of the front and back contact points c, c'. These contacts ride in a carriage which is movable, within certain limits, in the cylinder R.

The carriage is movable back and forth by the screw H. The armature may be placed directly in the "center" between the two poles of the electro-magnet by the movement of the screw H. The cores of the relay may be independently moved to and from the armature by the screws N N'.

A form of polarized relay, a modification of what is known in Europe as the Stroh relay, now the standard of the Western Union Company, is shown in side view, fig. 41. Its chief working parts are inclosed in a brass case with an ebonite top, in which there is an opening through which the armature lever comes. There is also a small opening in the sides of the brass case through which the pole pieces of the electro-magnets can be observed for purposes of adjustment. In the figure this opening is enlarged in order to show more clearly the relative positions of the coils E E', pole pieces, etc. In this relay an ordinary horseshoe magnet is employed as the permanent magnet. It lies horizontally under the base B of the relay as outlined in fig. 41, which is a side view of the relay. The relay has two electro-magnets with separate cores. In this form the electro-magnets lie horizontally, lengthwise, with pole pieces facing, and the armatures are vertical, lengthwise, the lower ends of the armatures being loosely inserted in a recess in short iron extensions from the respective ends of the permanent magnet by which the armatures are inductively magnetized. The pole pieces extend across the ends of the coils, but are connected to the cores as indicated. The pole pieces and coils are moved to and from the armature by means of the adjusting screws S S'.

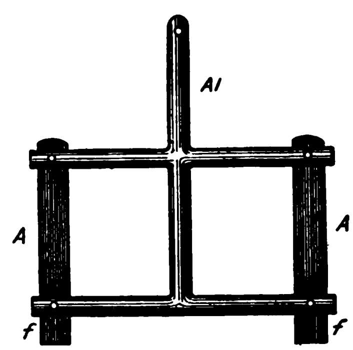


Fig. 42.

The local-contact point and back stop C C are movable in a frame which is adjustable by the screw H. The moving parts of this relay are much lighter than in some of those previously in use by this company, the light, nonmagnetic metal aluminum being used wherever practicable. As intimated, the relay has two separate armatures, which, however, are carried on a common frame, which is outlined in fig. 42. This frame is pivoted at f f. A A are the soft-iron armatures. $A1$ is the armature lever, also of aluminum.

THEORY OF THE POLAR DUPLEX.

The theoretic connections of a polar duplex at two stations, X and Y, are shown in fig. 43. In this, P C and P C' are the pole changers.

P R and *P R′* are differentially wound polarized relays. *B* and *B′* are main batteries.

R R′ are rheostats, or coils of insulated wire, adjusted to equal the resistance of the main-line wires. This, it has been explained, is necessary in order that, when the distant end is "grounded," the same amount of current shall flow through each coil of the differential relays, which will be the case when the resistance of the rheostats equals that of the main line.

In fig. 43 the pole changers at both ends of the line are open. This places the positive pole of batteries *B* and *B′* to the line. As these batteries are supposed to have an equal electro-motive force, no current flows over the main line. But a current from the respective batteries *B B′* flows to "ground," via the artificial lines, in a direction

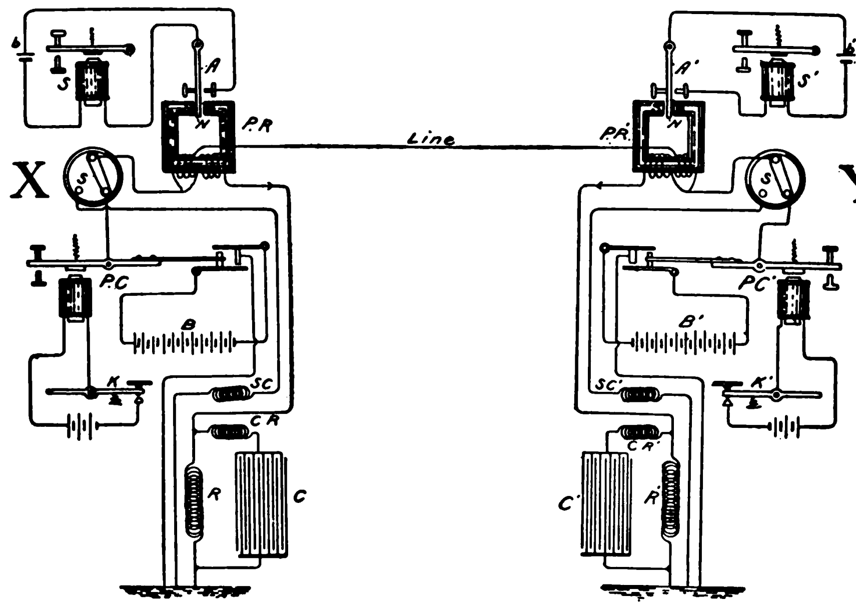


Fig. 43.

which so magnetizes the cores of *P R* and *P R′* that their armatures are withdrawn from their local-contact points, thus leaving the sounders open. It may perhaps be useful to explain these statements. When the terminals of a wire are at similar potentials no current will flow in that wire. In the case in point, when positive poles of equal electro-motive force are placed to the main line at each station it is plain that the terminals of that wire are at similar potentials. In the case of the artificial wires, on the other hand, the distant terminal of each is at zero, under which conditions, of course, a current will flow in these wires.

If, now, the pole changer *P C′* at *Y* be closed, it will place a negative pole to the line.

That action should reverse the magnetism in *P R*, but should have no effect on the relay *P R′* at *Y*. That such is the case we shall see. It is here suggested to the student that he draw diagrams to show these changes, inserting arrows to indicate the changed direction of the current.

With the positive pole to the line at *X* and the negative to the line at *Y* there will be twice the current flowing over the line wire that flows through the artificial lines. Before the reversal of *P C′* the current was flowing only through the artificial-line coil of *P R*, shown by the arrow, etc. After the reversal that current continues to flow, but now there is a current of twice its strength flowing in the main-line coil around the core of *P R* in an opposite direction. The result is that the magnetism of the core of *P R* is reversed and the armature *A* is moved over against its local-contact point, closing the local circuit. So far the result desired is brought about. Now let us see whether the polarized relay, *P R′* at *Y*, has been affected by the action which has reversed the polarity of *P R* at *X*.

Before the reversal of *P C* a current was flowing only through the artificial-line coil of *P R′* in the direction shown by the arrow. After the reversal of battery *B′* twice the current flows through the main-line coil that flows through the artificial-line coil, but its course through the main-line coil is in the same direction, around the core of *P R′*, as was the current which previously flowed through the artificial-wire coil, so that the magnetic polarity of *P R′* remains unaffected and its sounder continues open.

If the pole changer at *X* should also be closed, that action will place a negative pole of battery *B* to the line. The result will be that, since the pole changer at *Y* is also closed, the negative pole of *B′* is to the line, consequently no current will flow over it. But now the current through the artificial-line coil is in an opposite direction around the core to that which had made its magnetism north and south, as marked at its poles in the figure, and hence its magnetism is changed and the sounder is closed. It will also be found on examination that this reversal of the battery at *X* has not affected the relay at *X*, although the magnetizing current has been transferred from the main-line coil to the artificial-line coil.

From all of which it is evident that, with a proper "resistance" and "static" balance, the home relays will not have their magnetism changed by reversals of the home batteries, regardless of whether the poles of the batteries at the respective ends of the wire oppose or assist each other.

BALANCING THE POLAR DUPLEX.

The polar duplex is balanced by asking the distant station to "ground." This he does by throwing the 3-point switch *s*, fig. 43, to the left. (Sometimes the left-hand lower "point," or disk, is connected to the earth via *SC*, sometimes it is the right-hand lower point that is so connected.) This action disconnects the pole changer and battery from the line and transfers the latter to the earth via the resistance coil *SC* or *SC′*. These resistance coils are inserted, as in the Stearns duplex, to compensate for the internal resistance of the battery at each end. When the distant switch has been turned the

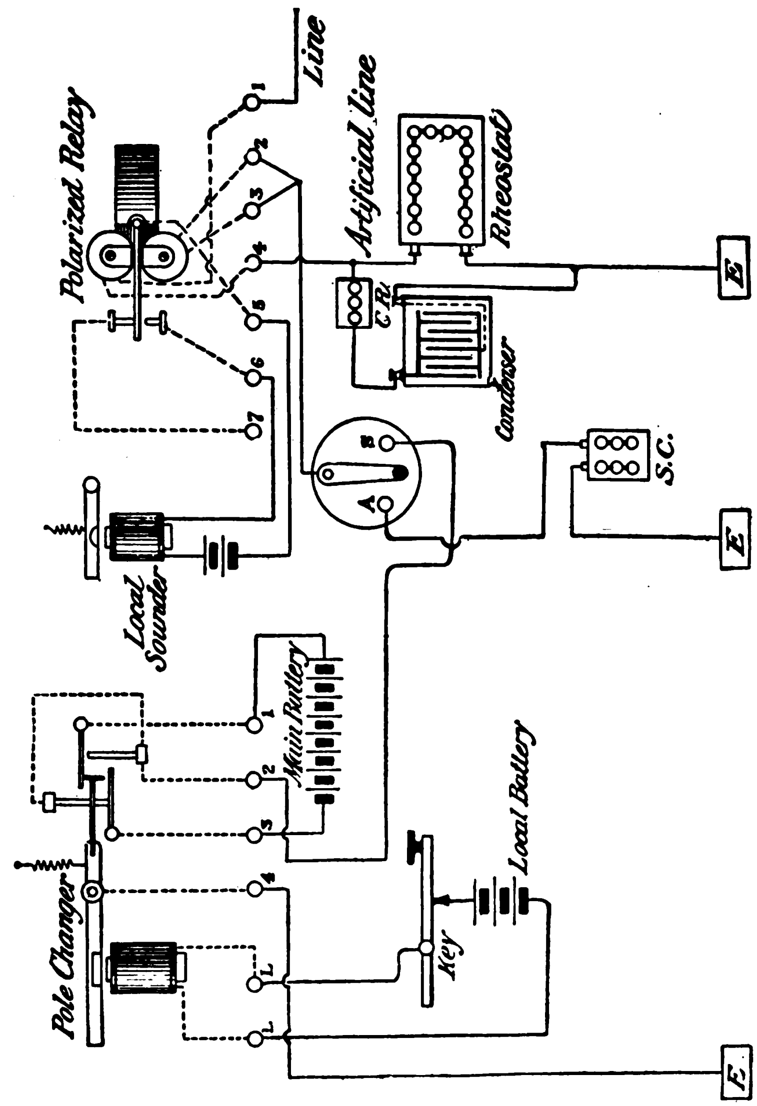


Fig. 44.

home switch is also turned similarly. The adjusting screw of the polarized relay is turned forward or backward until the armature remains on whichever side it may be placed. The home battery is then placed to the line by turning the switch *s* to the left. Then the pole changer is opened and closed and the resistance in *R* or *R′* is adjusted until the armature of the relay remains on either side, as before. This insures a "resistance" balance. The pole changer is now closed and opened rapidly, and if short clicks are heard the capacity of the condenser is varied until these disappear altogether. This shows that a "static" balance has been obtained. A static balance can also be got by asking the distant station to "cut in," which he does by turning the switch to the right. When he has done so, ask him to close his key, so that the armature of the home relay will rest against its contact point. The armature may then be given a slight bias away from its contact point and the home pole changer again operated. If clicks are still heard in the sounder, the condenser and its resistance coil are adjusted until they disappear, when the distant end may be asked to write a few words, to give an opportunity to readjust the armature to its proper place. As a rule, however, a good

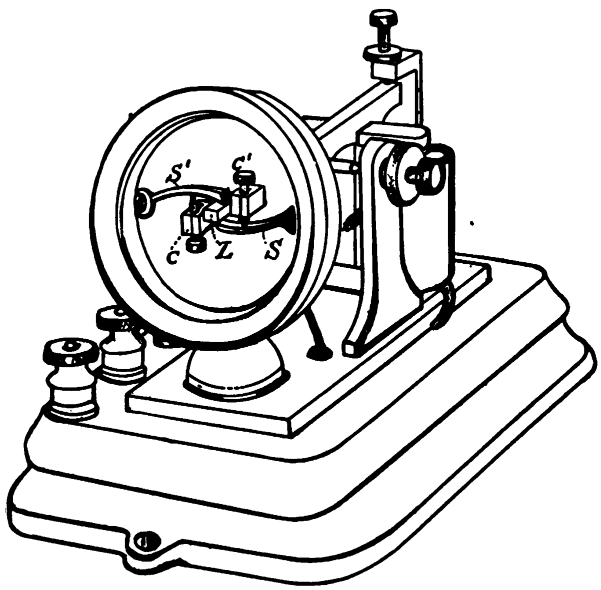


Fig. 45.

working static balance can be obtained on a polar duplex without giving the armature of the polarized relay a bias.

A diagram of actual connections of a polar duplex "set" at one station is given in fig. 44, with a gravity, or other chemical battery, as the source of electromotive force. The dotted lines represent the small wires connecting the apparatus to the binding posts. In the figure the polarized relay is shown with front and back local contact points leading to screw posts 6 and 7, respectively. The polar relay is not always equipped in this way, binding post 7 being generally omitted.

But the former arrangement is often useful, as it affords an easy means of putting the sounder on the "front stroke" when the distant battery connections are reversed, which frequently happens in practice. *CR* is the condenser resistance. *AS* is a 3-point switch used in "grounding" the line. *SC* is a "spark coil" or resistance box adjusted to equal the internal resistance of the main battery. The other instruments are as marked.

WESTERN UNION POLE CHANGER.

The Western Union standard pole changer for gravity batteries is shown in fig. 45. The contact points of the instrument are inclosed in a circular glass-incased box. The end of the lever *L* is seen extending into the box through an aperture in the back of the framework. The tension springs *S*, *S′* are insulated from the box. The contacts *C*, *C′* are attached to the framework. The poles of the battery are generally connected to the springs *S*, *S′* by way of their respective binding posts on the side of the baseboard. The lever is connected to the earth, and the contact points *C*, *C′* to the line, or vice versa, as desired; also via the binding posts.

Chapter VI.

THE ADJUSTMENT OF TELEGRAPH APPARATUS.[a]

If operators in general could be made to realize how much more comfort they might take in their daily work did they but acquire even a slight knowledge of the knack of adjusting their instruments properly, they would certainly make a move in that direction for their own interest if not for that of the company employing them.

There is positively no excuse for the indistinct manner in which signals are so frequently recorded on the really first-class instruments employed by telegraph companies to-day. When the signals do not arrive in proper shape there is some good reason for it, but the theory of the fault given by the average operator is usually wide of the mark, and as he " adjusts " in accordance with his ideas of the trouble, he generally makes matters worse by such efforts.

For the purpose of demonstration let us see what may be learned in the way of adjustment and care of an ordinary single-line relay and sounder. Now, we will assume that the wire, battery, and instrument coils are in first-class order and then introduce a few conditions for the purpose of noting the different effects produced on the apparatus.

WET-WEATHER EFFECTS.

In wet weather the quantity of current which traverses the coils of a relay is greatly increased at or near the battery station over and above that which normally flows in clear weather, while distant-station instruments receive less than the usual amount. This condition is caused by the numerous " escapes " or side paths down the poles along the route which draw additional current from the dynamo, all of which must necessarily pass through the relays inserted between them and the battery. Distant relays receive less than they are entitled to, because much of the current on the wire " escapes " down the wet poles before reaching them. Now, a strong current in the coils means a strong magnetic pull on the relay armature, while a weak current, of course, causes a correspondingly weak attraction.

It follows from this that the wet-weather method of adjusting a distant relay is directly opposite to that followed for the home relay at the battery end of the circuit. The operators at distant points

[a] By Willis H. Jones, in the Telegraph Age, September and October, 1902.

must get the magnets closer and closer to the armature as the downfall of rain increases, while the home operator is compelled to draw his relay coils away from it. This seems like a very simple operation to perform, but the manner in which most operators go about it explains why they fail to secure the best results.

Now, the first principle of adjustment lies in maintaining at all times, whether the current is weak or strong, a practically constant or normal tension of the retractile spring attached to the relay armature. The explanation is that a relay spring responds best to the magnetic attraction of the armature when the tension is such that the "curling" is not stretched to any great extent out of its original close-fitting construction when new.

The adjustment should invariably be done by moving the magnet backward or forward by means of the thumbscrew. The tension of the retractile spring need not be altered perceptibly except to give the operation a finishing touch. The habit of stretching the relay spring to meet a strong magnetic pull not only causes the former to work less efficiently at the time, but soon injures it permanently by destroying its sensitiveness.

FEELING FOR A DISTANT STATION.

It frequently happens in very wet weather that a distant office can not break the operator at or near the battery station on account of the difficulty the latter has in getting a fine adjustment. When informed via some other circuit that such is the case the best method to pursue is as follows: Make a few dots to attract his attention (he will hear you; the distant office has the advantage in this respect) and then tell him to "dot." Now pull the magnets back from the relay armature until the circuit stands apparently just open. Next, turn down the retractile spring very slowly until you hear the signals. If you miss them, you may sometimes catch them by placing your finger on the lever of the relay and giving it a gentle pressure back and forth. If the operator is dotting, you will feel the impulses and thus be able to readjust the instrument.

The latter method is an excellent one to pursue on a way wire when in doubt as to whether anyone is using the circuit, for by this precaution one operator need never break in while another is sending. However, as it is only in very wet weather that an operator is bothered to any great extent by the relay, the real source of daily discomfiture usually lies in an improper adjustment of the sounder.

ADJUSTMENT OF SOUNDERS.

When a sounder does not give out a loud enough tone to suit an operator, he almost invariably proceeds to give the lever a wider play, as if that was the only remedy. As a matter of fact that process in itself seldom brings about the desired results unless the lever at the time happens to be screwed down abnormally close. The important thing to know is that if you give the lever a play which will permit the armature to move away from the magnet cores beyond a normal distance, the magnet has a hard time getting control of it again. The explanation is that a magnet loses its power to attract the armature in a degree directly proportional to the square of the distance separating them; or, in other words, to the square of the air gap. For example, if two magnets similarly constructed in all respects be fed by an equal strength of current, and the air gap between the cores and the armature of one made the thickness of a cardboard, while two cards could occupy the gap in the second magnet, the former would be practically four times as strong as the latter. It is plain, therefore, that to give the sounder lever too great a play will so weaken the pull on the armature when in its "open" position that when the local circuit is again closed the lever moves so slowly at first that it hardly has time to cross over the space before the current is again broken. The result is that a signal is partially broken up before completion.

The lesson to be learned from this is that the play given to an armature lever must never be so great that the magnet can not bring it back promptly within the time allotted to complete a signal. This, in turn, suggests that the amount of play given should be decreased in proportion to the speed with which the signals are increased. The proper method to increase the volume of sound is as follows:

ADJUSTING FOR MAXIMUM STRENGTH.

Place a sheet of paper between the armature and the poles of the sounder magnet and then lower the former until there is just space enough to move the paper back and forth without catching. This permits the magnet to exert its maximum strength on the lever, and the position should seldom be altered. Whatever changes are necessary during the process of adjusting should be effected by means of the spring, the upper thumbscrew, and those which regulate the trunnion. The adjustment of the trunnion screws is a matter too generally overlooked. It is there that the pitch or quality of the sound is regulated. The pivot must not bind too tightly, nor yet be too loose.

When signals do not reach the operator in the particular style that suits his fancy, he usually attempts to remedy the fault by giving the sounder lever a greater or a lesser play. If the trouble happens to lie in an improper adjustment of that part of the apparatus he may possibly succeed in helping matters, but the fact is that indistinct signals may be due to a great variety of causes, any one of which, in his ignorance, he may never suspect.

For the purpose of illustration, let us again take the case of an ordinary single-line relay and sounder and assume that despite a careful adjustment of the relay and sounder magnets after the manner suggested in the preceding installment of this article the signals continue to " drop out " at times.

Now, the first thing to determine is whether the fault lies in the relay or the sounder. Such disturbances are usually due to a loose or improper connection somewhere in the local circuit, but not always. Naturally the first move made toward locating the trouble should be to examine all binding posts, and operators in general would save themselves many annoyances if they would acquire the habit of doing this whenever they sit down to a different set of instruments. If the binding-post connections prove to be secure, open the key and " dot " or " write " with your finger on the relay armature or lever, using the latter as a key. If the signals then respond firmly and distinct, the local circuit is not to blame, and attention should be directed to the relay.

In many cases the source of the trouble will turn out to be too tight an adjustment of the trunnion binding posts, thus preventing the restrained armature from responding readily to the influence of the magnet. This fault is particularly applicable to circuits in which the strength of the current flowing through the relay coils is weak. Where the main-line current is strong, the magnet is frequently able to overcome this drawback, but it is evident that even then the working margin of that instrument has been cut down to the extent that the trunnion binds. It follows, then, that the trunnion binding posts should always be so adjusted that the cross bar or axis upon which the lever and armature rests may move perfectly free in its sockets.

If, however, the signals made in the manner suggested continue to drop out despite this precaution, the fault will possibly be found in a loose connection somewhere in the local circuit. If tightening the binding posts fails to remove the trouble, examine the fine wire wound around the shaft of the relay lever, one end of which is attached to the shaft and the other to a part of that trunnion binding post where the local battery makes its exit. If this wire becomes broken, the sounder signals will certainly " drop out " at times owing to the loose connection made between the shaft and the post as the former turns in the socket. The purpose of the fine wire is to bridge over this unavoidable break in the local circuit, and the operator will at once see the necessity of keeping that connection intact.

When a sounder stands " open " and it is desired to ascertain if the break in the local circuit lies in some of the relay connections, place the blade of a knife across both local binding posts (situated just behind the relay spring). If the opening is in that instrument, the sounder will then close. If the latter remains open, try the same method with the two posts of the sounder itself. If the coil or wire connections there are broken, a spark will be noticed the moment the blade makes and breaks contact with the two posts. The sounder, however, will not close, because the magnet coils are cut out.

The knife-blade method, however, should never be resorted to where sounders are connected up in multiple, such as is usually the case in our large modernly equipped offices, because the cutting out of the coil draws so much current through the low-resistance route via the blade that it melts the fuse and opens the other four or five companion sounders comprised in that particular group. Operators see this fact demonstrated nearly every day in large telegraph offices when some one thoughtlessly or ignorantly permits a steel penholder or other piece of metal to simultaneously make contact with both binding posts of the sounder or resonator connections. When this occurs the "locals" go off on several adjacent desks and business is suspended until a new fuse is substituted. The blade may be placed across the local posts of the relay, however, because it will not cut out the coils of the magnet, hence the resistance is not lowered. It may also be done where the sounder coils are in series with a loop or lamp resistance, such as the arrangement obtaining on duplex and quadruplex circuits.

It will be seen from what has already been said that the adjustment and understanding of even an ordinary relay and sounder requires considerable skill and a fair degree of electrical knowledge, yet an operator who does not possess ambition enough to interest himself to the extent of understanding the instrument before him certainly deserves much of the needless provocations which come his way.

Up to this point the suggestions concerning various methods of adjusting telegraph apparatus have been confined to the receiving instruments. The sending apparatus, however, demands quite as much attention and skill on the part of the operator as the receiving instruments do.

Operators, as a rule, hardly realize the fact that with but a very little study on their part it lies within their power to not only make their own work much easier but that also of the man at the distant end of the circuit.

One of the most common mistakes the operator makes is to find fault with the key frequently because of his inability to send fast or to make the Morse alphabet easily. It may surprise many readers to learn that as a matter of fact the key is seldom to blame. It is really a matter of what is called the electrical and the mechanical inertia of the instruments that cause the trouble.

For example: In a telegraph wire, where there are a great many offices close together, such as we find on some railroad circuits, there are necessarily many relays, the highly wound coils of which compose the greater part of the total resistance. Where such a condition exists the counter electromotive force developed within and by the coils is so great that it checks the quick action of the current in its operation of building up the magnetism in the iron cores of the relays, and thus demands a slower rate of speed on the part of the sending operator in order to fully form his characters. Unless he complies with this law the second impulse in the formation of a character will be begun before the preceding one has been fully "built up," with the result that the key will "stick," as he erroneously believes, and the key gets the blame.

With sounders, as usually arranged, the case is different, but the effect is just the same. If you give the lever of a sounder an abnormally great degree of play, and then make "dots" exceedingly rapid, the lever will probably remain in an "open" position during the experiment. Decrease the speed somewhat and it will respond indifferently. If, however, you open and close the key very slowly, the lever will follow the movement faithfully. Finally, if you adjust the lever armature close to the magnet and give it but very little play, every "dot" will be heard, no matter how fast you make them.

The lesson to be learned from these experiments is that where speed is required the lever must be given as little play as practicable in order to reduce the mechanical inertia to a minimum. Where an operator ignores this rule in order to get a greater volume of sound to receive by he will experience the same difficulty in forming the alphabet as his friend with the choked relay did, and probably vie with him in condemning the greatly abused key.

The application of these lessons is directed principally to those in charge of duplex and quadruplex apparatus, and cautionary to operators in branch offices working sounders on legs or loop extensions. On account of the tongue and the retractile spring on transmitters, and the accuracy with which pole changers must be manipulated, those instruments demand very careful adjustment to the speed of the transmitting operator. Sounders, on the other hand, once properly adjusted, respond so clearly (on the transmitting side) that operators in branch offices working on duplex loops find that the sending side works, apparently, as well on a poor wire as a good one. The result is that in bad weather the fact is frequently overlooked that the pole-changer or transmitter, as the case may be, can not perform their functions properly at a dry-weather speed, and thus by maintaining their usual speed cause no end of trouble both to themselves and the quadruplex chief at the main office.

Chapter VII.

THE BUZZER.

THEORY OF THE BUZZER.

The principles upon which this instrument operates depend upon the comparatively high voltage developed at the terminals of an electro-magnet when the battery current through it is suddenly interrupted, and upon the sensitiveness of the telephone as a receiving instrument for feeble momentary currents, especially when they are of the sharply accentuated character produced in the manner just described. An automatic make and break vibrator gives a buzzing sound in the telephone receiver which, by short or long contacts of the key, produce the dot or dash of the Morse alphabet.

The first prominent mention of its use in military telegraphy is that by Major Cardew, R. E., in 1881. Its utility in working through a poorly insulated line where the ordinary Morse was impracticable was mentioned in the account of the expedition of the English up the Nile in the attempt to relieve Gordon at Khartoum in 1884. Some use was made of it in the French army.

It remained, however, for Col. James Allen, of the Signal Corps, U. S. Army, to perfect this instrument in its form and manner of working so as to make it an indispensable adjunct to any army operating in foreign territory. The American army in the Philippines and China has made a most extensive and continuous use of the buzzer as a means of maintaining communication between an army in the field and its base, and as an habitual means of telegraphy over hastily constructed lines where the insulation was too imperfect for Morse working.

An instance may be mentioned: In General Lawton's advance through central Luzon in November, 1899, communication was almost continuously maintained by this means for a week between Cabanatuan, the head of navigation on the Rio Grande, and San Jose, 30 miles north. About 10 miles of this was imperfectly insulated line and 20 miles was bare wire of various kinds laid on the earth, trees, and bushes. During part of the time heavy rain prevailed, and flooded rivers would have prevented messengers from going back. In spite of these apparently prohibitive conditions, the buzzer continued to operate. Of course it was very faint, and the utmost attention and complete quiet were required.

Such proofs of its utility, under trying conditions in the field, show plainly its rôle in military telegraphy for flying line and other temporary field connections.

Before describing the actual wiring of the standard buzzer the following explanation of the action of the instrument will make the principle clear.

If we join up four cells of dry battery and connecting them with a telephone receiver make and break the circuit, we hear the clicks whenever the circuit is broken. If the connections are now made as shown in fig. 46, *B* being the four cells, *K* a key for making and breaking the circuit, *E* an electro-magnet of about 5 ohms resistance, and *R* a telephone receiver, the click upon breaking the circuit will be very much louder and sharper than before, the reason for this being the high voltage self-induced discharge of the electro-magnet through the receiver when the battery current is broken. If we introduce an automatic interrupter into the circuit, whenever we close the key a loud buzzing sound will be produced in the telephone, and by regulating the length of contacts the dot or dash of the Morse alphabet

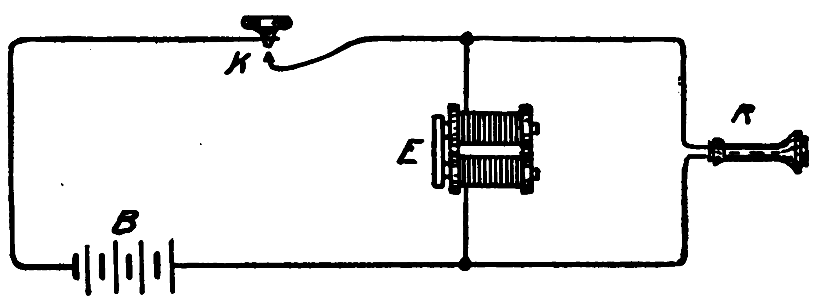


Fig. 46.

may be produced. The diagram (fig. 47), which is the simplified one of the buzzer, will now be plain.

The only changes are that an automatic interrupter I is introduced into the circuit with battery, key, and electro-magnet, and one of the receiver wires is carried to line and to the receiver at the distant station *R′*, thence to ground and return to the sending electro-magnet.

If by a switch we introduce all or a part of a battery, and a transmitter into the coil circuit instead of a key and interrupter, we may use the instrument as an ordinary telephone set. This is shown in the dotted-line connections with *T*, which represents a telephone transmitter with its switch. When the switch is closed and the transmitter is spoken into, the two cells of battery, on the right in the circuit, give undulatory currents through the transmitter and coils, which are transmitted to the distant receiver and reproduced as speech.

It may often be desired to utilize existing telegraph lines as part or the whole of the circuit for buzzer and telephone working, at the same time not interfering with the use of the wire for Morse working.

This is effected by using condensers interposed between the line and the buzzer. The condenser, as previously described in connection with duplex telegraphy, consists of many sheets of tin foil separated from each other by sheets of paraffined paper, all the alternate sheets of tin foil being connected together, thus making two sets of tin-foil leaves, the two sets being separated by the paraffined paper yet being very close together. No current will flow through the condenser if the battery be steadily applied, and if one set of leaves is connected with the telegraph line and the other with the ground no appreciable effect will be produced by the comparatively slow pulsations of the ordinary Morse sending; but if a buzzer is put on the line and another be connected in the wire leading from condenser to ground the very rapid pulsations or undulations produced by the buzzer or transmitter on the line will cause such correspondingly rapid charges and discharges of the condenser that it will transmit from one buzzer to the

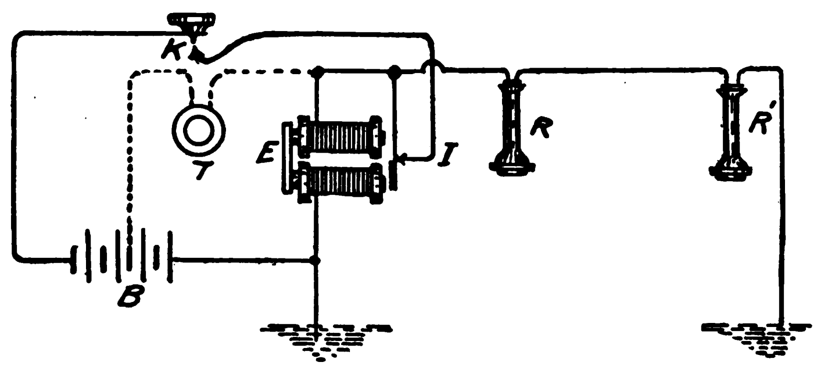


Fig. 47.

other with little diminution of the sound. At the same time ordinary telegraph business will not be interfered with.

Inside the cases of the service buzzer and the cavalry buzzer, condensers are provided, and one terminal is led to a separate binding post. Connection should be made to the line with this when the buzzer is attached to a telegraph line.

COMBINATION BUZZER AND TELEGRAPH TABLE SETS, UNITED STATES SIGNAL CORPS.

On top of the table the following instruments are mounted: Vibrator *B*, buzzer key *C*, sounder *D*, relay *E*, Morse key *F*, cylindrical switch *G*.

Beneath the table top are: Buzzer magnetic coil *A*, resistance coil for telegraph battery *I*, resistance coil for buzzer battery *H*, condenser, choke coil, and 6 cells of dry battery for operating buzzer.

A telephone receiver is connected to binding posts 48 and 49 for receiving either by buzzer or "receiver Morse." The buzzer battery is connected to binding posts 46 and 47. In case the dry battery runs down, 8 cells of the Edison battery may be connected to 46 and 47 instead of the dry battery. The main-line battery is connected to 20 and 21. In case no main-line battery is used at the station, 20 and 21 should be connected together.

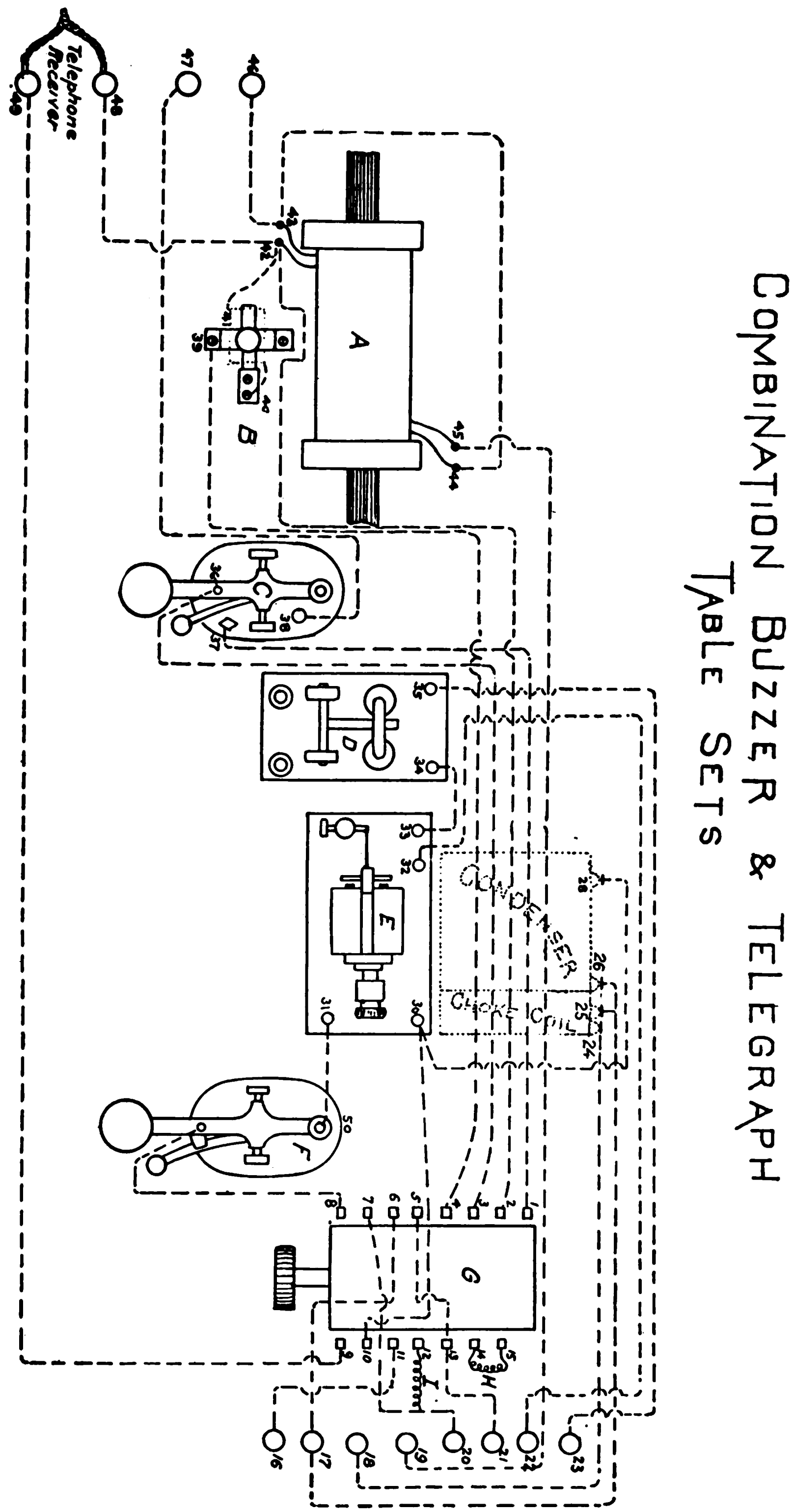
Local battery is connected to 22 and 23; 19 is connected with the ground. If the station is a terminal one, 18 is also connected with the ground. Sixteen is always connected with the line. In case of a way station, 16 is connected with one of the line wires and 17 with the other. With the pointer on the switch set at "telegraph," proper connections exist for sending and receiving Morse on relay and sounder, using key *F*. The main-line battery (if any) is thrown in, the buzzer battery is cut out, and the condenser is so connected that it "bridges" the station, permitting stations on either side to work through it with buzzer, or "receiver Morse." If at a terminal station, the choke coil is in circuit, connected with the ground through 18. With switch set at "buzzer," relay and sounder are cut out, and the main line battery is connected with a 1,000-ohm resistance coil *I*, to keep it in good condition. The line is connected, through the condenser, with the telephone receiver; the coil *A* with the ground through 19. When the key *C* is operated, the current from buzzer battery goes through vibrator *B*, key *C*, coil *A*, and switch *G* to battery, with branch circuits through receiver to line and to ground, as explained later. When switch is set at "telephone receiver Morse," and switch of key *C* is thrown to right (sending position), the vibrator is cut out, and the coil *H* is brought into circuit through front contact of key *C*, the other connections remaining the same. This gives good Morse in the telephone receiver, which may be used when line is too bad for relay and sounder working. The buzzer may be used under still more difficult conditions, and also may be of service in duplex working, as the simultaneous use of buzzer and ordinary Morse on the line is entirely practicable. Always throw switch of key *C* to the left when through working, otherwise the buzzer battery will soon be completely exhausted.

CIRCUIT TRACING.

Morse—Way station.—Current comes in on 16 from line, goes to 11, to 10, 30, 31, 50, through key to 8, 7, 20, through main-line battery or short circuit to 21, 5, 6, 17, out to line again. Note that 20 and 21 are connected through a short piece of wire if there is no main line battery at the station.

Terminal station.—On reaching 17 the current goes to choke coil at 25, out at 24, and to ground at 18.

Buzzer receiving.—Sixteen and 17 are connected together by switch; so current coming in on either goes to condenser at 26, out on 28, 30,



Wiring Diagram

FIG. 48.

10, 9, 49, through the telephone receiver to 48, 42, through first coil to 44, into second at 43, and out on 45 to 19 and ground.

Buzzer sending.—Current comes from battery, in at 47 to 38 on key *C*, 36, 3, 4, 39, through vibrator to 40, out at 41, 42, through one coil of *A* to 44, 43, 46, back to battery. When vibrator interrupts current,

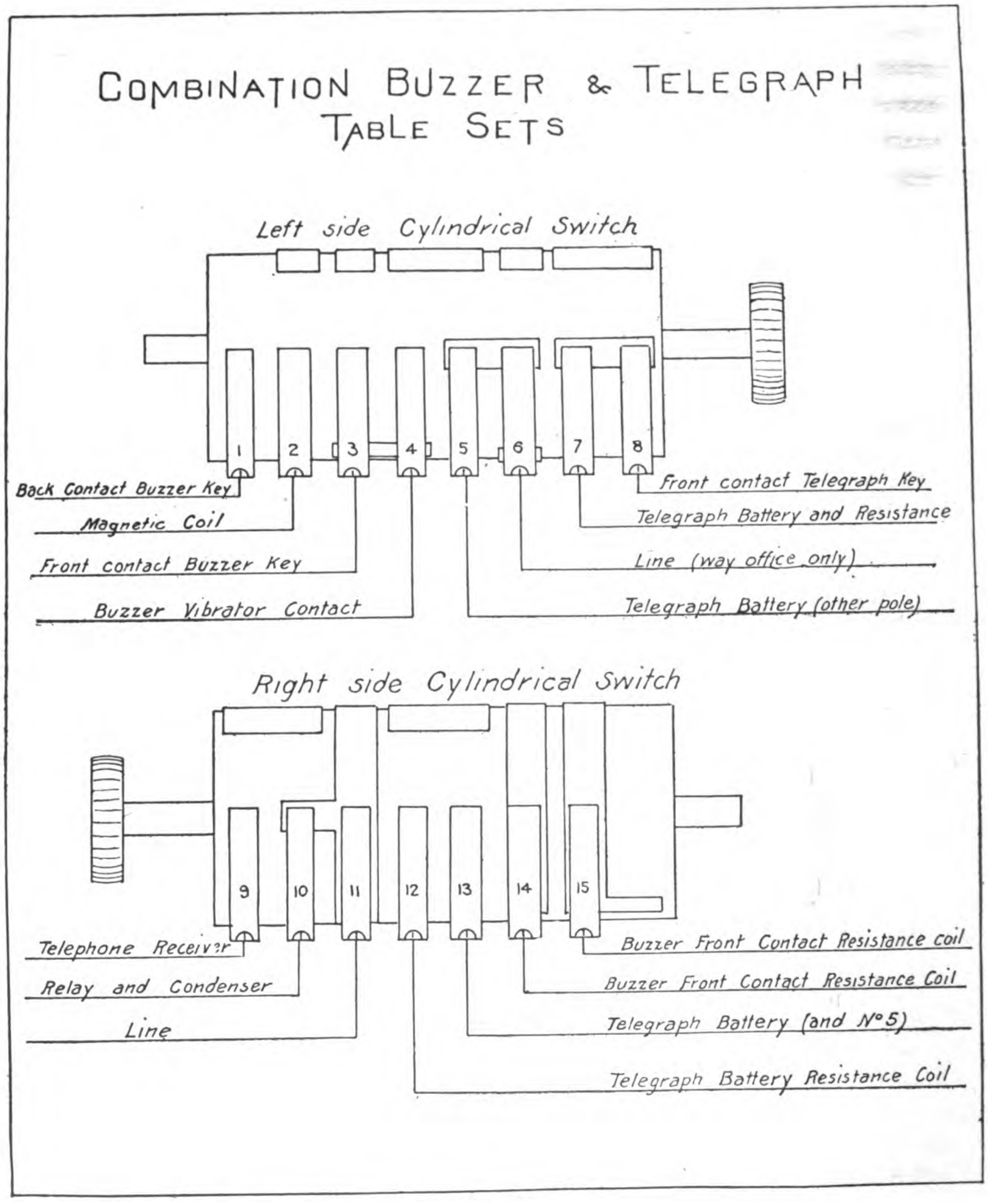


Fig. 49.

coil *A* discharges through 42 to 44, to 43, to 45, to ground at one end, and from 42 to 48 through telephone receiver, 49, 9, 10, 30, condenser, and line at the other.

When telephone receiver is used as Morse receiver, the circuits are as follows:

Receiving.—Same circuits as described in receiving by buzzer.

Sending.—Lever on key C in contact with 37. Current comes in from buzzer battery on 47, to 38 on key C, to 37, 1, 2, 42, through one coil of A to 44, 43, 46, back to battery.

When key is depressed the breaking of current at back of contact makes a loud click in the receiver through same circuits as explained in interruption of vibrator. When key is depressed contact is made in front (at 36) and current passes from key to 3 on the switch, 14, through small resistance coil H, 15, 2, 42, through coil A, 44, 43, 46, to battery. When this circuit is broken, the current being weaker than that through back contact owing to resistance H being included, the click is weaker, giving the effect of back stroke of sounder lever.

The telephone receiver terminals should be connected with 48 and 49, so as to get clear Morse. If unsatisfactory, reverse the connections to test for best result.

VARIOUS TYPES OF BUZZERS.

In the service and field buzzers, which are used for both telegraphy and telephony, the buzzer is simply a coil of low resistance and high self-induction in series with a circuit breaker, a telegraph key, and battery. On opening the circuit the discharge of the coil goes to line, and, owing to its high self-induction and consequently comparatively high electro-motive force of break, enough current reaches the telephone receiver at the other end of the line to give audible signals.

SERVICE BUZZER.

The service buzzer, fig. 50, is contained in a hard-wood box of cubical form, 8½ inches on the edge, and weighs about 8 pounds. The working parts are fastened to the front, which is hinged, and when in use lowered on a table. The back is also hinged to give access to the cells of dry battery that are contained in the body of the box. The transmitter and receiver fit in the space above the battery. A condenser of one-third microfarad capacity is placed under the board on which the working parts are mounted, and is connected to binding posts 2 and 3. The buzzer coils E are simply two coils wound in parallel, eight ohms each, one side of the windings of each coil being grounded on the frame at 8, and the other side connected at 9.

The circuit breaker consists of a thin iron reed, fastened by a screw to the core of the left-hand coil, and supported in the middle by a brass rod, which passes through a vertical standard at 12, and is capable of being adjusted by the two antagonistic lock nuts. There is a particular note for working best adapted to each condition of the line, and this note is obtained by changing the tension of the reed and altering the air gap between the free end of the reed and the core of the right-hand coil. The two contact points at 10 are of platinum, and the pressure of the stationary contact point is regulated by an adjusting screw, which also assists in changing the pitch of the note given by the buzzer. The circuits are shown in fig. 51. The receiver is attached to 4 and 5, and the transmitter to 6 and 7. The

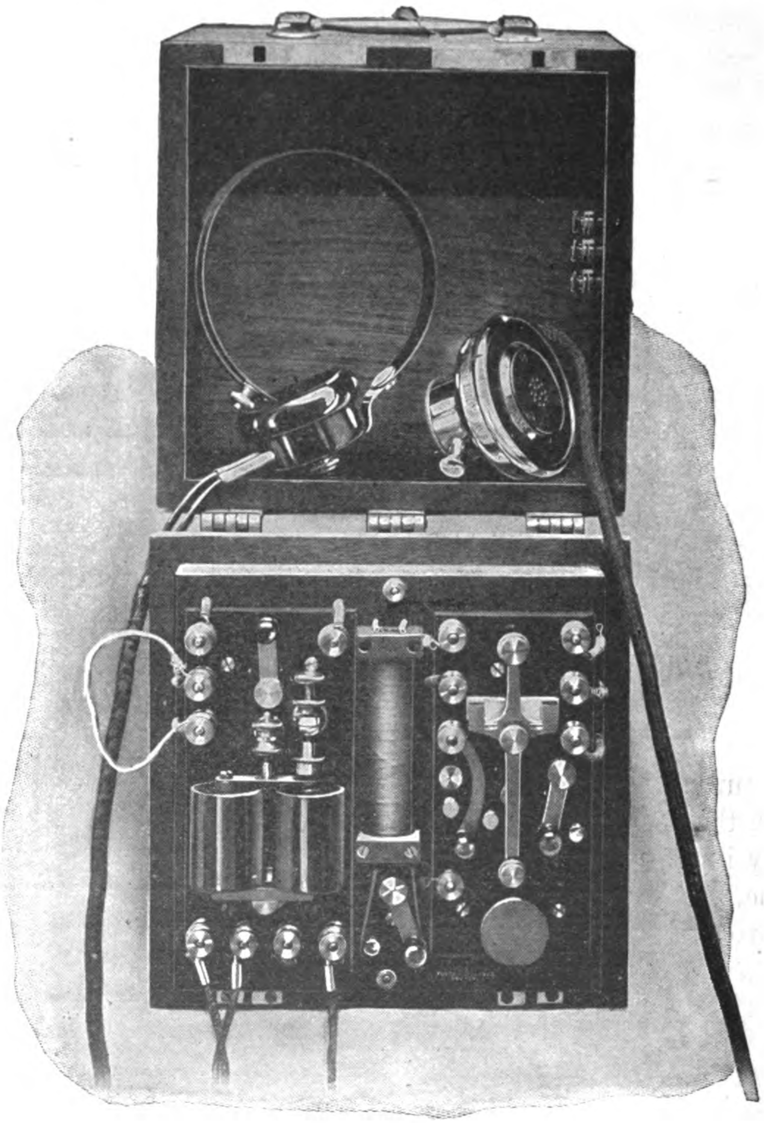


Fig. 50.

switch *A* short-circuits the contact breaker; the switch *B* changes the connection from telegraph to telephone; switch *C* is used in changing from buzzer to ordinary Morse; switch *D*, when closed, puts one-half battery on the Morse circuit; coil *F* is an ordinary telephone induction coil. When in use for sending buzzer Morse *A* is open, *B* is on 15, *C* on 25, and *D* open.

For ordinary Morse, A is on 12, B on 15, C on 26, and D on 34. For telephoning, A is either open or closed, B on 14, C on 25 or 26, and D open. The battery, which consists of six dry cells, is connected with 30 and 31, the middle of battery with 32. The sending key is the ordinary telegraph key with an additional front contact 35, which is so adjusted that it will barely break when the key is up. When sending buzzer Morse the current passes through battery, key, and coils to contact breaker, and thence back to battery. Each

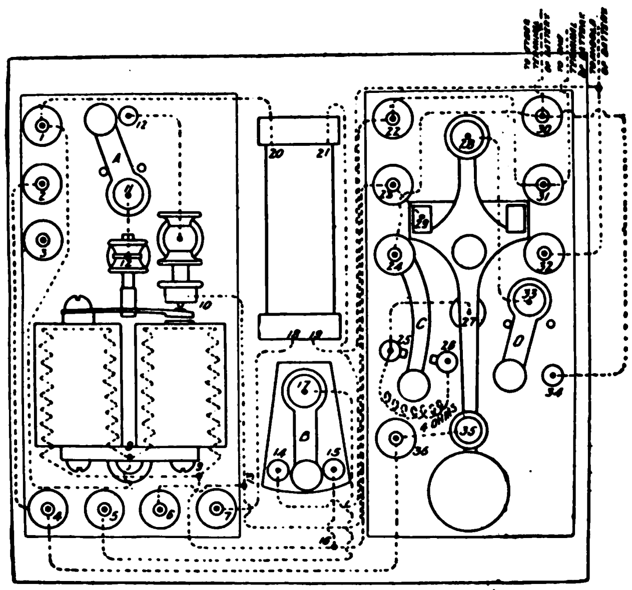


Fig. 51.

time the current is broken by vibrations of the reed at the contact points 10, the coils discharged at 8 and 9, and go through 16, and as the key is down to 23 and 29, through key to 35 and 36, and 4 to 2 and line, 1 being earthed. In receiving buzzer Morse the current passes through 2 to 4, through telephone receiver to 5, and back through 15 and 17 and coils to earth. In sending ordinary Morse the current is passing steadily from the battery to 30 and 34, through D to 33, to 28, through back contact of key to 29, and through coils as above, no buzz occurring as the vibrator is short-circuited. When the key is depressed the coils discharge, due to the break occurring at 28. This discharge goes to line as above, and gives a note in the receiver at the distant end. As the key is depressed contact is made at 27, and current now passes from battery through 30 and 24, through C to 26, and through the resistance to 25 and 27, through the key to 29, and through the coils as above. The current is consequently weaker than before, and when the break occurs on the up stroke the sound in the distant receiver is less than on the down stroke; thus giving the same effect as with an ordinary sounder.

The telephone circuits are the same as in the ordinary telephone. The condenser is used when it is desired to cut the kit in on a telegraph line.

THE FIELD BUZZER.

The field buzzer, old model, is a simplification of the service buzzer. The leather containing-case is divided by a vertical partition in two

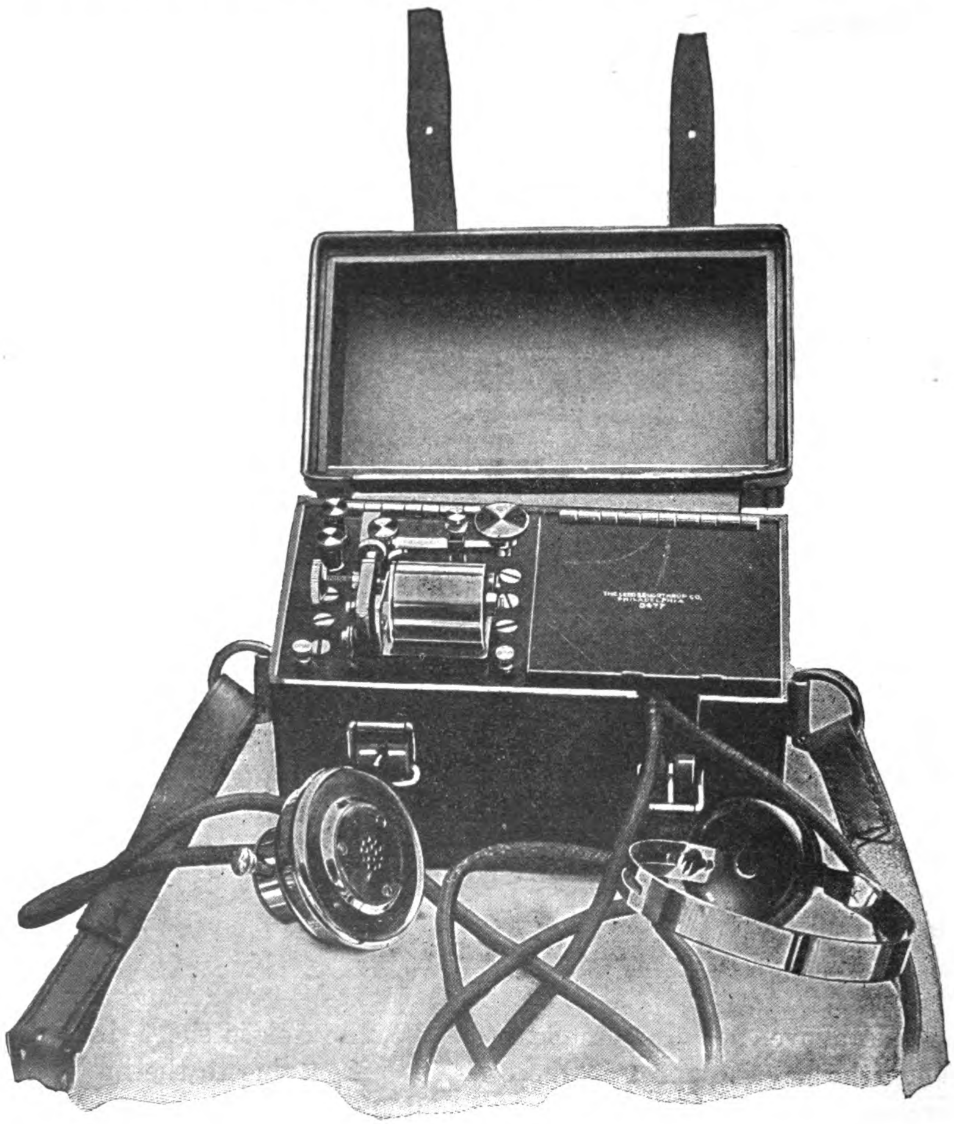


Fig. 52.

parts, one half containing four cells of dry battery; the upper part of the other half is covered by a hard-rubber plate, which supports a simple make-and-break key, circuit breaker, and buzzer coil, together with the line binding posts. Underneath this hard-rubber plate is a pocket for the head receiver and transmitter; this pocket is closed by a leather flap on the side. The wiring of this buzzer is the same in principle is that of model 1905, shown in fig. 53, except there is no condenser or 25-ohm coil. When used as a telephone instrument the buzzer serves as a call, and the battery circuit is closed by a switch in the side of the transmitter case. When the receiver is being used it must be held in a vertical position, otherwise the carbon granules may not touch the front electrode of the transmitter.

The field buzzer, model 1905, is shown in figs. 52 and 53. In this

WIRING DIAGRAM

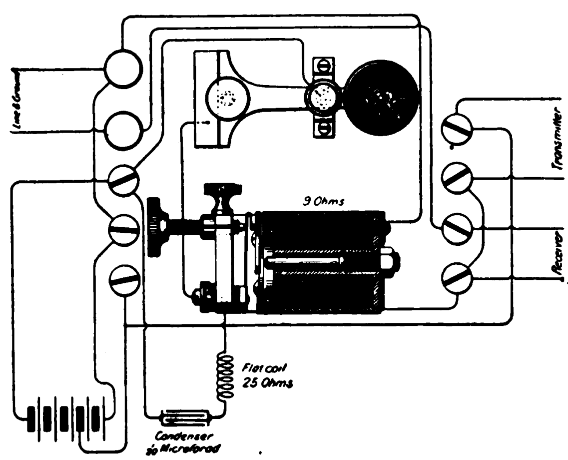


Fig. 53.

instrument the five dry cells and condenser are under the hinged half supporting the key and buzzer coil, and the transmitter and receiver are contained in the other half.

THE CUT-IN TELEPHONE.

The cut-in telephone (model 1905), as shown in fig. 54, is used for cutting in on an ordinary telegraph line to talk with repair parties without interrupting telegraphic communication and for outpost service in the vicinity of a telegraph line. The simplified diagram of the wiring of this instrument is shown in fig. 55. If a telephone receiver is inserted in the ordinary telegraph circuit the make and break of the current will cause a series of snappings of the diaphragm, which would completely obscure any talk; if, however, this snapping of the diaphragm is eliminated, talk coming over the line can be heard in the receiver. To do this the rise and fall of the current, due to the opening and closing of the Morse circuit, must be regulated with respect to the receiver so that no audible indication of it can be heard. This is done by inserting a coil of high self-induction between the telegraph instrument and the telephone. This coil so regulates the Morse current with respect to the receiver that when the telephone is joined through a condenser to the line no sound of the telegraph instruments can be heard, but telephonic speech coming over the line will be audible. The condenser, in addition to helping regulate the Morse current, prevents the telegraph line from being grounded

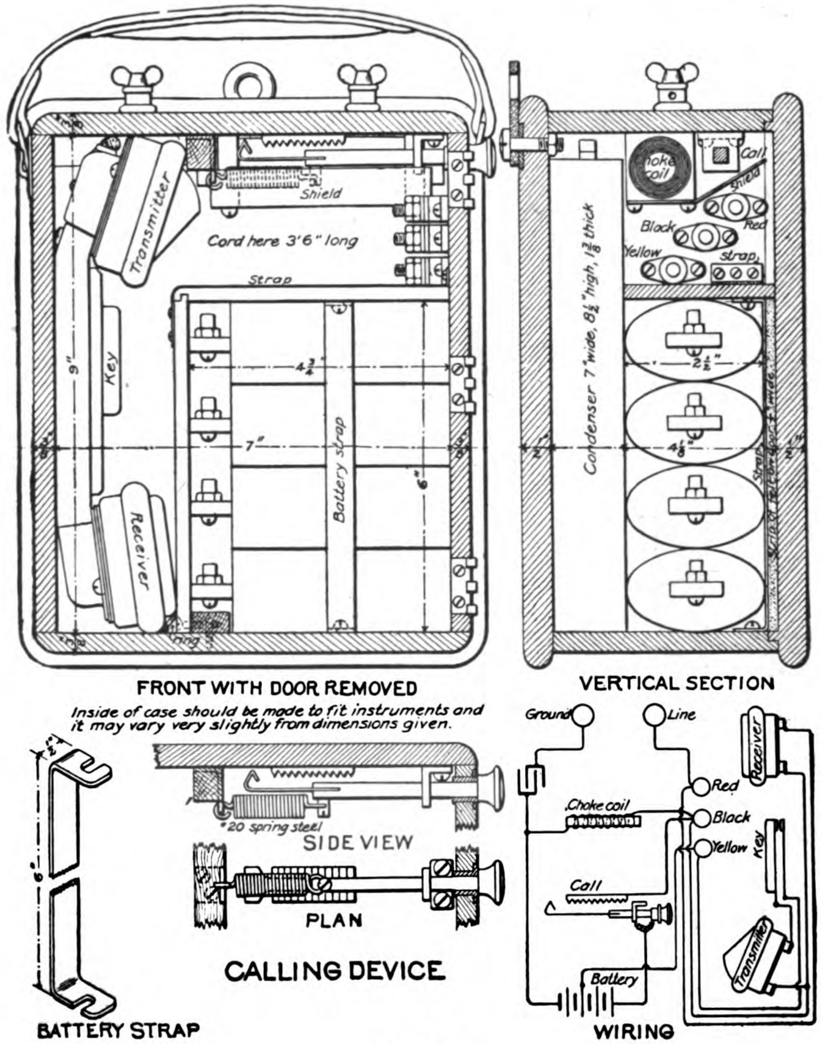


Fig. 54.

through the telephone. The hard-wood box contains a hand set combining the receiver and transmitter, the circuit of the latter being controlled by a spring switch in the handle. The box also contains the calling device, the choke coil, condenser, and the cells of dry battery. The choke coil, whose core consists of a number of soft-iron wires projecting a couple of inches beyond the ends, is wound to four ohms, so that when the serrated metal plate is scratched by the spring controlled by the button on the left the discharge current will be of such volume as to produce a loud note in the receiver at the distant station. When the two stations that are communicating with each other are between two telegraph stations, one binding post on

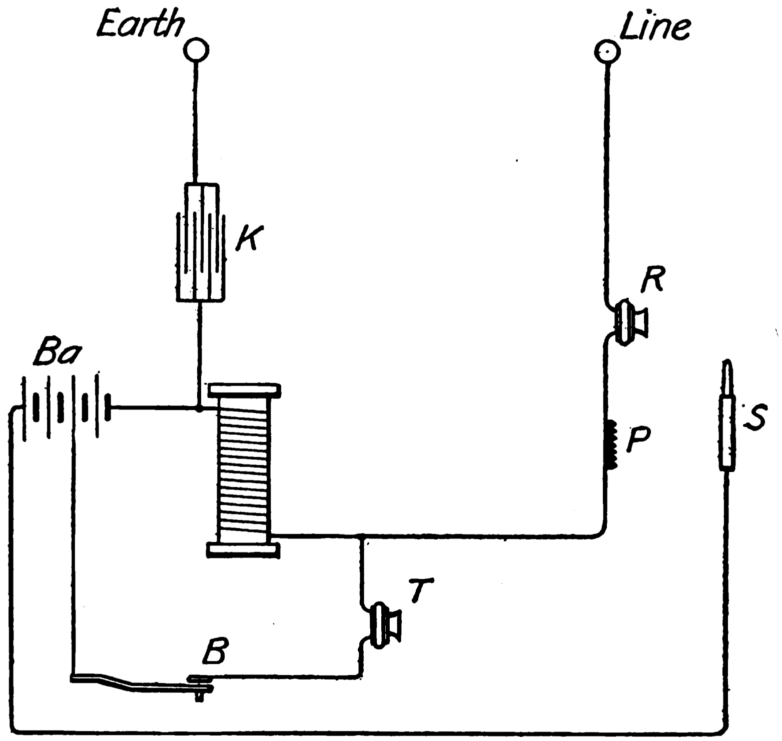


Fig. 55.

the top of each box is connected to the telegraph line and the other grounded. When a telegraph station intervenes between the two telephone stations, the telegraph set must be bridged by a condenser.

Chapter VIII.

SIMULTANEOUS TELEGRAPHY AND TELEPHONY.

The use of the buzzer in superposing a vibratory telegraph system on a line used for Morse transmission is described on pages 89–99, and the use of the telephone in connection therewith is also described. The " cut-in " telephone is designed for operation over short distances (usually between adjacent stations) on telegraph lines.

For permanent circuits over greater distances the following methods have been used: A modification of the Van Rysselberghe system is shown in fig. 56. The usual Morse set, consisting of key K, battery B, relay R, and sounder S, is connected to the end of the line. At

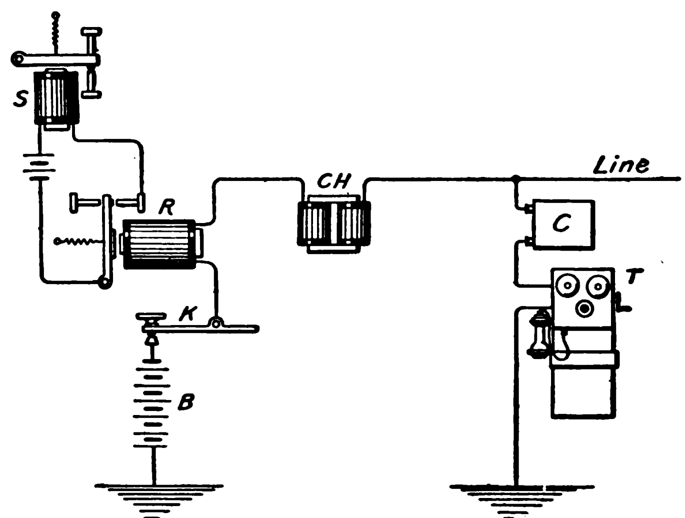


Fig. 56.

the same station a choke coil CH is introduced in the circuit. The telephone T at the same or adjacent station is connected to the line through a two-microfarad condenser C, the other terminal being connected with the ground. All telephones are connected to the line and ground similarly. At the other terminal station is a similar arrangement of Morse apparatus, choke coil, etc.

If there is an intermediate Morse station it is shunted by a two-microfarad condenser. If there is no Morse office at the terminal station, the last thing on the line should be a choke coil. The choke coils, assisted by the condensers, round off the telegraphic current waves, so to speak, and they produce comparatively little disturbance in the telephones. The condensers permit the rapidly alternating currents produced by the call bells or transmitters to pass, but do not " ground " the telegraph circuit.

If it is desired to utilize a metallic-circuit telephone line for telegraph purposes, as is now frequently done on the long-distance telephone lines, the arrangement of circuits shown in fig. 57 is made. *B* is the main battery, *KK* the keys, *RR* the relays, and *SS* the sounders of the Morse stations. From each relay the circuit leads to the wire connecting the two bobbins of the choke coils *CH*. The line wires are connected to the terminals of the choke coils. The telephones *T* are connected to the line wires as usual. It will be seen that the current coming from the battery and Morse set on the left divides at

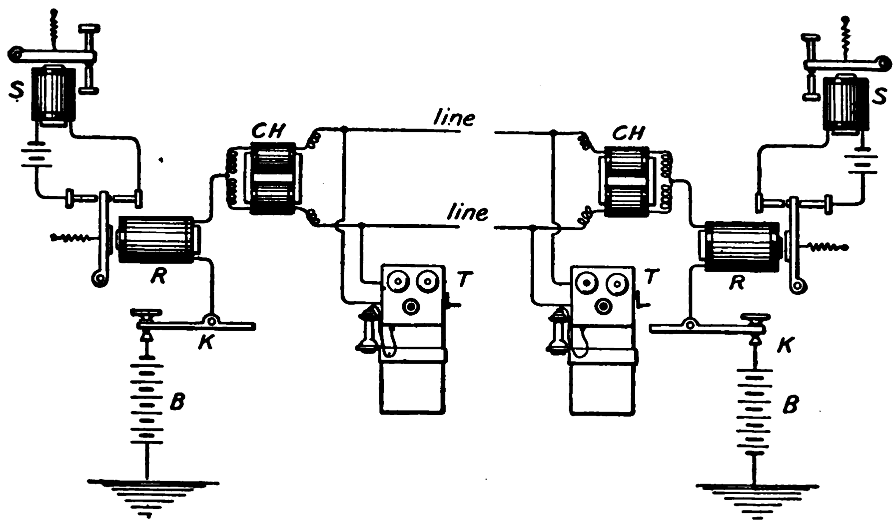


Fig. 57.

the choke coil, passing along both line wires, reunites at the middle of the choke coil on the right, and passes through Morse set on the right to ground. It does not disturb the telephones, because the *E M F* at both terminals of either telephone is always the same, since the current divides equally between the line wires. The telephone current, on the other hand, being a rapidly vibratory one, can not pass through the choke coils, and is confined to the line and two telephones, practically the same as if the Morse sets and choke coils were not connected to the wires.

It is essential that the choke coils be balanced quite accurately in the resistance of the bobbins of each pair, and that the line consist of two equal wires. Of course, any leak on either wire will destroy the balance of the circuit, and the telephones will be disturbed by the interrupted currents of the Morse grounded circuit. The choke coils in regular commercial use for this work have a large amount of iron and low ohmic resistance.

Chapter IX.

CONSTRUCTION AND EQUIPMENT OF PERMANENT AERIAL LINES.

Aerial lines constructed by the Signal Corps are in two general classes, namely, open wire lines and aerial cable lines. The construction of these two classes of lines varies to some extent, and they will therefore be treated under separate headings.

OPEN WIRE LINES.

KIND OF POLES.

