THE THOUGHT IS IN THE QUESTION THE INFORMATION IS IN THE ANSWER

HAWKINS ELECTRICAL GUIDE

NUMBER EIGHT

QUESTIONS ANSWERS & ILLUSTRATIONS

A PROGRESSIVE COURSE OF STUDY FOR ENGINEERS, ELECTRICIANS, STUDENTS AND THOSE DESIRING TO ACQUIRE A WORKING KNOWLEDGE OF

ELECTRICITY AND ITS APPLICATIONS

A PRACTICAL TREATISE

by

HAWKINS AND STAFF

THEO AUDEL & CO. 72 FIFTH AVE. NEW YORK.

TABLE OF CONTENTS GUIDE NO. 8.

CHAPTER LXIX

THE TELEGRAPH

The word telegraph means *an apparatus for transmitting messages between distant points.*

Broadly, it includes telegraphs operated by mechanical, pneumatic, and hydraulic means, but now these devices are known as signalling apparatus, and the term telegraph is restricted to mean some form of apparatus employing electricity and transmitting more than mere calls or signals.

Ques. What are the essential parts of a telegraph?

Ans. 1, a *line wire*; 2, a *battery*, or other source of electricity; 3, a *transmitting instrument*, and 4, a *receiver*.

Ques. What is the transmitting instrument usually called?

Ans. A key.

Ques. What is the receiver usually called?

Ans. A sounder.

NOTE.—*A new word:* A friend desires us to give notice that he will ask leave, at some convenient time, to introduce a new word into the vocabulary. The object of this proposed innovation is to avoid the necessity, now existing, of using two words for which there is very frequent occasion, where one will answer. It is "*telegram*," instead of "telegraphic despatch" or "telegraphic communication." . . . Telegraph means to write from a distance—*telegram* the writing itself, executed from a distance. Monogram, logogram, etc., are words based upon the same analogy and in good acceptation.—*Albany Evening Journal*, April 6, 1852.

Classification.—The telegraph, like other inventions, has been considerably developed, resulting in numerous systems. A classification of these various systems, to be comprehensive, must be made from several points of view, as with respect to:

1. The kind of circuit, as

   a. Ground return·
   b. Metallic.

2. The method of operating the circuit, as

   a. Closed;
   b. Open.

3. The transmitting capacity.

   a. Single Morse line;
   b. Diplex.
   c. Duplex { single current or differential; double current; polar; bridge; high pressure "leak"; high efficiency; city line; short line.
   d. Quadruplex. { gravity battery; Jones; Field; Davis-Eaves or Postal quad; single dynamo; metallic circuit; Gerritt Smith; Western Union; British post office.
   e. Multiplex { synchronous.
   f. Phantoplex.

4. The method of receiving, as

   a. Non-recording
   b. Recording { by perforations; by printing.

The Morse Single Line System.—This ordinarily includes a battery for supplying a low tension current and a line wire connecting two or more stations serving to establish a circuit between them: a return connection to the battery, formed either by another wire or by the earth to a transmitting key, and a sounder or recording apparatus at each station.

Ques. How does this system operate?

Ans. On depressing the transmitting key at the sending station, the electric circuit is completed in a manner corresponding to a predetermined code of signals; these signals are transmitted along the wire by the electric current to the distant receiving station, where they are reproduced by the electromagnetic action of the sounder or receiver.

Ques. On what does the operation of the telegraph depend?

Ans. It is possible, because of the fact that an electromagnet can be magnetized and demagnetized with great rapidity on respectively making and breaking the magnet circuit, the magnetic action thus obtained being used to operate a sound producing mechanism so that the various combinations of "dots" and "dashes" representing the letters of the alphabet are indicated audibly.

Ques. What circuits are included in the term "Morse single line?"

Ans. Those that are so equipped and operated that transmission is carried on in one direction only at a time.

Ques. What instruments are necessary on a Morse single line of short length?

Ans. A key and sounder at each station.

Ques. Describe a key.

Ans. As shown in fig. 3,050, it consists essentially of a pivoted lever provided with a contact and adjusting screw, and carried on a base having an insulated contact and a spring to keep the lever normally in the open position. A switch is provided to close the circuit when the key is not in use.

Ques. Explain its operation.

Ans. The operating disc is grasped by the 1st, 2nd, and 3rd fingers; depressing the disc causes the two contacts to touch,

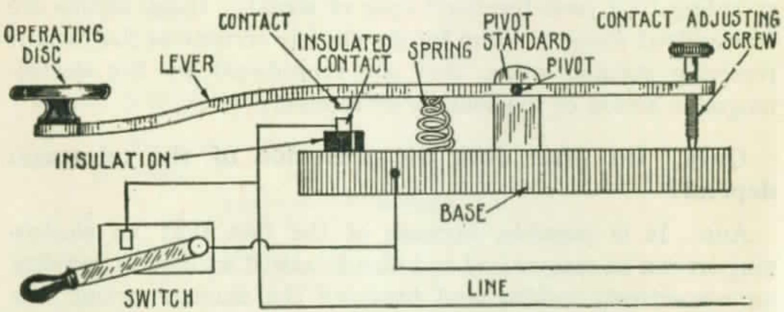


FIG. 3,050.—Elementary key. In actual construction the switch is attached to the base, but is here shown separately, in order that the connections may be more plainly seen.

thus closing the line circuit. When the operator ceases pressing on the disc, the spring forces the contacts apart and breaks the circuit.

Closing the circuit for a short period corresponds to a "dot" and, for a longer period, to a dash. The periods in which the circuit is closed are indicated audibly by the "sounder."

Ques. Describe a sounder.

Ans. As shown in fig. 3,051, it consists essentially of a heavy pivoted lever arranged to vibrate between two stops and held normally against one of these stops by the action of a spring, there being an electromagnet which when energized acts on an armature attached to the lever causing the latter to move from the upper stop to the lower stop.

Ques. Why is the instrument called a sounder?

Ans. Because, in operation the lever is forced against the stops with considerable rapidity, the blows thus produced, owing to the heavy construction of the lever, being distinctly audible.

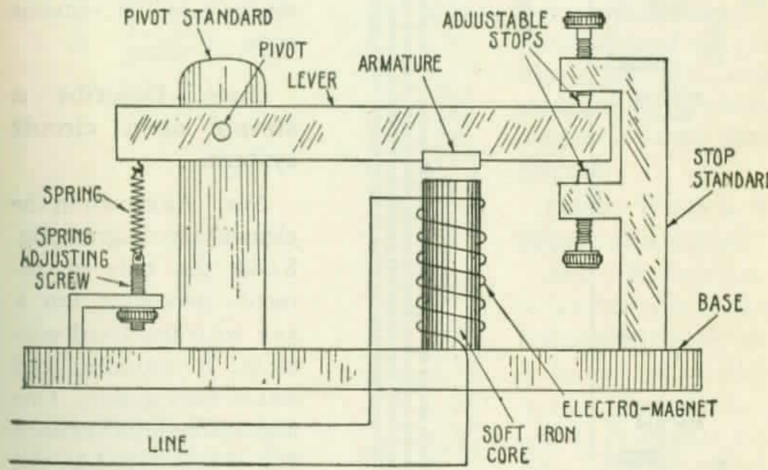


FIG. 3,051.—Elementary sounder showing essential parts.

Ques. Describe a simple short line circuit.

Ans. A simple line having two stations is shown in fig. 3,052. Each station is provided with a key, including a switch, sounder, and one or more cells according to the length of the line, the apparatus being connected in series as shown.

The diagram shows the elementary apparatus for clearness in illustrating the circuit; of course, in actual construction the details are different, for instance the switch forms a part of the key, the standards are double, giving two bearings instead of only one, etc.

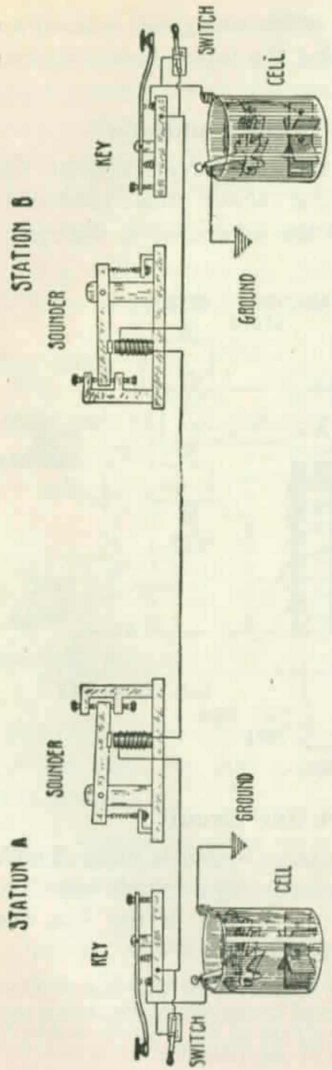


FIG. 3,052.—Elementary diagram showing a simple short line **closed circuit** system. It is called closed system from the fact that the circuit is normally closed with current on the line, that is to say, when not in operation the switches are closed and current flows which energizes the magnets and holds the instrument armatures in the down position. This necessitates the use of a closed circuit cell as for example the crow foot gravity type which is capable of supplying a very weak current for a long duration of time.

Ques. What is the circuit shown in fig. 3,052 called, and why?

Ans. It is called a closed circuit, because both switches are kept closed except during operation, when the sender's switch remains open.

Ques. Describe a simple open circuit system.

Ans. As shown in the elementary diagram, fig. 3,053, the only instruments necessary are a key with insulated contacts, a sounder, and cell at each station. One insulated contact of each key is connected to the cell, and the other insulated contact is connected in series with the sounder and the latter grounded as shown. The base of each key is connected to the line.

In operation only the battery at the send-

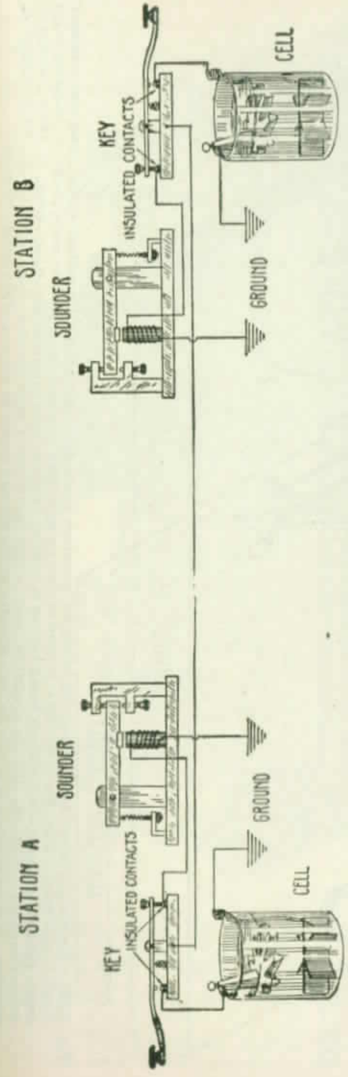


FIG. 3,053.—Elementary diagram showing a simple short line **open circuit** system. In Europe this system is in general use; it consists essentially of so arranging the apparatus that the battery shall only be placed to the line when a message is being transmitted; A main battery is necessary at each station, whereas in the *closed system*, employed in America, main batteries are required only at the terminal stations. An advantage of the open circuit system is that when not in use, the battery is not required to supply current to the line; another advantage is that the resistance of the sounder (or relay) is not always in the circuit, since the closing of a key cuts out the relay. On relay lines local sounders or registers are provided. In some cases a "telltale" galvanometer is placed in the main line at each station to indicate to the operator the condition of his transmitted signals, etc.

ing station is available, hence twice the battery capacity is required as compared with the closed circuit system. Ordinary keys may be used by insulating the back contact of each.

Ques. What is a relay?

Ans. In general, a relay is *a device which opens or closes an* **auxiliary circuit** *under predetermined electrical conditions in the* **main circuit.**

Ques. What is the object of a relay?

Ans. Its function is to act as a sort of **electrical multiplier,** that is to say, *it enables a comparatively* **weak** *current to bring into operation a* **much stronger** *current.*

Ques. What is accomplished by the use of relays on telegraph lines of moderate or long distance?

Ans. It reduces considerably the battery capacity required.

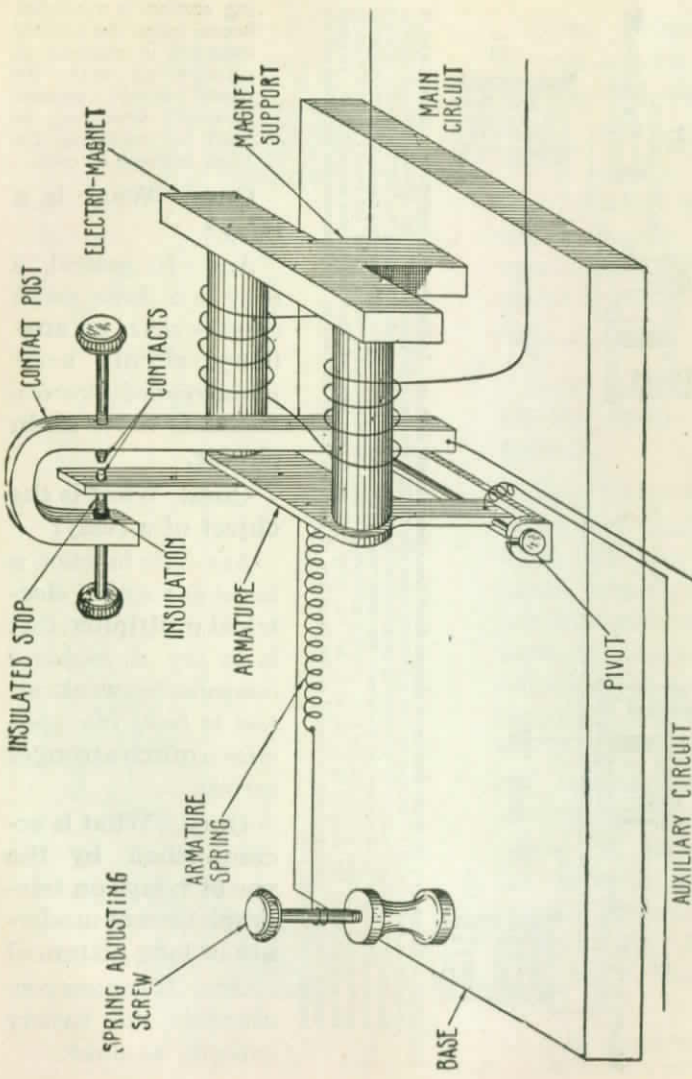


FIG. 3,054—Elementary relay showing magnet, insulated armature contacts, insulated stop, armature spring, main and auxiliary circuit connections. *The office of a relay is to open or close an* **auxiliary current** *under predetermined electrical conditions in the* **main circuit,** so that *a comparatively* **weak** *current may bring into operation a* **much stronger** *current* to effect a saving in battery capacity. Note the delicate armature construction as compared with sounder, thus requiring very little energy to **operate. A** relay is virtually a very delicate sounder with a contact maker at the end of the armature lever.

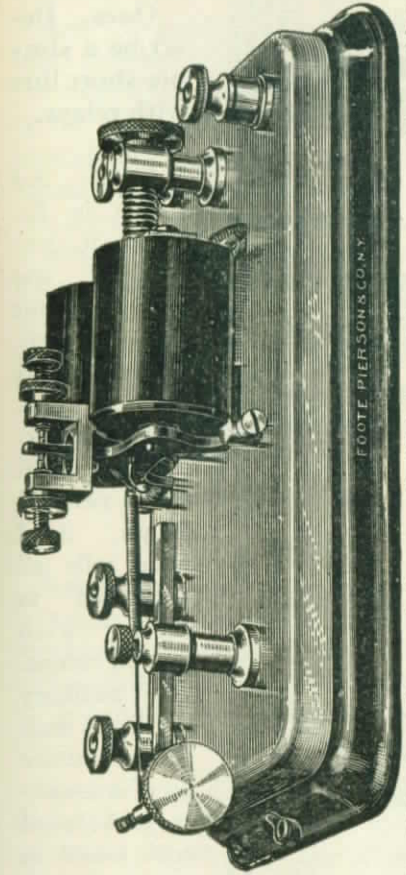


FIG. 3,055.—Foote, Pierson main line relay. In this instrument the magnets are regularly wound from 150 to 300 ohms.

