# TELEPHONY

*Telephony* is the art of transmitting articulate speech and other sounds between distant points by means of fluctuations in an electric current flowing between those points. The successive vibrations of the human voice that form distinguishable and intelligible sounds constitute *articulate speech*. These vibrations are probably the most complex in the whole realm of sound.

## TELEPHONE APPARATUS

### TELEPHONE TRANSMITTERS

A *telephone transmitter* is an instrument that serves to produce variations in the current flowing in the circuit in unison with the sound waves that reach the transmitter. Practically all telephone transmitters now used depend on the fact that the electrical resistance between two or more bodies either in light or in loose contact is varied greatly by slight changes in the pressure between them. Such transmitters are frequently called *microphones*, or *battery transmitters*.

A view of the working parts of a Dean transmitter is shown in Fig. 1. A metal cup *a*, plated or lined on the inside with platinum, forms the front electrode, and is held in an opening in the center of an aluminum diaphragm. The rear electrode *e* is held rigidly in a metal bridge piece *f*, which is fastened to the frame that supports the mouthpiece *g* and the whole transmitter. This rear electrode

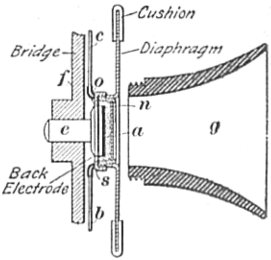


FIG. 1

consists of a hard, polished carbon button *n* secured to a brass button, between two parts of which is clamped a mica ring, or diaphragm, *o*, the outer edge of which is clamped against the front electrode *a* by means of an annular metal ring *s* that screws over *a*. The space between the rear carbon button and the platinum-faced surface inside the cup is partly filled with hard, granular carbon of uniform size. Two light dampening springs *b*, *c*, having tips covered with rubber or felt, press lightly against the cup system and prevent the diaphragm from vibrating at its natural rate when the air waves have ceased, which would cause indistinctness. To adapt the transmitter for local-battery or common-battery systems, the cup and the rear electrode, which form an easily changed unit, are the only parts that have to be changed.

The current from a battery passes from one terminal through *e*–carbon electrode–granular carbon–metal cup to the other electrode. When talking close to the transmitter, the aluminum diaphragm and the cup are forced to vibrate in unison with the sound waves produced in the air, thus causing the pressure of the front and rear electrodes on the granular carbon to vary and, consequently, the resistance of the transmitter, to vary in a similar manner. Therefore, with a constant E. M. F. supplied by a battery, the variation in resistance causes a variation of current that is in unison with the original voice vibrations. In the Dean transmitter, the entire granular carbon chamber is well shaken up, which probably decreases the liability of the granules becoming packed. The thin mica ring *o* is flexible enough to allow the diaphragm and its cup to vibrate sufficiently to produce good articulation and volume of sound.

The variation in resistance of any transmitter of similar construction is undoubtedly due to the variation in area of the surfaces of granules and electrodes that are in contact at any instant, and not to any compression within the carbon itself. The greater the area of the surfaces in contact, the less the resistance, and vice versa. While transmitters of different makes vary more or less in construction, all those in practical use in the United States depend on the principle just mentioned. Practically all transmitters have rear and front electrodes of carbon, or one may be a gold-plated or platinum-plated metal, granular carbon being placed between them. The front electrode is attached to the diaphragm in various ways, while the rear one is rigidly supported.

## TELEPHONE RECEIVER

A *telephone receiver* of modern construction is shown in Fig. 2. It consists of a U-shaped permanent magnet *a*, to the ends of which are fastened soft-iron pole pieces *c*, *c'*; over each pole piece is placed a coil of fine wire. The two coils are connected in series, so as to tend to make the front end of one a north pole and the front end of the other a south pole when a current flows through both coils in a certain direction. The coils are usually wound to a resistance of about 70, 100, or 125 ohms, although they have been wound

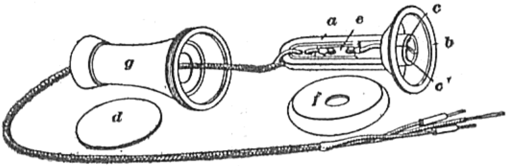



FIG. 2

as low as 10 ohms and as high as 5,000 ohms. The pole pieces pass through the bottom of a metal cup *b*, which is thus secured firmly in place. On the rim of this cup rests a tinned sheet-iron diaphragm *d*, which is about 2 in. in diameter. The receiver cords are connected to the terminals of the coils at *e*, being secured at the rear in such a manner that if the receiver is dropped the strain comes upon the cord and the rear end of the permanent magnet and not upon any connections nor upon the hard-rubber or composition shell *g*. This shell slips over the working parts of the receiver and is held in place by the ear piece *f* that screws on the shell. When all parts are in place, the diaphragm is held as close to the pole pieces as is possible without allowing it, even while vibrating, to touch either of them. The distinguishing feature of this particular receiver is the nearly semicircular shape of the pole pieces; this shape, it is claimed, gives a more uniform distribution of the lines of force through the diaphragm than the rectangular-shaped pole pieces which are more extensively used. The permanent magnet of many double-pole receivers consists of two permanent bar magnets, held the proper distance apart by means of a piece of soft iron, and a bolt at the rear end. A receiver having a **U**-shaped permanent magnet is called a *double-pole receiver*, because both poles are presented to the diaphragm. Formerly, straight-bar magnets with one pole only presented to the diaphragm were almost exclusively used in the United States; they were called *single-pole receivers.*

**Operation of Receivers.**—If a current flows through the coils in such a direction that the lines of force due to it coincide with those due to the permanent magnet, the diaphragm will be pulled closer toward the pole pieces; whereas, if the current flows through the coils in such a direction that the lines of force due to it oppose those due to the permanent magnet, the strength of the magnetic field will be reduced and the diaphragm will spring farther from the poles. If an undulating current always flowing in the same direction is sent through the coils, the lines of force due to it and, hence, the pull on the diaphragm, will increase while the current is increasing and decrease while the current is decreasing. Thus, whether the lines of force due to the current in the coils assist or oppose those due to the permanent magnet, a varying pull is produced on the diaphragm that causes vibrations in the latter that are in unison with the changes in the current. Thus, either an undulating or an alternating current may cause the receiver to produce sounds.

## INDUCTION COIL

One more step will explain the principles involved wherever an *induction*, or *repeating*, *coil* is used in telephone systems, In Fig. 3, $T$ represents a transmitter, $B$ a battery, $P$ the primary, and *S* the secondary winding of an induction coil, and *R* a receiver. By speaking toward the transmitter, its resistance varies, causing a variable current to flow through the primary winding. This induces in the secondary winding an alternating current that flows through the receiver and causes the receiver diaphragm to vibrate in exactly the same manner, though somewhat less vigorously,

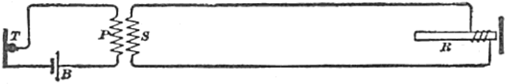



FIG. 3

than the transmitter diaphragm. Hence, sounds produced at the transmitter are reproduced by the receiver. The primary winding is usually composed of a small number of turns of about No. 22 B. & S. copper wire, and the secondary winding of a large number of turns of about No. 34 B. & S. copper wire wound over the primary. Hence, the E. M. F. produced in the secondary is many times greater than that in the primary.

Repeating coils are wound with an equal number of turns in each coil, so that they will repeat equally well in both directions. They are used in central-energy systems and also where it is desirable to have communication between

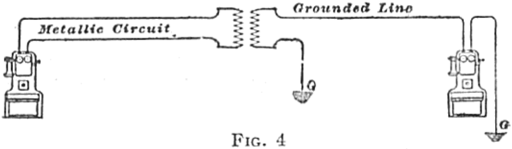



FIG. 4

a complete metallic circuit and a ground-return, or common-return, system, without making a metallic connection between the two circuits. This is shown in Fig. 4. The metallic circuit is thus kept free from grounds, and induction from outside disturbing circuits is limited to that which ordinarily affects the grounded line.

## CALLING APPARATUS

For attracting the attention of a party at a distant station, the magneto generator and the polarized bell have been extensively used.

**Magneto Generators.**—A *magneto generator* is a very simple form of dynamo. It consists usually of an armature of iron, wound with a large number of turns of fine insulated copper wire, and is adapted to be readily revolved between the poles of a powerful permanent magnet. In Fig. 5, *A* represents the armature, around the shank of which is wound a coil of wire. *S* and *N* are the south and north poles of one

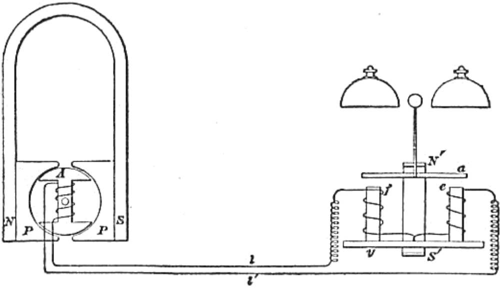



FIG. 5

of 3 to 6 permanent magnets placed in a row, and *P*, *P* are the pole pieces, usually of soft cast iron, fastened to the magnets and bored out so as to afford a space in which the armature may revolve. When the armature revolves, the coil cuts the lines of force produced by the permanent magnets and an E. M. F. is developed in the winding. In a complete revolution of the armature, the number of lines passing through the coil will vary from a maximum in one direction through zero to a maximum in the other direction, and then through zero again to the first maximum. It therefore follows that for one revolution two impulses of current will flow in the coil, first in one direction and then in the opposite direction. The current is therefore an alternating one.