The supports of a line must be poles of the most durable timber, preferably of red cedar, black locust, or heart of yellow (pitch) pine. Should these not be procurable, or only at too great cost, recourse must be had to other kinds of timber, such as chestnut, redwood, white cedar, red cypress, yellow cypress, tamarack, fir, larch, spruce, white or post oak, sassafras, and others, from which good service may be expected. Pine and cottonwood poles, wired to mesquite, cedar, or juniper stubs, can be satisfactorily used.

All poles shall be of the first quality of live green timber, free from rot, and sound and substantial in every respect. Each pole shall contain the natural butt of the tree and shall have an approximately uniformly decreasing cross section from butt to top.

All poles shall be cut between November 1 and March 1, and shall be free from all bark and soft wood. All knots shall be trimmed closely and smoothly. The sizes and dimensions of poles shall conform to the table below.

When octagonal poles are ordered they shall be of the same material as specified for standard poles, and shall conform in general to the dimensions of the table.

Dimensions of poles.

Length of poles in feet	Circumference in inches	
	At top.	At 6 feet from bottom.
20	14	24
20	16	25
25	16	25
25	19	27
25	22	30
30	19	30
30	22	34
30	24	36
35	22	37
35	25	40
40	22	40
40	25	43
45	22	45
45	25	46
50	22	46
50	25	48

Guy stubs and anchor logs.—The timber used for guy stubs and anchor logs shall conform in all respects with that specified for poles. Anchor logs shall not be less than 24 inches in circumference nor less than 4 feet in length.

Guy stubs shall not be less than 22 inches in circumference.

The timber to be used for pole braces shall be of the same quality as that specified for poles. No braces shall be less than 18 inches in circumference at smaller end.

NUMBER OF POLES.

The number of poles to be provided depends upon the character of the country, whether open, timbered, prairie, hilly, mountainous, etc., and upon the roads, whether crooked or straight. No less than 25 poles per mile must be used, but in timbered country, with crooked roads, it may be necessary to increase the number to 30, or even more in special cases.

PREPARATION OF POLES.

When practicable, the poles must be cut while the sap is down, and the bark removed, and allowed to season before they are placed in the line. This increases the durability of most kinds of poles, and facilitates the transportation and erection of the same. Well-seasoned poles may be preserved, but unseasoned poles are injured by charring. The top of the poles should be made wedge shape, so that they will completely shed rain and snow. The bottom of the wedge should be at least 4 inches above the top of the upper gain. The direction of the wedge should be in a line parallel with the wires and at right angles to the cross arms.

PROTECTION AGAINST LIGHTNING.

Wherever there is danger from atmospheric electricity, lightning rods must be attached to every fifth pole to facilitate atmospheric discharges and prevent the splintering of the poles. They consist of ordinary line wire, attached to one side of the poles by staples, and from end to end thereof continuously.

CROSS ARMS.

The standard cross arms supplied by the Signal Corps are indicated in the following table:

Dimensions of standard cross arms.

Length in feet.	Number of pins.	Pin spacing.		
		Ends.	Sides.	Centers.
3	2	4	....	28
5	4	4	15	22
6	6	4	12	16
10	8	4	15	22

INSULATORS.

The common screw-glass insulator, with a well-seasoned open bracket, gives excellent results. The brackets are attached with one 20 and one 40 penny nail. Various patent insulators have value for special uses.

WIRE.

For lines not subject to deterioration from salt water, galvanized iron wire in No. 14 or No. 9 B. W. G. is supplied. This wire is designated as extra best best. The tie wires are supplied in lengths of 12 inches in the same gauge as line wire, but annealed.

For lines exposed to the action of salt air and for common battery telephone work on comparatively long lines, No. 12 B. & S. hard-drawn bare copper wire is furnished. This wire is supplied in coils of 1 mile and should be handled with extreme care to avoid danger of bruising its surface. Any scratch or bruise should be cut from the wire before it is installed. Splices should be made, invariably using McIntyre sleeves, and no solder. The use of a soldering iron endangers the strength of this type of line. Tie wires are furnished in annealed copper wires, No. 12 B. & S., 18 inches long.

BUILDING TOOLS.

Adz; house carpenter's full-head, 4-inch blade.

Ax, hand (specified as broad hatchet); 5-inch blade.

Axes, handles for; to be hickory, clear, straight-grained.

Ax, lineman's; 5-pound, long-handle, all-steel.

Bags, lineman's; best canvas, with leather bottom, 20-inch.

Bars, crow; wedge-point, 17-pound, best tool steel.

Bars, digging; 1-inch round, 8 feet long, weight 17 pounds, and $1\frac{1}{8}$-inch round, 8 feet long, weight 28 pounds; both to be of solid steel.

Bars, digging and tamping; 1-inch round, tool-steel, 7 feet long, weight 19 pounds; 1-inch octagonal, tool-steel, 8 feet long, weight 25 pounds.

Bars, digging (electric spud); steel tubing with cast blade and tamper.

Belts, lineman's, for tools; 38, 40, and 44 inch, with loops, rings, and safety strap.

Bits, auger; sizes $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, and $\frac{3}{4}$ inch, all 8 inches long.

Bits, expansion; $\frac{1}{2}$ to $1\frac{1}{2}$ inch.

Bits, pole; 12 by $\frac{5}{8}$ inch and 16 by $\frac{5}{8}$ inch.

Braces, ratchet; 8-inch sweep.

Buffalo grip, with pulleys; No. 1 size, for wires up to No. 6; No. 2, for wires up to No. 0.

Chain, cow; 4-foot, with rings.

Chain, steel measuring; 100-foot.

Chisels, cold; $\frac{3}{4}$ to 1 inch, tool steel.

Chisels, socket framing, handles for; ring-topped, best quality hickory.

Chisels, socket framing; $1\frac{1}{2}$ to 2 inch.

Climbers; 16 and 18 inch, with straps.

Climbers, straps for.

Connectors (splicing clamps); for wires Nos. 9 to 16, iron; for Nos. 8 to 12, copper (for McIntire connections).

Coppers, soldering, with handles; 1, 2, and 4 pound.

Coppers, soldering, handles for, with ring ferrule.

Drill, rock; made of best tool steel, per pound, large and small sizes.

Files, dentist files; 5-inch, triangular; 8-inch, round; flat; bastard; half round, 8-inch.

Files, handles for; wood.

Furnace, gasoline, with 5-inch pot and ladle.

Hatchet; 4-inch blade.

Hammers, claw; 18-ounce.

Hammers, machinist; 2-pound.

Handles for hammers and hatchets; best grade hickory.

Handles with tools.

Hooks, cant; 4-foot, with handle.

Hooks, carrying; 4-foot handle.

Kit, inspector's pocket tool.

Knives, draw, telegraph pattern; 12 and 14 inch blade.

Knives, electrician's.

Lanterns, excavation; ruby globe.

Pick handles; straight-grain hickory.

Pike poles; 12, 16, and 18 foot, 2 inches in diameter, straight live ash or white or yellow pine, to suit locality.

Picks; 7 to 8 pound.

Post-hole augers; 12-inch, 5 feet long.

Post-hole diggers; 7-foot handle.

Pike, guarded or raising; 14-foot.

Pliers, lineman's; 6-inch side cutting, 8-inch side cutting, and 6-inch diagonal.

Pole support, jenny.

Pole support, mule.

Reels, pay-out; with handles and shoulder straps.

Reels, take-up.

Reel jacks; H. I. W. make.

Reel jacks, axles for; steel, 1, $1\frac{1}{2}$, 2, and $2\frac{1}{2}$ inch per foot.

Rope, pure manila hemp; $\frac{3}{8}$-inch, in coils of 1,000 feet; $\frac{1}{2}$-inch, in coils of 1,000 feet; ⅝-inch, in coils of 500 feet; ¾-inch, in coils of 500 feet; 1-inch, in coils of 500 feet.

Rules, carpenter's; 2-foot, brass-tipped and brass-hinged.

Rules, zigzag; 4-foot.

Saws, crosscut.

Saws, hack; blades, 12-inch.

Saws, hack; frame, 9 to 12 inch, adjustable.

Saws, hand; 26-inch, No. 7, 8-point.

Saws, rip; 26-inch, 5½-point.

Screw-drivers, perfect; 3, 4, 6, and 12 inch.

Shovels; 6 and 8 foot handles, with 18-inch straps.

Shovels, handles for.

Spades, grading; round and square pointed, D handles.

Spades, handles for.

Spoons; 6 and 8 foot handles, 18-inch strap.

Sheaves; double and single, wood or iron, with one or two beckets, or with becket and hook, Ford's patent bushings, sizes 3, 4, 5, and 6.

Tapeline; high-grade cloth, 100 and 50 foot, in feet and inches, leather case.

Torches, blow; hot-blast.

Tree trimmers, large size, without saws.

Tree trimmers, large size, with saws.

Tree trimmers, handles for; 18-foot, with ferrule joint.

Vise, jackstrap and; 5½-inch vise, black leather strap.

Wrench; combination lag and nut screw.

Wrench; steel tie wrench for Nos. 8, 10, and 12 wire.

Wrenches, monkey; 10 and 12 inch.

ERECTION OF LINE.

SURVEYING.

The route of the line having been decided upon and the materials prepared or procured, a competent person must proceed to measure the distances and indicate, by stakes, the places at which poles are to be erected. When the line follows highways or other defined routes, he will necessarily be governed by the bounds of such route, and must place his stakes within those bounds, and in such a manner as to avoid, as far as possible, danger to the line from passing vehicles.

As a general rule, in open (unfenced) country, where the ground is practicable for wagons, the stakes must be run in straight lines, but where there is a well-defined and traveled road the line of stakes must follow the general direction of such road, and be set at such distance from it that the line (when completed) shall not be exposed to injury from passing vehicles, or in case the wires should become detached from the insulators it can not, by any chance, hang in the road and interfere with or endanger traffic. With this in view, the stakes must be so placed that the line can be readily inspected and examined by repair men from the road. Whenever practicable, the line must be removed from the road a distance of about 30 feet. Roads should never be crossed unless imperatively necessary to avoid bad lands or trees which are too numerous to cut away, or to make material saving by shortening the line. In rolling country stakes must be planted on the crests of hills and not on each side, as in the latter case the wire will not be raised sufficiently high above the ground to be free from danger of being broken by passing herds or vehicles.

In level country the stakes must be set 70⅖ yards apart, or at the rate of 25 to the mile. This distance may be increased when the configuration of the ground renders it necessary, as in crossing streams, ravines, etc. In hilly, rolling, and timbered country, especially with crooked roads, it will be necessary to shorten the distance, even to 60 yards (29 poles to the mile), or in special cases to a less distance.

At all crossings the distance between the stakes must be shortened.

DIGGING HOLES.

The depth to which poles should be set depends upon the character of the soil in which they are placed. In rock, gravel, or stiff clays a depth of 4 feet is sufficient, while in light loam or sand it is necessary to increase the depth to 4½ and even 5 feet.

A foreman (or officer) must follow the surveyor with a sufficient number of men equipped with cutting bars and spoon shovels (particularly well adapted to digging in light soils), the ordinary long-handled shovel, which is more easily procured, or post-hole diggers, where the soil will admit of their use. This party will dig the holes for the reception of the poles at the stakes. If there is a sod, one of his men must be equipped with an ordinary spade, with which to cut and remove the sod, indicating the size of the hole to be dug, and facilitating the work by performing a part thereof for which the bars and spoons are not well adapted. The foreman (or officer) must see personally that the holes are put down to the proper depth, and are of the same size at bottom and top. He will have, of course, direction of the force, and be held responsible for good service. For poles at crossings, curves, and long spans, the holes must be dug to a depth corresponding to the strain to be brought upon them. For different lengths of poles the following rules will be observed: 22-foot poles, 4 feet deep; 25-foot poles, 4½ feet deep; 30-foot poles, 5 feet deep; 35-foot poles, 5½ feet deep; 40-foot poles, 6 feet deep; 45-foot poles, 6½ feet deep; 50-foot poles, 7 feet deep; 55-foot poles, 7 feet deep.

DELIVERY OF POLES.

The poles must be delivered as soon as practicable after the stakes have been set or the holes dug, with the butt of the pole by the stake or hole and the top in the direction from which the raising party will come. No equipment is necessary for this labor, except the means used for the transportation of the poles and stout staves upon which to carry them, if it should be necessary to move them to reach the holes. For crossings and long spans the heaviest and longest poles must be selected; for angles and sharp curves, select from the strongest.

ATTACHING INSULATORS.

As soon as the poles are delivered and before they are erected, the insulators and brackets must be distributed. A man (or men, as may be needed) equipped with a hatchet and supplied with nails will attach the brackets, first cutting a seat for them upon the side of the pole and at such a distance from its top that the insulator, when in place, shall not extend beyond the top of the pole. One 20-penny nail at the point and one 40-penny nail at the shoulder of the brackets will be required. The insulator must then be screwed on.

ATTACHING CROSS ARMS.

All cross arms carrying four wires and upward must be braced (fig. 58). Gains on these cross arms will not exceed 1 inch in depth and in no case shall gains exceed $1\frac{1}{4}$ inches in depth.

The distance from the upper side of the top gain to the extreme top of the pole will be 8 inches, and the distance between gains from center to center 2 feet. Cross-arm braces should be attached to the face of the pole and to the face of the arm. Two bolts will be used in all cross arms which are not braced and all shall be machine bolts. Cross arms must be placed alternately, first in one direction and then in the opposite except when special arrangement of line wires may require otherwise.

When building a bracket line cut the gain for the arm, then blaze a flat surface on the pole at right angles to the gain and fasten the bracket to the pole so that the top nail of the bracket is exactly opposite the top line of the gain, which will allow the installation of an arm in that gain without interference.

Cross-arm fixtures should, if practicable, be attached to buildings, with bolts passing through the wall. If this is not practicable the large size of expansion bolts should be used. Window casements or woodwork of buildings should never be used for resisting the strain of the line.

Poles shall invariably be armed before they are erected.

DOUBLE ARMS.

The operation of double-arming poles will be as follows: After cutting gains three-quarters of an inch in depth, put machine bolts through the two arms and through the sides of the pole in such a position that the bolts will have at least 2 inches of bearing in the

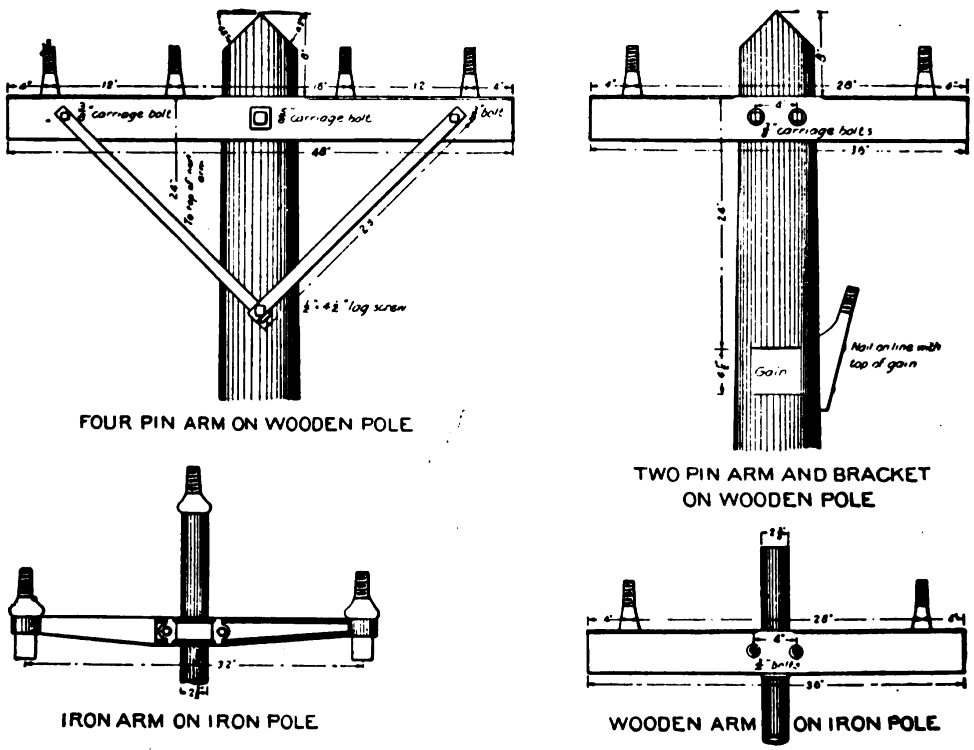


Fig. 58.

pole, and draw the bolts up securely; then place a block of wood of proper length between the ends of the two arms in such a position that the machine bolts, which will extend through both the arms and lengthwise through the block, will be just outside of the end pins. The top of the block should be flush with the tops of the arms, with the machine bolts just their thickness above the center of the arms. (See fig. 59.)

At points where iron and copper wires meet, the poles should be double armed, and double-grooved glass should be used as indicated in the sketch. The juncture of iron and copper wires should be thoroughly soldered.

Fourteen, 16, and 18 inch bolts should be used in putting double cross-arms on poles. Each bolt is furnished with two 2-inch washers, and the threads on these bolts are 3 inches in length. A 14-inch bolt can therefore be used as a 11, 12, 13, or 14 inch bolt, as the case may require, and there is the same margin on 16 and 18 inch bolts.

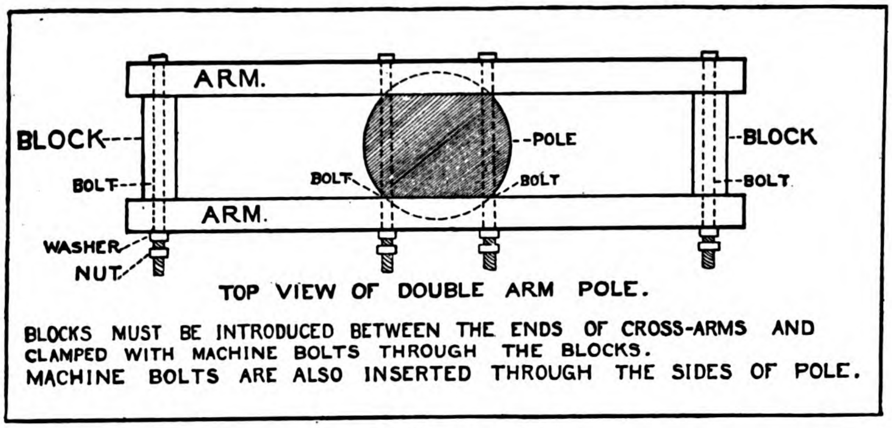


Fig. 59.

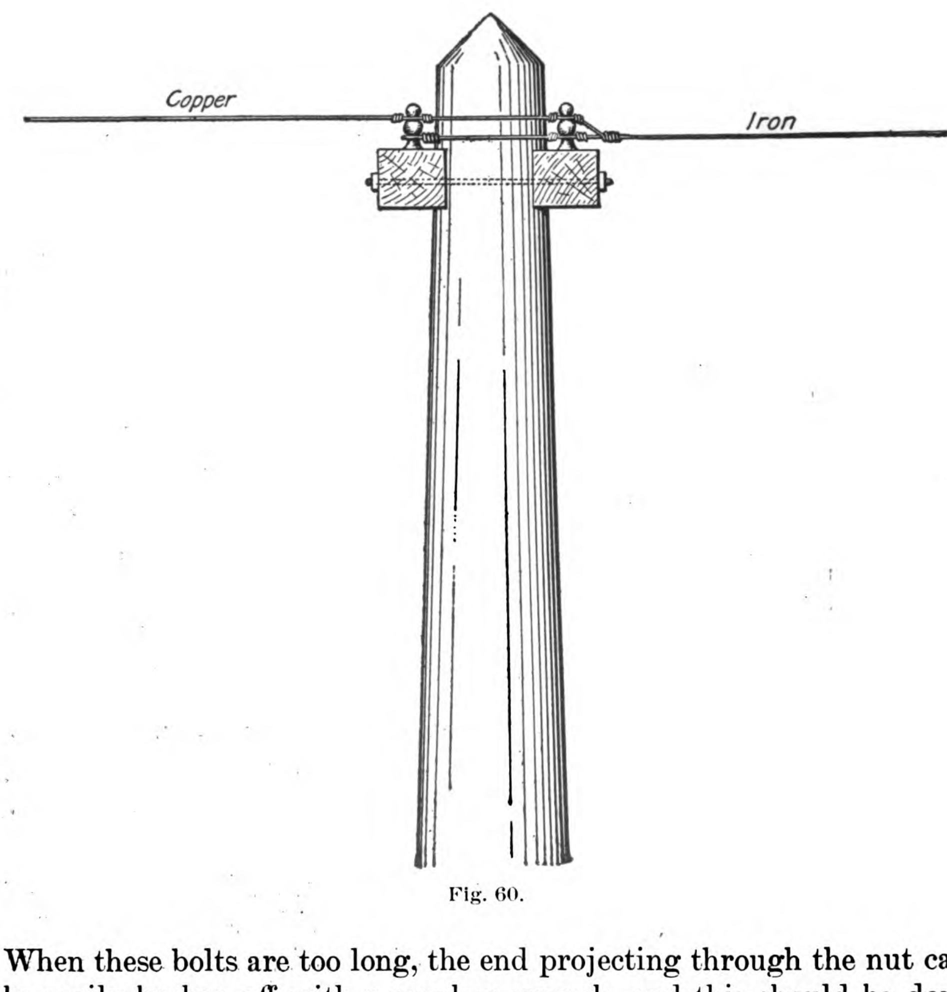


Fig. 60.

When these bolts are too long, the end projecting through the nut can be easily broken off with a monkey wrench, and this should be done in all cases where the end projects more than one-half inch.

LIGHTNING RODS.

The same man (or men) who performs the labor of attaching the brackets and insulators must also attach the wire lightning rods, and for that purpose must be supplied with the rods and staples. Lightning rods made of ordinary line wire must be attached to every fifth pole before erecting the latter. These will be securely fastened to the pole with staples in such manner that the line wire, in case it should become detached from the insulator, can not come in contact with the rods (one-fourth of the distance around the pole from the insulator). The rods must extend above the top of the pole about 3 inches and extend under and be firmly secured to the bottom of the pole.

RAISING AND SETTING POLES.

After the brackets, insulators, and lightning rods are in place the poles must be erected. A sufficient number of men (the number depending upon the weight of the poles), equipped with pikes, footplate (ordinary short-handled shovel will do), cant hook, shovels, and rammers, and directed by a foreman (or officer), will erect the poles, turning them so that the insulators shall occupy their proper positions.

The insulator must be placed upon the same side of all the poles and preferably away from the road, except at angles, crossings, or curves, where they will be so placed that the strain when the wire is strung will tend to press the insulator toward the pole. The foreman (or officer) must see personally that in every case the earth is well tamped around the pole from the bottom to top of the hole with tamping bars and heaped so as to shed water and prevent pools of water forming at the base of the poles. The success of the work depends greatly upon this, and on no account should it be neglected. Poles must be set vertically, except at angles or curves, where a slight inclination will be given them in such manner that the component of the strain in the direction of the length of the pole will tend to press it into the ground.

The slant of poles on curve should be gradual, so that the strain will be evenly distributed. All sharp curves or angles should be well braced or anchored. Braces are preferable where there is plenty of room, but under ordinary conditions one of the types of anchors shown in figs. 62 and 63 should be made use of. Braces should be set just below the bottom gain. In cities, where poles are liable to damage, pole shims or a wrapping of wire should be applied, to prevent abrasion from vehicles, etc., from weakening the line.

STRINGING THE WIRE.

To complete the line it is only necessary to string the wire. The force for this purpose consists of an officer (or foreman), a wireman and assistant, and a number of climbers, together with a wagon or other means for the transportation of the wire. The wireman is equipped with tools for connecting the coils, as file, vise, and pliers or joint tools, and should have also a hatchet and a few insulators to replace any which may have been broken in erecting the poles. A soldering pot is necessary, if it be practicable, to solder the joints. Great care must be taken in jointing the wire. This is done by turning the end of each wire—for four or five turns—closely and as neatly at right angles as possible around the other; the ends must be cut off short and, when practicable, the joint dipped in a vessel containing melted solder. The men for tying are equipped with climbers, climbers' belts, and pliers, and furnished with tie wires. The tie wires are short pieces of the line wire or of wire specially procured for the purpose, cut, annealed, and formed on an insulator, so that they will embrace the insulators and the ends project parallel to each other 2 or 3 inches beyond the line wire. The wagon contains a reel and one or more coils of wire. A coil of wire is placed upon the reel, the binding wires removed, the outer end of the wire led out and attached to the starting point. Then the wagon moves along the line as near the line of poles as possible, the wireman maintaining such a check upon the reel as will allow the wire to run out straight and preventing too much from being drawn off. The climbers, all at the same time, ascend the poles, carrying the wire which has been extended. Upon reaching the top of the poles and so securing their positions that their hands are free, each climber places a tie wire upon the insulator, the line wire against the insulator above the tie wire, and bends the ends of the tie wire upward, so as to sustain the line wire. The wireman then carefully strains the line wire, either by the motion of the wagon or the labor of men, as may be advisable, until the deflection in the center of a 70-yard span does not exceed $1\frac{1}{2}$ feet (allowing less in cold weather and more in warm weather), when the climbers, using their

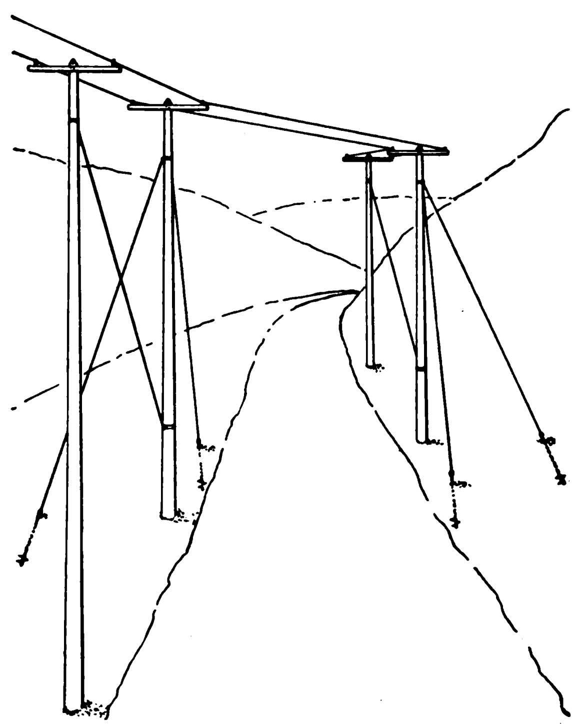


Fig. 61.

pliers, give each end of the tie wire $1\frac{1}{2}$ turns about the line wire, leaving the points of the tie wire toward the insulator, which secures the line wire and completes the work. In country free from timber the line wire must be secured to the insulator on the side toward the pole, so that the bracket will catch the wire in case of breakage of insulator; in timbered country, on the side away from the pole, so that falling trees will not break line wire, but merely tear it from the tie wire. The officer (or foreman) must see that each man performs his duty promptly and well; will order "up" when the wire is ready and the climbers in place at the foot of the poles; "haul" when the climbers have reached the top of the poles and placed the wire in position; "bind" when the wire is sufficiently strained. Wire should not be tied to trees when it can be avoided. It may save time and labor in the first instance, but the cost and labor of keeping such a line in repair will soon exceed what would have been necessary to erect poles throughout its entire length when the line was being built. When necessary to tie to trees, the regular tree insulator should be used or the tie wire fastened with the ends wound loosely to allow of an easy lateral movement of the wire.

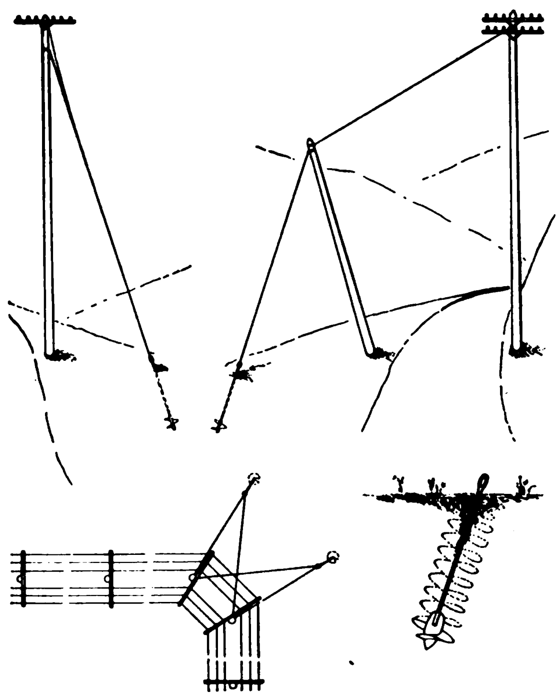


Fig. 62.

GUYING.

Figs. 61 and 62 show the proper method of guying a pole line with the standard guy anchor supplied for use in sand or clay bottoms. In case the soil is rocky, the anchor, shown in fig. 63, is used. Particular care must be taken at crossings, curves, and terminal poles to properly guy the line.

WIRES.

Wires must be tied on the side of insulators nearest the pole, except on curves or corners, where it may be necessary to place the wire on the opposite side, so that it will draw against the insulator. The ends of tie wires should be bent in and pointed toward the groove in the insulator.

Full-sized line wires should be carried to the inside of buildings from a cross-arm attached with iron fixtures to the wall, equipped with standard glass-and-pin insulators in such manner that the wires will have an upward direction from the insulators to the point where they enter the building. This will prevent rain and moisture from following them to the wall. Where exposed wires run into the building, they should be covered with a sloping roof board of sufficient width to perfectly protect them from rain and snow, and should be insulated with tubing where they pass through walls and partitions, using tubing of sufficient length to go entirely through the wall from the outside to the inside of the building, the object being to keep dry the outer end of the tube to prevent escape.

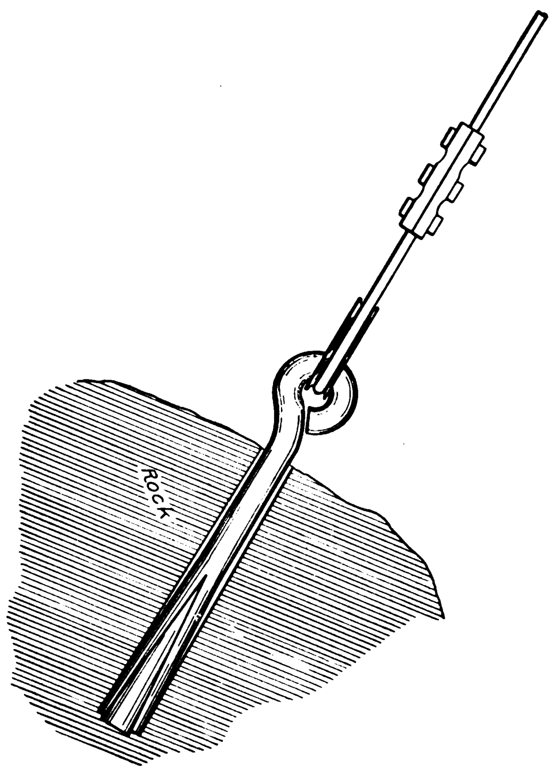


Fig. 63.

Where telegraph offices are located in railway depots or similar long buildings, the wires should enter at the window or other opening nearest the switchboard, and should be so strung that they can be plainly seen and easily inspected at all times.

At railroad crossings all the wires must be kept at a height of not less than 25 feet above the rails, and at public and highway crossings not less than 18 feet above the roadway. State or railroad regulations in the matter of crossings should be followed whenever they conflict with this rule.

In the construction, reconstruction, and general repair of lines all splices must be soldered, except on copper wires, where McIntyre sleeves are used as hereinafter directed.

All connections between copper and iron wires must be soldered.

The wires inside of a building should be insulated on porcelain knobs or wooden cleats, and kept as far apart and as far from the "ground" as possible. The use of staples for attaching office wires is forbidden.

Porcelain insulators and knobs must not be used outside of buildings. Rubber-hook insulators must not be used outside of buildings, except in places where they are completely protected from rain, snow, or moisture, and where it is impracticable to use the standard glass insulation.

All connections in main-battery wires must be soldered and the wires insulated.

Permanent terminal ground wires should be composed of large copper wire, soldered to the main gas or water pipes. (See p. —.)

Tubing for insulating wires through walls, wooden cleats, and all other material required will be furnished on application.

When necessary to make joints in iron wires which have been up a year or more use a third piece of wire, making a three-ply joint.

To solder joints in old wire, clean the wire at each end of joint, outside of the spiral turns, by use of file (instead of acid). When all rust is removed bridge the joint with No. 14 iron wire and solder thoroughly. Copper wire must not be used to bridge joints in iron wire.

Splicing and tying of copper and iron wires must be done by the use of the combination steel splicing and tie wrench.

HANDLING HARD-DRAWN COPPER WIRE.

While hard-drawn copper wire possesses hardness and strength for all practical purposes, it will not stand without injury the rough handling to which iron wire is ordinarily subjected.

Every coil should be examined before the outside cover is removed. In case the covering is torn, the wire itself should be carefully inspected to see that it has not been cut or bruised. In case the wire is found to have sustained injury, the injured portion should be cut out before using.

Copper wire should never be thrown from a moving train.

While unreeling, great care must be taken to avoid twists and kinks. Wherever either is found, it must be cut out and a good splice made. This should apply to splits, bruises, or indentations of any kind.

In tying the wire, care must be used not to tie it so tight as to cramp or kink it between the tie wire and the glass. Hard-drawn copper wire must not be tied or repaired with any wire other than copper.

When once hard-drawn copper wire is carefully put in place without kinks, indentations, or bruises, it will bear all the tests incident to change of temperature, sleet storms, etc., practically as well as iron or steel wire of a much lower conductivity.

Combination connecting pliers, Klien's all-brass clamps, or smooth-jaw Buffalo grips and steel splicing and tying wrenches are used for handling this wire.

JOINTS IN COPPER WIRE.

Joints in copper wire should be made by using McIntyre sleeves. To make these joints, pass each end of wire through the sleeve until it extends one-eighth of an inch beyond each end of sleeve (in order to bring ends of wire about flush with ends of sleeve when joint is completed). Then place steel tie wrench properly on each end of sleeve, hold left hand rigid and make three complete turns with right hand, which will complete the joint. The wire on each side of the man making the joint should be kept tight, so that an even spiral will be formed, and the joint not become humped or out of shape.

To tie copper wire to insulators, use soft tie wires 18 inches in length for 210-pound wire and 20 inches in length for 300-pound wire. Pass the tie wire around the glass and across it in front or on line side, with each end of tie wire projecting an equal distance on each side of the glass in the direction of the main-line wire. Place the line wire above the cross formed by the tie wire, and then turn each end of tie up as far as can be done by use of a steel tie wrench, forming a close spiral on main line each way from glass. This applies to level country and to poles situated on ground higher than the balance of the line. If a pole is in a low place and the main-line wire bears upward each way from that pole, place the main-line wire under the tie wire instead of above it.

GUARD WIRES.

Where guard wires are necessary to protect wires from other wires crossing above, they will be put up as described and illustrated below.

Poles 1 and 4 should be framed so as to leave 1 foot of the pole above the top arm. Poles 2 and 3 should be framed in the regular way, with pin in ends of arms, as shown in sketch. The dotted lines represent guard wires, which should be of No. 8 guage where the crossing is under low-tension wires. Where the crossing is under electric-light, power, or other high-tension wires, standard guy wire or No. 4 wire should be used as guards.

The guard wires terminate on the top of poles 1 and 4, where heavy porcelain knobs or other circuit breaks should be used when the crossing is under high-tension wires. The straight lines show the working wires as they will appear after guard arms and wires are up.

Where crossing under heavy lead, and heavy guard wires are used, guy wires should be run from the top of poles 1 and 4 to a point 8 or more feet from the butt of the next pole, to hold the strain of the guard wires.

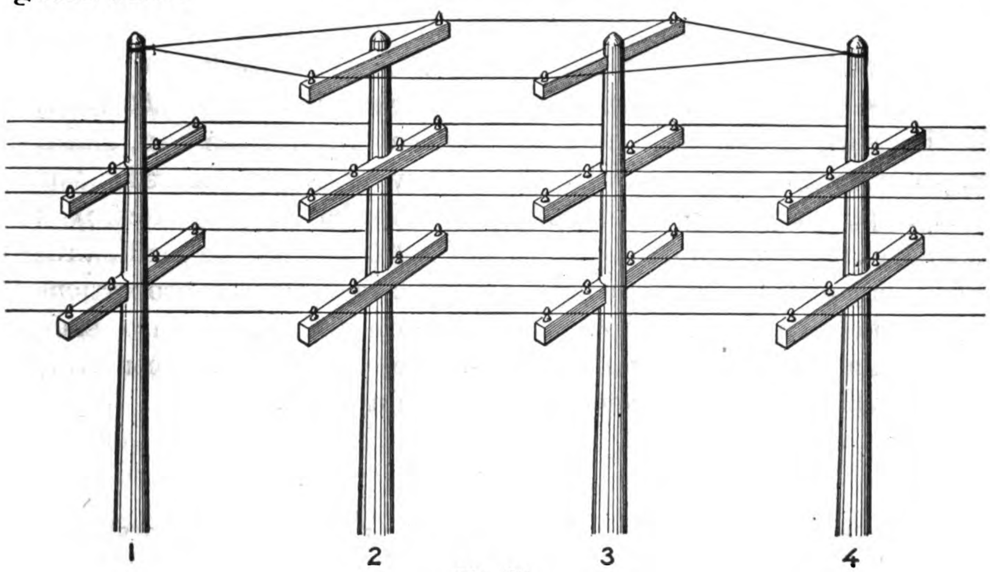


Fig. 64.

NUMBERING POLES.

Distinctly mark with paint each twenty-fifth (or mile) pole with its proper number, from the initial to the terminal point of the section, to facilitate rendering reports and to enable repair men to report locations of repairs made and needed.

CLEARING AND TRIMMING.

In forests or groves, especially such as are dense or choked with undergrowth, axmen must precede all others, except the surveyor, and clear the way for the work. When the line has been erected, they must follow and remove all branches or twigs which may be, or liable to be, thrown into contact with the wire, clearing back for a space of 4 to 6 feet, and removing all dead branches, no matter what their distance, that might be thrown down by high winds and, falling, endanger the line.

When the line passes through regions where it is liable to be injured by prairie fires, the sod should be broken and grass turned under to a distance of 10 feet from each pole. Officers in charge of telegraph lines running through such sections should send a party along the line each year to break the sod around the poles.

RIVER CROSSINGS.

When navigable streams cross the route of line, it is usually the better plan to use cables, except where they are liable to be washed out by freshets; but if this method be for any reason impracticable, elevated supports must be found or constructed and the wire suspended above danger from passing vessels. Natural supports, such as trees well rooted in safe positions, if such can be found of sufficient height, may be used, or masts erected and securely stayed with wire or wire-rope guys. If the span between supports be not more than 1,500 feet, the line wire can be used, care being taken to select the best, and a length without joints or with joints very carefully secured. For greater spans a steel wire (or compound wire having a steel core) is necessary, with which spans upward of 2,000 feet can be made, provided the points of support are high enough to allow of a proportionately deep curve to the wire. Extreme care must be given to such crossings, and too great strain avoided. The supports, whether natural or artificial, must be protected by lightning rods.

CABLES.

In placing a cable across an inlet, stream, or other body of water, it must be laid, whenever practicable, directly from the reel on which it has been received from the manufacturer. The reel will be rigged on a horizontal axle, in the stern of a suitable boat, or a small vessel when the weight of the cable is too great for a boat, and paid out as steadily and regularly as possible. Especial care is necessary to prevent the formation of kinks, and to cause the cable to lie smoothly on the bottom. Both shore ends of the cable must be buried sufficiently deep in trenches to thoroughly protect them from exposure to the air and injury from vessels, wheels, etc., and must be covered with stones or rocks of sufficient weight to keep them down, and prevent the earth from being washed away. The ends must be carefully secured to the cable pole in such a manner that the pole will serve as a buoy in case of the washing away of the pole. Lightning arresters must be used at both extremities of a cable, and placed in the cable boxes. These boxes must be made of well-seasoned pine plank, lined with woolen cloth or asbestos and well painted. The door must be hung with strong hinges, and the whole box must be water-tight when closed. In connecting the line wire with the cable, a hole large enough to admit the wire is bored through the side of the box. This hole must have considerable inclination from the inside downward to the outside, to prevent the rain from coming in. The wire must be brought down from the top of the pole, to which the box is attached, to the side of the box, and the end passed to the inside through a gutta-percha or porcelain tube, and bent over to prevent it from being pulled out.

The line wire must then be connected by a piece of bridle wire to the binding post at the fuse end of the lightning arrester. The cable should be connected to the binding post at the other end of the arrester. The ground terminal of the lightning arrester must then be tested to make sure that no ground exists between the coils and the ground plate. The door should be provided with a type of Yale or Corbin lock which is rust proof. The cable from the ground to the box should preferably be inclosed in an iron pipe, but where an iron pipe is not available a wooden box may be substituted. All cables should be anchored, using either a log buried in the ground below the permanent moisture line or Stombaugh guy anchors. Enough slack cable should be provided beyond the point of attach-

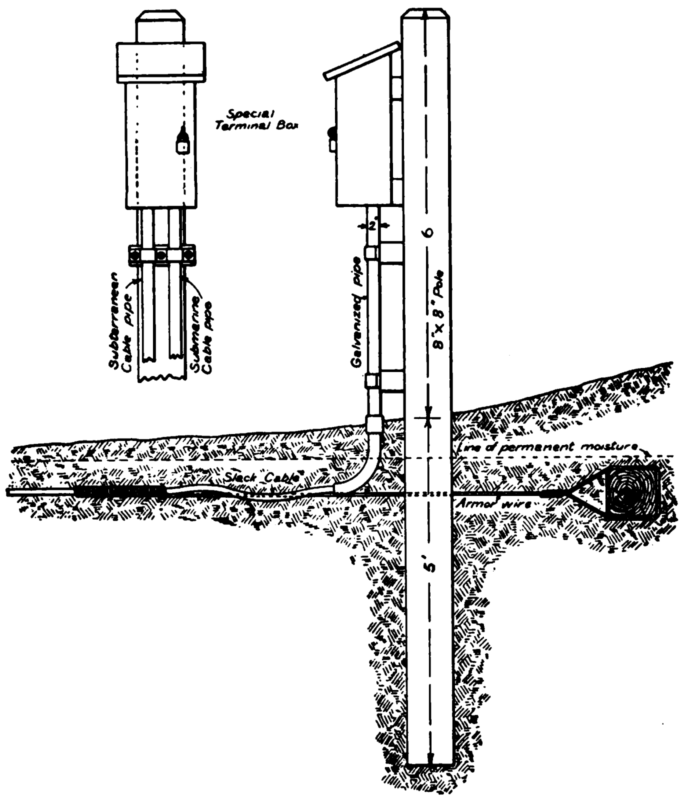


Fig. 65.

ment to the log or anchors to permit paying out some cable in case the cable has been caught by anchors and drawn taut. Anchoring should never be omitted unless the body of water crossed is not liable to floods or is not navigated by boats carrying anchors. (See fig. 65.)

AERIAL CABLE LINES.

CONSTRUCTION.

The construction of aerial cable lines follows the same method as described for open-wire lines so far as the erection of the poles is concerned. It should be noted, however, that these lines require especial care in guying.

In addition to the tools indicated under "Open-wire construction" there are supplied the following:

- Messenger cars.
- Reel jacks.
- Spinning jenny or cable spinner.

The supplies issued for aerial cable work comprise the following:

- Arresters.
- Balconies.
- Cable clips.
- Cable heads.
- Cable-pole boxes.
- Distributing rings.
- Guy anchors.
- Lag bolts.
- Lead pipe for pot heads.
- Marline.
- Marline cable clips.
- Messenger strand, $\frac{1}{4}$ to $\frac{1}{2}$ inch.
- Messenger supports.
- Ozite.
- Pasters.
- Plumber's solder.
- Pole steps.
- Pot-head wire.
- Resin solder.
- Tape.
- Thimbles.
- Three-bolt clamp.
- Two-bolt clamp.

CABLES.

The aerial cables furnished by the Signal Corps are invariably paper insulated dry core. They are furnished in standard sizes, as given below, the conductors being always No. 19 B. & S. and in twisted pairs.

Type No.	Kind.
401	10-pair.
402	15-pair.
403	20-pair.
404	25-pair.
405	30-pair.
406	40-pair.
407	50-pair.
408	75-pair.
409	100-pair.

MESSENGER STRAND.

The messenger strand will usually be supplied in either $\frac{1}{4}$ or $\frac{3}{8}$ inch sizes. The $\frac{1}{4}$-inch strand will be used for guys. The $\frac{3}{8}$-inch strand will be provided for cables up to 50-pair.

INSTALLATION OF CABLE LINES USING SPINNING JENNY.

After the pole line has been erected, as described under "Open wire lines," the messenger supports are secured to the pole in the position desired, usually below the brace of the lower cross arm. The hangers are secured in place by two standard lag bolts. After the hangers have all been installed, the messenger strand is strung out and pulled taut with block and tackle and secured either to a well-guyed pole or pole anchor. When the strand has been drawn taut the hangers should be screwed up in the same way that an aerial line is tied in. When this strand has been completely installed and all necessary side and head guys are in place, the cable should be strung through roller blocks, hung on the messenger at poles, and hung at the center of the strand or through leather straps provided for the same purpose. The marline should then be wound on the spinning jenny and the jenny drawn along the messenger wire, as shown in fig. 66. The cable will invariably be double spun, the jenny operating in the same direction each time. This will be accomplished by winding the marline on the jenny in a right-hand direction in the one case and in a left-hand direction in the other.

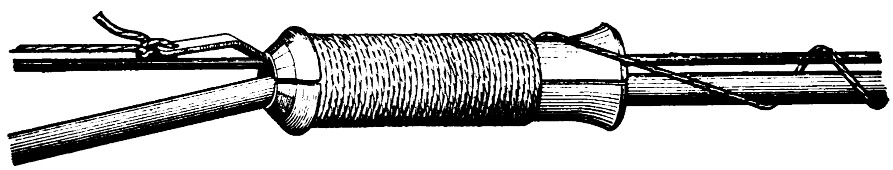


Fig. 66.

If the cable is small it may be laid directly along the ground to the base of the pole, allowing the spinning jenny, assisted by the man on the pole ahead, to lift the cable into place.

The marline should be securely lashed to the messenger at each pole, so that the failure of the marline at any one point will only release one-half of the support of the cable between two poles and will have no effect on the cable at any other point.

THE INSTALLATION OF AERIAL CABLE USING CLIPS.

Two forms of aerial cable clips are approved. These clips are known as the standard Boston cable clip, which is of metal, and the marline clip, which consists of a galvanized-steel hook and a strong loop of marline varying in length with the size of the cable to be installed. These clips are shown in fig. 67.

The same general method is to be used in installing both types of clip, care being taken that the Boston clip is attached to the cable exactly as shown in fig. 67. The messenger strand is installed and clamped in place at every pole or at every other pole, depending upon the average length of span and the number of men available for the installation of the cable. The strand, after passing through

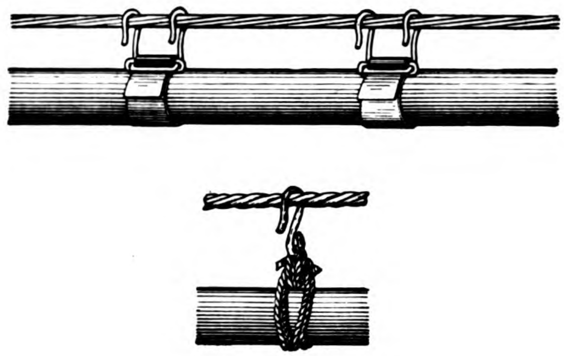


Fig. 67.

the last support, is secured to a guy stub set in the ground near the reel. The reel is placed on jacks on a line with the poles and the cable is paid out along the strand as shown in fig. 68. It is desirable that rollers to support the cable between the reel and the anchor

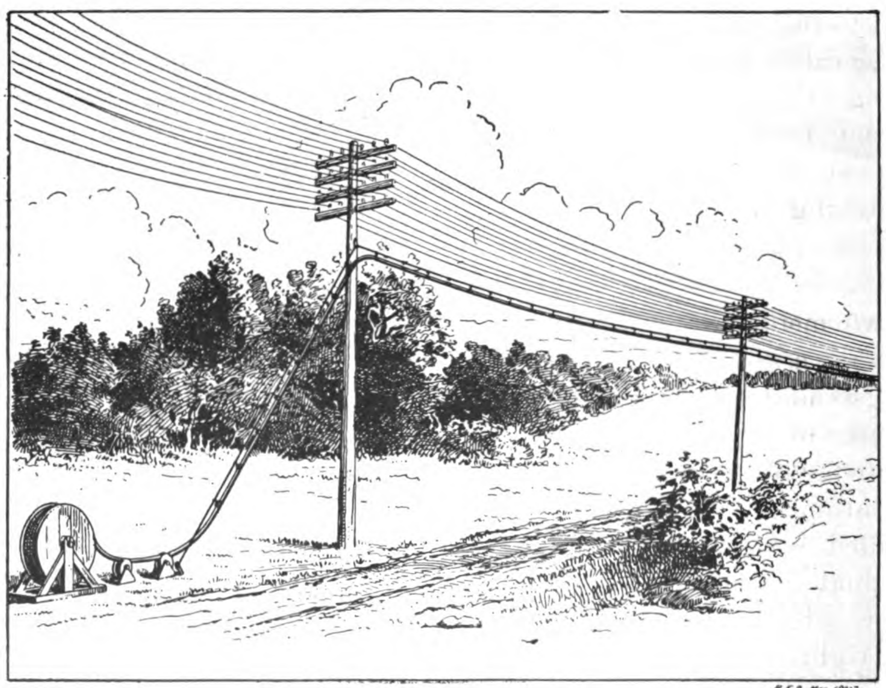


Fig. 68.

of the messenger wire be installed and that a man be stationed at this point to secure the clips to the cable as it is paid out. A "pulling in" line of wire is firmly attached to the end of the cable and is passed along the line of messenger wire in such a manner as to make the pull at all times in a horizontal direction. The exact method of running up this wire will be determined by local conditions. It may be practicable to lay the "pulling in" line along the entire length over which the cable is to be drawn.

A lineman is now stationed at every pole to which the messenger wire has been secured, it being his duty to pass the messenger clips over the hangers as the cable is drawn forward. It will usually be found desirable to omit placing all of the clips on the cable at the reel and to supply each lineman with a sufficient number of clips to provide for the stretch between his pole and the pole occupied by the nearest lineman. When the cable end passes the lineman nearest the terminal pole a signal is passed down the line and the linemen hook on all the clips, so that when the cable is finally drawn into place all clips are in position.

Under usual conditions the clips are installed on 24-inch centers, and before the installation is completed care should be taken to see that the distribution is uniform. No marked sagging of the cable at any point should be allowed. Where a considerable amount of cable is installed and clips are used, a messenger car may be required to facilitate the distribution of these clips.

In installing heavy cable care must be used to avoid undue strain on the cable sheath, which might cause it to become very thin without giving evidence of its weakness on casual inspection. Paper cable depends for its efficiency absolutely on its lead covering, and too much care can not be taken to provide against a possibility of damage or weakening of this sheath.

CABLE TERMINALS.

Two methods of terminating aerial cables are approved. These are known as the "pot-head" method and the "cable-head" method. The standard aerial pot-head terminal is shown in fig. 69. This consists of a lead pipe about 18 inches long, enclosing a rubber-covered wire known as "pothead" wire, having a very high-class insulation, which is spliced to the cable conductors. The pot head is filled with ozite after the splices are complete. This form of terminal is considered the more reliable.

The cable head is shown in figs. 70 and 70*a*. This terminal consists of a tight iron box having a brass nozzle to which the sheath of the aerial cable is soldered. The end of the cable having been thoroughly boiled out with paraffin, its conductors are led to the terminals of the binding posts inside the box, and a quantity of quicklime is inserted in the box to absorb moisture of condensation. The boxes are provided with a gasket and made water and air tight. The

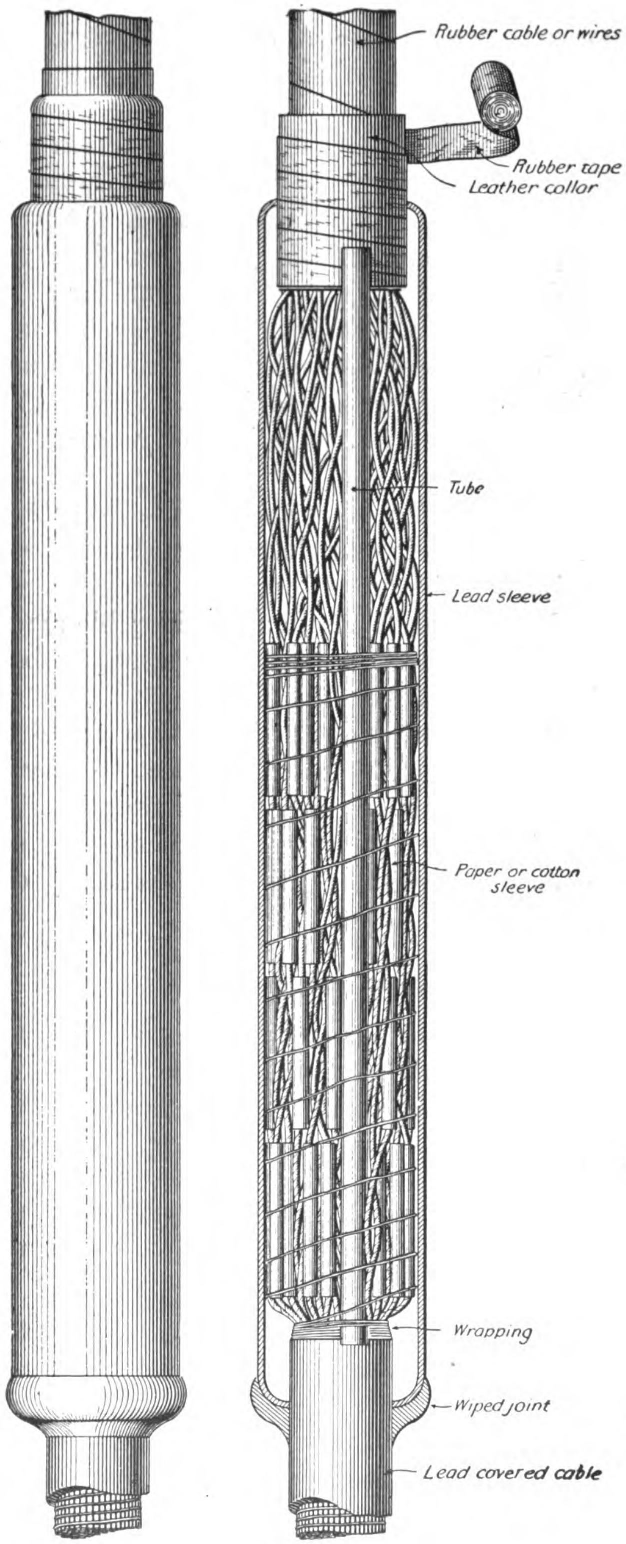

Rubber cable or wires
Rubber tape
Leather collar
Tube
Lead sleeve
Paper or cotton sleeve
Wrapping
Wiped joint
Lead covered cable

Fig. 69.

efficiency of this form of cable terminal depends entirely upon the care used in the assembly of the binding posts which pass through the sides of the cable head and in attaching cable and cover. If this

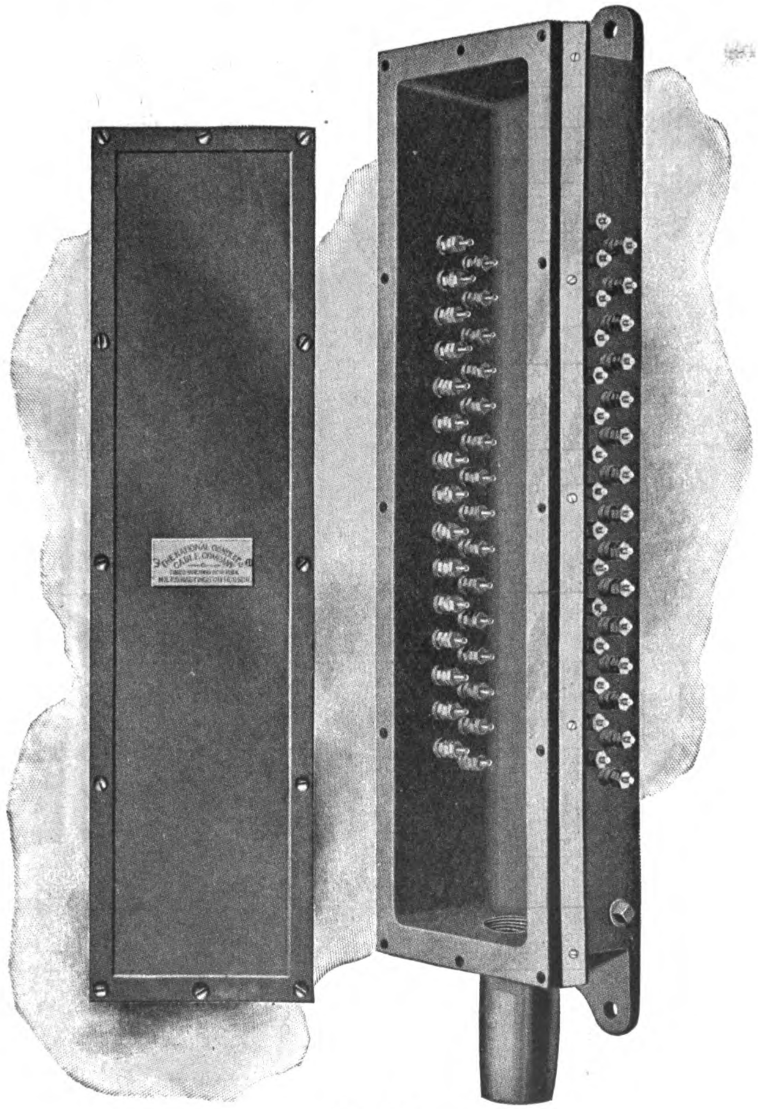


Fig. 70.

work is thoroughly well done and all joints are tight at the outset, this type of terminal should be entirely satisfactory. Cable heads are usually furnished with fuse terminals. If the fuses are not desired the terminals may be strapped.

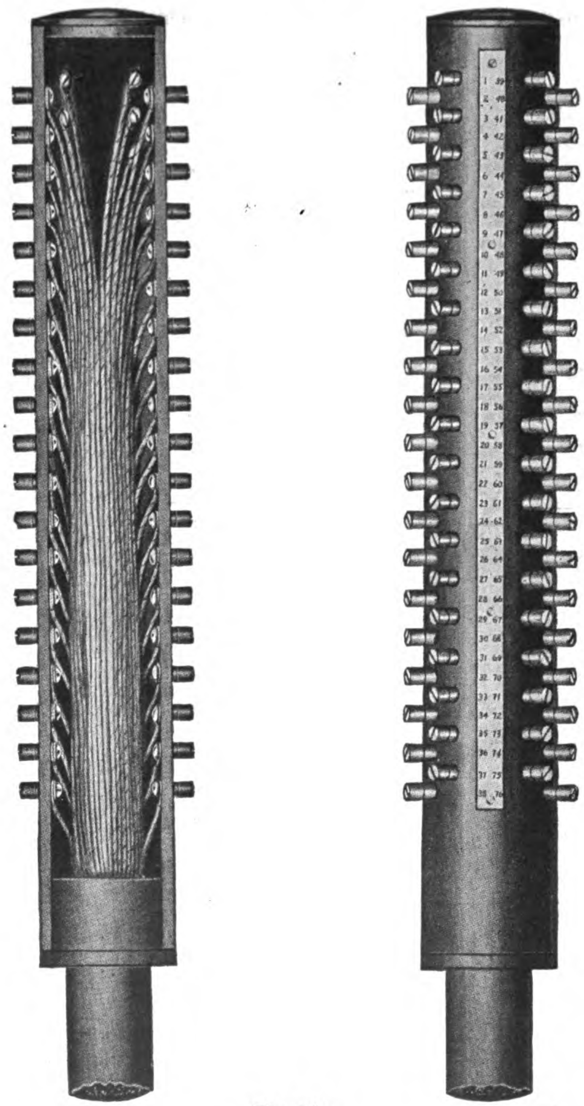


Fig. 70*a*.

CABLE BOXES.

Cable boxes are provided for all pot-head or cable-head terminals. The box should be securely attached to the pole. as shown in fig. 71.

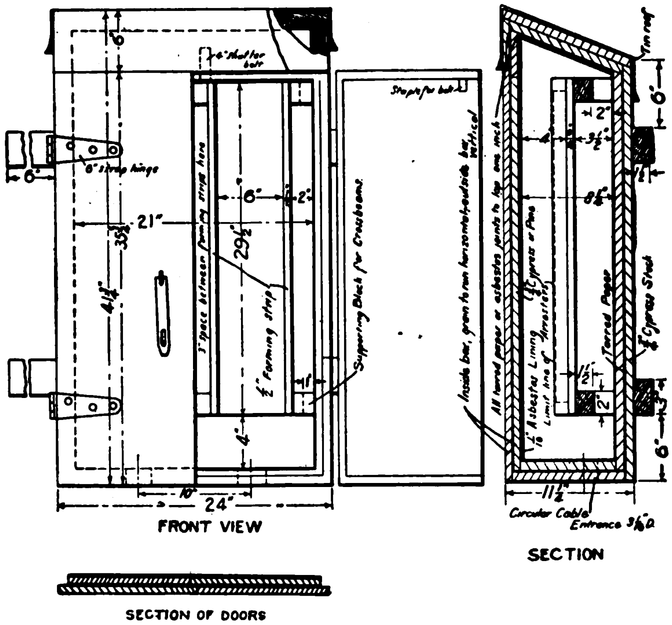


Fig. 71.

Arresters, as shown in fig. 24, may be supplied. No aerial line should be connected to a cable, either submarine or aerial, except through a fused lightning arrester.

SPECIAL CABLE TERMINAL DISTRIBUTING RINGS, ETC.

Figs. 70 and 70*a* show approved forms of cable heads.

The distributing ring may be supplied where the terminal pole has radiating from it a considerable number of outside twisted pairs. The installation of this ring is shown in fig. 73.

TERMINAL POLE FITTINGS.

The attachment of the balconies, pole steps, guys, and terminal pole boxes are shown in fig. 199.

INSTRUCTIONS FOR SPLICING LEAD-COVERED, PAPER-INSULATED CABLES.

These instructions are intended to cover approved methods, together with the materials required, for splicing lead-covered, paper-insulated cables.

All work should be done in the best possible manner, and all materials used should be of the quality indicated.

MATERIAL REQUIRED.

The following material will be required for each splice:

(*a*) Paper sleeves, or their approved equivalent, for covering the joint in each conductor.

(*b*) Paraffin for drying the splice.

(*c*) Strips of muslin, or its approved equivalent, for wrapping the splice.

(*d*) Lead sleeves.

(*e*) Solder for seams and wiped joints.

(*f*) Gummed paper for limiting the wiped joints.

Before being used the paper sleeves should be immersed in hot paraffin, or otherwise thoroughly dried, until they are entirely free from moisture.

For wrapping the core after splicing and for binding the ends of a splice, strips of muslin, or its approved equivalent, should be used.

Sleeves should be made of the same material of which the cable sheaths are made or of pure lead.

The thickness of the lead sleeve covering the splice shall be one-eighth of an inch when the inside diameter of the sleeve is 3 inches or less, and three-sixteenths of an inch when the inside diameter of the sleeve is more than 3 inches.

The dimensions of sleeves which may be used in splicing cables of various sizes are given in the following tables. Where the cables to be spliced together are not of the same size, the proper sleeve for the largest of the cables shall be used.

LEAD SLEEVES FOR STRAIGHT SPLICES.

	No. 19 gauge table.		No. 22 gauge table.	
Number of pairs.	Inside diameter.	Length.	Inside diameter.	Length.
	Inches.	*Inches.*	*Inches.*	*Inches.*
15	1	16	1	16
20	1½	16	1	16
25	1½	16	1½	16
30	2	16	1½	16
50	2	16	2	16
75	2½	16	2½	16
100	3	16	2½	16
150	3	18	2½	16
180	3½	18	2½	16
200	3½	18	3	18
300	4½	22	3½	18
400	----------	----------	3½	22

LEAD SLEEVES FOR 3-WAY OR "Y" SPLICES.

10	1	16	1	16
20	1½	16	1½	16
25	1½	16	1½	16
30	2	16	2	16
50	2½	16	2½	16
75	3	16	3	16
100	3½	18	3½	18
150	4	18	4	18
180	4½	18	4	18
200	4½	22	4	18
300	4½	22	4½	22
400	----------	----------	4½	22

For splicing cables with larger conductors than are given in the preceding tables, sleeves may be used of which the length is about eight times the outside diameter of the cable and of which the inside diameter is about 50 per cent greater than the outside diameter of the cable.

So far as possible, splices should be finished and soldered the day they are begun. Where necessary, if the surroundings be dry, an unfinished splice may be left open overnight, provided it be carefully wrapped and protected from moisture by a rubber blanket or other suitable covering. In wet or damp surroundings, however, work on

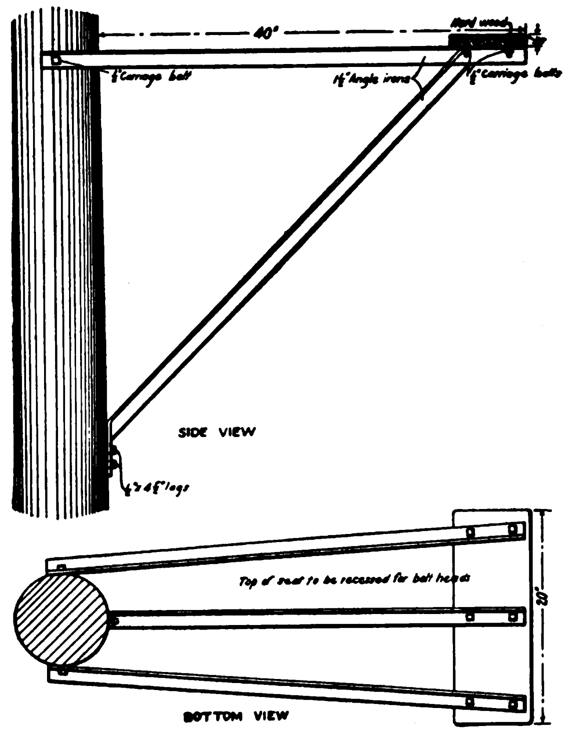


Fig. 72.

a splice should be continuous until finished. In such cases the splice should be "boiled out" with paraffin at intervals—say after each fifty pairs have been connected.

Whenever it may be necessary to leave the cable end, it should be throroughly dried and sealed with solder, as much care being taken as if the joint were to be permanent.

If it is suspected that moisture has entered the end of a cable, a short length of it should be cut off and dipped into hot paraffin, when the presence of moisture will be indicated by a characteristic frying sound. If there is length to spare, the cable should be cut back, a short portion at a time, until it gives no evidence of dampness.

After this the end should be thoroughly dried with paraffin and a splice made or the end sealed as already described.

A record should be kept of all splices, with the name of the splicer and any item of interest. Each splicer should be held personally responsible for any faults which may develop in his work due to defective workmanship.

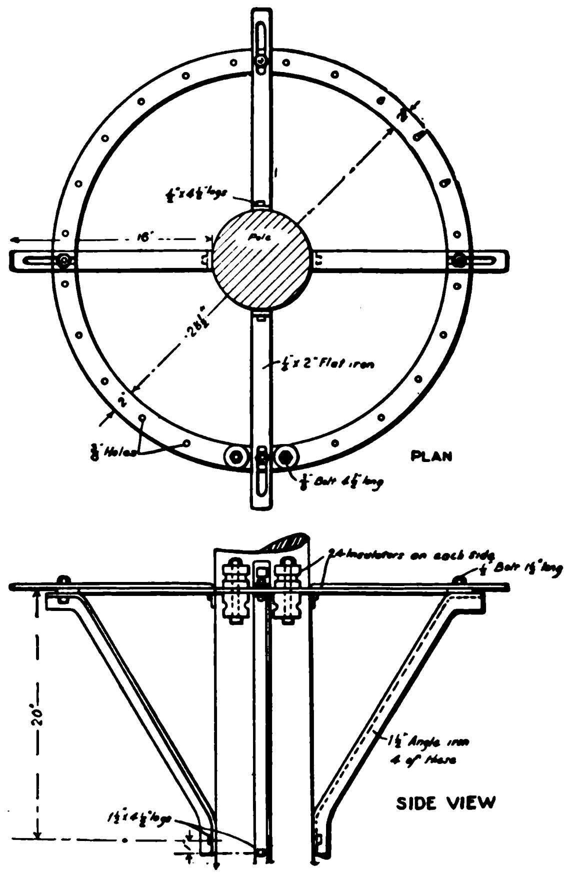


Fig. 73.