Ques. How is this done?

Ans. When relays are used, a very weak current will suffice for the main line, since the moving parts of these instruments are very light they require very little energy for operation. The relay controls a comparatively strong local current to operate the sounder.

Ques. Of what does a relay consist?

Ans. Its essential parts, as shown in fig. 3,055 are: 1, an electromagnet, energized by the main circuit current; 2, an insulated armature of very light construction and pivoted so as to vibrate between a contact and an insulated stop as shown; 3, an adjustable spring to hold armature against stop when not attracted by the magnet; 4, leads connecting the magnet winding to the main circuit, and 5, leads connecting the insulated armature and contact post with the auxiliary circuit.

The insulated stop and contact maker at the end of armature lever is very clearly shown on the elementary diagram fig. 3,054.

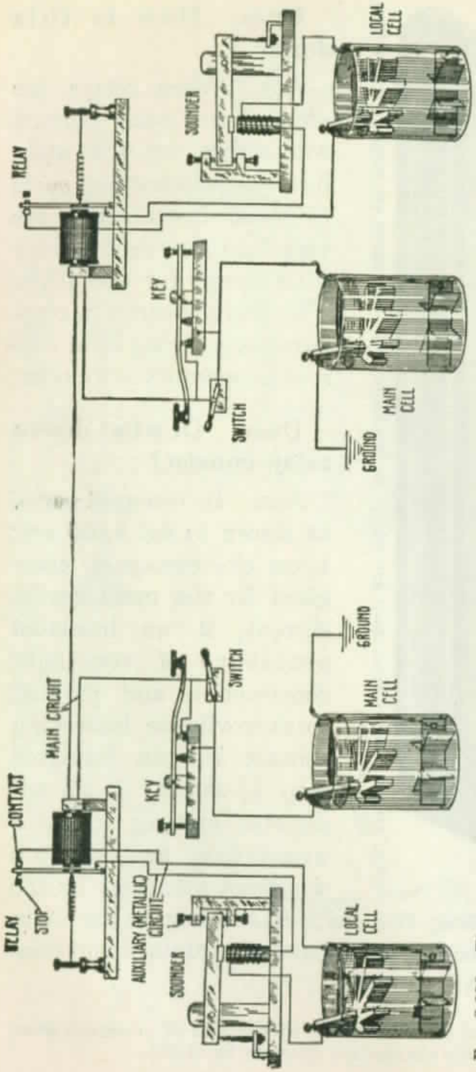


FIG. 3,056.—Elementary short line with relays, showing the main circuit and the auxiliary circuit at each station. The relay, as stated in the text *acts as a sort of* **multiplier,** that is to say, *it enables the* **comparatively weak current** *of the main circuit to bring into operation the* **much stronger current** of the auxiliary circuit to operate the sounder. On lines of moderate or long distance, as can readily be seen, a considerable saving in battery capacity is effected, by localizing the strong current necessary to operate the sounder, it being understood that considerably more energy is required to operate a sounder than a relay.

Ques. Describe a simple short line with relays.

Ans. As shown in fig. 3,056, it consists of one main circuit and an auxiliary circuit at each station. The main circuit includes the relays, keys, and main cells all connected in series with ground return. The auxiliary circuit at each station is made up of a sounder and local cell joined in series and connected with the auxiliary circuit of the relay as shown.

Ques. How does it operate?

Ans. Normally both switches are closed; this energizes the relay magnets and keeps the auxiliary circuits closed by holding the relay contacts together. In operation, the sender opens his switch and with the key sends the message by successively making and breaking the main circuit in proper sequence. This causes the relay armature to move back and forth against the contact and stop, thus making and breaking the auxiliary circuit in synchronism with the movements of the key. In this way, the very weak main current is enabled to bring into action the much stronger current of the auxiliary or local circuit, thus, the movements of the delicate relay armature are reproduced by the heavy armature of the sounder.

Ques. For what length lines is the system shown in fig. 3,056 suitable?

Ans. For lines not exceeding about 500 miles.

Repeaters.—When the length of a telegraphic circuit exceeds a certain limit, dependent upon the ratio of its insulation to its conductivity resistance, the working margin becomes so small that satisfactory signals cannot be transmitted even by the aid of increased battery capacity. This limit under existing conditions is much less in wet weather than in dry weather.

There is no difficulty of directly operating a telegraph of three hundred miles or less, if the line be fairly well insulated and there are not too many offices connected in the circuit. The difficulty arising from the number of office usually settles itself, since the traffic cannot be handled without great delay when the number of office is too great, and accordingly, it becomes necessary to employ more wire and divide the offices among them. When, however, the length of a single line increases, the difficulties with *leakage* and *retardation* increase, until the speed and certainty of signalling are largely reduced. Under such conditions it was formerly necessary to retransmit all communications at some intermediate station, but this duty is now performed by an instrument called a *repeater*.

Ques. What is a repeater?

Ans. *A sounder provided with a circuit maker, for synchronously controlling a second circuit.*

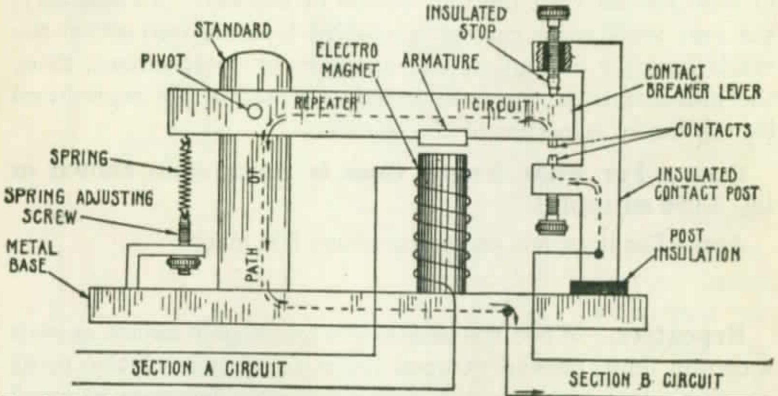


FIG. 3,057.—Elementary repeater showing the insulated parts essential for the contact maker, and path of the current through the repeater portion of the instrument. The insulated stop on the upper arm of the contact post is shown in sectional view to clearly indicate the insulation at this point. Compare this instrument with the elementary sounder fig. 3,051 and note the essential points of difference.

That is to say, it is simply a piece of apparatus in which the sounder (or in some cases the relay), receiving the signals through one circuit, opens and closes the circuit of another line, in the manner that a relay opens and closes the auxiliary circuit of a sounder.

Ques. Describe a simple repeater.

Ans. As shown in fig. 3,057, it consists essentially of a sounder of the same construction as in fig. 3,051, with the exception that the contact post is insulated and is provided with an insulated

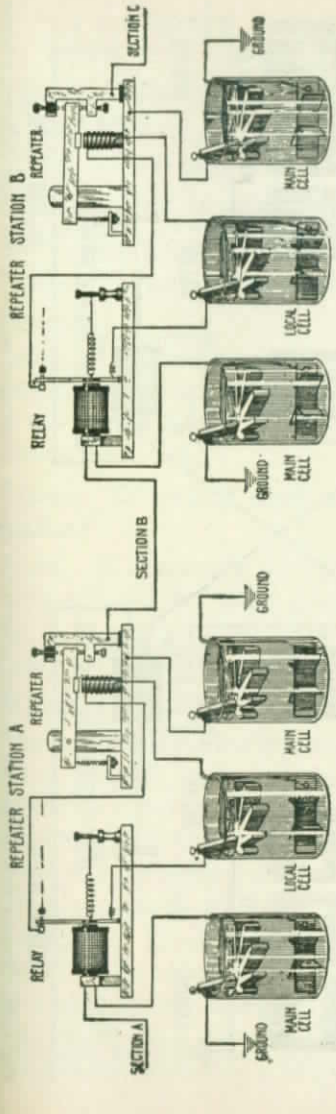


FIG. 3,058.—Elementary repeater as connected in a circuit. **In operation**, if the home station or beginning of section A line send a message, the movements of the relay at station A will cause similar movements of the repeater, this in turn is repeated at station B, and all other stations on the line.

stop, thus forming a contact maker for the repeating section of the circuit. As indicated by the dotted line and arrows, the path of this circuit is (when closed) through contact post, contacts, contact maker lever, pivot, standard, and out through base.

Fig. 3,058 shows how the elementary repeater shown in fig. 3,057 is connected in the circuit.

As shown, the line is divided into a number of section A, B, C, etc., depending upon its length, there being a repeater station joining each section to the preceding one.

The end of section A is connected to the relay main circuit, and the auxiliary circuit to the electromagnet of the repeater.

There is a ground return on main circuit, and metallic return on auxiliary circuit, one or more cells being included in each of these circuits as shown.

The contact maker circuit of the repeater (which corresponds to the auxiliary circuit of the relay) is connected to section B and ground.

At the end of section B is another repeater station identical with the one just described,

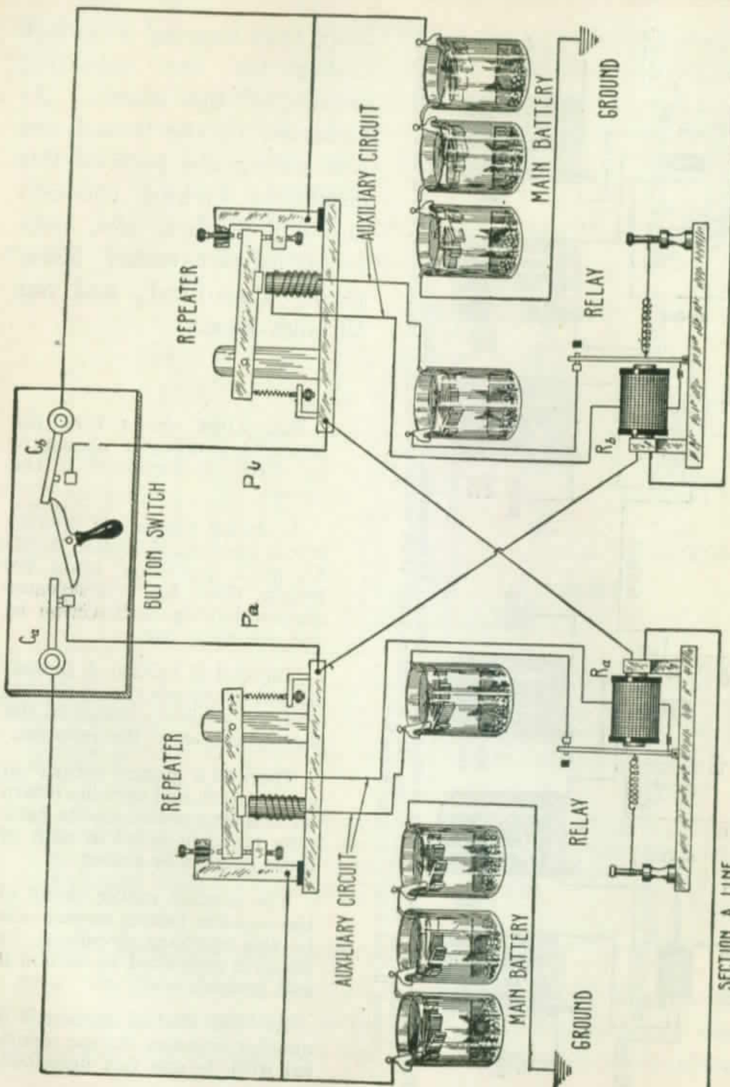


Fig. 3,059.—Diagram showing essentials of the so called button repeater, consisting of two relays, two simple repeaters, a button switch and connections as shown.

and from which section C begins, the number of repeater station depending on the total length of the line.

Ques. What is the objection to the arrangement shown in fig. 3,058?

Ans. It will only work in one direction.

Ques. How is this overcome?

Ans. By use of a button type repeater or equivalent.

Ques. What is the principle of operation of the button repeater?

Ans. The line circuit is extended by making the receiving instrument at the distant terminal of one circuit do the work of the transmitting key of the next circuit, by opening and closing the latter.

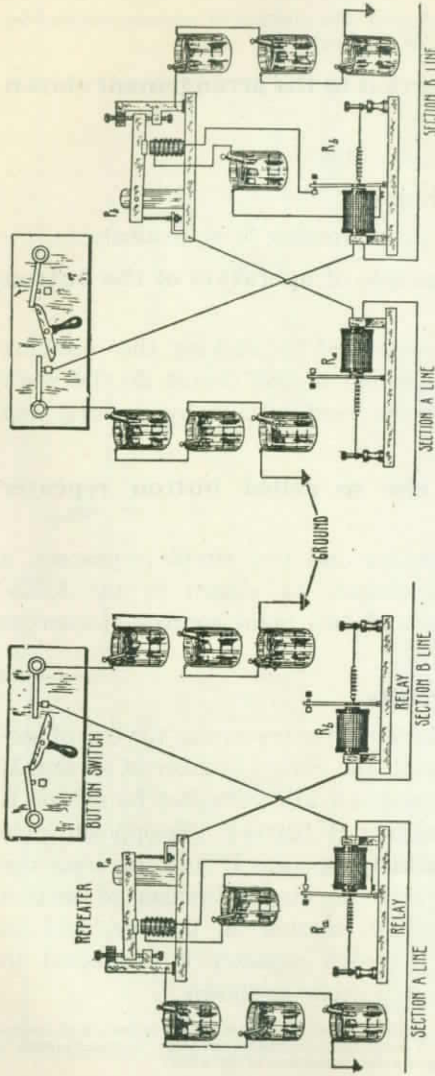
Ques. Of what does the so called button repeater consist?

Ans. It comprises two relays and two simple repeaters, a "button" switch, and connections as shown in fig. 3,059. For its operation, two local and two main sources of current supply are required.

Ques. Describe the circuits.

Ans. Section A line (fig. 3,059), after traversing the coil of section A relay R_a, passes through the circuit breaker of section B repeater P_b (the movements of which are controlled by section B relay R_b), and thence to section B battery, the opposite pole of which is grounded. **Similarly,** section B line traverses the coil of section B relay R_b, and the circuit breaker of section A repeater, P_a, thence through section A battery, and to ground. The circuit maker of each repeater is connected to the button switch and to main battery as shown.

NOTE.—The author objects to the use of the word repeater for the collection of instruments necessary to permit repeating in both directions, and prefers the term "repeater system"; the word repeater is properly used to designate the instrument in fig. 3,057.



FIGS. 3,060 and 3,061.—Button repeater diagrams showing circuits actually in operation when communicating from section A of the main line to section B, and from section B to section A. The complete apparatus is shown in fig. 3,059, in each of the above diagrams parts are omitted in order to clearly show the circuits in use when operating at either end of the line.

Ques. What is the object of the button switch?

Ans. It provides means for cutting out or closing the circuit around the breaking points of each sounder, otherwise the apparatus would remain unopened.

Ques. Describe the operation of the button repeater.