A very important adjunct to the magneto generator is an automatic device that either short-circuits the armature or opens the armature circuit when the armature is at rest. It is found desirable in series telephones, while the generator is not in use, to remove the resistance of the armature from the circuit by means of such an automatic device, called a *shunt*, which forms a path of practically no resistance around the armature. In a bridging telephone, however, it is desirable to have the automatic device open the armature circuit when the latter is at rest. This short-circuiting or opening of the armature circuit is accomplished automatically in a variety of ways. At the usual rate of turning by hand, the voltage given by a telephone generator is from 65 to 75 volts, at a frequency of about 15 complete cycles per second.

**Polarized Bells.**—A *polarized bell*, or *ringer*, as it is often called, is shown at the right-hand side of Fig. 5, in which $f$ and $e$ represent soft-iron cores, upon which are wound coils of wire connected in series with the line wires $l$, $l'$. $N'$, $S'$ is a permanent magnet, and $a$ is a soft-iron armature pivoted at the middle. To the center of the armature is fastened a slender rod, terminating at the top end in a small ball. When no current is flowing through the coils, the permanent magnet causes both of the upper ends of the soft-iron cores $e$, $f$ to be south poles and the both ends of the armature $a$ opposite the cores to be north poles. Consequently, the armature will be attracted by both cores and will rest against the core to which it happens to be nearest. If a current passes through the coils in such a direction as to increase the stength of the south pole at $f$ and to make $e$ a north pole or a weaker south pole, then $f$ will attract the end of the armature opposite it, while $e$ will repel its end of the armature or attract it with a much smaller force. If the current is now reversed in direction so that $f$ becomes a north pole or a weaker south pole and $e$ a stronger south pole, the action will be reversed, and $e$ will attract its end of the armature and $f$ will repel its end or attract it with a much smaller force. By thus reversing the direction of the current about fifteen times per second, the ball at the top of the rod fastened to the armature will vibrate between the two gongs and produce a continuous ringing sound. For series telephones, the ringer coils are wound to a resistance of from 80 to 120 ohms. For bridging telephones, the ringer coils are usually wound to a resistance of 1,000, 1,200, 1,600 and even as high as 5,000 ohms.

**Magneto-Bells.**—The term *magneto-bell* is usually applied to the combination of a magneto generator and a ringer mounted in the same box. A fairly good generator will ring its own bell through a resistance of 10,000 ohms, which is an ordinary test applied to them. Thus, a 10,000-ohm magneto-bell or magneto generator does not mean that either the bell or the generator has a resistance of 10,000 ohms, but that the generator should be able to ring its own bell through a circuit whose total resistance is 10,000 ohms.

**Hook Switches.**—As the apparatus for sending and receiving both articulate speech and signals performs entirely different functions, it has been found necessary to provide means for cutting one set out of the circuit while

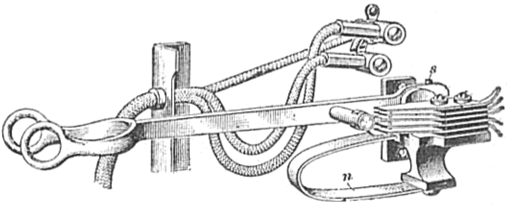



Fig. 6

the other is in use. During the idle periods of the instrument the ringer must be left in the circuit, but as soon as the call is received or sent, it is necessary to cut the calling apparatus out of the circuit and the talking apparatus into the circuit. For this purpose *automatic hook switches* are used.

The Kellogg hook switch is shown in Fig. 6. The hook is held down by the weight of the receiver, which causes the lower contact springs to be electrically connected together. When the receiver is removed from the hook, the spring *n* lifts the hook, thus separating the lower contact springs from one another and causing the upper contact springs to be electrically connected together. Evidently the number of spring contacts above or below the middle spring may be diminished or increased, or some of the springs may be left unused, or the middle spring may have an insulating piece on the top or bottom of the movable end, so that it will make connection only with the springs below or above; thus, this hook switch may be made suitable for almost any system. By removing the screw *s*, the hook lever may be slipped out, which is desirable for shipment. This is a good example of modern hook switches.

## BATTERIES FOR TELEPHONES

With the various forms of solid-back transmitters, a battery of any two good Leclanché or dry cells will give good results. Dry cells are now being used extensively. The adoption of central-energy systems is doing away with primary cells at the subscriber's instrument for local city service and even for quite long distances. In long-distance work, two and even three Fuller bicromate cells have been used a great deal. For central-energy systems, storage batteries at the central office are nearly always used, and no magneto generator is required at the subscriber's instrument; consequently, the energy for all telephones connected with the switchboard, both for talking and for signaling purposes, is supplied by the central office.

## CONNECTIONS OF TELEPHONE INSTRUMENTS

**Series Instruments.**—*Series telephones* are designed so that they may be connected in series with each other in the line circuit. Fig. 7 shows the Post method, and Fig. 8 the Western Electric No. 2 method—two ways of wiring a series wall telephone that accomplishes the same purpose. *G* is the magneto generator, *C* the bell, *R* the receiver, *T* the

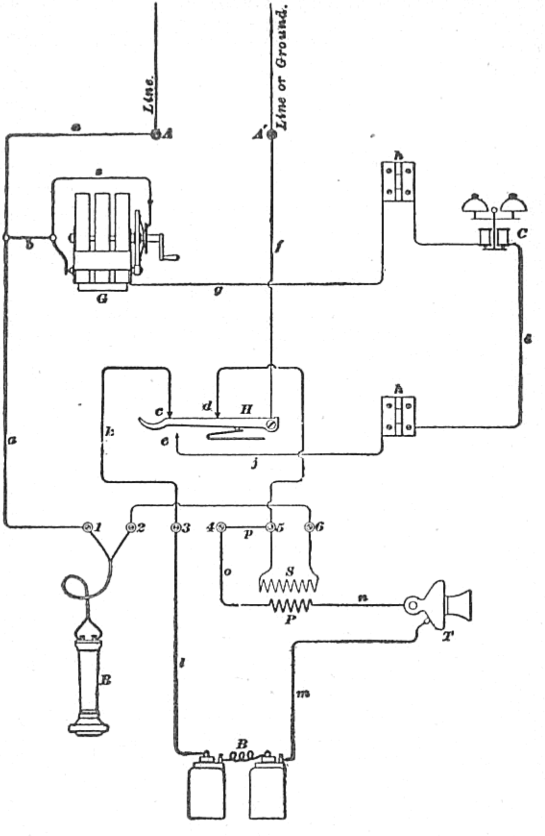



FIG. 7

transmitter, *H* the hook switch, *B* the battery, and *S* and *P* the secondary and primary windings, respectively, of the induction coil. While supporting the receiver, the hook is depressed and thus connects the bell *C* and the generator

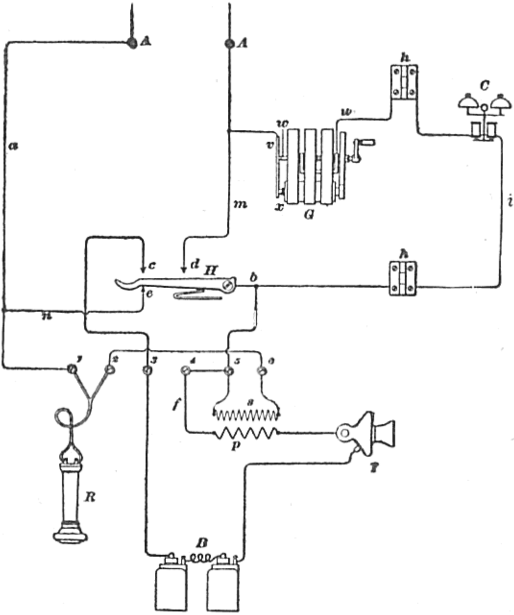



FIG. 8

*G* in series across the two line wires. In Fig. 7, the circuit containing the receiver and secondary coil is open at *d*, while it is short-circuited by *n-e-b* in Fig. 8. When the generator is at rest, its armature is short-circuited; when the hand of the generator is turned, the short circuit around the armature is opened; and when the receiver is removed from the hook, the transmitter, battery, and primary winding of the induction coil are connected in a local circuit, and the receiver is also connected in series with the secondary winding of the induction coil and across the two line wires. The generator and bell circuit is open at *e*, Fig. 7, and short-

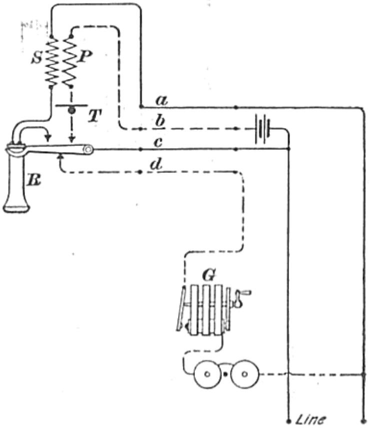



FIG. 9

circuited by *m-d-b*, Fig. 8. The same principles are employed in wiring series desk instruments.