The operations in making a straight splice in their sequences are as follows:

1. The lead sheath shall be removed from the ends of the cables to be spliced for a distance equal to the length of the lead sleeve to be

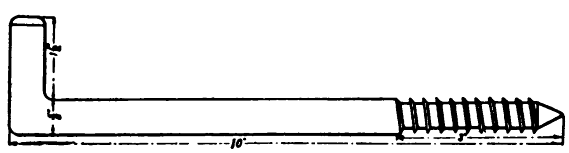


Fig. 74.

used in covering the splice. In removing the sheath, care must be taken not to injure the insulation of the wires. (Figs. 78 and 79.)

2. The core shall be tightly bound with strips of muslin, or its approved equivalent, at the end of the cable sheath, packing the binding close to the sheath. This is done to prevent the wires from being cut on the edge of the sheath. (Fig. 80.)

3. In general, as soon as possible after the removal of the lead sheath, the exposed conductors shall be thoroughly "boiled out" by pouring hot paraffin over them until all traces of moisture are re-

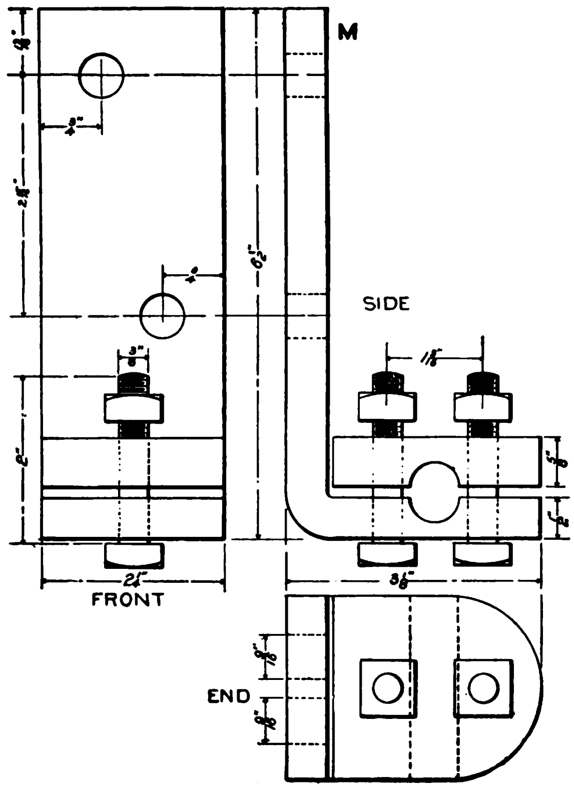


Fig. 75.

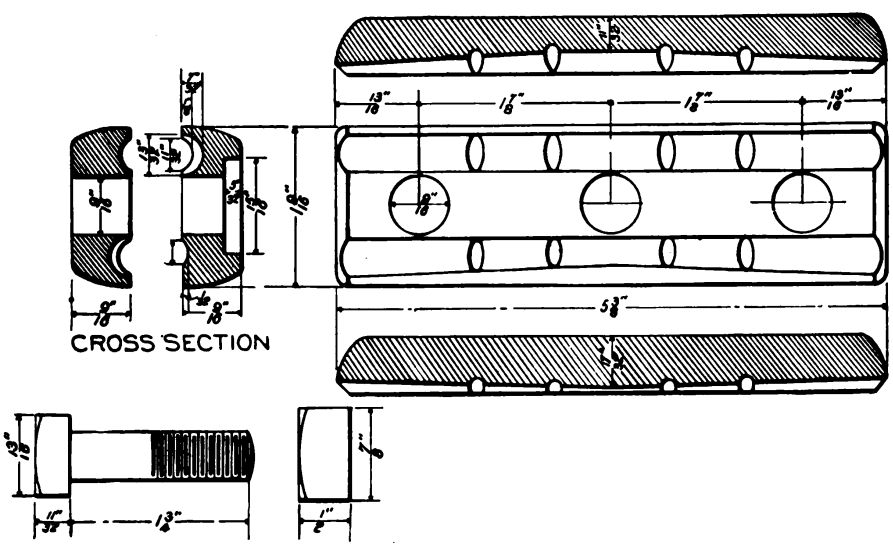


Fig. 76.

moved (fig. 83). The binding must be saturated with paraffin as well as the core. Enough paraffin remains in the core to form a seal, which protects the cable against moisture while the splice is being made. The temperature of the paraffin shall be above that of boiling water, but must not be high enough to scorch or make brittle the paper insulation.

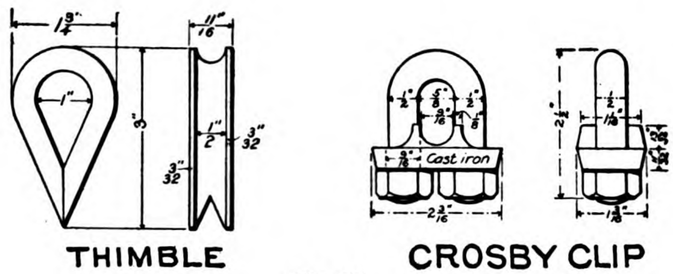


Fig. 77.

In drying or "boiling out" a splice with paraffin, always work away from the cable sheath toward the end of the conductors or

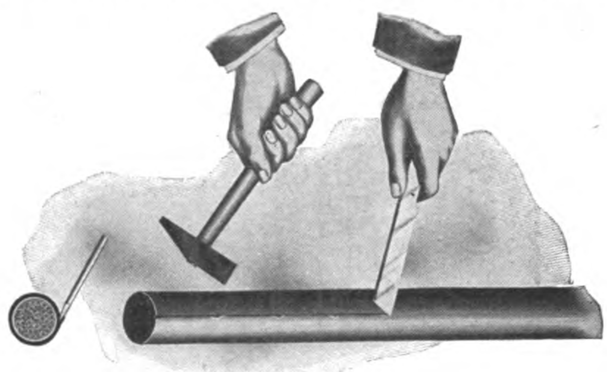


Fig. 78.

middle of the splice, in order to prevent any moisture being driven under the sheath. The paraffin should be poured on with a ladle. The paraffin draining off may be caught in the melting pot or a pan.

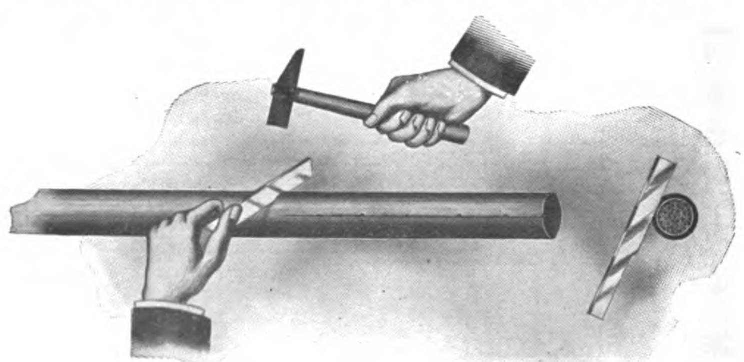


Fig. 79.

4. The ends of the cable sheaths and of the lead sleeve shall be scraped bright for 3 or 4 inches and rubbed with tallow, or its approved equivalent, to keep them clean during the subsequent work

on the splice. The tallow also acts as a flux in making the wiped joints.

5. The lead sleeve shall next be slipped over the end of one cable and moved back out of the way.

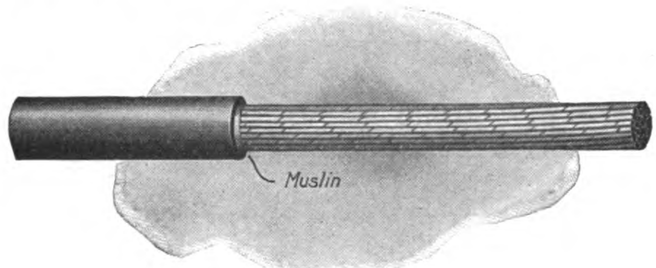


Fig. 80.

6. The two cables shall be placed and firmly secured in the same straight line, with the distance between the ends of the sheaths about 3 inches less than the length of the lead sleeve.

7. After the cables are in position the conductors shall be bent at

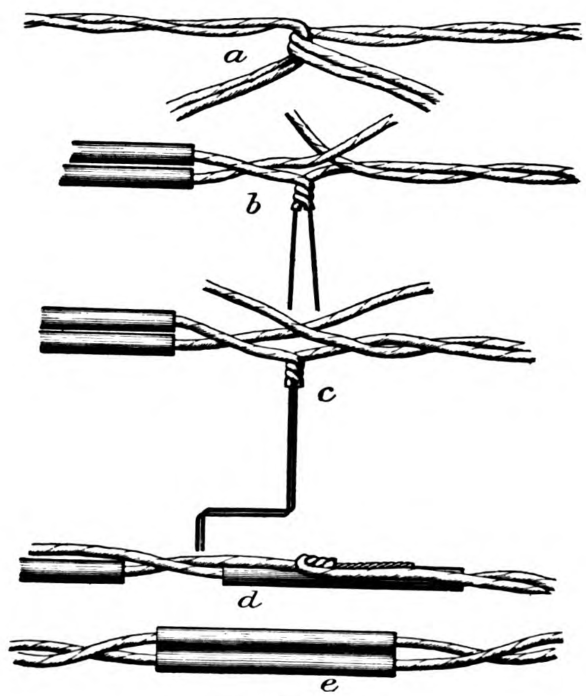


Fig. 81.

the sheath out of the way and shall then be spliced in the following manner:

8. Starting at the center or the lower back side of the cables, a pair of wires from each cable is loosely brought together with a partial twist (*a*, fig. 81), thus marking by the bend in the pairs the point at which the joint is to be made. Slip on a paper sleeve over each wire

of one pair and push the sleeves back far enough to allow room for making the joint.

The wires are now to be connected by a splicer's ordinary twist joint (*b*, fig. 81). The like wires from the two pairs to be spliced shall be brought together at the point marked by the bend and given two

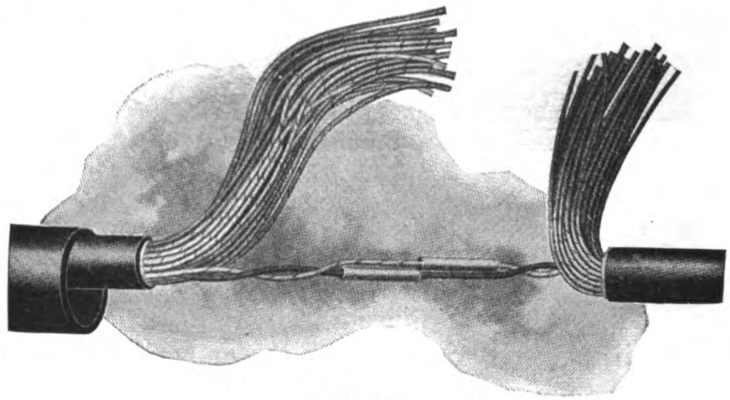


Fig. 82.

or three twists (*c*, fig. 81). Remove the insulation of both wires beyond the twist, being careful not to nick or scrape the conductors. The wires are now to be bent as shown and twisted together as if turning a crank. The ends shall be cut off, so as to leave the twist

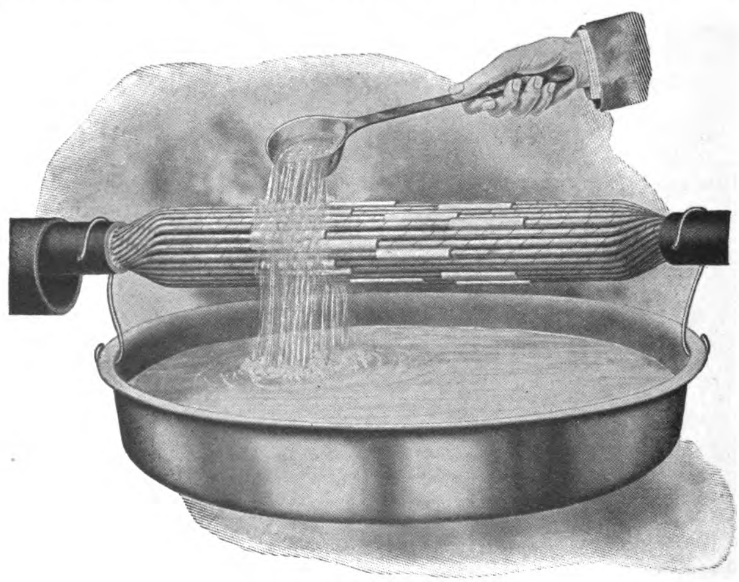


Fig. 83.

of bare wire not less than 1 inch in length. The twist shall be bent down along the insulated wire and the paper sleeve slipped over the joint (*d*, fig. 81). The completed joint, with the sleeves in place, is shown in *e*, fig. 81.

For conductors of large size (No. 13 B. & S. gauge or larger) the wires may be joined by means of a Western Union Telegraph joint or other approved method. The joint shall be covered with a paper sleeve.

In splicing, care shall be taken to splice the center and lower pairs first, forming the outer pairs about the center pairs so that the finished splice may have a uniform shape.

In picking out the pairs to be spliced together care shall be taken to transpose the circuits thoroughly. It is sufficient if the trans-

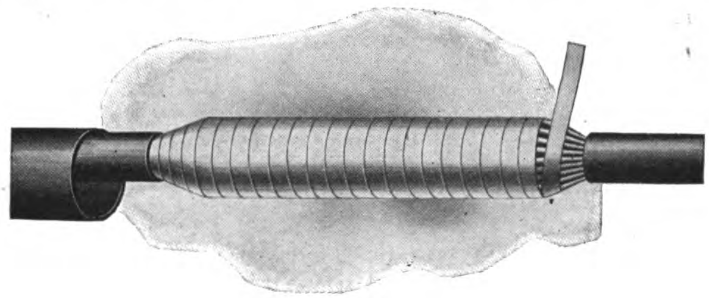


Fig. 84.

posing be done between pairs in the corresponding layers of the two cables.

The wire joints shall be distributed along the whole length of the splice in order to keep the splice uniform in size and shape.

9. When all the wire joints have been made the splice shall be again "boiled out" with hot paraffin until all traces of moisture have been removed. In applying this paraffin, work from the ends of the splice toward the middle.

10. The splice shall then be wrapped with strips of muslin, or its

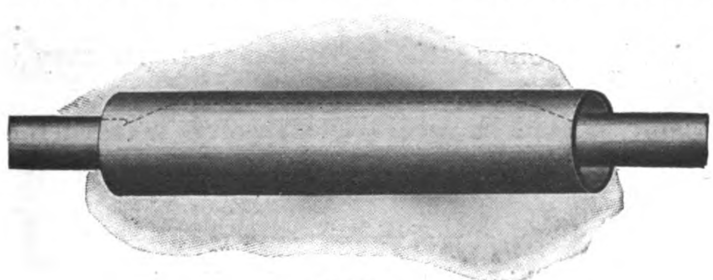


Fig. 85.

approved equivalent, and compressed until the lead sleeve will just slip over the splice. Care must be taken not to compress the splice too tightly or the wires may be forced through the insulation and crosses in the splice result.

The splice shall be dried out with hot paraffin after the first wrapping of muslin has been put on and again after the wrapping of the splice is complete. The drying out shall be continued until bubbles cease to appear on the splice.

11. The lead sleeve shall be slipped into place before the splice has had time to cool, taking care, however, to see that the sleeve is perfectly dry.

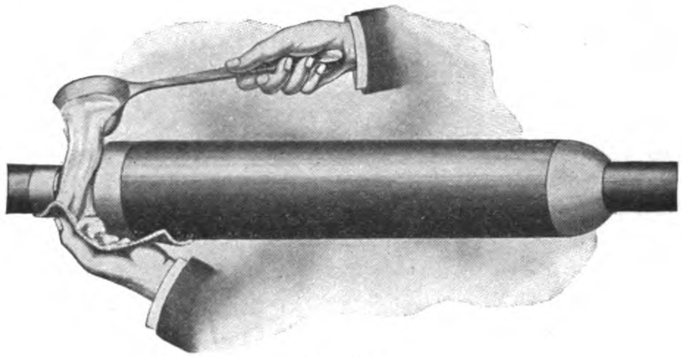


Fig. 86.

The ends of the sleeve, which should overlap the cable sheath at each end by about $1\frac{1}{2}$ inches, shall be beaten down to conform to the cable sheath and a wiped joint carefully made at each end. In

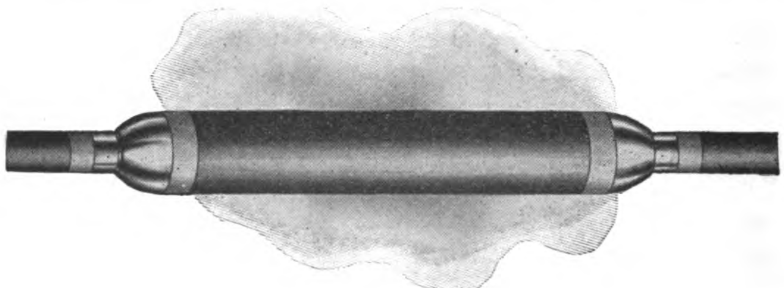


Fig. 87.

making the wiped joints strips of gummed paper may be used to limit the joints.

Wiped joints should be carefully inspected, using a mirror when necessary to detect any imperfections in the seal.

3-WAY OR "Y" SPLICES.

The method of making a 3-way or **Y** splice is the same as for a straight splice except in the following particulars.

There are two general classes of **Y** splices.

1. Where the cables all end at the splice.
2. Where a branch cable is to be spliced into a continuous cable.

In the first case the method is generally similar to a straight splice. The sheaths of all three cables are removed for a length equal to the length of the lead sleeve. The two cables forming the main cable are secured in a straight line with the distance between the ends of the sheaths about 3 inches less than the length of the sleeve. The branch cable shall be lashed beside one of the main cables with the end of its sheath opposite the end of the sheath of the main cable.

The joint shall be made by twisting together like wires of pairs from each of the three cables, taking care to include two or three twists of the insulation in the joint in the manner hereinbefore described for straight splices.

The lead sleeve in this case may be a whole sleeve. It should be slipped on and pushed back on that portion of the main cable away from the branch.

In the second case a split lead sleeve must be used.

The sheath of the main cable shall be removed for a length of about 3 inches less than the length of the sleeve. The sheath shall be removed from the end of the branch cable for an equal distance.

The branch cable shall be lashed to the main cable with the end of the sheath opposite the end of the sheath of the cable.

A pair of conductors in the main cable is cut. To one end of each conductor shall be spliced a short piece of bare wire of the same size as the cable conductors. This wire should be twisted into the insulation two or three times in order to prevent its pulling back on the conductors. The second end of the main conductor, the free end of the bare wire, and a like conductor of a pair in the branch cable shall be twisted together, in the manner already described, and covered with a paper sleeve which shall be long enough to cover both ends of the bare wire.

If there is slack enough in the main cable the joint may be made without splicing in the bare wires.

In putting on a split lead sleeve the seam must be carefully soldered, then the ends beaten down to conform to the sheaths of the cables and soldered with wiped joints in each end. Care should be taken to retouch the ends of the seam after the wiping is complete, in order to make sure that the seam has not been opened while the wiping was in progress.

A grooved wooden block should be placed in the fork of each Y splice in order to keep the cables apart. This block is kept in place and the cables at the same time protected from the possibility of too great a separation by means of a wrapping of wire soldered to the cable sheaths.

METHOD OF MAKING A POT HEAD.

This description covers the method of making a flexible cable terminal or pot head for terminating the conductors of a lead-incased, dry-core cable in rubber-covered conductors, and at the same time effectually sealing the lead-incased cable against the ingress of air and moisture.

The lead sleeve or pipe of this terminal shall have a length of eight times the outside diameter of the cable to which it is to be attached, plus 10 inches; and an outside diameter of at least one and one-half times the outside diameter of the lead cable. The lead sleeve should have a thickness not less than that of the sheath of the lead cable.

The wires of this terminal, which are to be spliced to those in the lead cable, should be covered with okonite insulation or its approved equivalent. The rubber-covered wires may be loose or in the form of a taped cable, and should be of the size and length required.

All tape used in the terminal should be adhesive or rubber tape of the best quality.

The paper or cotton sleeves used should be of the ordinary form for covering wire joints in lead cables.

The tube for adding the compound to the terminal should have an inside diameter of one-half inch and a length 2 inches less than that of the lead sleeve. The tube should have thin walls and may be made of metal, vulcanized fiber, or manila paper rolled about a half-inch rod and bound thereto with string.

The sole leather should be approximately three-sixteenths of an inch in thickness, 3 inches in width, and long enough to wrap once about the rubber cable or rubber-covered wires.

Heavy cotton twine or wicking should be used for binding purposes.

The wiping solder used should contain about 43 per cent of tin.

The sealing compound should be of any approved waterproof, semi-elastic, insulating material which, when melted, will flow readily into the lead sleeve and about the wires and adhere tenaciously to the wires and lead sleeve. The compound should not be sufficiently affected by the conditions of exposure as to endanger the seal.

DIRECTIONS FOR SETTING UP THE POT HEAD.

No paraffin shall be used in "boiling out" cable ends and sleeves for pot heads.

The proper amount of sheath should be removed from the lead cable, the lead sleeve slipped over the cable and the cable wires spliced to the rubber-covered wires in the usual manner, using paper or cotton sleeving.

In doing this work care must be taken to remove all pieces of paper, jute, tape, or other things which might obstruct the flow of the compound which is to be poured in after the lead sleeve is in place.

Close to the end of the lead-cable sheath the wires should be tightly wound with a number of layers of twine or wicking in such a manner as to prevent the compound from entering the cable.

If rubber cable is used the wrappings should be removed to such a distance that only about $1\frac{1}{2}$ inches of the wrapped cable will enter the sleeve when the sleeve is drawn up into position.

At that point on the rubber-covered wires which will come immediately at the end of the lead sleeves should be wrapped, first, a single layer of sole leather, and over this several layers of adhesive or rubber tape. The leather shall enter the finished splice about $1\frac{1}{2}$ inches and project the same distance.

The entire splice should next be opened up as much as possible in order that the sealing compound may flow readily about every wire. If a hemp cord be found in the rubber cable it should be cut off as close as possible to the cabled portion.

The one-half inch tube should then be laid along in the splice with one end on a line with the end of the lead cable sheath and fastened in position with several turns of twine. This twine serves the double purpose of keeping the tube in place and reducing the splice to a diameter which will allow the lead sleeve to be drawn on without disturbing the sleeves covering the spliced wires. The turns of twine should not extend beyond the last of the wire joints on the rubber-covered wire end of the splice. It should not be drawn too tightly, but should allow the compound a chance to get at the wire. If the manila-paper tube is used, the rod on which it is rolled should be retained in the tube until the splice is ready to be filled.

The lead sleeve should be drawn over the splice, allowing it to project over the lead cable sheath $1\frac{1}{2}$ inches, and then connected to the lead cable sheath by means of a "wiped" joint.

The lead cable sheath, with sleeve attached, should now be fastened in an upright position, the sleeve warmed until it becomes barely possible to touch it with the hand, and the sealing compound, heated to as high a temperature as is possible without burning the insulation from the wires, slowly and cautiously poured in through the tube, using a funnel to assist in the operation. The compound should fill the sleeve to within one-half inch of the top. If the compound on cooling should settle, more compound should be poured in at the top of the sleeve, not using the tube.

After the splice has become thoroughly cold, the open end of the lead sleeve should be carefully dressed into contact with the taped leather which surrounds the rubber-covered wires or cable.

No pot head should be mounted in other than an upright position, if exposed to the weather. When it is necessary in inside construction to place the pot head in a horizontal position the open end of the lead sheath should be wrapped with tape to prevent the compound from running out, and care should be taken to locate the terminal where it will not be exposed to excessive heat.

SUGGESTIONS IN REGARD TO SPLICES.

In branching a small lead-covered cable from a flexible splice it is considered advantageous to run it out at the base of the lead sleeve, making a double wiped joint, rather than to run it out parallel with the rubber-covered wires or cable.

Should occasion arise when it becomes imperative to shorten the length of the lead sleeve, a sleeve of a greater diameter than is ordinarily recommended should be selected and the space occupied by the joints in the wires contracted, keeping the space between the last wire joint on the rubber-covered wire end and the leather wrapping the same as it would be in a regular splice, this being the space where the efficiency of the seal is maintained.

The sealing compound should rise at least one-half inch above the top of the paper tube.

Chapter X.

METHODS OF TESTING.

MISCELLANEOUS TESTS.

The importance of testing both for regularly ascertaining the condition of the lines with a view to anticipating breakdowns and as a means of locating faults when they occur, is something that should be recognized by all telegraphers. On land telegraph lines and the apparatus connected therewith the electrical units with which we are usually concerned in measurements and tests are those given in Ohm's law—the current in amperes equals the electromotive force in volts divided by the resistance of the circuit in ohms; expressed algebraically $C=\frac{E}{R}$. The galvanometer, in one or the other of its forms, measures current. When of low resistance and graduated properly it is called an ampere-meter or ammeter. When of high resistance, since

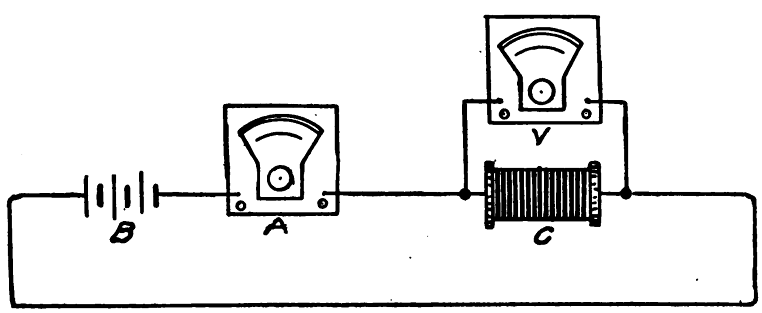


Fig. 88.

the current flowing through it is practically independent of the relatively small variations of outside resistance, the galvanometer readings are directly proportional to the electromotive force E. And when properly graduated it becomes a voltmeter. The Weston ammeter and voltmeter, on account of their portability and quickness and accuracy with which readings are taken, are very satisfactory instruments for telegraph testing. It is evident if C and E are measured by an ammeter and voltmeter respectively, that R becomes known—for Ohm's law may be written $R=\frac{E}{C}$. For example, if we connect the ammeter A, battery B, and a resistance coil C together, as in fig. 88, we may read the current flowing. The small current commonly used in telegraphy is conveniently expressed in milliamperes, and the ammeter graduated for these, the milli- or mil-ammeter. If we attach a voltmeter V to the terminals of the resistance coil C, it will give the difference of potential (E M F) produced at these two points by the current flowing between them.

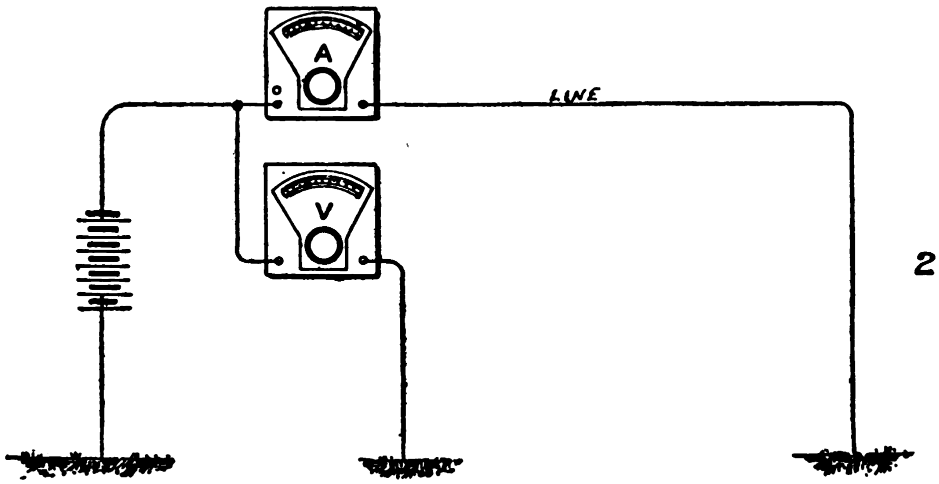


Fig. 89.

Suppose the milliammeter reads 28 milliamperes (0.028 ampere) and the voltmeter 4.23 volts. Substituting in $R=\frac{E}{C}$, $R=\frac{4.23}{.028}=151$ ohms. The general rule in connecting up the ammeter and voltmeter for such measurements is to put the ammeter in the circuit, and the voltmeter shunting the part of the circuit whose resistance is desired. The practical use of the instruments, in testing, is given in the sub-

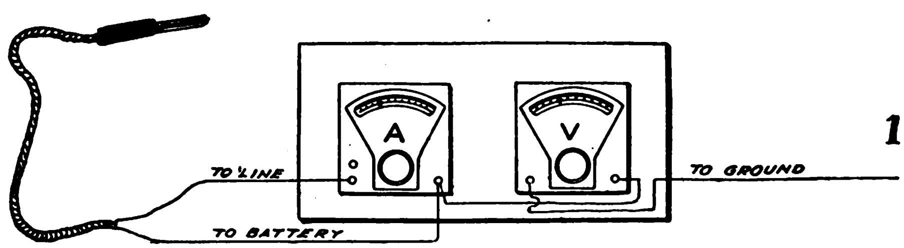


Fig. 90.

joined description of the method employed in the United States Signal Corps central telegraph office in Manila, P. I. The theoretical connections are shown in fig. 89, the voltmeter being connected in shunt to line and ground, and the milliammeter in the circuit. The correspondence of this with fig. 88 will be noted. The practical connections are shown in fig. 90.

A portable voltmeter reading to 200 volts (V), and milliammeter reading to 150 milliamperes (A), are mounted on a board and connected with the regular switch-board cord and wedge, as shown, the other terminal of the voltmeter being connected with the ground.

When the wedge is inserted in any line spring jack, the ammeter is connected in the circuit and the voltmeter shunted to the ground, as shown in fig. 90. The deflections of the ammeter and the voltmeter thus give C and E in the formula $C=\frac{E}{R}$ and the third (R) becomes known. The computation was made graphically by a simple device, as will be explained. The method of testing in Manila was to call up the most distant station, have him cut off his line battery, and ground, noting readings. Then the key was opened for a few seconds and instruments read. This was repeated with all stations up to the nearest one. The readings with stations grounded would give resistance of line (including relay) to each successively, while readings with the keys opened successively would give the insulation resistance to each. Practically it is found that the milliammeter readings alone are required in readings with key opened. The voltage of the battery being obtained at the first reading, its value may be taken as constant throughout unless the line is very faulty and the insulation resistance consequently low. Very little skill was required to make the tests, and in twenty minutes the data for obtaining the resistances to about forty stations have been taken. In addition to the tests giving correct indications of the condition of each section of the line, the stations where keys were left open or where unauthorized ground wires were being used were picked out a number of times from the central office. The lines were most hastily built and running through country where trees and bamboos abound, and comparison of each morning's tests showed quite clearly if the lines were being kept up and foliage trimmed.

The device used for quickly ascertaining the resistances from the indications of the volts and milliamperes is shown in fig. 91. On a small board is pasted a sheet of squared paper laid off in half-inch squares, the paper being 12½ inches long and 12 wide. A pin is driven into A and a thread or wire, with a bit of metal B attached for a handle, is secured to the pin. The horizontal divisions are taken to represent milliamperes and the vertical one on the left the volts. Then the resistances corresponding to 100 milliamperes and the various voltages can be laid off as shown on the right, as can be observed by applying the formula $R=\frac{E}{C}$.

When a reading on the instrument is made, the thread is put at the intersection of the indicated volts and milliamperes and note made of the resistance at the point crossed by the thread on last vertical line. If the offices close in should ground, the current may be more than 100 milliamperes, in which case we may read the horizontal line at double values. Say, for instance, the current is 120 milliamperes.

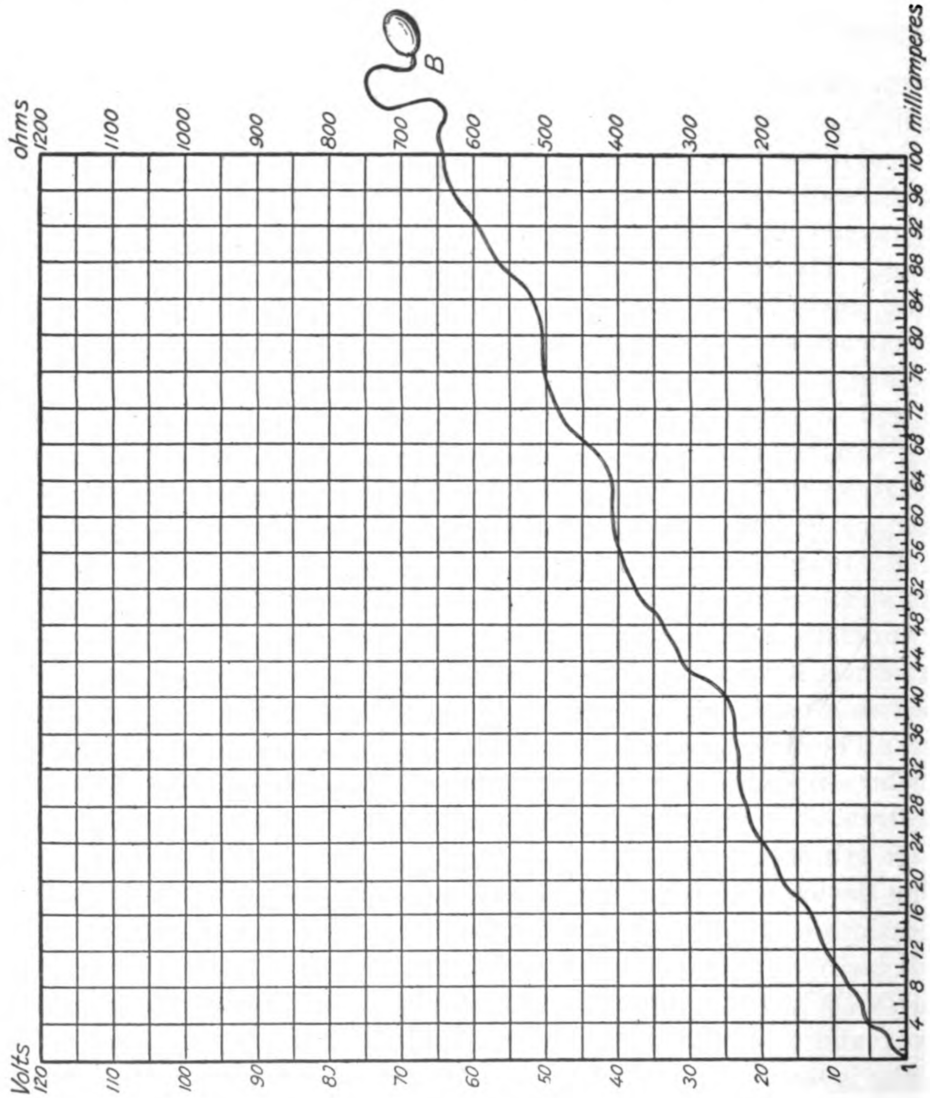


Fig. 91.

Call the 60-milliampere mark 120, take the reading in the resistance column, and one-half will be the correct resistance reading. On the other hand, it may be desirable to measure resistances larger than 1,200; in which case read the horizontal line at half values and double the reading crossed on the ohms column by the thread. At important terminal offices the daily tests should be recorded on a "test sheet" and filed for ready reference. A blank like the following could be used to advantage:

Record of tests.

Date__________________ Hour__________________M.

	Ground.			Open.			Ground.			Open.	
	Mil.[a]	V.[b]	Resist.	Mil.[a]	V.[b]		Mil.[a]	V.[b]	Resist.	Mil.[a]	V.[b]
Line No. 1:						Line No. 4:					
Dagupan											
Bautista											
Paniqui											
Caloocan											
Line No. 2:						Line No. 5:					
Line No. 3:						Line No. 6:					

[a] Weston milammeter (*Mil.*). [b] Weston voltmeter *V*.

State of weather during tests: ———

Tests made by ——— ———

The following method of using the voltmeter alone for various measurements when the ammeter is not available is taken from the United States Signal Corps publication, Instructions for the Use of Weston Voltmeters:

The Weston Voltmeter (Signal Corps Service Pattern, 150–5 Volts).

This instrument is a galvanometer of the D'Arsonval class, in which a light pivoted coil, controlled by a delicate spiral spring turning in jeweled bearings, carries a light aluminum pointer moving over a scale divided into equal divisions. This coil turns, when a current passes through it, in the strong field between the poles of a powerful permanent magnet. In the base are two resistance coils, one or the other of which is always in series with the movable coil, depending upon which scale is used—the 150 or 5 volt scale.

Caution.—To prevent bending the pointer by violent action, always test first with the 150 scale. If the pointer indicates less than 5 volts, use the other binding post and take advantage of the greater accuracy of the 5-volt scale.

TO TEST THE VOLTAGE OF A BATTERY OF A NUMBER OF CELLS.

Use the 150-volt scale and connect up as shown (fig. 92).

For not more than 3 sal ammoniac, 4 bluestone, or 2 storage cells in series, use the 5-volt scale.

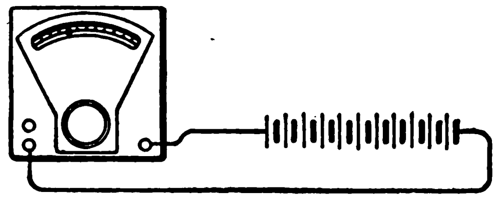


Fig. 92.

TO MEASURE THE DIFFERENCE OF POTENTIAL (PRESSURE) BETWEEN ANY TWO POINTS OF A WIRE OR EXTREMITIES OF A COIL CARRYING A CURRENT.

The connections indicated in figs. 93 and 94 would give the differences of potential at the two points on the wire, or at the extremities of the coil, respectively.

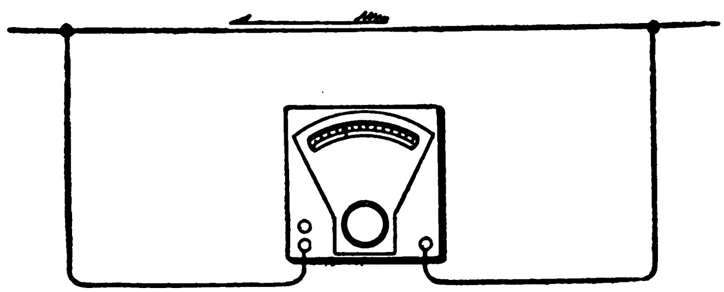


Fig. 93.

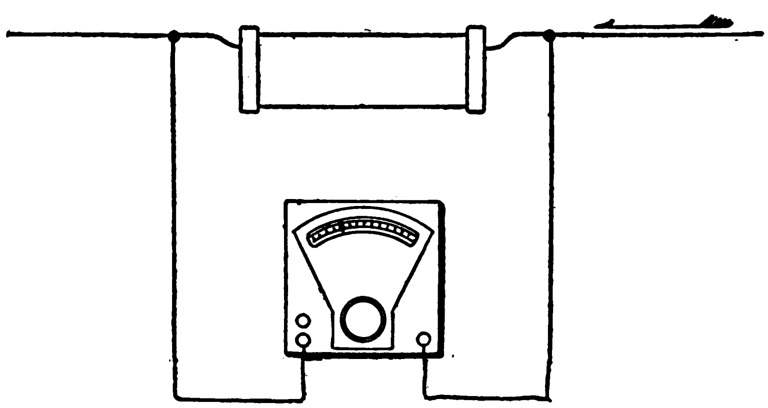


Fig. 94.

TO MEASURE A RESISTANCE.

To measure a resistance less than 3,000 ohms use two or three dry or Gonda cells in series, get their voltage as in fig. 92, using the 5-volt scale. Call this V. Then connect up with the unknown resistance X (Fig. 95), as shown, and call this scale reading V'.

The resistance of the voltmeter, using 5-volt scale, is given in the sliding cover of box. Call this R.

Then

$$X=\frac{R\ (V-V')}{V'}.$$

This is very inaccurate for resistances of only a few ohms unless the resistance of the battery is taken into account.

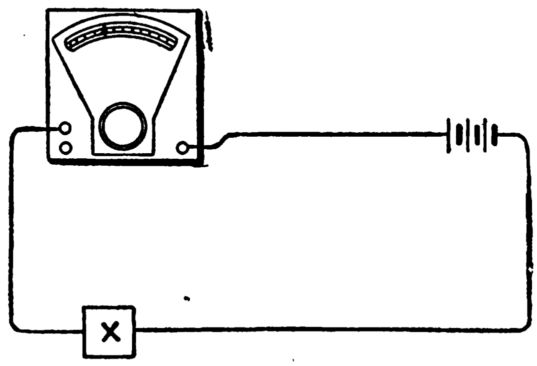


Fig. 95.

In measuring resistances from 3,000 to 250,000 ohms use the 150 scale, noting the value of R given on the cover for this. The same connections and formula are applicable.

To secure greater accuracy in either of above cases, the battery should have sufficient E M F to bring the value of V as near 5 or 150 as practicable.

Examples.—(1) Using 5-volt scale. Resistance to be measured (X) is an ordinary telegraph relay magnet.

Suppose $R=520$. Three cells dry battery in series give $V=4.35$ volts. When X is connected in, $V'=3.40$.

Then

$$X=\frac{520\ (4.35-3.40)}{3.40}=146 \text{ ohms}.$$

(2) Using 150-volt scale. Determine the insulation resistance of 110-volt storage battery (leakage from either pole of battery, or its connections, to earth).

Suppose R for this scale=15,500 ohms. Voltage across terminals, $V=110$ volts; voltage between one of the terminals and earth (V')=12 volts.

$$X=\frac{15{,}500\ (110-12)}{12}=126{,}583 \text{ ohms}.$$

This would indicate a slight leak, probably at or near the negative end of battery if the tests were made at the positive terminal.

If some coils of known resistance are available, resistances can be measured more accurately as follows:

The known coil and the resistance to be measured, marked respectively r and x, are connected with each other and a battery, as shown (fig. 96). The voltmeter is connected first as indicated by the full, and then as by the broken lines. If the voltage indicated in the first case is E and in the second it is E',

$$E : E' : : r : x. \quad \therefore x = \frac{E'r}{E}.$$

Use enough battery to make a good readable deflection, and if several known coils are available use the one which is somewhere near the resistance to be measured.

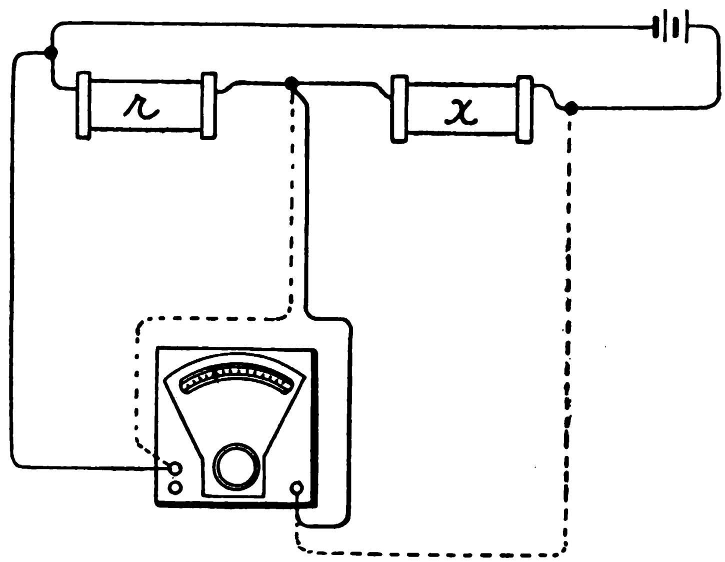


Fig. 96.

Example.—Known coil, 10 ohms. Voltmeter shunting this gave 3.2 volts, and shunting the unknown gave 4.7 volts. Hence

$$x = \frac{4.7 \times 10}{3.2} = 14.7 \text{ ohms.}$$

TO MEASURE CURRENT WITH THE VOLTMETER.

If we know the resistance of a wire or coil, and have a steady current flowing through it, the voltmeter wires applied at the terminals of the wire or coil will give a certain deflection, E. Hence, since $C = \frac{E}{R}$, if we substitute for E and R the known values we get C. (Connections shown in figs. 93 and 94.)

Example.—A certain current is flowing through a 4-ohm telegraph sounder. When the wires from the voltmeter (5-volt scale) are connected at sounder binding posts, the voltmeter indicates 0.8 volt.

Substituting as above,

$$C = \frac{.8}{4} = .2 \text{ ampere.}$$

TO MEASURE THE INTERNAL RESISTANCE OF A BATTERY.

Using the 5-volt scale, first take the voltage of the cell. Then take the voltage at the terminals of a coil of rather low resistance (a 4-ohm sounder, for instance), in circuit with the cell (fig. 94), being careful not to close battery circuit until ready to read the voltmeter. Multiply the voltage of the cell by the resistance of the coil and divide by the voltage at terminals of coil. From the result subtract the resistance of the coil. The remainder is the internal resistance sought.

Example.—The voltage of a dry cell is 1.41, and the voltage at terminals of 4-ohm sounder in circuit with the cell is 1.24.

$$1.41 \times 4 \div 1.24 = 4.5$$

$4.5 - 4 = .5$ ohm, internal resistance of cell. Care must be taken to read voltmeter quickly after closing the circuit through coil, or the result will be vitiated by the polarization of the cell.

THE TANGENT GALVANOMETER.

This instrument was formerly much used in telegraph testing, and when used with care remains one of the most reliable means of measuring. The theory concerning its action may be found in any of the standard text-books.

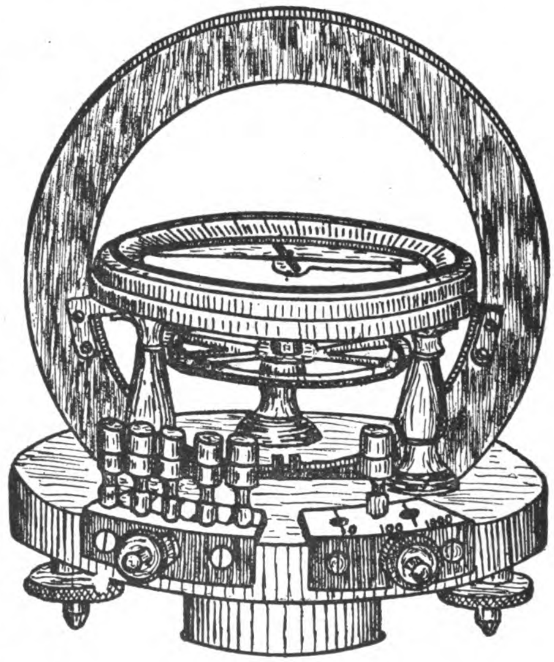


Fig. 97.

Different currents producing deflections of the pointer are proportional, not to the angles of deflection, but to the tangents of these angles. A table of angles with their tangents is found on page 151. So if two currents produce deflections of 20° and 40°, respectively, the second is not twice as great as the first, but, as shown by the table of tangents, is in proportion of 839 to 364; that is, it is about 2.3 times the first. As seen from figs. 97 and 98, the Western Union tangent galvanometer, being the form used by the Signal Corps, has five coils. The first (0), of no appreciable resistance, is a copper band of one turn. This may be used when measuring heavy currents. The others, of 1, 10, 50, and 200 ohms, respectively, and a correspondingly greater number of turns of wire, when brought into circuit by inserting the plug in the corresponding number, give greater and greater deflections for a given current. Standard resistance coils of 10,500 and 5,000 ohms are connected with the other binding post. These are cut out when all the plugs are inserted and the corresponding resistance brought in by taking out the plug.

To use the galvanometer, it should be placed on a firm support away from iron, steel, wires carrying currents, or electro-magnets, and leveled with the three leveling screws. It is then turned until the pointer is accurately at zero. Currents may be compared by placing the plug at the 0, 1, 10, 50, or 200 point to get good deflections. Comparisons can not be made if different coils are used in the different cases, unless the instrument was first "calibrated."

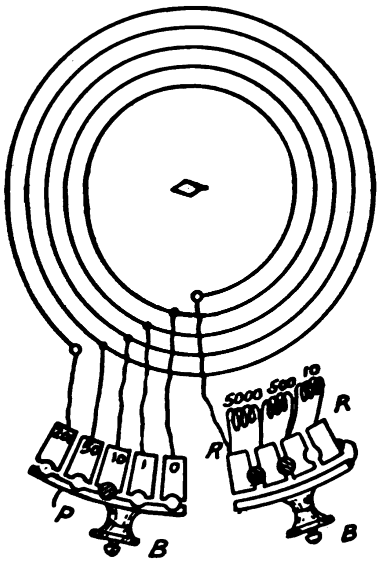


Fig. 98.

To measure resistance by substitution, we may proceed as follows: Suppose with a given battery (a rather constant one, if possible), the unknown resistance, and galvanometer in circuit, we get a deflection of 32°, using the 10-ohm coil. Then, taking out the unknown resistance, we unplug the 500-ohm standard coil of the galvanometer base, and again close the circuit. This time the deflection is 24°. Looking in the table we find the tangents of 32° and 24° to be 0.625 and 0.445, respectively. The currents flowing in the two cases are proportional to these, and as the battery E M F is the same in the two cases the currents are inversely proportional to the resistances. Calling the unknown resistance X and the currents in the two cases C and C', we have these proportions:

$$C : C' :: .625 : .445$$

$$C : C' :: 500+10 : X+10$$

$$510 : X+10 :: .625 : .445$$

$$510 \times .445 = .625\,X + 6.25$$

$$.625\,X = 220.7$$

$$X = 353.1 \text{ ohms.}$$

Battery resistance is neglected in this computation. The standard resistance coil should be used which comes nearest in value to the resistance to be measured.

Opposite the degree graduation there is a scale on the instrument with divisions proportional to the tangent of the angle. For approximate work these may be used, in which case no reference to tangent table need be made, the numbers from this scale being used instead.

Table of tangents.

Deg.	Tangent.	Deg.	Tangent.	Deg.	Tangent.	Deg.	Tangent.
1	0.017	23.5	0.434	46	1.030	68.5	2.53
1.5	.026	24	.445	46.5	1.053	69	2.60
2	.035	24.5	.455	47	1.07	69.5	2.67
2.5	.043	25	.466	47.5	1.09	70	2.75
3	.0524	25.5	.477	48	1.11	70.5	2.82
3.5	.061	26	.488	48.5	1.13	71	2.90
4	.070	26.5	.498	49	1.15	71.5	2.98
4.5	.078	27	.509	49.5	1.17	72	3.08
5	.087	27.5	.520	50	1.19	72.5	3.17
5.5	.096	28	.532	50.5	1.21	73	3.27
6	.105	28.5	.543	51	1.23	73.5	3.37
6.5	.113	29	.554	51.5	1.25	74	3.49
7	.123	29.5	.565	52	1.28	74.5	3.60
7.5	.131	30	.577	52.5	1.30	75	3.73
8	.140	30.5	.589	53	1.33	75.5	3.86
8.5	.149	31	.601	53.5	1.35	76	4.01
9	.158	31.5	.612	54	1.37	76.5	4.16
9.5	.167	32	.625	54.5	1.40	77	4.33
10	.176	32.5	.637	55	1.43	77.5	4.51
10.5	.185	33	.649	55.5	1.45	78	4.70
11	.194	33.5	.661	56	1.48	78.5	4.91
11.5	.203	34	.674	56.5	1.51	79	5.14
12	.212	34.5	.687	57	1.54	79.5	5.39
12.5	.221	35	.700	57.5	1.56	80	5.67
13	.231	35.5	.713	58	1.60	80.5	5.97
13.5	.240	36	.728	58.5	1.63	81	6.31
14	.249	36.5	.740	59	1.66	81.5	6.69
14.5	.258	37	.753	59.5	1.69	82	7.11
15	.268	37.5	.767	60	1.73	82.5	7.60
15.5	.277	38	.781	60.5	1.76	83	8.14
16	.287	38.5	.795	61	1.80	83.5	8.77
16.5	.296	39	.810	61.5	1.84	84	9.51
17	.306	39.5	.824	62	1.88	84.5	10.38
17.5	.315	40	.839	62.5	1.92	85	11.43
18	.325	40.5	.854	63	1.96	85.5	12.70
18.5	.334	41	.869	63.5	2.00	86	14.30
19	.344	41.5	.884	64	2.05	86.5	16.35
19.5	.354	42	.900	64.5	2.09	87	19.08
20	.364	42.5	.916	65	2.14	87.5	22.90
20.5	.373	43	.932	65.5	2.19	88	28.63
21	.384	43.5	.949	66	2.24	88.5	38.18
21.5	.393	44	965	66.5	2.29	89	57.29
22	.404	44.5	.982	67	2.35	89.5	114.59
22.5	.414	45	1.000	67.5	2.41	90	Inf.
23	.424	45.5	1.017	68	2.47		

DETECTOR GALVANOMETERS.

In their simplest forms these would be more properly called current detectors, and are of various kinds and degrees of sensitiveness. The elementary form is a compass needle parallel to a wire above or below it. The effect is multiplied by carrying the wire around in a number of convolutions. An improvised form of detector galvanometer[a] is shown in fig. 99. About 20 feet of fairly small magnet wire wound in the square groove in a wooden block, shaped as shown (fig. 100), and a pocket compass are required. The compass is turned so the needle is parallel with the wires, as is shown by the deflections being the same on each side of N S line when the current through it is reversed. An instrument like this may be roughly "calibrated" by comparing its readings with those of a Weston milammeter in circuit with it, and could serve a useful purpose in the field.

[a] Experimental Science, George M. Hopkins.

It should be noted, however, in using this or any needle galvanometer standardized or calibrated at any place, by comparison with

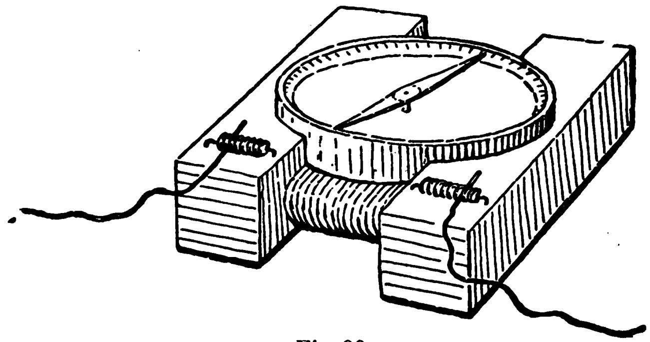


Fig. 99.

some standard instrument, that its readings will change if taken to some place much north or south of the first, on account of the change in the horizontal component of the earth's magnetism and its effect on the directive force of the needle.

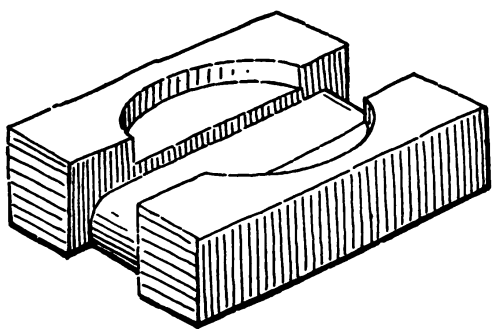


Fig. 100.

The more elaborate and sensitive forms of galvanometers used in connection with Wheatstone bridge sets are sometimes of the magnetic-needle kind and sometimes of the same class as the Weston; that is, with permanent magnets and pivoted coils instead of needles.

THE WHEATSTONE BRIDGE.

This has long maintained its position as the best means for measuring resistances, and in one or the other of its various forms can be used for a great range of measurements.

The "fall-of-potential" principle is applied, which may be illustrated as follows (fig. 101):

If a current is flowing along a wire in the direction of A B, and the terminals of a voltmeter V are applied at A and B, a certain potential difference between these points will be indicated; that is, there will be a fall of potential from A to B, which will be uniform if the wire is of uniform resistance. This may be represented graphically, for if the height of A C represents the total difference of potential, and the line C B represents the fall of this to B along the uniform wire, then at any point, say at E, the height D E will represent the potential difference between B and E, which is proportional to the length of wire or resistance remaining.

If we take a circuit divided at A (fig. 102), the fall of potential along the wire $A\ E\ B$ is equal to that along the wire $A\ G'\ B$; and having passed over a certain proportion of the total resistance $A\ E\ B$, if we join the point E through the galvanometer (voltmeter) with a

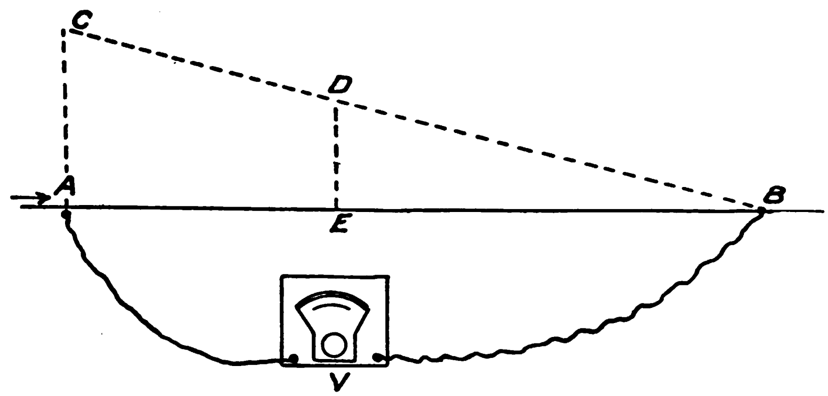


Fig. 101.

point G', where the same proportional part of resistances $A\ G'\ B$ have been passed over, E and G' will be of the same potential, and no current will pass through the galvanometer. It can be proven that when the resistances of the divided circuit bear this proportion—$A\ E : A\ G' :: E\ B : G'\ B$—the points E and G' are at the same

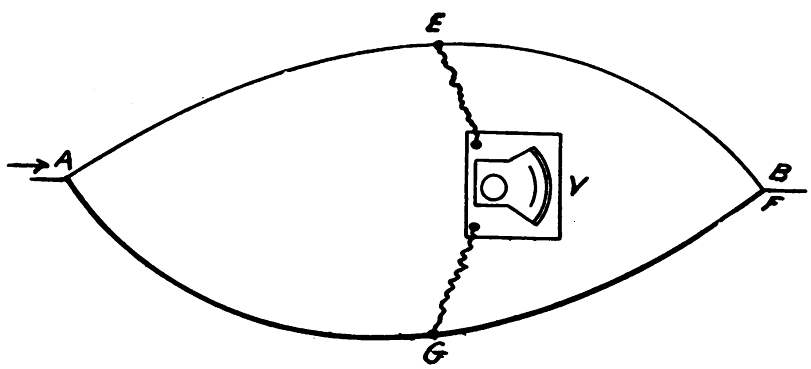


Fig. 102.

potential with respect to each other and the galvanometer will not be deflected.

The relation of parts in the conventional diagram of the Wheatstone bridge (fig. 103) will now be apparent. If the resistance in the coils of A and B are equal or bear any other simple numerical relation, then the same numerical relation exists between R and X, and if R be a box of known resistance coils, X, the unknown resistance, becomes known from the above-stated relation $A : B :: R : X$.

If we straighten out A and B and bend up R into compact form, put keys into the galvanometer and battery circuits, we shall have the diagram of the ordinary or "post-office" form of the bridge (fig. 105). The resistance in the "balance arms" A and B, and in R are short-circuited by inserting the plugs, and they are introduced by with-

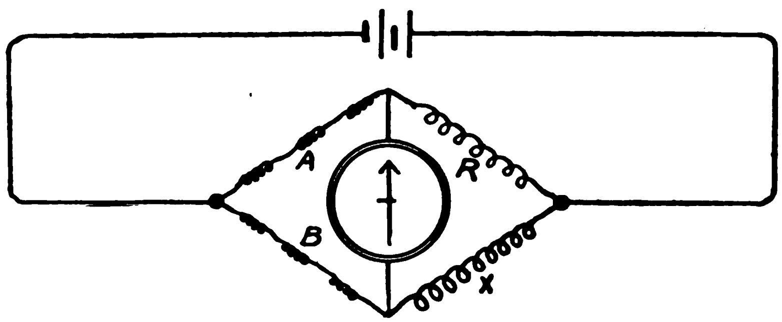


Fig. 103.

drawing the plugs. The galvanometer now most usually employed is some sensitive form of the suspended-coil kind.

The simplest measurement is made with A and B equal. Start out with, say, A and B 100 ohms each. Then connect up the terminals of the unknown resistance X ("*line*" and "*ground*"), and, closing the battery key, tap the galvanometer key. There being no resistance unplugged in R, the galvanometer needle will be deflected to the side

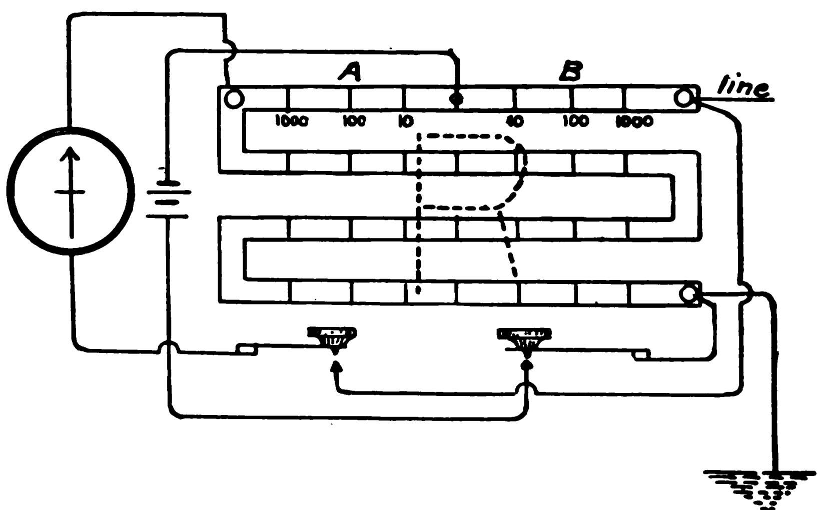


Fig. 104.

indicating "too small" for R. Now unplug in R and test until the right amount is unplugged in R to get a balance or no deflection. Always close battery key before galvanometer key and open galvanometer key first; then, since $A=B$, $R=X$. If fractional ohms are to be obtained, A must be 10 or 100 times greater than B; then R is 10 or 100 times greater than X. Likewise, if X is greater than can be obtained by unplugging in R, then make B the greater and it reverses the multiplier. Practice and care are requisite to obtain accurate results.

In measuring resistances of a telegraph line be certain all line batteries are disconnected before making the measurement. The line is

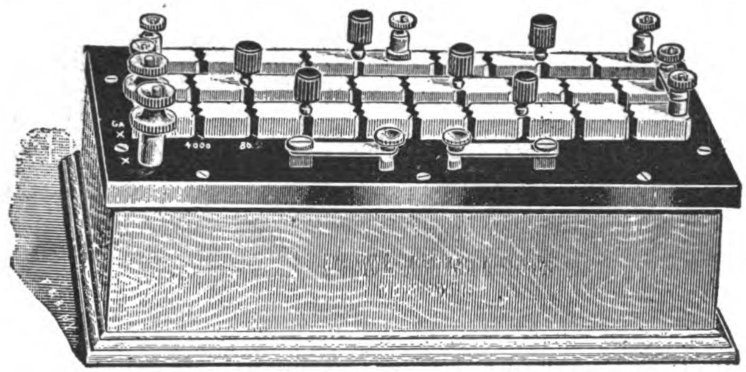


Fig. 105.

connected with one of the X binding posts, the ground to the other. (See fig. 104.)

Many modifications of this form of bridge are in use. Some are arranged so the plugs are inserted at the points where the introduction of resistance marked is desired.

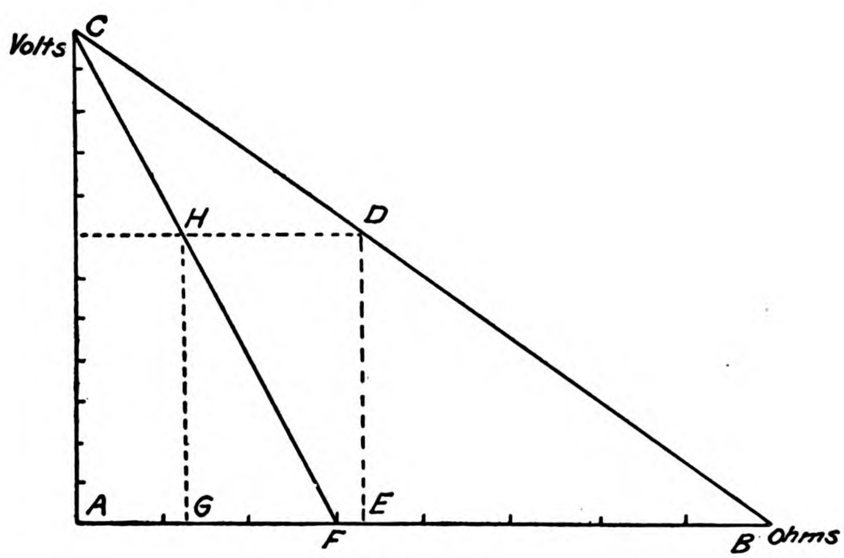


Fig. 106.

One of the familiar forms in which the bridge is made for laboratory use is shown in fig. 105. In this the resistances are introduced by taking out plugs. The further row of strips are for the A and B arms, the other rows constituting the R arm. The keys are for introducing battery and galvanometer into circuit.

The following graphical demonstration of the stated proportionality of the resistances in the four arms of the Wheatstone bridge when balance is obtained is of interest in connection with the foregoing:

Lay off $A\ B$ to represent the resistance in the upper branch of the bridge (fig. 106) and $A\ F$ to represent resistances in the lower. Let $A\ C$ represent the difference in potential between the two ends of the bridge, and draw lines $C\ B$ and $C\ F$. These are the "fall of potential" lines along the upper and lower branches respectively.

A horizontal line $H\ D$ touches points H and D at the same potential. These projected on lower lines represent the points of galvanometer connection. The resistances passed over in lower and upper branches to reach these points of equal potential, measured on the lower line, are $A\ G$ and $A\ E$.

Similar triangles give these proportions:

$$C\,D : D\,B :: A\,E : E\,B$$
$$C\,H : H\,F :: A\,G : G\,F$$
$$C\,D : D\,B :: C\,H : H\,F$$
$$A\,E : E\,B :: A\,G : G\,F$$
$$A\,E : A\,G :: E\,B : G\,F$$

F and B being at the same point in the conventional diagram of the bridge (fig. 102), the last proportion will be seen to be identical with that accompanying that figure.

The wide range of resistances that can be measured with a Wheatstone bridge has caused it to be likened to a pair of scales which may be converted from hay scales to a chemical balance. It has been noted that when the "balance arms" are equal the resistances of standard coils and measured resistances are equal; and by changing the ratio of these balance arms, which correspond to shifting the fulcrum in the steelyard, the standard resistance may be made to bear any desired ratio to the measured resistance.

One of the late modifications of an old laboratory form of the bridge (called the meter or slide-wire bridge) is the one described below, called the ohmmeter.

In this only a few coils are put in the R arm (usually four), the A and B arms being simply wires of high-resistance metal carried back and forth over a graduated scale for compactness, instead of using one long straight wire. Assuming that a certain coil is plugged in (say 100), it is evident from the principle of the Wheatstone bridge that if balance is obtained at the middle of this bridge wire, when the wire connected with the current indicator (galvanometer or telephone) is touched there, the unknown resistance is 100 ohms. Likewise if no deflection of galvanometer (or silence in the telephone) is obtained at a point which divides the bridge wire into parts bearing any other simple ratio to each other, the known coil and unknown resistance bear the same ratios and the bridge wire may be marked with the appropriate resistance at that point.

Readings may be made very rapidly with this instrument, and it gives quite accurate results at points not too near the ends of the bridge wire.