Ans. If, say, section B line be opened by the key of the operator, the armature of section B relay will open, which in turn opens section B repeater, whose circuit breaker breaks the circuit of section A. This causes the armature of section A relay to open, followed by that of section A repeater,

the circuit breaker of the latter also breaking the circuit of section A. The operator of section B line cannot now close the circuit, because it is still open in another place, viz., at the circuit breaker of section A repeater. The button switch eliminates this difficulty, for when it is swung to the left, it closes a

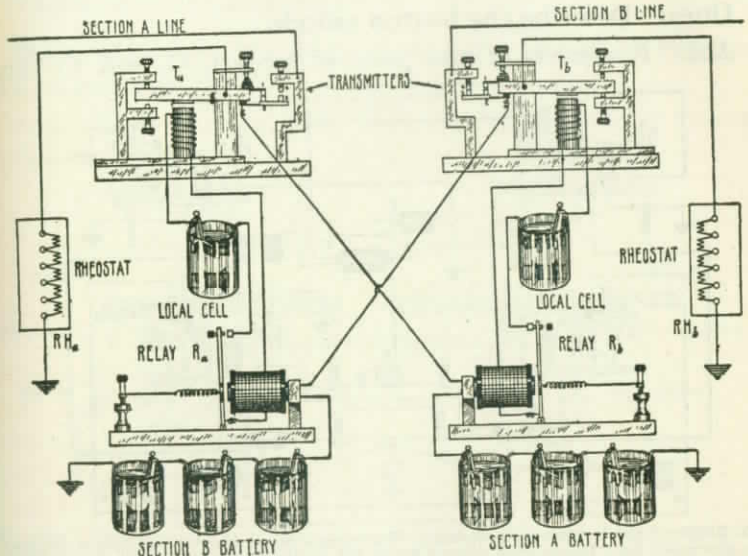


FIG. 3,062.—Diagram of Toye "repeater" or transmitter system, used extensively in the United States and Canada. It comprises two relays, two transmitters with tongue contact breakers, two rheostats and connection as shown. **In operation**, if section B send or open his key, the armature of relay R_a will open as shown, thus opening transmitter T_a lever, which causes contacts 2 and 1 to close and 4 and 3 to open. This change opens section A line, and puts in circuit with relay R_b, section A battery and rheostat RH_a, the resistance of the rheostat being adjusted so that it equals the resistance of section A line. Since this transposition of circuit maintains the current passing through relay R_b at the same strength as before the change of circuit was made, that relay remains closed and likewise also transmitter T_b, thus preserving the continuity of the line while a communication is being sent from section B to section A. Since repeater T_1 connects and cuts out section A battery from section A line in response to the operation of relay R_a, relay R_b is prevented opening because section A battery when not in contact with the A line, is given a path to earth through the rheostat RH_a by way of contacts 1 and 2 of transmitter T_a, thus holding relay R_b closed until section A operator desires to "break" or begins sending to section B. In sending from section A to section B a process the reverse of the foregoing holds. A disadvantage of this system is the excessive consumption of current, moreover the adjustment of the artificial resistance must be varied to equal that of the line or lines connected through the transmitters, in order to have equal magnetic pull on the relay armatures whether the relay be in circuit with the artificial line or the main line.

spring contact C_a, forming a connection between the circuit breaker of section A repeater, enabling the operator of section B to open and close its circuit, at pleasure, while his signals are repeated into Section A by the action of the circuit breaker of section A repeater.

Ques. Describe the button switch.

Ans. It consists of two pairs of contact, C_a and C_b (fig.

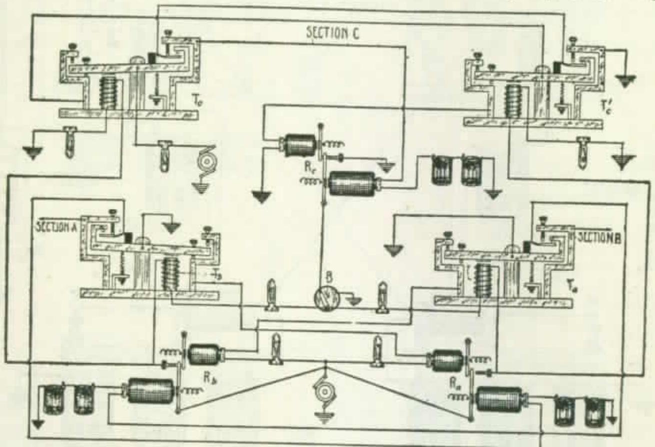


FIG. 3,063.—Kitton's three wire repeater. The current starts from the generator or other source and flows through the contact points (when closed) of relay R_a, to a tap where it divides, one half going through the magnet of T'_c and its lamp to the ground. The other half traverses the coil of magnet T_a through lamp and button B and contact points of R_c to the ground. The back contact points of transmitters T_a and T'_c hold section B and C main circuits closed while similarly the local circuit is maintained intact through relay R_b and transmitters T_b and T_c. The open contact points of relay R_a and transmitters T_a and T'_c indicate that the operator at section A has his key open or is sending to sections B and C. While section A line is open it is necessary that T_b and T_c be held closed in order to preserve continuity through the points of these transmitters.

3,059), normally closed by a spring action, one pair or the other being separated as the handle H is moved to the right or left. If the handle remain in the center, both sets of contact are closed and both sections of the line are independent of each other.

Ques. To what class does the button repeater belong?

Ans. It is called a *manual* repeater as distinguished from the *automatic* type.

The manual repeater is usually employed for temporary purposes and is so called because it requires the constant attendance of an operator to change the position of the button switch, in accordance with the direction in which the message is passing. The automatic repeater requires no attention other than that necessary to insure the apparatus being kept in proper adjustment.

Ques. In operation when should the attendant reverse the button switch?

Ans. When he hears either repeater fail to work in unison with the other.

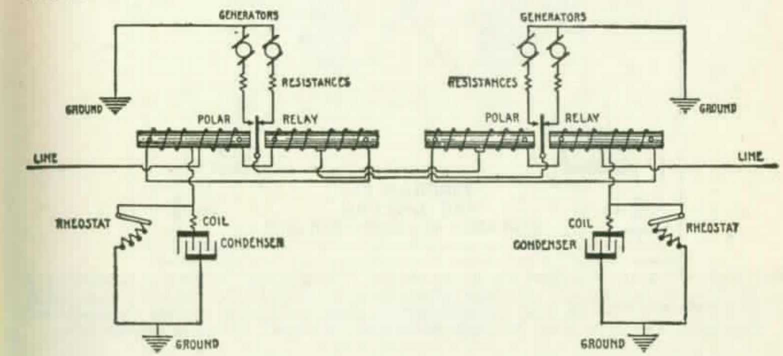


FIG. 3,064.—Diagram of the Postal telegraph repeater system. The Postal direct point duplex repeater is an arrangement by which the respective armature levers of two polar relays at the repeater office connect the positive and negative main battery currents direct to the line wires. Its principle is represented diagrammatically in the figure. The armatures of both polar relay are closed when a distant office closes th key, as shown in the diagram. This results in placing the duplex negative battery in contact with the other line. As the current passes through the coils differentially, the armature of the open line will not be affected by the impulse thereof. When the closed key is opened the positive battery is presented to the line.

Ques. Describe a simple automatic repeater.

Ans. One of the simplest repeater systems for single telegraph working is shown in fig. 3,065. This repeater consists of a transmitter having a second lever placed above the regular armature lever in such a position that one electromagnet is employed to work both. There are three distinct pairs of circuit, the main line circuits, the local circuits, and the shunt circuits.

Ques. How does it operate?

Ans. When a key on the western circuit is opened the instruments assume the positions shown in the diagram. The

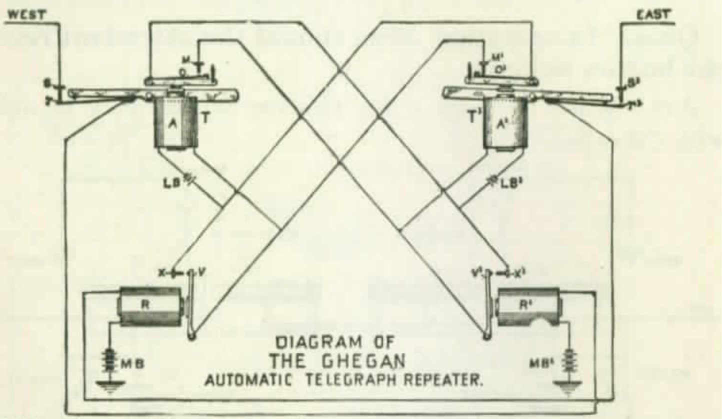


FIG. 3,065.—Diagram of Ghegan automatic repeater. Its principle of operation is based upon the fact that an armature, on being drawn towards a magnet becomes itself magnetic by induction, and that the closer it approaches the magnet cores, the stronger the magnetism becomes. The circuits and operation are further explained in the accompanying text.

armature of relay R^1, first falls back and opens the local circuit of transmitter T^1, which in turn opens the eastern circuit s^1 r^1, 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^1 r^1, the shunt around the local contacts of relay R was closed at M^1 O^1.

On closing the western key, the armature of relay R^1 closes the local circuit of transmitter T^1, which in turn first closes the eastern circuit at s^1 r^1, 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^1 O^1.

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^1, and so break the western circuit at s r.

There being no extra weight or attachment of any kind to either the relay or transmitter armatures, the quickest possible action can be obtained with this repeater. As both **relay armatures** work in **unison,** it can always be seen at a glance if the signals are being **properly repeated.**

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

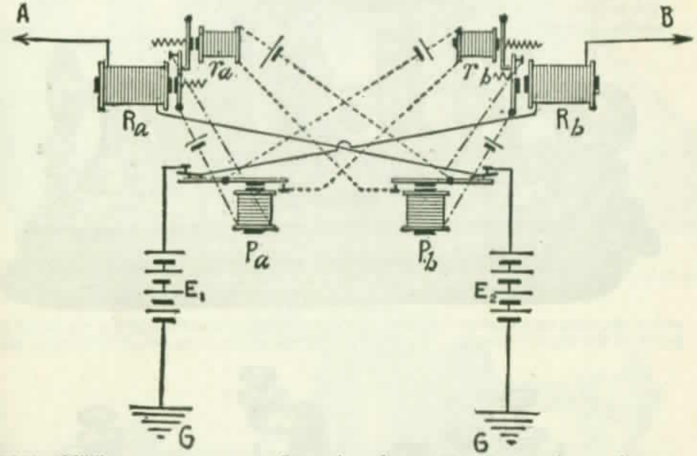


FIG. 3,066.—Milliken repeater system. It consists of two extra magnet relays and two tongue contact repeaters, connected as shown. In the figure, the relays R_a and R_b are provided with additional or extra magnets r_a and r_b, whose levers press against the main levers in such a manner that when the working current is cut off, the working winding, the spring of the extra magnet closes the local contact against the tension of its spring, so that in order that the relay should open its local circuit at the local contact, it is necessary that the current should be cut off its main line circuit and the current should be passing through the local circuit of the extra magnet. The repeaters are provided with two contacts, one, for the local circuit of the opposite extra magnet, and the other, for the closing of the opposite main line circuit. When one of these repeaters opens, its local contact is always broken very shortly before the main line contact is broken, while in closing, the opposite takes place. If section A operator be sending to section B, the incoming signals will be repeated by the tongue of relay R_a. This operates repeater P_a, which in its turn repeats the signals into section B. The repetition of these outgoing signals in the relay R_a, would cause the circuit on the incoming side to open at its local contact, if the extra magnet r_b were not coincidently demagnetized by the action of the repeater P_a opening the circuit. Accordingly the outgoing signals cannot disturb the line on the incoming side.

Diplex Telegraphy.—Within thirty years from the first establishment of the telegraph, the inconveniences arising from the multiplication of wire proved so serious that it became urgently necessary to adopt measures of relief. The effort to

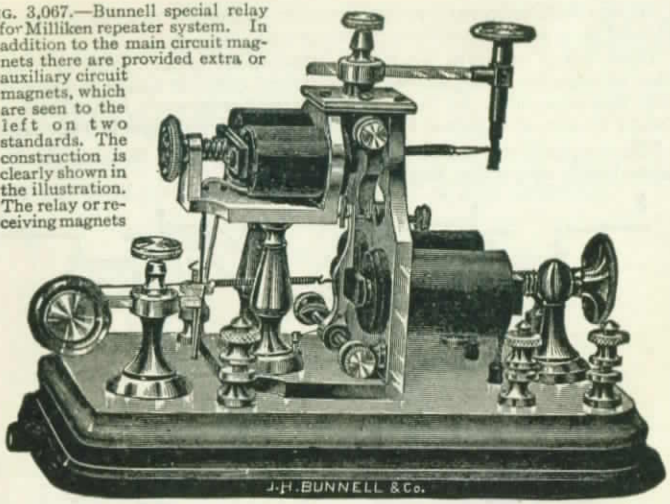


FIG. 3,067.—Bunnell special relay for Milliken repeater system. In addition to the main circuit magnets there are provided extra or auxiliary circuit magnets, which are seen to the left on two standards. The construction is clearly shown in the illustration. The relay or receiving magnets are in the main circuit which connects the battery and ground through the repeating contact points of the opposite sounder. The local sounder magnets are operated by the relay magnets.

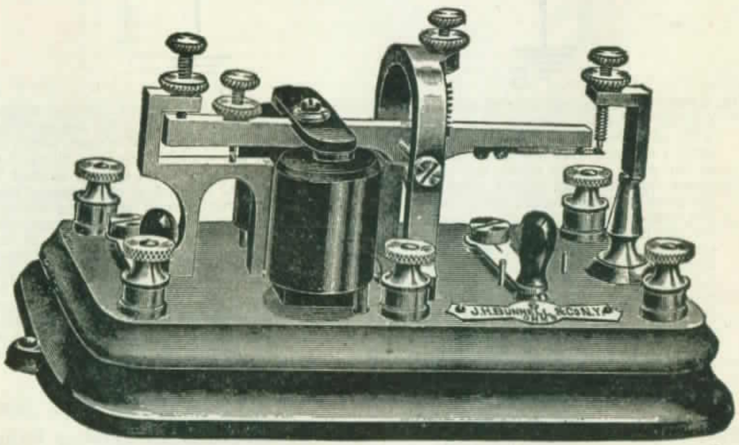
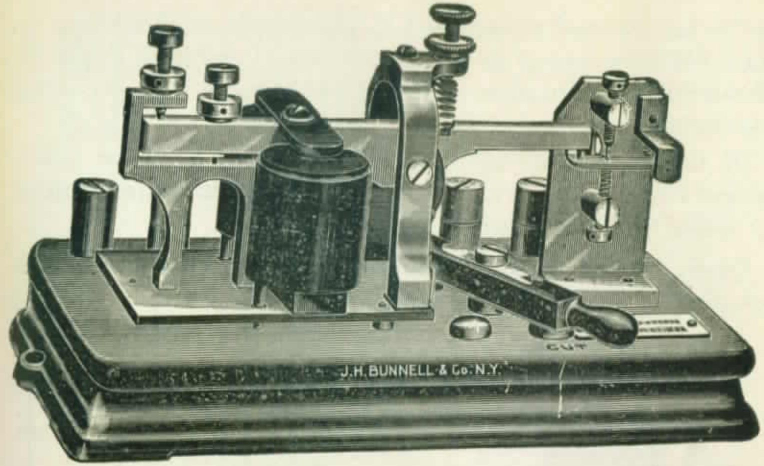


FIG. 3,068.—Bunnell tongue contact repeater as used for Milliken repeater system. Duplicate connections are made at and between the special relay and repeater or sounder here shown and consequently the relay operates the repeater and produces the loud sound from which the signals are read.



FIGS. 3,069.—Bunnell spring contact breaker repeater as used for Weiny-Phillips repeater system.

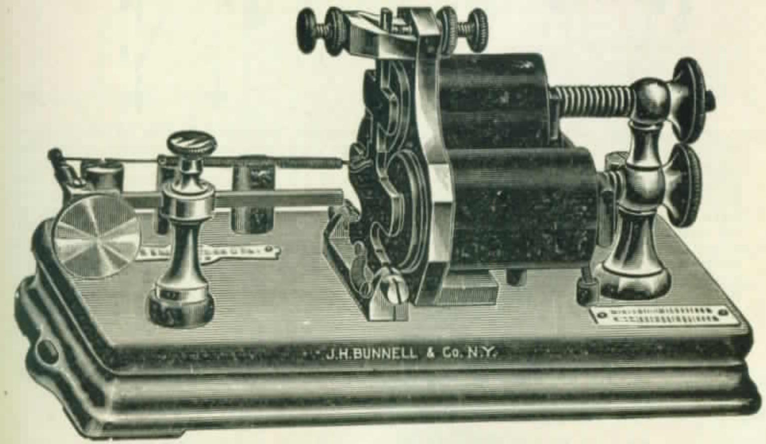


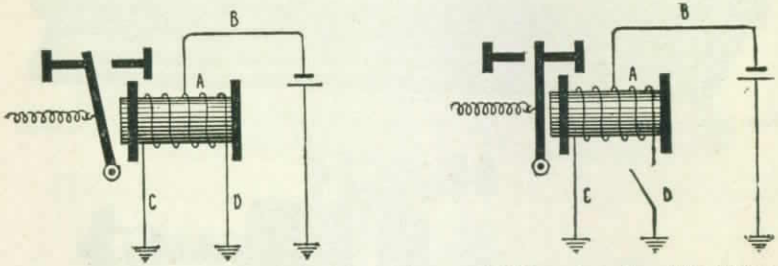
FIG. 3,070.—Bunnell three spool differentially wound relay as used for Weiny-Phillips repeater system. The third spool of relay is differentially wound, so that normally the windings neutralize each other and no magnetism is developed in this spool. One of the coils of the differential spool is in circuit with the front contact of the repeater of opposite side so that the instant the repeater circuit is broken, the corresponding coil of the differentially wound spool is opened, thereby permitting the second coil to act and hold the relay armature closed.

devise an effectual remedy led to the invention of systems of multiplex telegraphy, in which the same conductor might be used for the transmission and reception of more than one communication at the same time.