A *series desk telephone*, with the induction coil in the base of the stand, is wired as shown in Fig. 9, *a*, *b*, *c*, *d* being the flexible conductors in the desk-stand cord. The generator and bell are usually placed in a separate case or box. The wiring of a series desk telephone, with the induction coil in the base of the desk stand, the generator in one box, the bell in another box, and the necessary binding posts on a terminal block, is shown in Fig. 10. Generally, the ends of the flexible cord running from the desk stand to the binding

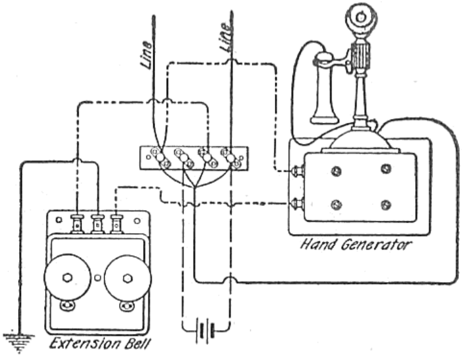



Fig. 10

posts on the terminal block are numbered or lettered, so that it is only necessary to connect each flexible conductor in the desk-stand cord to a similarly numbered or lettered binding post on the terminal block. Sometimes, the induction coil is mounted on the terminal block.

**Hand Microtelephone.**—In Fig. 11 is shown a *hand microtelephone*, which consists of a transmitter, watch-case receiver, and switch, all mounted in one handle. The switch can easily be held closed by the same hand that holds the microtelephone. The connections in Fig. 12 show how this instrument may be used as an ordinary series telephone; it may also be wired as a bridging telephone by connecting wire $d$ to line $L$ and omitting the wire $d$–$1$–$a$.

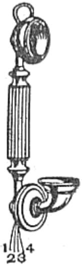



Fig. 11

**Bridging Instruments.**—In Fig. 13 is shown the arrangement and connection of apparatus forming a complete *bridging wall telephone.* The bell and the generator circuits are permanently connected across the line binding posts $A$, $A'$, but the generator circuit is normally open between $q$ and $r$, being closed only while the crank is being turned. When the switch is up, the receiver $R$ and the secondary winding $S$ are connected in series and across the binding posts $A$, $A'$ through $a$–1–$R$–2–6–$S$–5–$d$–$H$–$f$, and the transmitter-battery circuit is closed through $B$–$l$–3–$k$–$H$–$d$–5–4–$o$–$P$–$n$–$T$–$m$–$B$. The bell is wound so as to have a large number of turns and

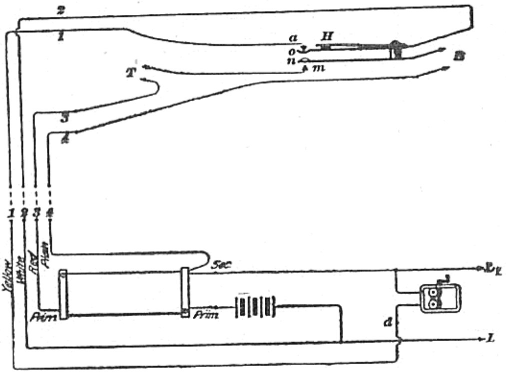



Fig. 12

a high resistance (1,000, 1,200, 1,600, or 2,500 ohms), and, consequently, may be left permanently connected across the line, because its inductance, together with its resistance, is so high that the very rapidly fluctuating voice currents do not pass through the bell to an appreciable extent, but pass into the line or receiver circuit, which offers much less opposition to them.

The wiring for an ordinary *bridging desk telephone set* is shown in Fig. 14. The binding posts $e$, $f$, $g$, $h$, $i$ are located in the base of the desk stand. The binding post $h$ and

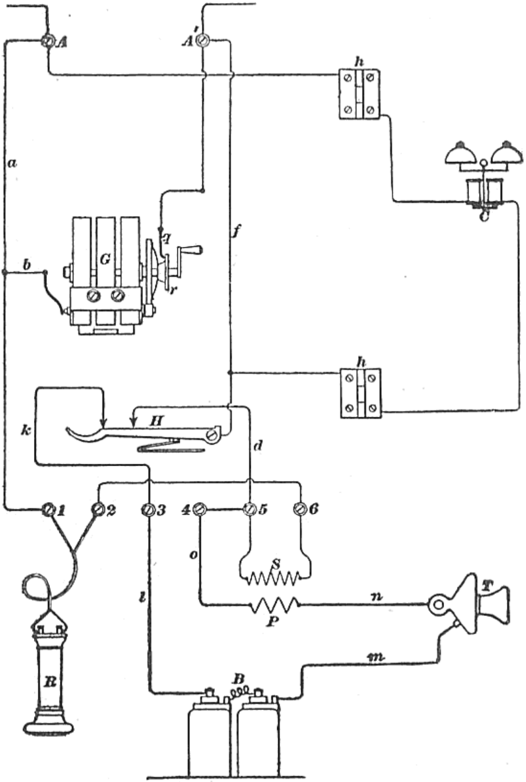



FIG. 13

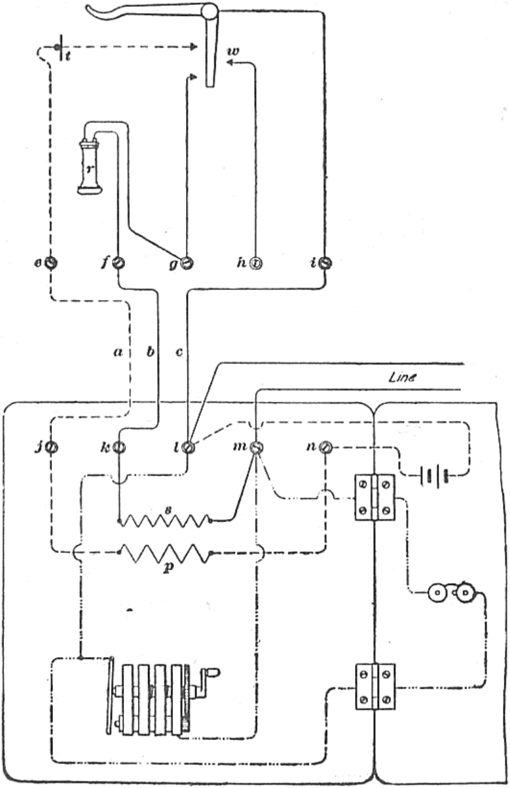



Fig. 14

contact *w* are not used for this bridging circuit, but are provided because they are required in an arrangement to be shown presently, as well as in series sets. Flexible conductors *a*, *b*, *c* connect the desk stand with the box containing the bell, generator, and induction coil. On the top or bottom of this box are placed the binding posts *j*, *k*, *l*, *m*, *n*. The induction coil may be placed in the base of the desk stand without increasing the number of flexible conductors; *a* will then connect *e* to *n* and *b* will connect *f* to *m*, *p* being between *t* and *e*, and *s* between *r* and *f*. The binding posts *j*, *k* will not then be required.

**Bell Desk Set.**—The connections of a bridging *desk set* used by the Bell Telephone Companies on local-battery systems is shown in Fig. 15. The induction coil is mounted on a wooden base having five binding posts *n*, *j*, *l*, *k*, *m*. One of the cords *b* is connected to an insulated terminal *w* in

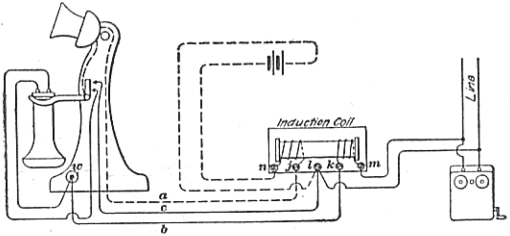



FIG. 15

the foot of the stand, to which is also attached one terminal of the receiver cord; *c* is connected to one contact of the hook switch, and *a* to the transmitter. The other terminal of the transmitter is connected through the metal work of the stand to the hook switch.

**Other Methods of Connecting Instruments.**—Another way of connecting bridging generators and bells, shown in Fig. 17, is to arrange them so that both the bell and the generator will be cut out when the hook switch rises. This is especially desirable but only necessary for party-line circuits having a number of instruments bridged across the same circuit. The same object is also accomplished by connecting the generator terminal *q* directly to binding post *A′* instead of to contact *w*, the bell still being left connected between contact *w* and binding post *A*.