The theoretical diagram of the ohmmeter is given in fig. 107, in

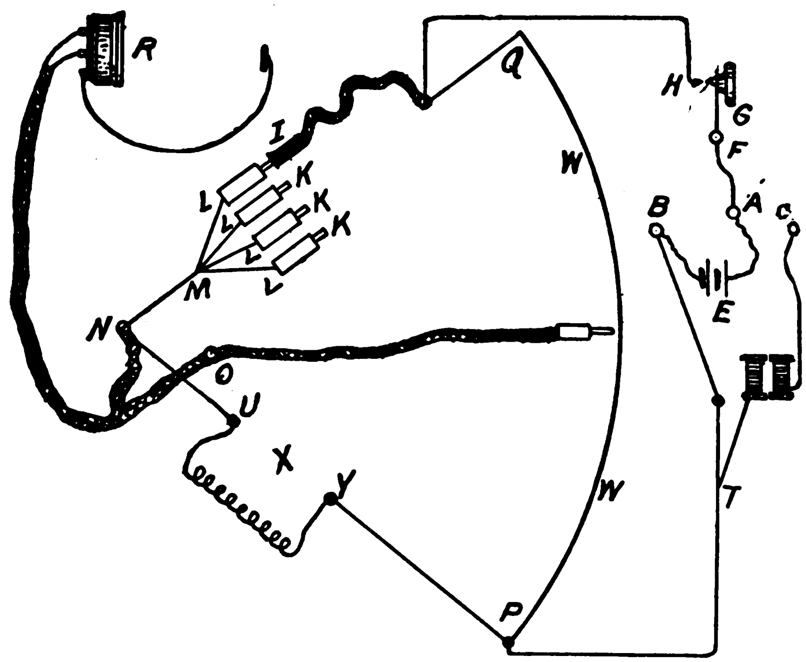


Fig. 107.

which the parts of the conventional form of the Wheatstone bridge are apparent. The *A* and *B*, or " balance arms," are the two parts of the bridge wire *W W* into which it is divided by the " toucher." The four standard resistance coils, 1, 10, 100, and 10,000 ohms, respectively, are *L L L L*, corresponding to the *R* arm of the bridge, *X* (the unknown resistance) forming the other arm. The telephone receiver may take the place of the galvanometer, balance being indicated by the cessation of the clicks and frying sound when the toucher has reached the proper graduation on the bridge wire. The graduations are in colors corresponding to each of the standard coils.

The wiring diagram (fig. 108) is lettered to correspond with the theoretical diagram, and the connections and course of the currents may be easily traced on account of its resemblance to the other forms of Wheatstone bridge already described.

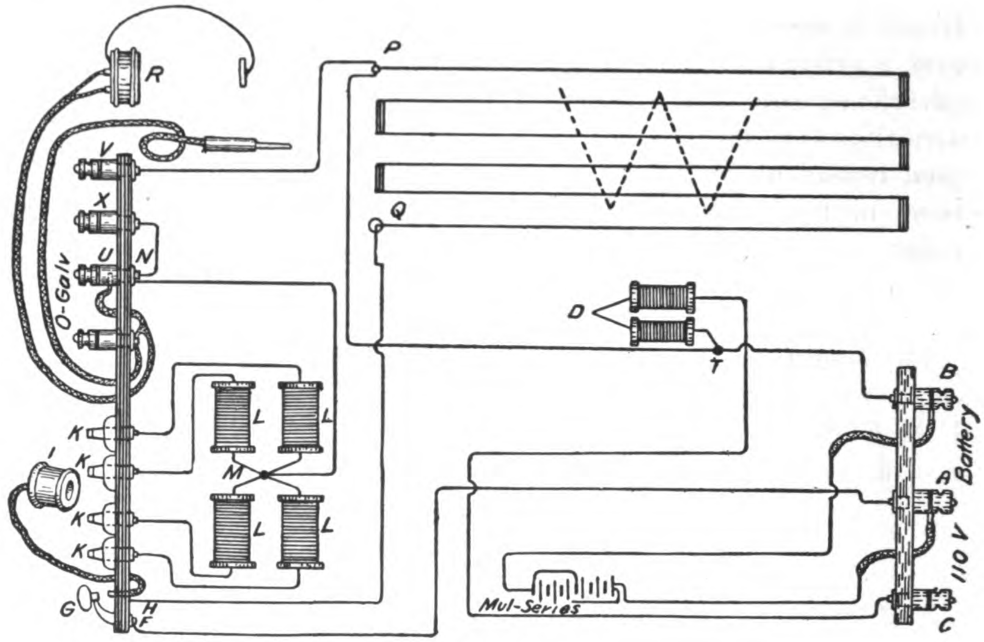


Fig. 108.

DIRECTIONS FOR USING THE OHMMETER (MODEL 1902).

TO MEASURE RESISTANCE.

Connect the unknown resistance to the two binding posts marked "*X*," at the left. Connect the U-shaped clip on flexible cord to the middle post at the right. There are four nickel-plated cones at the left, indicated by colored circles. By means of these the scale which is desired is put in service. For example, if it is desired to use the blue scale, connect the flexible cord which comes up between these cones to the cone indicated by the blue circle. Having thus connected in one of the scales, place the telephone in position on the head and proceed by depressing the key and touching each wire in succession. By feeling along the wire giving least sound in the telephone with the toucher find a point at which no sound is heard in the telephone. Generally speaking, of the three scales (black, blue, and green) the one should be chosen which will bring the balance point as near the center of the scale as possible. If the operator has no idea of the value of the resistance under measurement, he will have to make a preliminary measurement of it with any of the scales and then substitute the scale best suited. The red scale will be found to work best when 110 volts are used (see below), and should only be used for measuring very high resistances. The balance thus obtained, the reading on the proper scale gives directly the resistance under measurement. In some cases it will be found that there is a length of wire rather than a definite point which gives no sound in the telephone; in this case the balance is to be obtained by moving toward this length in one direction and noting the point which gives the last audible sound, then repeating the operation, moving from the other direction. A point halfway between the two points thus obtained is the balance point.

TO USE OUTSIDE BATTERY.

Disconnect the U-shaped clip from the post marked "*Bat.*" and connect the battery to these posts. The battery should not have an E M F of more than 3 to 5 volts if the low scales are used and low resistances are under measurement.

TO USE THE 110-VOLT CIRCUIT.

Disconnect the U-shaped clip from the post marked "*Bat.*" and connect the 110-volt circuit to the posts marked "*110 V.*" This connection may be made direct without using any resistance in the outside circuit. It may be used for measurement on any of the scales, but will be found specially useful for measurements on the high (red) scale.

TO USE A GALVANOMETER IN PLACE OF THE TELEPHONE.

Disconnect the flexible cord from one of the posts marked "*Galv.*" at the left and connect the galvanometer to these two posts; then proceed as under "To measure resistance," using the galvanometer to indicate a balance instead of the telephone.

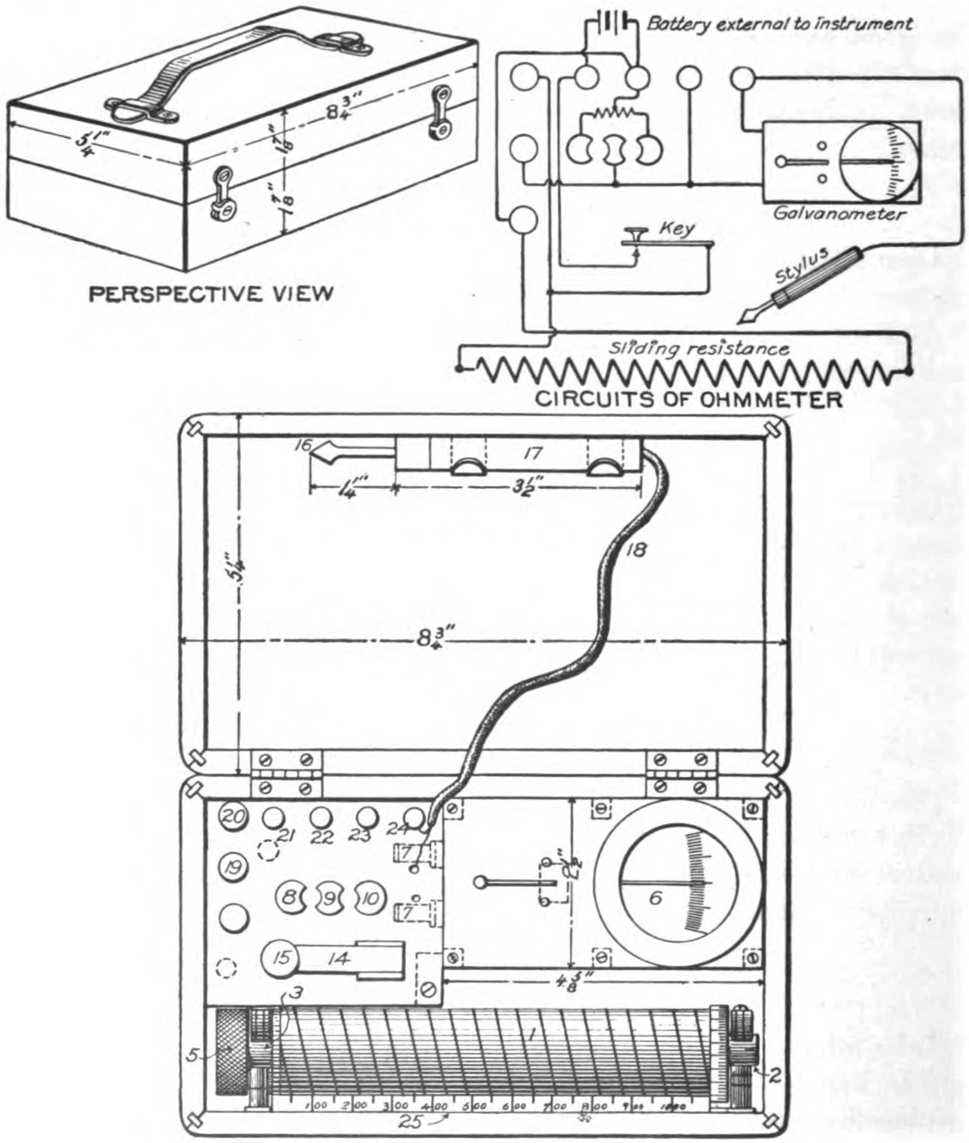
TO PUT IN A NEW BATTERY.

Take off the bottom by unscrewing the screws which hold it. It will be noted that the space inside is largely taken up by a box held in place by screws. This box holds the battery, and may be removed after disconnecting two wires which come from it. The battery is composed of six cells of No. 2 O. K. dry battery, which are connected in two sets of three in series. They should be replaced by batteries of the same kind, connected in the same way, and the wires reconnected to the same binding posts. In doing this great care should be taken not to disturb the other connections or any of the coils.

DIRECTIONS FOR USING THE OHMMETER, MODEL 1904.

(See figs. 109 and 112.)

Connect a battery, preferably a couple of dry cells external to the testing set, to posts marked BA and the unknown resistance to posts



PLAN WITH COVER OPENED

Fig. 109.

X_1, X_2. If the resistance is small, insert the plug at 10, and if large at 100. Depress the key and operate catch; then draw the stylus *lightly* across the horizontal scale, touching the convolutions of wire until the galvanometer reverses its deflection.

Multiples of 50 are read on the horizontal scale, and fractions of a turn on the drum at the right. The tabular number corresponding to this number, as found in the table on the lid of the ohmmeter, when multiplied by 10 or 100, depending on whether the plug is at 10 or 100, will give the correct resistance.

For example, if the balance is found between convolutions Nos. 150 and 200 on the horizontal scale and the drum scale reads 46, the exact reading is 196. Referring to the table, the number corresponding to this is 0.2438, and the resistance, if the plug is inserted in 10, will be 2.438 ohms; or, if the plug is inserted in 100, will be 24.38 ohms.

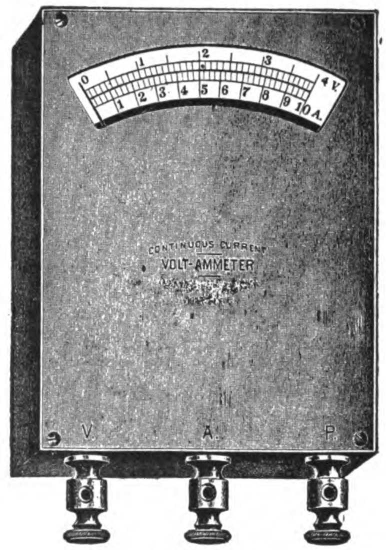


Fig. 110.

A telephone receiver may be used in place of the galvanometer in the ohmmeter by disconnecting one of the cords from the post marked "*Tel.*" and connecting the receiver to those posts.

The portable galvanometer may be used in the place of the galvanometer in the ohmmeter by proceeding as for the receiver. In this case it would be advisable, however, to make use of the galvanometer with shunt.

VOLTAMMETER, UNITED STATES SIGNAL CORPS PATTERN, FOR INSPECTION AND TESTING OF BATTERIES.

RESISTANCE OF VOLTMETER COIL, 100 OHMS; OF AMMETER COIL, 0.5 OHM.

This is a low-range instrument, designed especially for inspecting telephone and telegraph batteries and storage cells. (See fig. 110.)

Caution.—Never connect with more than one storage cell or more than three of other kinds. Too large a current or high voltage will bend the indicator or burn out the coils.

Dry batteries and salammoniac batteries (such as Leclanche, Gonda, etc.) should have voltages between 1.4 and 1.5. This is obtained by connecting with binding posts V P—P being positive. Then, by connecting with A instead of V, the current is indicated on the ampere scale. Since the resistance of the ampere coils is 0.5 ohm, the internal resistance of the cell is given by the formula $\frac{E-0.5\,C}{C}$ where E=voltage of the cell and C=current in amperes. The deterioration of a dry or sal-ammoniac battery is shown by a fall in voltage much below 1.4 and a rise in its internal resistance. This latter should not exceed a few ohms.

The voltage of a bluestone cell is ordinarily about 1. Its internal resistance after it is in good working order should not exceed 8 ohms.

The voltage of a storage cell varies between 1.8 when about discharged to 2.5 when being charged fully. After charge it is about 2. The internal resistance should be very small.

Edison-Lalande and Gordon cells have about 0.75 volt E M F and internal resistances from .06 to .25 ohm.

Fuller cells (with electropoion fluid) have from 1.8 to 2 volts E M F and an internal resistance varying from one-fourth to one-half ohms. A table of internal resistances should be made out for the class of batteries to be tested to save computations in making the round of inpections.

LOCATION OF FAULTS IN TELEGRAPH LINES.

In order to secure the best possible result in the working of telegraph lines we must keep down the resistance of the conductor in the circuit and increase the resistance of the insulator to the greatest possible extent. In other words, the resistance must be as small as possible in the route we wish the electric current to travel and as great as possible in every other direction. The practical working value of a telegraph line is the margin between the joint resistance of the conductor and the insulator, and that of the insulation alone. The tension of the retracting spring of the relay armature when upon a "working adjustment" is the measure of this margin or difference. It is evident that this margin may be increased in two ways, viz: (1) By increasing the insulation resistance; (2) by decreasing the resistance of the conductor.[a]

Faults causing departure from normal working conditions are due to partial or complete contacts of the line wire, directly or indirectly with the ground, usually called by telegraphers "escapes" and "grounds;" crosses, caused by two or more wires coming together; and partial or complete disconnections, causing abnormally high resistance, or complete interruption.

"Escapes" mean imperfect insulation, due to defective insulators, contact of foliage with the wire, or defective office wiring. "Grounds" are often brought about by the wire being down on the ground, to its being detached from an insulator and lying against an iron pole, or defective office wiring.

Abnormally high resistance is due to defective and corroded joints in the line wire or to bad connections in the office wiring, instruments, batteries, or grounds.

When stations are not very far apart, especially where they are along a railroad or good road, the location of the fault between two stations by calling up each station in succession is usually sufficient.

[a] Pope's Modern Practice of the Electric Telegraph.

In case of escapes it is evident that opening the key beyond the escape will not entirely open the circuit at the testing office where the main-line battery is located. So by opening in succession, beginning at distant stations, until we come to a station where practically all current ceases when the key is opened, will indicate that we have passed the escape.

The inability to work beyond a given station indicates a "dead ground."

Total breaks are located by stations successively grounding, beginning at the nearest office to the testing office.

High resistances due to imperfect connections are located by successive grounding in a similar way, a sudden marked falling off in strength of current indicating that the high resistance has just been passed.

In the case of crosses an intermediate office is asked to open No. 1 of the crossed wires and work on No. 2. If, upon opening No. 2 at the testing office, the cross remains, as shown by distant stations' sending coming in on No. 1, it is evident that the cross is between the testing office and the intermediate one. If the cross had disappeared upon opening No. 1 at the intermediate office it is beyond the intermediate office.

In the first case the office next nearest the testing office is called and the test repeated there. In the second case we should proceed outward from the intermediate office. A metallic cross may be distinguished from a leakage or "weather cross" by the sending through the cross in the first case coming nearly as strong as it does on its own wire.

If a high resistance fault is due to bad office connection it can be detected by cutting out the offices in succession until an evident improvement is noted in working. If due to bad joints in the line it can generally be detected by grounding at each station in succession; but these can best be located by measurements of resistances from point to point.

Faulty ground plates often introduce very large resistance in the line. Connections with these should be very carefully made. Only soldered joints should be permitted, if possible, and a good-sized rod, plate, or a good length of coiled wire buried in thoroughly damp ground should be used. It has often been found that the resistance of the ground connection was as much as all the rest of the circuit.

Two lines connected with a bad ground plate will behave as if crossed.

Intermittent or swinging escapes, grounds, and crosses are exceedingly troublesome to locate. They often require accurate and prompt measurements. The Weston voltmeter and milammeter set described, being capable of almost instantaneous readings, is particularly useful in this kind of measurement. The ohmmeter measures resistances directly and almost as quickly. The Wheatstone bridge gives the most accurate results, but considerable skill and experience are necessary in its use.

The tangent galvanometer will give good results in experienced hands, but, except for rough indications, it can not be relied on if used by inexperienced persons.

The ohmmeter and Weston set will, it is believed, give greatest satisfaction in ordinary office measurements of resistance. The Weston set has the additional advantage of giving means for measurements of voltage and current as well.

Its use in daily measurements, as described in the Manila central telegraph office, will give the normal conditions to each station; any departure therefrom is easily detected by measurement in case of line trouble.

The ohmmeter furnishes not only a ready means of measuring resistance, but lends itself to loop tests as well. Its application in locating crosses and grounds, especially of the troublesome "swinging" variety, when the line consists of two or more wires, according to methods suggested and practically tested by Mr. Robert C. Lord, is given below.

METHOD FOR LOCATING A CROSS WHEN ONLY CROSSED WIRES ARE AVAILABLE.

This requires the ohmmeter (pages 158 and 160), one or more known resistances (150-ohm relays will answer), and a special scale of equal parts. These scales are supplied with the ohmmeters, model

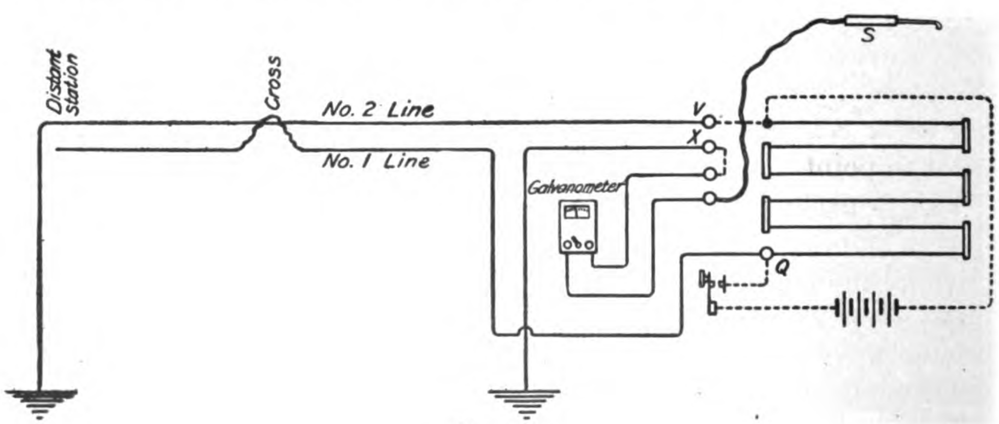


Fig. 111.

1902. It is the length of one of the ohmmeter wires, and is divided into 100 equal parts.

On account of induction from neighboring lines a galvanometer is needed as a detector in place of the telephone receiver. The galvanometer is furnished with ohmmeters used in telegraph-line testing.

The procedure in testing for crosses is as follows:

Some station beyond the cross is called up and asked to open, say, No. 1 and ground No. 2—intermediate stations to cut out. Connect No. 1 with ohmmeter (see fig. 111) by binding post Q, No. 2 with V, and ground with X. Leave socket plug off the tapered posts and find a point of balance on galvanometer with "toucher" S. Suppose balance point is on third wire from top near the right. The six bridge wires may be considered as divided into 100 parts each, making the

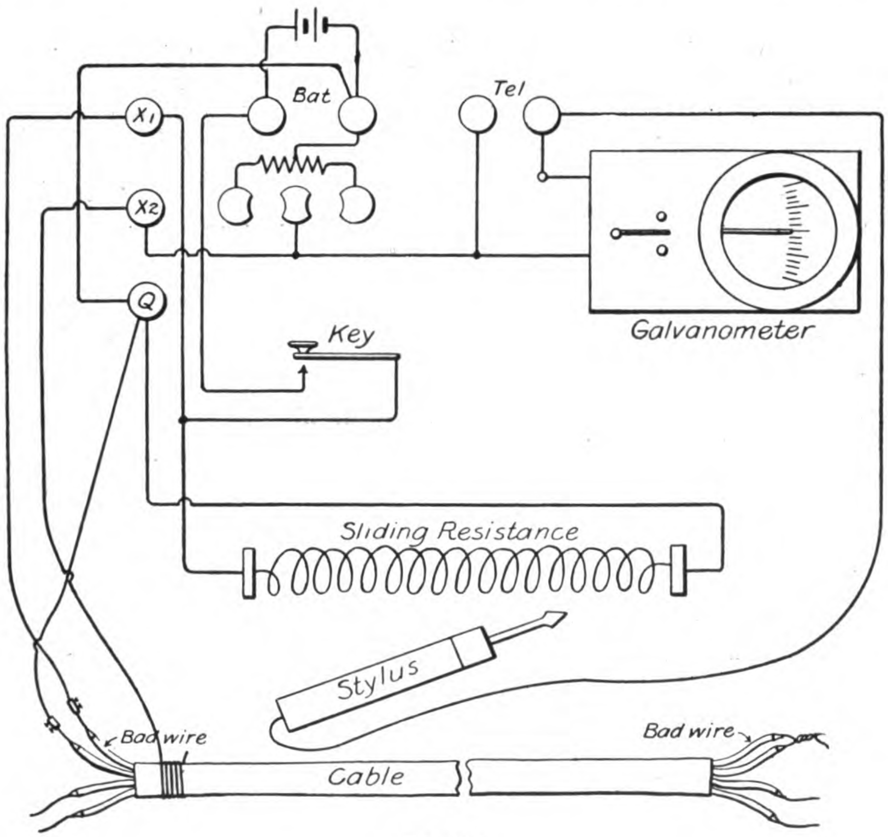


Fig. 112.

whole 600. Consequently the two upper wires are 200, and, applying the movable scale, suppose point of balance is at 85 from the left; then the point of balance divides the whole 600 into 285 and 315 parts, 285 being next to V (No. 2 line) and 315 next to Q (No. 1 line). Now, attach the relay to Q and No. 1 to the other binding post of relay, thus introducing the relay resistance into No. 1. Get a balance again. Suppose point of balance is now on third wire from the top, at 270 by the scale.

The numbers corresponding to No. 2 and No. 1 now are, respectively, 270 and 330. Calling R' the resistance to the cross on No. 2, and the resistance of the relay 150 ohms,

$$R' = \frac{150 \times 270 \times 285}{285 \times 330 - 315 \times 270} = 1{,}282 \text{ ohms.}$$

And if the line wire of No. 2 had a resistance of 20 ohms per mile the distance to the cross would be $\frac{1282}{20} = 64$ miles.

METHOD OF LOCATING FAULTS IN MULTIPLE CONDUCTOR CABLES WITH MODEL 1904 OHMMETER.

Arrange to have the distant end of the faulty conductor connected to a sound conductor in the same cable. Attach the faulty conductor to post X_1 on the ohmmeter and the sound conductor to post Q. See that the variable plug is not inserted at either 10 or 100. Attach a ground wire to X_2. Find a balance as in testing for copper resistance. If the reading, in scale parts, is A and the length of the cable, in feet, is L, the distance to the fault will be L multiplied by $2A$ divided by 1,000. These values hold for any sized cable, but assume that the conductors used are of the same gauge. The connections are shown in fig. 114.

The following example will indicate the method of making this test:

Suppose connections have been made as above and the stylus is at 150 on the scale when a balance has been obtained. Suppose the cable to be 6,000 feet long; 6,000 multiplied by 300 will equal 1,800,000, which divided by 1,000 equals 1,800 feet, the distance from the observer to the fault.

METHOD FOR LOCATING A GROUND OR ESCAPE.

Suppose there are two wires, Nos. 1 and 2. Nos. 1 and 2 and ground should be connected to the ohmmeter, fig. 111, when wires are in good working order, the lines being joined and grounded at the distant station; in fact, this should subsequently be done for a number of intermediate stations. Balance is then taken and record made. Suppose the distance to the station selected is 50 miles. The scale numbers corresponding to balance is, for No. 1, 380, and that for No. 2, 220. The decimal of a mile of each line corresponding to one division of the scale, for future use, may then be made thus:

$$\frac{50}{380} = .132 \text{ for No. 1.}$$

$$\frac{50}{220} = .227 \text{ for No. 2.}$$

These numbers, as multipliers, are always used for finding faults on No. 1 or 2 occurring between testing and distant stations.

Suppose an escape comes on No. 2. The distant station is asked to join, but not ground, Nos. 1 and 2. Suppose, now, balance is obtained at 170, corresponding to No. 2.

Then $170 \times .227 = 38.6$ miles, distance to escape.

Where more than two wires are in a line, systematic measurements of them in pairs should be taken from time to time with the ohmmeter, when wires are in good condition, and the results recorded for reference when faults occur.

The multipliers of No. 1 with No. 3 and No. 2 with No. 3, and so on, should also be taken and recorded. With this data, in case of a cross, swinging, or otherwise, we loop the remaining good wire with one of the faulty ones at the distant station, ground the other faulty one at one or both ends, and proceed to locate the cross as we did to locate the escape or ground, as just explained, as the cross is now simply an escape in the wires looped together.

In the last methods named, by inserting a relay or other known resistance between the ohmmeter bridge wire and a line wire we may find the resistance of the line up to the fault instead of working it directly in miles.

This would be useful in case we are compelled to measure through some intermediate station, the resistance of its relay being, of course, known.

The method of procedure is exactly that given on pages 164–166.

When the line consists of two or more wires on one of which there is an escape or ground, a good wire is joined (not grounded) with the bad one at the distant station. The scale numbers at balance are recorded. The resistance (relay) is then inserted in circuit with the good wire, as just explained, and another balance made. These two sets of numbers and the resistance of the relay will then give the resistance to the fault (as in calculation on page 166).

Where only one wire connects the stations, grounds or escapes may be approximately located by the Weston instruments, as stated on pages 141–145. This can be done only by keeping daily record of line conditions and judging by the local departures therefrom where the faults are. Grounds may be located by measurements of resistance, by Weston set or ohmmeter, up to the fault.

No very satisfactory simple methods exist for locating escapes when only the faulty wire is available, and the tests can be made at one end only.

The simplest one is the Blavier test. This consists of making measurements of resistance, first with the distant end grounded and next with the distant end open. The resistance of the entire line, when in good condition, must be known. (See fig. 113.)

Suppose measurements are made from A, B is asked to open, and measurement is made from A through wire to fault and through fault. Call the resistance M ohms. B then closes and another measurement is made. Call this N ohms. If the resistance of the line is L when in good condition, the resistance in ohms X to the fault will then be given by the formula:

$$X=N-\sqrt{(L-N)\ (M-N)}.$$

A number of pairs of readings, using each end of the battery, if possible, should be made, and the mean of those pairs that agree most nearly should be taken.

The ohmmeter or Weston set may be used to advantage in these measurements and readings obtained as quickly as possible when the battery current is thrown on, as the resistance may vary rapidly, due to the polarization at the fault. It is an advantage to have the current through the escape Z the same when measuring M and N. As a rough compensation in land line measurement, use double the battery in measuring N as when M is measured.

When the resistance of the line in good condition is not known,

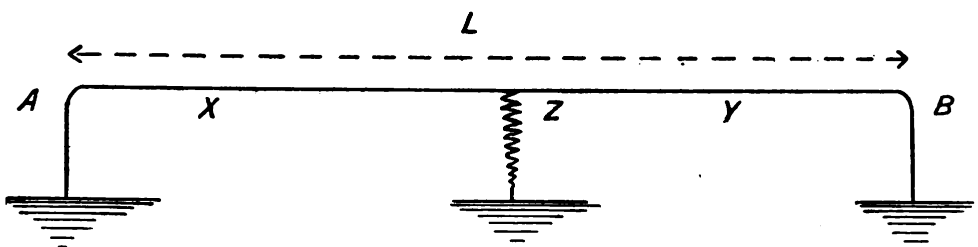


Fig. 113.

the method of procedure adopted may be that given in Chapter V, Manual No. 4, called the Ayrton modification of the Blavier test.

LOCATION OF A CROSS BY MEANS OF THE VOLTMETER.

In general, the resistance of the wire to the cross and through the point of contact (the cross) of the two wires is small compared with the resistance of the voltmeter itself. The following method depends upon the approximate correctness of this assumption. The connections are shown in fig. 114.

One of the wires is grounded at some station E beyond the cross, the other being opened there. The line battery being connected up through a known resistance, R (a 150-ohm relay, for instance), as shown, readings are taken of the voltmeter V connected as shown, first by the full lines and second as shown by dotted lines.

Calling the first reading V^1 and the second V^2 and R 150 ohms, the resistance of the wire X to the cross is given by the formula $X=\frac{V^1}{V^2}\times R$; and if the resistance of the wire per mile is A ohms, the number of miles to the cross is given by $\frac{X}{A}$.

The quick readings that can be made with the voltmeter make this a useful method of locating swinging crosses.

The importance in all these tests, excepting ohmmeter, model 1904, of having some standard known resistances available is apparent. Spare relays and sounders, if not already measured up accurately, should be so measured up and marked at the first opportunity or request made for such standardized coils. So-called 150-ohm relays and 4-ohm sounders frequently vary 5 per cent from their stated

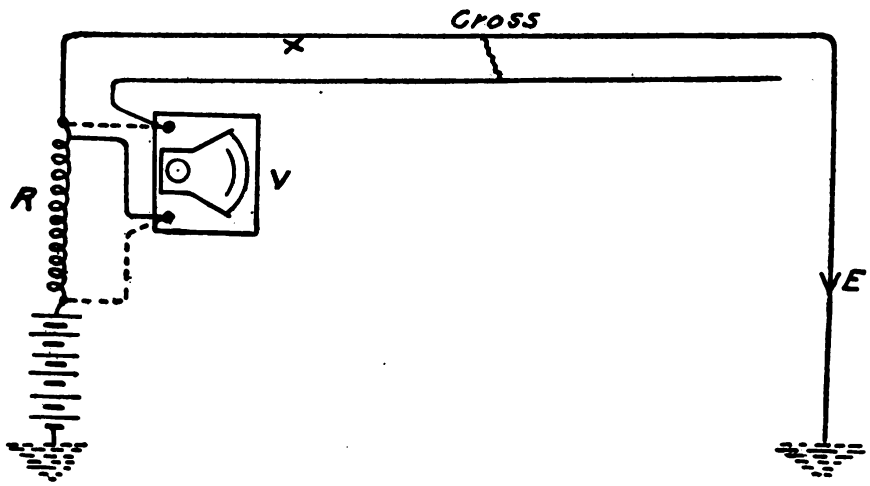


Fig. 114.

resistance and would make considerable error in the calculated positions of faults if used as standards.

TESTING, AND LOCATING FAULTS IN SHORT CABLES WITH IMPROVISED APPARATUS.

The following notes on cable testing and the location of faults where accurate instruments are not available will be found of great value where apparatus must be improvised.

The extensive use of short subterranean and submarine cables for fire control, post telephone, and submarine-mine systems generally makes some method of easy testing desirable. Very frequently testing sets are not on hand. If so, they are out of order or no one sufficiently skilled in their use for location of faults is available. By far the commonest class of faults is that due to defects in insulation. It is desirable to locate these in submarine cables, and very necessary in case of multiple-core cables buried in trenches or drawn into conduits, which, of course, prevents their being taken up for examination.

In the absence of better instruments, a fairly good idea of the insulation resistance of a cable may be arrived at by means of a battery and telephone receiver, as follows:

A telephone receiver (T) is connected with the battery (B) of a few cells, the latter being connected with the cable armor at C. A well-insulated wire (I) is connected with the other terminal of the telephone (fig. 115). The ends of the conductor are prepared and insulated as above described. When the end of I is touched on the cable conductor a click is heard in the receiver. If after about one second it is touched again and no click is heard in the receiver, the insulation resistance, if one cell of battery is used, is about 50 megohms; if two cells of battery, 100 megohms, and so on for about the proportion of cells.

The click produced on first contact is due to the current rushing in to charge the cable; and if the insulation is good, in one second so small an amount of this charge will be lost by leakage that little or no sound will be produced by subsequent contacts, as cable will still be charged. Care should be taken that wire I and telephone terminal

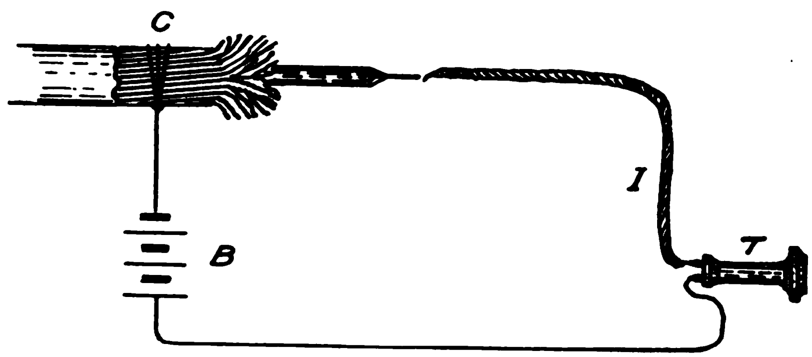


Fig. 115.

attached to it are well insulated, otherwise leakage from them may give false indications.

Having found the faulty conductors, the location of these faults may then be proceeded with by the methods suggested below (figs. 116 and 117). It is applicable to cables having two or more similar conductors, or to a single conductor cable when both ends are available, as when it is coiled in a tank or on a reel. It is the Murray loop test with a "slide wire," in which simple relations of resistance to lengths exist, owing to the uniformity of resistance along the wires in the cable conductors and slide wires, respectively. It is, in fact, a combination of several well-known instrumental methods.

To prevent serious errors care must be taken that one of the conductors in this test has sound insulation.

No resistance measurements are involved, and the only apparatus required are a few cells of battery, a telephone receiver, and from 10 to 50 feet of bare resistance wire. Of this latter about No. 28 "Climax" or "S. B." wire, such as made by the Driver-Harris Company, of Newark, N. J., is suitable. However, if resistance wire is not to be had, fair results may be obtained by using No. 36 bare copper wire.

First taking the case of a multiple-conductor cable, say 3,000 yards long, in which there is one or more conductors with defective insulation and at least one good one, join the defective one to be tested with the good one at the distant end. Drive two small bright nails (A and C in fig. 116) and convenient to the terminals of the conductors at the testing end and stretch from these a piece of the resistance wire around another nail (D) and back, making each equal branch of the wire AD and CD of such a length as to be some exact submultiple of the length of the cable being tested. For example, have each branch of the wire in this case three thousand thirty-seconds of an inch long, or $\frac{3000}{32}$ 93.75 inches. Join one of the two nails at the end by the cable terminals to the defective cable conductor, the other nail to the good conductor. Join one terminal of the telephone

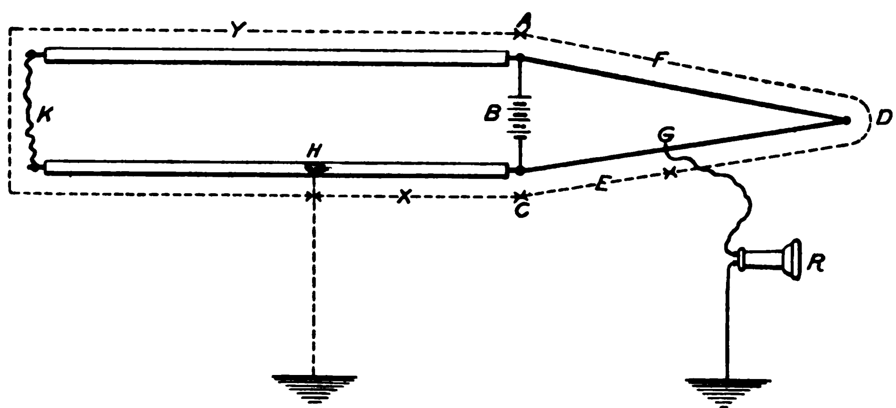


Fig. 116.

receiver R to the ground and the other terminal to a short wire, which will be used as a "searcher." Connect a few cells of battery B across the nails to which the cable terminals are attached. Now, putting the telephone receiver to the ear, feel along the resistance wire, which is attached to the defective conductor, with the searcher wire attached to the telephone. A point G will be found where the frying sound produced in the telephone will cease, and if the searcher wire be moved either way from this it will again become audible. Mark this point on the resistance wire, reverse the connections of the battery, and again find the point of silence. If it is not coincident with the first, take the mean position between them.

The distance of this point G, in *thirty-seconds of an inch*, from the nail C, to which the defective cable terminal is attached, is the distance in *yards* from the cable terminal to the fault.

It is evident that for short cables greater accuracy is secured by taking larger representative units in proportion for the resistance wires. For example, if the cable were 1,250 yards long, the units on the resistance wires could be sixteenths, and the wires be convenient in length: $\frac{1250}{16}=78\frac{1}{8}$ inches.

Care should be taken to stretch the resistance wires evenly and not wrap the loose ends back on the stretched portion, as that would destroy the uniformity of resistances throughout the length on which the assumed proportion depends.

In testing a defective single-conductor cable the two ends are joined to the resistance wire, as just stated, the *whole length* of the resistance wire being in some simple proportion to the length of the cable.

For example, if the cable is 1,980 yards long, the whole length of of the resistance wire would be $\frac{1980}{32}$ or $\frac{1980}{16}$ inches, as desired—the greater length giving the result with greater accuracy. It will be readily seen that this and the former case are identical, as the " loop " formed by joining the distant ends of two multiple conductors is in this case replaced by the " loop " of the single conductor.

The method of securing ends of wires by nails is given to show with what ease and simplicity the necessary parts for the test may be set up. But, even roughly and hastily set up, the test will locate faults with surprising accuracy if a sufficient length of resistance wire be used to eliminate small accidental irregularities in attachments of wires.

The test is a simple application of the Wheatstone bridge principle. It may be of interest to trace this out (fig. 117).

AK and CK are the two cable conductors joined at the distant end K. The lower one is defective at some unknown point H. The resistance wire ADC is joined up as shown with the cable conductors and battery B. The point of silence in the telephone is found at G. The Wheatstone bridge relation of resistances then exists in the lengths of the wire, $X:Y::E:F$. And since these resistances are along uniform wires the same relations exist between *lengths* as between *resistances*. Consequently E can be read off directly in the terms of X if the lengths AD and CD are laid off numerically equal to AK and CK.

The foregoing method involves no computation. It is evident from the above proportion that if the entire length of resistance wire were made some even number of any convenient unit (say sixteenths of an inch) that a substitution of values in the proportion would give the distances. For example, if the resistance wire had a length of 1,000 and balance were found at 432 from the end to which the faulty conductor was attached, the distance to the fault would be 432/1,000 of the *entire* length of the conductors, or $432/1{,}000\times 2$ of the length of the *cable* from the testing point.

By this method, involving simple computations, the same wire stretched on a convenient board may be used for all measurements. It becomes in effect an ohmmeter.

If more than one faulty place exists in the conductor the test will give approximately the mean position. So, having made the test and cut the cable at the indicated place, test both ways to ascertain if both parts are not defective. If sound toward either station, the fault should be relocated in the defective part.

It will probably be found near the position of the first cut and, having allowed a reasonable percentage error, on the second cut it is highly probable the faulty section will be cut off. It is the experience of the writer that generally the error of determination will fall within 1 per cent.

A word may be said regarding the telephone receiver as a detector

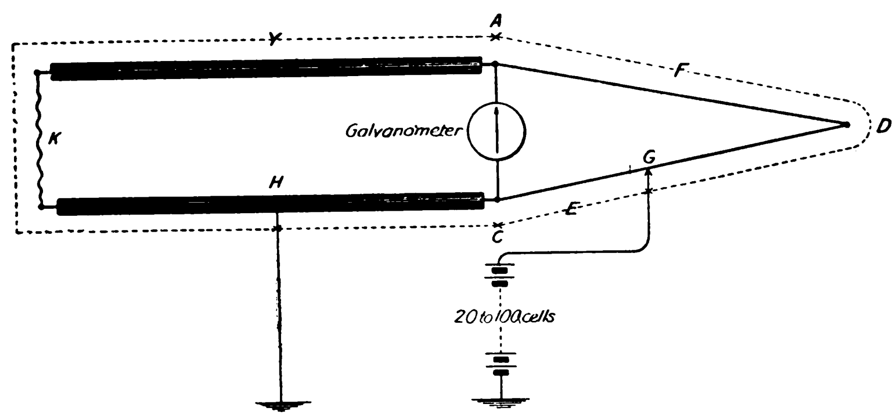


Fig. 117.

of feeble currents. It is much more sensitive than the average pivoted galvanometer and will stand indefinitely more abuse. However, in noisy places the galvanometer may be substituted for the telephone in this test to advantage.

If the fault has a high resistance, so that the four or five cells of battery permissible in the manner of connecting shown in diagram can not send sufficient current through, then some form of rather sensitive galvanometer becomes necessary with the increased battery and change of connections required. In place of the battery in fig. 116, connect the galvanometer. In place of the telephone receiver, connect a battery of from 20 to 100 cells in series. Then proceed as with the telephone receiver, noting that for each break or irregularity of contact of the searcher wire there may be a kick of the galvanometer, due to capacity or inductance of the circuit, and that balance is obtained only when the galvanometer shows no deflection when the searcher wire is at rest. (Fig. 117.)

A fault in a single conductor cable, or one involving *all* the conductors of a multiple cable, may be located if two additional wires

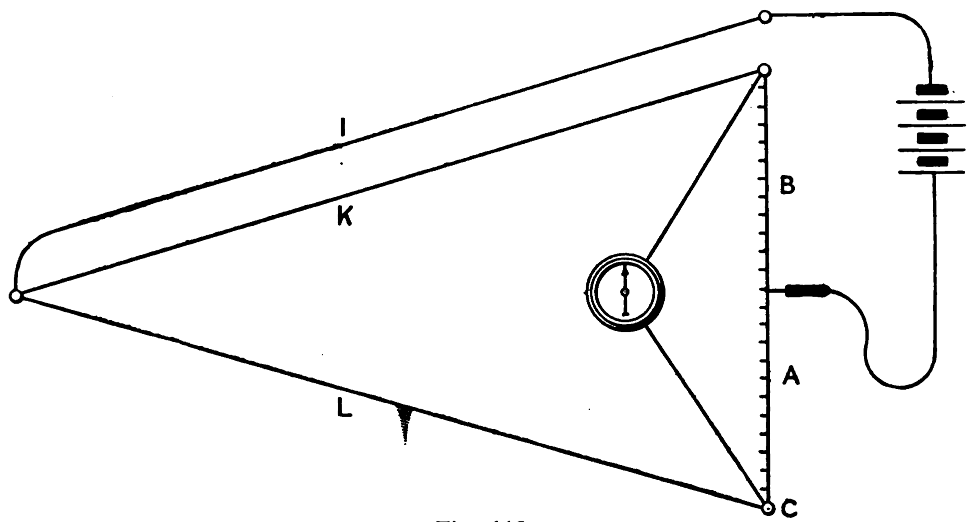


Fig. 118.

of sound insulation between the points connected by the faulty cable are available.

As the lengths and resistances of these wires are immaterial, temporary or roundabout wires may be utilized.

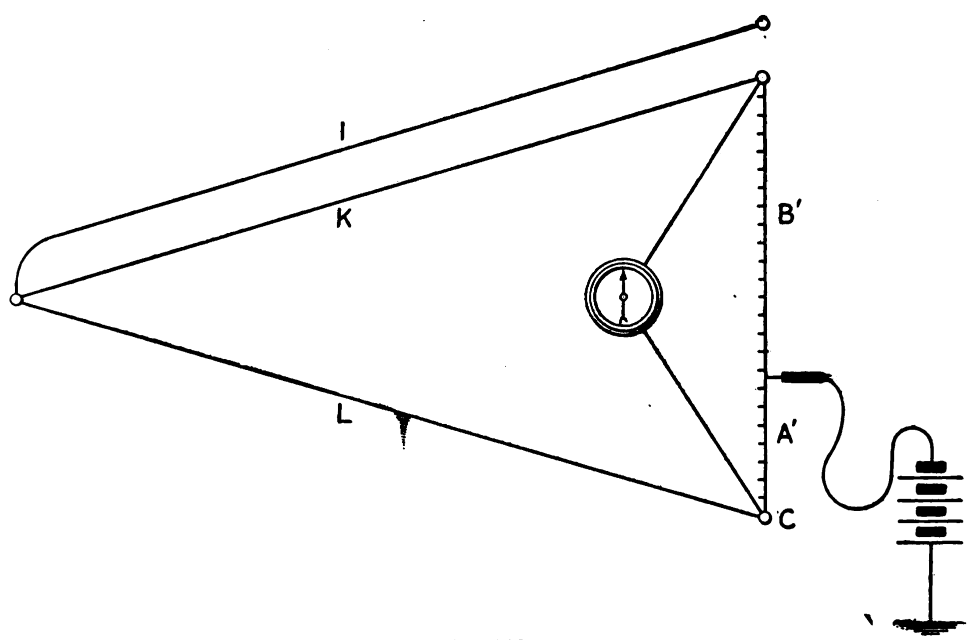


Fig. 119.

The method of procedure is as follows: Stretch a single piece of resistance wire *A B* (figs. 118 and 119) whose length is some even number of parts, say 1,000 sixteenths of an inch. The two sound outside wires *I* and *K* and the defective one *L* are connected at the distant end. The galvanometer, battery, and searcher are connected, as shown in fig. 118, and the point of balance obtained. Call the reading A from the point C.

Then connect up as in fig. 119, joining the battery to earth or to the cable sheath. If the fault appears as a leak between two adjacent wires of the multiple cable, the lower end of the battery should be joined to the other faulty wire instead of the cable sheath or ground.

When balance is obtained, note the reading on the resistance wire from point C. Call it A'. Then if length of faulty conductor is L feet, the distance of the fault from C is $\frac{A'L}{A}$ feet.

This method is particularly applicable to paper cables where a leak has made the insulation of all the conductors faulty.

Location of break in conductor.—The method applicable when the wire is broken inside the insulation, leaving the latter intact, is given below. This is the character of the fault generally produced when a conductor parts in a paper cable. Owing to the small capacity of this kind of cable the method is useful because of the practical difficulty in getting correct capacity values by galvanometer methods in small lengths of this cable.

The connections for the test are the same as that described in fig. 117, except the telephone receiver is used in place of the galvanometer. The point H, instead of representing a fault in insulation, in this case represents the location of a break in the wire. It is best to use quite a number of cells, say, 20 or 30, if available. The battery circuit is interrupted rapidly while a point is sought with the searcher along the resistance wire where the clicks are no longer heard in the receiver. When this point of balance is reached, the distance to the break is then read off on the scale along the resistance wire from C to the point G, as explained in locating insulation faults.

Chapter XI.

FIRE CONTROL MATERIAL.

The peculiar requirements of artillery work have led to the development of much special and unique apparatus. The trying conditions of sea air, moisture, blasts from heavy ordnance, and frequent long-continued drills combined to make ordinary commercial apparatus unsuitable for the service.

Many of the instruments used are fitted particularly for artillery work and are made the subject of a special technical publication of more limited application.

However, much of the material is of general application and is described herein as follows:

Tool and instrument equipments.
Meteorological equipments.
Cable types for fire control purposes.
Cable terminals.

INSTRUMENT AND TOOL EQUIPMENTS.

The standard instrument equipment provided for fire control comprises:

Portable Weston voltmeter.
Voltammeter.
Portable ammeter.
Electrical instrument case.

The electrical instrument case consists of a strong oak box, fig. 120, equipped as follows:

1 cable-testing phone.
1 file of cable blanks.
1 inspector's pocket kit.
1 insulation and capacity testing set containing:
  1 combined shunt and key.
  1 condenser set.
  1 galvanometer, portable.
  1 galvanometer, portable, repair kit for.
  1 galvanometer, portable, telescope for.
  1 galvanometer, portable, telescope arm for.
  1 galvanometer, portable, scale for.
  1 100,000-ohm box.
1 memorandum, No. 5, Signal Corps.
1 micrometer caliper.

1 set of spare parts, consisting of—
- 1 bottle of typewriter oil.
- 1 bottle vaseline.
- 1 card, ohmmeter.
- 1 chamois, piece.
- 1 coil, galvanometer.
- 1 coil, galvanometer, connections for.
- 1 cord, battery, 6 feet long.
- 1 felt, piece.
- 4 scales, paper.
- 2 screws, milled head.
- 8 solder, ounces.
- 1 window, glass.
- 19 wire, advance, No. 28, gr.
- 85 wire, bare copper, No. 22, gr.
- 18 wire, manganin, No. 22, gr.
- 14 wire, manganin, No. 28, gr.
- 9 wire, manganin, No. 34, gr.
- 5 wire, manganin, No. 40, gr.

1 tripod.

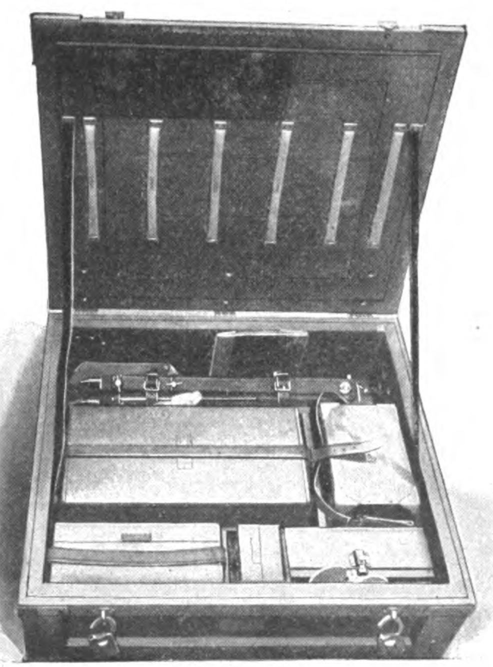


Fig. 120.

In addition to the above list of apparatus and parts, which should always be kept in the case, the tester should supply himself with standard cable blanks and with standard cable tags.

THE GALVANOMETER.

A reflecting D'Arsonval galvanometer is supplied, arranged for mounting on a tripod. It is provided with a short insulated telescope arm and an optical system which magnifies the image of the scale. Owing to this magnification, it is necessary to mount the instrument on a solid floor or to provide against jars while testing, which tend to make the image indistinct.

As in all the instruments of this type the frame is on one side of the circuit, and the tripod legs should be wiped thoroughly dry before making a test. This precautionary measure should always be taken.

The sensibility of this instrument is 300 megohms. This is determined by the fact that one volt through one megohm will deflect the mirror 300 scale divisions.

Fig. 125 shows the essential features of this instrument.

100,000-OHM BOX.

The 100,000-ohm box is a circular rubber case having mounted therein 10 coils wound with No. 40 B. & S. manganin wire. Should

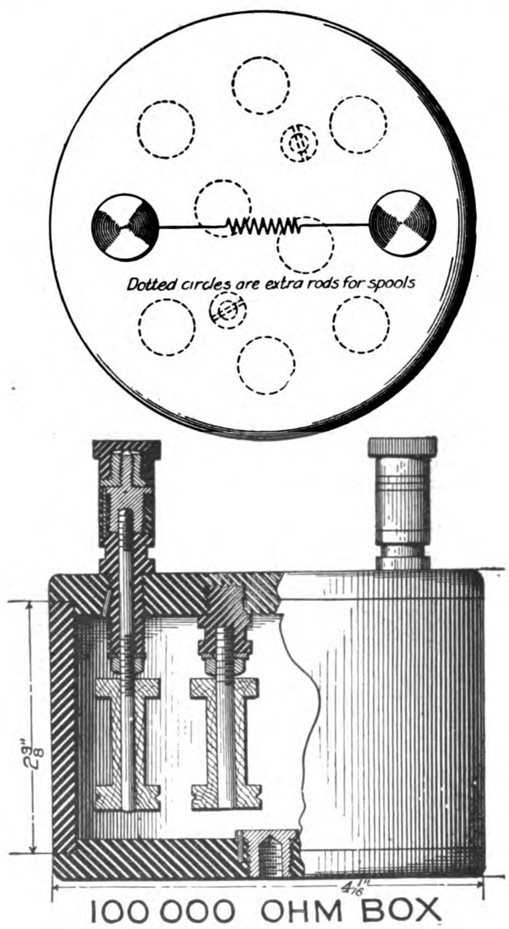


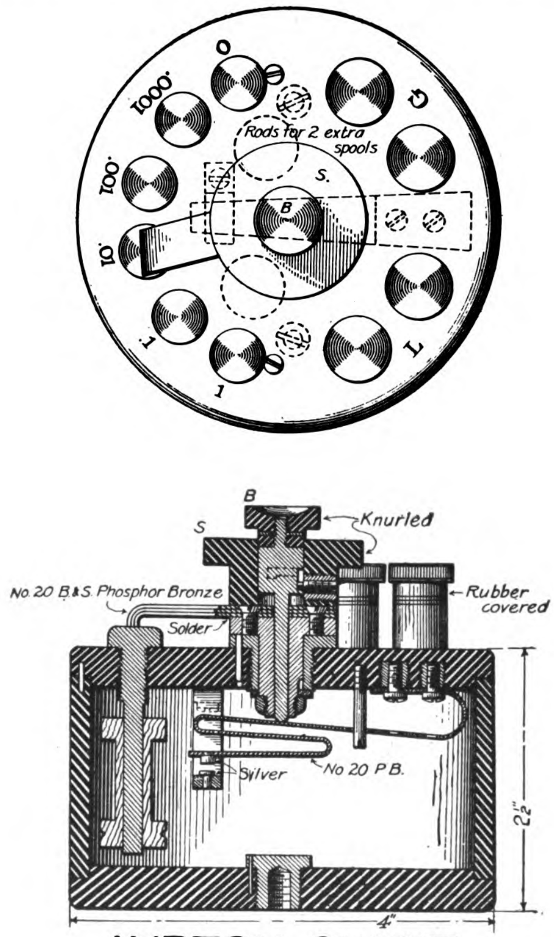
Fig. 121.

trouble occur with this device, the proper-sized wire will be found in the spare-parts case. This box is held together by two screws (fig. 121).

COMBINED SHUNT AND KEY.

This shunt and key, or button, takes the place of the usual Ayrton shunt, battery key, and short-circuiting key. Its connections and general construction are shown in fig. 122.

The key is provided with a bayonet joint. The shunt should always be on 0.0001 at the beginning of the reading, and the lower button is then turned until a readable deflection is obtained.



AYRTON SHUNT

Fig. 122.

The button *B* controls the battery and the button *S* controls the shunt.

This method of operating the galvanometer insures against sudden heavy currents, and consequent violent disturbance of the moving system incident to low insulation, and dispenses with the short-circuit key.

STANDARD CONDENSER.

The standard condenser set consists of a one-third microfarad non-adjustable condenser, with a key for its operation, and the necessary binding posts and plugs, as shown in fig. 123. Its connections are also shown in the figure. By moving the switch S to the right either the cable or condenser may be charged, depending on the location of the

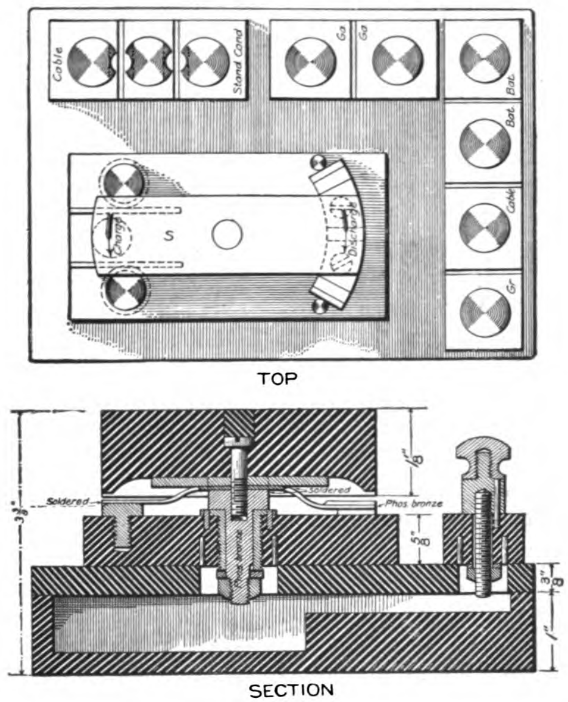


Fig. 123.

plug. The condenser is best-grade mica, with resin and beeswax filling.

SERVICE-TESTING BATTERY.

The service-testing battery consists of 100 cells of small dry batteries. (Fig. 124.) They should be examined once a month.

The battery is tapped for 5, 10, 25, 50, 75, and 100 cells. When new it should give an E M F between 140 and 150, and should not drop below 100 within a year or a year and a half. When certain cells show deterioration they should be removed and the circuit restored. New cells should be requisitioned for throughout when a majority of the cells show discoloration and the voltage of the whole battery is under 80 with all connections in good order and the poorest cells cut out. The maximum life of the cells in this battery is assumed to be two years in a temperate climate, stored in a dry room, and used *under normal testing conditions.*

Care must be taken to keep the battery connections clear of short circuits, as the high voltage of these small cells will cause a heavy

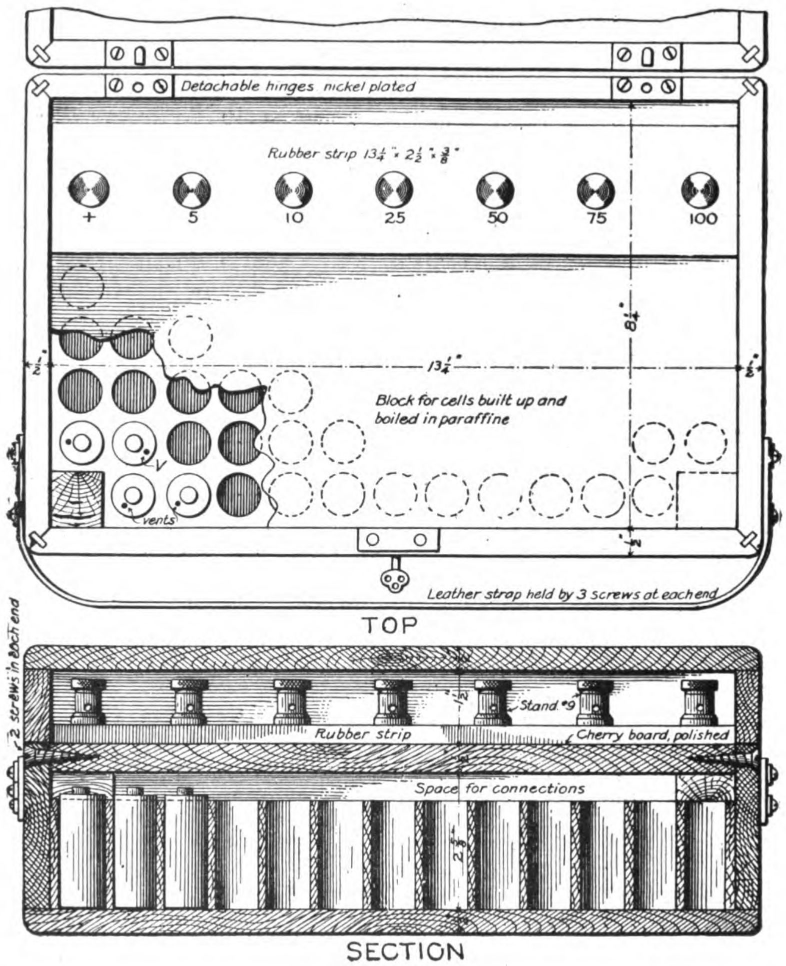


Fig. 124.

current to flow and ruin the battery very quickly if connected to a circuit of low resistance.

OHMMETER MODEL, 1904.

The ohmmeter furnished with this case is a compact form of the original model ohmmeter. The variable resistance is wound on a cylinder so arranged as to be divided into 1,000 equal parts by a horizontal scale of 20 equal parts and a drum scale of 50 unit parts. The reading obtained from the stylus is arbitrary, and reference is had to the table in the cover of the instrument for the actual resistance corresponding to any given position of the stylus. (See figs. 109–112.) The battery key has a bayonet catch.

THE GALVANOMETER.

A reflecting D'Arsonval galvanometer (fig. 125) is supplied, arranged for mounting on a tripod. It is provided with a short insulated telescope arm and an optical system which magnifies the image of the scale. Owing to this magnification, it is necessary to mount

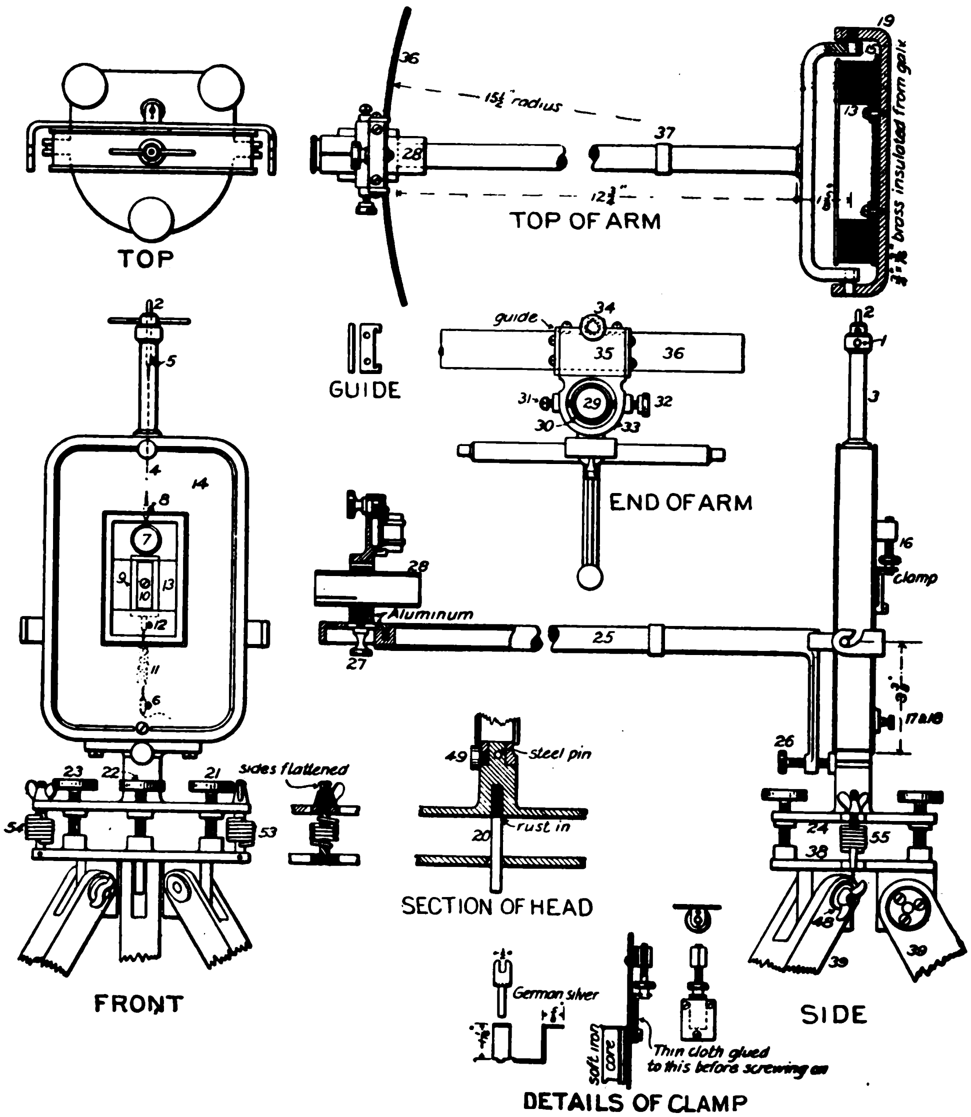


Fig. 125.

the instrument on a solid floor, or to provide against jars while testing, which tend to make the image indistinct.

CABLE-TESTING TELEPHONE.

This telephone was designed in the electrical division, Signal Office, for use of cable testers, and, as will be noted, is especially arranged for this work. (See fig. 126.)

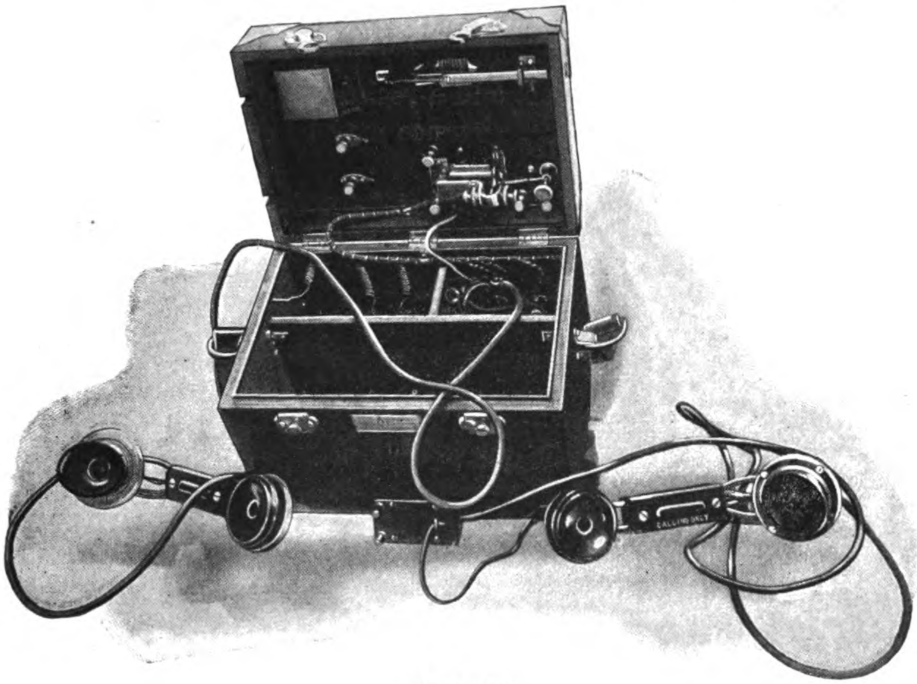


Fig. 126.