Of these systems, the diplex is defined as *a system which permits* **two messages** *to be transmitted in the* **same direction** *at the* **same time** *over a single wire.*

Ques. What is the principle common to the various systems of multiplex telegraphy?

Ans. *The receiving instrument at the home station, while free*



FIGS. 3,071 and 3,072.—Detail of the differentially wound third spool of relay of the Weiny-Phillips system. In fig. 3,071, one terminal of the battery is shown grounded while the other terminal is shown connected differentially with two equal windings of the magnet. The current divides at A, half going through each coil. It may be observed that the direction of the winding of one coil is opposite to that of the other. Thus, when current flows through the wire B, the magnetization of the core due to the action of current in the coil A-C is neutralized by the presence of current in the coil A-D, and as a result the core is not magnetized at all; so that the retractile spring attached to the armature holds the latter in the "open" position as shown in fig. 3,071. If, however, while the coil A-C remains closed, the coil A-D be opened, as in fig. 3,072, the core will be magnetized due to the presence of current in the coil A-C while no current exists in coil A-D, the latter no longer neutralizing the magnetic effect of the former. The armature, therefore, is attracted and held in the "closed" position as shown in fig. 3,072.

to respond to the signals of the key at the distant station, shall not respond to the signals of its associate key.

Ques. How does the diplex system operate?

Ans. Referring to fig. 3,073, if the operator depress key K_2, this brings both sections of the battery in circuit on the line, causing the armature of the neutral relay R_2 to be attracted

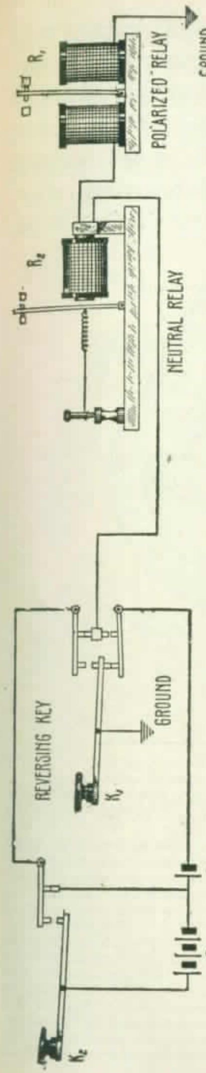


FIG. 3,073.—Diagram illustrating the principle of duplex telegraphy. K_1 is a reversing key and K_2 a non-reversing key. The battery is in two sections, B_1 and B_2, both sections being included in a loop, the terminals of which are reversed by the depression of key K_1, but the greater section B_2 of the battery only comes into action when the other key K_2 is depressed. In operation K_1 controls the polarity of the outgoing current regardless of its pressure, while K_2 controls the pressure of the outgoing current regardless of its polarity. At the receiving end of the line is a neutral relay and a polarized relay connected in series, as shown. If the armature spring of the neutral relay R_2 be adjusted to such tension that it cannot respond to the comparatively weak current of the battery B_1 it is obvious that signals may be sent by reversing the smaller battery section by means of K_1 which will actuate the polar relay R_1, but will produce no effect whatever upon R_2. Again, signals may be sent by K_2, each depression of which throws upon the line the additional pressure of the stronger battery B_2, the additional strength of current thus secured will operate R_2 but not R_1 other than to increase the pressure of its armature against whichever stop it may happen to be in contact. The polarized relay will however respond to each reversal whether of the weak or strong current.

If now another signal be sent by the depression of key K_1, the full strength of the current traversing the neutral relay R_2 will be reversed. If the armature spring of the neutral relay R_2 be adjusted so that it cannot respond to the weak current of battery B_1 it is evident that signals may be sent by reversing the smaller battery B_1 by means of K_1, which will operate R_1 but not R_2.

The principle and operation of polarized relays is explained in the accompanying cuts.

Duplex Telegraph.—This system is one which permits the sending of two messages simultaneously in opposite directions over a single wire.

There are several systems of duplex telegraphy, namely:

1. Differential;
2. Polar { with battery; with dynamo;
3. Bridge.

Differential Duplex System.—This method employs a relay wound with two sets of coil, in each of which the current flows in a different direction. Consequently, when two currents of equal intensity are passed through the relay at the same time, they neutralize each other, and the relay does not become magnetized. Each station is provided with a differential relay, and there are two complete circuits, one including the line wire,

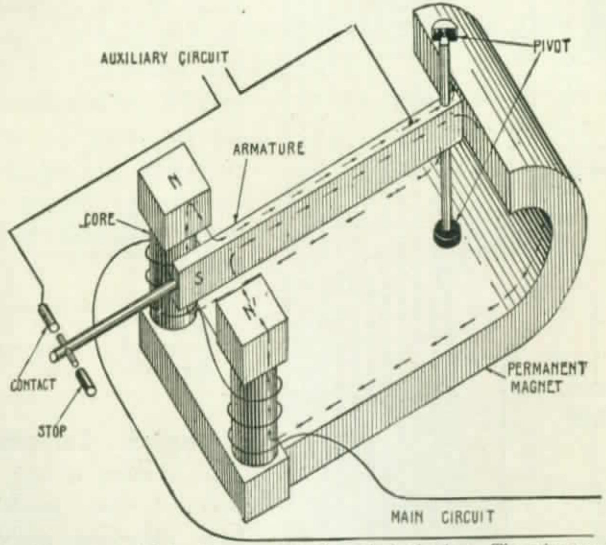


FIG. 3,074.—Diagram explaining the operation of a polarized relay. The relay consists essentially of a permanent magnet, electromagnet, and an armature arranged to vibrate between a contact and a stop. The permanent magnet is of a curved shape as shown; at one extremity is attached the electromagnet, and at the other is pivoted the armature so as to work between the two pole pieces of the electromagnet. The armature being pivoted at one extremity of the permanent magnet is permanently magnetized of the same polarity as the end, which may be assumed to be a south pole. Similarly the ends of the electromagnet cores being under the influence of the other extremity of the permanent magnet are north poles, that is at times when they are not neutralized or reversed by the electromagnet Accordingly when no current flows through the electromagnet, the armature (having no spring), when placed midway between the poles of the electromagnet will be attracted equally by each and accordingly will approach neither. When, however, the electromagnet is energized, the magnetism thus reduced in its cores either increases or overcomes that due to the permanent magnet, producing unlike poles according to the direction of the current. Thus the armature is attracted by one and repelled by the other. The magnetism of the electromagnet of the polarized relay changes in response to the reversals of the distant battery and the armature vibrates to and fro between its front and back stops in accordance with those changes.

and the other consisting of resistance coils having a resistance equivalent to that of the line and known as the *artificial line.* The key and battery at each station are common to both circuits, the points of divergence being at the relay and at the ground plate.

When the key at one station which may be called the *home station* is depressed, the current flows through both sets of coil of the relay at that

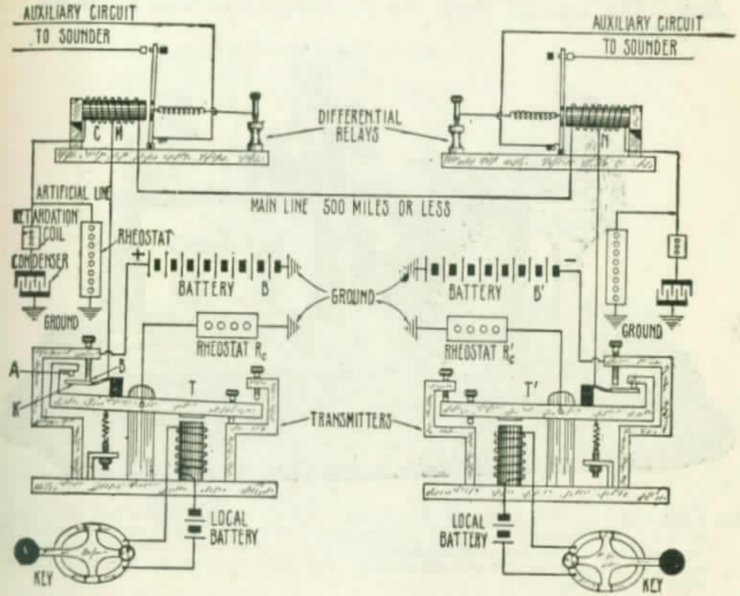


FIG. 3,075.—The Stearns differential duplex telegraph system. The equipment for each station consists of a key, transmitter, differential relay, sounder, rheostats, condenser, retardation coil, batteries and connections as shown. The batteries B and B′ contain the same number of cell. The lever of the transmitter T is connected to ground through the resistance R_c which compensates for the internal resistance of the battery, making the resistance of the circuit the same whether the transmitter be open or closed; similarly for T′. The circuit can be traced from the tongue contact K to the point of division M, known as the "split." At this point one branch goes through the right portion of the relay winding to the main line, and the other through the left portion of the relay, the artificial line and to ground. When K is in contact with B, the circuit is through battery B to ground, and when in contact with A, it is through the transmitter lever, and rheostat R_c to ground. The purpose of the rheostat R_c is to divide the current passing through the relay coils equally between the main and artificial lines. When this condition is established, no matter what be the size of battery, the current will pass through the relay with no appreciable effect upon it and the duplex is said to be "*balanced.*"

station without producing any magnetizing effect. Consequently, the relay and sounder at the home station remain unresponsive, but at the distant station, the current will flow through only one set of coil at that station and will cause it to operate the local sounder. The same effect, of course, is produced when the key of the distant station is depressed.

Ques. What happens when the keys at the two stations are depressed simultaneously?

Ans. The current from the combined batteries increases the

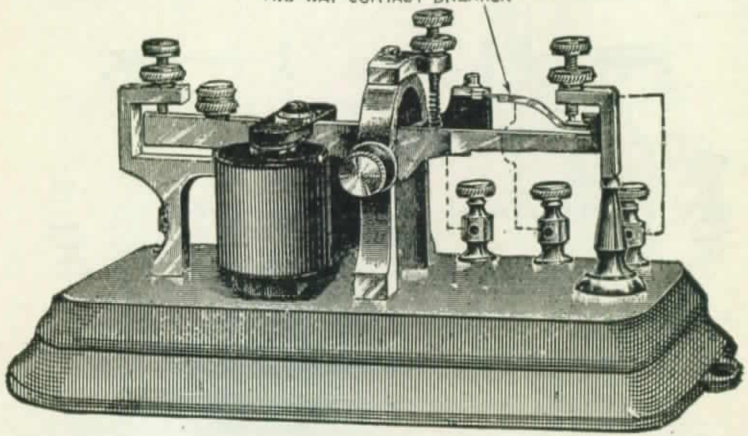


FIG. 3,076.—View of transmitter showing construction and circuits of the two way contact breaker. The distinction between a repeater and a transmitter should be noted, viz: a repeater has a two point contact breaker and a transmitter a three point contact breaker, controlling respectively one and two circuits. The three point contact breaker is shown in detail in fig. 3,078.

strength of the current flowing through one set of the differential coils of each relay, magnetizing them and causing them to work their respective sounders in response to the signals sent from the opposite station.

Ques. In practice are the relays connected direct to the keys as indicated in the preceding questions?

Ans. No.

Ques. How are they operated?

Ans. The relays are operated indirectly by the keys by means of transmitters.

Ques. What is a transmitter?

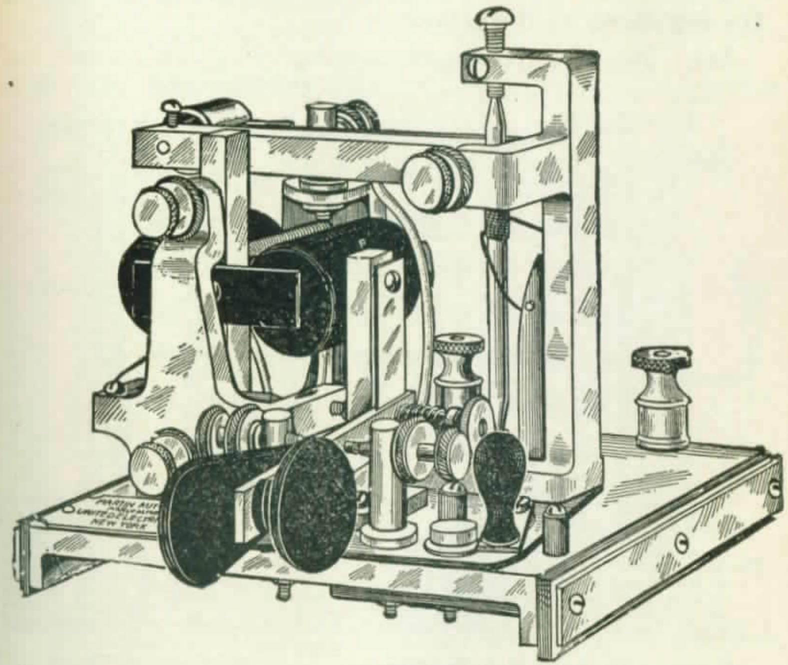


FIG. 3,077.—Bunnell autoplex or semi-automatic transmitter. This apparatus is for automatically making dots, so as to enable operators to transmit Morse characters without the excessive strain necessary for such transmission with ordinary key. It is a simple instrument, and has a highly polished base, upon which is placed the dotting mechanism and the binding posts for main and local batteries. Its speed can be adjusted from 10 to 90 or more words per minute. Explicit directions for use accompany each instrument.

Ans. A sounder provided with a two way circuit breaker.

That is to say, it is equivalent to a single pole two way switch, or a key with an insulated contact at each end.

Ques. What is the difference between a repeater and a transmitter?

Ans. A repeater has a one way contact breaker and a transmitter has a two way contact breaker.

Ques. Why is a transmitter used instead of connecting the key direct to the relay?

Ans. To obtain prolonged contacts.

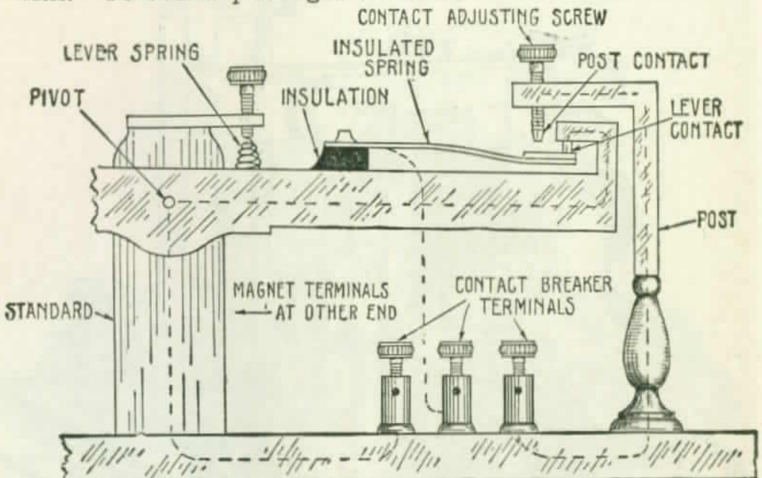


FIG. 3,078.—Detail of contact breaker end of a transmitter showing the three contacts, method of mounting the spring contact, and the circuits from the contacts to terminals. The duration of contact, or portions of the stroke of lever during which the circuit through the post contact and spring contact remains closed is regulated by the contact adjusting screw. This adjustment and other construction details are clearly shown in the illustration.

Ques. Explain this feature.

Ans. One of the three contacts of the contact breaker is mounted on a spring, which by its elasticity allows the contacts to remain together during a considerable portion of the stroke of the lever, whereas the key contacts touch each other only at the end of the stroke.

Fig. 3,078 illustrates the construction of a transmitter.

Ques. At what point of the relay winding is the "split" M located?

Ans. At the middle point.

Ques. What is the object of the condensers?