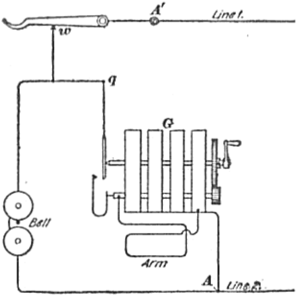


Fig. 16

Fig. 17 illustrates another way of connecting bells and generators in a bridging telephone. A platinum-pointed spring is provided that short-circuits the generator when at rest and short-circuits the bell when the generator crank is turned, thereby preventing the bell from ringing when the generator is being used and protecting the generator armature, when at rest, from burnouts through the entrance of foreign currents. This arrangement reduces, by one, the number of bells on a party line that the generator must ring. Moreover, the home bell in the ordinary arrangement takes somewhat more current than any of the other bells, because it has no line resistance in series with it; hence, cutting it out is quite desirable, especially on long party lines.

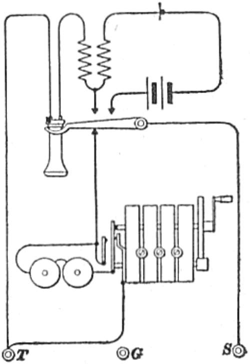


Fig. 17

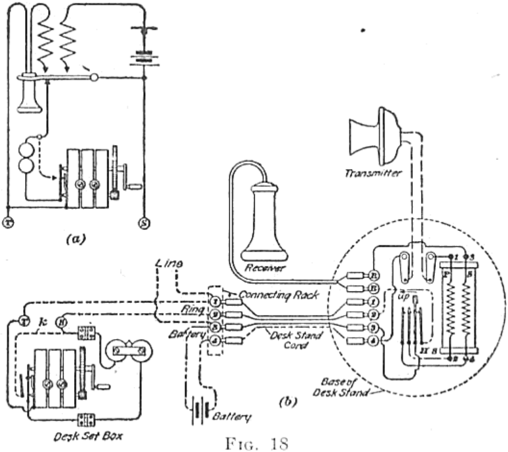

(a)
Transmitter
Receiver
Line
Connecting Rack
Ring
Battery
Desk Stand Cord
Base of Desk Stand
Desk Set Box
Battery
(b)

FIG. 18

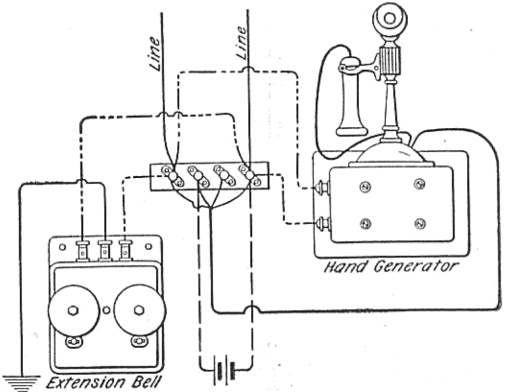

Line
Line
Hand Generator
Extension Bell

FIG. 19

The connections of the Dean desk set, in which the receiver, transmitter, hook switch, and induction coil are mounted in the desk stand, the bell and generator in one box, and four binding posts on a connecting rack, are shown in Fig. 18. At (*a*) is shown a simplified diagram of the connections.

**Separate Bridging Generator and Bell Box.**—The wiring for a bridging desk set using separate generator and bell boxes and a terminal block is shown in Fig. 19.

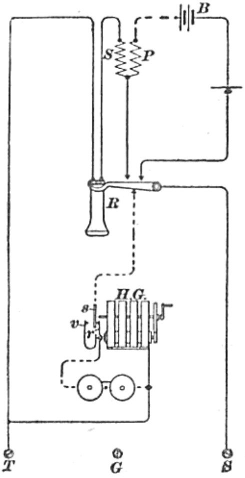


FIG. 20

**Kellogg Bridging Wall Telephone.**—Still another slight modification suitable for use on party lines is shown in connection with Fig. 20. When the generator handle is turned, the spring *s* is pushed away from *r* and into contact with *v*. Since the armature winding is connected between the frame of the generator and through an insulated pin in the end of the shaft with the spring *v*, the generator is cut in and the bell is cut out when the generator handle is turned. Thus the bell and generator are not only cut out by the rising of the hook switch, but the bell is also cut out when the generator handle is turned.

**Kellogg Bridging Desk Telephone.**—The connections for a desk set, when the induction coil is mounted on a separate connecting rack along with the necessary binding posts, is shown in Fig. 21. Four flexible conductors *a*, *b*, *d*, *c* connect the terminals *e*, *f*, *h*, *i* with binding posts, *1*, *4*, *3*, *2*, respectively, on the connecting rack. The bell and generator are cut out when the hook switch rises and the bell is cut out when the generator handle is turned.

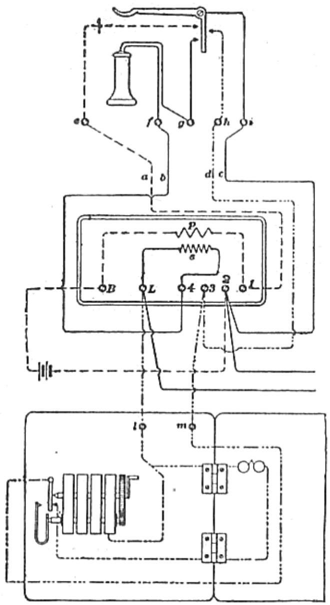

a
b
c
d
e
f
g
h
i
p
s
B
L
4
3
2
L
l
m

FIG. 21

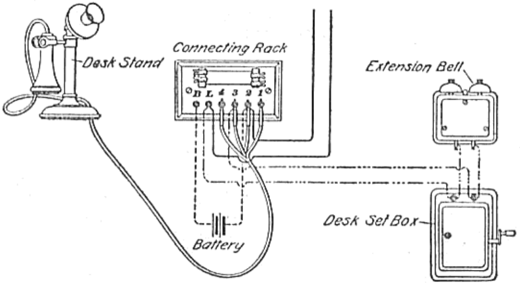

Desk Stand
Connecting Rack
B L 4 3 2 1
Extension Bell
Desk Set Box
Battery

FIG. 22

Fig. 22 shows the wiring when the generator and bell are mounted in separate boxes and the induction coil on a connecting rack. The battery in Figs. 20 and 21 is placed on the floor or wherever convenient.

## EXTENSION BELLS

All bells used in connection with a telephone, except the bell in the telephone instrument or generator box, are termed *extension bells.* They are used so that signals may be received in places where it is not desired to locate the telephone. The extension bell rings whenever

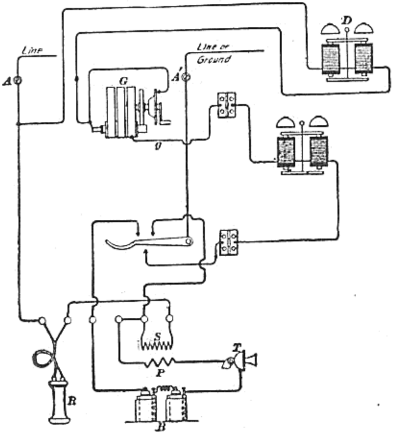



Fig. 23

the telephone bell rings. Ordinary extension bells can be used in connection with either series or bridging telephones, but, in either case, the extension bell should have exactly the same resistance (which implies also the same number of turns) as the telephone bell with which it is to be used.

**Series Extension Bell.**—Fig. 23 shows the proper way to connect an extension bell $D$ to a series telephone in

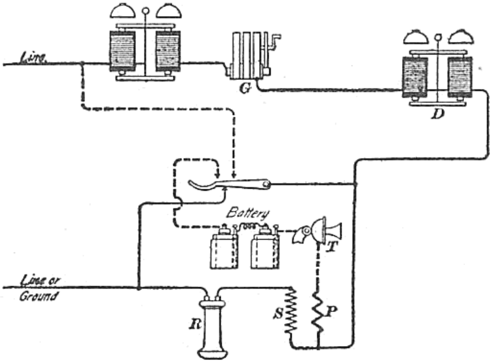



FIG. 24

which the Post circuit is used, while Fig. 24 shows the same thing when the Western Electric No. 2 circuit is used.

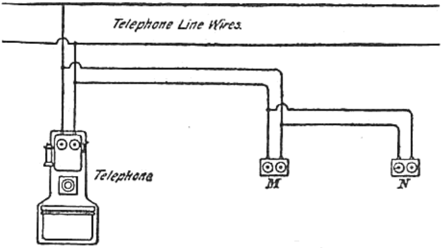



FIG. 25

**Bridging Extension Bells.**—The extension bell, which should be of the same resistance as the bridging telephone bell, may be bridged across the line circuit of a bridging telephone at the most convenient point. Two *bridging extension bells M, N* are shown in Fig. 25 properly connected across a bridging-telephone circuit. When bridging telephones are connected on the ground return circuits, the extension bells are connected between the one line wire and the most convenient ground connection.