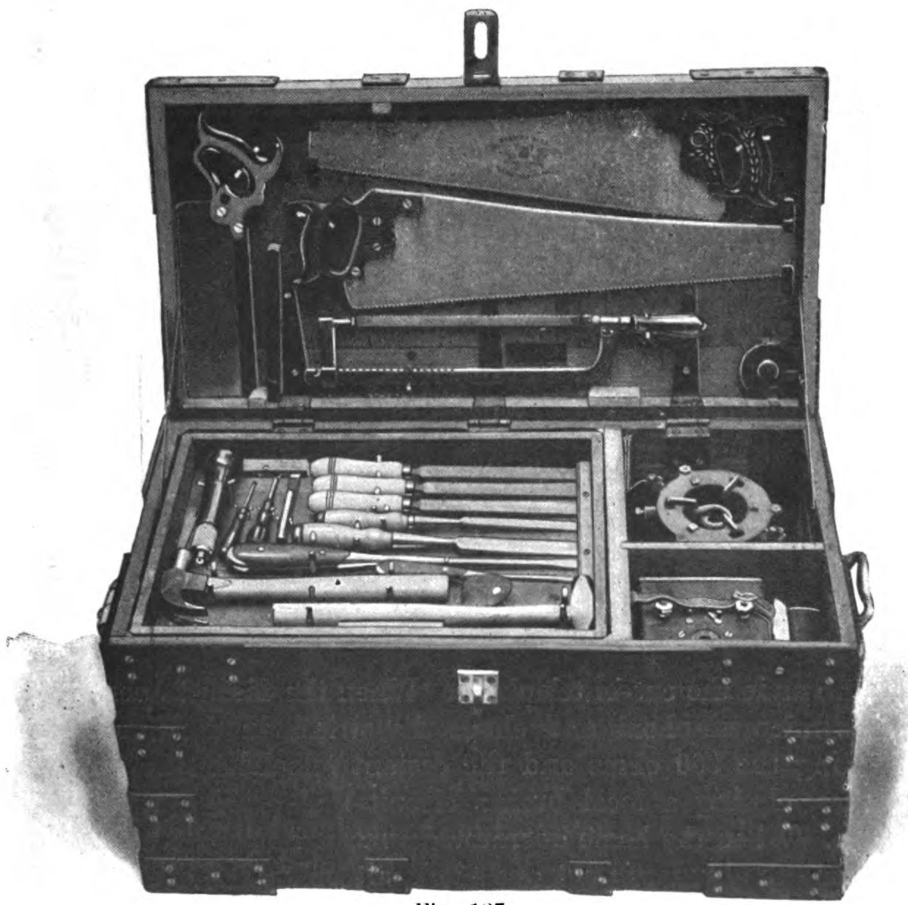


Fig. 127.

The home station is provided with four cells of 4–0 battery, a pony relay, a buzzer, a choke coil, an interrupter, and a hand set. The distance station has a hand set and a resistance of 500 ohms normally in circuit with it, but which resistance may be cut out by depressing the switch in the handle of the set.

When the home operator wishes to call the distant station he draws out the ring *R* of the interrupter, which causes the distant receiver

Fig. 128.

to rattle as in the cut-in telephone. When the distant operator picks up his microtelephone and closes the switch in the handle, short-circuiting the 500 ohms and the distant telephone, the home relay operates, closing a local buzzer circuit and causing the buzzer to vibrate. When the home operator depresses his switch in the micro-telephone the buzzer is cut out of circuit and conversation may take place. The distant hand switch is used for *calling only*.

TOOL EQUIPMENTS.

The standard tool equipment comprises—

The electrical engineer's tool chest.
The construction tool chest.
Service tool bag.
Cable-splicer's chest.
Pipe-fitter's kits.
Inspector's pocket kit.

The electrical engineer's tool chest, as shown in fig. 127, consists of a strong oak chest heavily ironbound, containing a complete list of the standard tools required by an electrical expert in connection with the installation and repair of the apparatus used in a fire-control system.

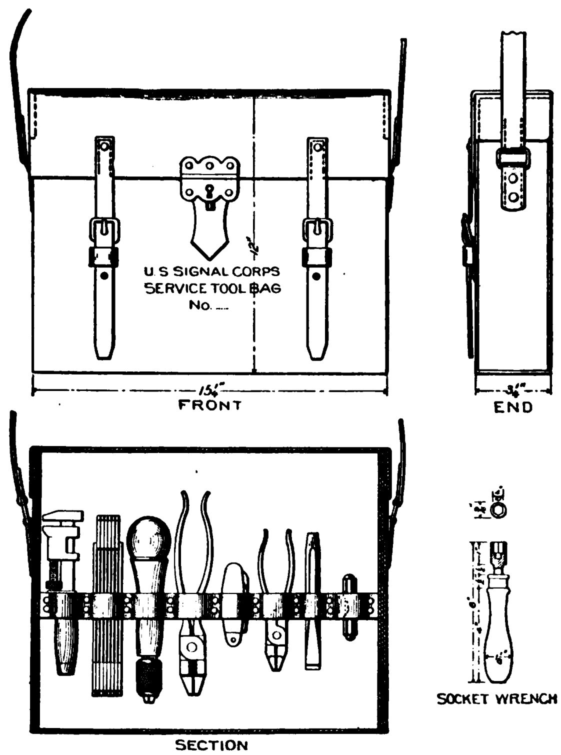


Fig. 129.

The construction tool chest includes a considerable number of plain tools, such as are required for issue to unskilled help in installation work. This chest, as shown in fig. 128, is also heavily ironbound and built to withstand shipment.

The service tool bag (fig. 129) contains all the necessary tools for the ordinary work of wiring, and is issued to the enlisted men of the Signal Corps engaged on fire control installation.

The cable-splicer's kit and pipe-fitter's kit are issued where such tools are necessary, and contain, respectively, the necessary apparatus for all forms of cable splicing and pipe fitting.

METEOROLOGICAL EQUIPMENT.

The meteorological equipment furnished by the Signal Corps comprises the following:

- Anemometer.
- Stop watch.
- Device for operating stop watch.
- Single-stroke bell with switch.
- Psychrometer.
- Aneroid barometer.
- Mercurial barometer.
- Thermometer.
- Wind vane.

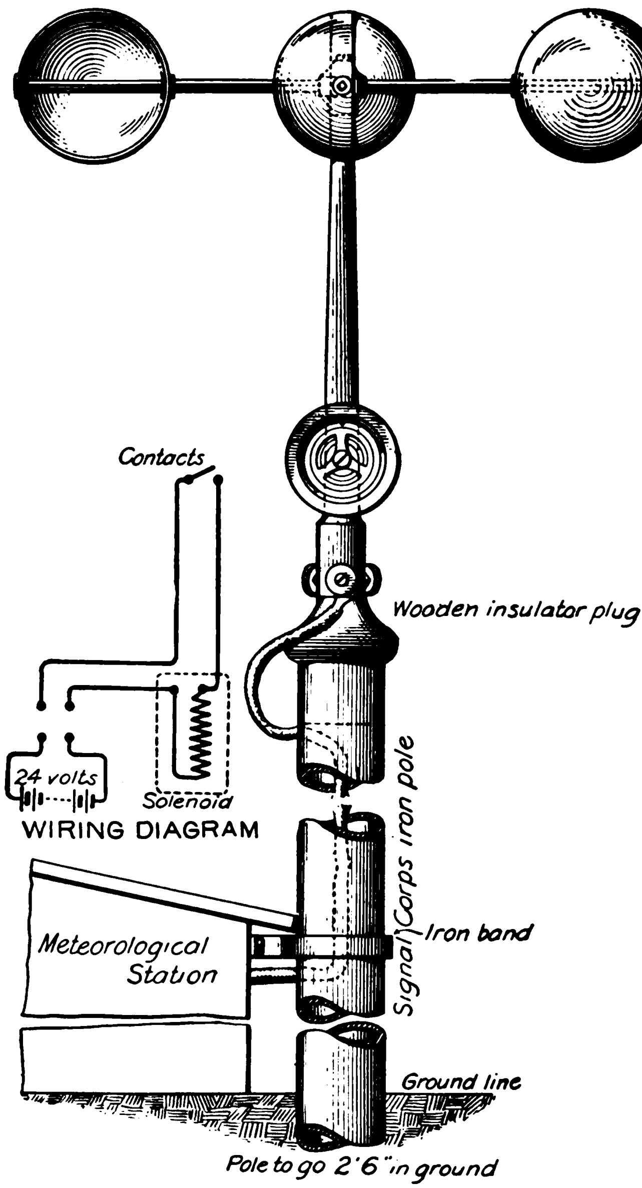


Fig. 130.

The anemometer is the standard Weather Bureau pattern which closes an electrical circuit at every 24 revolutions of the cups. It is normally wired, as shown in fig. 130; the closing of the circuit operating a solenoid which starts and stops the watch. The watch is graduated both in seconds and miles per hour. Should the watch or solenoid get out of order the switch *S* is thrown over to the bell circuit and an ordinary watch may be used to time the interval between strokes. The speed of the wind in miles per hour is then computed by referring to the face of the stop watch, the speed for the interval read being found direct without computation. If the solenoid, only, is out of order the watch may be operated by hand, at the stroke of the bell.

THE SLING PSYCHROMETER.

The sling psychrometer consists of two thermometers attached side by side to a light strip of aluminum or brass, the wet bulb being considerably below the dry. About 6 inches of light chain of very strong construction is attached to the eye at the top and fitted with a small wooden handle so arranged as to permit of the free movement of the chain in the whirling of the thermometer. A substitute for the chain is often used, consisting of a special swivel and link arrangement (see fig. 131), that is stronger and safer than the chain.

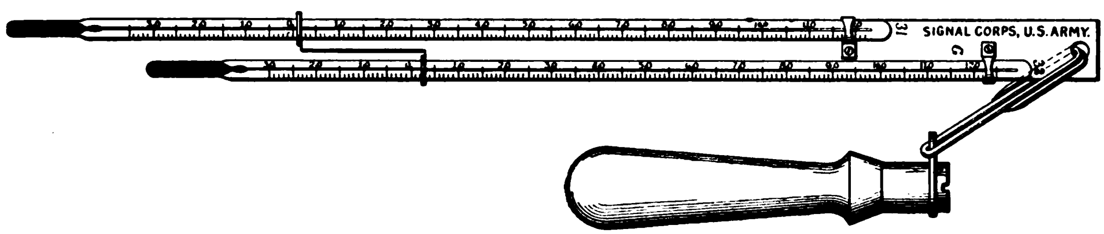


Fig. 131.

This instrument affords at once the simplest and the most accurate means at general command for the determination, not only of the true air temperature, but also of the amount of moisture contained therein, and is considered the standard instrument for observations of this character. While the use of the instrument is attended with considerable risk as to its breakage, especially when in the hands of those not familiar with its use, yet many thousands of observations have been made with a single pair of thermometers without an accident.

Observers should make their first trials on learning to whirl the psychrometer by using some object as nearly as possible like the psychrometer in weight and dimensions. With a little practice one will quickly acquire the knack of whirling and stopping the psychrometer with perfect safety.

While the psychrometer will give quite accurate indications even in the bright sunshine, yet observations so made are not without some error, and where great accuracy is desired the psychrometer should be whirled in the shade of a building or tree, when such is available. In all cases there should be perfectly free circulation of the air, and the observer should face the wind, whirling the psychrometer in front of his body. It is a good plan to step back and forth a few steps to prevent the presence of the observer's body from giving rise to erroneous observations.

It is difficult to effectually describe the method of whirling and stopping the psychrometer. The forearm should be about horizontal, and the hand well to the front. A peculiar swing starts the thermometers whirling, and afterwards the motion is kept up by a slight but very regular action of the wrist, in harmony with the whirling thermometers. The rate should be a natural one, so as to be easily and regularly maintained. If too fast or irregular, the thermometers may be jerked about in a violent and dangerous manner. The stopping of the psychrometer, even at the very highest speed, can be perfectly acomplished in a single revolution when one has learned the knack. This is only acquired by practice, and consists of a quick swing of the forearm, by which the hand also describes a circular path, and, as it were, follows after the thermometers in a manner that wholly overcomes their circular motion without the slightest shock or jerk. The thermometers may, without great danger, be simply allowed to stop themselves. This will generally be quite jerky, but, unless the instrument is allowed to fall on the arm or strike some object, no injury should result.

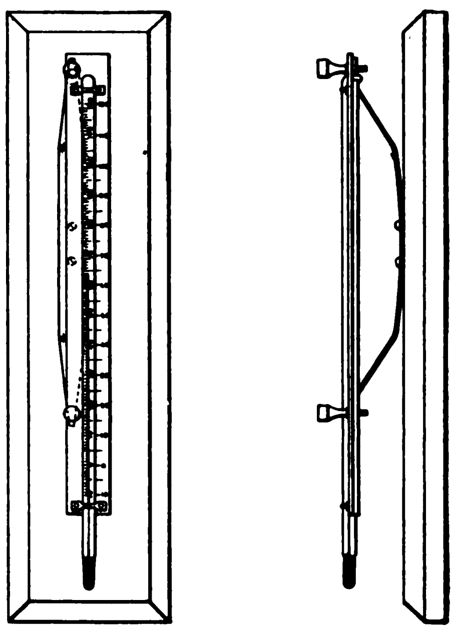


Fig. 132.

THERMOMETERS.

In fig. 132 is shown the form of thermometer issued by the Signal Corps. This is the Weather Bureau pattern and requires no description.

ANEROID BAROMETERS—THEIR CONSTRUCTION.

The general principle of construction of all aneroid barometers is the same. A box with flexible sides, hermetically sealed, the air having been first partially exhausted, changes its form as the pressure of the atmosphere varies. The chief differences in the various kinds lie in the mechanical devices by which the motions of the sides of the box are rendered apparent to the eye, and measured in such a manner as to allow the corresponding pressure to be expressed in inches of mercury.

The aneroid barometer was invented about the beginning of the past century, but was first made in a serviceable form by Vidi in 1848. It is substantially the form most used to-day. The vacuum box is a low, thin cylinder, and the motion of the thin, flexible head of the cylinder is conveyed by suitable mechanism to the index hand.

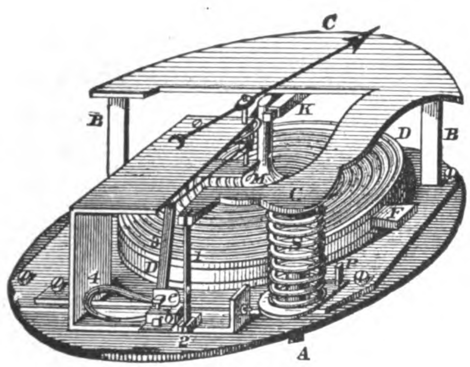


Fig. 133.

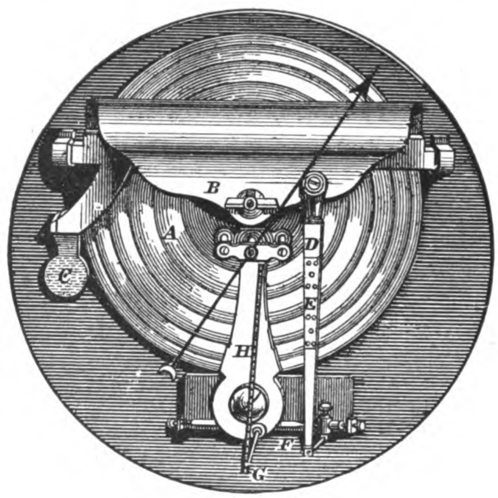


Fig. 134.

Vidi's aneroid is shown in fig. 133. D is the vacuum box, supporting the upright pillar M upon its center. As M rises or falls corresponding motion is given to plate C; a counter pressure is afforded by the spiral spring S.

The motion of C is conveyed by the links 1 and 2 to a little rocker shaft shown in the figure. An arm (3) attached to this shaft is connected by a minute chain with the shaft which carries the index pointer. It is kept wound to the proper tension about this shaft by a fine spiral hand spring.

Naudet's aneroid barometer is the most reliable and is the one now chiefly used. It differs from Vidi's in the substitution of the thin laminated spring (B, in fig. 134) for the spiral spring (S, in fig. 133). The graduations of these instruments are made to correspond with the height of the mercurial barometer, and is expressed as inches or millimeters. Some corrections for temperature and pressure are required in the use of many forms of the aneroid barometer, but in the best constructed of the Naudet instruments a compensation has been effected which renders a correction for temperature unnecessary.

All aneroids should be frequently and carefully compared with standard mercurial instruments in a series of trials at known altitudes, in order to determine the proper correction for instrumental error.

The best aneroids are now marked compensated, and are presumably free from error arising from changes of temperature in the instrument itself. Whether or not such be the case can be readily determined by a series of readings with a standard mercurial barometer, the readings of the latter instrument being corrected for temperature and instrumental error. In making a comparison it should be remembered that the aneroid acts more rapidly under rapid changes of pressure than does the mercurial barometer and care taken to avoid errors from the sluggishness of the latter instrument.

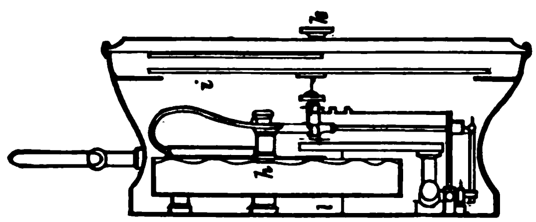


Fig. 135.

Aneroids are variously graduated; some of them are capable of indicating a fall of pressure to 20 inches, corresponding to a height of over 11,000 feet, while many are designed for continual use below 3,000 feet of altitude. In two instruments of the same diameter, but differing as above, it is clear that the latter will have the largest scale divisions, and will therefore be the better instrument to use at the lower altitudes.

It should be carefully remembered that all aneroids vary in their readings with the position in which they are held, reading always a little higher with the dial horizontal (face uppermost) than when vertical. The difference is clearly owing to the direct weight of the mechanism exerted on the vacuum box. There is no objection to allowing this weight to be always added, but the practice of the observer should be uniform, and to read from the horizontal dial is probably the most convenient practice. A tap with the finger just before taking the reading is required to bring the springs to their proper bearings; also, in case of rapid ascents, as some aneroids will not at the moment of attaining an altitude indicate the entire fall of pressure, a few minutes' delay in reading is necessary.

The pointer should be very fine and very close to the graduated scale, and the reading should be taken by looking along the direction of the pointer. For ordinary work it should not be considered important to adjust the aneroid to an absolute agreement with the mercurial barometer. The difference between the readings should be noted and the necessary corrections applied to the readings of the aneroid, but the aneroid should not be forced to agree with the mercurial by use of the adjusting screw.

THE MERCURIAL BAROMETER.

The mercurial barometer issued by the Signal Corps is a modification of the Fortin pattern and consists of a tube, a cistern, a scale, and a thermometer.

ZERO POINT.

The point of a small ivory pin which extends downward from the ceiling of the cistern is the zero point of the barometer scale, and also the point from which the elevation of the barometer above sea level is measured.

THE SCALE.

The scale of the barometer from which the readings are made is usually divided into inches and tenths of an inch. The tenths can be further divided to hundredths by means of the vernier. As the fluctuations of the barometer column extend only over a few inches, the scale is never graduated down to the zero point. The scale of a barometer should never be moved without proper authority, and then only when comparative readings are made with some reliable standard instrument.

The vernier is a short scale which is moved by a screw and ratchet along the barometer scale. The divisions on the vernier of the barometer used by the Signal Corps are one more than the divisions on the part of the barometer scale which it covers. If the vernier has ten divisions, the barometer scale has nine divisions in the same length. To determine the value of a division on the vernier, divide the length of the smallest division on the barometer scale by the number of divisions on the vernier.

Example.—If the length of the smallest division on the barometer scale is 0.10 inch and the vernier has ten divisions, we have $\frac{0.10 \text{ in.}}{10} = 0.01$ inch as the smallest reading which can be made with the vernier.

ATTACHED THERMOMETER.

The attached thermometer is placed so that its bulb rests against the tube of the barometer near the point where the average temperature of the whole column of mercury prevails.

MOVING THE BAROMETER.

In moving a barometer always force the mercury to the top of the cistern by means of the adjustment screw; detach the barometer from its support, or bring it carefully to a horizontal position, invert it, then give the adjustment screw another turn, leaving, however, a small air space in the cistern; for if the mercury fills that and the tube it may be forced through the joints of the cistern. While the cistern is uppermost the tube is full (one solid mass of metal and glass) and is not easily injured. Never swing the barometer or endeavor to force the mercury against the top of the tube without first filling the cistern by means of the large adjusting screw.

PACKING BAROMETERS FOR TRANSPORTATION BY HAND.

In packing for transportation by hand, place the barometer, cistern uppermost, in the wooden box or leather case provided for the purpose; allow no play between the barometer and the case, but to prevent the instrument from shaking fill the spaces with yielding material, such as cotton or excelsior. On steamboats or railroads the barometer should be hung in a stateroom or car, and to prevent jarring the lower end should be firmly strapped to the side of the room or car. In wheeled vehicles the barometer should be carried by hand, supported by a strap over the shoulder or held upright between the legs; it should not be allowed to rest on the floor, as a sudden jar might break the tube. On stage routes, when impracticable to carry it by hand, hang the barometer on a hook inside the stage and securely fasten the lower end so that it will not swing when being thus transported. If carried on horseback, it should be strapped over the shoulder of the rider, where it is likely not to be injured.

In packing for transportation by mail or express, the barometer should be placed in its wooden case and the latter in a box of sufficient size to admit packing on the sides and ends. Excelsior or other pliable material should be closely and evenly packed around the barometer case to prevent its moving in any direction.

All barometers issued from the office of the Chief Signal Officer or returned in good order by mail should be accompanied by a printed letter addressed to mail agents and signed by the General Superintendent of the Railway Mail Service, containing directions for the care of these instruments while in transit. When received by mail or express the party to whom the barometer is addressed should open the box in the presence of some disinterested officer and determine its condition. If broken or injured in any way a full report should be made to the Chief Signal Officer without delay in order that the responsibility for its unserviceable condition may be fixed.

To unpack and suspend the barometer, take it, cistern uppermost, from its case, lower the milled-head screw at the bottom of the cistern one or two turns, invert the barometer slowly and gently, and then hang it in a vertical position.

BAROMETER BOX.

At stations where the standard barometer box is not furnished the barometer will be suspended near a window, so that the 30-inch line of the barometer scale will be $5\frac{1}{2}$ feet above the floor. The barometer should be well lighted, without either exposure to direct rays of the sun or to currents of air, which are usually found at window casings and doors. To protect the instrument from external injuries, from dust, and from the direct radiation of warm bodies or air currents, fasten the wooden case in which it is carried firmly against the wall in a vertical position. An opening large enough to admit the tube of the barometer must be cut in the upper end of the box, and directly above this, at a distance of 1 inch, a strong hook inserted into the wall on which to hang the barometer. This hook must be small enough to allow the ring in the top of the barometer to move freely upon it and allow the instrument to hang in a perfectly vertical position. The hook should extend 2 or 3 inches beyond the box. When an observation is to be made the door of the box should be opened and the barometer drawn out on the hook clear of the box. After the observation is made the barometer should be slipped back and the box closed. Care will be taken not to remove from or return the barometer to its box with a sudden jar, as such handling will injure the instrument.

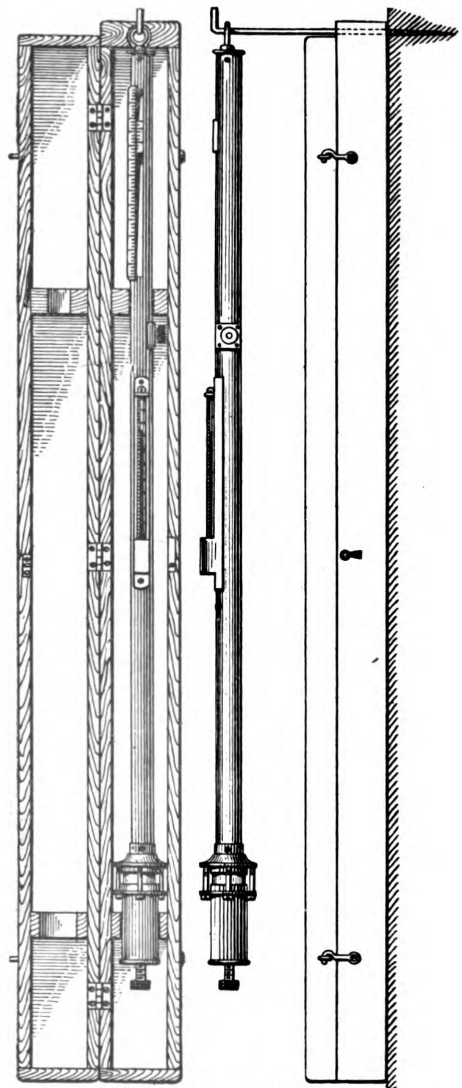


Fig. 136.

The standard barometer box will be erected as follows:

Place the box horizontally upon a table and fit the barometer into it. Carefully lay the barometer upon the four grooved blocks in the box, moving the blocks so that one will be under the cistern just below (when the barometer is in position for observing) the projecting ring; one under the brass tube which incloses the glass tube, and just above the cistern; one just below the top of said brass tube, but not against the scale, and one at a point as nearly midway between the latter two blocks as possible, but below the scale. Leave sufficient space between the bottom of the cistern screw and bottom of the box so that the screw may have sufficient play for making adjustments. Fasten the first two in place by means of the small screws through the sides and back of the box, first boring holes to prevent splitting. The third block must then be fitted into the space between the top of the box and the second block just below it, cutting off a portion of the third if necessary; then fasten it into place against the back of the box by the two screws. Fasten the curved brass plates over the barometer and against the blocks by the small screws, being sure they fit neatly over the barometer. Place the large screw through the ring at the top of the barometer and screw it through the third block and the back of the box, first boring a hole to prevent splitting. When in position the barometer will hang on that screw. Mark the box opposite the 30-inch line of the barometer scale. Remove the curved brass plates, large screw, and barometer, and erect the box so that the 30-inch line will be 5½ feet above the floor. Screw the metal braces accompanying each box one above the other against the window casing at the side of the window, where the sun will not shine upon the box, in such a manner as to allow placing the box directly between them; fix the box in position by screws passing through appropriate holes in the braces and into the ends of the box, using a plumb line to secure the box being in a vertical position. Before firmly fastening the latter screws, turn the box so that its back will be to the full light of the window and in such a manner that at night a light may be held directly behind the windows of the box.

Paste a thin sheet of white paper over the outside of the glass window of the box if it has not already been reduced to translucency. Carefully invert the barometer, place it in its box, replace the large screws, secure the curved brass plates over the barometer and against the box sufficiently tight to hold the barometer in its place and yet permit the observer to turn the barometer around on its axis vertically, should he find it necessary, in order to secure a good light at the ivory point while taking an observation. Close the door of the box and keep it closed except when taking an observation.

In placing barometers in the standard boxes it is very important that they should be vertical, for if one end of the barometer is one-fourth of an inch out of the vertical it will cause the reading to be at least 0.004 inch in error. Use the plumb line both from a front and a side position. To verify the verticality of the barometer, adjust the mercury in the cistern to the zero point and slowly turn the instrument around; if the adjustment continues in all positions, the barometer is vertical.

WIND VANE.

The wind vane consists of an aluminum tube 6 by 18 inches, provided with brass fittings and pivot bearings. It is very little

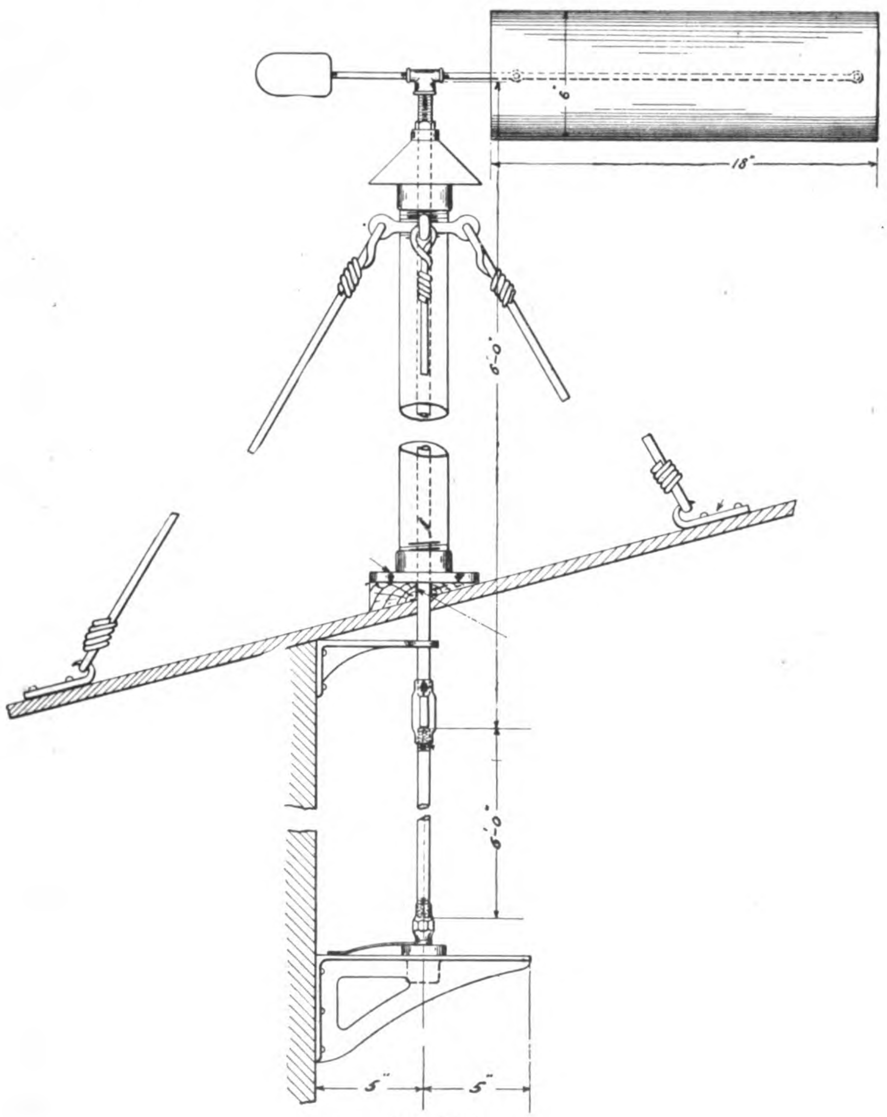


Fig. 137.

affected by gusts of air and tends to point steadily in the general direction of the wind. It has an azimuth circle and conforms to fig. 137.

Chapter XII.

MISCELLANEOUS DATA.

Single cells of battery of the kinds ordinarily used have voltages approximately as follows when in good condition:

	Volts.
Salammoniac batteries (such as dry cells, Leclanche, Gonda, Samson, etc	1.45
Blue vitriol (gravity, etc.)	1
Edison-Lalande and Gordon	.8
Storage cell	2
Fuller	2

The salammoniac, Edison-Lalande and Gordon, fall off when in use, but "pick up" on open circuit if not worked too long continuously.

They vary greatly in internal resistance, but average per cell about as follows:

Type.	Ohms.
4-0 dry	0.25
4 dry	.25
5 dry	.20
6 dry	.20
7 dry	.12
8 dry	.10
Leclanche and Gonda	1.5
Samson	.25
Gravity	3
Edison-Lalande and Gordon	.1
Storage cell	.005
Fuller	.25

The resistances of the ordinary electrical instruments in use run about as follows:

	Ohms.
Telegraph relay	150
Telegraph sounder	4
Ordinary vibrating bell	2.5
Telephone receiver	80
Telephone magneto generator	300
Telephone bell coils	1,000
Telephone induction coil local battery:	
Secondary	37
Primary	.5

The above, regarding the telephone, is based on the 1904 Signal Corps Service telephone.

The 1902 model service telephone has its secondary in two sections, one section being 37 ohms and the whole secondary 200 ohms.

The American Bell instruments formerly issued have all the coils except primary approximately 1,000 ohms.

The current required to operate instruments properly is about as follows:

Telegraph relay, 0.035 ampere (35 milliamperes).

Telegraph sounder, 0.25 ampere (250 milliamperes).

Vibrating bell, 0.3 ampere.

[Full instructions for signaling will be found in Signal Corps Manual No. 6, "Visual Signaling."]

The Myer system for United States Army and United States Navy signaling. (*Prescribed by General Orders, No. 32, Adjutant-General's Office, 1895.*)

A	22	J	1122	S	212
B	2112	K	2121	T	2
C	121	L	221	U	112
D	222	M	1221	V	1222
E	12	N	11	W	1121
F	2221	O	21	X	2122
G	2211	P	1212	Y	111
H	122	Q	1211	Z	2222
I	1	R	211	tion	1112

NUMERALS.

1	1111	2	2222
3	1112	4	2221
5	1122	6	2211
7	1222	8	2111
9	1221	0	2112

ABBREVIATIONS.

a	after	n	not	ur	your
b	before	r	are	w	word
c	can	t	the	wi	with
h	have	u	you	y	yes

CONVENTIONAL SIGNALS.

End of a word	3	Cease signaling	22 22 22 333
End of a sentence	33	Wait a moment	1111 3
End of a message	333	Repeat after (word)	121 121 3 22 3 (word)
xx3 numerals follow (or) numerals end.		Repeat last word	121 121 33
sig. 3	signature follows.	Repeat last message	121 121 121 333
Error	12 12 3	Move a little to right	211 211 3
Acknowledgment, or "I understand"	22 22 3	Move a little to left	221 221 3
		Signal faster	2212 3

CODE CALLS.

I C U—International Code Use.
T D U—(Navy) Telegraph Dictionary Use.
G L U—(Navy) Geographical List Use.
G S U—(Navy) General Signal Use.
N L U—Navy List Use.
V N U—Vessel's Numbers Use.
C A U—Cipher "A" Use.
C B U—Cipher "B" Use.
C C U—Cipher "C" Use.
} These calls are for preconcerted use in or with the Navy.
A C U—Army Code Use (War Department Telegraphic Code).
W C U—War Department Cipher Use.
S C U—Signal Cipher Use.
P C U—Use preconcerted code agreed upon between officers signaling.

INSTRUCTIONS FOR USING THE SYSTEM.

The whole number opposite each letter or numeral stands for that letter or numeral.

TO SIGNAL WITH FLAG, TORCH, LANTERN, OR SEARCHLIGHT.

There are one position and three motions.

The first position is with the flag or other appliance held vertically, the signalman facing squarely toward the station with which it is desired to communicate.

The first motion ("one" or "1") is to the right of the sender and will embrace an arc of 90°, starting with the vertical and returning to it, and will be made in a plane at right angles to the line connecting the two stations.

The second motion ("two" or "2") is a similar motion to the left of the sender.

The third motion ("front," "three," or "3") is downward directly in front of the sender, and instantly returned upward to the first position.

Numbers which occur in the body of a message must be spelled out in full. Numerals may be used in signaling between stations having naval signal books, using the code calls.

The beam of searchlight will be ordinarily used exactly as a flag, the first position being a vertical one.

To break or stop the signals from the sending station, make with the flag or other signal 12 12 12 continuously.

To use the torch or hand lantern, a footlight must be used as a point of reference to the motion. The lantern is more conveniently swung out upward, by hand, from the footlight for "1" and "2" and raised vertically for "3."

TO SEND A MESSAGE.

To call a station, signal its call letter until acknowledged; if the call letter be not known, signal "E" until acknowledged. To acknowledge a call, signal "I understand," followed by the call letter of the acknowledging station.

Make a slight pause after each letter and also after "front." If the sender discovers that he has made an error, he should make 3, followed by 12 12 3, after which he begins the word in which the error occurred.

FLASH SIGNALS WITH LANTERN, HELIOGRAPH, OR SEARCHLIGHT.

Use short flash for "1," two short flashes in quick succession for "2," and a long steady flash for "3." The elements of a letter should be slightly longer than in sound signals.

The first position is to turn a steady flash on the receiving station. The signals are made by alternate obscuration and revelation.

To call a station, make the call letter until acknowledged. Each station will then turn on a steady flash and adjust. When the adjustment is satisfactory to the called station it will cut off its flash, and the calling station will proceed with its message.

If the receiver sees that the sender's mirror needs adjusting, he will turn on a steady flash until answered by a steady flash. When the adjustment is satisfactory the receiver will cut off his flash, and the sender will resume his message.

To break the sending station for other purposes, turn on a steady flash and call for repeat, etc., as occasion requires. All other conventional signals are the same as for the flag, etc.

SOUND SIGNALS WITH FOG WHISTLE, FOR HORN, OR BUGLE.

Use one toot (about half second) for "1," two toots (in quick succession) for "2," and a blast (about two seconds long) for "3." The ear and not the watch is to be relied upon for the intervals.

The signal of execution for all tactical or drill signals will be one long blast, followed by two toots in quick succession.

In the use of any other appliance, such as a bell, by which a blast can not be given, three strokes in quick succession will be given in place of the blast to indicate "3."

When more than two vessels are in company, each vessel, after making "I understand," should make her call letter, that it may be certain which vessel has acknowledged.

ADDITIONAL INSTRUCTIONS.

Each word, abbreviation, and conventional signal is followed by "3."

To start the sending station, signal 121 121 3 22 3, followed by the last word correctly received, the sender will resume his message, beginning with the word indicated by the receiver.

To acknowledge the receipt of a message signal 22 22 3, followed by the personal signal of the receiver. Each station should have its characteristic call letter, as Washington, W, and each signalist his personal signal, as Jones, Jo.

The full address of a message shall be considered as one sentence, and will be followed by the signal "33."

This is prepared under authority of General Orders, No. 32, Adjutant-General's Office, 1896; it replaces all preceding and undated codes prior to October 30, 1896.

A. W. Greely,
Brigadier-General, Chief Signal Officer.

Telegraph codes.

LETTERS.

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

Telegraph codes—Continued.

NUMERALS.

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

PUNCTUATIONS, ETC.

Period	. . — — . .	. . . . . .
Colon	— . — . .	— — — . . .
Semicolon	. . . . .	— . — . — .
Interrogation	— . . — .	. . — — . .
Exclamation	— — — .	— — . . — —
Fraction line	.	
Dash	— . . . — . .	
Hyphen	. . . . . — . .	— . . . . —
Pound sterling	. . . . . . — . .	— . — . .
Capitalized letter	. . . . — . .	
Colon followed by quotation	— . — . . — .	
Dollar mark	. . . . — . .	
Decimal point	Spell ‘dot.”	
Comma	. — . —	. — . — . —
Paragraph	— — — —	
Underline (begin)	. . — . — . .	. . — — . —
Underline (end)	. . — — . — .	
Parenthesis (begin)	. . . . . — .	— . — — . —
Parenthesis (end)	. . . .	
Quotation marks (begin)	. . — . — .	. — . — . — . —
Quotation marks (end)	. . — . — . — .	
Quotation within a quotation (begin)	. . — . . — . .	
Quotation within a quotation (end)	. . —	
Apostrophe		. — — — — .

COMMON ABBREVIATIONS.

[In use in United States telegraph services.]

Abt......About
Af.......After
Agn......Again
Amn......American
Amt......Amount
Anr......Another
Ar.......Answer
Arv......Arrive
Atk......Attack
Atl......Atlantic
Awa......Away
Awi......Awhile
Ax.......Ask
Ay.......Any
B........Be
Bal......Balance
Bd.......Board
Bld......Bundle

Bf .... Before
Bg .... Being
Bn .... Been
Bot ...... Bought
Bro ...... Brother
Bk .... Break or back
Bt .... But
Btn ...... Between
Btr ...... Better
Bu .... Bushel
Byd ...... Beyond
Bz .... Business
Bat ...... Battery
Bbl ...... Barrel
C .... See
Ca .... Came
Cg ...... Seeing
Chg ...... Charge
Cr .... Care
Ct .... Connect
Cty ...... City
Cvl Civil
Cx .... Capital letter
Col ...... Collect
Ck .... Check
Da .... Day
Dd .... Did
Deg ...... Degree
Dld ...... Delivered
Dr .... Doctor
Drk ...... Dark
Dux ...... Duplex
DH ...... Deadhead
Ea .... Each
Ed .... Editor
Eng ...... Engine
Etc ...... Et cetera
Ev .... Ever
Evn ...... Even
Exa ...... Extra
Fl .... Feel
Fld ...... Field
Flg ...... Feeling
Flo ...... Flow
Flt .... Felt
Fm ...... From
Fri ...... Friday
Frt ..... Freight
Gr .... Ground
G. B. A .. Give better address
G. A ..... Go ahead
G. S. A .. Give some address
G. M ..... Good morning
G. E ..... Good evening
G. N ..... Good night
Gen ...... General
Ger ...... German
Gg ...... Going
Gu ...... Guard
Gv .... Give
Gvg ..... Giving
Hb .... Has been
Hhd ..... Hogshead
Hld ...... Held
Hlm ..... Helm
Hm ...... Him
Hnd ..... Hundred
Hon ..... Honorable
Hpn ..... Happen
Hqrs ..... Headquarters
Hr .... Here
Hs .... His
Hu ..... House
Hv .... Have
Hw ...... How
Ify .... Infantry
Imp ..... Import
Ix .... It is
Ixu ...... It is understood
Kp .... Keep
Kpg ..... Keeping
Kpt ...... Kept
Kw ...... Know
Kwg ..... Knowing
Kws .... Knows
Las ...... Last
Lat ...... Latitude
Lft ...... Left
Lit .... Little
Lk .... Like
Lt .... Lieutenant
Lv .... Leave
Lvg ...... Leaving
Lvs ...... Leaves
Lyg ...... Lying
Ma ...... May
Mab ..... May be
Maj ...... Major
Mar ..... March
Mas ...... Master
Mat ...... Material
Max ..... Maximum
Mch ..... Machine
Mcy ..... Machinery
Md ...... Made
Mem ..... Member
Mfd ...... Manufactured
Mgr ..... Manager

Mh	Much
Mil	Military
Min	Minute
Mk	Make
Mkg	Making
Mkr	Maker
Mks	Makes
Mkt	Market
Ml	Mail
Mng	Morning
Mny	Many
Mo	Month
Mon	Money
Mrl	Marshal
Msg	Message
Msk	Mistake
Mst	Must
Mv	Move
Myn	Million
Na	Name
Nd	Need
Nec	Necessary
Neg	Negative
Ni	Night
No	No, and New Orleans
Nun	None
Nv	Never
Nw	Now
Nx	Next
N. M	No more
Ofc	Officer
Ofr	Offer
Ofs	Office
Opr	Operator
Ot	Out
Otr	Other
Ov	Over
O. K	All right
Pc	Per cent
Pd	Paid
Ph	Perhaps
Pha	Philadelphia
Pm	Postmaster
Po	Post-office
Pod	Post-Office Department
Pot	President of the
Potus	President of the United States
Pr	President
Pra	Pray
Prt	Part
Pt	Present
Qk	Quick
Qmg	Quartermaster-General

Qr	Quarter
R	Are
Rc	Receive
Rcd	Received
Rcg	Receiving
Rcr	Receiver
Rcs	Receives
Rct	Receipt
Rek	Wreck
Rht	Right
Rlf	Relief
Rp	Report
Rpt	Repeat
Rr	Railroad
Ru	Are you
Ruf	Rough
Ry	Railway
Sa	Senate
Scotus	Supreme Court of the United States
Sd	Should
Sdn	Sudden
Sec	Section
Sed	Said
Sem	Seem
Sen	Seen
Sh	Such
Shf	Sheriff
Shl	Shall
Sig	Signature
Sik	Sick
Sis	Sister
Slf	Self
Slo	Slow
Slr	Sailor
Sm	Some
Sma	Small
Sn	Soon
Snc	Since
Snd	Send
Snr	Sooner
Snt	Sent
Sor	Soldier
Sp	Ship
Spfy	Specify
Spl	Special
Spo	Suppose
Ss	Steamship
St	Street
Sta	State
Stn	Station
Sto	Store
Str	Steamer
Sud	Surround

Sv	Seven
Svc	Service
Svd	Served
Sve	Serve
Svg	Serving
Svl	Several
Swo	Swore
Sx	Dollar mark
Sy	Say
S. Y. S.	See your service
T	The
Tan	Than
Tg	Thing
Tgh	Telegraph
Tgm	Telegram
Tgr	Together
Tgy	Telegraphy
Th	Those
Thk	Thank
Tho	Though
Thr	Their
Ti	Time
Tk	Take
Tkg	Taking
Tkn	Taken
Tkt	Ticket
Tlk	Talk
Tm	Them
Tn	Then
Tnd	Thousand
Tni	To-night
Tnk	Think
Tr	There
Tru	Through
Ts	This
Tse	These
Tt	That
Ttt	That the (5)
Tuf	Tough
Tw	To-morrow
Ty	They

U	You
Uc	You see
Un	Until
Uni	United
Upn	Upon
Ur	Your
Urg	Urge
Val	Value
Vy	Very
W	With
Wa	Way
Wat	Water
Wd	Would
Wea	Weather
Wg	Wrong
Wh	Which
Wi	Will
Wit	Witness
Wl	Well
Wlk	Walk
Wn	When
Wnt	Want
Wo	Who
Wom	Whom
Wos	Whose
Wr	Were
Ws	Was
Wt	What
Wu	Western Union
Wy	Why
Y	Year
Ya	Yesterday
4	Please start me, or where
5	Have you anything for me
9	Important official message
13	Understand
25	I am busy now
30	No more
73	Accept best regards
77	Message for you
92	Deliver

"Wire"—Give instant possession of line for test.

Copper-wire table, giving weights, lengths, and resistances of wires at 20° C. or 68° F., of Matthiessen's standard conductivity, for A. W. G. (Brown & Sharpe).

A. W. G. (B. & S.).	Diameter (inches).	Area (circular mils.).	Weight.	
			Pounds per foot.	Pounds per ohm.
0000	0.460	211,600	0.6405	13,090
000	.4096	167,800	.5080	8,232
00	.3648	133,100	.4028	5,177
0	.3249	105,500	.3195	3,256
1	.2893	83,690	.2533	2,048
2	.2576	66,370	.2009	1,288
3	.2294	52,630	.1593	810
4	.2043	41,740	.1264	509.4
5	.1819	33,100	.1002	320.4
6	.1620	26,250	.07946	201.5
7	.1443	20,820	.06302	126.7
8	.1285	16,510	.04998	79.69
9	.1144	13,090	.03963	50.12
10	.1019	10,380	.03143	31.52
11	.09074	8,234	.02493	19.82
12	.08081	6,530	.01977	12.47
13	.07196	5,178	.01568	7.840
14	.06408	4,107	.01243	4.931
15	.05707	3,257	.009858	3.101
16	.05082	2,583	.007818	1.950
17	.04526	2,048	.006200	1.226
18	.04030	1,624	.004917	.7713
19	.03589	1,288	.003899	.4851
20	.03196	1,022	.003092	.3051
21	.02846	810.1	.002452	.1919
22	.02535	642.4	.001945	.1207
23	.02257	509.5	.001542	.07589
24	.02010	404.0	.001223	.04773
25	.01790	320.4	.0009699	.03002
26	.01594	254.1	.0007692	.01888
27	.0142	201 5	.0006100	.01187
28	.01264	159.8	.0004837	.007466
29	.01126	126.7	.0003836	.004696
30	.01003	100.5	.0003042	.002953
31	.008928	79.70	.0002413	.001857
32	.007950	63.21	.0001913	.001168
33	.007080	50 13	.0001517	.0007346
34	.006305	39.75	.0001203	.0004620
35	.005615	31 52	.00009543	.0002905
36	.0050	25.0	.00007568	.0001827
37	.004453	19 83	.00006001	.0001149
38	.003965	15 72	.00004759	.00007210
39	.003531	12.47	.00003774	.00004545
40	.003145	9.888	.00002993	.00002858

Copper-wire table, giving weights, lengths, and resistance, etc.—Continued.

A. W. G. (B. & S.)	Length.		Resistance.	
	Feet per pound.	Feet per ohm.	Ohms per pound.	Ohms per foot.
0000	1.561	20,440	0.00007639	0.00004893
000	1.969	16,210	.0001215	.00006170
00	2.482	12,850	.0001931	.00007780
0	3.130	10,190	.0003071	.00009811
1	3.947	8,083	.0004883	.0001237
2	4.977	6,410	.0007765	.0001560
3	6.276	5,084	.001235	.0001967
4	7.914	4,031	.001963	.0002480
5	9.980	3,197	.003122	.0003128
6	12.58	2,535	.004963	.0003944
7	15.87	2,011	.007892	.0004973
8	20.01	1,595	.01255	.0006271
9	25.23	1,265	.01995	.0007908
10	31.82	1,003	.03173	.0009972
11	40.12	795.3	.05045	.001257
12	50.59	630.7	.08022	.001586
13	63.79	500.1	.1276	.001999
14	80.44	396.6	.2028	.002521
15	101.4	314.5	.3225	.003179
16	127.9	249.4	.5128	.004009
17	161.3	197.8	.8153	.005055
18	203.4	156.9	1.296	.006374
19	256.5	124.4	2.061	.008038
20	323 4	98.66	3.278	.01014
21	407.8	78.24	5.212	.01278
22	514.2	62.05	8.287	.01612
23	648.4	49.21	13.18	.02032
24	817.6	39.02	20.95	.02563
25	1,031.0	30.95	33.32	.03231
26	1,300.0	24.54	52.97	.04075
27	1,639.0	19.46	84.23	.05138
28	2,067.0	15 43	133.9	.06479
29	2,607.0	12.24	213.0	.08170
30	3,287.0	9.707	338.6	.1030
31	4,145.0	7.698	538.4	.1299
32	5,227.0	6.105	856.2	.1638
33	6,591.0	4.841	1,361.0	.2066
34	8,311.0	3.839	2,165.0	.2605
35	10,480.0	3 045	3,441.0	.3284
36	13,210.0	2.414	5,473.0	.4142
37	16,660.0	1.915	8,702.0	.5222
38	21,010.0	1.519	13,870.0	.6585
39	26,500.0	1.204	22,000 0	.8304
40	33,410.0	.9550	34,980.0	1.047

COIL WINDINGS.

The following for use in winding coils is abstracted from a paper by A. V. Abbott:

DATA FOR WINDING COILS.

Size of wire (B. & S.).	Resistance ohms per cubic inch.			
	Single cotton.	Double cotton.	Single silk.	Double silk.
0000	0.0000111	0.0000086	------------	------------
000	.0000155	.0000119	------------	------------
00	.0000233	.0000166	------------	------------
0	.0000412	.0000360	------------	------------
1	.000114	.000108	------------	------------
2	.000177	.000163	------------	------------
3	.000268	.000253	------------	------------
4	.000514	.000423	------------	------------
5	.000760	.000692	------------	------------
6	.001175	.001080	------------	------------
7	.001760	.001650	------------	------------
8	.00290	.00264	------------	------------
9	.00413	.00396	------------	------------
10	.00662	.00638	------------	------------
11	.01065	.01006	------------	------------
12	.01830	.01585	------------	------------
13	.02665	.02425	------------	------------
14	.03860	.03585	------------	------------
15	.06980	.05572	------------	------------
16	.1035	.09250	------------	------------
17	.1491	.1320	------------	------------
18	.2655	.2055	------------	------------
19	.3415	.2665	------------	------------
20	.6100	.4799	0.7190	0.5580
21	.9150	.7110	1.104	1.010
22	1.345	1.000	1.541	1.442
23	2.218	1.600	2.760	2.367
24	3.241	2.339	4.280	3.625
25	4.361	3.415	6.620	5.530
26	6.666	5.003	10.400	8.382
27	11.01	7.250	15.79	12.73
28	17.04	10.50	24.30	19.49
29	23.11	14.26	37.00	28.60
30	34.42	21.21	56.21	43.12
31	49.85	30.10	85.98	63.60
32	70.58	41.00	128.90	91.55
33	102.00	57.90	197.00	127.00
34	147.60	81.30	307.90	201.10
35	209.10	100.4	434.80	287.5
36	294.0	150.4	506.0	410.0
37	445.0	201.0	943.0	533.0
38	544.0	268.0	1,385.0	823.0
39	762.0	364.0	2,060.0	1,145.0
40	1,085.0	488.5	3,050.0	1,611.0

Data for winding coils—Continued.

Size of wire (B. & S.).	Inches per turn or layer.			
	Single cotton.	Double cotton.	Single silk.	Double silk.
0000	0.6418	0.7309		
000	.6231	.7112		
00	.5510	.6536		
0	.3521	.3731		
1	.3155	.3236		
2	.2924	.2895		
3	.2519	.2597		
4	.2222	.2326		
5	.1965	.2044		
6	.1762	.1842		
7	.1613	.1653		
8	.1418	.1490		
9	.1340	.1357		
10	.1171	.1198		
11	.1031	.1068		
12	.0893	.09624		
13	.0833	.08772		
14	.0769	.08000		
15	.0651	.07262		
16	.0597	.06579		
17	.0564	.05988		
18	.0513	.05452		
19	.0439	.04965		
20	.0389	.04444	0.03610	0.03814
21	.0353	.04082	.03228	.03440
22	.0322	.03745	.03978	.03114
23	.0291	.03552	.02618	.02814
24	.0271	.03190	.02360	.02555
25	.0263	.02984	.02127	.02328
26	.0249	.02726	.01921	.02136
27	.0208	.02567	.01734	.01938
28	.0184	.02403	.01578	.01772
29	.0177	.02259	.01426	.01624
30	.0168	.02131	.01296	.01497
31	.0156	.02009	.01182	.01381
32	.0146	.01911	.01078	.01279
33	.0137	.01815	.009842	.01188
34	.0128	.01737	.008921	.01106
35	.0121	.01666	.008354	.01032
36	.0115	.01600	.007686	.009662
37	.0109	.01546	.007112	.009074
38	.0105	.01497	.006622	.008561
39	.00993	.01475	.006120	.008163
40	.00943	.01404	.005630	.007740

Data for winding coils—Continued.

Size of wire (B. & S.).	Feet of wire per cubic inch.			
	Single cotton.	Double cotton.	Single silk.	Double silk.
0000	0.2025	0.1559		
000	.2145	.1647		
00	.2745	.1950		
0	.3824	.3275		
1	.8389	.7950		
2	1.0460	.9630		
3	1.223	1.1510		
4	1.875	1.5410		
5	2.159	1.9930		
6	2.670	2.4580		
7	3.205	3.0500		
8	4.140	3.7680		
9	4.875	4.5260		
10	6.072	5.8120		
11	7.830	7.4000		
12	10.450	8.9820		
13	12.000	10.8300		
14	14.070	13.0200		
15	19.680	15.7000		
16	23.330	20.8100		
17	26.220	23.2500		
18	31.710	27.9900		
19	43.200	33.7400		
20	54.200	42.6000	63.90	58.50
21	65.170	50.8000	78.90	72.10
22	80.100	59.3100	91.80	85.90
23	98.300	70.9000	122.3	105.2
24	113.300	81.7800	149.6	126.7
25	121.200	95.0100	184.1	153.6
26	147.000	109.6000	225.9	182.5
27	192.000	126.3000	277.1	221.8
28	234.000	144.2000	334.5	266.2
29	255.200	163.2000	409.5	315.8
30	296.600	183.5000	486.9	373.3
31	342.600	206.3000	597.2	436.6
32	392.000	228.0000	716.0	509.2
33	444.500	253.0000	860.0	545.0
34	502.800	276.1000	1,046.0	682.0
35	569.100	300.5000	1,182.0	782.0
36	632.000	326.0000	1,410.0	890.2
37	703.000	348.5000	1,640.0	926.5
38	750.000	371.8000	1,910.0	1,137.0
39	844.500	394.5000	2,225.0	1,251.0
40	935.000	421.0000	2,630.0	1,390.0

Data for winding coils—Continued.

Size of wire (B. & S.).	Bare wire.	Diameter, in mils., over insulation.			
		Single cotton	Double cotton.	Single silk.	Double silk.
0000	460.000	610.000	697.000	....	....
000	409.640	590.000	677.000	....	....
00	364.800	525.000	622.000	....	....
0	324.950	475.000	572.000	....	....
1	289.300	299.300	311.300	....	....
2	257.630	267.630	277.600	....	....
3	229.420	239.420	249.400	....	....
4	204.310	214.310	222.300	....	....
5	181.940	189.940	196.440	....	....
6	162.020	170.020	176.520	....	....
7	144.280	152.280	158.780	....	....
8	128.490	136.490	142.990	....	....
9	114.430	122.430	128.930	....	....
10	101.890	108.190	113.590	....	....
11	90.742	97.042	102.442	....	....
12	80.808	87.108	92.508	....	....
13	71.961	78.261	83.661	....	....
14	64.084	70.384	75.784	....	....
15	57 068	63.368	68.768	....	....
16	50.820	57.120	62 520	....	....
17	45.257	51.557	56.957	....	....
18	40.303	46 603	52.003	....	....
19	35 390	41.690	47.090	....	....
20	31.961	37.861	42 161	34.261	36.161
21	28 462	34.362	38.662	30.762	32.662
22	25.347	31.247	35.547	27.647	29.547
23	22.571	28 471	32.771	24.871	26.771
24	20.100	26 000	30.300	22.401	24.300
25	17.900	23.800	28.100	20.200	22.100
26	15.940	21.840	26.140	18.240	20.140
27	14.195	20.095	24.395	16.495	18.395
28	12.641	18.541	22.841	14.941	16.841
29	11.257	17.157	21.457	13.557	15.457
30	10 025	15.925	20.255	12.325	14.225
31	8 928	14.828	19.128	11.228	13.128
32	7.950	13.850	18.150	10.250	12.150
33	7.080	12.980	17.280	9.380	11.280
34	6.304	12.204	16.504	8 504	10.504
35	5.614	11.514	15.814	7.914	9.814
36	5.000	10.900	15.200	7.300	9.200
37	4.453	10.353	14.653	6.753	8.653
38	3.965	9.865	14.165	6.265	8.165
39	3.531	9.431	13.731	5.831	7.731
40	3.144	9.044	13.344	5.344	7.344

Data for winding coils—Continued.

Size of wire (B. & S.).	Turns per linear inch.			
	Single cotton.	Double cotton.	Single silk.	Double silk.
0000	1.558	1.368		
000	1.605	1.406		
00	1.815	1.530		
0	2.140	1.980		
1	3.170	3.090		
2	3.540	3.400		
3	3.970	3.850		
4	4.500	4.300		
5	5.090	4.890		
6	5.660	5.430		
7	6.200	6.050		
8	7.050	6.710		
9	7.460	7.370		
10	8.540	8.350		
11	9.700	9.360		
12	11.200	10.390		
13	12.000	11.400		
14	13.000	12.500		
15	15.370	13.770		
16	16.740	15.200		
17	17.740	16.700		
18	19.500	18.340		
19	22.770	20.140		
20	25.700	22.500	27.70	26.22
21	28.300	24.500	30.97	29.07
22	31.000	26.700	34 39	32.11
23	34.400	28.970	38.19	35.53
24	36.900	31.350	42.37	39.14
25	38.000	33.920	47.02	42.94
26	42.000	36 290	52.06	46.81
27	48.000	38.950	57.67	51.59
28	53.000	41.610	63.36	56.43
29	56.500	44.270	70 11	61.56
30	59.660	46 930	77.14	66.79
31	64.125	49.780	84 64	72.39
32	68.600	52.340	92.72	78.19
33	73 050	55.100	101.65	84.17
34	77.900	57.570	112.11	90 44
35	82.600	60.040	119.70	96.90
36	87.100	62.510	130.15	103.55
37	91.870	64.700	140.60	110.20
38	95.000	66 800	151.05	116.85
39	100 700	68.800	163 40	122.55
40	106.000	71.200	177.65	129.20

Data for winding coils—Continued.

Size of wire (B. & S.).	Turns per square inch.			
	Single cotton.	Double cotton.	Single silk.	Double silk.
0000	2.4285	1.8714	------	------
000	2.5760	1.9768	------	------
00	3.2942	2.3409	------	------
0	4.5070	3.9300	------	------
1	10.0489	9.5481	------	------
2	12.5400	11.55000	------	------
3	14.7609	13.8125	------	------
4	20.2500	18.4900	------	------
5	25.9081	23.9121	------	------
6	32.0356	29.4849	------	------
7	38.4400	36.6025	------	------
8	49.7025	45.0241	------	------
9	54.6516	54.3169	------	------
10	72.9216	69.7225	------	------
11	94.0900	87.6096	------	------
12	125.4400	107.9521	------	------
13	144.0000	129.9600	------	------
14	169.0000	156.2500	------	------
15	236.2369	189.6129	------	------
16	280.2276	251.0400	------	------
17	314.7076	278.8900	------	------
18	380.2500	336.3556	------	------
19	518.4729	405.6196	------	------
20	650.4900	506.2500	767.2900	687.4884
21	800.8900	610.2500	959.1400	845.0649
22	961.0000	712.8900	1182.6721	1031.0521
23	1183.3600	839.2609	1468.4761	1262.3809
24	1361.6100	982.8225	1795.2169	1532.9396
25	1454.0000	1150.5664	2210.8804	1843.8436
26	1764.0000	1316.9641	2710.2436	2191.1761
27	2304.0000	1517.0925	3326.8289	2661.5281
28	2809.0000	1731.3920	4014.4896	3184.3449
29	3062.2500	1959.8329	4915.4121	3789.6336
30	3559.3156	2202.4249	5841.4796	4460.9041
31	4112.01562	2478.0484	7163.9296	5240.3121
32	4705.9600	2739.4756	8595.9984	6113.6761
33	5336.3025	3036.0100	10332.7225	7084.5889
34	6068.4100	3314.3049	12568.6521	8179.3936
35	6822.7600	3604.8016	14328.0900	9389.6100
36	7586.4100	3912.5001	16939.0225	10722.6025
37	8440.0969	4186.0900	19768.3600	11144.0400
38	9025.0000	4462.2400	22816.1025	13653.9225
39	10140.4900	4733.4400	26669.5600	15018.5025
40	11236.0000	5059.4400	31578.5225	16692.6400

WIRE.

Except for special purposes, where the specifications must be clearly set forth, requisitions for wire will be confined to the following-named classes, which comprise the standard wires of this service:

Galvanized-iron wire, No. 9. (See specifications.) Adopted for use in permanent lines.

Galvanized-iron wire, No. 14. This may be used for semipermanent lines, or where the distance is comparatively short.

Hard-drawn copper wire (generally No. 10 or 12). Used for permanent telephone lines or in other special cases.

Copper, aluminum-bronze, or silicon-bronze wire (weighs about 8 pounds to the mile). This is used in connection with hand reels for connecting outposts at short distances.

Buzzer wire consisting of two fine steel and one fine copper wire insulated with cotton saturated with compound used in connection with hand reels.

Field wire consisting of 18 fine steel wires and one fine copper wire covered with cotton insulated with rubber and finished with saturated braid. This wire is used for temporary field lines and is suitable for use on the reel cart or pack reel.

Seven-stranded wire (6 steel, 1 copper), insulated and braided. Weighs about 240 pounds to the mile, and is generally run out from reels placed on cable wagon, or may be run out with litter reels. It is used when lances or poles are not available; also for temporary lines on the ground or through marshes and woods. All four of the wires last named should be replaced by aerial lines and recovered as soon as possible.

Lead-covered cable, containing appropriate number insulated conductors, to be used underground in connection with fire-control or cable system.

Inside twisted pair, for office or telephone, used inside houses or through perfectly dry places. Can not be subjected to strain or moisture.

Outside twisted pair, insulated, hard-drawn copper conductor, used for outside work and for damp places. Each wire has a breaking strength of approximately 200 pounds.

Single outside wire, the same as one conductor of the outside twisted pair, for leading-in purposes.

Office wire, paraffin insulation, No. 14 or 18, used for making ordinary office connections.

Office wire, rubber covered and braided, Nos. 14 to 18 for office wiring in damp climates.

PRINCIPAL INSTRUMENTS FURNISHED.

Morse relay, key, and sounder.

Main-line sounder.

Pocket relays.

Repeaters.

Duplex instruments.

Field buzzer. This instrument sends vibratory currents of high intensity, to be used on badly insulated wire. It may also be superimposed on the ordinary Morse circuit, and used in connection therewith either for telegraphing or telephoning.

Station buzzer. Used for the same purpose as field buzzer, but in addition sends a current that gives the ordinary Morse sounds on the telephone. In this buzzer there is a condenser connected with the instrument, and in placing it on the Morse line it is only necessary to place condensers around the Morse instruments in circuit. At terminal stations buzzers must be placed first on the wire, the Morse being the last thing on the line.

Combination buzzer and telegraph table set. (See p. 89.)

Field telephone, containing call bell, generator, batteries, and hand telephone.

Service telephones.

Desk-set telephones.

Special types of telephones for artillery use.

All of the above telephones are of the bridging type.

Cut-in telephone. (For description see p. 97.)

Voltameter, for testing batteries. (See p. 161.)

Ohmmeter. (See p. 160.)

Magneto testing set, for identifying wire, and rough indications.

Condensers, one, one-third, and one-tenth microfarad, used for placing vibratory system on Morse circuit.

Voltmeter.

Milliammeter.

Resistance coils.

BATTERIES.

Batteries furnished are gravity, Leclanche, Gonda, Samson, Fuller, Lalande, dry, and storage.

SPECIFICATIONS FOR IRON WIRE.

The wire to be soft and pliable, and capable of elongating 15 per cent without breaking, after being galvanized.

Great tensile strength is not required, but the wire must not break under a less strain than two and one-half times its weight in pounds per mile. Tests for tensile strength will be made by direct appliance of weight, or by means of a single lever, at the option of the inspecting officer.

Tests for ductility will be made as follows: The piece of wire will be gripped by two vises 6 inches apart and twisted. The full number of twists must be distinctly visible between the vises on the 6-inch piece. The number of twists in a piece 6 inches in length not to be under 17.

The wire to be cylindrical and free from scales, inequalities, flaws, sand splits, and all other imperfections and defects. Each coil must be warranted not to contain a weld, joint, or splice whatever in the rod before drawn; and all wire to be "killed," or stretched about 2 per cent before delivery.

It is desired to obtain the wire in 1-mile coils all of one piece, but the contractor may tender wire with two pieces only to the coil, joined by the ordinary twist joint carefully soldered. It should be stated in the tender whether there will be one or two pieces in each coil.

The wire will be well galvanized, and capable of standing the following test: The wire will be plunged into a saturated solution of sulphate of copper and permitted to remain one minute, and then wiped clean. This process will be performed four times. If the wire appears black after the fourth immersion it shows that the zinc has not all been removed, and that the galvanizing is well done; but if it has a copper color, the iron is exposed, showing that the zinc is too thin.

FOR NO. 9 BIRMINGHAM WIRE GAUGE.

The weight per mile to be 320 pounds, or as near these figures as practicable.

The electrical resistance of the wire in ohms per mile, at a temperature of 68° F., must not exceed the quotient arising from dividing the constant number 4,700 by the weight of the wire in pounds per mile. The mileage resistance of a wire weighing 320 pounds per mile (No. 9) should not exceed 4,700 divided by 320, equals 14.7 ohms. The coefficient 0.0033 will be allowed for each degree Fahrenheit in reducing to standard temperature.

No. 14 Birmingham wire gauge is the same as No. 12 American wire gauge, and No. 9 Birmingham wire gauge is the same as No. 7 American wire gauge (to within 0.003 inch).

LIST OF REFERENCE BOOKS.

Foster, Electrical Engineer's Pocket Book.
Houston, Electrical Dictionary.
Jones, Willis H., Pocket Edition of Diagrams, and Complete Information for Telegraph Engineers and Students.
Kempe, Handbook of Electrical Testing.
Lockwood, Handbook of Electric Telegraphy.
Maver, American Telegraphy, third edition.
Miller, K. B., American Telephone Practice, fourth edition.
Pope, The Electric Telegraph.
Sheldon, Dynamo Electrical Machinery.
Signal Corps Technical Manuals:
II. Military Telegraph Lines.
III. Electrical Instruments and Telephones.
IV. Submarine Cables.
V. Manual of Photography.
VI. Visual Signaling.
Treadwell, The Storage Battery.
Webb, Testing Wires and Cables.
Wolcott, Kennelly and Varley, The Electro Magnet.

TRANSMISSION OF TIME SIGNALS.

The division of the United States into sections 15 degrees in width, in which the standard time differs by one hour in each contiguous section, is well known. Beginning in eastern Maine with Colonial time, we had, successively, Eastern, Central, Mountain, and Pacific time, corresponding to the local time on the middle meridian of each section.

In April, 1899, the Chief Signal Officer of the Army, Gen. A. W. Greely, invited attention to the need of extending the time system to Cuba and our new possessions, Porto Rico and the Philippines. To Porto Rico, lying as it does east of the 67° 30′ meridian, was assigned Colonial time, and to Cuba Eastern time.

Fortunately the one hundred and twentieth meridian east of Greenwich passes very close to Manila and the middle of the Philippine Archipelago. This was selected as the time meridian, and, consequently, Philippine time is just four hours later than local time on the international date line (one hundred and eightieth meridian), thirteen hours ahead of New York or Washington (Eastern) time, and sixteen hours ahead of San Francisco (Pacific) time.

The duty of furnishing this standard time devolved upon the Signal Corps in accordance with the following circular:

CIRCULAR NO. 17.
DIVISION OF CUSTOMS AND INSULAR AFFAIRS.