Ans. To give a capacity equivalent to that of the line. The electrostatic capacity of overhead telegraph wires is much less

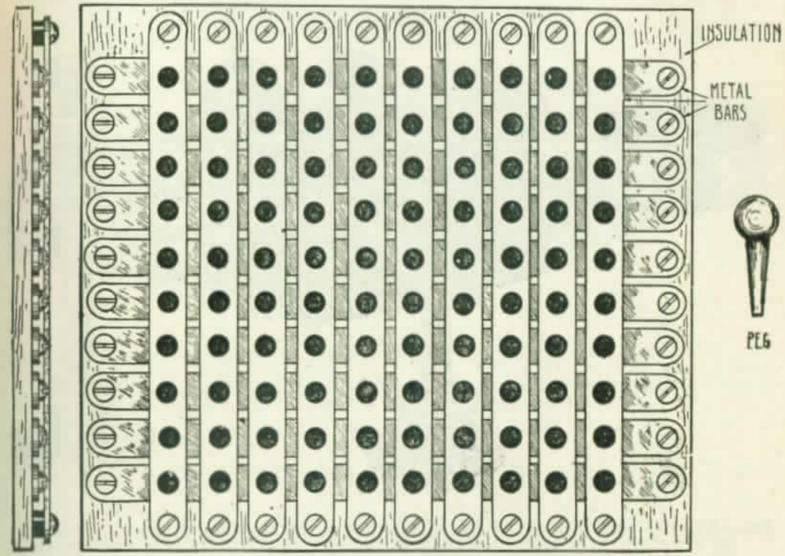


FIG. 3,079.—Western Union type of cross bar switchboard. The bars are made of copper or brass and are connected by plugging metal pegs into the holes, which closes the horizontal and vertical bar circuits.

than underground or marine cables, in the ratio of about 1 to 23. The effect of charging a conductor is that, at the moment of charge a greater rush of current takes place into the wire than would be the case if the capacity were zero. When the battery is removed and a route to earth provided, the accumulated charge rushes out in a direction opposite to that of the charging current. **Accordingly,** when, *due to electrostatic charge or discharge of the main line, the current in the main line coil of the relay is increased above that traversing the artificial coil of the relay,* **a false signal** *will be produced* **unless,** *at that instant, the current flowing in the artificial line side of the relay is increased to an equal value.* This is what is accomplished by using **condensers** and **retardation coils** in connection with the artificial line.

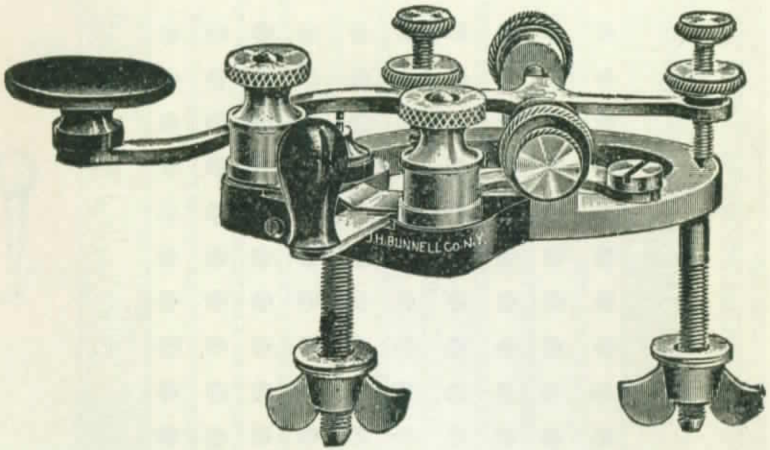


FIG. 3,080.—**Voltaplex key** as used in the voltaplex system of duplex telegraphy. The voltaplex is a system of duplex telegraphy of the superposed type; that is, a wire provided with ordinary Morse instruments is also equipped with the voltaplex instruments, and as neither system interferes with the other, they may be used as independently as if wired separately. As there is no artificial line, as in other duplex systems, no balancing is required for changing conditions on the line. No expert knowledge is required, for this system and operators of average ability are able to take care of it after it has been installed. The system is, therefore, especially adapted to situations where it is impractical to employ men trained in wire work.

Were it not for the compensation accomplished by the condensers, the effects of the electrostatic charges and discharges upon the home relays when both stations are sending would be of such an injurious nature that duplex and quadruplex telegraphy (especially the latter) would be impracticable.

Ques. Explain the use of the retardation coil.

Ans. It is employed to retard and diminish the condenser charge and discharge to conform more closely to the actual conditions in the main line.

Ques. Describe some features of the type of condenser commonly used.

Ans. There are usually five discs, marked 40, 32, 16, 8, 4, to denote the percentage of tin foil area connected to the disc.

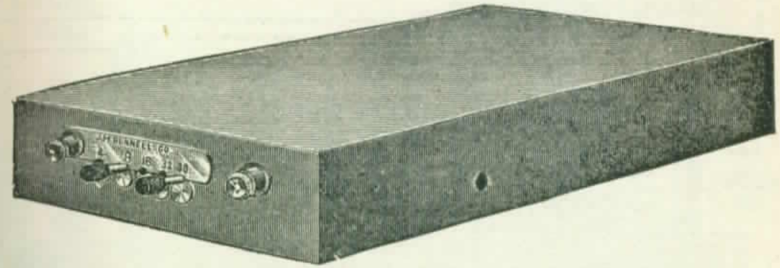


FIG. 3,081.—Bunnell adjustable telegraphic condenser showing 4, 8, 16, 32, and 40 per cent. peg adjustment. The interior construction consists of a number of sheet of tin foil interleaved with insulation, usually mica. As connected in the duplex system alternate leaves are connected with the artificial line and the intervening leaves to ground.

If pegs be inserted uniting the bar with the discs 4, 16, 40 and 60 per cent. of the capacity is in use, and the charge and discharge will be in just that proportion. Fig. 3,081 shows the appearance of a telegraphic condenser.

Ques. What size of condenser is usually employed?

Ans. 2.5 or 3 micro-farads. One micro-farad is equal to the capacity of about three miles of Atlantic cable.

The Polar Duplex System.—This method is an important modification of the differential method. Each station is provided with two batteries or dynamos, which are arranged in such a manner that the direction of the current in the line depends on whether the key is in its raised or depressed position. As in the case of the differential method, the current divides at the relay, which instead of being of the differential type is known as a *polarized relay*.

In regard to this instrument, which has already been described, it should be remembered, that in the ordinary relay the movement of the armature is effected by the action of a retractile spring in combination

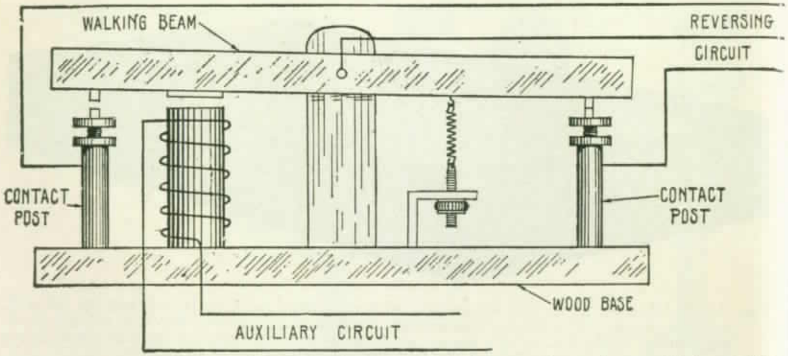


FIG. 3,082.—Essential parts of a walking beam type pole changer. As can be seen it is impossible for all three wires of the reversing circuit to be connected at any instant, that is before each reversal, the circuit is broken, thus interposing an air gap; this is an undesirable condition where dynamos are used for current supply, because, their very small internal resistance would otherwise permit considerable sparking.

with the magnetization and demagnetization of the relay electromagnet, but in the polarized relay the retractile spring is not employed to effect the backward movement of the armature, this being done by means of a reversed current or a current having a direction opposite to that which caused the forward movement.

Ques. How is the reversal of the direction of the current effected?

Ans. By means of a pole changer.

Ques. What is a pole changer?

Ans. A sounder or relay having a circuit reverser.

Ques. What is the difference between a pole changer and a pole changing transmitter?

Ans. The construction of a pole changer is such that the circuit is momentarily broken at each reversal, whereas in the pole changing transmitter, continuity of circuit is preserved.

When dynamo currents were introduced in the operation of telegraph lines it was found that pole changing transmitters or circuit continuity preserving pole changers were not satisfactory owing to the momentary

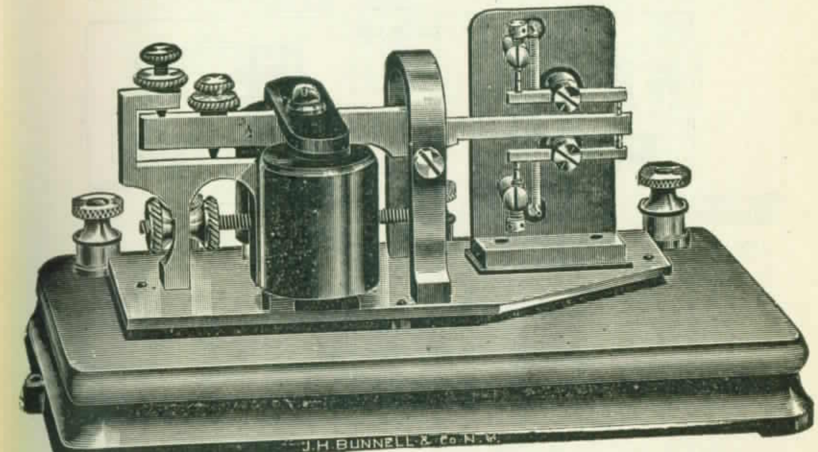


FIG. 3,083.—Bunnell, new type Western Union model pole changing transmitter, or circuit continuity preserving reverser, suitable for use with battery currents.

short circuit existing at each reversal, which, on account of the extremely small internal resistance of the dynamo as compared to the battery, resulted in excessive sparking. Accordingly, a pole changer or air gap preserving reverser became necessary. An instrument of simple construction which has this feature is the walking beam type of pole changer as shown in fig. 3,087.

Ques. Describe the operation of the battery polar duplex system.

Ans. The diagram fig. 3,084 shows the system. The equipment and connections are exactly the same at both terminals, and the description of the operation at one will serve for both. The diagram shows the keys open and the batteries of equal strength connected in opposition. Accordingly no current flows in the main line but in the artificial line, the current flows round the core in a direction to produce north and south polarities, as indicated. When the key K′ is depressed, thereby closing the

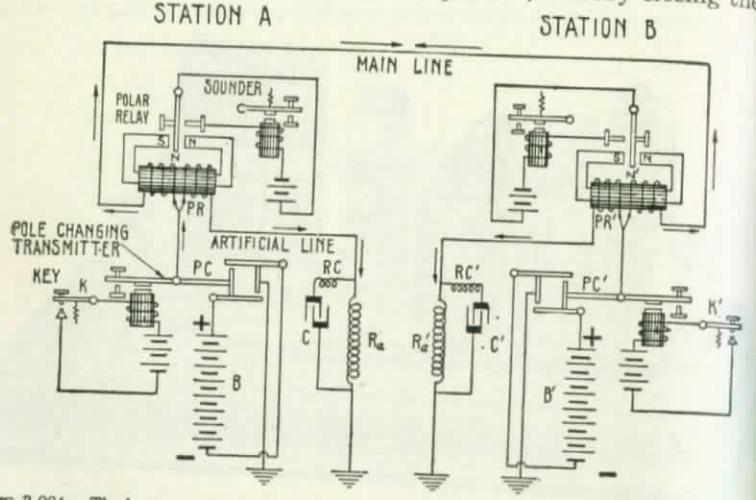


FIG. 3,084.—The battery polar duplex system. When the resistance of the main line is balanced by the resistance of a set of adjustable coil in the rheostat R_a of the artificial line, the current will divide into two equal parts at the polarized relay, and passing around the cores in different directions will neutralize each other and thus fail to magnetize the relay. This is called the *ohmic balance*. The *static balance* is effected by neutralizing the static discharge on the line by shunting the rheostat R_a, by means of an adjustable condenser C and a retarding coil RC.

pole changing transmitter PC′ at station B, the connections of battery B′ are changed or reversed, and it adds its pressure to that of battery B, and the current flows from the positive terminal of battery B to the negative terminal of battery B′, or from the station A to station B. The current in the main line is, however, twice as strong as in the artificial line, and the

magnetic conditions produced on each side of the armature N and N′ of the permanent magnets are such that the relay PR′ is held open and the relay PR is caused to close thereby closing the local sounder also. If the key K at station A terminal be closed at the same instant the key K′, is closed, the batteries will be placed in opposition with their negative (—) poles

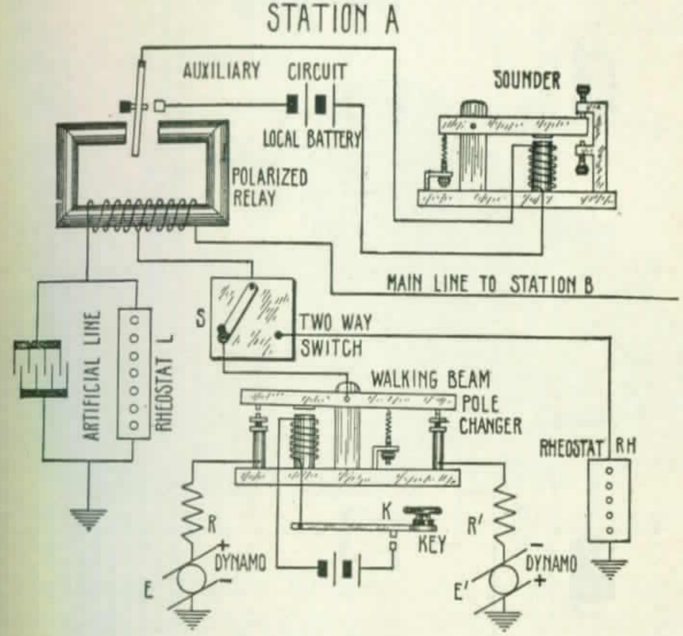


FIG. 3,085.—The dynamo polar duplex system. E and E′ are the dynamos, E for the positive and E′ for the negative current. These supply their currents through resistance coils R R′ either of German silver wire or of incandescent lamps. K is the key which closes the local circuit of the walking beam pole changer. The position of the lever of the pole changer determines which current is being sent to line through the pivot of the lever. The two way switch S is for changing from duplex to ground connection through a rheostat RH for the purpose of enabling the distant station to obtain a balance. From the switch the current goes to the junction of the two coils of the relay where it divides, one-half going to the main line, if the line circuit be closed at the distant station, and the other half through the artificial line to ground. The resistance in the artificial line is made equal to the resistance of the line and relay coils at the distant station. This is adjusted, not by measurement, but by trial. The operator at the distant station turns his switch to the ground position and signals are then sent by the operator at the home station.