## CENTRAL-ENERGY INSTRUMENTS

Instruments for use on central-energy, or common-battery, systems can hardly be classified as series or bridging instruments. No generators are used, the central office being signaled by merely removing the receiver from the hook. These instruments usually have an ordinary polarized bell, varying in resistance from 80 to 2,500 ohms (usually in series with a condenser of about 2 microfarads capacity), connected across the line circuit, or between one line wire and the ground when the receiver is on the hook. The transmitters and receivers are arranged in various ways. In the simplest arrangement, the transmitter and receiver are connected in series across the line circuit when the receiver is removed from the hook. With this arrangement, satisfactory results can undoubtedly be obtained for short distances if the transmitter and the receiver are suitably designed; but the use of induction or impedance coils and condensers in connection with a subscriber's telephone instrument seems to give better results.

**Transmitter and Receiver in Series.**—The simplest arrangement of a subscriber's instrument for use on central-energy circuits is shown in Fig. 26. When the receiver rests on the hook, the ringing current flows from one line wire through the bell, condenser, and contact *a*, to the other line wire. The bell usually has a resistance of 500 to 1,000 ohms and the condenser a capacity of ½ to 2 microfarads. When the receiver is not resting on the hook, it is in series with the transmitter across the line circuit, and the bell and condenser are on open circuit. The bell circuit may be connected from contact *a* to the ground, instead of to line *L*, the ground then being used as a common return for all ringing currents, but it is cut out when the receiver is off the hook. For an arrangement of this kind, the receiver should have a low resistance and the transmitter a high resistance, a large proportion of which is variable. From 20 to 25 ohms has been found to be about the lowest resistance for an

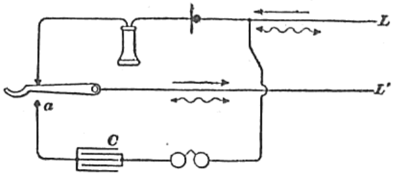



FIG. 26

efficient receiver for such an arrangement. The one main drawback to this arrangement is that the battery current flows through the receiver; this is all right if the current passes in the direction to increase the magnetism, but the current may at some time be reversed on the line, in which case the receiver becomes demagnetized. Another fault is

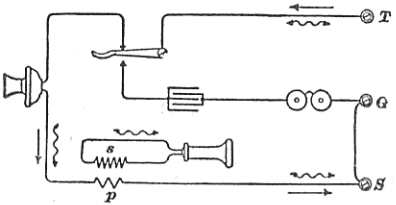



FIG. 27

that this arrangement lacks the proper quality that many other combinations possess.

**Receiver in Closed Local Circuit.**—In Fig. 27, the receiver is in a permanently closed local circuit containing the secondary winding *s* of an induction coil. Both battery and voice currents pass through the primary winding *p* and the transmitter, but the latter current, being fluctuating in character, induces a similar current in the secondary *s*, thereby operating the receiver. When the receiver rests on the hook, the transmitter circuit is open and the bell and a condenser are connected in series across the signaling circuit.

**Impedance-Coil Circuit.**—In Fig. 28 is shown a subscriber's conversation circuit in which a receiver and 2-microfarad condenser are connected in series and shunted by a 25-ohm impedance coil. The direct current from the exchange battery passes through the impedance coil and

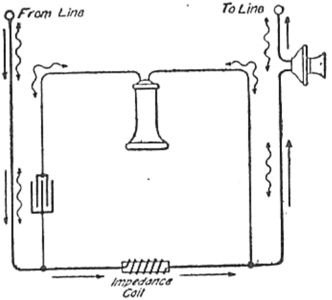



FIG. 28

the transmitter, but is prevented from flowing through the receiver by the condenser, which is opaque to direct currents. The incoming voice currents, however, are practically prevented from flowing through the impedance coil, on account of its high reactance to such high frequency currents, but find a comparatively low-impedance path through the condenser and receiver, as indicated by the double-headed wavy arrows.

**Dean Central-Energy Subscriber's Circuit.**—The subscriber's talking circuit used in telephones made by the Dean Electric Company is shown in Fig. 29. The coils *A*, *B*, *C*, *D* are arranged in the form of a Wheatstone bridge, the usual position of the galvanometer being occupied by the receiver. *B* and *C* are non-inductively wound, while *A* and *D* are wound so as to have a high inductance. The bridge is balanced for direct currents, as indicated by the straight single-pointed arrows, by making the resistance of the four arms so that *A* is to *B* as *C* is to *D*. No direct current will then flow between the points *2* and *3*, as their potential is the same; hence, the receiver will be free from direct-current action. However, the bridge is entirely out of balance for the high-frequency voice currents, which cannot readily penetrate the inductively wound coils *A* and *D*

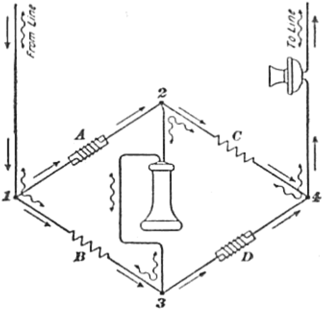
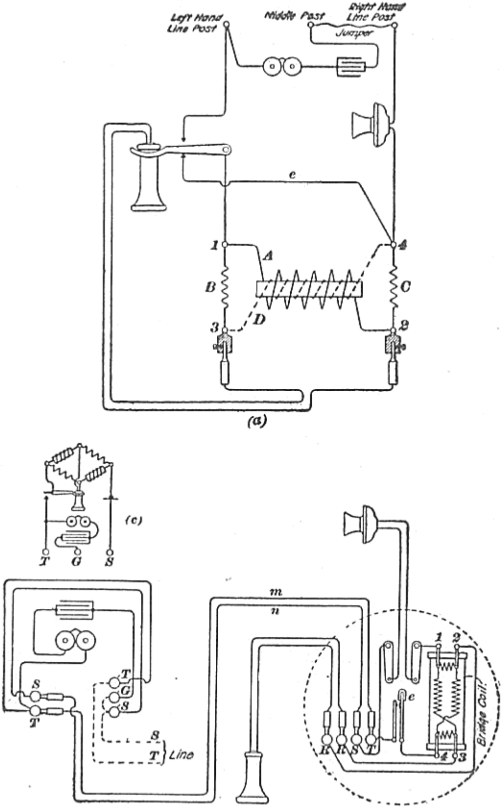



Fig. 29

and are thus forced through the receiver and non-inductive resistances *B* and *C* in the path indicated by the wavy arrows. The resistances of the four windings, which are wound on one iron-wire core with four terminals *1*, *2*, *3*, *4*, are approximately 20 ohms for *A* and *B* and 30 ohms for *C* and *D*. The direct current from the exchange battery passes through the two 50-ohm halves of the bridge, as indicated by the straight single-headed arrows, and thence through the transmitter.

The method of wiring a complete wall instrument, using the Dean circuit, is shown in Fig. 30 (*a*). When the hook is down, the coil and receiver are shunted by the wire *c*, thus


Left Hand Line Post
Middle Post
Right Hand Line Post
Jumper
e
1
A
4
B
C
D
3
2
(a)
(c)
T
G
S
m
n
S
T
T
G
S
S
T } Line
1
2
e
Bridge Coil
R
R
S
T
4
3

(b)

FIG. 30

preventing any damage from lightning discharges or high-tension currents, which are liable to jump the gap between the springs of a hook switch. The Dean central-energy desk set is wired as shown in Fig. 30 (*b*), while (*c*) shows a simplified diagram of the same circuit.

## COMMON FAULTS AND THEIR REMEDIES

The most common troubles in telephone instruments are due generally to one of three causes: (1) Loose or dirty connections at the binding posts of the instrument, at the binding posts of the batteries, or in joints in the line wires; (2) exhausted, poor, or weak batteries; (3) crossed, open, or defective wires. These troubles, of course, do not include those arising from inferior or defective instruments, which it is impossible to enumerate on account of the large number of different makes of instruments now in use.

In the case of a defective instrument, the best thing to do is to return it to the dealer for repairs. If the connections are dirty, corroded, or greasy, scrape the wires and clean out the binding posts; then, screw the wires firmly in place. If the telephone does not then work properly, examine the batteries and see whether they are run down, or whether the zincs are eaten away. With wet batteries, it may be possible that the water has evaporated; in dry batteries, the zinc may be eaten through, or the batteries may be otherwise defective. The simplest way to test the battery is to try a new battery, and see whether it will make the telephone work properly; if it does, the trouble was with the old battery. If the trouble is present after changing the battery, examine the line connections and the line outside; if any loose connections are found, correct them at once. When inspecting the line outside see that it does not touch anything except the insulators, and that it is neither crossed nor broken. On grounded lines, examine the ground connection the first thing and see whether it is in good condition; and if a plate is used, see that it is in moist ground.

A frequent trouble with transmitters is a frying noise; this is usually caused by too much current or by loose connections.