WAR DEPARTMENT,
Washington, May 11, 1899.

The following is published for the information and guidance of all concerned.

Standard time is hereby established in the territory under government by the military forces of the United States, and it is hereby directed that all departments under such military government officially observe the time furnished by the United States Signal Service as standard time, as follows:

For Cuba, seventy-fifth meridian (west longitude) time;

For Porto Rico, sixtieth meridian (west longitude) time;

For the islands of the Philippine Archipelago, one hundred and twentieth meridian (east longitude) time.

G. D. MEIKLEJOHN,
Assistant Secretary of War.

The standard time for the United States is sent out daily at noon from the Naval Observatory, at Washington, and from the Manila Observatory for the Philippines.

The method adopted in the United States to do this telegraphically is as follows:

The Observatory clock beating seconds is connected to the telegraph circuit, starting in at 11.55 a. m. It omits the twenty-ninth second of each minute, and beats seconds up to fifty-fifth second, when five seconds are omitted. In the last minute before 12 noon, ten seconds are omitted in order to give a chance to adjust instruments to receive the final corrected time. Then, at the expiration of the ten seconds, a long, heavy dash is given, thus completing the time and correcting all clocks in the circuit.

In the Philippines the method was slightly different. The Observatory clock closed the circuit every half minute. The line was taken for time at 11.56. In the last half minute the operator at central office dotted with the key during twenty seconds to indicate that it was the last half minute. He ceased dotting at ten seconds before 12. The clock gave the 12 o'clock signal.

This noon signal operates all clocks electrically regulated and time balls. It also is indicated on electrically operated chronographs.

Chapter XIII.

GENERAL INSTRUCTIONS REGARDING TELEPHONES.

The following instructions are issued for the guidance of all those who use telephones supplied by the Signal Corps, United States Army:

GENERAL DIRECTIONS.

The telephones issued by the Signal Corps, United States Army, to the various signal officers are furnished for use on ranges during the prescribed target season, for fire-control communication at artillery posts, and for facilitating intercommunication at the various garrisons and in the field.

All officers to whom instruments are issued will thoroughly familiarize themselves with their construction, use, and means of discovering and correcting the usual faults that may develop during service, and they are charged with seeing that the following rules are strictly enforced:

The dismounting of any part of the telephone will be resorted to only in emergencies when such a course seems absolutely necessary to secure satisfactory communication. The important component parts of a set—namely, the receiver, transmitter, bell mechanism, and magneto—are kept in stock at the various signal corps supply depots. Whenever tests locate trouble in one of these which can not be remedied without dismounting it, requisition should at once be made for a new one to replace it in the instrument, and the defective part be carefully packed and shipped, by mail if possible, to the depot issuing the new one. The wiring of the armatures, coils of call bell, and bobbins of receiver and induction coil should never be unwound. The diaphragms of the receiver and transmitter are not to be disturbed, e. g., by poking with a pencil, etc. The battery connections and tops of cells are to be kept clean and free from salts, solutions up to proper strength, and water up to water line on cells. In case of failure to work, all circuits, both inside and out of the instruments, should be carefully inspected and tested.

For a grounded line the instrument is connected as follows: One binding post to line and one to ground plate, which should be of ample size and located in damp earth. One end of the wire should be firmly soldered to the ground plate and the other attached to the ground post. The ground wire should be as straight as possible, without unnecessary bends or convolutions.

If the telephone is supplied with a plate lightning arrester, the center post should be connected by a wire to the ground wire outside of the instrument. If the instrument is of the bridging type and the circuit a metallic one, connect both right and left hand posts on top of magneto to the line wires and ground the middle one, which is on the lightning arrester. Where there is any danger from power circuits, the instruments should be properly fused.

When using local battery telephones, call by briskly turning the handle in the call box and wait until the call is answered by a ring before unhooking the receiver, if the line is not connected to an exchange. If connected to an exchange, as soon as the ring has been made, unhook the receiver and listen for "Central's" call. When through talking, hook up the receiver and ring off. When using common battery instruments it is only necessary to remove the receiver from the hook to make a call. Hanging up the receiver signals the switch-board operator to disconnect. *Never leave the instrument with the receiver off the hook.*

Chapter XIV.

THEORY OF THE TELEPHONE.

In the act of speaking the vocal cords are lengthened and shortened by muscular action. This lengthening and shortening causes air vibrations in the mouth and air passages, from which waves of sound proceed. When these wave sounds fall upon the drum of the ear they are recognized by the auditory nerves as speech. If, instead of falling on the eardrum, these vibrations should fall upon a diaphragm which is capable of changing them into electrical vibrations, and there is some means of transmitting them along a line and again reproducing at the other end into similar air vibrations, we have the telephone. In order to understand the action of the telephone it is

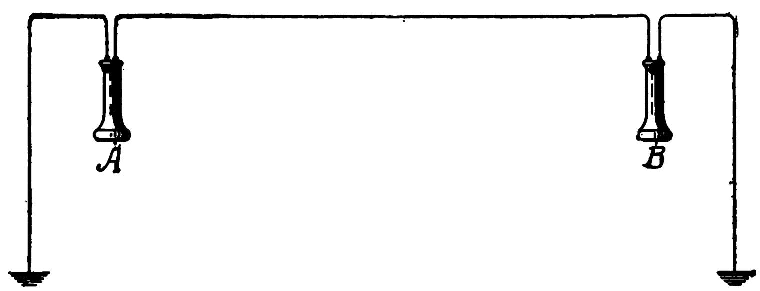


Fig. 138.

necessary to define lines of force and explain two simple laws of magnetic induction. Lines of force are the imaginary lines which are supposed to surround a magnet and indicate by their position and number the direction and strength of its action. The laws of magnetic induction referred to are: First, if a number of lines of force thread or pass through a coil of wire and this number is increased or diminished, a momentary current will flow in the coil; second, if a coil of wire be wound around a permanent steel magnet and a current of electricity be sent through the windings, it will, if in a certain direction, increase the strength of the permanent magnet, and if in the opposite direction will diminish its strength.

To understand how a telephone works, let us take the simplest case of two telephone receivers, A and B, connected to the line as shown in fig. 138.

The telephone receiver (a more detailed description of which will be given later) consists of a soft-iron diaphragm placed a short distance away from a permanent magnet. Around the diaphragm end of this magnet is wound a coil of fine insulated copper wire. The air vibrations caused by the act of speaking upon striking the iron diaphragm at *A* cause it to vibrate. The vibrations of this diaphragm produce changes in the number of lines of force which thread through the windings of the coil. These changes, according

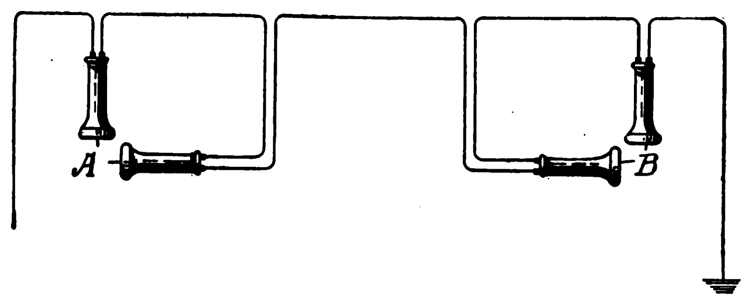


Fig. 139.

to the first law, produce a current in the winding which will be of greater or less strength and in opposite directions, following the vibrations of the diaphragm. This varying current proceeds along the line, and when it arrives at *B* will increase and diminish the strength of *B*'s magnet. The variation of the strength of *B*'s magnet will produce a varying pull on *B*'s diaphragm and cause it to vibrate in a manner similar to the diaphragm of *A*. The vibration of the diaphragm at *B* is recognized as speech coming from

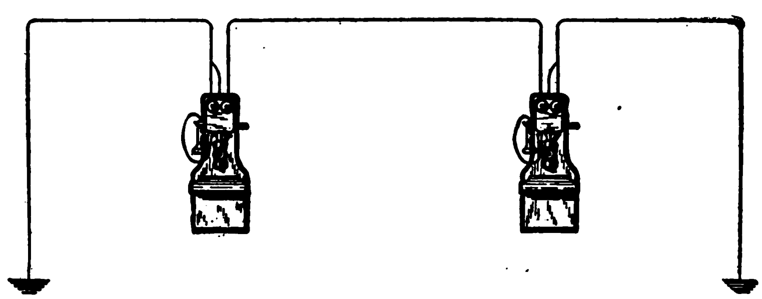


Fig. 140.

A. The simple circuit shown in fig. 138 would permit a person to talk or hear, as the case may be. The first modification of this circuit, fig. 139, is to introduce two telephone receivers at the point *A* and two at the point B, all being in series, one serving as the transmitting and the other as the receiving instrument at each point.

For certain reasons this type of receiver just described does not make a good transmitter, and in practice is replaced by a battery transmitter.

The series telephone is connected as shown in fig. 140. This instrument is no longer issued for Signal Corps work and reference is made to it to cover cases as may arise where the old series telephone may be in use.

A complete local battery telephone instrument consists of a receiver, local battery transmitter, induction coil, magneto generator, call bell, and certain switching devices, which are contained in the magneto-generator box.

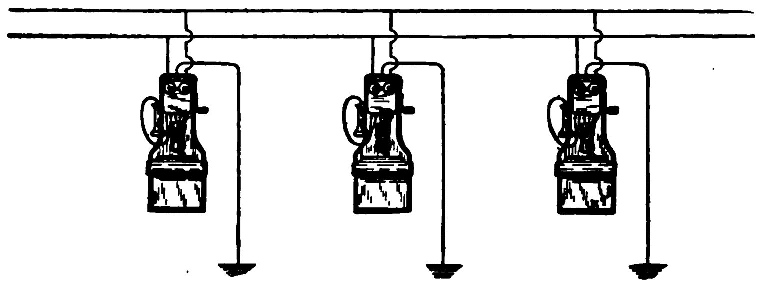


Fig. 141.

A complete common battery instrument consists of a receiver, transmitter, induction coil, condenser, call bell, and switch hook.

LOCAL BATTERY TRANSMISSION.

The local battery transmitter depends for its action on the fact that a varying pressure changes the resistance of carbon. The transmitter consists of a number of carbon particles or granules in a proper receptacle with a means of varying the pressure upon the granules in circuit with a battery and the coarse-wire winding of an induction

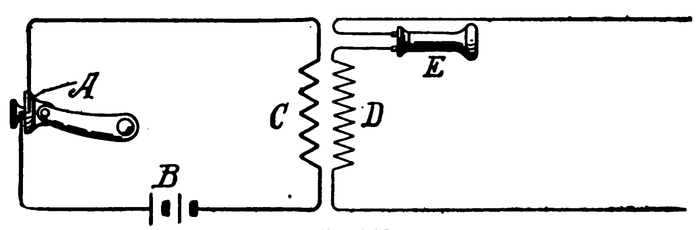


Fig. 142.

coil, which consists of a bundle of soft-iron wires surrounded by two windings of insulated copper wire, one being of coarse wire, with few turns, called the "primary," and the other of fine wire, with a large number of turns, called the "secondary," the latter being connected to the line. The relative position of these various parts of a local battery transmitter is indicated in fig. 142, in which *A* is the receptacle that contains the carbon granules through which the current from a battery ,*B*, flows. *A* also contains a diaphragm which presses on the carbon granules, or is so connected with them as to vary the pressure as the air waves fall on it. *C* is the coarse and *D* the fine-wire winding of the induction coil, which is connected to the receiver E and the line. As the air vibrations fall on the diaphragm at A, they produce a change in the resistance of the carbon particles. This change of resistance causes the current flowing in the coarse-wire coil to fluctuate, thereby producing a fluctuating induced current in the fine-wire coil, which goes to the line and receiver and reproduces speech as has been explained before.

COMMON BATTERY TRANSMISSION.

The common battery transmitter operates like the local battery in its essentials. The principal point of difference lies in the fact that in common battery operation the current flowing in the line is partly direct and partly induced, whereas the local battery instrument transmits only an induced alternating current. Fig. 143 shows the essential parts of the common battery instrument so far as transmission is concerned. In the common battery instrument the primary and secondary windings of the induction coil have nearly the same number of turns and resistance. The construction of the receiver and transmitter is practically identical with these parts of the local battery telephone.

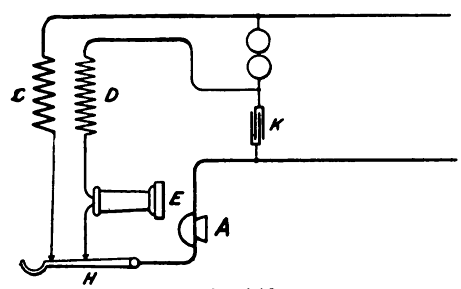


Fig. 143.

Direct current from the common battery flows through the transmitter A, the hook H, the primary of the induction coil C, and back to the line. Variations in the position of the diaphragm of the transmitter due to air vibrations from the voice produce a change in the resistance of the carbon particles in the transmitter. This varying resistance causes an induced current in the secondary of the induction coil D of the home telephone and the distant telephones, and, passing through the receivers, reproduces speech. The position of the condenser K strengthens the effect of the transmitter on the line by alternately charging and discharging, with the varying resistance of the transmitter, through the secondary windings of the induction coil and the receiver.

Owing to the fact that the common battery instrument depends for its operation on direct current in the line the range of such operation is necessarily limited by the resistance of the line circuit. When the resistance of the line becomes so high as to cut down the current materially the efficiency of the circuit is correspondingly decreased, and when a common battery telephone is intended to operate over a considerable distance repeating coils are installed to overcome this difficulty.

MAGNETO GENERATOR.

The magneto generator, or "magneto," as it is called, consists of three or more permanent steel magnets, rigidly connected together, with an armature so placed that it can be rotated between their poles. The armature consists of a core of soft iron which is wound with a coil of insulated copper wire whose terminals are connected with the line. The revolution of the armature changes the number of lines of force passing through it and produces a current that rings the bell.

The call bell consists of a permanent magnet which is so mounted as to magnetize a soft-iron armature and the iron cores of two coils of insulated wire over which it is pivoted. A thin rod is attached to the center of the armature and at right angles to it. Two bells are so placed that the hammer while vibrating will alternately strike each.

The series instrument, figs. 146 and 148, is one in which the call bell and magneto are in series, or directly connected with the line and the receiver of the instrument, while the magneto is automatically short-circuited.

The bridging or parallel instrument is shown in figs. 145 and 147.

Chapter XV.

COMPONENT PARTS OF VARIOUS TYPES OF TELEPHONES.

Since the calling and talking part of the instrument are used alternately, there must be some switching device for changing from one to the other. When the instrument is not in use it must be ready to respond to a call, and when the talking circuit is used the resistance of the magneto and call bell must be cut out of the circuit. In addition to this, when the transmitter is in use the battery current must be cut off from the transmitter, or else the battery, owing to the low resistance of the transmitter circuit, would soon exhaust itself and run down. To accomplish these various changes a switching lever is so designed as to be held down by the weight of the receiver. In this position the calling circuit is on the line, and when the receiver is unhooked the lever flies up, putting the

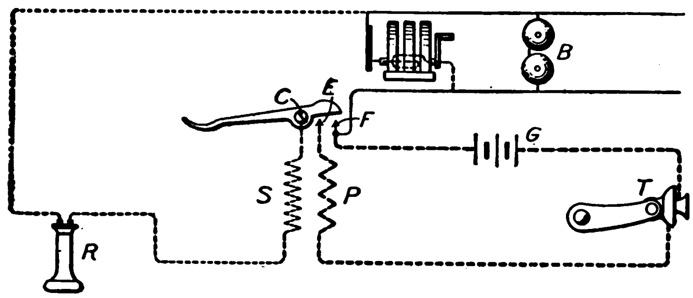


Fig. 144.

receiver and secondary of the induction coil on the line and the battery on the transmitter circuit. The lever arm or switch hook usually consists of a pivoted arm, which is spring controlled, and when the receiver is hooked up its weight pulls the lever arm down and breaks the rear contacts. When the receiver is unhooked, a spring throws the arm up and closes the listening and talking circuits.

Figs. 144 and 145 show the ordinary arrangement of circuits and operation of the lever arm for the bridging type of telephone. The bell *B* and the magneto are permanently bridged across the line, but the armature circuit of the magneto is open, except when it is being used for calling a distant station. It will be noticed that the circuit from the line is through the receiver and secondary of the induction coil to the pivot of the lever arm, and when the arm is down both receiver and transmitter circuits are open. An incoming call will simply ring the bell B, and when a distant station is called both the bell B and the distant one will ring.

When the receiver is unhooked, as shown in fig. 145, the circuit is from the line through the receiver R, the secondary of the induction coil S, the pivot C, thence through back of switch arm to F, and from F to line, the other side of the line and the transmitter circuits being joined below the point F. The battery circuit is now from the battery G through the transmitter T and the primary of the induction

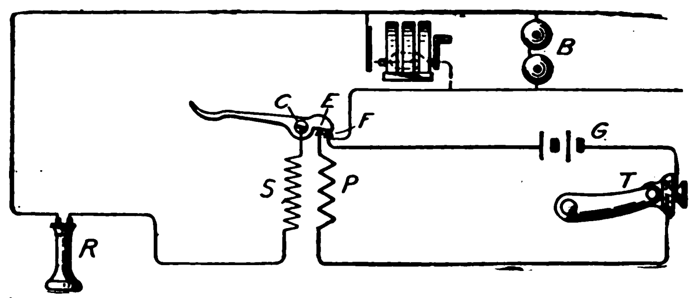


Fig. 145.

coil P to E, then through the back of the switch arm to F, and thence back to battery.

In the series instrument when the lever arm is down the bell is in series with the line, but the magneto cut out by the automatic shunt Y.

Fig. 146 shows the circuits in the series telephone when the receiver arm is up, thereby closing the rear and opening the front contacts. The circuit in this case comes from the line to E, from E

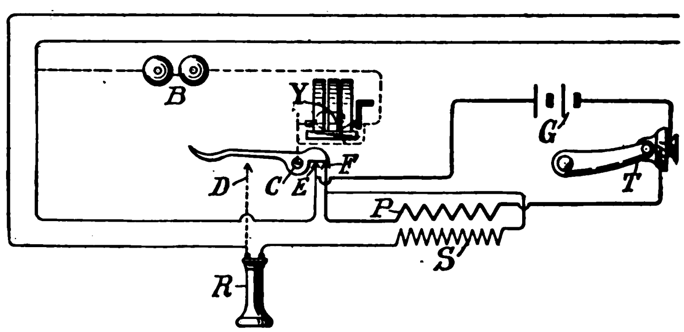


Fig. 146.

through back of switch to F, and from F to H, thence through the secondary of the induction coil S and the receiver R to line or ground, the bell B and the magneto being cut out as the front contact D of the switch arm is open. The transmitter circuit is the same as in the bridging instrument.

WIRING OF BRIDGING TELEPHONE.

The wiring of a standard bridging set is shown in fig. 147, where it is observed that both the bell and magneto are permanently bridged across the wires leading from binding posts 1 and 3. When the hook is up, the listening circuit is as follows: From 1 through to 10, from 10 through switch arm and pivot to 8, from 8 through secondary of

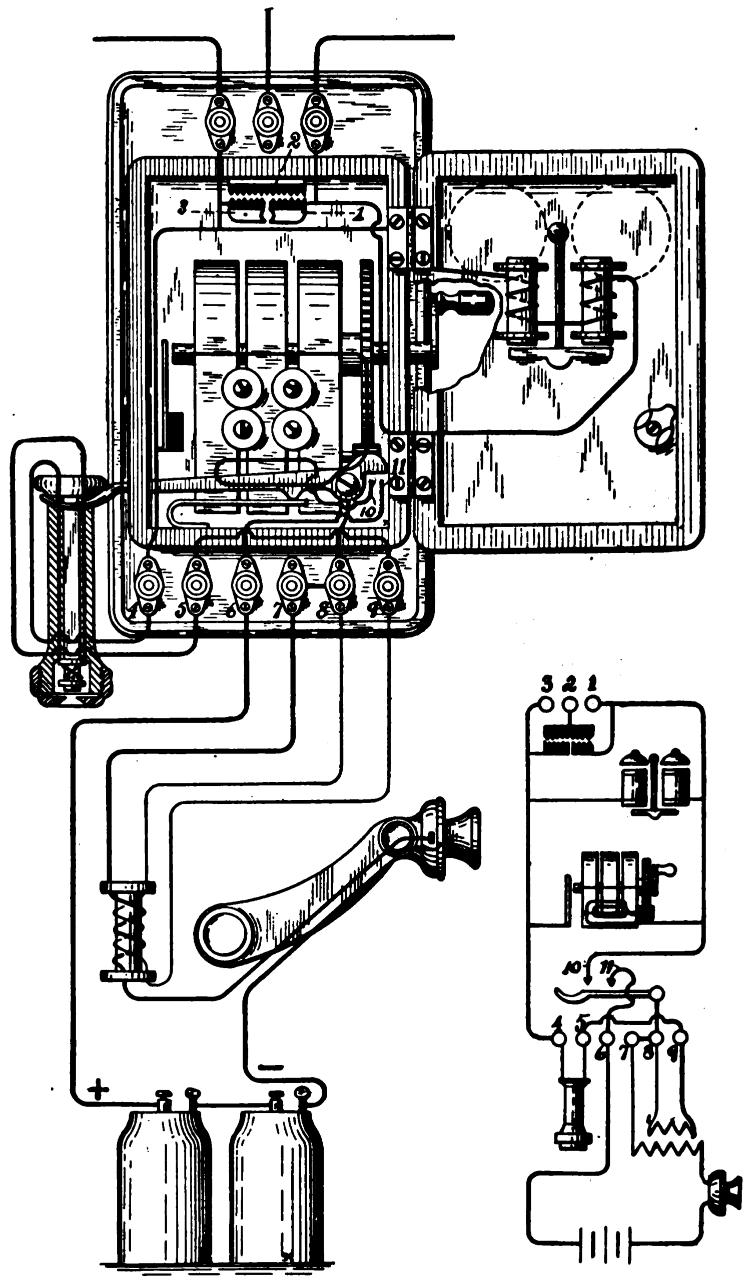


Fig. 147.

the induction coil to 9, from 9 to 5, from 5 through the receiver to 4, and from 4 to 3, and line. The talking circuit, starting at the battery, is from the battery through the transmitter, then the primary of the induction coil to 7, and from 7 to 8, from 8 through pivot of switch and switch arm to 11, from 11 to 6, and from 6 to the other side of the battery.

A description of the connections in the transmitter arm will be given later.

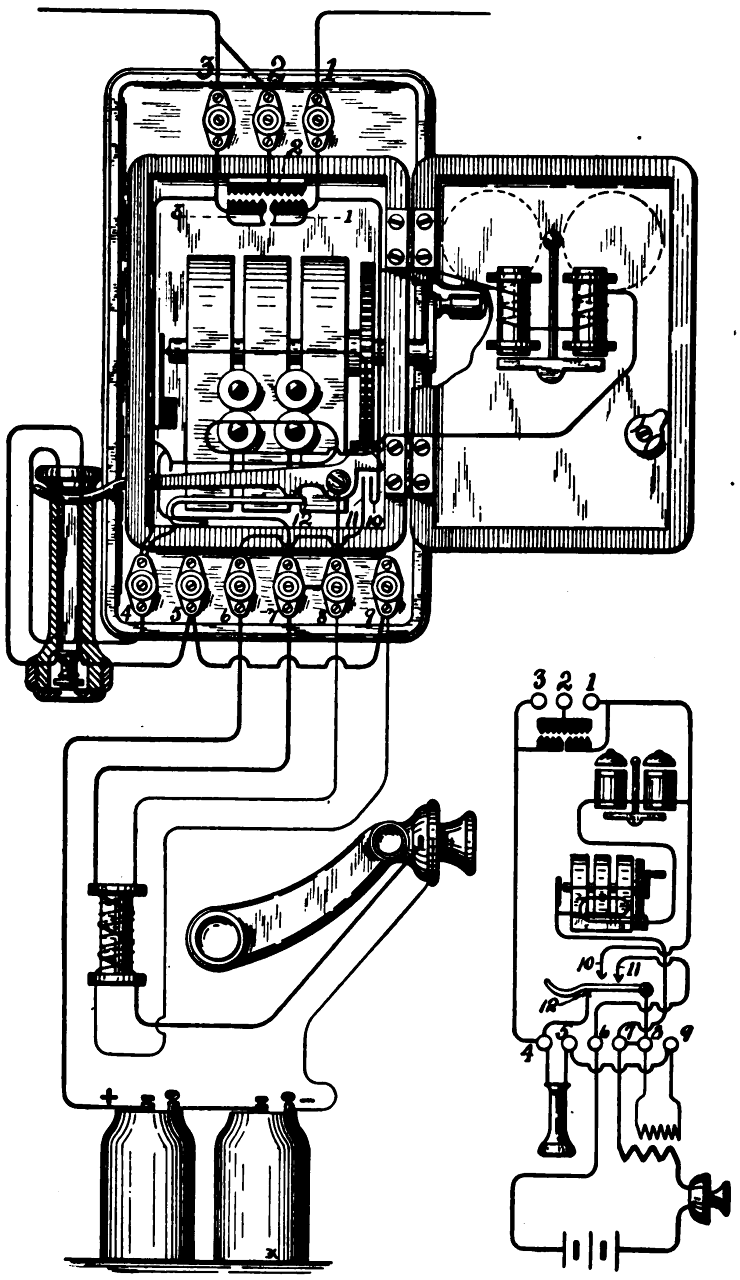


Fig. 148.

WIRING OF SERIES TELEPHONE.

The wiring of the standard series wall instrument is shown in fig. 148, and the following are the circuits: From binding post 1 a wire is led to the back contact 10. This circuit is bridged to the upper hinge of the magneto box, and passes from thence through the windings of the call bell to the lower hinge and from this point through the automatic shunt and armature of the magneto and from there to post 7, from post 7 to post 8, through the secondary of the induction coil to 9, from 9 to 5, from 5 through the receiver to 4, and from 4 to binding post 3, and also to the front contact 12 of the hook switch. The back contact 11 of the hook switch is connected to post 6, from thence through the battery to the transmitter, and from the transmitter to the primary of the induction coil to post 7. Post 8 is connected to the pivoted part of the hook switch. The interior wiring of the magneto is always properly

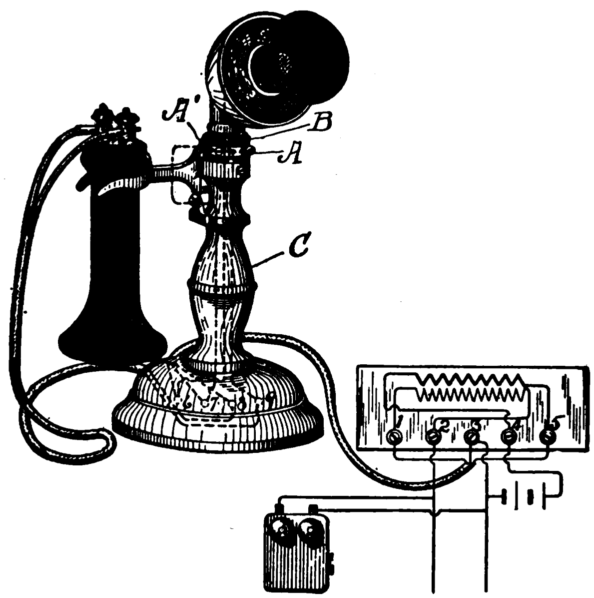


Fig. 149.

connected up before issuing, and in case the instrument is dismounted from the backboard it may be reconnected by the following simple rule: Connect the receiver terminals to the two left-hand posts (looking at the instrument) on the bottom of the magneto, one side of the battery circuit to the left-hand middle post, the other side of the battery and of the primary coil to be connected together through the transmitter, while both leads from the secondary coil are connected to the two right-hand posts.

DESK SET, LOCAL BATTERY.

Fig. 149 shows the circuits of the standard desk set. The hook switch when up closes the two clip springs A A', which are mounted on the hard-rubber block *B*. The springs are connected by insulated wires passing through the hollow standard *C* to posts 7 and 9, which, together with 6 and 8, are mounted on a hard-rubber block (not shown in the drawing) in the base of the instrument. One electrode of the transmitter is connected by an insulated cord to post 6 and the other grounded to the frame. The receiver cords are connected to 8 and 9, and the set is connected by a three-wire cable at 6, 7, and 8 to binding posts on the wooden block holding the induction coil. This block serves as a mounting for the induction coil and has five binding posts. The line with the magneto bridged across it is connected to 2 and 3, the primary of induction coil to 4 and 5, the secondary to 2 and 1, the battery to 3 and 4, and the three leads from the instrument to 1, 3, and 5.

SERVICE TELEPHONE, 1902 MODEL.

The service telephone is a bridging set with magneto box that has the induction coil fastened in the top, and a transmitter of the solid-arm type fastened on the bottom. The magneto box is securely fastened in the upper half of the case, while two cells of dry battery are screwed in its lower half. The box, when closed, serves as a packing case for shipment. When the box is closed for shipment the transmitter arm is removed from the bottom of the magneto box and held by a clip in the battery half.

The containing box, figs. 150 and 151, is of two halves securely fastened together by three strong hinges; each half is 16½″ by 11½″ by 5¼″ outside measurement. The halves are so arranged that when the cover is closed the instrument is protected and ready for shipment. The box is locked by two screw bolts, each fastened into a brass lug. When the instrument is packed for shipment, the front board over the lower half of the box, as shown in the figure, is screwed to the back of the upper half. The back of the upper half is bored with four holes for the screws which hold it to the wall, and these screws and the magneto handle, when the instrument is ready for shipment, are placed in a small block of wood indicated in the figure on the left side of the upper half of the box.

On the bottom of the upper half is a two-point switch for changing from dry to wet batteries; when the switch is turned to the left the dry batteries are in circuit with the transmitter, and when turned to the right the wet batteries can be used when their terminals are attached to *W* and *Y*. The upper and lower of the three binding posts on the magneto are the line terminals, and the middle one, marked *Gr*, is the ground terminal.

The following are the circuits: An incoming ring will come from the line through A, around to the hinge B, thence through the bell to the hinge C, from the hinge C around to the other line post F. To ring, starting at one terminal of the armature D, from D around

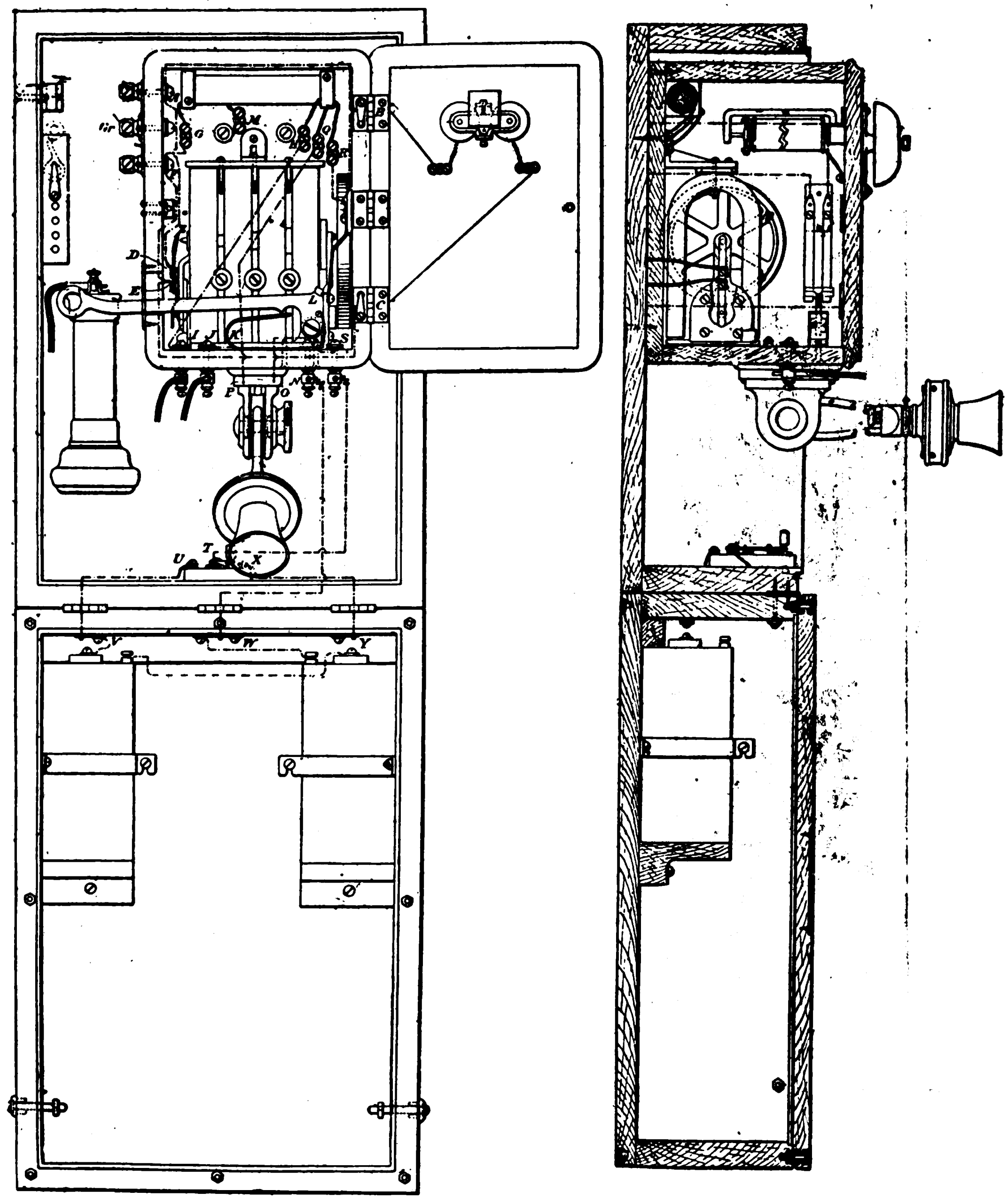


Fig. 150.

to A, where the circuit divides, going to line and through the bell, from line through F back to E and through the armature to its starting point D. When the switch arm is up, the listening circuit is from A through the hinge B, and through the switch arm to J, from J through the receiver to I, from I to H, thence through the secondary of the induction coil to G, and from G to F, the other line terminal. The talking circuit, when dry batteries are used and the battery switch is on the contact U, is from one terminal of battery V through the hinge in the bottom of the box to U, from U through the battery switch arm to T, from T to the right-hand binding post in bottom of the magneto box, thence to S, from S through the switch arm and contact to R, from R through the primary of the induction coil to Q, from Q to P, and to one of the solid arms of the transmitter, thence back to the other solid arm to O, from O to N, and from N to W and the other side of the battery. In case wet battery is used the terminals are W and Y and the circuits as above.

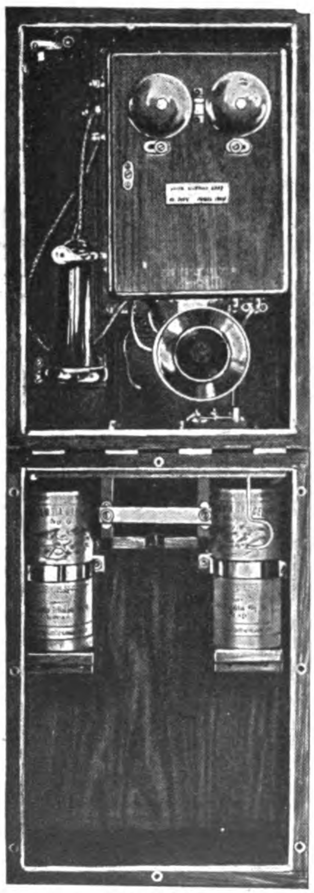


Fig. 151.

In the 1901 model the dry batteries are placed in a small box below the magneto and behind the transmitter arm, which in this case is shorter and permanently fastened to the bottom of the magneto box. The two-point switch in the 1901 model is on the front of the battery box; the circuits are the same as in the 1902 model.

THE FIELD TELEPHONE.

The field-telephone kit, model 1901, shown in fig. 153, is contained in a strong wooden box, which holds the magneto, call bells, combined receiver and transmitter, and dry battery. The magneto handle, when in use, passes through a hole in the side of the box and screws on to the driving axle. When not in use the handle is slipped into a wooden block in the top of the box. The combined receiver and transmitter, or microtelephone, consists of a transmitter of the Swedish or gold-button type and watch-case receiver. These are connected together by steel rods for strength, which form part of the circuit and are partially covered by a wooden handle, containing a compression switch for controlling the dry batteries. The circuits in this kit are the same as those in a standard bridging telephone.

COMMON-BATTERY INSTRUMENTS.

The transmitter and induction coil used in common-battery work differ from these parts in local-battery instruments in that their resistance is considerably higher. Otherwise the component parts of the common-battery telephone are similar to the parts used in local-battery operation.

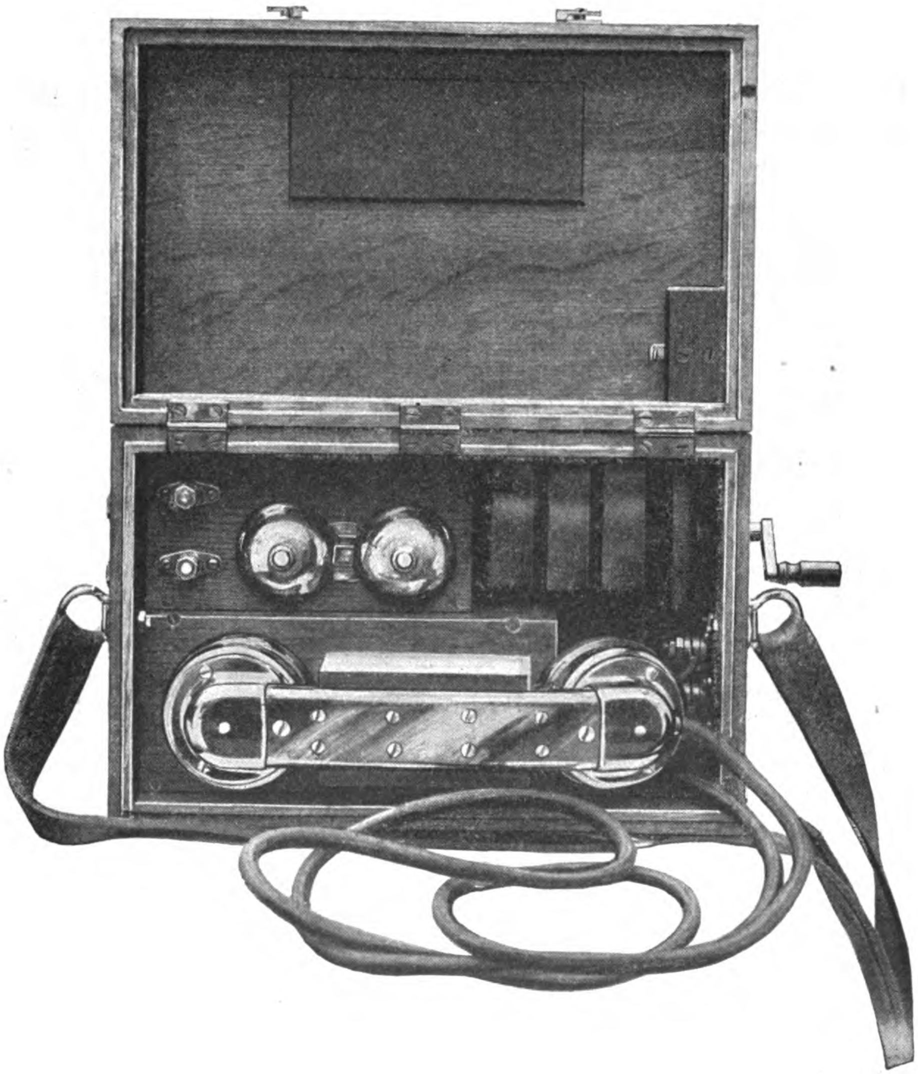


Fig. 152.—Field telephone. Model 1904.

The approved type of common-battery wall set is shown in fig. 154. In this set the transmitter is mounted on an adjustable arm above the writing shelf. Underneath this writing shelf and inclosed by woodwork there is mounted a condenser, an induction coil, a ringer, and contacts on the hook switch. The transmitter connections are wired permanently in the backboard.

An approved form of common-battery desk telephone is shown in fig. 155. This telephone is similar to the local-battery telephone in its essential features. The extension bell set, however, provides only the ringer, condenser, and induction coil with the necessary binding posts, omitting the generator used in the local battery.

SCHMIDT MAGNETO.

(Supplied with model 1902 service telephones.)

In the Schmidt magneto, as shown in fig. 156, the four permanent steel magnets *M* are slipped between projecting lugs *A* on the two cast-iron pole pieces *P*, which are bored to receive the armature,

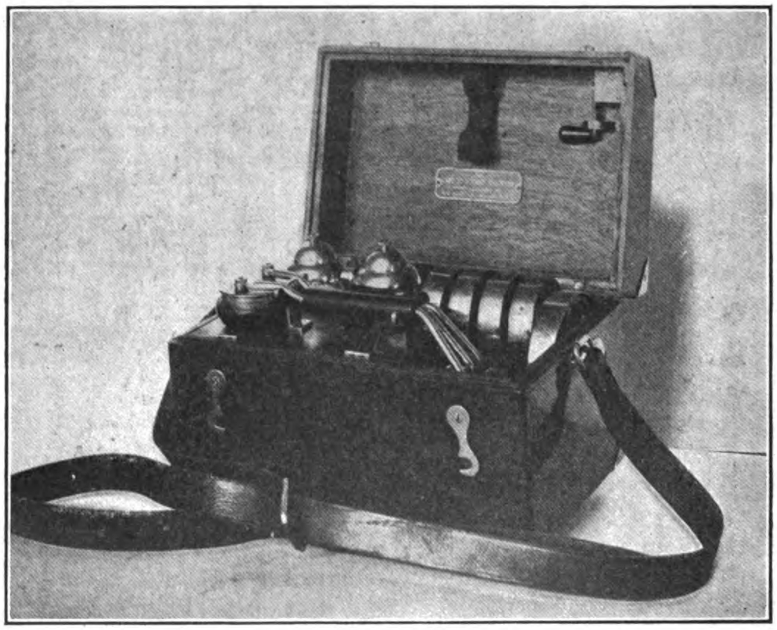


Fig. 153.

that consists of a coil of fine insulated wire *B*, wound on soft-iron disks *C*, that are mounted on the armature shaft *D*. One end of the coil is connected with a pin on the shaft at *E* and the other to the pin *F*, which is insulated from the shaft by a hard-rubber bushing *G*. This pin rests on another insulated pin *H*, which passes out through the end of the shaft and touches the spring *I*. The armature shaft is supported by the two brass castings *K K′* that are screwed to the ends of the pole pieces. The casting *K* terminates in a cylindrical bearing through which the driving axle *L* can move in the direction of its length. A steel sleeve *J*, brazed to the driving gear, is slipped over the axle and supported by the brass casting *N*, which is screwed to the inner face of the upper part of the casting *K′*. The brass collar O is fastened to the sleeve by a set screw and shouldered against the casting N; the sleeve J terminates in a knife-edged face that engages in the **V** groove of the steel collar R, which is fastened to the driving shaft by a pin. At the outboard end of the driving shaft is the nut S, between which and the gear wheel is a coiled spiral spring T, slipped over the driving axle. The tendency of this spring is to keep the **V** groove of the collar R seated against the knife-edged

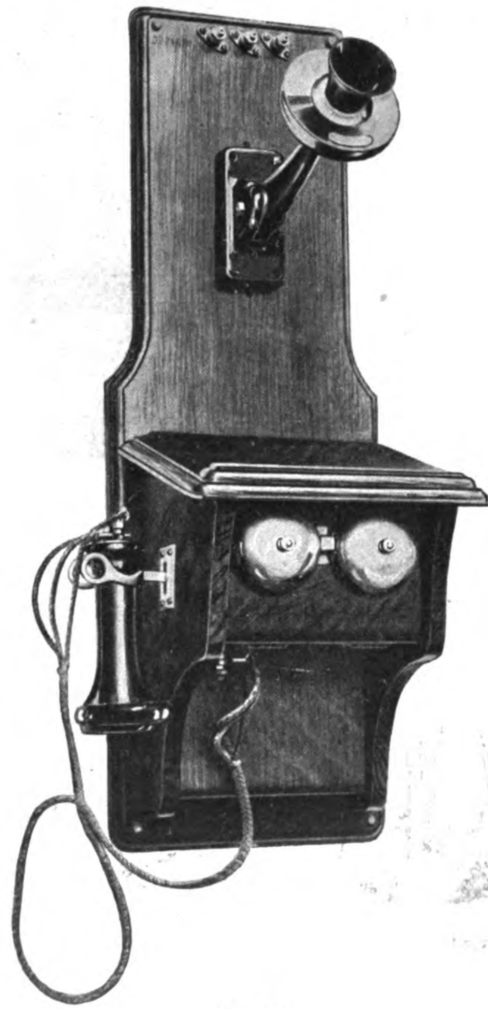


Fig. 154.

end of the sleeve J and the end of the axle away from the spring Y. When the handle of the generator is turned, the knife edge slips along the **V** groove and brings the end of the driving shaft against the spring Y, which is fastened to and insulated from K. The end of the armature winding, which is connected to the pin at E, is consequently connected through the frame of the magneto to the spring Y, which, with spring I, serve as terminals for the generator.

WESTERN ELECTRIC MAGNETO.

(Supplied with old American Bell telephones.)

Fig. 157 shows the operation of the automatic shunt in the Western Electric Company's type of series magneto. The outboard end of the shaft *A*, that carries the driving wheel *B*, is turned down to a shoulder *C*, which has a V-shaped groove cut across its face at a right angle to the driving shaft. In the rear of the bearing is a cylindrical box *D*, that contains a coiled spring *E*. This box

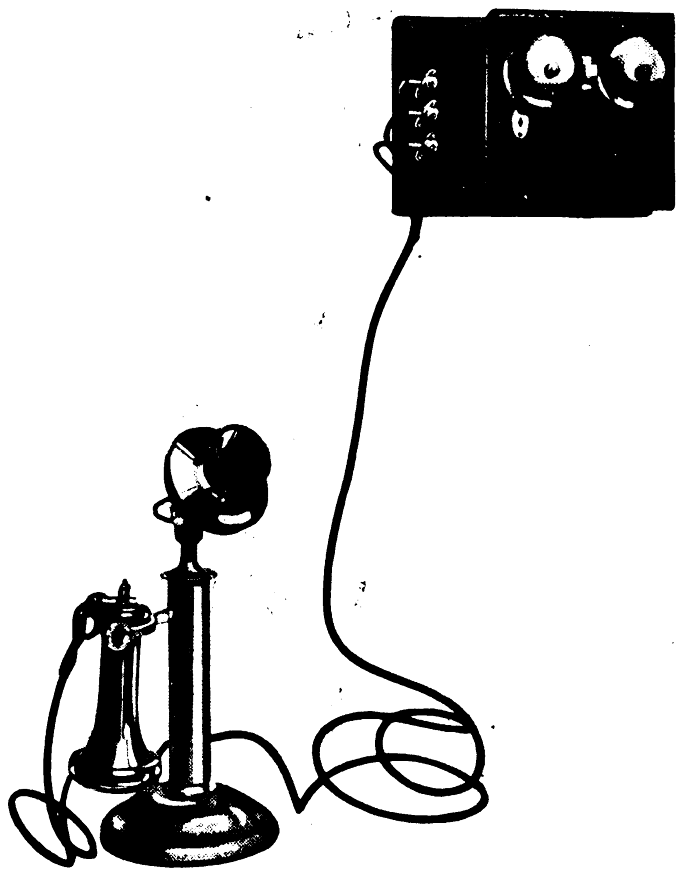


Fig. 155.

is securely fastened to the shaft by means of set screws. The tendency of this spring is to force the shaft against the spring *H*. A driving handle *F* is slipped over the front end of the shaft. This handle is fitted with a stud *G* with a knife-edge face that engages in the V groove on *C*. As the handle is revolved the knife-edge slips along the V groove, compresses the spring *E*, and throws the end of the shaft away from the spring *H*, as shown by the arrow. This spring *H* and the gear wheel being in metallic connection with the armature, when the handle is turned the short circuit around the armature is broken.

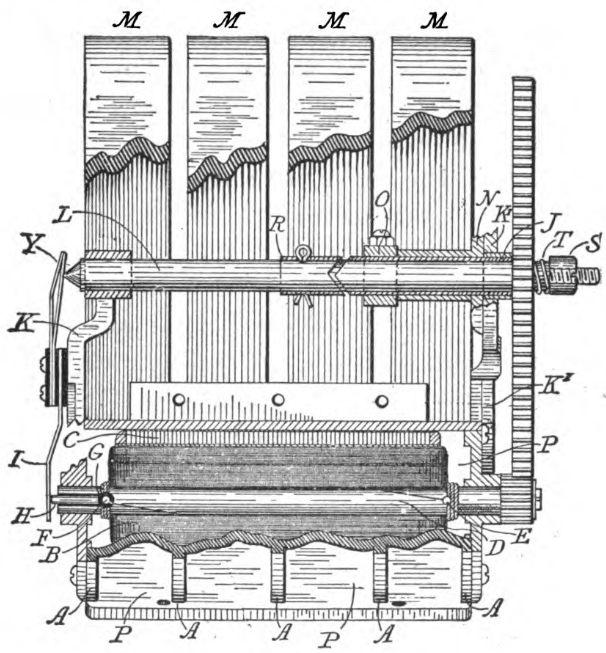


Fig. 156.

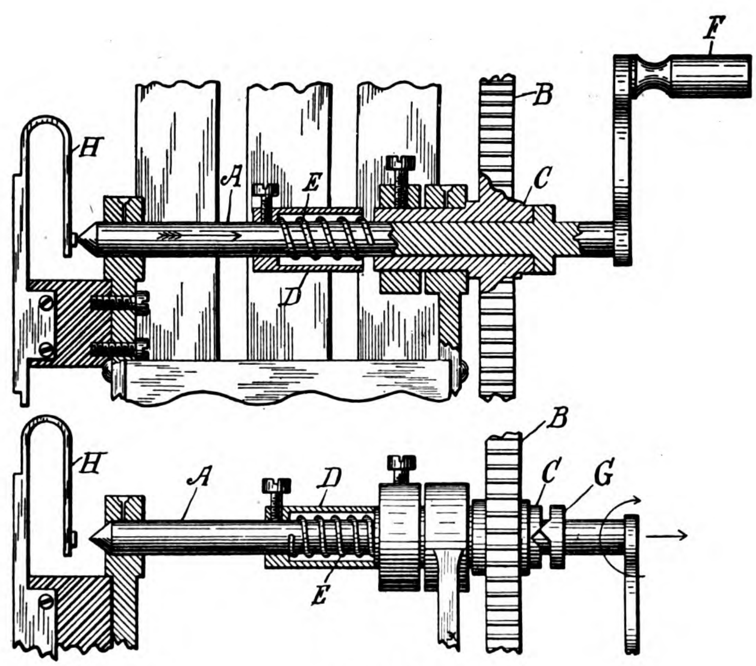


Fig. 157.

The call bell of the Western Electric Company's type of ringer is shown in fig. 158. The two bells A are fastened to the posts B by the screw *C*. These posts are part of the yoke base, which is secured to the front of the door by the screws *E*. The permanent steel magnet *D* is so shaped as to inclose the windings of the bell and is fastened to the base by a screw *O*. The cores of the coils are of soft iron and fastened to the yoke base by the screws *F*. The armature *H* is pivoted to the brass supporting piece *J*, which in turn is held in place by hexagonal nuts on standards *K*, the hexagonal nuts serving to adjust the distance of the armature from the cores of the windings. Attached to the pivoted armature is a rod which, passing through the door of the box, carries a striker, and as the armature oscillates alternately strikes each bell. The coils *L* are wound in the same direction, and as both cores have been polarized alike by the permanent magnet the calling current in the windings will strengthen the pull of one and weaken the pull of the other core on the armature, and being alternating in character will cause the armature to vibrate from one to the other.

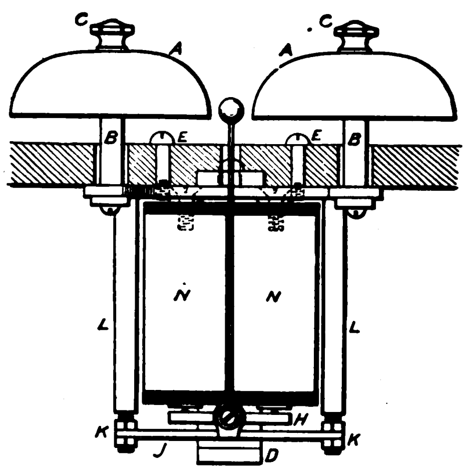


Fig. 158.

BIPOLAR RECEIVER, AMERICAN BELL TELEPHONE COMPANY.

This receiver is shown in fig. 159. The shell *A* and ear piece *B* are of hard rubber and clamp between them the soft-iron diaphragm *D*. The magnet consists of two separate steel bars *F F* connected at the back end by a soft-iron yoke *I*, which is made out of a short piece of round rod and which is held in place by the rivet *R*, which passes clear through both steel bars and the yoke. The steel bars are so magnetized that the south pole of one and the north pole of the other are toward the diaphragm. These ends are held in position by an adjustment block *H*, of brass composition, which has two segmental projections extending outward between the steel bars. On the outer surfaces of these segmental projections is cut a thread, which thread fits the thread *g*, cut upon the interior surface of the shell *A*. At the front end of the steel bars, between the segmental projections, are the soft-iron pole pieces *P P*, which are held in position by the brass bolt *b*, that also holds the block *H*. The space between the steel bars, the yoke, and the adjustment block *H* is filled by the block of wood *W*.

On the pole pieces *P P* are wound the coils *G G*, which are made of fine insulated wire. The ends of this wire are connected by the lead wires L L to the binding posts J J. The screw thread g serves the double purpose of holding the magnets in place in the shell and of adjusting the distance between the pole pieces and the diaphragm. When this distance is once correctly adjusted it should not be altered, and in this receiver the adjustment is first made, then the lead wires L L are inserted and soldered to the magnet wires. If at any time it should become necessary to remove the magnet from the hard-

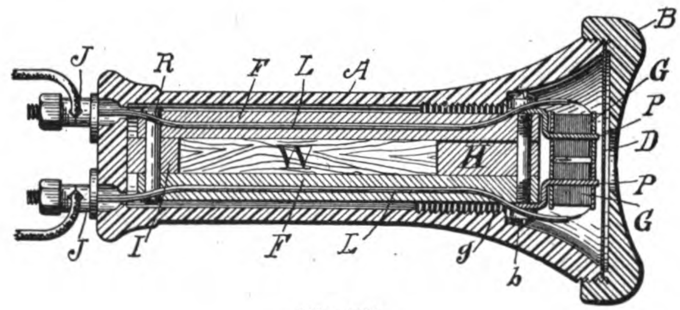


Fig. 159.

rubber shell, the lead wires L L must first be removed before attempting to turn the magnet in the screw thread g.

SCHMIDT BIPOLAR RECEIVER

(Old type.)

This receiver is shown in fig. 160. The shell is of two pieces, the tube A of hard rubber and the cap B of metal, the ear piece C being

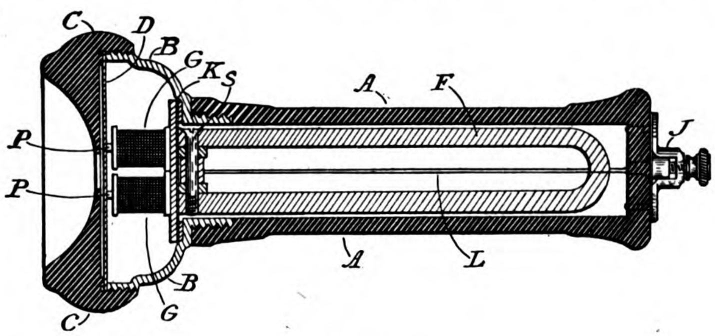


Fig. 160.

of hard rubber screwed over the outside of the cap in the usual manner, thereby binding the diaphragm D between it and the edge of the cap. The magnet is made of a single piece of steel F, doubled upon itself in horseshoe form so as to present a north-and-south pole to the diaphragm. The pole pieces P P are of soft iron and secured to the magnet by the screw S. On the pole pieces are wound the coils G G, of fine insulated wire, the ends of which are soldered to the lead wires *L*, the other ends of which are connected with the binding posts *J*. Three washers *K*, one of soft iron and two of fiber, are slipped between the bobbins and the poles of the magnet, the lower of the three washers being seated on a shoulder in the cap B and held in place by two screws, not shown in figure, passing through the washers into the hard-rubber tube *A*, thereby holding the magnet and bobbins in the shell.

IMPROVED RECEIVER.

The receiver shown in fig. 161 is supplied with all of the model 1905 Signal Corps telephone instruments and provides an improvement

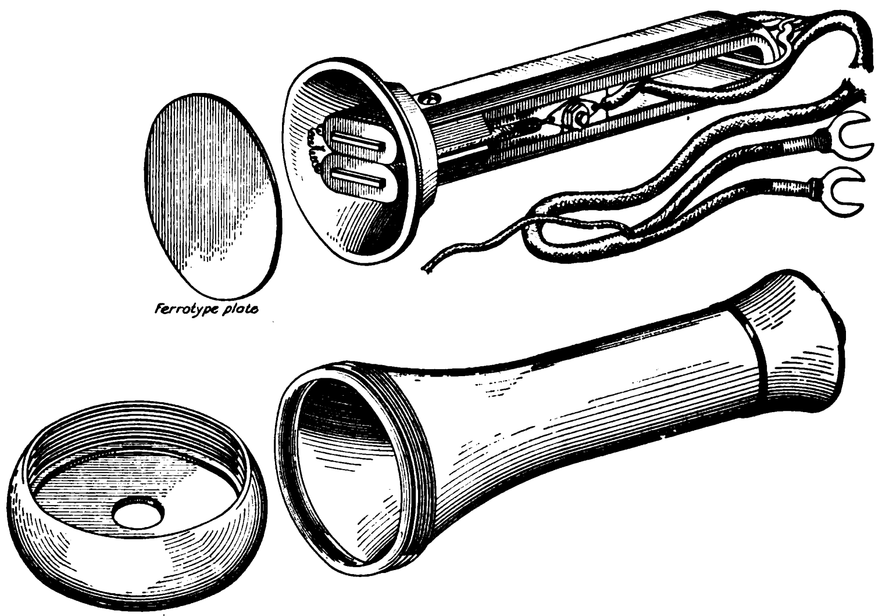


Fig. 161.

over the old type of receiver in that the terminals are entirely inclosed and the likelihood of trouble from loose binding posts is reduced to a minimum.

THE WATCH-CASE RECEIVER.

This receiver, shown in fig. 162, is bipolar and used as a head receiver for switch-board work in the combined receiver and transmitter and in certain types of field apparatus. The figure shows a section and a view with the cover and diaphragm removed. It consists of a metal case *A*, on which is screwed a hard-rubber ear piece *B*, clamping the diaphragm *C* in the usual manner. The magnets consist of three steel rings *D*, between the lower of which and the metal case *A* the curved soft-iron pole pieces *E* are inserted and fastened to the magnets by the screws *F*. The bobbins are slipped over the ends of the pole pieces, and the windings are brought to the two screws *G*, *H*. When used as a head receiver it was formerly mounted as shown in fig. 163. The headpiece consists of two flexible metal straps *A*,

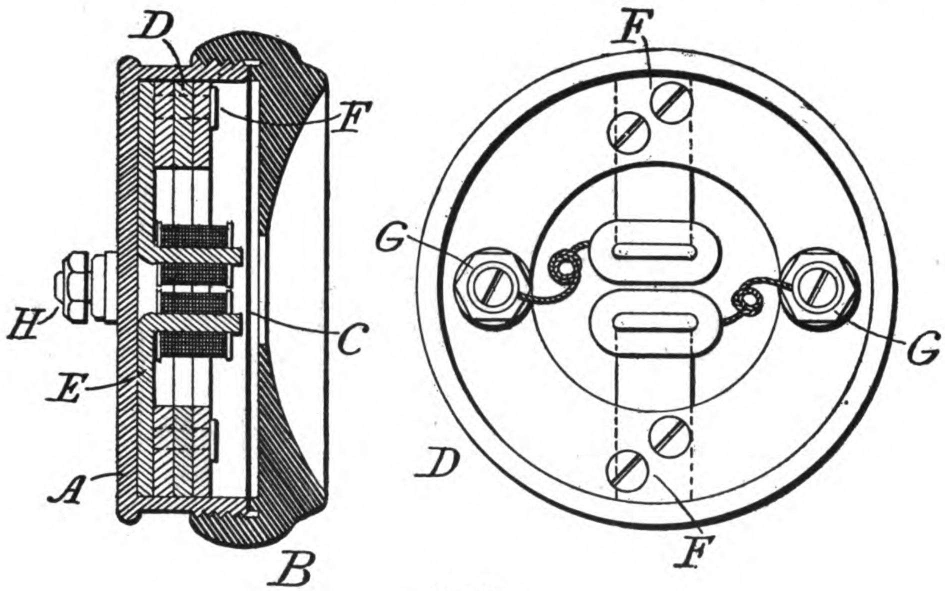


Fig. 162.

of the form shown in the figure, which are pivoted at *B* to the short connecting piece *C*, that is in turn pivoted to the fork *D*, that contains two studs *E*, that are sprung into the metal case of the receiver,

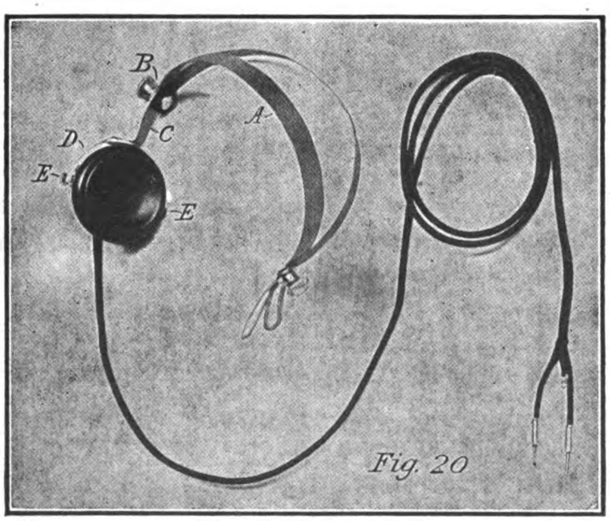


Fig. 163.

tains two studs *E*, that are sprung into the metal case of the receiver, which is free to turn around these studs, the three pivots permitting the receiver to be fitted and adjusted to any head.

IMPROVED KELLOGG HEAD RECEIVER.

The head receiver shown in fig. 164 is furnished with the latest type of field-telephone equipment and provides a simpler form of headband than the old type.

This type of receiver has a steel headband, which is covered with

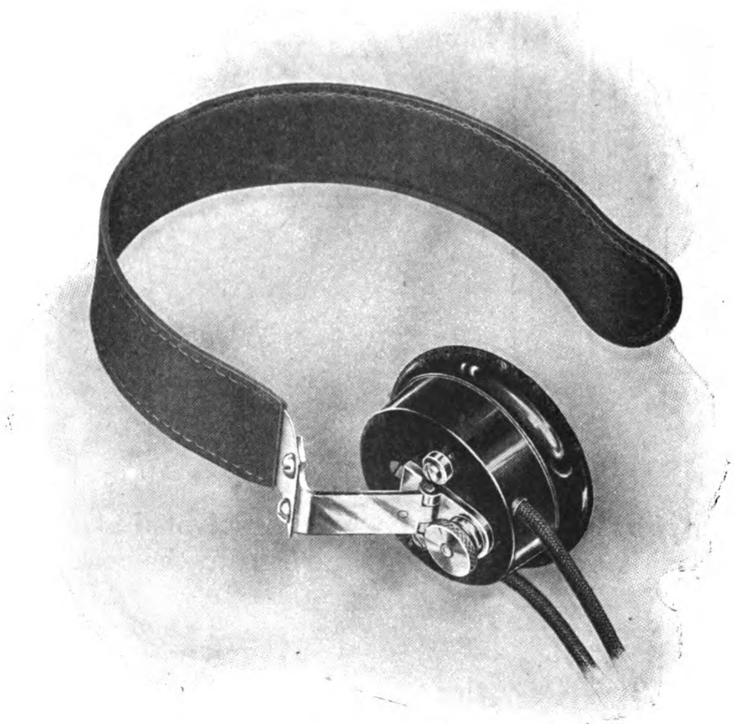


Fig. 164.

leather and is so pivoted that it fits the head of the operator very comfortably. Fig. 165 shows the component parts of this receiver.

WHITE SOLID BACK.

The White solid-back transmitter of the American Bell Telephone Company is shown in figs. 166 and 167. The transmitter is inclosed in a metallic cover *A*, which is attached to a movable cast-iron arm *B*, that is pivoted to the case *C*, containing induction coil *e*. The case *A*, which contains the working parts of the transmitter, is made in two sections. The front section holds a circular soft-iron diaphragm *D*, whose edge is incased in a soft-rubber ring *E* and held in place by damping spring *F*, screwed to the front part of the case. A hollow cylindrical box or a case *G*, of two parts screwed together, holds two carbon disk electrodes *L L′*. This cylindrical cell is supported by the brass arm M screwed to the front part of the case. The interior circumferential walls of G are lined with paper (not shown

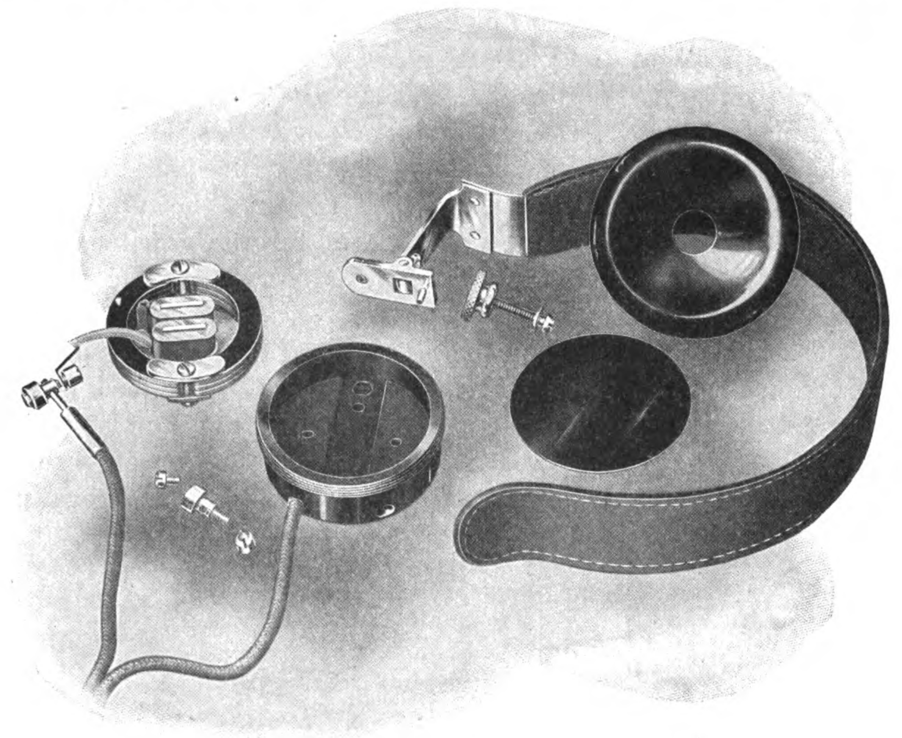


Fig. 165.

in the drawing). The back electrode L is secured to the back of the cell G by a screw (not shown). The front electrode is carried on a

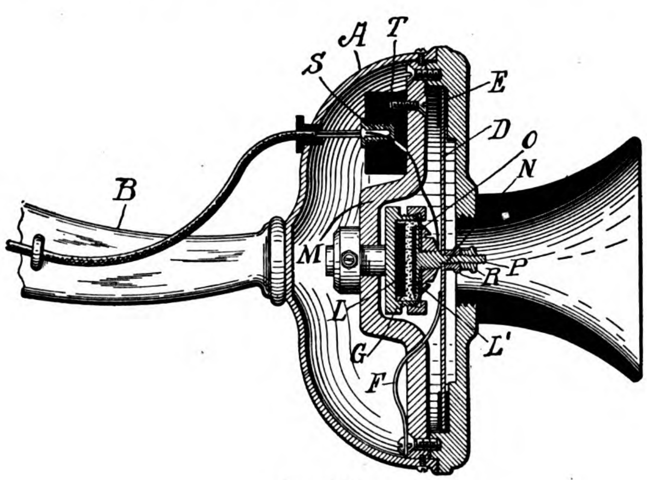


Fig. 166.

metallic piece N, over which is slipped a mica washer O of sufficient diameter to completely cover the opening in the cell G. The metallic piece N terminates in the screw P, which passes through the diaphragm D and is locked against it by two nuts R. The space in the cell G is filled with granules of carbon. When the required amount of granular carbon has been put in the cavity and the front electrode slipped into position, the plate N is screwed home, binding the mica washer O firmly against the face of the cell G, thus firmly confining the granules in place. The electrodes are of somewhat less diameter than the interior of the cell, so there is considerable space around their edges filled with carbon granules, which prevents the binding of the electrodes and allows room between them for the expansion of the granules when heated by the passage of a current. The vibrations of the diaphragm are transmitted directly to the front electrode, which is allowed to vibrate by the elasticity of the mica washer, while the back electrode is held stationary in the case. The back electrode is mounted on the frame, while the front electrode is connected by an insulated wire to the terminal S, which is mounted on an insulating block T, in the manner indicated in the drawing. The terminal S

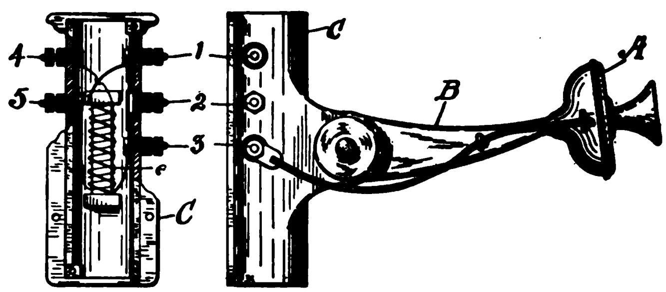


Fig. 167.

is connected by a flexible conductor to binding post 3 on the case C. Posts 1 and 2 are the battery posts and 4 and 5 the terminals of the secondary winding of the induction coil. This form of arm mounting and connection is similar in nearly all the transmitters used on the wall instruments of the old American Bell type employed by the Signal Corps.