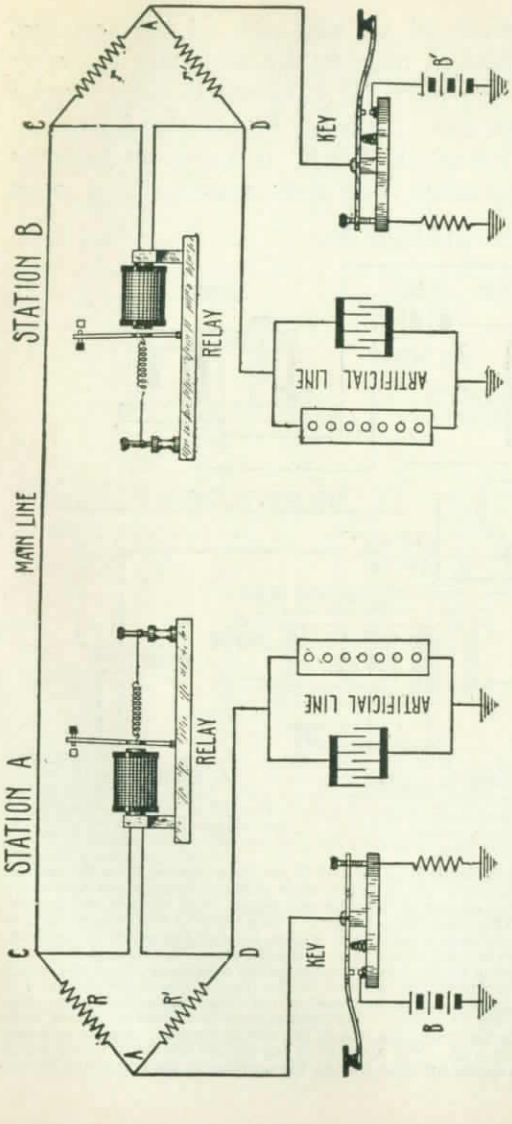


FIG. 3,086.—Diagram illustrating the operation of the bridge duplex system. In the figure, B and B' are the main line batteries, one at each station. R, R' and r, r' are the bridge resistances at each station. The various connections are clearly shown in the diagram. **In operation,** closing station A key sends out a current which divides at A, half passing over the main line to station B, and reaches earth via the apparatus at that end of the line, while the other half passes through the artificial line at station A, reaching the earth at that end of the circuit. Since the resistance between C and D is the same as R or R', the pressures at C and D are equal, and no current will flow through station A relay. This holds only when the resistance of station A artificial line is made equal to the resistance of the actual line to ground at the distant end. The relay at A is accordingly not affected when A sends to B. The same condition obtains when B alone sends to A. Signals from A operate the relay at B because the incoming signals have a joint path made up of the branches CD and CA, thus setting up a difference of pressure between the points C and D sufficient to operate the relay. The operations which take place with different key combinations at either end of the bridge duplex may be traced without difficulty. Since the line relay employed in the bridge duplex does not need to be differentially wound, it is evident that any ordinary relay may be used with this method of duplexing. It is apparent, also, that the outgoing currents do not pass through the windings of the home relay, and, as the currents pass directly to line, there is a minimum amount of retardation in the sending circuit.

to the line and there will be no flow of current on the main line, but the current in the artificial line, flowing from the ground to the negative poles of the batteries will produce the magnetic condition required to close relay PR' at station B while the relay PR remains closed by the action of the key K', thus fulfilling the conditions necessary for duplex working, viz, *that the movement of the key at either of the two terminals should have no effect upon its own local relay, but should operate the relay of the other terminal.*

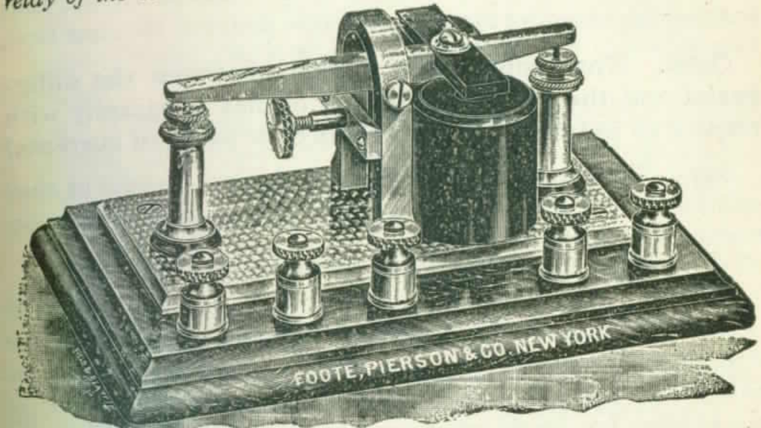


FIG. 3,087.—Foote, Pierson walking beam type pole changer or circuit breaking reverser for use with dynamo currents.

The Bridge Duplex System.—This method is based on the principle of the **Christie** or so called Wheatstone bridge*. It is used in the operation of submarine telegraph cables. In

*NOTE.—The author desires to again emphatically protest against applying the name Wheatstone to this bridge. This ingenious and useful system of electrical measurement was first described by **Samuel Hunter Christie**, in *Phil. Trans. R. S.*, 1833, 95–142. Its importance remained unappreciated until attention was directed to it by Professor Charles Wheatstone, in a lecture before the Royal Society in 1843, entitled "An account of several new Instruments and processes for determining the constants of a voltaic circuit." *Phil. Trans. R. S.*, cxxxiii, 303–327. *Although full credit was accorded to* **Christie** *by Wheatstone for his admirable device,* electricians have ever since persisted in calling it the *Wheatstone Bridge,* and it seems probable that it will always continue to be known by that name, despite the injustice of such error.

this method, the relay is placed in the cross wire of a Christie bridge and the key is so arranged that connection is made with the battery before the line leading to the earth is broken. Adjustable resistance coils are placed in the arms of the bridge and a wire connects the key with one arm of the bridge, which is completed at the opposite end by a suitable arrangement. If the resistances be equal, the relays will not operate when the current is transmitted, but since the earth is employed to complete the circuit, they will respond to the received current, thus enabling each operator to send and receive signals at the same time.

Ques. What comparison is there between the differential and the bridge method of duplex telegraphy with respect to induced line disturbances or to earth currents?

Ans. The line relays of the bridge duplex, because of their position in the bridge are less responsive to induced line disturbances or earth currents.

Ques. Why?

Ans. Because in the bridge system only a portion of the line currents pass through the relay, no matter whether the currents be the result of an induced impressed pressure, or of conduction for neighboring circuits, while in the differential duplex, all currents existing in the main line pass through the windings of the line coil of the relay magnet.

The bridge duplex has been more highly developed in Europe than in America, and several of the refinements applied to its operation there are particularly noteworthy as having a bearing on the general subject of high speed signaling.

The Quadruplex System.—This method of telegraphy permits the simultaneous sending of two messages in either direction over a single wire. Theoretically it consists of an

arrangement of two duplex systems, which differ from each other so greatly in their principles of operation that they are capable of being used in combination. The earliest system was devised by Edison, and was first used by the Western Union Telegraph Company in 1874. Since then new and improved methods have been devised by Prescott, Gerritt Smith, Stearns, Fields, and others, and at the present time quadruplex working is employed on all busy lines, particularly those between large cities.

Ques. What devices are essential for quadruplex working?

Ans. The sending apparatus consists of a reversing key and a variable current key (or equivalent), and the receiving apparatus consists of a neutral relay and a polar relay, batteries and connections as shown (in part) in fig. 3,088.

Ques. What are the two divisions of the main battery called?

Ans. The long end and the short end.

Ques. What is the name of the wire joining the intersection of the long and short end of the battery?

Ans. The tap wire.

Ques. What is the object of the resistance inserted in the tap wire?

Ans. To act as a compensation for the sudden change in resistance when the long end of the battery is short circuited by the variable current key.

Ques. Where should the tap wire connect with the battery?

Ans. At a point dividing the battery in the ratio of about 1 to 4.

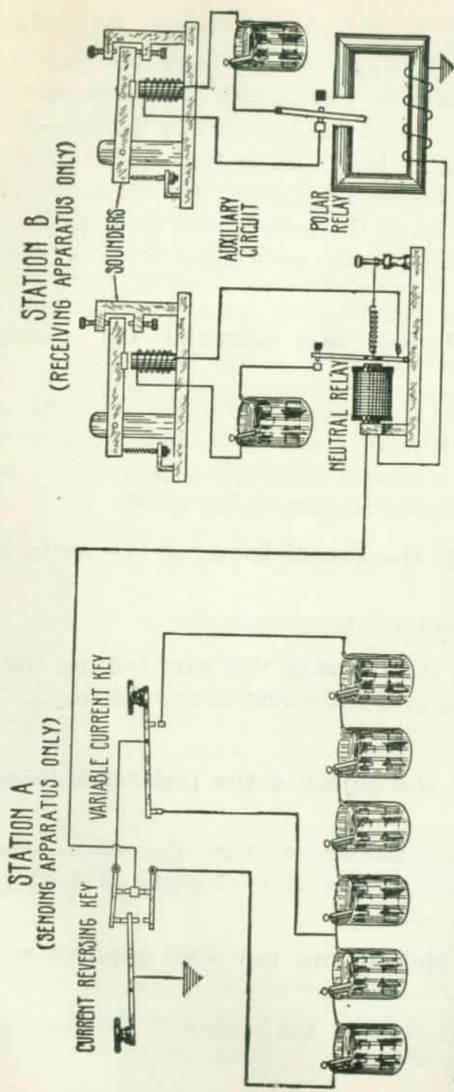


FIG. 3,088.—Elements of the quadruplex system. For simplicity, the receiving apparatus is omitted at station A and the sending apparatus at station B, the complete installation being shown in fig. 3,089. Because of the fact that a polar relay responds solely to changes in direction of the current, and a neutral relay to changes in strength of the current, it must be evident that, if the two relays be connected in series as shown, signals may be produced by the polar relay by operating the current reversing key, and with a sufficiently weak current the neutral relay will not respond; also, if the *direction* of the current be maintained constant by using the variable current key signals will be produced on the neutral relay but not on the polar. Hence, with this arrangement, two messages may be sent from station A to station B simultaneously, and by extension, if the reader imagine each station fitted with both sending and receiving apparatus, four messages may be sent at one time, thus giving quadruplex operation.

Ques. Of what does the "No. 1 side" of the quadruplex consist?

Ans. The polar key, pole changing transmitter, polar relay, and their auxiliaries.

Ques. The No. 2 side?

Ans. The neutral key, transmitter, neutral relay, and their auxiliaries.

Ques. What name is sometimes applied to the battery compensating resistance?

Ans. The ground coil.

How to Adjust the Quadruplex.—The following method of procedure has been recommended by experienced operators, though it is proper to say that some difference of opinion exists in reference to the minor details of adjustment:

1. Instruct distant station to "ground." He will then put the line to ground through his ground coil. Both stations should assure themselves that the resistance of the ground coil is equal to that of the battery.

2. Center the armature of the polar relay. When centered, it should remain indifferently in either an open or closed position of the local circuit as placed by the finger.

3. Switch in the home battery, and vary the rheostat resistance in the artificial line until the polar relay can be again centered.

4. Instruct the distant station to switch in his battery. This may assist in adjusting the polar armature.

5. Instruct distant station to close both keys, thus sending full current to you. Close No. 2 key; send dots with polar key, and alter the capacity of condenser until its effects on the home polar relay are eliminated. This condition is termed the *electrostatic balance*.

6. Instruct distant station to send dots with polar key and words with neutral key. While this is being done, alternately open and close both keys at the home station. If both sets of signal from distant station come distinctly under all circumstances, the balance is obviously correct. The same test should be repeated by the distant station, in order to insure an accurate working adjustment.

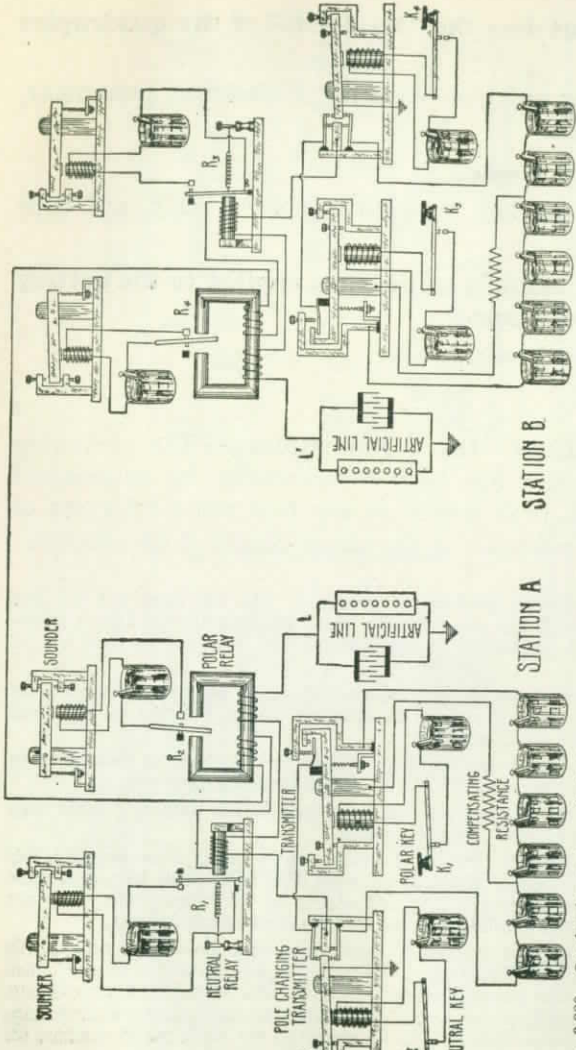


Fig. 3,089.—Quadruplex system with battery current supply. The apparatus employed in operating the polar system of the duplex is generally called the "No. 1 side of the system," or the polar side. It consists of the polar key and the polar relay at either station. The apparatus employed in operating the other system of the diplex is called the "No. 2 side of the system," or the neutral side. It consists of the neutral key and of the neutral relay. **In operation,** when none of the keys are depressed, no current flows through the line, but a comparatively feeble current flows through the artificial lines L and L′, insufficient to operate the neutral relays, and to maintain the polarized relay tongues on the dead stops. Consequently, none of the sounders respond. If now K_1, be depressed, a strong positive current is sent to line at station A. This does not affect the relays at A, since it passes through them in opposite directions but on arriving at B, it tends to keep the polarized relay tongue R_4, on the dead stop, while it has sufficient power to operate the neutral relay R_3. In the same way if K_3 alone be depressed, relay R_1 alone will respond. If K_2 alone be depressed, a feeble negative current will flow to line, in a direction which will actuate R_4, but it will not have sufficient power to actuate R_3. If K_4 alone be depressed R_2 alone will similarly respond alone. The depression of any key will cause its corresponding relay to close its local circuit at the distant end of the line, regardless of the condition of the keys at that end. In practice the reversed position of neutral relay stop requires a repeater with contact on the upstroke between each neutral relay and sounder, or the equivalent secured by transposition of battery, for synchronous operation: these modifications are here omitted for simplicity.

If the sending on No. 2 side should fail to come well, instruct distant station to hold No. 1 key open for a few seconds, and then closed the same length of time. If the signals come imperfectly in both cases, it indicates that the contact points of the distant pole changing transmitter require cleaning. A very fine flat file is the proper tool to use for this purpose.

If the dots on No. 1 fail to come well at the same time with the writing on No. 2, instruct distant station to alternately open and close No. 2 key at intervals of a few seconds; the trouble may usually be traced to defective contacts upon the transmitter, provided the balance has been properly attended to.

It should not be forgotten that a change of weather which is sufficient to affect the insulation of the line, may necessitate a eadjustment, to a greater or less extent, of both the rheostat and condenser balance of the quadruplex. Both the line resistance and the electrostatic capacity are diminished by a defective state of insulation.

Telegraph Codes.—There are three *codes* or systems of signa used for general telegraphic purposes, ***the Morse code,*** which is exclusively used in the United States and Canada; ***the Continental code,*** used in all European and other countries, and in all submarine telegraphy by international agreement; and ***the Phillips code,*** which is used for "press" work in the United States.

In the *Morse code* the letters of the alphabet are made up of the simplest combinations of the three elements defined as:

1. The dot;
2. The dash;
3. The space.

The shortest combinations are given to the letters which are most frequently used. For example: E and T are the letters which occur most frequently in the English language, therefore, E is represented by the simplest signal, a dot, and T by the next simplest, a dash.

In the *Continental code* spaces are not used, the letters being made up of the simplest combination of the dot and the dash.