If any coils in the instrument have been damaged by lightning, the smell of the charred insulation can frequently be detected when the door of the telephone is opened. If this is the trouble, the only thing to do is to replace the coil that has been burned out. One thing that should be carefully avoided is the placing of nails, screws, screwdrivers, scissors, or metallic instruments on the top of the telephone box. In a series telephone, this might cut out the instrument; on the bridging line, it might result in all the instruments on the line being thrown out of service. A very short list of only the most common faults that occur in ordinary series and bridging instruments, with suggestions as to their cause, will now be given.

**Cannot Ring nor Receive a Ring.**—The line or generator circuit may be open in a series instrument or short-circuited in a bridging instrument. If a series bell, connect the two main binding posts together; if the bell will not then ring when the generator is operated, the trouble is probably a broken wire inside the box. For a bridging instrument, remove the two line wires at the top of the instrument; then if the bell will ring, when the generator is turned, the trouble was due to a short circuit outside the instrument, probably between the line wires.

**Can be Called, but Cannot Call Others.**—This trouble may be due to weak or defective generators, or to bell coils of different resistance on the same line. If a call from another station rings the bell loudly but the home generator rings its own and other bells weakly, the trouble is probably due to a weak generator, poor connection in the generator circuit, or partial short circuit of the generator armature. On a grounded, bridging, party-line system, the trouble may be due to a high resistance in the ground connection at the home station only; for this high resistance may cause such a decrease in the current sent out by the home generator that when it subdivides through all the other bells, each part is too feeble to ring any of them, whereas the small incoming current may still be large enough to ring the bell.

**Cannot be Called, but Can Call Others.**—This trouble may be due to imperfect adjustment of the bell, armature, or gongs, or to bell coils of different resistance on the same line. In a bridging instrument, it may be due to a defect in the automatic cut-in device of the generator; in a series instrument, it may be due to a short circuit around the bell.

**Can Hear, but Cannot be Heard.**—In such cases, the trouble is usually with the battery or transmitter circuit. A careful examination of all connections therein should be made. It may be due to a defective, packed, or improperly adjusted transmitter, an exhausted battery, cells improperly connected, or a broken wire or short circuit in the battery circuit, or a short circuit in the secondary or primary winding of the induction coil. The person talking into the instrument may stand too far away; the proper way is to stand so that the lips are about 1 in. from the transmitter. The trouble may also be due to a defective receiver at the distant telephone, such as weak magnets, improperly adjusted receiver, dented diaphragm, or short circuit in receiver or its cords.

**Weak Receiver.**—This trouble may be due to poor connections in the receiver circuit, partial short circuit, bent or dirty diaphragm, diaphragm too close or too far from pole pieces (should usually be .015 in. from face of pole pieces), or permanent magnet may be weak (should usually support an 8-oz. iron weight or hold diaphragm on edge).

**Cannot Hear, but Can be Heard.**—In such cases, the trouble is usually in the receiver circuit, and is probably due to a defective or improperly adjusted receiver, dented diaphragm, or to a short circuit in receiver coil or in receiver cords. However, it may be due to a defective transmitter or a weak or improperly connected battery at the transmitting station; or, possibly, in a bridging instrument with a ground return, to an imperfect ground connection, the ground connections at the several other instruments on the same line being good.

**Weak Ringing of Bells.**—This may be due to loose connections, bad joints in the line, or imperfect ground connection at terminals, in case a ground return is used; a cross on the line if a bridged-metallic circuit is used; to a ground, if a bridged-grounded circuit is used. The bell adjustment may also be defective.

**Instrument Receives and Transmits Rings, but Nothing Can be Heard at Either Station.**—This trouble may be due to loose connections or a broken wire in either receiver, in either receiver cord, in either secondary winding of the induction coil, or to poor or loose contacts in the switch hook, or to weak batteries, improperly connected cells, open or short circuits in primary circuits at both stations, or short circuits in both receivers, or in the secondary windings of both induction coils. With a series-instrument, the following test may be made to determine whether the trouble is in the receiver or cord: Disconnect the cord from the box, but allow the receiver to remain on the hook. Remove the line wire from the binding posts, and place the two ends of the receiver cord in the line binding posts and turn the generator handle; if the receiver or cord circuit is not broken, the bell will ring. The wires in a cord may be broken, and yet the break may not be apparent if the cord is held in a certain position; hence, move the cords while making the test. If either conductor is broken, a scraping sound is produced in the telephone, or it may interrupt the speech so that a word is only audible occasionally.

**Clapper Clings to One Gong.**—If the clapper clings to one gong, move that gong toward the other gong and against the clapper. A slight adjustment of this kind will usually remedy the difficulty.

**Rasping, Grating, or Sizzling Noises in Receiver.**—This trouble may be caused by loose connections or excessive current in the battery circuit, by a buckled diaphragm in the receiver, or by particles of foreign substance lodged between the diaphragm and the pole piece of the receiver; or, the position of the diaphragm may not be correct. In modern receivers, no provision is usually made for adjusting the distance of the diaphragm from the magnet. Where such adjustment is possible, the diaphragm should be .015 in. from the magnet. This trouble may also be due to a weak magnet; the magnet should be strong enough at least to hold the diaphragm by its edge. It may also be due to a live wire of a power, electric-light, or other circuit lying across the telephone line.

**Bell Rings Frequently Without Apparent Cause.**—The line wire swings across telegraph or other live wires. On some selective-ringing party-line systems, a bell will often give one or more taps when another bell on the same line is being rung, especially if some receiver at another instrument on the opposite side of the line is off the hook. When the ground is used as one side of the ringing circuit, bells will sometimes give a few taps when the line side of its circuit forms a better return to the exchange than the ground between some other instrument that is being rung and the exchange. This may sometimes be remedied by putting an extra bell (removing the moving parts and gongs) or an impedance coil in the circuit between the bell and the ground.

**Poor Hook-Switch Contacts.**—Dirty contacts or weak springs of hook switches are generally the cause of troubles that can be very easily remedied by cleaning or retempering the springs. The latter may be done by bringing the spring to a red heat and then dipping it into water. Oil may be used instead of water if it makes the spring too hard.

## TESTING MAGNETO GENERATORS

One way to test a magneto generator consists in placing the fingers across the terminals and turning the crank; if the generator is in proper working order, a shock will be felt. This method of testing is preferred by some, because if the magneto is bridged, the ringer might be open and the generator O. K.

To test a series-bell and generator, place a piece of metal across the binding posts of the telephone, and turn the crank; if the bell rings, it is O. K., if not, trouble is inside. This is not specific, however, and both this and the former test should be made. Assume that the latter test has been made and that the bells did not ring clear and strong, but when another generator was used to send current through the defective magneto, the bell in the latter rang all right; then the wires were taken off the terminals and it tested clear, that is, the bell did not ring. If taken apart and examined closely, it will probably be found that the trouble is due to the automatic cut-out on the armature not working properly. If no shock can be felt, the fault will be due to a short circuit (crossed wires) or to a broken wire; if, however, a shock is received, but the bell does not respond, then the fault is in the ringer and may be due to bad adjustment or to broken or crossed wires. If the shock is weak, the fault may be due to defective or weak magnets or to a partial short circuit in the generator armature. All contacts in generators should be made and kept tight; also, the springs should be examined often, as holes are frequently worn in them and cause trouble. Very little oil should be used, as it is liable to cause trouble.

## INSPECTOR'S OUTFIT

The following list of tools and materials for setting up and repairing instruments will be found very useful. Although not complete for all and too complete for some work, it can be added to or subtracted from as may be found necessary. One pair of long-nosed 5-in. pliers; one small hammer; three 6-in. screwdrivers, with blades of different sizes; one keyhole saw; one set of drills; one pair of tweezers; three small files; one pair of side-cutting pliers; one box of fuses; one box each of screws, tacks, washers, staples, etc.; one racket brace; one set of bits, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$ in.; one small can of oil; emery paper or cloth, size 0000; crocus cloth; cloth and polishing paste; black insulating tape; 8-oz. weight for testing strength of receiver magnets; soldering lamp, iron, solder, and flux; small dusting brush; receiver and transmitter diaphragms and granular carbon; insulated and bare wire; candle or small lamp; battery material and battery gauge (for local-battery instruments only); satchel for carrying the tools and material mentioned.

Telephone installers should have an angle or ratchet brace, a long bit of proper size to take circular loom conduit, a Syracuse drill, a long gimlet bit, a pair of side cutting pliers, long-nosed pliers, a hammer, a small keyhole saw, two sizes of screwdrivers, an alcohol torch, a small gimlet, a coarse, flat file, some screws, washers, tacks, staples, etc.