THE GOLD-BUTTON TRANSMITTER.

(As provided with old model L. S. service telephone.)

The gold-button transmitter of the Lambert-Schmidt Telephone Company is shown in fig. 168. The transmitter is inclosed in a metal case, A, consisting of two parts flanged together, into which is screwed the hard-rubber mouthpiece. The case is shouldered on the hollow cylindrical brass block B, which slips into the transmitter socket of the solid arm, and is held in place by a set screw. The metal diaphragm *C*, whose edge is incased in a soft-rubber ring, *D*, is held in place by two damping springs (not shown in figure) in the same manner as the solid-back transmitter. The outer edge of the cup *E*, which is made of insulating material, is threaded to fit the ring *F* of the same material, which clamps a small aluminum diaphragm, *M*, over the top of the cup. The back electrode *G* is of gold-plated metal. The screw *H*, fastened to the back of the electrode, passes through the cup, holding it in place, and is attached to the standard *I* that is passed through the insulating bushing *K* in the sleeve *L*. *I* is threaded at its end and engages in a hole in the standard *J* (shown in fig. 169) of the solid arm, and serves as one terminal of the transmitter. The

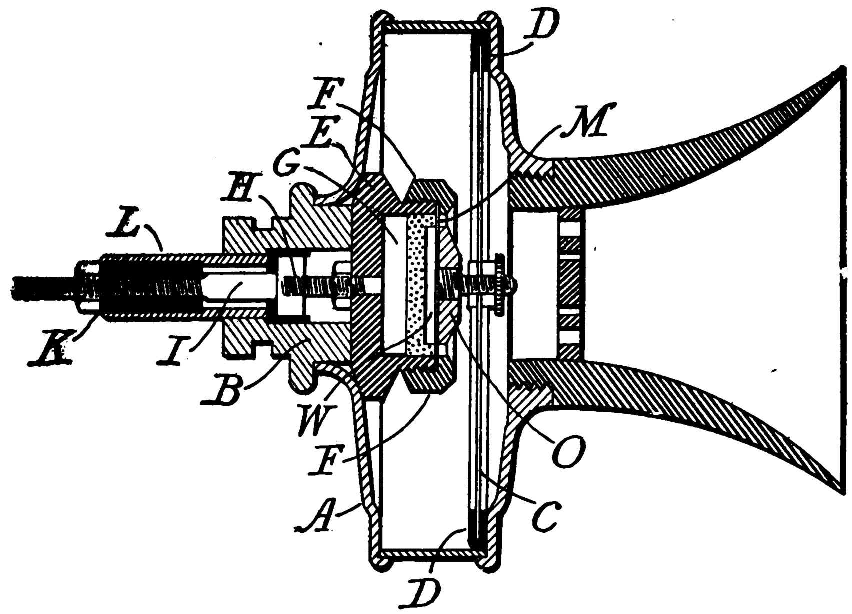


Fig. 168.

front electrode *N* is also of metal, gold plated, and is firmly held against the aluminum diaphragm by a clamp nut, *O*. The front electrode is connected to the diaphragm *C* by lock nuts in the usual manner, and the cup is filled with fine granulated carbon. The standard *I* and the collar *L* form the two terminals of the transmitter.

SOLID ARM FOR TRANSMITTER.

(As supplied with L. S. service telephones.)

The transmitter above described slips into the transmitter socket *P*, which is attached to two solid arms or rods, *R* and *S*, fig. 169, and held there by a set screw. *R* is fastened directly to the transmitter socket and *S* passes into and is insulated from it by a hard-rubber bushing *T*. In the rear of the socket the standard *J* is fastened to the arm *S* and its top tapped to take the screw thread on the end of *I*. The other ends of the rods are embedded on the opposite sides of the hard-rubber disk *W*, which is pivoted between the cast-iron cheek pieces *X* by the bolt *Y*. On each side of the hard-rubber disk a spring is attached to each of the rods, giving a rubbing contact against the inside of the cheek pieces and permitting the arm to be raised and lowered without breaking contact. The cheek pieces are mounted on hard-rubber foundation plates and connections made

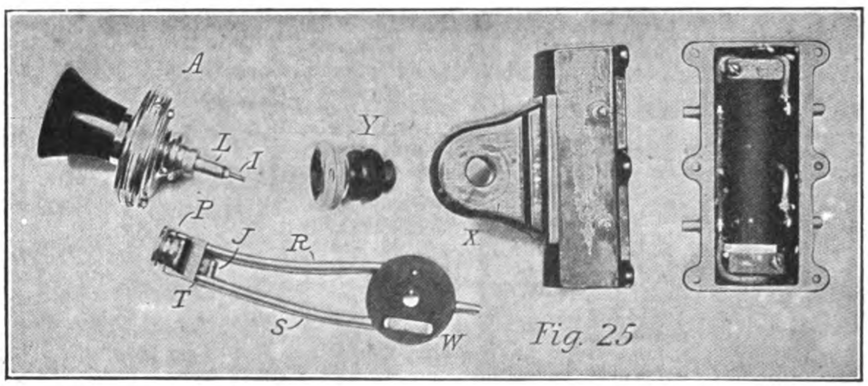


Fig. 169.

to the binding posts on the side of the casting that contains the induction coil.

THE STANDARD HAND SET.

The standard hand set is shown in fig. 170. This set provides a very strong permanent mechanical connection between the standard watch-case receiver and a solid back transmitter. The switch located in the handle of the set provides for a transmitter cut-out if it is desired.

This set is supplied with the latest model cut-in telephone and with the 1905 model field telephone. In the latter instrument the switch cuts off both the receiver and the transmitter, while in the former only the transmitter is cut off.

BREAST TRANSMITTER.

The standard breast transmitter supplied for general service operation provides a solid back transmitter in a brass case set at right angles to a brass breastplate.

The breastplate is secured to the operator by means of a leather strap having a clip at one end and an adjusting buckle.

The mouthpiece is of hard rubber and is retained on the transmitter horn by friction.

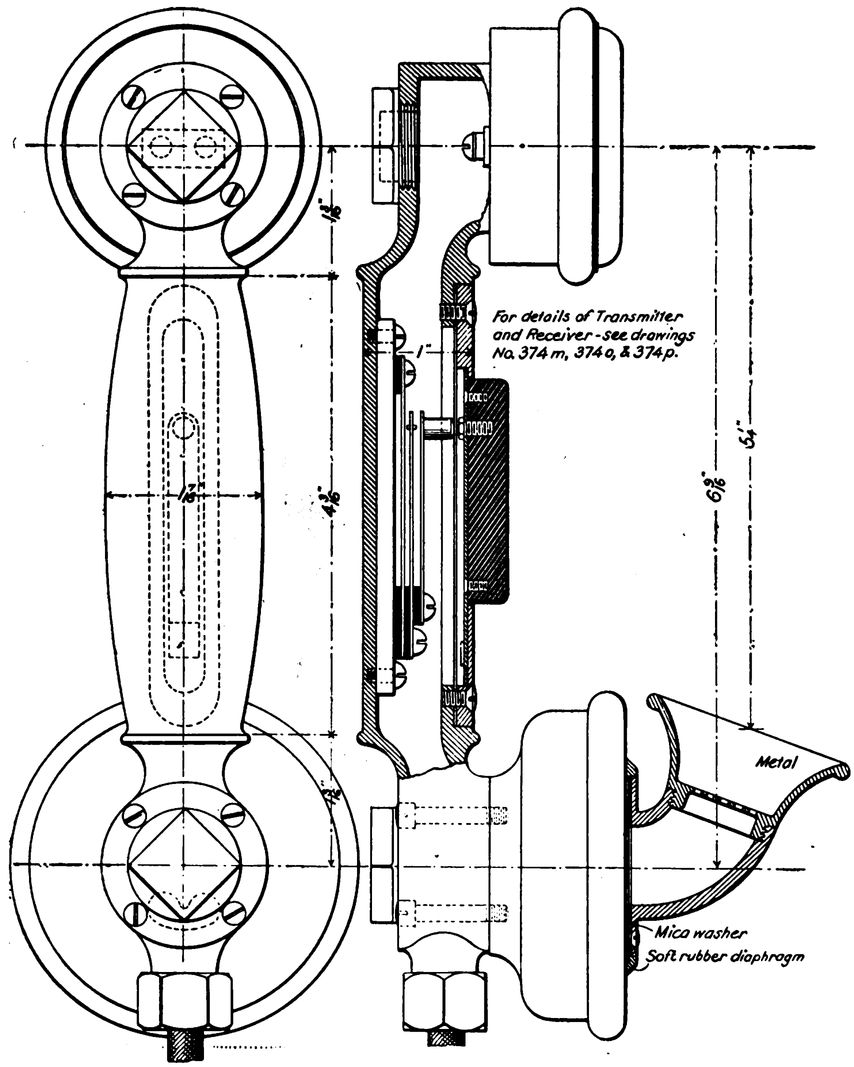


Fig. 170.

The terminals of the transmitter are on the interior of the case and are brought through it in a water-tight gland. The cord is rubber insulated and braided.

This transmitter is shown in fig. 171, and may be supplied with either local or common battery carbon chamber.

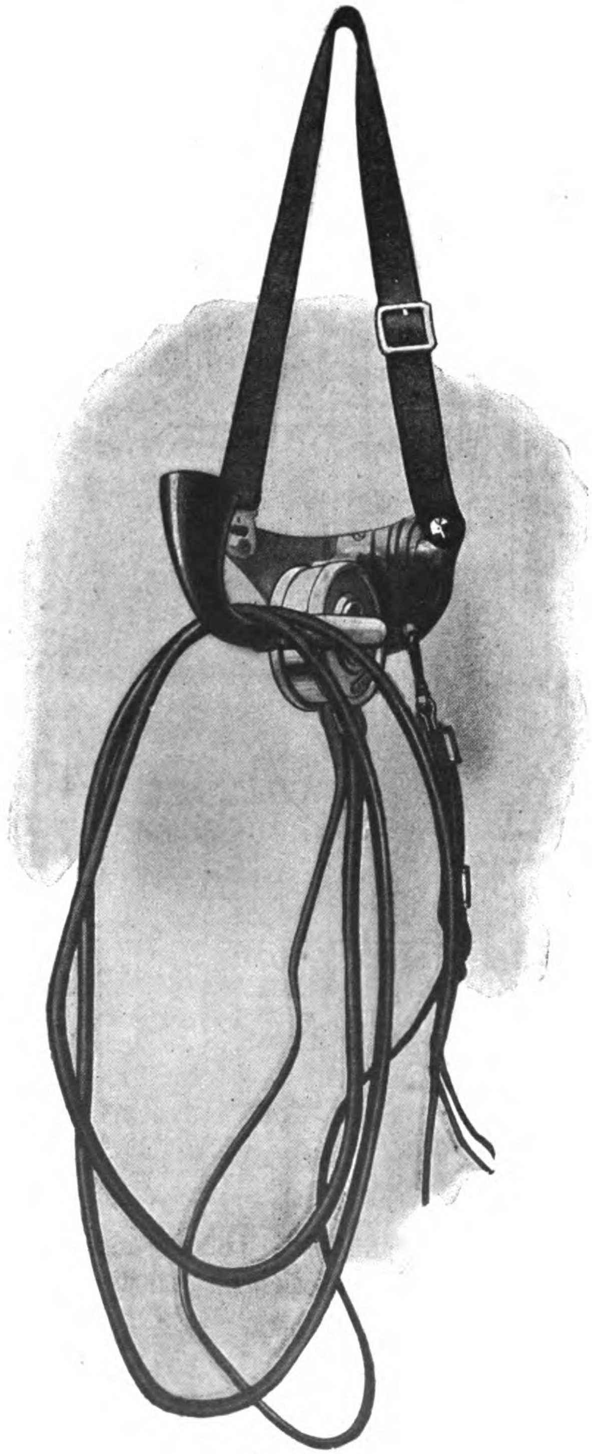


Fig. 171.

Chapter XVI.

TELEPHONE SWITCHBOARDS.

The switchboards supplied by the Signal Corps for permanent work will be operated in most cases on a local battery circuit. In special cases of large military posts which include schools of instruction, a common battery cabinet may be supplied with an ultimate equipment of 30 or 100 lines including a varying number of cords and drops to conform to the installation required.

The switchboard supplied for small posts, having a standard telephone equipment, is designated as the post telephone switchboard and operates on local battery. This board is normally equipped with 15 lines, providing a spare line for emergency during the repair of lines regularly in use.

The switchboard supplied for field work accommodates 10 lines and an equipment the equivalent of 4 pairs of cords. This switchboard is known as the portable telephone switchboard. It operates on a local battery circuit.

In connection with Coast Artillery work a special type of switch board has been developed which has certain characteristics common to both local and common battery. This board, which is installed in several artillery posts, is designated as " telephone switch board, fire-control type."

OBSOLETE TYPES.

To cover those types of switch board now in more or less extended use, but no longer supplied, there is retained a description of the wall cabinet type of 10 and 20 line boards, of the cordless board models of 1902, and of the cordless board model of 1901.

COMMON-BATTERY SWITCHBOARD EQUIPMENT.

The battery.—The common-battery equipment includes, besides the switchboards, a central battery of 30 volts. This battery is preferably of the PT type, but any of the closed-circuit batteries shown in Chapter — or a large dry battery may be used, providing that a condenser of suitable capacity is bridged across the battery terminals. This condenser prevents cross talk between cord circuits, which would result otherwise, because of the comparatively high internal resistance of the primary cells.

The switchboard.—The 100-line and 30-line cabinets are alike in arrangements of parts, in operation, and in wiring. A description of the 100-line equipment, therefore, fits both. This board is shown in fig. 172.

This switchboard is built of oak and provided with an upper and lower rear door, a front panel, a foot-rail bracket, and is designed to

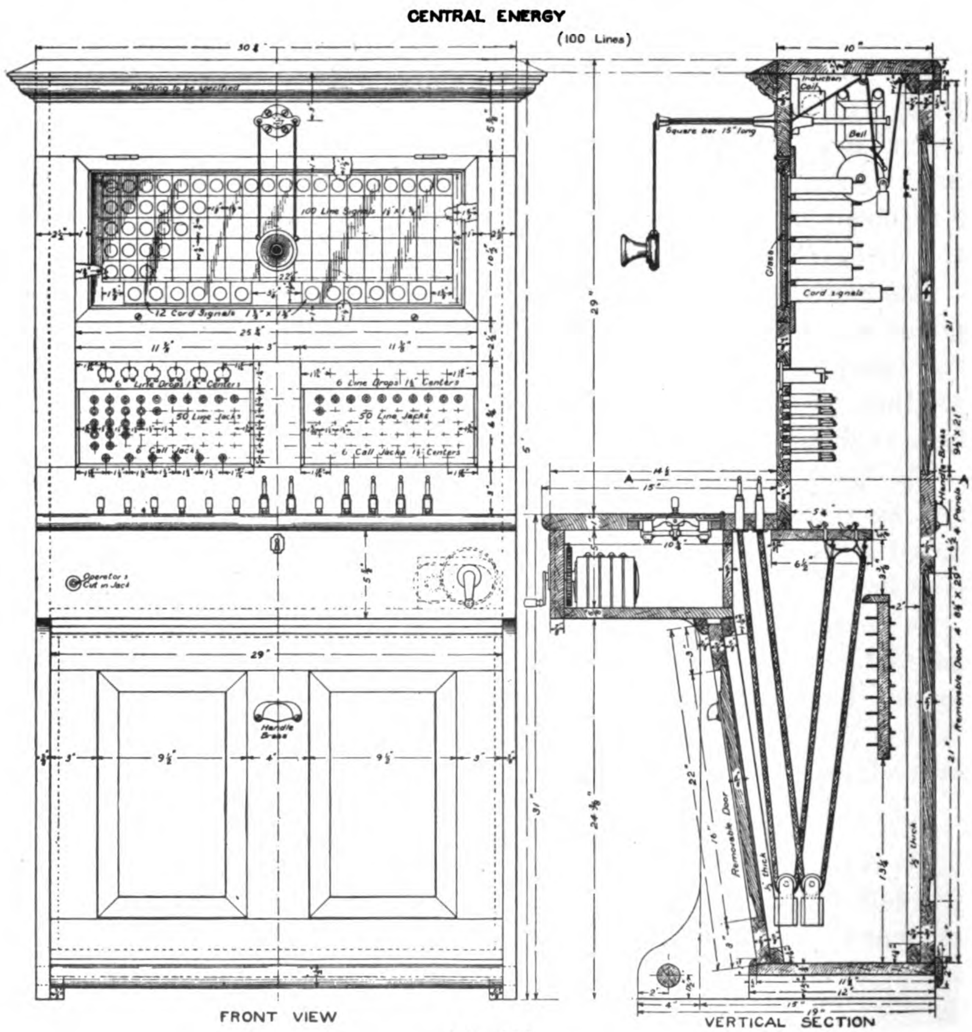


Fig. 172.

accommodate all of the apparatus necessary for the operation of the system except the battery.

In addition to the 100 common battery lines this switchboard provides a mounting for 12 magneto call lines for long-distance operation. It is intended that these lines should, under ordinary conditions, be operated through condensers.

Twelve cord circuits are provided. The cords are made of steel strands and are two-way. The keys are of the pattern shown in fig. 177, and provide for ringing on the calling cord only. This arrangement simplifies the wiring and equipment. The supervisory signal acts also as a retardation coil, through which the battery is fed to the coil circuits. This signal shows in the form of a hemispherical target, which projects outward from the face of the signal, so as to be visible from all parts of a room.

The supervisory signal operates when the cord is in use and clears when the parties hang up. A movement of the subscriber's hook up or down operates this signal.

The line signal is thrown when the calling party removes his receiver from the hook and is restored automatically when the operator inserts the answering plug.

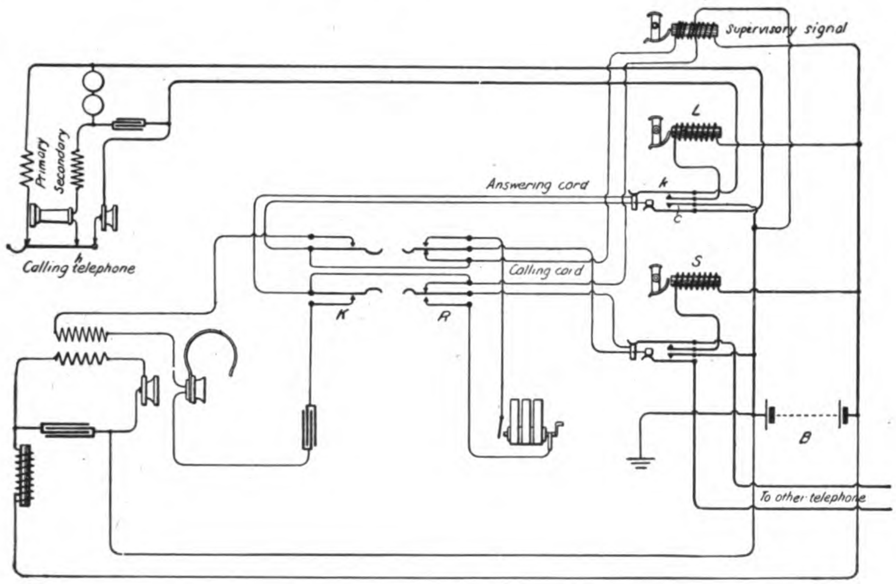


Fig. 17[illegible].

The common battery is bridged on the line through the supervisory signals.

The operator's circuit has a standard common battery induction coil, is connected to battery through a retardation coil, and a condenser is bridged across the source of current supply. A condenser is also placed in the secondary circuit to prevent a flow of direct current when the listening key is thrown. The cord connecting the transmitter in circuit is provided for in the transmitter arm and the operator's head receiver is attached to a cord which terminates in a special plug fitting the jack in the keyboard. The insertion of this plug puts battery on the operator's transmitter.

The night-bell circuit provides a relay and vibrating bell, and operates, if desired, whenever a call is received.

The circuits of this switchboard are shown in fig. 173. Reference to this figure indicates that when the subscriber's hook h is up current flows from the battery B through the jack contact c to the subscriber's instrument, through the transmitter and primary winding of the induction coil to jack contact k, through line signal L, and thence to battery.

When an answering plug is inserted in the jack J the line signal is

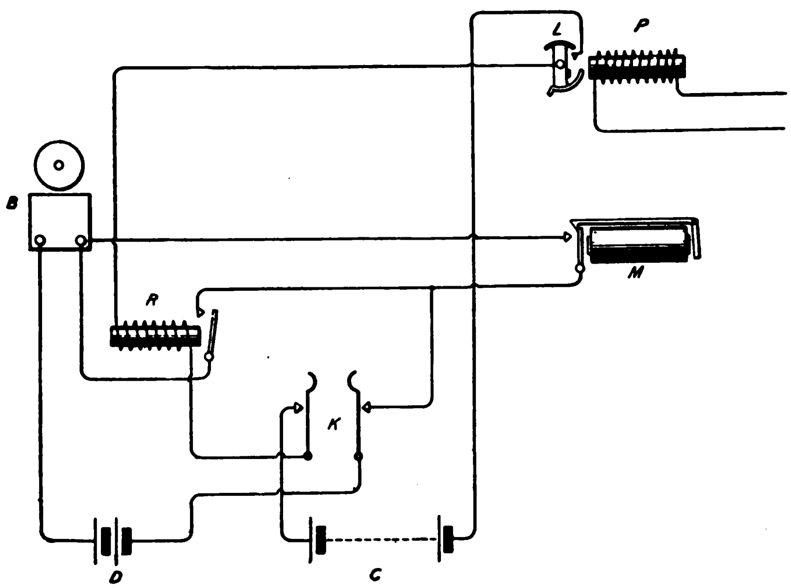


Fig. 174.

cut off and falls back. Current now flows to the subscriber's instrument through one winding of the supervisory signal S, returning through the other winding of the supervisory signal to the battery. The operator depresses listening key K and the subscriber's voice currents flow into the receiver circuit at the switchboard. The calling cord of the same pair as the answering cord just used is now

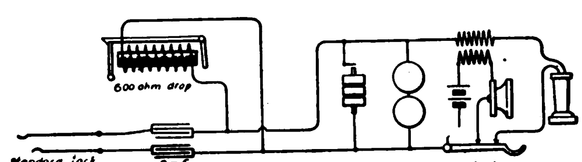


Fig. 175.

inserted in the jack corresponding to the line desired, the key R is depressed, the generator turned and the connection is established. As soon as the plug is inserted current flowing through the supervisory signal causes it to operate and this signal shows " busy " until both parties hang up their receivers. Should either party desire to attract central's attention a movement of the switch hook will cause this signal to flutter.

The night-bell circuit of the central energy switchboard is shown in fig. 174. It will be seen that when the visual signal operates a current will flow from the common battery through the contact of the night-bell key K, thence through the relay, thence through the contact of the armature of the signal returning to the battery. The operation of the relay, however, permits current to flow from the dry cell D through the right-hand contact of the key K, thence through the bell and back to the battery D. When the magneto drop operates current will flow from the battery D through the right-hand contact of the key K, through the armature contact of the magneto drop M, through the bell B, returning to the battery D.

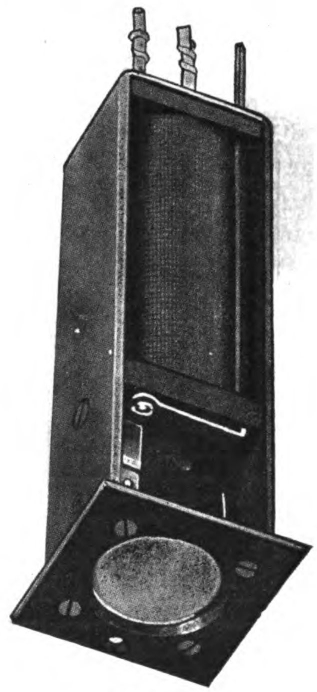


Fig. 176.

Where the length or resistance of the lines makes common battery signaling impracticable or when a grounded line must be connected to this switchboard, one of the generator call drops is brought into service. Fig. 175 shows approved methods of wiring in a circuit which is not operated on the common battery. These circuits are so wired as to provide for satisfactory operation on the same cord circuit as the common battery lines. Under special conditions, if the

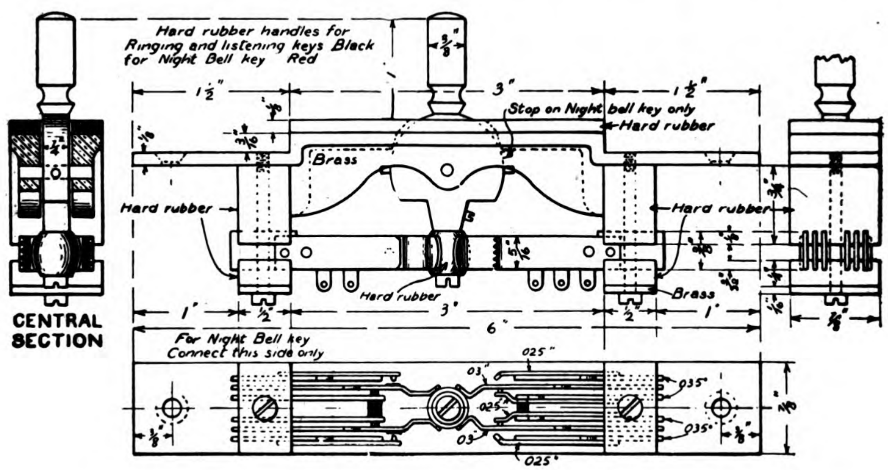
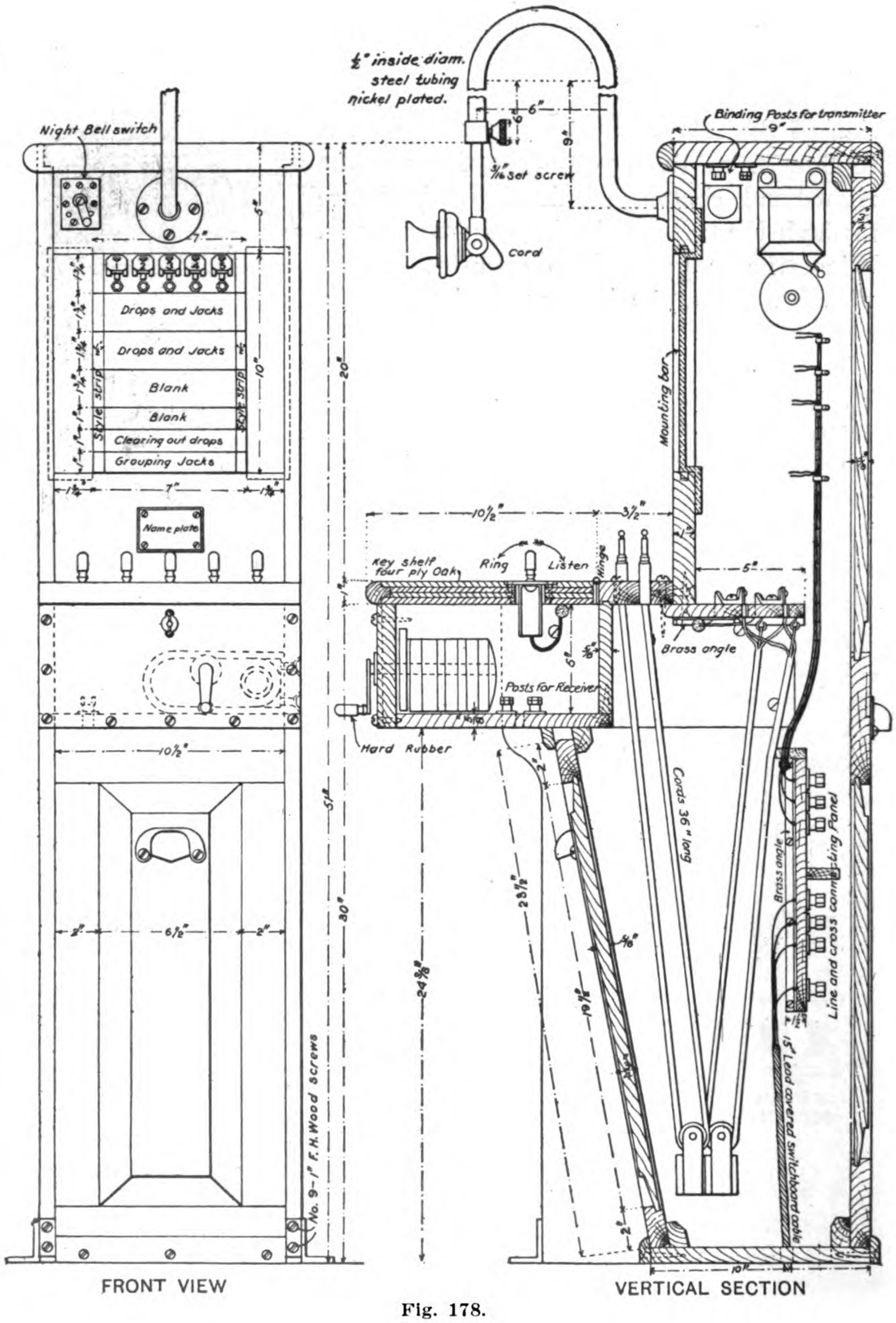


Fig. 177.

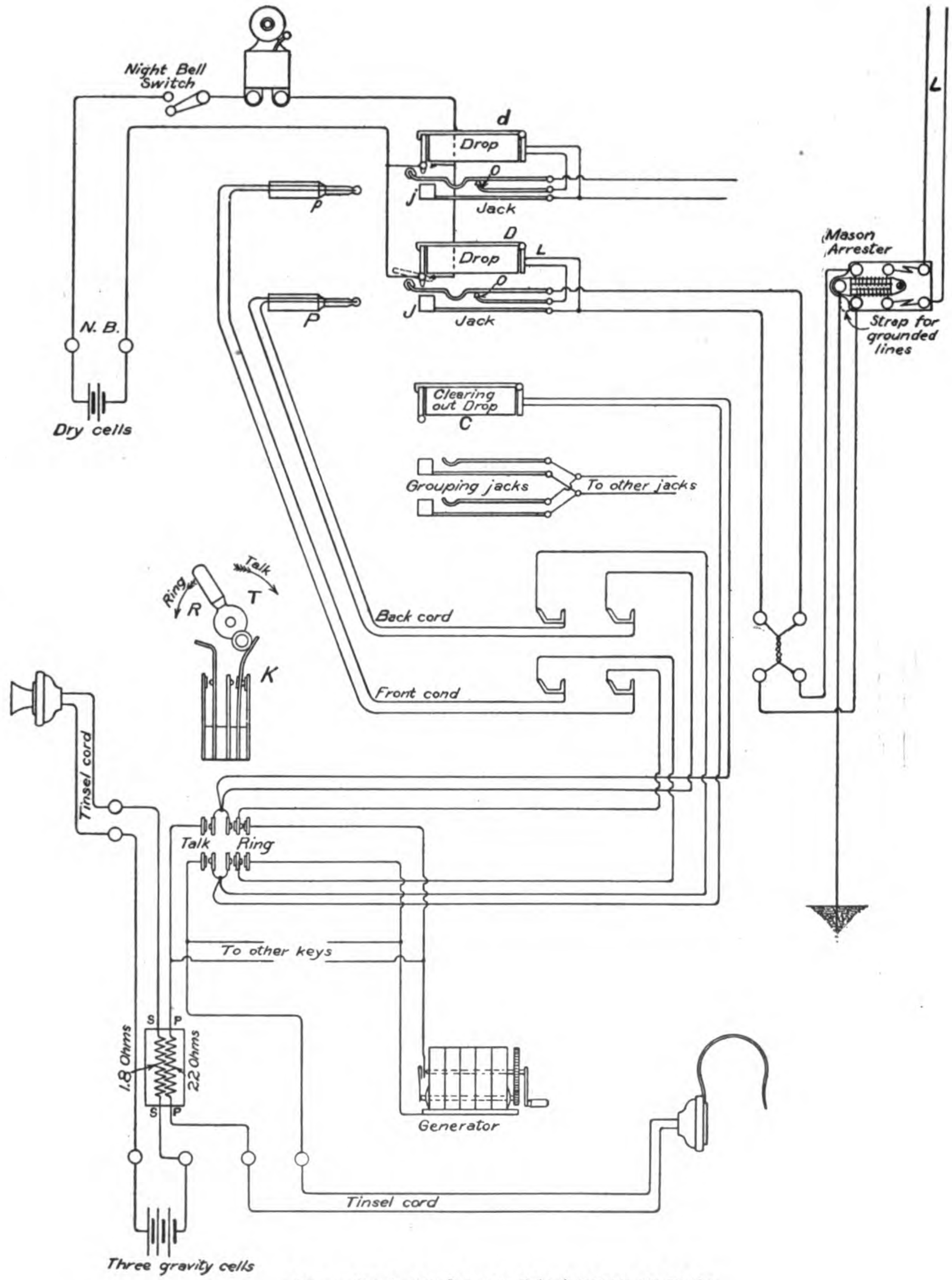
lines are long, however, it may be necessary for a repeating coil to be installed in the cord circuit, as shown in fig. 198[a].

The line signal is shown in fig. 176 and consists of a simple magnet



½" inside diam. steel tubing nickel plated.
Night Bell switch
Binding Posts for transmitter
5/16" set screw
Cord
Drops and Jacks
Drops and Jacks
Blank
Blank
Clearing out drops
Grouping Jacks
Style strip
Style strip
Name plate
Mounting bar
Key shelf four ply Oak
Ring
Listen
Hinge
Brass angle
Posts for Receiver
Hard Rubber
Cords 36" long
Brass angle
Line and cross connecting Panel
15' Lead covered switchboard cable
No. 9-1" F. H. Wood Screws
FRONT VIEW
VERTICAL SECTION

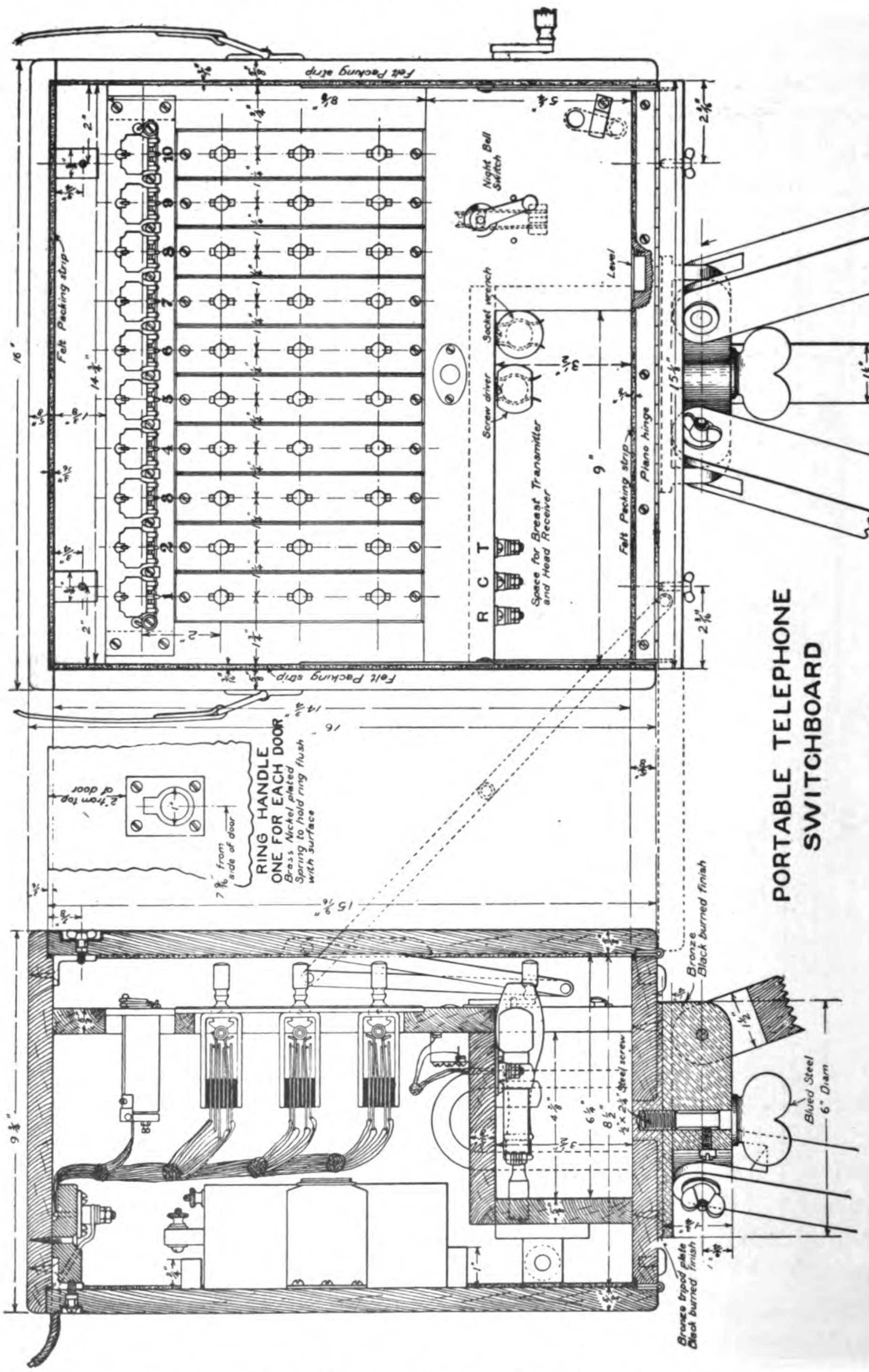
Fig. 178.



NOTE:—*Cords should connect in fasteners tip to tip and sleeve to sleeve, ground lines coming in on long or tip springs of jack.*

Fig. 179.

having a long pull armature bearing a hemispherical aluminum disk. The signal has no adjustments.



PORTABLE TELEPHONE SWITCHBOARD

Fig. 179a.

The supervisory signal is similar to the line signal in its action, but provides two windings, supplying the function of a retardation coil as well.

The key is a powerful horizontal type, as shown in fig. 177. The ringing contact is serrated instead of being provided with the usual platinum contacts. All springs are heavily reenforced and insulation is of hard rubber. The action is positive and in a horizontal direction, as indicated in the figure, which shows the cam in a listening position.

The cord is of steel, heavily reenforced at the plug end.

POST TELEPHONE SWITCHBOARD.

The post telephone switchboard, fig. 178, is designed for installation in military posts having a standard equipment of 12 telephones.

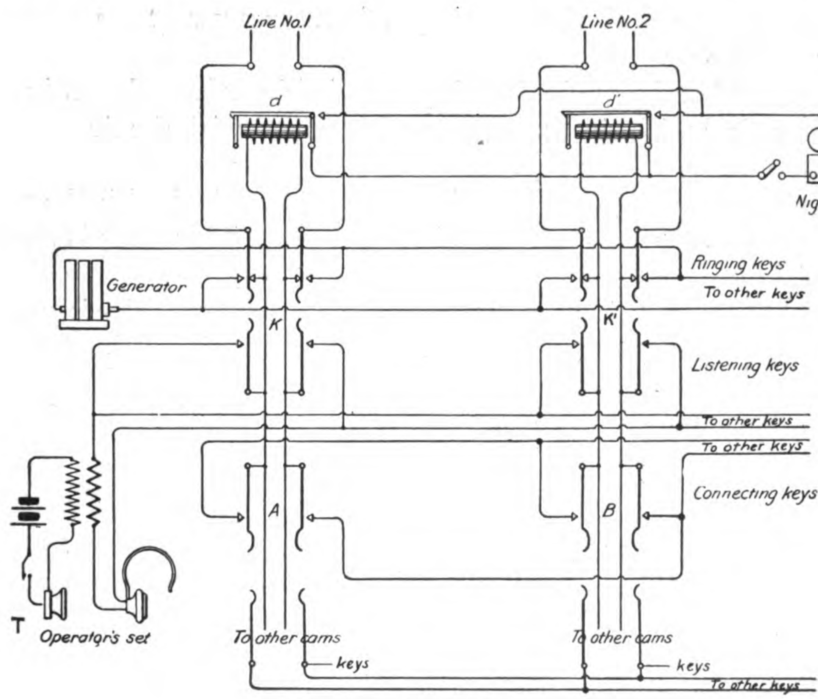


Fig. 179b.

This switchboard operates on local battery circuit. It consists of a neat oak cabinet accommodating 15 combined drops and jacks, 5 pairs of cords with clearing out drops, and 5 grouping jacks. The operator is provided with a single head receiver and the switchboard has an adjustable operator's transmitter with the usual night bell circuit.

An arrester cabinet providing for an ultimate installation of 20 Mason lightning arresters with fuses accompanies this switchboard, sufficient cable being provided to reach from the usual location of the switchboard to the cabinet on the wall at its rear. Lock nut terminals are plainly marked; the cross connection is done in the rear of the switchboard. The operator's circuit is supplied with gravity cells.

The circuit is as follows:

The calling party signals central by a magneto call, throwing the line drop *D*. The operator inserts a back plug *P* (opening the drop circuit at *O* and at the same time automatically restoring drop shutter) and depresses key *K* in direction *T*.

The connection is established by inserting the corresponding plug *p* into desired line jack *j*. The conversation completed, the usual ring-off throws the clearing out drop *C*, signaling the operator to disconnect. All instruments operating through this board are on local battery.

Grouping jacks are provided to connect several lines together at once by placing plugs *P* in line jack and *p* in grouping jack.

The operator's circuit is the simple induction principle used in ordinary telephones.

The drop and jack supplied with this switchboard, as shown in fig. 185, are identical with the drop and jack supplied with the fire control type switchboard.

The plug supplied with this switchboard is identical with the plug supplied with the fire control type switchboard. This plug is shown in fig. 187.

The key supplied with this switchboard conforms to the key supplied with the portable telephone switchboard as shown in fig. 181, and is interchangeable with it.

THE PORTABLE TELEPHONE SWITCHBOARD.

The portable telephone switchboard (fig. 179*a*) is designed for field use and is patterned after the cordless switchboard, model 1902. It consists of a strong oak box provided with a leather carrying case, tripod, and ground rod. The box contains ten line drops with the necessary ringing, listening, and connecting cams to enable four sets of connections to be established simultaneously. The operator is provided with a breast set and single head receiver, and four cells of dry battery are furnished for operator's and night bell circuits.

This switchboard is designed for installation in a tent and is capable of being set up and connected, providing the necessary ground for protectors and grounded lines under any condition of field service.

A portable arrester box is supplied with the equipment, and repeating coils are furnished in case it is necessary to establish a semi-permanent installation and trouble is experienced from cross-talk.

The circuit is as follows (fig 179*b*):

The incoming call throws the drop *d*. When the key *k* is depressed the operator's set is connected to the line, the drop remaining in circuit. Should the line *d′* be desired, it is simply necessary to throw two keys in the same row in the same direction. Keys *A* and *B* are shown so connected. To ring it is necessary to throw key *K* upward and turn the generator. This action disconnects the drop and other line. When the conversation is completed the "ring-off" throws the drops. A night bell or buzzer is supplied, having the usual key in circuit.

A transmitter key, *T*, is provided, which must be depressed when the operator desires to speak.

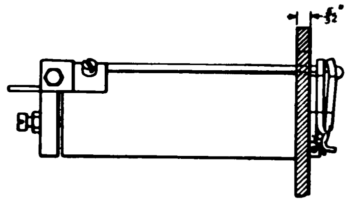


Fig. 180.

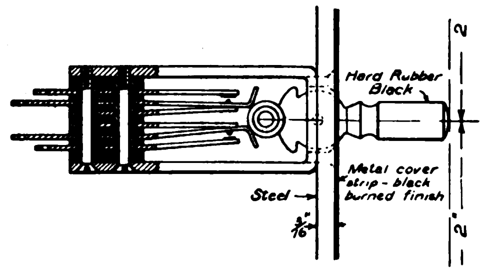


Fig. 181.

The drop supplied with this switchboard is shown in fig. 180. This drop is of the tubular iron clad type and is supplied with brass shutter and screws. Night-bell contacts are provided.

The key supplied is of extra-heavy material in all the details of its design, but otherwise follows familiar types, providing a direct cam action, heavy platinum contacts, and ample sweep. (Fig. 181.)

The transmitter and receiver are standard and conform to the improved head receiver and standard breast transmitter described in Chapter XV.

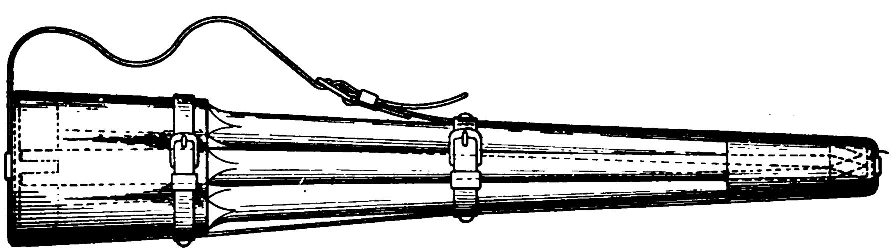


Fig. 182.

The ground rod is telescoped for transport, and carried with the tripod, fig. 182.

The tripod is of oak and provided with a carrying sling.

TELEPHONE SWITCHBOARD, FIRE-CONTROL TYPE.

This switchboard provides a line circuit requiring a magneto call like all standard magneto boards. The drop is restored mechanically by the insertion of the plug.

This board has an ultimate capacity of 20 lines, and provides clearing-out drops conforming to the drop shown in the portable board. The keys are arranged to ring on both cords, but otherwise conform to the keys in the standard common battery switchboard.

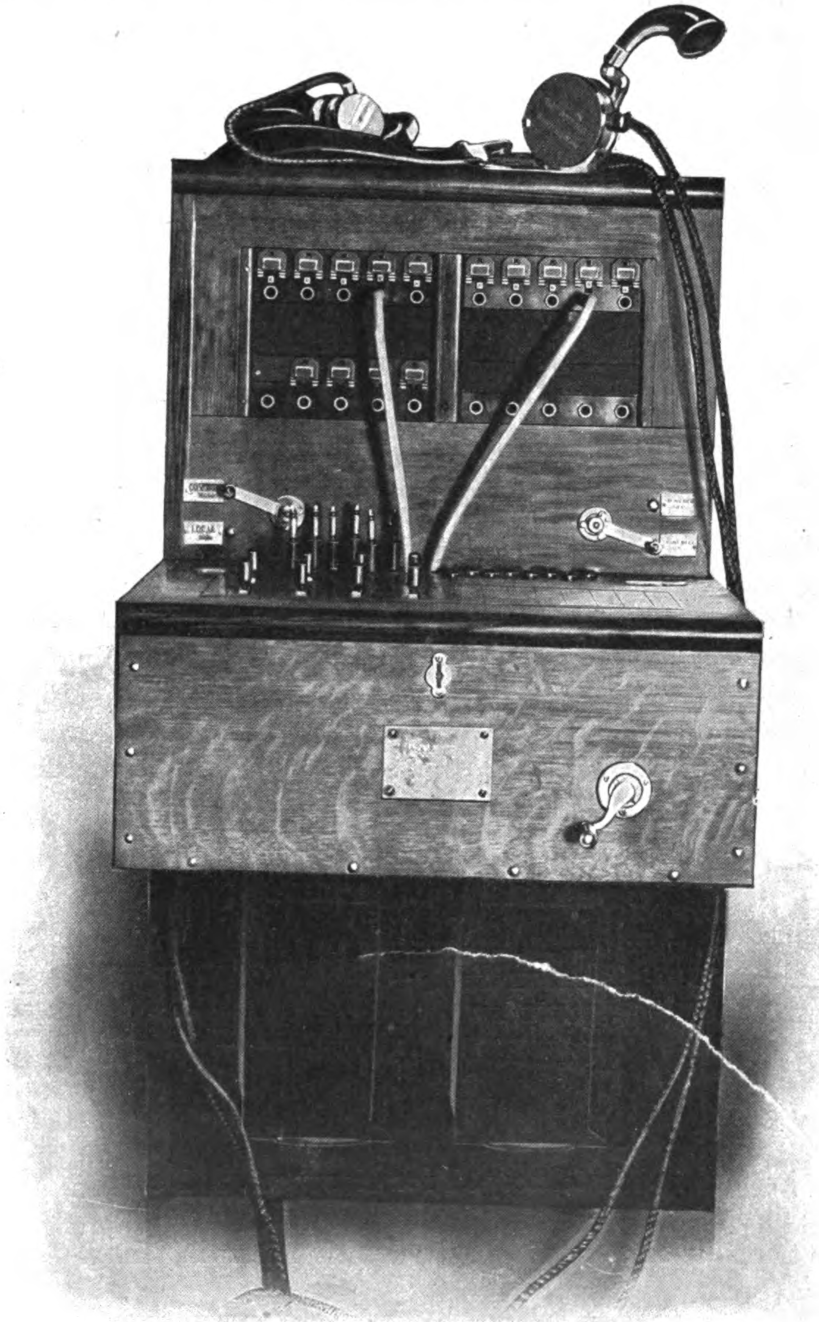


Fig. 183.

The operator's set is either a standard breast transmitter or a standard hand set, as desired. (Chapter XV.)

This board is designed for mounting against a wall and is arranged to revolve outward for inspection, fig. 183.

Lock-nut line terminals are provided plainly marked, and line connections are made after the board has been secured to the wall.

The operator's set is energized either from a 30-volt common battery or two Fuller cells, or three gravity cells, depending upon the character of service required.

A battery switch is provided for cutting the local battery on or off from the operator's set. If the board is wired up in connection with common battery, the operator's set is energized as soon as battery is cut on the board. The battery switch provides a reserve in this instance.

The operation of this board conforms to any magneto board. The subscriber signals central by a magneto call, throwing the line drop *D* (fig. 184.) The operator inserts a plug *P* and depresses key *L*. The connection is established by inserting the corresponding plug *P*

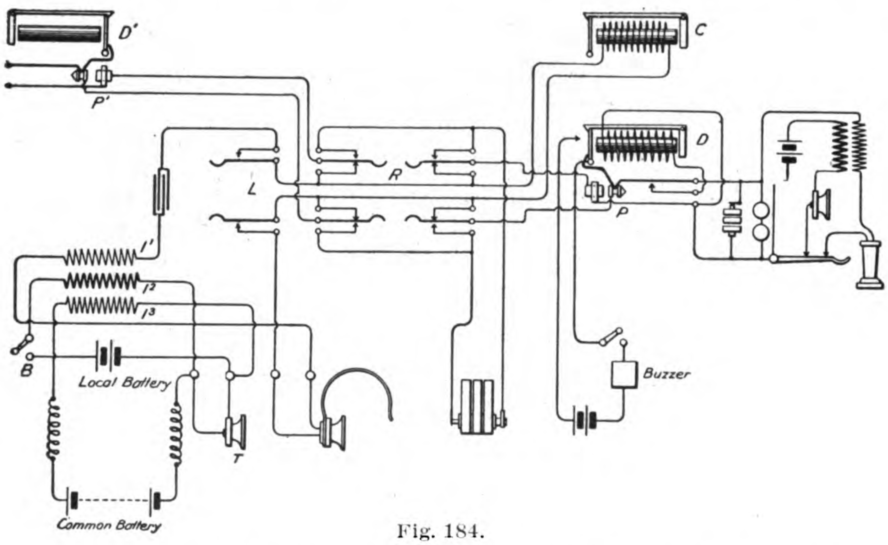


Fig. 184.

into the line jack which is desired, depressing the ringing key *R*, and turning the magneto crank. The insertion of the plug mechanically restores the drop. The conversation completed, the usual ring-off throws the clearing-out drop *C*, signaling the operator to disconnect. Subscribers' instruments operating through this switchboard are on local battery.

The operator's circuit may be operated either on local or common battery by movement of key *B*.

When this key is closed, local battery flows through the induction-coil winding I_2, thence through the transmitter *T*, and back to battery.

Common battery flows through winding I_3, and thence through the transmitter *T* and back to battery.

If local battery is used exclusively, the key *B* serves as a transmitter cut-out.

This drop (fig. 185) is so constructed that the shutter is mechanically restored by the insertion of the plug, as shown. The winding is very readily removable. The jack and drop form a complete unit.

The key is shown in fig. 186 and provides for ringing on both cords.

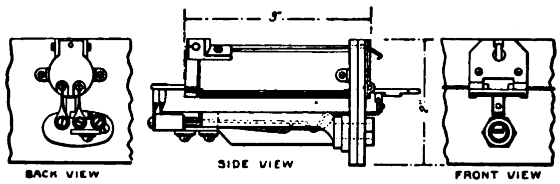


Fig. 185.

The key conform to the key shown in the central energy switchboard in all essentials except in the matter of ringing, as above indicated.

When instruments that are supplied with common battery through

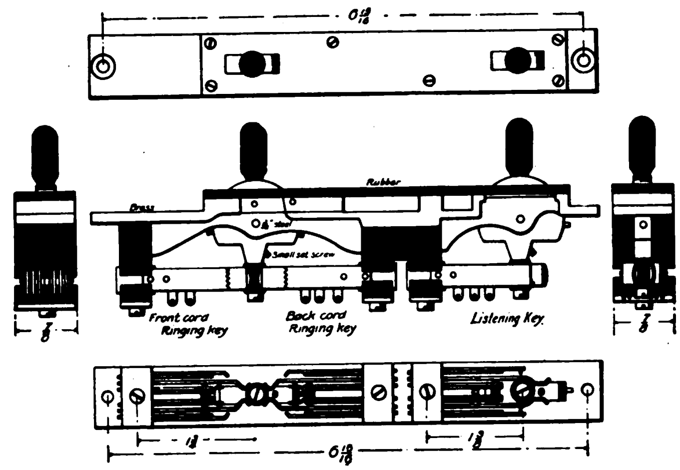


Fig. 186.

retardation coils are connected to this board the connection will be made through condensers.

The plug and cord conform to standards previously described.

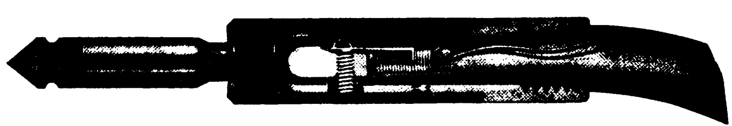


Fig. 187.

WALL CABINET SWITCHBOARD.

The wall-cabinet switchboard, as shown in fig. 188, is designed for small exchanges, from 20 to 40 lines, where it is desired to save space.

The working parts are mounted on a hard-rubber panel in the front of the box, which is fastened with strong hinges to the back-board. In the 20-drop board, illustrated in the fig. —, three pairs of plugs and cords are used, and in the 40-drop board six. The jacks are located immediately below the drops. The upper row of keys serve as listening keys for the pair of cords below them, while

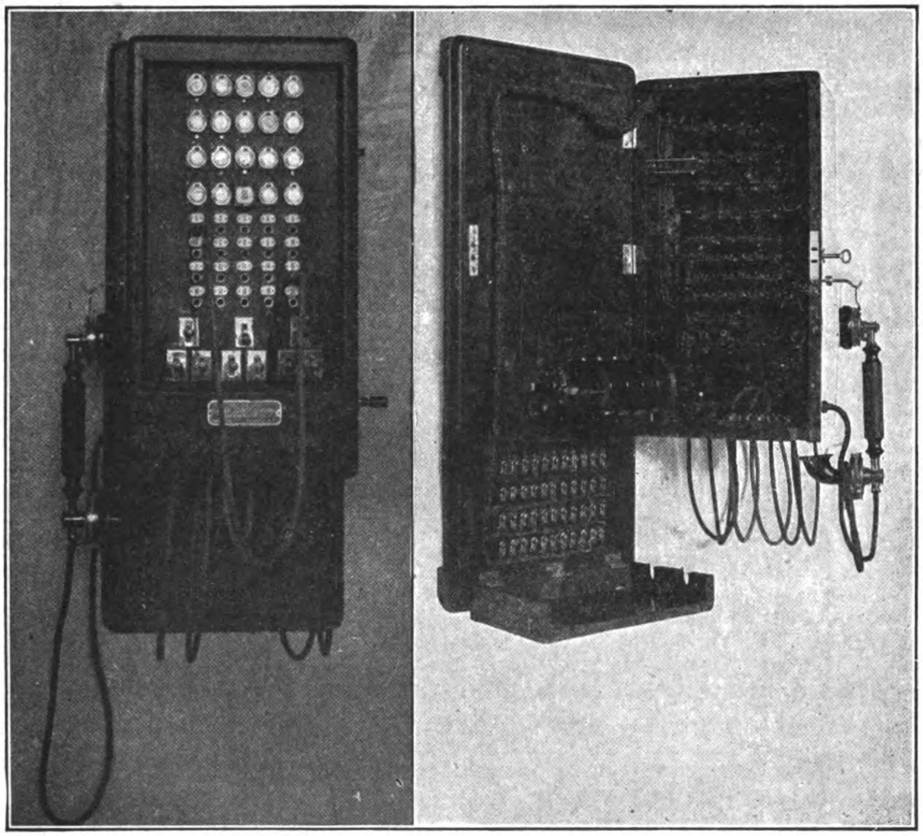


Fig. 188.

the ringing keys are located just below the listening keys, each one above its own cord. A microtelephone is used for the operator's

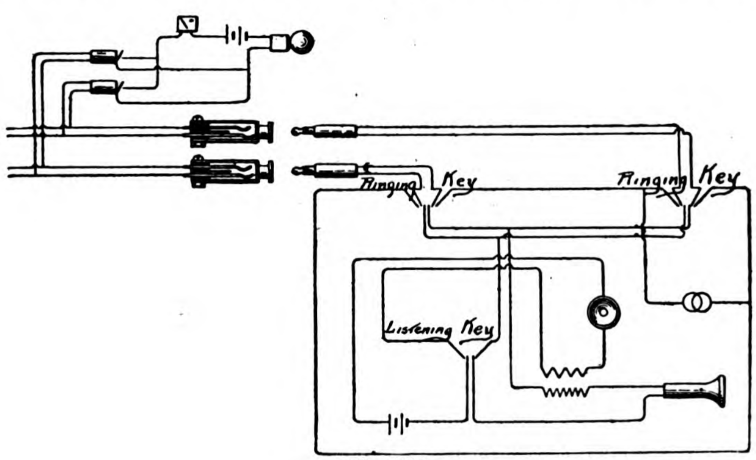


Fig. 189.

set, and the drops are supplied with a night-bell circuit. The wiring of this board is shown in fig. 189.

CORDLESS BOARDS.

1902 model.—A front view and section of this model is shown in fig. 190. This board has neither jacks nor cords. The working parts are contained in a strong wooden case, *A;* the front and back being closed by strongly hinged doors, *B* and *C*. A partition, *E*, is inserted in the front of the box, in the upper part of which is the hard-rubber panel *F*. This hard-rubber panel contains ten line drops, *G*, of the same construction as those described in the metallic switch board. Immediately below this line of drops are inserted two metal strips, *H* and *I*, that contain the keys for ringing and making the necessary connections between the line circuits. Below the panel is inserted a small strip, *K*, holding three listening keys, and below this is the key *L*, that closes the night battery circuit. The magneto *M*, dry battery *N*, and induction coil *O* are securely fastened in the box behind the partition *E*. In a recess in the bottom of the box is the combined receiver and transmitter *P*. On the top is a row of binding posts, *Q*, which serve as the line terminals, and are protected by a hinged cover, *R*. The box is carried by the strap *S*, which passes over the top and is fastened to the sides. The line drops *G* are bridged across the leads connecting the binding posts *Q* with the line of keys *H*. The details of these keys will be described later. The keys in the rows *H* and *I* are normally in a horizontal position, but can be turned either up or down. When the keys in the row *H* are turned up they serve as ringing keys for the lines immediately above them. When any two keys of the row *H* are turned down they cross connect their corresponding lines. The keys in the row *I* when turned up or down cross connect the lines corresponding to them. The keys in the row *H* are combined ringing and cross-connecting keys and the keys in the row *I* are cross-connecting keys. The left-hand key of the row *K* serves as a listening key for the lines cross connected by the down position of the keys in row *H*, the middle for the up position in the row *I* and the right-hand one for the down position of *I*. The key *L* serves to put the night-bell circuit on the drops. As there are practically three rows of cross-connecting keys, six of the ten circuits can be used simultaneously. To illustrate how the board is operated: When an incoming ring releases the shutter of its drop (if the row *H* is used) the corresponding key in that row is first turned down and then the left-hand listening key is turned down. When the station which the calling station desires to communicate with is ascertained, the key in the row *H* corresponding to the desired line is turned up and the generator revolved. This will then call the line desired. As soon as the call is made the key is then turned down and the two lines are cross connected. As there is no clearing-out drop when a conversation is finished the ring off will throw both drops, when the connecting keys are then returned to their normal position. Using the row *I*, any two lines are cross connected by turning their

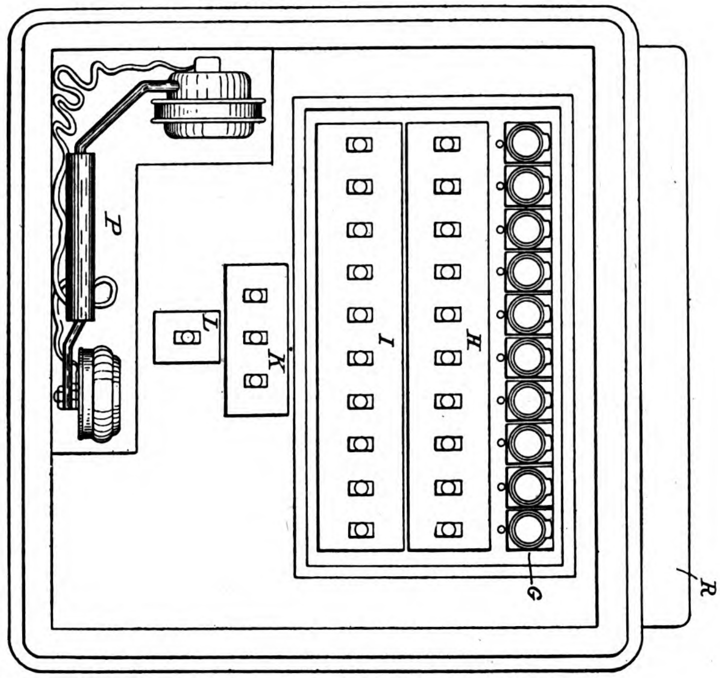
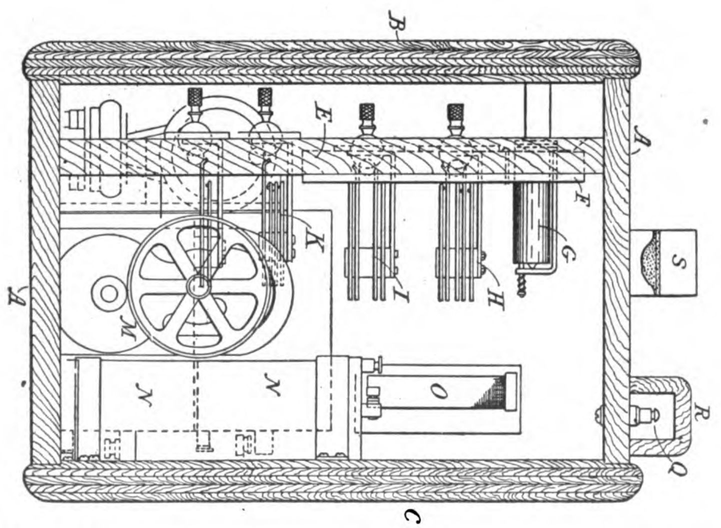


Fig. 190.



corresponding keys in the same direction, remembering that the middle listening key corresponds to the up position and the right-hand one to the down position in *I*. The combined ringing and listening key *H* is shown in section and plan in fig. 191. It consists of a frame, *m*, which is fastened to the metal plate of the row *H*; passing through this plate is the cam lever *n*, which has at its bottom the hard-rubber cylinder *o* that bears against the four long springs, *a*, *a′*, *b*, and *b′*. There are six other shorter springs, *c*, *c′*, *d*, *d′*, *e*, and *e′*, that are fastened together and to the frame by screws, but insulated from each other and the frame by hard-rubber blocks. The springs *a* and *a′* have riveted platinum contacts on their lower

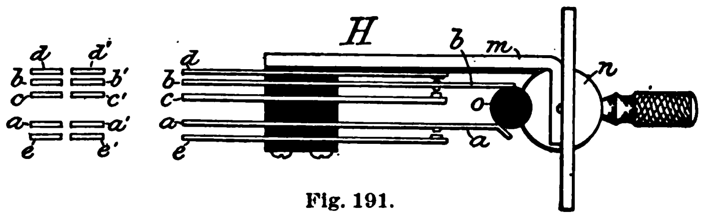


Fig. 191.

sides, while the springs *b* and *b′* have riveted platinum contacts on both sides. The springs *c* and *c′* have platinum contacts on their upper sides, and when the key is in the normal or horizontal position the contacts on *b* and *b′* touch those on *c* and *c′*; *d*, *d′*, *e*, and *e′*, also have platinum contacts which are open when the lever is in its normal position. The spring *a* is permanently connected to *b* and

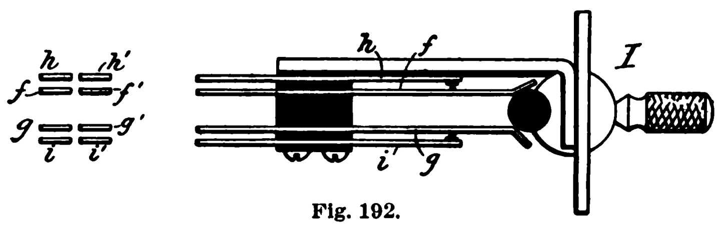


Fig. 192.

a′ to *b′*. The line leads are connected to *a* and *a′*, and the magneto bridged across *e e′*. All the springs *d* are bridged together, as are also the springs *d′*, making the first cross-connecting row. A cross-

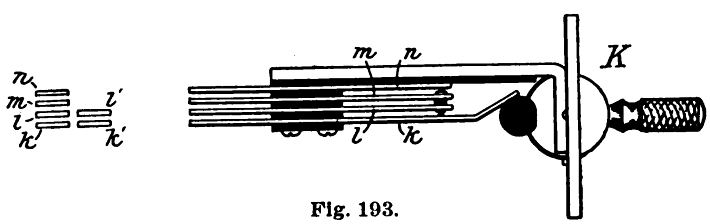


Fig. 193.

connecting key of the row *I* is shown in plan and section in fig. 192, and is of the same general type as the key above described, with the exception that it has eight instead of ten springs. These springs are supplied with platinum contacts that are all normally open. The springs *c* of each key in fig. 191 are connected to both *f* and *g* of fig. 192 and *c′* with *f′* and *g′*. The springs *h* are bridged together, as are *h′*, *i*, and *i′*, the line *h h′* making the second cross-connecting row and *i* and *i′* the third cross-connecting row. The construction of the listening key K is plainly indicated in fig. 193. The first cross-connecting strip is connected with the springs k and k' of the left-hand listening key; the second cross connecting row to similar springs of the middle-listening key, and

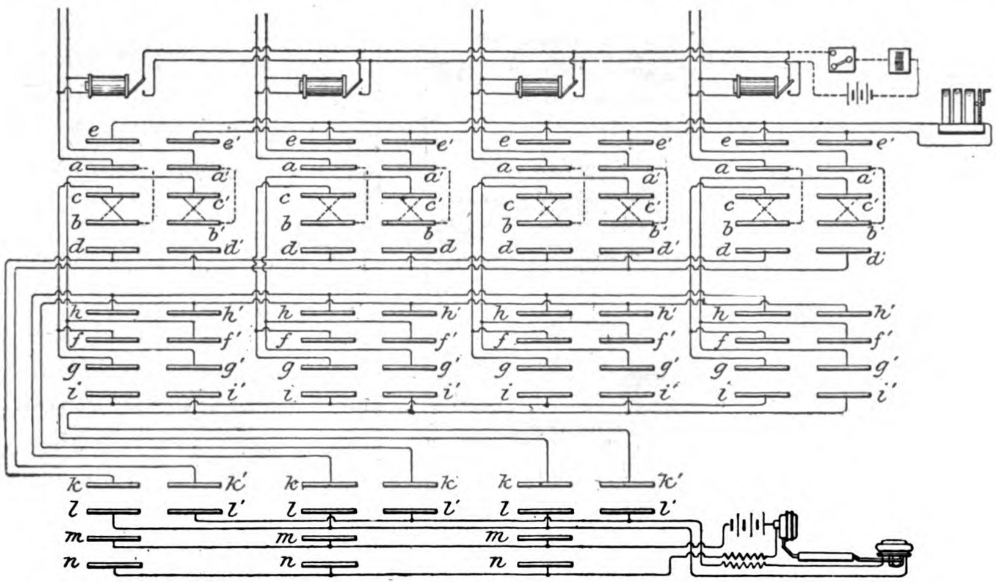


Fig. 194.

the third cross-connecting row to the corresponding springs in the right-hand listening key. The receiver circuit is bridged across the springs l and l', and the battery circuit across the springs m and n.