The Codes

LETTERS			
Morse	Continental	†Navy	*Bain
A ·—	A ·—	A ——	A ·—
B —···	B —···	B —··—	B ·—·
C ·· ·	C —·—·	C ·—·	C ···
D —··	D —··	D ———	D ··—
E ·	E ·	E ·—	E ·
F ·—·	F ··—·	F ———·	F ·———
G ——·	G ——·	G ——··	G ·—··
H ····	H ····	H ·——	H ·——
I ··	I ··	I ·	I ··
J —·—·	J ·———	J ·——	J ···—
K —·—	K —·—	K —·—·	K ·——·
L ——	L ·—··	L ——·	L ····
M ——	M ——	M ·——·	M ·— ·—
N —·	N —·	N ··	N ··——
O · ·	O ———	O —·	O —
P ·····	P ·——·	P ·—·—	P —·—
Q ··—·	Q ——·—	Q ·—··	Q —·—·
R · ··	R ·—·	R —··	R ——·
S ···	S ···	S —·—	S —··
T —	T —	T —	T —···
U ··—	U ··—	U ··—	U —·
V ···—	V ···—	V ·———	V ———·
W ·——	W ·——	W ··—·	W ——··
X ·—··	X —··—	X —··—	X —··—
Y ·· ··	Y —·——	Y ···	Y ——
Z ··· ·	Z ——··	Z ————	Z ———
& · ···	&	&	& ————

NUMBERS			
1 ·——·	1 ·————	1 ····	1 ·————
2 ··—··	2 ··———	2 ——·—	2 ··———
3 ···—·	3 ···——	3 ···—	3 ···——
4 ····—	4 ····—	4 ———·	4 ····—
5 ———	5 ·····	5 ··——	5 ·····
6 ······	6 —····	6 ——··	6 ————·
7 ——··	7 ——···	7 ·———	7 ———··
8 —····	8 ———··	8 —···	8 ——···
9 —··—	9 ————·	9 ·——·	9 —····
0 ——	0 —————	0 —··—	0 ——·——

PUNCTUATION MARKS			
	Morse	Continental	Phillips
Period	··——··	·· ·· ··	··——··
Colon	—·— · ·	———···	—·— · ·
Colon Dash	—·— ·—··	—·— —·	—·— ·—··
Semi-colon	··· ··	—·—·—·	··· ··
Comma	·—·—	·—·—·—	·—·—
Interrogation	—··—·	··——··	—··—·
Exclamation	———·	——··——	———·
Fraction Line	·	——	·
Dash	—·· ·—··	—·· —··—	—·· ·—··
Hyphen	···· ·—··	—····—	···· ·—··
Apostrophe	··—· ·—··	·————·	··—· ·—··
Dollar Mark	··· ·—··	··· —··—	··· ·—··
Pound Sterling	····· ·—··	—··—··	····· ·—··
Shilling Mark	··— —	—·· —·	··——
Pence Mark	·····	—··	—··
Capital Letter	·· · ·—··	—·—· —··—	·· · ·—··
Colon Followed by Quotation	—·— ··—·	—·— —··—	—·— ··—·
Cents	·· ·	—··—·	·· ·
Decimal Point	—·· · · —	·——·	—·——
Paragraph	————	·—·—··	————
Italics or Underline	··— ·—··	··——·—	··— ·—··
Parenthesis	····· —·	—·— —·—	······—· ·······—·
Brackets	—··· ·—··	—··· —··—	—··· ·—·· —··· ·—··
Quotation	··—· —·	·—·—·—·—	··—· —· ··—· —·
Quotation in Quotation	··—· ·—··	·—··—·	··—· ·—·· ··—· ·—··
Per Cent	—·—	————··———	——··——

Learning a Code.—The student should first thoroughly commit to memory the groups of signs representing the letters of the alphabet, the numerals and the principal punctuation points, viz., the period, comma, and point of interrogation; the remaining characters can be learned afterwards, as they will be little needed by the beginner. By constant drill the habit of making dots with regularity, uniformity, and precision must first be acquired; then dashes, and lastly in order, group of dots and dashes, letters and words. If possible for the student to obtain a register, he should by all means employ it in his practice, for he will then be more easily enabled to observe and correct the faults in his own manipulation. The student should learn to form the conventional characters accurately and perfectly; speed will come in good time, but only as the result of constant and persistent practice.

†NOTE.—The Navy code is now obselete, being discontinued Nov. 16, 1912; the Navy at present uses the Morse.

*NOTE.—The Bain code was at one time in use in parts of America and Europe in connection with the Bain chemical telegraph system, but is now obsolete, though of historical interest.

The following specifications based on the duration or length of time allowed for a dot, are applicable to the combinations employed in all the codes.

The dash is equal to two dots.
The long dash is equal to four dots.
The space between the dots and dashes of a letter is equal to one dot.
The interval in spaced letters is equal to two dots.
The space between letters of a word is equal to two dots.
The space between words is equal to three dots.

In the *Phillips code* the letters and numerals are the same as the Morse, but the punctuations and symbols are different from the other two codes, some being taken from each code.

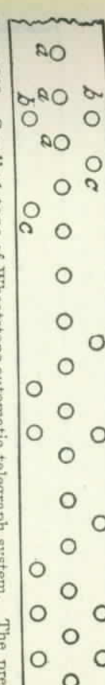


FIG. 3,030.—**Sending tape** of Wheatstone automatic telegraph system. The preparation of the transmitting tape is accomplished by means of three key mallet perforators, or by keyboard perforators, which may be operated by any telegrapher after a little practice. The Wheatstone transmitter is practically a high speed pole changer operated automatically instead of by means of a Morse key in the hands of a telegraph operator.

Automatic Telegraphy.—This method is employed for increasing the speed of transmission of messages. The speed of the ordinary Morse instrument is limited to the rapidity with which the hand of the operator can move the key standard and varies from about 25 to 50 words per minute. A speed of 50 words per minute is the sending rate of expert operators.

There are telegraph keys used for wire and wireless work which will send one hundred words a minute, but unless there is an automatic registering receiver it is impossible for an operator to receive more than fifty words a minute; consequently these so called "bug keys" are seldom used for commercial work.

The Wheatstone Automatic Telegraph.—This is employed for increasing this speed to at least 150 words per minute, and consists of a perforator, a transmitter and a printing receiver.

These instruments are operated as follows: By means of the three punches constituting the perforator, the operator punches a series of holes in a paper tape to correspond with the code signals required for the message, as shown in fig. 3,090. The center punch produces a row of holes along the center line of the tape, which are of no use electrically, but which merely serve to carry the tape forward. At each stroke, the left hand punching disc produces two holes, *bb*, located directly opposite each other, along the edge of the tape. At each stroke, the right hand punch produces two holes *cc*, located diagonally to each other. The tape thus punctured is passed through the transmitter by the movement of a clock work mechanism.

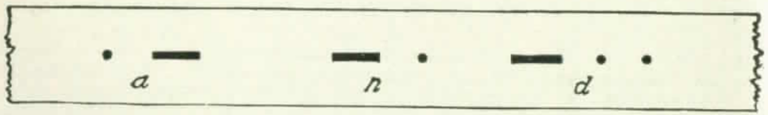


FIG. 3,091.—**Receiving tape** of Wheatstone automatic telegraph system. The receiving tape is passed to copyists who understand the Morse code and who translate the characters. The receiver complete includes the polarized relay, the inking gear, the tape moving mechanism and the paper tape. The speed at which the tape travels under the inking wheel may be regulated to suit the speed of the received signals.

The holes of the *bb* order allow a momentary passage of current through the transmitter, thus sending a dot to the receiver. The holes of the cc order allow a current of longer duration to pass through the transmitter, thus sending a dash.

The dots and dashes thus transmitted are reproduced by the receiver on a paper tape as shown in fig. 3,091, both the transmitting and the receiving being done with a mathematical accuracy which is unattainable with the standard key. The speed of transmission depends upon the length of the line and the atmospheric conditions at the time, but the movements of the clockwork, of both the transmitter and receiver, can be adjusted to any speed up to 150 words per minute.

The Delaney Multiplex Telegraph.—This system provides for the simultaneous transmission of a number of messages either in the same or opposite directions. The apparatus employed consists of a circular disc or table carrying a number of contact pieces, some of which are connected with the separate transmitting instruments, while others are connected with the local relays, the batteries and the earth.

A rapidly revolving arm, called the trailer, connected with the line wire passes over these contact points and successively completes the circuit through the different instruments at one station, while the trailer at the other station, revolving synchronously with the trailer at the first station, makes connections with an equal number of receiving instruments.

The speed at which the trailers revolve is regulated by means of two tuning forks or pitch pipes of the same pitch and an ingeniously designed synchronizer keeps them always revolving together. With this arrangement it is possible to transmit simultaneously twelve different messages over a single wire. The manner in which this is accomplished may be briefly explained as follows: When an operator closes his transmitting key, the contacting of the revolving trailer will connect his instrument to the line wire about 36 times per second, thus transmitting that number of impulses to the synchronizing receiver. Therefore, if the operator desire to send a signal corresponding to a dot, and closes his key for a brief interval of time such as a fraction of a second, the impulse will be transmitted to the receiving instrument at the other station, which is the only one in a position to receive the signals from his transmitter. The same holds true for the other operators and their instruments, each one using the wire for a certain fraction of the same second.

The Rowland Multiplex Printing Telegraph.—This system has been used in several European countries. It employs four transmitters and receivers, which are operated by alternating current and can be used in connection with one wire. The signals are transmitted by means of a mechanical keyboard somewhat similar to that of a typewriter, and are reproduced on tape or ordinary letter pages in type written characters by an automatic printing receiver.

Submarine Telegraphy.—The practice of submarine telegraphy differs in many ways from that of land lines. This is due to the fact that usually the current has to be transmitted along a conductor of great length and necessarily of small cross section, consequently having considerable resistance. Furthermore, due to electrostatic induction the cable acts as a condenser, the core of the conductor forming one of the plates or conducting surfaces, and the metallic sheathing acting as the other.

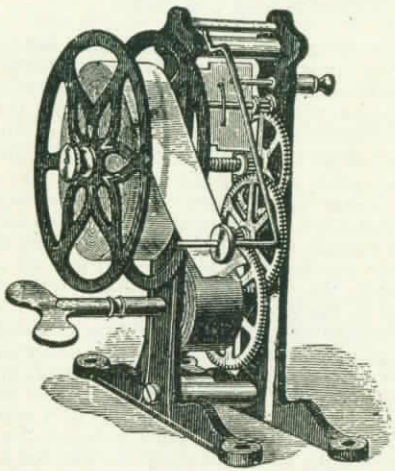


FIG. 3,092.—Bunnell automatic paper winder; view showing clockwise mechanism, winding key and paper reel.

As a result of these conditions, it takes an appreciable length of time for the cable to become charged and discharged when a current is passed through it, so that there is a certain limit to the speed of transmission beyond which the signals lose definition and become confused and unintelligible. As the length of the cable increases, the time required by it to charge and discharge increases, and the rate of transmission varies inversely as the square of the length.

Another serious drawback is the attenuation of the current on long cables. On those over 500 miles in length the current

is so feeble, that the use of ordinary telegraph instruments is impossible, and only on lines not exceeding 150 miles can an ordinary rate of transmission (about 25 words per minute) be maintained by means of hand worked keys.

Ques. What special device is necessary on long lines?

Ans. A sensitive instrument, such as a mirror galvanometer or Thomson siphon recorder.

Ques. Describe the Thomson Siphon recorder.

Ans. It consists of an exceedingly light coil of fine wire suspended between the poles of a powerful magnet. When the

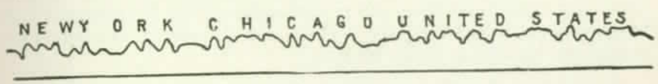


FIG. 3,093.—Siphon record of a message received over a long ocean cable.

current transmitting the signals passes through the coil, the latter is swung around by the attraction of the magnet, either backward or forward, according as the current is positive or negative. The motions of the coil are communicated by means of silk fibres to a little glass siphon about the thickness of a needle and three or four inches in length, so suspended that while one end dips into a vessel containing ink, the other is in very light or vibratory contact with a strip or tape of paper, which is moved through the apparatus either by electrical means or by clockwork.

When the coil moves in response to the signals transmitted, the pen end of the siphon traces a wavy line on the tape, as shown in fig. 3,093, the curves of which represent the message or signals by the code of dots and dashes. These curves are above or below the line of rest or normal position of the pen on open circuit, depending upon the direction of the current passing through the coil, an upward curve representing a dot produced by a positive current over the wire, and a downward curve representing a dash produced by a negative transmitting current.

In transmitting, the current reversals necessary to produce the results described above, are effected either by means of keys worked by hand or by the use of automatic transmitters.

Ques. Describe a submarine key.

Ans. In construction, it is practically the same as the ordinary Morse key employed for land telegraphy, except that two keys are used side by side, constituting a pole changing device, by which either a positive or a negative current can be sent over the circuit by simply pressing one or the other of the two keys.

With this key, a first class cable operator can send a maximum of about 30 words per minute for a few minutes at a time, but a speed of 20 words per minute is a good average in sustained working.

The method of automatic transmission used on the trans-Atlantic cable and other busy lines is a modification of the Wheatstone automatic telegraph described on page 1,293. By its use an average rate of 50 words per minute is easily attained.

Condensers on Submarine Cable Circuits.—In the practical operation of submarine cables it was soon discovered that the efficiency of the cable, as represented by the speed of transmission, was doubled, and the effect of **earth currents** eliminated by the insertion of a condenser between the transmitter and the cable at both ends of the line. Fig. 3,094, shows the connections of a simple cable circuit of this description.

The Duplexing of Submarine Telegraph Cables.—This was effected in 1875 by Dr. Alexander Muirhead and Herbert Taylor, and their system employing a special form of cable relay was first successfully used on the trans-Atlantic cable in 1878. Since then, over 80,000 miles of submarine cable have been duplexed almost entirely with the Muirhead system, thereby increasing the rate of transmission to about 90 words per minute, and consequently doubling the commercial value of the cables thus operated.

Tests and Troubles.—Conductivity tests of wires are essential with telegraph systems as well as battery and generator troubles and proper adjustments of relays. The **Christie** or so called Wheatstone bridge is therefore much used by telegraph men for testing.*

The wire to be tested is grounded at some distant station after the distant operator has been informed to ground it. At the testing station the ring side of battery is applied by plugging a peg in the proper switchboard disc. The mil-ammeter is then connected in the circuit with

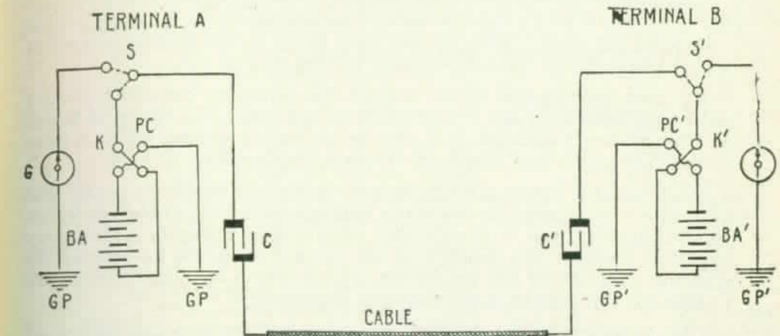


FIG. 3,094.—Diagram of a simple submarine telegraph cable circuit. The equipments of both terminals A and B are exactly the same, consisting of the transmitting keys K, K', the pole changing switches PC, PC', line switches S, S', galvanometers G, G', condensers C, C', batteries BA, BA', and the necessary ground plates GP, GP'. By means of the switches S and S', the current may be allowed to pass either to the earth through the galvanometers or other recorders, or to the transmitting keys K and K', thence through the batteries BA, and BA' to the earth, depending on whether the signals are being sent or received at the respective terminals. By means of the pole changing switches PC and PC', operated by the keys K and K', either pole of the battery can be connected to the condensers C and C', and thereby to the line at the will of the respective operators, and the cables charged inductively, the corresponding signals being reproduced at the distant terminals by connecting the galvanometer with the line by means of the switches S or S' as the case may be.

plug and cord at a spring jack. The meter reading will then show the strength of the current flowing, which is noted, and the mil-ammeter disconnected. As this meter resistance is less than one ohm it does not alter the current flowing. Then the meter is connected in series with the ground side of battery and the line (across the battery) and used as a voltmeter, showing the voltage used in causing the current previously noted, to flow in the line. From these current and voltage readings the resistance of the wire is calculated by Ohm's law; that is,

*NOTE.—See note on page 2,239.

the voltage is divided by the current to give the resistance. This test will show whether or not the wire be clear; that is, well insulated from other conductors and from dampness and other high resistance grounds.

To eliminate static discharges of the line the distant operator is asked to close his key and the condenser is then adjusted. If the static do not appear when the relay point is closed it cannot cause trouble at any other time.

The adjustment of relays must necessarily be experimental and uncertain and is left to the judgement of good operators and branch office attendants.

If a station be informed that difficulty is being found with a distant station relay, even though the balance be apparently O. K., and that the relays are interfered with by the local battery, the station attendant so informed should immediately inspect his ground coil.

An open ground coil would compel the incoming current to find a path to ground through the rheostat or the leak coil, either of which contain greater resistance than the compensating ground coil. A loose connection might add hundreds of ohms resistance to the coil.