# DISTURBANCES IN TELEPHONE LINES

## CAUSES OF NOISES IN TELEPHONE CIRCUITS

Strange noises are frequently heard in instruments connected with grounded telephone lines of considerable length. These noises may be due to one or more of several causes. The sudden shifting of the earth's magnetic field may induce currents in the line, which will cause sounds in the receiver; earth currents, due to differences in potential between the ground plates at the ends of the line, may also pass through the telephone instruments, producing the same result; there may be leakage from other lines; a neighboring wire carrying fluctuating currents will have set up about itself a varying magnetic field of force, which field may embrace the telephone line under consideration and by its fluctuations cause corresponding alternating currents to flow in the telephone line; and there may be a condenser action between the telephone wire and the neighboring wire, by which the latter may induce fluctuating charges on the former, and these charges will produce currents capable of affecting the receivers.

## GROUNDED AND METALLIC CIRCUITS

*Grounded telephone systems* are those in which one line wire is used, the ground forming one side of the circuit, or, as it is commonly designated, the *return circuit*. Such telephone lines frequently form part of the return circuit for electric street-railway systems and, moreover, induction from neighboring parallel lines may be considerable; in either case, the result may be what is commonly termed a *noisy line*. The first source of trouble just mentioned may be eliminated by the use of a common return wire in place of the earth, constituting what is called a *common-return system*.

To eliminate noises due to induction as well as those due to leakage, two separate wires must be used for each circuit. The two wires must be placed on adjacent insulators and transposed about every ¼ mile, care being taken that no two adjacent pairs are transposed in exactly the same manner.

In case the circuit runs through a cable containing other similar telephone circuits, the two wires constituting each circuit are invariably insulated with dry paper and twisted spirally about each other. Where two conductors are used for each circuit, it is said to be a *complete metallic*, or merely a *metallic, circuit system.*

## TRANSPOSITIONS

The proper way to make a *transposition*, where McIntire sleeves are used, is shown in Fig. 31. In Fig. 32 is shown

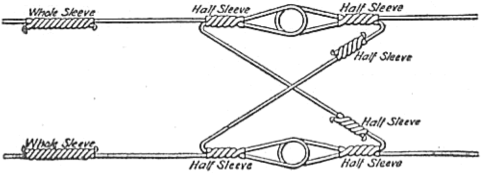



FIG. 31

the transposition insulator used where these transpositions are made.

The *single-pin*, or *Murphy, transposition* is shown in Fig. 33. Suppose that pole *b* is the one on which the transposition is to be made between the wires *l*, *k*, which take at the pole *a*, the pins *2* and *1*, respectively. A transposition insulator is placed on pin *1* at the pole *b* and the conductor *k* is tied in the lower groove, while the conductor *l* is tied in the upper groove. On the next pole *c*, the conductor *k* will be tied in the usual manner to pin *2*, while the conductor *l* will be tied to pin *1*. Their mutual positions are thus reversed.

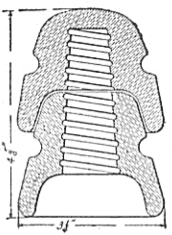


FIG. 32

To make this transposition, all that is necessary is to take up slack enough in the conductors to enable them to be shifted one pin to the right or left as the case may be. The single-pin transposition is said to have the comparative advantage of less first cost and simpler construction. It can be cut in at

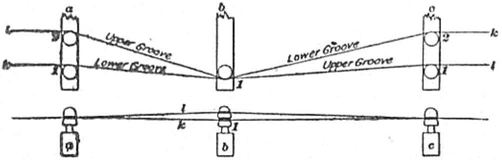



FIG. 33

any time, cut out, or moved several poles, at less cost and with much less work than in the case of a square, or ordinary, transposition.

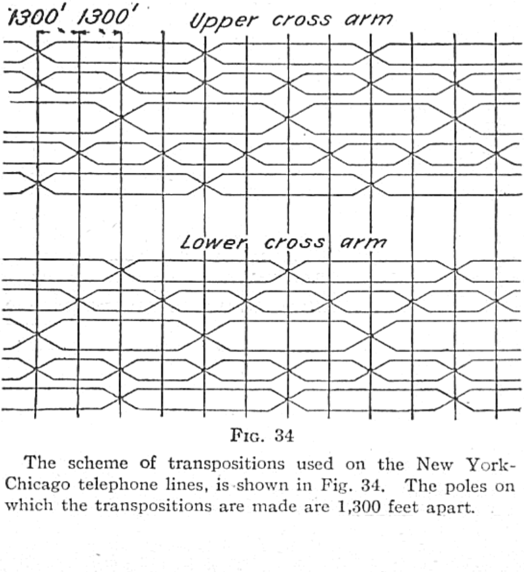



FIG. 34

The scheme of transpositions used on the New York-Chicago telephone lines, is shown in Fig. 34. The poles on which the transpositions are made are 1,300 feet apart.

## CAPACITY AND INDUCTANCE OF LINE WIRES

The length of time necessary for an impulse to rise to an appreciable strength at the distant end of a line depends on the distributed electrostatic capacity and the resistance of the line; in fact, it seems to be proportional to the product of these two quantities. For good transmission, both clear and loud, over telephone circuits, this product should be kept as low as practicable.

The electrostatic capacity of overhead wires, suspended at a height of about 30 feet above the ground, is approximately as shown in the table on page 219. The electrostatic capacity of an overhead wire will depend on the number and proximity of other wires, and especially if any of the neighboring wires are grounded. Where there are a number of grounded circuits on the same pole line, the electrostatic capacity will be higher. The capacity will also vary with the number of insulators per mile and the moisture on them. When one overhead wire is grounded at one end only (insulated at the other end), the capacity is twice as great as when both ends are grounded, that is, twice as great as the capacity given in the third column of the table on page 219. When a high inductance, such as a high-resistance (1,200-ohm) bridging bell, is connected between the end of the line and the ground, the capacity for high-frequency currents will be very nearly as great as when the end is insulated.

The capacity and inductance of one copper wire, .104 in. in diameter, weighing 173 lb. per mi., with both ends grounded, are given in the following table:

### CAPACITY AND INDUCTANCE OF SINGLE LINE WIRES

| Height of Wire Above Ground Feet | Capacity Microfarads per Mile | Inductance Henrys per Mile |
|---|---|---|
| 10 | .01060 | .002796 |
| 20 | .009796 | .003019 |
| 30 | .009379 | .003149 |
| 40 | .009105 | .003242 |

The capacity and inductance, when two copper wires, .104 in. in diameter, are suspended at the same height and 1 ft. apart, are given in the following table:

### CAPACITY AND INDUCTANCE OF LINE WIRES

| Height Above Ground Feet | Capacity Between Wire Grounded at Both Ends and the Ground Microfarads per Mile | Capacity Between Two Wires (Distant Ends Open) Microfarads per Mile | Inductance of One Wire Grounded at Both Ends Henrys per Mile | Mutual Inductance of Two Wires Connected Together at Distant End Henrys per Mile |
|---|---|---|---|---|
| 20 | .01171 | .004732 | .003019 | .001187 |
| 30 | .01150 | .004936 | .003149 | .001318 |

The increase of capacity between one wire and ground due to the adjacent grounded circuit is .01171 − .009796 = .001914, or 19.6% at a height of 20 ft. and .0115 − .009379 = .002121, or 22.6% at a height of 30 ft.

The capacity and inductance of metallic circuits of copper wire., .104 in. in diameter, for various separations, are given in the following table:

### CAPACITY AND INDUCTANCE OF METALLIC-CIRCUIT LINES

| Separation Inches | Capacity Microfarads per Mile | Inductance Henrys per Mile |
|---|---|---|
| 10 | .008503 | .003546 |
| 12 | .008218 | .003663 |
| 14 | .007992 | .003762 |
| 16 | .007806 | .003848 |
| 18 | .007649 | .003924 |

**Formulas for Capacity.**—The electrostatic capacity of a single wire of length $l$ and diameter $d$ at a height $h$ in the air above the ground when grounded at both ends may be theoretically calculated by the formula

$$C=\frac{.0388l}{\log_{10}\left(\frac{4h}{d}\right)} \text{ microfarads} \qquad (1)$$

The electrostatic capacity of two parallel wires each of length $l$ and diameter $d$ at a distance $h$ from each other may be theoretically calculated by the formula

$$C=\frac{.0194lK}{\log_{10}\left(\frac{2h}{d}\right)} \text{ microfarads} \qquad (2)$$

In these two formulas, $l$ must be expressed in miles, but $h$ and $d$ may be expressed in any units of length, provided both are expressed in the same units. $K$ is the inductivity of the dielectric filling the space between the two wires. For a bare overhead line, $K=1$. Values calculated by these formulas agree closely enough with results obtained for bare overhead wires by actual measurement. The effect of adjacent circuits is to increase the effective capacity of a line as determined by the foregoing formulas.