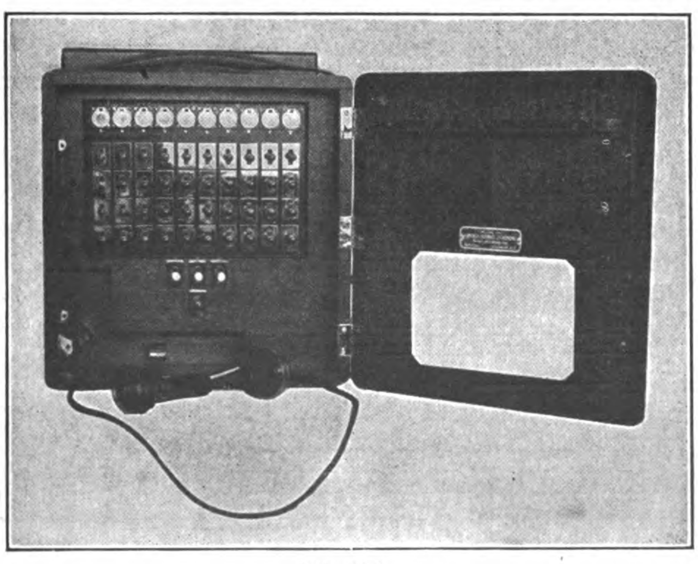


Fig. 195.

When the lever of the listening key is in the normal position all the contacts are open. The wiring of the board is shown in plan in fig. 194, where the keys for four lines are shown.

1901 model.—The 1901 model is shown in fig. 195, and is of the same general construction as the one above described, the difference consisting in the rows of ringing and cross-connecting keys. There are four

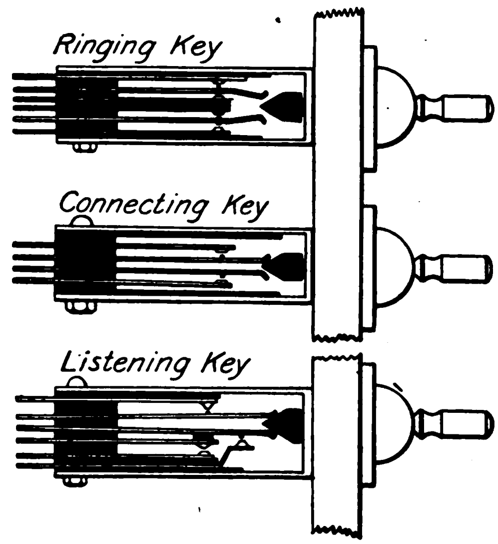


Fig. 196.

rows of keys, the upper row being the ringing keys and the other three rows cross-connecting keys. The method of operation of the board is similar to that of the 1902 model, the only difference being in the

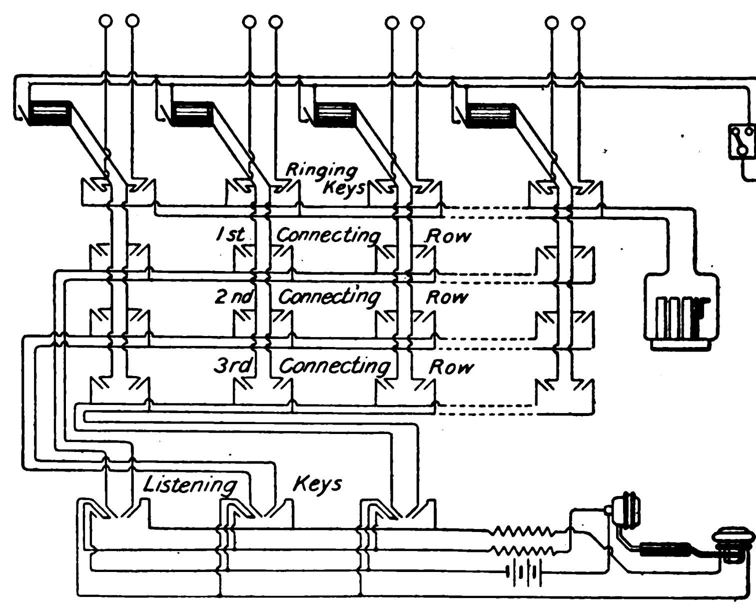


Fig. 197.

fact that the first row of keys in the 1902 model corresponds to the two upper rows in the 1901 model, and the second row in the 1902 model to the third and fourth rows in the 1901 model. The keys of the 1901 model are different in construction, and sections of a ringing, cross-connecting, and listening key are shown in fig. 196, while the circuits are indicated in fig. 197.

PROTECTIVE APPARATUS.

The arresters described in Chapter III are used in connection with telephone instruments, and may also be installed in connection with switchboard apparatus.

Where the lines protected are liable to cross with power wires, however, additional apparatus is necessary, and the combination of heat coil and carbon-plate arrester shown in fig. 198 should be pro-

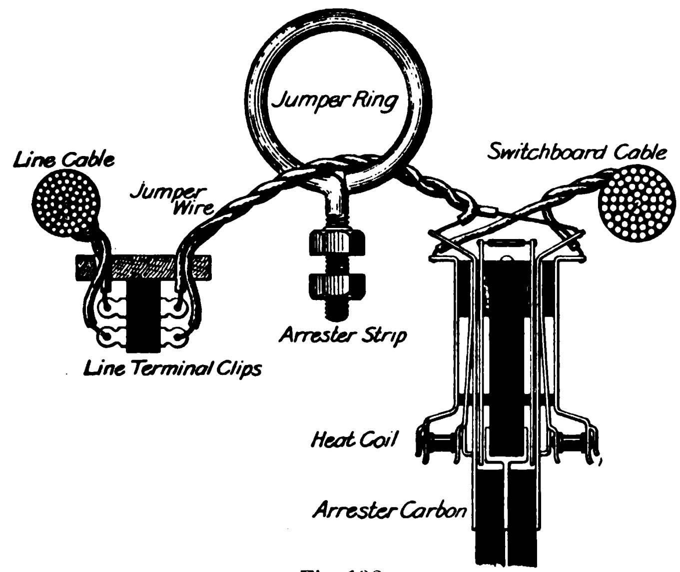


Fig. 198.

vided. This apparatus provides a lightning arrester consisting of two carbon plates which are separated from the ground by a mica disk having a small hole in its center, across which the discharge may jump, and a sneak current arrester which, while not of sufficient magnitude to blow a fuse, would damage the switchboard signals by "heat coils." The heat coil depends for its action on a low melting soldered connection, which, when fused, causes the coil to ground the line, diverting the dangerous current from the switchboard.

If none of the lines are exposed to power or lightning circuits, the Mason arrester, described in Chapter III, is sufficient protection. The Mason arrester is supplied with the portable switchboard.

The common battery feeds to each cord circuit are fused in order to prevent trouble on any line from affecting the main battery. It is unnecessary to fuse the individual lines, since each circuit is poled and all feed through the very considerable resistance of the line signal. In addition to this, a resistance is ordinarily wired in the feed from the battery to the line signals, in order to furnish protection to the battery.

REPEATING COILS.

Repeating coils are provided for the purpose of connecting dissimilar telephone lines. In signal corps work no circuits are used which require a repeating coil as a unit part. These coils are used commercially, however, in connection with regular common battery switchboard operation. This description applies only to the application of repeating coils to the connection of grounded and metallic lines.

The standard repeating coils of the Signal Corps are of two general

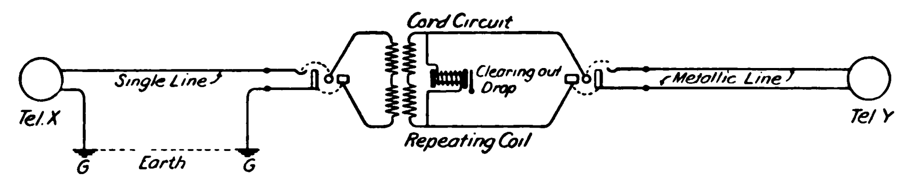


Fig. 198*a*.

types, designed for talking currents only, or for both ringing and talking.

If it is necessary that the coil give maximum efficiency in a talking circuit, as, for example, over a long line, it is designed with a small amount of iron and a small winding, approaching in its characteristics the standard induction coil. A coil so designed is suitable for talking currents only, and should be installed in a cord circuit as indicated in fig. 198*a*.

If it is impracticable to install the coil in cord circuit, it is necessary that it be designed providing a considerable amount of iron and

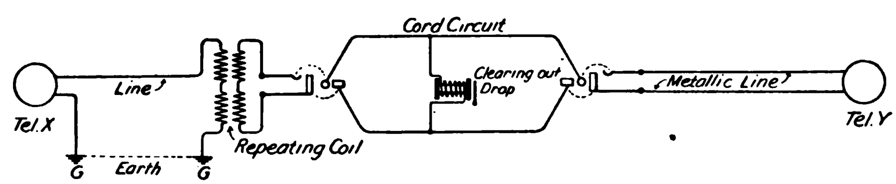


Fig. 198*b*.

approximating transformer construction as regards winding. The ringing current, which has a frequency seldom exceeding 16 per second, will be transmitted efficiently only through such a coil and voice currents with a frequency of 1,500 per second, will necessarily be much less efficiently transmitted. Coils for both ringing and talking are a compromise in design between these opposing requirements.

Fig. 198*b* shows a "ringing and talking" coil permanently wired in circuits.

In determining upon the type of repeating coil to be used, it is important that all the conditions of operation be taken into consideration, and the class of coil desired should be clearly specified.

Chapter XVII.

INSTALLATION OF POST TELEPHONE SYSTEMS.

COMMON BATTERY SWITCHBOARD.

The switchboard should be located in a well-lighted, dry room. It should be set a sufficient distance from the wall to enable a repair man to remove the rear panel and make any necessary repairs to the drop mechanism and wiring from the rear of the board.

The terminal cabinet should be located near the board, in full view of the operator when seated at the switchboard.

The batteries should be located in a dry place and installed on a well-insulated rack which provides easy access for repairs or renewals. The battery leads will in all cases be carried direct to the terminal cabinet.

The office ground should consist of a sheet of copper buried in moist earth, having a large copper wire soldered to it, run in as straight a line as possible to the lightning-arrester bar. Should it be impracticable to bury the ground plate in moist earth, connections should be made to a water pipe, as follows:

First, clean the pipe with a file; second, wrap the ground wire at least fifteen times tightly around the pipe; third, cover the wire wrapping with tinfoil; fourth, cover the tinfoil with tape.

It is impracticable to solder a joint of this character if the pipe contains water.

The cables from the terminal cabinet should be carried to the switchboard through an opening in the floor.

The incoming lines should invariably enter the cabinet in cables, as shown in fig. 199. The switchboard will be provided in each case with sufficient cable for its connection to the terminal cabinet without additional wiring. The battery will be connected with the terminal cabinet by a No. 8 B. & S. rubber-covered wire, which should be protected by a circular loom conduit and porcelain tubing at all exposed points in its run. This wire should be installed on standard porcelain knobs.

The terminal box will be supplied with a heat-coil or approved arrester equipment and will be furnished wired, requiring only the connections between the battery and its terminals and the cabling between the switchboard and the terminal cabinet. In wiring

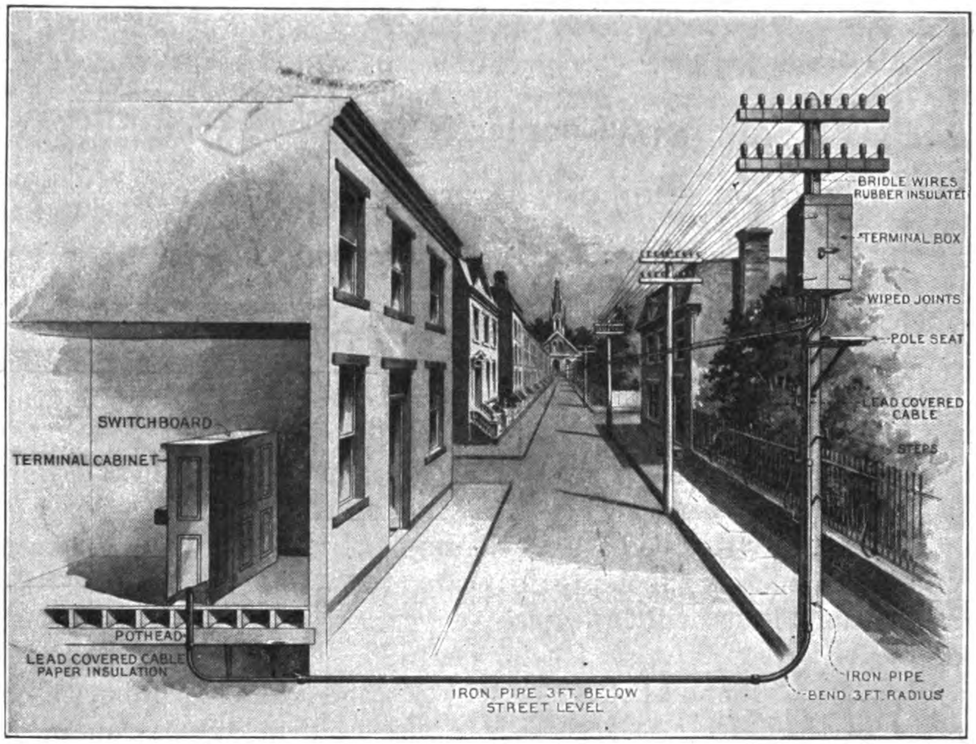


Fig. 199.

through the floors, porcelain tubes of ample size should be made use of, and great care should be taken in all the cabling that no damage may result to the installation from carelessness on the part of the occupants of the building in which the board is installed.

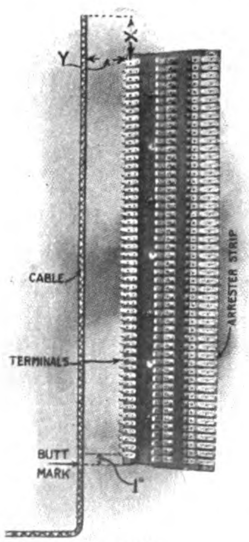


Fig. 200.

Where cable forms are required, and particularly at the ends of the cable which is to be used to connect the line wires to the arrester strips, cable forms should be made up as follows:

After the cable is laid in its permanent position its free ends shall be laid parallel to terminals to which it is to be attached. The end of the cable should extend a distance *X* (fig. 200) beyond the top clip of the strip. At the bottom of the strip a butt mark should be made about an inch below the lowermost clip, to which this cable is to be attached.

The outer covering of the cable should then be removed from the butt mark so as to expose the twisted pairs. This is accomplished by the use of a sharp knife, being careful not to cut the insulation of the wires. As shown in fig. 201, the knife should be held in a slanting direction to the cross section of the cable in this operation. In cutting the cable around the butt mark, so as to leave a clean end, care should be taken not to cut the insulation or damage the wires. All binding strips should be removed from the cable with the sheath.

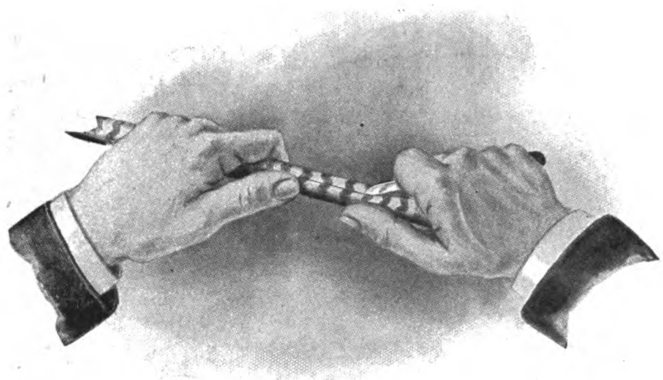


Fig. 201.

A strip of tape one-fourth of an inch in width should now be bound tightly around the exposed edges of the cable covering. The operation of binding the cable at this point is known as "butting," and should proceed as shown in fig. 202. The tape is first looped, and then its long end is wound around the cable four or five times and threaded through the loop which was first formed. The end *A* is then drawn under the turns by pulling the end *B* and closing the loop. Next

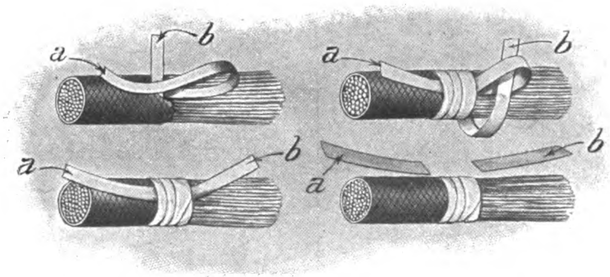


Fig. 202.

the loose ends are cut away and a coating of shellac is applied, completing the butt. The exposed twisted pairs of the standard switchboard cable should now be put in boiling paraffin or yellow beeswax up to the butt until all the bubbles disappear from the liquid. The purpose of this wax is to expel all moisture and improve the insulation of the wires, and also to prevent the braid loosening up while the form is being completed. All surplus wax should be gently beaten with a stick from the cable when it is removed from the boiling paraffin.

A soft-wood board should now be marked as shown in fig. 203. The lines *EF* and *SL* should have a separation equal to the distance the cable has to be located from the clips when strapped in place, and the lines *SL* and *GH* should have a separation of about 1 inch. The

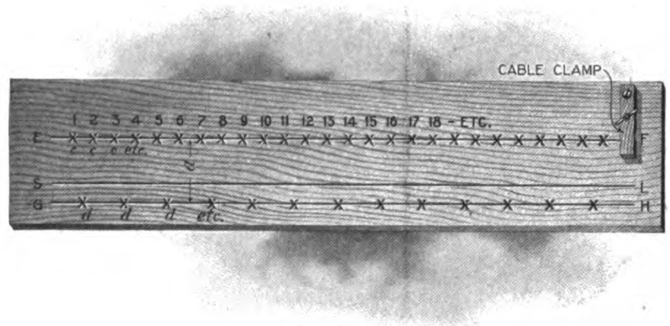


Fig. 203.

points *CCC*, etc., along the line *EF*, are placed to conform to every other terminal clip, so that when a pair of wires is brought out at each of these points they will be exactly opposite a pair of clips when the cable is installed. Wire nails are driven in at this point and at points *DDD* on the line *GH*. The board thus arranged is called a temporary form, from which the prepared end of the cable is to be fanned out.

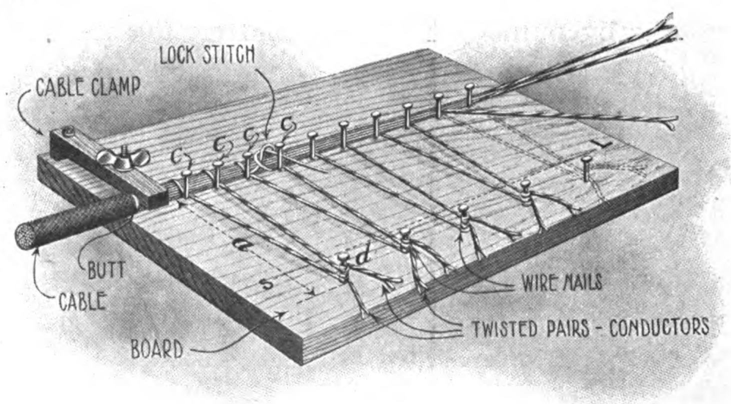


Fig. 204.

The cable is now clamped at the butt to the board, as shown in fig. 204, and each pair of wires is selected in numerical order, according to the color code, dyed in the insulation of the conductor, and drawn into place and fastened around each successive nail. A spare pair of wires is left projecting at the end of the cable, so that it may be used in case any one of the regular pairs becomes defective. The formed part of the cable is sewed up with a stout waxed linen twine by the aid of a 4-inch packer's needle, which facilitates the passing of the twine under the bunches of wire.

This needle, with the method of threading it, is shown in fig. 205. Before sewing up three turns of twine should be taken next to the butt, drawn up taut, and tied with the knot shown in fig. 205, in

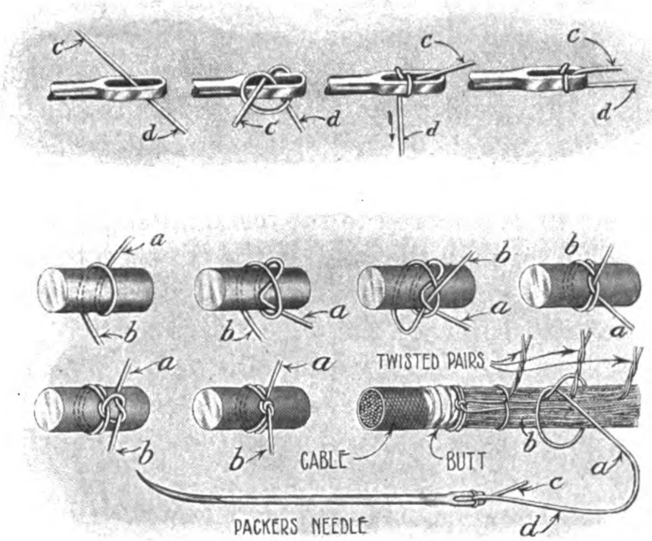


Fig. 205.

which a is the needle end of the twine and b the short end. All line wires are bound together from this point to the end of the twine with what is called a lock stitch, shown in fig. 205.

A stitch is taken at each nail, and if the space between is over 1 inch an extra stitch should be taken. In making the stitch the

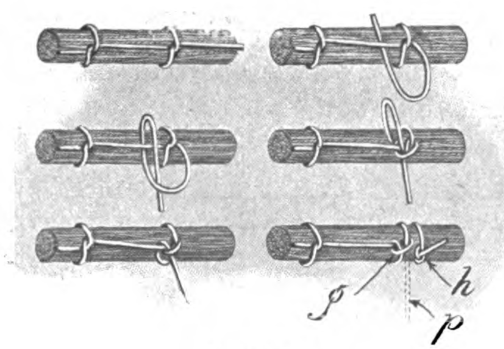


Fig. 206.

needle is passed under the wires and through a loop, as shown in figure, being careful not to include in the loop the stitched part. The loop should hold without fastening after the string is removed from the needle end of the cord. The last stitch is reenforced by a knot, g, fig. 206, after which it is preferable to take another stitch and knot *h* around the spare wires and the other side of the last regular pair.

Before taking the cable from the forming board the ends of the nails should be cut off even with the wires and the insulation removed from the ends of each, using the line *SL* as a guide.

The skinning should be done with a sharp knife, drawing it from the line *SL* toward the end of the wire, at the same time pulling off the covering, which will slip off as soon as the threads are severed. Great care must be taken not to nick the wire, as it would then be liable to break at this point upon being moved or handled.

The tips should now be shellacked lightly and allowed to dry. This prevents unraveling of insulation when soldering.

If the wires are to be soldered to the terminal clips, their bare ends should be threaded, through the holes in the clips, up to the insulation and bent back. If no holes are provided, they should be wound close around the notched portion of the clip. Care must be taken to get the insulation out of the notch in the clip or the hole. Only resin solder should be used in making soldered joints. After soldering the free end of the wire should be cut off close to the clip and each joint tested.

The cable should now be strapped in place with leather saddles. When the forms are installed they may be finished with a coat of white shellac, which keeps the dust and dirt from sticking to the wires which have been boiled.

A standard signal corps switchboard cable is provided in two sizes, containing, respectively, 20 twisted pairs with 1 spare pair and 1 odd wire, and 40 twisted pairs with 2 spare pairs and 1 odd wire.

In connecting this cable the following arrangement of colors should always be adhered to. Under no conditions should any other sequence of colors be followed, as this arrangement is standard and is a very important guide to the operator in maintaining this system. The code is as follows:

For the 20-pair:

First pair	Blue.	White.
Second pair	Orange.	White.
Third pair	Green.	White.
Fourth pair	Brown.	White.
Fifth pair	Slate.	White.
Sixth pair	Blue-white.	White.
Seventh pair	Blue-orange.	White.
Eighth pair	Blue-green.	White.
Ninth pair	Blue-brown.	White.
Tenth pair	Blue-slate.	White.
Eleventh pair	Orange-white.	White.
Twelfth pair	Orange-green.	White.
Thirteenth pair	Orange-brown.	White.

For the 20-pair—Continued.		
Fourteenth pair	Orange-slate.	White.
Fifteenth pair	Green-white.	White.
Sixteenth pair	Green-brown.	White.
Seventeenth pair	Green-slate.	White.
Eighteenth pair	Brown-white.	White.
Nineteenth pair	Brown-slate.	White.
Twentieth pair	Slate-white.	White.
For the 40-pair:		
Twenty-first pair	Blue.	Red-white.
Twenty-second pair	Orange.	Red-white.
Twenty-third pair	Green.	Red-white.
Twenty-fourth pair	Brown.	Red-white.
Twenty-fifth pair	Slate.	Red-white.
Twenty-sixth pair	Blue-white.	Red-white.
Twenty-seventh pair	Blue-orange.	Red-white.
Twenty-eighth pair	Blue-green.	Red-white.
Twenty-ninth pair	Blue-brown.	Red-white.
Thirtieth pair	Blue-slate.	Red-white.
Thirty-first pair	Orange-white.	Red-white.
Thirty-second pair	Orange-green.	Red-white.
Thirty-third pair	Orange-brown.	Red-white.
Thirty-fourth pair	Orange-slate.	Red-white.
Thirty-fifth pair	Green-white.	Red-white.
Thirty-sixth pair	Green-brown.	Red-white.
Thirty-seventh pair	Green-slate.	Red-white.
Thirty-eighth pair	Brown-white.	Red-white.
Thirty-ninth pair	Brown-slate.	Red-white.
Fortieth pair	Slate-white.	Red-white.

The switchboard will be supplied with one or more spare jacks and drops. One of these jacks should be used for the purpose of testing cords. The line signals should be disconnected from one of the spare jacks and a cell of dry battery should be soldered across the line terminals. When a plug is installed in this jack and the cord is shaken, a cut-out will be detected by a rasping noise in the receiver of the operator.

The generator call drops should be adjusted so as to fall readily on about five cells of dry battery.

When the switchboard is completely installed, and before it is cut over to the working lines, care should be taken to test for cross talk and erroneous connections in the circuit from the heat-coil terminals to the line jacks. Under no conditions should the switchboard be put into commission when any cross talk is noticeable. It will be found sometimes that the key contact fails to break on the operator's listening circuit and thus cross the lines with the other keys. Dampness in the switchboard may also cause trouble of this kind.

All power connections should be poled alike.

THE BATTERY.

The battery should be installed on a substantial rack, so located that it will not be liable to trouble from dampness.

If a storage battery is provided it should have a vent not smaller than 3 inches in diameter leading out of doors, ample provision being made for draft. Unless this draft is provided, the ventilator will not perform the function for which it was intended. This vent will preferably be of lead, but, if it is necessary to use galvanized iron, care should be taken to install in such position with reference to the battery that particles of the metal may not fall into the cells. This pipe should be thoroughly covered with insulating paint, both inside and outside, before it is installed.

An open storage battery should never be installed in the same room with the switchboard or other electrical apparatus. It should always be covered, and provided with the ventilator above described, which connects it with the outer air. Glass or hard-rubber covers to the cells greatly mitigate troubles from fumes.

A panel will be provided in all cases in connection with the terminal cabinet on which the cord circuits are fused, protecting the main battery in case of trouble on any cord circuit.

The standard batteries provided may be one of the following:

15 cells P. T. type chloride accumulator.
16 cells improved Fuller.
20 cells No. 8 dry battery.

The former battery will be provided with a bank of lamps and charging switch, and the last two will be equipped with a 10-microfarad condenser across their terminals.

All types of battery will be provided with cord and main-circuit fuses.

Connections between the battery and terminal cabinet should be as indicated under "Switchboard."

PROTECTORS.

The terminal cabinet will usually be supplied with a standard heat-coil protector, as shown in fig. 198. This protector grounds the line in case high-tension current gets upon it or in case a foreign current flows continuously through it in sufficient strength to damage the switchboard apparatus. This protector operates in connection with fuses in the terminal shown in fig. 199. No line fuses are provided in the terminal cabinet, but an extra supply of heat coils and carbon blocks forms a part of the terminal equipment. The cable forms for the terminal cabinets shall be made up as described under "Switchboard."

INSTALLATION OF POST TELEPHONE SWITCHBOARD.

The same general remarks apply to the installation of the post telephone switchboard of 15 lines as to the common-battery type of a larger number of lines.

In this type of switchboard the terminal cabinet containing the main arresters is mounted on the wall of the room back of the switchboard and cabled directly to connecting panel in the rear portion of the switchboard cabinet, and cross connects directly by short lengths of inside twisted pair to the wires running from panel to jacks.

The cross-connecting panel is designed to allow a rearrangement of lines to the various line jacks so that the lines shall always have the same number.

The wires for the local battery for transmitter and night bell are run direct from marked posts to batteries using ordinary rubber-covered, inside twisted pair.

THE LINE.

The installation of the line will, in general, conform to Chapter —. The terminal pole will contain a full set of fuses for wires entering the terminal cabinet and should conform to fig. 199. As shown in fig. 199, the cable will be led down this pole through an iron pipe or duct up to the cabinet, being formed into a pot head, and connected as shown in fig. 199.

Care should be taken that the terminal pole is amply guyed and that the line throughout is free from defective insulators, brackets, or knobs. The leading-in wires to the telephone instruments will usually be standard outside twisted pair.

THE INSTRUMENT.

The wires leading into the instrument should enter the building through holes sloping upward from without and separated at least 3 inches. These holes should be provided with fireproof bushing as long as the thickness of the wall. Each wire shall be provided with a drip loop.

If the instrument is connected to an open wire line a Mason lightning arrester with fuses (see Chapter III) should be installed. The fuse end of the lightning arrester should be connected to the line wires. The ground wire should be run with the same care as the ground wire for the switchboard, but a No. 12 or No. 14 rubber-covered wire may be substituted for the larger wire used in switchboard installation. A ground rod may be used if necessary.

Care should be taken, in locating the arrester, that it be not dangerously near inflammable materials, as more or less of an arc will be formed by its operation. The arrester should be mounted on a piece of asbestos if the wall to which it is fastened is inflammable, and should be located as near as possible to the point of entrance of the leading-in wires.

The instrument should be located against a dry wall, or, lacking this, on a shellacked backboard at a height adapted to its environment. The wires from the instrument to the arrester should in all cases be standard inside twisted pair, rubber-covered, and should be secured to the wall with a single groove porcelain insulator. Under special conditions it may be practicable to install this wire with leather loops, but under no conditions should a bare, double-pointed tack be used.

In crossing metal work, porcelain tubes or circular-loom conduit shall be used. Pipes which are liable to dampness should be crossed on the upper side.

Splices should be avoided, but where they are necessary the joint shall be made mechanically secure before soldering and insulated with rubber tape and friction tape.

As soon as the instrument is installed and the board put in commission, a careful inspection should be made of all the parts, signals being interchanged with the switchboard. Everything should be left clean, contacts should be positive throughout, and the bells in perfect adjustment.

Should a transmitter or receiver prove defective, requisition should be made immediately for a new transmitter or receiver, and the damaged instrument should be returned to the supply depot.

Chapter XVIII.

ELIMINATION OF TROUBLE IN TELEPHONES AND SWITCHBOARDS.

LOCATING FAULTS.

Experience is the best guide in discovering faults or locating troubles in telephone instruments or in switchboards, and consequently general suggestions only are given. A thorough understanding of the wiring of the telephones and switchboards issued is presupposed. The inspector should be supplied with a key for the magneto box, a small screw-driver, a pair of pliers, an extra receiver, a couple of cells of dry battery, a piece of chamois skin, some crocus cloth, and two testing cords, which can be conveniently made by soldering spring clips to the ends of a piece of insulated wire of suitable length. The ordinary spring clips in a sleeve supporter or garter will serve and can be obtained anywhere.

It is supposed that the line has been tested and trouble has been located either in an instrument or in a switchboard, and the suggestions given are divided into two classes—those for locating faults in the telephone instruments and those which refer to the switchboard.

The connections in any telephone must be made with the greatest care, and should be so arranged that there is no possibility of any of the wires coming into accidental contact. No acid should be used in soldering any of the joints. Where it is necessary to make connections under the head of a screw that passes through the box, such an arrangement must be made as to prevent the loosening of the connection by the shrinkage of the wood. Wherever practicable all connections must be soldered, otherwise spring washers can be supplied. Cleanliness of all parts of the instrument is absolutely necessary for the successful working of the telephone, and whenever an instrument is inspected it should be cleaned up. Loose connections, breaks in the receiver cord, and defective battery are the principal sources of trouble in the instrument and can be readily discovered. The continuity of any circuit can be ascertained by the use of the extra receiver and testing cords by joining the suspected circuit in series with the receiver and battery. If on opening or closing the circuit a click is heard in the testing receiver, the circuit is probably continuous, unless a cut-out, as it is called, exists. A cut-out usually occurs in a cord, and is due to the fact that the ends of the broken conductor touch each other and sometimes are separated. It can be discovered by closing the test circuit and shaking the cord. If a succession of clicks is heard in the instrument, it is to be inferred at once that it is due to the ends of the broken conductor touching each other and falling apart.

TELEPHONE.

The usual faults in an instrument are developed under the following conditions: First, the station can not ring; second, the station can ring, but speech can not be heard in either direction; third, the station can hear, but can not be heard.

In the first case the fault is in the call box or on the line; in the second case the speaking circuit is either short-circuited or open-circuited; in the third case the fault is in the primary circuit of the transmitter, and may be due to the battery, bad contact in the hook switch, a break or short circuit in the primary or a short circuit in the secondary coil, or else to a broken transmitter. When the station can not ring, first disconnect the instrument from the line and short-circuit the line posts by a piece of wire. If the instrument is of the series type the bell should ring, and if of the parallel type the bell should not ring and the handle turn with difficulty. If this occurs the fault is not in the magneto itself, but must exist on the line. If in the magneto, look first to see whether the joint connecting the two magnet coils of the bells is not loose, or whether the soldered joint at the hook switch is tight. These two joints are always soldered with rosin. If the joint is improperly made the wires frequently become loose. Test all parts of the circuit for continuity, and see that the automatic shunt is in proper condition. Inspect the pivots and armature of the bell, and see that the armature is at a proper distance from the cores. It is better to adjust the bell by getting the armature at the proper distance from the cores rather than to change the relative position of the bells on their base. The coiled spring in the shaft of the Western Electric type of magneto is sometimes found broken, and the short circuit is not removed from the armature when the handle is turned.

If the speech can not be heard in either direction, first test the receiver cords for continuity, and then see if the secondary coil is open. If the distant station can hear you, but you can not hear it, the receiver is probably out of adjustment. The adjustment of the receiver can be easily tested by unscrewing the ear piece and then holding the receiver in one hand and tapping it against the other lightly. The diaphragm should slide partially off. If it does not start it is either buckled or else too near the magnets. If it falls off it is too far away from the magnets. The receivers are always adjusted before issuing to the service, and their adjustment should not be altered until the inspector is satisfied that the trouble is entirely due to the adjustment of the receiver. In screwing up the ear piece on the body of the receiver care should be taken that it is not screwed home too violently, as it will sometimes force the diaphragm down against the magnets, or jam it so that it will lose its natural elasticity. In case speech is heard from the distant station, but it reports that it can not hear the home station, the trouble is in the primary side of the talking circuit. The battery should be examined first, and, as a general rule, whenever trouble develops in the talking circuit, examine the battery before making any other test. If the battery is in good working condition, examine the back contacts of the hook arm, and see that they close when the switch is up; then test the continuity of the primary coil; then examine the transmitter.

A vast amount of annoyance will be saved by frequent and careful examination of all screw connections, as there is a constant tendency for them to work loose, even if fastened by lock nuts. As a very large proportion of trouble is caused by loose connections it is always safe to first examine all connections before looking elsewhere for the trouble. A bad ground is likewise the frequent cause of a weak ringing of the bells or faint talking. The ground plate must be in contact with damp earth; it is not sufficient to put the ground plate a few feet under the surface of the earth where in summer the ground dries out and in winter the earth freezes around and below it. Where both gas and water pipes can be reached the ground wire must be secured to the water pipe. If none is available a gas pipe can be used, and the wire connected with the service pipe, outside the meter, otherwise when the meter is removed for repairs or other causes the line will be opened. The telephone must not be grounded on the same conductor that serves for a telegraph ground.

SUMMARY OF FAULTS.

(*a*) Station can not ring:

Broken wire in box; the ground wire open; the coiled spring on driving shaft broken. If the handle of the magneto turns with difficulty and the bell does not ring, on a bridging line, a short circuit exists in the line connections of the instrument. Disconnecting one of the line wires will determine whether this fault is on the line or in the instrument.

(*b*) Station rings distant station, but its own bell remains silent:

Bad connections in box, or bells out of adjustment.

(*c*) Station rings other bells strongly, but its own bells weak:
The ringer magnet is weak, or bells out of adjustment.

(*d*) Station rings other bells feebly, but receives incoming ring strong:
Magneto weak, bad connections in magneto, or armature partially short-circuited.

(*e*) Station rings and receives ring, but can not talk:
Receiver cord broken, bad connections in box, lever arm does not close, poor battery, open circuit in transmitter or induction coil, bad connections in transmitter arm or small retaining diaphragm of transmitter broken and carbon lost.

(*f*) Station rings frequently without apparent cause:
Swinging cross with telegraph or other exterior lines.

(*g*) Receiver weak:
Coil partially short-circuited, poor connections, diaphragm bent or dirty. (Diaphragm should be 0.015 inches from the ends of the pole pieces.)

(*h*) Home station can hear, but can not talk:
Transmitter circuit open or else short-circuited, or batteries run down.

(*i*) Home station receives speech strong, but its own talk is weak:
Transmitter packed, damping springs clamp diaphragm too tightly, or batteries run down.

(*j*) Speech at distant station is indistinct, a scratching or grating noise:
Loose connections, or battery too strong.

When the inspector is satisfied that the battery is strong, a quick test, which will disclose whether the trouble is on the line or in the instrument, can be made as follows: Disconnect the instrument from the line and short-circuit its terminals; place the ear piece of the receiver in the mouthpiece of the transmitter, and if a singing note is heard the talking circuits are clear. If the magneto rings in the case of a series instrument, or in the case of a bridged instrument when the short circuit is removed, the ringing circuit is clear and the trouble, if any, must exist in the line.

SWITCHBOARD.

In cord switchboards if the drop does not fall, test first for continuity of circuit and then see if the pivots are loose. If the pivots are loose the armature will frequently stick and fail to release the shutter. With a grounded board too great care can not be paid to the ground connections. If, when a ring comes in, more than one drop falls, it may be due to a cross in the lines outside of the board, or else on the lightning strip to which these lines are connected; or in case of a common return a branch of the return may be open. This can be readily cleared by inspection. In case of clearing-out drops the trouble may be due to the fact that the contacts on the magneto side of some one of the ringing keys are not broken when the key is in a normal position.

When it is discovered that a pair of cords do not perform their proper function they should be tested for an open or for a cut-out. Cross talk between circuits may be due to the fact that the listening keys do not break the contacts, or else to a cross on the lightning strip, caused by allowing ends of wire to project over and touch adjacent circuits. Whenever cross talk develops the operator of the switch board should notice the pair, or pairs, of cords in which this occurs, and the cause will probably be found due to the fact that the contacts of the listening key do not break when it is opened.

A frequent cause of trouble in the jacks is due to the fact that persons will stick pens or pins in them and break off the points, short-circuiting the springs. The only way to discover this is by thorough inspection of the jacks. To see whether the contacts in the ringing and listening keys break in the proper manner, the part of the board containing them should be placed between the light and the eye of the inspector. By looking at the keys against the light and opening and closing them, it will be discovered whether the contacts break properly or not. Trouble may very frequently be removed from the cord circuit by cleaning the tip and sleeve of the plug with crocus cloth. When a switchboard is new and first placed in service very frequently particles of metal are found in the jacks, and the board can be cleaned by using a hand bellows and blowing out all of the jacks thoroughly. It may sometimes happen that the screws holding the insulating blocks in the ringing and listening keys project far enough to short-circuit the adjacent springs.

The accepted method of cleaning key contacts, or mechanically testing for opens, is by putting a strip of paper between contacts when keys are open, closing the keys, and withdrawing it. If the key does not make firm contact of course the paper will be easily withdrawn. If it does, withdrawing the paper will clean off any dirt that may be on the contact. This trouble can be removed by adjusting the key.

The location of trouble in cordless boards is more difficult, as each part of the various circuits will probably have to be tested out in succession before the trouble is located.

BATTERY.

Cracked cells, allowing the solution to run out; loose, dirty, or corroded terminals; loose connections on zinc and carbon; zinc rod used up or solution too low, are the usual defects in the battery. The jars should be kept filled between the water lines marked on the cells, the tops kept thoroughly clean and free from salts, and the solution up to its proper strength. The necessary directions for setting up the cell and preparing the battery fluid are to be found on the printed label attached to the cell.

COMMON BATTERY.

Troubles in common battery instruments do not materially differ in character, and are located in much the same way as in local battery apparatus. Omission of the magneto necessarily reduces likelihood of fault at the substation. Condensers occasionally short-circuit, causing the switchboard signal to operate, and this fault can only be detected by testing the condenser for a flow of direct current.

Line troubles are usually detected by their effect on the central battery. Common battery switchboards as furnished for signal corps work have no adjustments and are in general simpler in their operation than the local battery switchboard.

Batteries used in common battery work are described under "Primary batteries," in this manual.

Chapter XIX.

DISTURBANCES IN TELEPHONE CIRCUITS.

Almost all the disturbances in an electrically continuous telephone circuit can be attributed to one of the following causes: Defective connections, electro-magnetic induction, electrostatic induction, and leakage.

DEFECTIVE CONNECTIONS.

Defective connections produce a grating sound, frequently accompanied by a momentary loss of connection, and render the circuit noisy. Bad connections or contacts are usually the cause of trouble in a telephone line in which the difficulty is confined to one instrument alone, or in which the noise continues, all other sources of disturbance being absent.

ELECTRO-MAGNETIC INDUCTION.

Whenever a current flows in a wire it establishes a magnetic field around the wire, in which the lines of force are closed circles in planes perpendicular to the wire, as indicated in fig. 207.

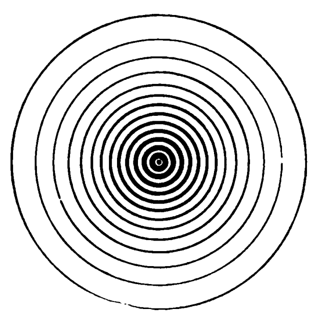


Fig. 207.

This figure gives a cross section of the wire, shaded, and the surrounding closed lines of force. The intensity of this field of force depends on the strength of the current in the wire. At any point outside of the wire it varies inversely with the distance of the point from the wire. If the current in the wire changes, the entire field of force will vary with the current. If a telephone circuit is sufficiently near a wire carrying a varying current, so that the varying magnetic field cuts acoss the telephone circuit, it will produce an induced current that causes a noise in the receiver connected to the line. The amount of electro-magnetic inductive disturbance depends upon the amount of variation and the intensity of the disturbing current, the distance that the disturbing wire parallels the telephone circuit, and the relative electrical condition of its two sides.

If a conductor carrying a varying current runs near a grounded telephone circuit, as shown in fig. 208, the field of force cutting the circuit will produce an induced current, which affects both receivers. If the conductor parallels a metallic circuit, as in fig. 209, and is equi-

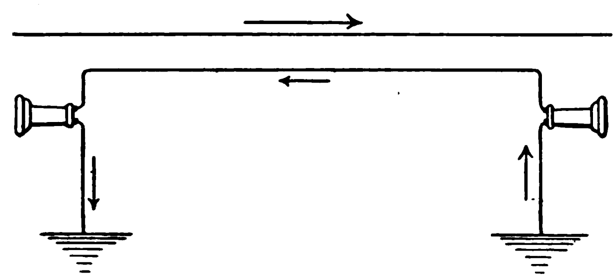


Fig. 208.

distant from both sides, the current induced in the one side will neutralize that in the other at the receivers, as the currents are of the same intensity and flow in the same direction. But if the dis-

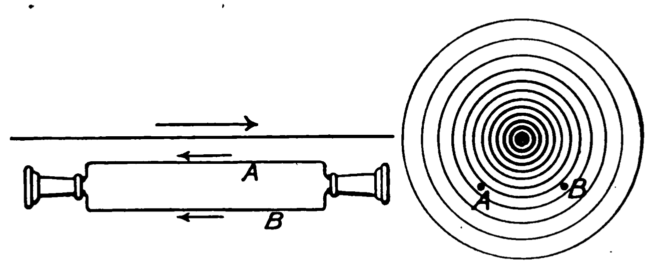


Fig. 209.

turbing wire is nearer one side, as in A, fig. 210, than the other side, B, the induced current in A will be greater than that in B, they will not neutralize each other at the receivers, and a noise will result.

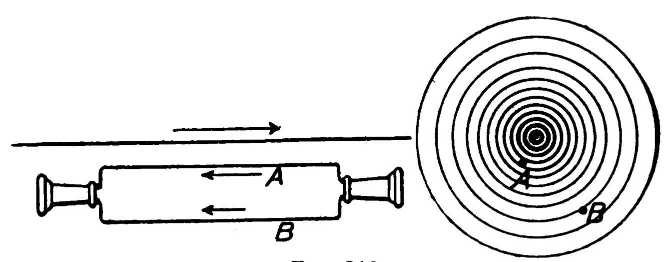


Fig. 210.

TRANSPOSITION FOR ELECTRO-MAGNETIC INDUCTION.

Should the sides of a metallic circuit be out of electrical balance, the induced current in each will not be the same and the circuit will be noisy. A complete annulment of the electro-magnetic induction will be obtained by a simple transposition in the center of the metallic circuit, as shown in fig. 211, provided the disturbing wire parallels the metallic circuit and carries the same current throughout its entire length, because A and A' are at the same average distance as B and B' from the disturbing wire.

ELECTROSTATIC INDUCTION.

Whenever a charge of electricity exists in a conductor it will induce in all conductors in its vicinity a bound static charge of opposite sign

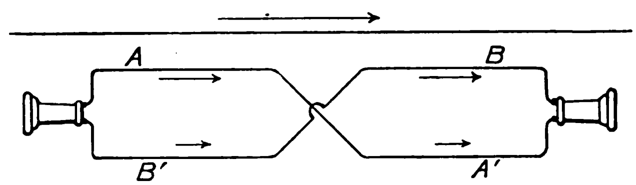


FIG. 211.

on the sides of the neighboring conductors nearest it, and a free charge of the same sign on the sides farthest away.

Suppose, as in fig. 212, the upper wire has a charge of positive electricity, it will induce a bound negative charge on the upper side of the grounded telephone wire and a free positive charge on its lower side. As this positive charge is free, it will flow from the center of the wire a in both directions through the receivers to earth. Let the charge in the upper wire now become negative and the reverse condition will occur—i. e., a positive bound charge will exist in the telephone

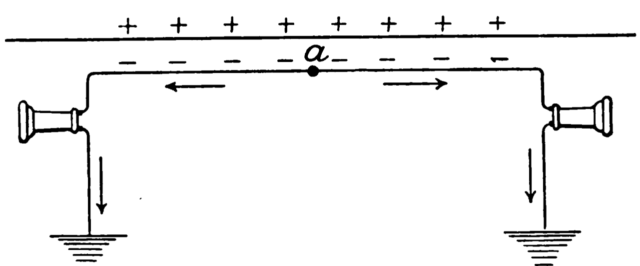


FIG. 212.

wire and a positive charge will flow from the earth through the receivers to neutralize the negative free charge on the telephone wire. If the upper wire carries a varying or alternating current the static charge will constantly change, and the induced charge on the telephone circuit will constantly vary and produce a varying flow of electricity through the receivers and render them noisy. If the upper wire carries a telephone current the conversation will be reproduced, by electrostatic induction, in the second circuit, giving the familiar "cross-talk."

If a charged wire is nearer one side of a metallic circuit than the other, as in fig. 213, the following will be the approximate condition, due to electrostatic induction when the disturbing wire is positively charged: The side A will have a negative bound charge, while the side B will have a positive one, because at first both A and B, having negative bound charges on their upper sides and positive on their lower sides, as shown in the illustration in fig. 213, the positive charge on A flows in both directions from its middle point, a, through the receivers, neutralizing the negative charge on B, the positive charge remaining there. Upon the disappearance of the charge from the

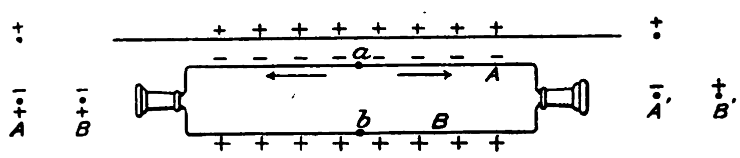


Fig. 213.

disturbing wire the positive charge on B will flow in both directions from its middle point, b, through the receivers and neutralize the negative charge on A. If the charge on the disturbing wire is negative, the reverse of the above takes place. If the charge on the disturbing wire varies, a varying inductive charge of opposite signs will exist in each side of the metallic circuit and current flows through both receivers. Neutral points exist at a and b, and if these are connected by a receiver no noise will be heard in it, although the noise continues in the receivers at each end.

TRANSPOSITION FOR ELECTROSTATIC INDUCTION.

The amount of electrostatic inductive disturbance depends upon the character of the insulation used and the capacity of the conductor, in addition to the factors mentioned under electrostatic induction.

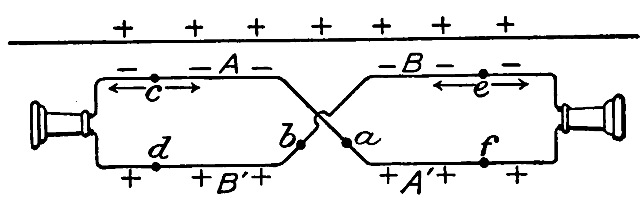
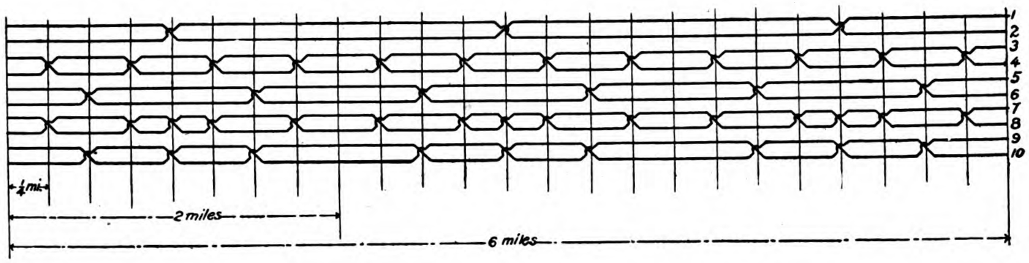


Fig. 214.

If the line be transposed once at its center, as in fig. 214, the noise in the end receivers will be reduced, but not entirely eliminated. Each half of each side is a neutral point at c, d, e, and f, the charge flowing away from c and e and toward d and f, a and b being no longer neutral. The neutral points are shifted from the center toward the ends as the impedence of the receivers causes more of the induced charge to pass through the transposition wires than through themselves. An infinite number of transpositions would theoretically be required to produce silence at the ends of the line, but practice has shown that in long transmission line transpositions at $\frac{1}{4}$ or $\frac{1}{2}$ mile are sufficient.

These transpositions must be so arranged that the circuits are always transposed against one another, thereby avoiding the danger of bringing them back into the same inductive relation as before.



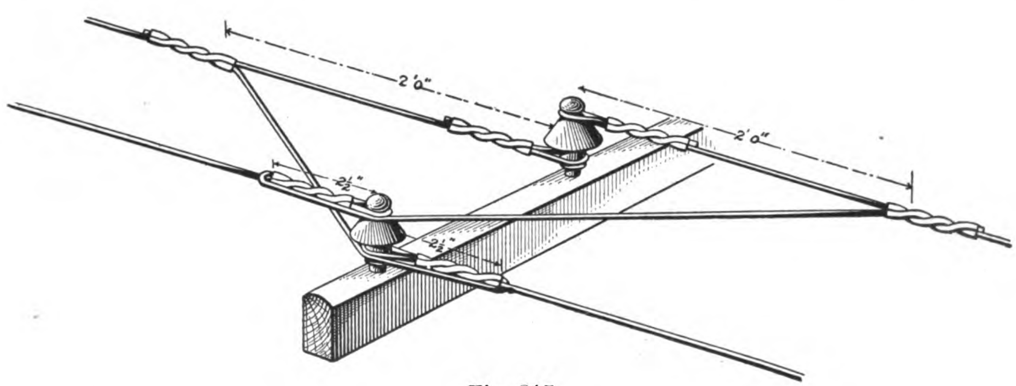


Fig. 215.

Fig. 215 shows the method of transposition adopted by the American Telegraph and Telephone Company on their long-distance lines.

COMMON RETURN.

Relief from inductive disturbance in a grounded system can be obtained by the use of a common return wire for all the circuits, one side of the instruments being connected to it and the other side to the lines through their respective line drops on the switchboard to the common return. If the lines are thoroughly insulated, the return should be insulated throughout, but if one or two of the lines have a low insulation, a ground at the central on the common return will improve the system at the expense of the badly insulated lines. Enough copper must be used in the common return to prevent the current in any one line from branching to the others, while an excess will only aggravate existing trouble. No. 8 B. & S. will prove large enough in all installations of the Signal Corps.

LEAKAGE.

If a ground occurs on one side of a metallic circuit, all the induced currents in both sides tend to leak to ground at this point and increase the noise in all the receivers on the line. If an equal leak exists on both sides of the circuit, no increased noise will result, but if the leak becomes too serious the line will be short-circuited and communication interrupted, while a leak on a grounded line reduces the volume of transmission or acts as a short circuit. Less than a millionth of an ampere of foreign variable current will create such a disturbance in the receiver as to render its operation impracticable. It is then evident that when a telephone circuit is crossed by a wire carrying a varying current, the slightest actual flow of current into the circuit will seriously interfere with conversation. The electrical condition of the ground at different localities will frequently show a marked difference of potential, and if a grounded telephone line

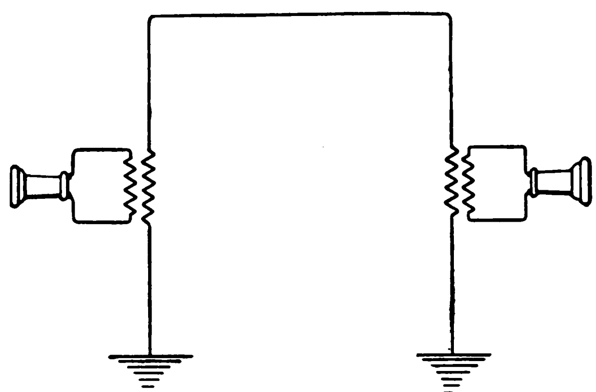


Fig. 216.

connects these two points an earth current will be completed through the line and noise will result. The slightest defect in joining or insulating such grounded lines results in serious disturbance.

ELIMINATION OF DISTURBANCES.

When a grounded line is found to be carrying earth currents the installation of a repeating coil, as shown in fig. 216, will serve as a remedy. The introduction of this apparatus will also eliminate the troubles caused by defective contacts within a telephone itself. The impedence and resistance of the repeating coils cuts down the transmission, eliminates many annoying foreign sounds, but transmits enough of the voice current to render conversation audible. When repeating coils are used it is especially necessary to have good grounds. Figs. 217 and 218 show two methods of obtaining this end. When a single-conductor submarine cable is used for telephones only, as in fig. 217, the armor wire may be used as a ground by bending out one of the strands of armor wire and sweating the ground wire to it, taping over the completed joint. An excellent ground is made by embedding a copper ground plate, to which the ground wire is soldered, as shown in fig. 218, in charcoal below the level of permanent moisture. Merely inserting the ground plate in a running stream of pure water will seldom give a serviceable ground.

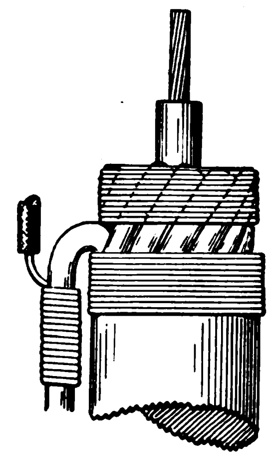


Fig. 217.

Whenever a grounded circuit is paralleled by a power wire for a short distance, repeating coils and a metallic circuit, installed as shown in fig. 219, will greatly reduce the disturbing effect, especially if the metallic circuit be properly transposed. If the disturbing wire parallels the circuit for a considerable distance the only remedy is to replace it by a metallic one.

A ground line and a metallic circuit may be safely carried on the iron poles of the Signal Corps by using a single insulator at

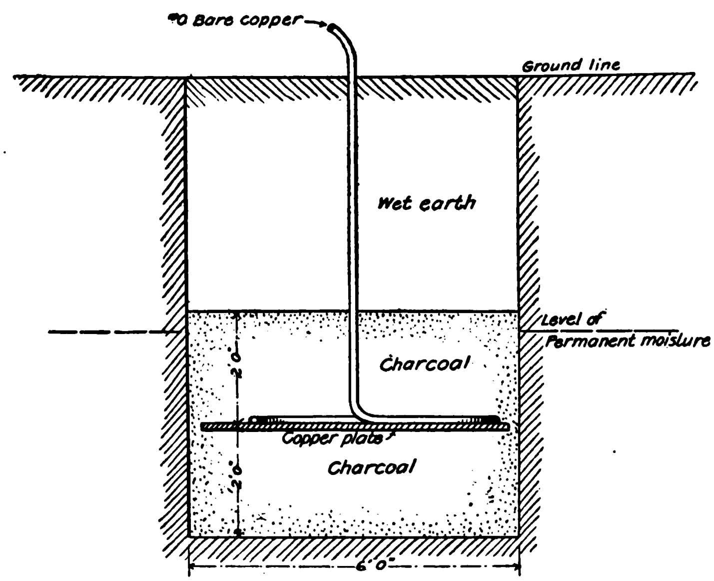


Fig. 218.

the top of the pole for the grounded circuit and a standard cross arm below the metallic circuit, the tie on the top insulator being made so as to bring the wire approximately in the center of the insulator. Two metallic lines can be carried on the iron pole by using the standard cross arm, as shown in fig. 220, attaching the sides of each circuit to diagonally opposite insulators. In the figure, *A* and *D* form one circuit and *B* and *C* the other.

Whenever a grounded line is connected to a metallic one, repeating coils must always be used or else the metallic part of the circuit

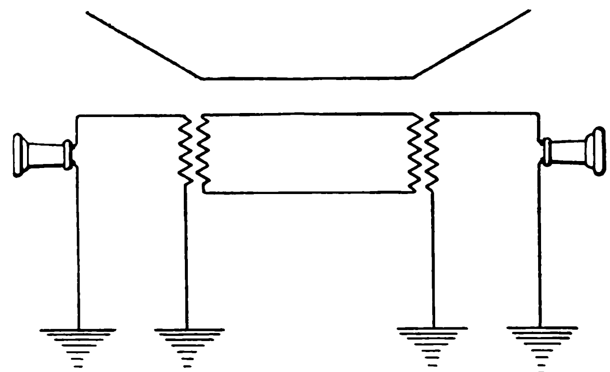


Fig. 219.

will be unbalanced, with the resulting annoying disturbances. The repeating coil may be installed in a box on the pole, in the central office, or in the switchboard cord circuit. (Figs. 198*a* and 198*b*.

As the repeating coils retard the ringing current, the above ar-

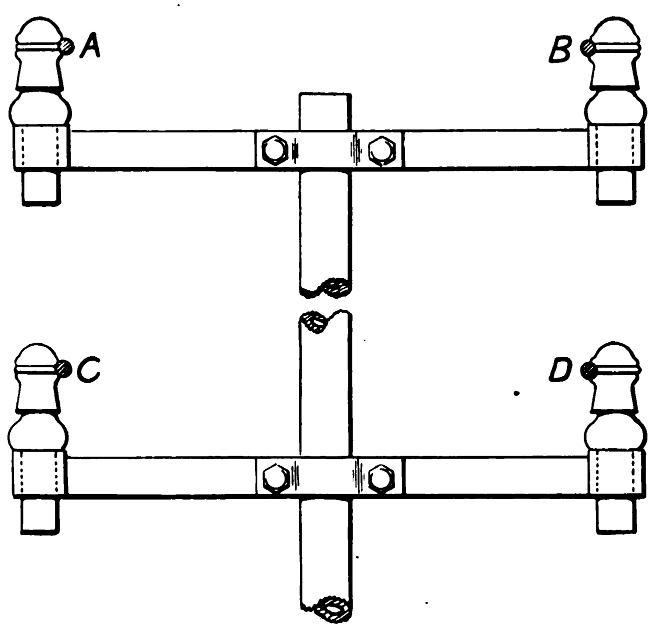


Fig. 220.

rangement is advantageous, as the ringing is done outside of the repeating coil.

In certain localities remote from sources of inductive or other disturbance a grounded system of lines will give satisfactory service. But as a general rule all circuits installed by the Signal Corps will be metallic. If a grounded system is for any reason contemplated, a series of tests over the district to be covered should be made at different hours of the day before the wiring system is definitely fixed.

Whenever aerial lines run near trolley or alternating-current circuits, the best method of preventing inductive disturbance is to use a lead-covered cable containing twisted pairs, as each twisted pair gives a complete transposition every 3 inches, and if the lead sheath is grounded the sheath acts as an additional guard against static charge.

The usual method of suspending a cable is indicated in figs. 67–68.

In the future the Signal Corps will supply submarine cable that contains twisted pairs for all telephone circuits. Under no circumstances shall a grounded line be connected to one of the wires of a twisted pair except in case of emergency. When it is necessary to connect a grounded line to a pair in a cable it is to be done in the usual way through a repeating coil.

In an emergency, straightaway multiple rubber-insulated submarine cable can be used for either telephone circuits, or for a combination of them with others, but the limit of satisfactory operation will, in general, seldom exceed 1,000 feet. The standard single-conductor submarine telegraph cable of the Signal Corps can be used satisfactorily for a telephone circuit alone up to a distance of about 10 miles by employing a repeating coil with a good ground at each end. Composite circuits—using both telegraph and telephone—(see Chap. VIII) can be used on lines, but the lines must be maintained in perfect order, and the coils and condensers must be carefully adjusted if satisfactory conditions of operation are expected.

Chapter XX.

INSPECTION OF SIGNAL CORPS TELEPHONE SYSTEMS.

The inspector of signal corps telephone systems will in all cases report as herein directed. Any data which he desires to add, and which may not be covered in the list, should be entered under "Remarks." The report should in all cases be specific, covering in non-technical language the exact condition of the installation.

This report will be forwarded in duplicate to the chief signal officer of the department in which the inspection is made. Where minor defects exist, it is desired that the inspector see to it that the necessary changes are made while he is on the ground. Where a general reconstruction is necessary, care must be taken to state specifically what is required to bring the system up to a proper state of efficiency, it being intended that all installations shall be made to be first class in every particular.

Specification No. 219 (see Chapter IX), covering line construction material, should be used as a basis for estimates on the necessary material to repair and reconstruct the line.

The instrumental and switchboard equipment *for repairs* should in all cases conform strictly to the existing equipment.

The instrumental and switchboard equipment *for reconstruction*, however, may conform to the latest type of apparatus which includes:

STANDARD EQUIPMENT.

Post telephone switchboards, 15 line.
15-line terminal cabinet.
Local battery wall set.
Local battery desk set.
Mason lightning arrester with fuse.

SPECIAL EQUIPMENT.

30-line central energy switchboard complete.
30-line terminal cabinet complete.
Central energy wall set.
Central energy desk set.

The estimate for line reconstruction in this case would, of course, be for metallic lines and aerial cables, with first-class construction in every particular.

This report shall include the following:

1. Name of station.
2. Date of inspection.
3. Number, make, and signal corps serial numbers of wall telephones.
4. Number, make, and signal corps serial numbers of desk telephones.
5. Type, make, and signal corps serial number, with equipment of line and cord circuits of the telephone switchboard.
6. Character of switchboard protectors.
7. Number and make of lightning arresters, protectors, and fuses.
8. Number and make of instrument arresters (if separate).
9. Specific statement concerning the number of instruments in excess and instruments lacking, as per General Orders, No. 59, War Department, 1905, with locations.
10. Whether operated on common or local battery.
11. Number of metallic circuits.
12. Number of grounded circuits.
13. *Lines.*—Type and construction; whether open wire, aerial cable, or subterranean cable. Kind of poles; whether wood or iron. Kind of line wire; whether galvanized iron or copper.
14. *Condition of switchboard equipment.*—Indicate exactly what defects exist, with probable cause. Indicate need, if any, for replacement of board or renewal of any part of the switchboard equipment.
15. *Condition of switchboard protectors.*—Indicate exactly what defects, if any, exist, and the necessity for renewal or replacement.
16. *Condition of line.*—Indicate specifically what defects, if any, exist, and recommend definitely what changes should be made for its improvement, with the approximate amount of material and labor required to accomplish it.
17. *Condition of instruments.*—Indicate any defects that may exist in instrument wiring or installation, with recommendations for radical changes, if such are necessary. Indicate necessity for replacement, if such necessity exists, and arrange for renewal of transmitters, receivers, and ringers if any are found to be defective. (This renewal may be made by the post authorities through the regular channels, but no repairs should be attempted by them on instrument parts.)
18. *Condition of instrument protectors.*—Indicate necessity for replacement or renewal. Indicate necessity for new ground or new location of instruments.

INDEX.

30222—05 M——20

O