In choosing a dynamo for telegraph circuits, it should be noted that very fine wire is used on the relay magnets and the problem is somewhat different from that of other electrical distribution. In every electrical problem the strength of the current must not be beyond the carrying capacity of the conductor, and nowhere is it more necessary to exercise this care than in telegraph engineering.

The resistances of the parallel circuits and of the series circuits must be well known and the liability of their variation.

Generally three or more dynamos are connected in series and taps from each extended to three separate rows of disc at the main switchboard. One side of the battery feed is grounded as is the tip side in telephone exchanges. These taps of the ring side would be designated the first, second, and third pressure, or sixty, one hundred and twenty, and one-hundred and eighty volts.

The telephone test receiver is used to a great extent in testing the quality of electric telegraph currents because of its sensibility to weak currents. Especially in cable testing is the test receiver valuable for locating faults. A trouble hunter will soon become accustomed to the several different tones or "clicks" which he hears in the receiver when connected in a circuit supplied with battery. In cases where the receiver and battery are connected through a high resistance the click will be faint and will be recognized as a "leak" click.

In the testing of open lines and fuses the test receiver is invaluable, for by strapping a receiver across the terminals of any open instrument or fuse the circuit is temporarily completed and the diaphragm will click sharply.

Printing or Typewriting Telegraphy.—In 1837 Alfred Vail, an associate of Morse, made elaborate and detailed working drawings of his proposed printing telegraph. However, this was never developed because both inventors were of the opinion that it could not successfully compete with the practically simple system which Morse had invented two years before.

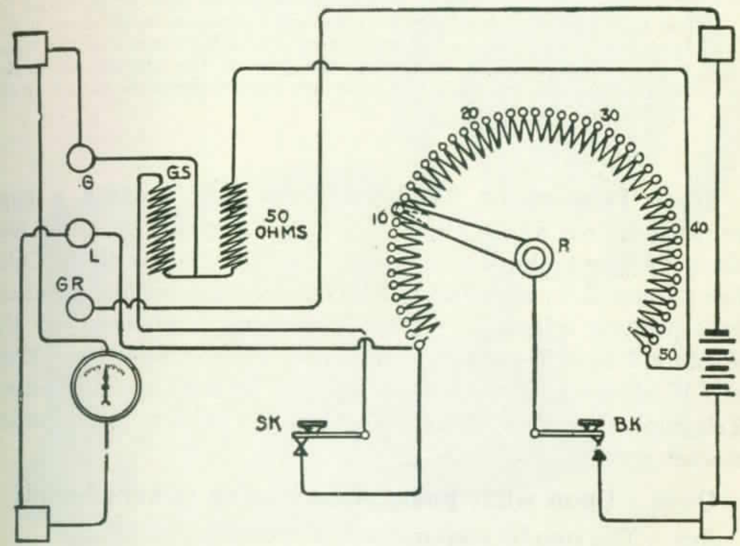


FIG. 3,095.—Circuit diagram of the Western Union proportional test set for the use of linemen and cable testers. This set consists of a simplified rheostat, a galvanometer and a battery contained in a box 7 × 9 × 5 inches in size. The component parts of the apparatus, with their connections, are here shown where GS is a galvanometer shunt, R a rheostat with a radial contact arm, BK a battery key, and SK a shunt key.

In 1846, E. House of Vermont invented and patented a system of printing telegraphy and ten years later D. Hughes of Kentucky patented another system.

In 1875, twenty years later, Phelps worked out and patented a practical system of telegraph printing which has since been improved.

Of the later systems developed there are three; the Wright, the Rowland, and the Buckingham-Barclay systems.

The Rowland and the Wright typewriting telegraph systems have each been tried out by the Postal Telegraph Company and while both performed excellent work under favorable conditions they have been abandoned temporarily and returned to the laboratory for further development.

The Buckingham-Barclay typewriting telegraph system is employed by the Western Union Telegraph Company for commercial work and is found favorable, but is still capable of further improvement.

Although the services of typewriter operators can be procured for less than the services of regular telegraph operators, in all cases it has been found that the cost of equipment and maintenance of the typewriting system equals or exceeds the cost of the services of expert telegraph operators, while the latter are more dependable for all traffic conditions.

Stock Printers or "Tickers."—As early as 1866 a type printing system was developed by S. S. Laws of New York, and the next year an improved system was patented by E. A. Calahan. Later Gray and Phelps developed a commercially practical type printing telegraph system which was introduced on the Western Union Telegraph Company's lines between New York and Washington. It was then adopted by the Gold and Stock Telegraph Company of New York for the sending out of stock market reports.

Ques. Upon what principle are stock tickers based?

Ans. The step by step method of operation.

Ques. Describe briefly the apparatus and its operation.

Ans. The operator has a keyboard consisting of two keys for opening and closing the circuit and a switch for starting or stopping the rotation of a small motor. Each key is connected to one of two wires and as many times as the operator breaks and closes the circuit with the keys, just so many steps forward or backward is the dial moved. Pulsating currents from these keys operate the relays and printing magnets of the distant

tickers with distinctly audible sound. When it is necessary to stop because the tickers are not working in unison a break switch is thrown.

Two standard tickers are in use by the Western Union Telegraph Company,—one of which is of the self-winding type. The other is

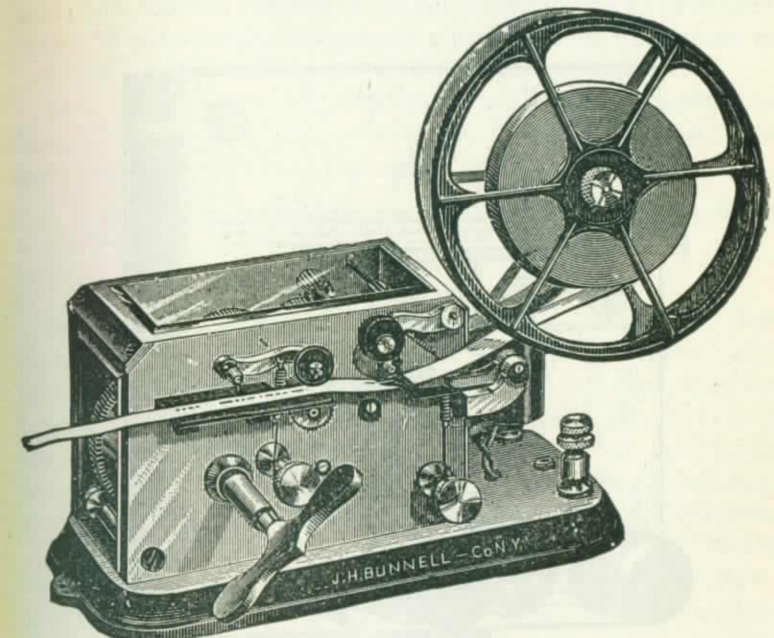


FIG. 3,096.—Bunnell double pen ink writing register for Morse telegraph with lever for starting and stopping at will.

called the "Universal" ticker and is the invention of Edison. Either can work at a speed of at least forty words per minute.

Messenger Call Service.—In former years, when any one wished to send a message by telegraph it had to be taken to the nearest branch office for transmission. But rivalry between competing companies finally resulted in the installation of mechanical call boxes in houses throughout New York City, whereby a patron could summon a messenger boy by turning a handle. By the turning of this handle, or lever, a revolving wheel with raised teeth is operated which closes the circuit a number of times, corresponding to the number of teeth, and rings an electrically operated bell a correspondingly number of times.

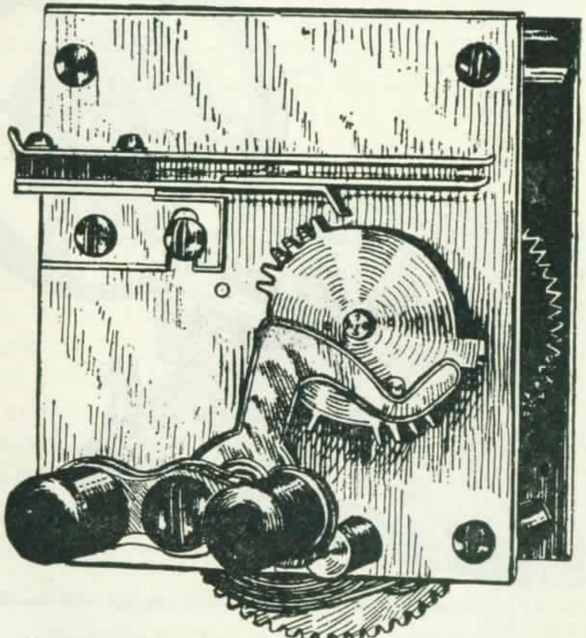


FIG. 3,097.—Messenger call box (cover removed). This box operates the Gill selector and is connected around a Morse key, the combination number of the box being stamped on the handle. In order to transmit the combination over the line the handle is given a quarter turn and then released.

Ques. Of what does the system consist?

Ans. It consists of two relays, a paper tape register, bell and switches for temporarily diverting the local and main line

circuits so that the register will catch incoming signals **regardless** of line defects.

Ques. How are the circuits arranged?

Ans. The circuits are looped together in pairs, and the office terminals of each loop are connected to a battery of opposite polarity.

Ques. What is done if an open or break occur?

Ans. The distant open station is temporarily grounded so that all stations on both sides of the break can send in their calls through one or the other of the two registers.

Only in the case of a defective call station is the call box circuit grounded.

Western Union Time Signals.—Since 1865, noon time signals have been sent out daily bv the United States Naval Observatory at Washington and since 1883 it has been standard time. About noon time, Washington is connected to all lines of the Western Union Telegraph Company east of the Rocky Mountains; the country west of these mountains being supplied by standard time from Mare Island Navy Yard, California.

The signals begin at three or five minutes before twelve o'clock noon and consist of a series of short beats of a transmitting clock at each observatory. The electrical connections of the transmitting clock are arranged to omit certain seconds of each minute.

As one hears the relays and sounders giving out the time, there are heard at first twenty-nine dots, then one is skipped, resembling a space and then twenty-five dots follow and a space of five dots which ends the number of seconds for the first minute. The second, third, and fourth minutes are signalled like the first; namely, twenty-nine seconds, one space, twenty-five seconds, and five dot spaces for each minute. Then for the minute preceding noon time twenty-nine seconds, one space, then twenty-seconds and ten dot spaces and then one long dash, corresponding to the final twelve o'clock beat at the government station.

Wireless telegraph circuits are worked at the same time through telegraph relays which automatically close the high pressure wireless current circuits.

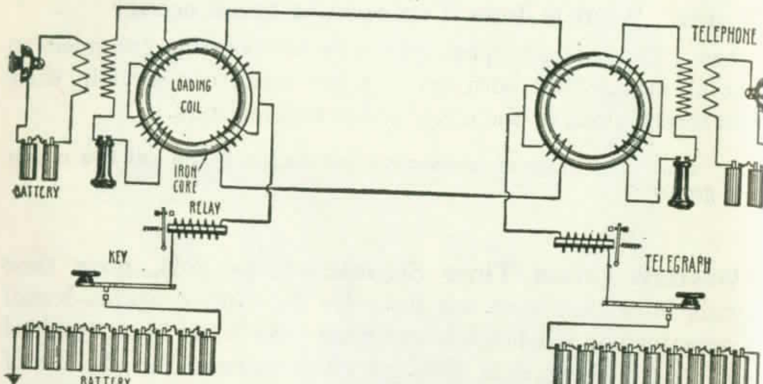


Fig. 3,098.—Diagram illustrating simultaneous telephony and telegraphy. Although in long distance telephony metallic circuits are used exclusively, it is possible to use single line grounded circuits for simultaneous telephony and telegraphy. In the diagram two telephone stations are connected by a metallic circuit through repeating coils. Taps are taken from the middle of one side of each coil to telegraph sets, thence to the telegraph main line battery and ground at each station. The two line wires carry the telephone current in opposite directions, but, acting as a joint circuit to the telegraph current, the two line wires form one side of a ground return telegraph circuit.

Simultaneous Telegraphy and Telephony.—The art of telegraphing and telephoning over the same line was the result of Van Rysselberghe's efforts to prevent the interference of induction from parallel telegraph wires on the telephone circuits.

By inserting coils of wire in the telegraph line the sudden rise and fall of current was choked or retarded and the induction thus reduced was not noticeable in the adjacent telephone line.

The original form of the magneto telephone consisted of battery, transmitter, and primary coil connected in series, and the secondary coil and receiver in series with the line which terminated in the secondary and receiver series circuit at the distant telephone. Consequently, a telephone similar to the magneto is used in connection with the telegraph for simultaneous operation; also circular retardation coils are used. Fig. 3,098 shows a simple diagram of the circuits. In practice there are two circuits used called the physical and the phantom; the former being the circuit proper and the latter an arrangement by which three circuits may be obtained from two pairs of line wire.

Fire Alarm Telegraphy.—In large cities call bell fire alarm boxes are mounted on street lamp posts or other suitable places along the streets. These boxes are of two kinds, the keyed

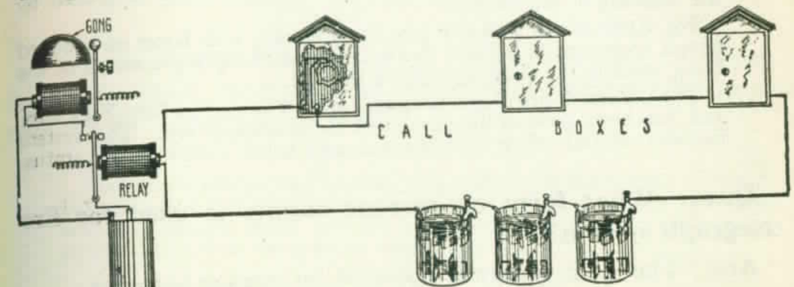


Fig. 3,099.—Diagram of elementary fire alarm circuit. Fire alarm apparatus forms that element of the system depended upon to announce to the fire fighting force the existence of and location of a fire. The equipment consists of gongs and indicators located in the fire department houses, and where volunteers form part of the fire department, public alarms are given by means of devices for automatically striking large bells or blowing whistles.

and the keyless, the former requiring the opening of a door by a key which is generally in the possession of a policeman on the beat.

The keyless boxes may be opened by anyone simply by the turning of a large handle. These are each provided with a gong operated to ring by local battery, so that the opening of one arouses the neighborhood. Then, by turning a small handle inside the door or by pulling a chain or knob, clocklike mechanism is set in motion, which causes a notched dial to revolve, thereby making and breaking the circuit periodically. Thus, the different signals are registered at the central office and automatically sent through to the various fire houses.

Ques. How are the signals automatically sent?

Ans. They are sent by a set of repeating relays to make sure of successful transmission.

Ques. How are the fire boxes connected?

Ans. In series.

They are generally placed on a closed circuit which is opened by the breaking of the contact.

Fig. 3,099 shows a simple fire alarm circuit, with boxes on a closed circuit connected in series. The breaking of the spring contacts at the boxes sends in the alarm by ringing the bell.

The Gamewell fire alarm telegraph system is used in New York City and has been successfully developed for municipal use. The system includes central office switchboards and other necessary apparatus.

Ques. What form of current supply is used for fire telegraph system?

Ans. The main system is operated by storage batteries.

Duplicate sets of cell are provided for each circuit in order that one set may be charged while the other is connected for use and discharged. Any call or break of the circuit is detected.

Ques. How are grounds located?

Ans. By an automatic ground detector.

CHAPTER LXX

WIRELESS TELEGRAPHY

The term wireless telegraphy may be defined as *any system of telegraphy which successfully substitutes some medium other than wire for the connecting conductors.*

Many have confounded wireless telegraphy with the system invented by Marconi, but the latter is only one form out of many, the term was used to describe other systems years before Marconi's spectacular success added it to the popular vocabulary.

History of Wireless Telegraphy.—A brief history of the method of electric signaling without the aid of conducting wires will serve to facilitate a thorough understanding of the art.

The systems of wireless telegraphy which have so far been proposed may be classified as:

1. Conduction;
2. Induction;
3. Radiation.

The first was an attempt to substitute the earth and bodies of water in place of the connecting lines, then came the induction systems, taking advantage of those peculiar electrical phenomena known as electrostatic and electrodynamic induction.