If the two parallel wires of a metallic circuit have an insulating covering, in addition to being suspended a distance apart in air, the capacity is slightly increased by the greater inductivity of the insulating covering. If the wires have a diameter $d$, an insulating covering of diameter $d_1$, the distance between them being $h$, the inductivity of the insulating covering $K$, and their length in miles $l$, then the capacity, in microforads, is given by the formula

$$C=\frac{.0194l}{\log_{10}\frac{2h}{d_1}+\frac{1}{K}\log\frac{d_1}{d}} \qquad (3)$$

The mutual capacity $C$, in microfarads, between two two-wire metallic aerial circuits, of length in miles $l$, one circuit consisting of wire of diameter $d_a$ and the other of wire of diameter $d_b$, is given by the formula

$$C=\frac{.15536 \log_{10}\frac{r_1 r_2}{r_3 r_4} l}{16 \log_{10}\frac{2r_5}{d_a}\log_{10}\frac{2r_6}{d_b}-\left(2 \log_{10}\frac{r_1 r_2}{r_3 r_4}\right)^2} \tag{4}$$

The distances $r_1$, $r_2$, $r_3$, $r_4$, $r_5$, and $r_6$ are shown in Fig. 35.

These formulas are correct for wires of magnetic or non-magnetic material. The presence of the earth beneath an aerial metallic circuit increases the capacity very slightly—less than a fraction of 1 per cent. if the wires are above the earth a distance at least several times the distance between them. The assumption made in the deduction of the formulas for electrostatic capacity is that there are no other wires in the immediate vicinity of those being considered. The effect of adjacent circuits is to increase the effective capacity of a line. For a pair of conductors in a telephone cable, the formula would be too complicated to be of any practical value (even if one could be derived), on account of the influence of neighboring conductors and the grounded lead sheath.

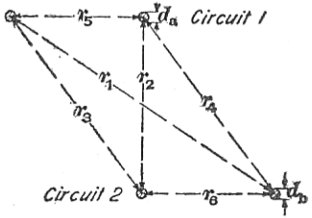



FIG. 35

**Formulas for Inductance.**—The formula for the inductance of a single aerial wire, composing a grounded circuit, is

$$L=\left(\frac{.08047+.7411 \log_{10}\frac{2h}{r}}{10^3}\right). \tag{5}$$

in which $L$=inductance per mile, in henrys;
$h$=height of wire above earth;
$r$=radius of wire.

$h$ and $r$ should be expressed in the same units. The inductance of a two-wire aerial metallic line may be expressed by the formula

$$L=\left(\frac{.1609+1.482 \log_{10}\frac{d}{r}}{10^3}\right). \tag{6}$$

in which $L$ = inductance per mile of the line circuit, in henrys;
$d$ = distance between centers of two wires;
$r$ = radius of wire (both same size).

$d$ and $r$ should be expressed in the same units. Formulas 5 and 6 are for wires made of non-magnetic material. The inductance of iron or steel wires is greater than that of copper wires of the same size. The effect of the earth on the inductance of a metallic circuit is less than a fraction of 1 per cent. if the wires are above the earth a distance greater than two or three times the distance between them. The inductance is decreased by the presence of the earth. These formulas assume that there are no magnetizable substances within a distance of the circuits less than several times the distance between the wires forming the pair, or the height of a wire above the earth.

The mutual inductance $M$ between two two-wire metallic aerial circuits is given in henrys per mile by the formula

$$M = \frac{.7411 \log_{10} \frac{r_1 r_2}{r_3 r_4}}{10^3}. \qquad (7)$$

in which the distances $r_1, r_2, r_3$, and $r_4$ are the same as in Fig. 35.

If, in formulas 4 and 7, the distances are such that $r_1 \times r_2 = r_3 \times r_4$, $C$ and $M$ become equal to zero. Therefore, it is possible to arrange two two-wire metallic circuits so that there will be no electrostatic or electromagnetic interference between the two circuits; in other words, so that there will be no cross-talk between two circuits so arranged. This is practically accomplished by twisting the wires in pairs as in ordinary telephone cables.

## PUPIN LOAD COIL SYSTEM

An articulate voice current consists of a fundamental wave and a large number of overtone waves of different frequency. Also, the greater the frequency of an overtone wave, the more does inductance tend to make it lag behind the fundamental; whereas, capacity has the opposite effect, so that the greater the frequency of an overtone wave, the more does it tend to lead the fundamental wave. Furthermore, the proper amount of inductance inserted in a circuit will neutralize a given capacity for one particular frequency. The difficulty with telephone circuits is the fact that the capacity between the line and the ground or other conductors is distributed throughout its length, and the frequency varies from about 32 to 40,000 periods per second. Prof. M. I. Pupin was the first to mathematically demonstrate and then practically prove that the distributed capacity of a line can be neutralized by inductance by connecting properly designed inductance coils in series with the line and at definitely calculated distances apart. He showed that, by neutralizing the capacity by inductance for the highest frequency commonly occurring in conversation, namely, about 750 periods per second, the neutralization was sufficient for all frequencies. The coils must have a definite inductance and be located definite distances apart along the line, so that there are at least several within the length of a half electric wave. The calculations, however, are too complex to be given here. When the neutralization is properly done, the overtone waves are so little displaced from each other and from the fundamental wave that distinct conversation can be held not only over much greater distances but also over smaller-sized wires.

The coils, known as the *Pupin load coils*, are now used on the New York-St. Louis, New York-Chicago, and other long circuits. On the New York-Chicago line, it is claimed that the use of the load coils has improved the transmission 100%. This circuit consists of No. 8 B. W. G. hard-drawn copper line wires, with load coils in series with the line every 2½ mi. In the underground cables between New York and Hartford, extra-large manholes are located every 6,600 ft. apart, in which Pupin load coils are placed. The use of load coils seems more beneficial and profitable in underground cable circuits than in bare overhead line circuits. Professor Pupin is confident that a conversation between New York and San Francisco may be held without difficulty over a circuit properly equipped with these inductance coils. A more complete discussion of this theory and the use of load coils is given in the International Correspondence Schools' Telephone Engineering Course.

## ATTENUATION AND DISTORTION

**Attenuation.**—By *attenuation* is meant the decrease in intensity, strength, or amplitude of an electrical wave between the transmitting and receiving ends. Contrary to the conception frequently held, the maximum, or mean, value of an alternating or variable current may not be the same in all parts of a line wire, even at any given instant, but may decrease gradually as the distance from the transmitting end increases; this is not necessarily true for a steady direct current, however. This reduction is due to the resistance of the conductors, insulation resistance, and improper relative values of distributed capacity and inductance of the line circuit.

**Distortion.**—The *distortion* of an electrical wave is due to the fact that some electrical property (usually, distributed capacity) of the line acts unequally on the component waves of different frequencies that together make up a complex current wave representing articulate speech, the result being that the change in the phase relations and intensity of the various overtones and the fundamental tone produces a change in the shape of the current waves that renders the articulation more or less defective. Increased distance interferes with the transmission over a uniform conductor, not only on account of the diminished volume of the sound transmitted, but also on account of the rapid deterioration of the articulation.

## PARTY LINES

Each telephone may be connected to a line circuit terminating in an exchange, where the proper switching devices are provided for connecting together any two lines. Such circuits are termed private, or, better, individual telephone lines. Frequently, several telephone instruments are connected to the same line circuit, such a circuit being called a *party line*. On party lines, the instruments may be connected in various ways.

In the method shown in Fig. 36, which represents a ground-return circuit, the instruments are connected in series, and such a party line is called a *grounded, series* *party line.* A line wire may be used in place of the ground return, and it is then called a *metallic, series party line.* Each bell is wound to a low resistance (from 60 to 120 ohms), and is so connected through the switch hook that the removal of the receiver from its hook cuts out the bell. Evidently, the ringing current encounters the impedance of all the bells

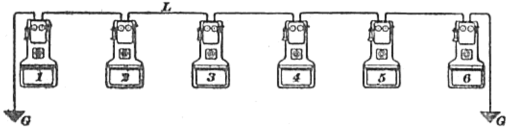



FIG. 36

in the same circuit in addition to the line resistance, and the talking current also encounters the resistance of the line and the impedance of all the bells, except at the stations where the receivers are removed from the hooks. As the frequency of the voice current is very high (average about 300 periods per sec.), while that of the ringing current is low (15 periods per sec.), the former is considerably reduced in strength, and the articulation becomes weak and indistinct if too many

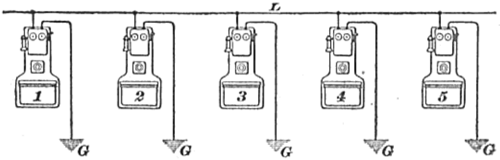



FIG. 37

telephones are connected in the same line. The bells in series telephones must not be too high in resistance, and the generators must develop sufficient E. M. F. to send a current of proper strength through the line and all the bells that are in series. The generator must be provided with an automatic device that short-circuits its armature when the battery is at rest and opens this short circuit when the generator is in use.

A better method, now extensively used, consists in connecting the telephone instruments in parallel across the line circuit, as shown in Fig. 37, which represents a *grounded, bridged party-line circuit,* so called because the telephones are said to be bridged across the circuit from the line wire to the ground. A *metallic, bridged party-line circuit* is shown in Fig. 38.

In bridging instruments, bells wound to a high resistance must be used, in order that the bells at telephones not in

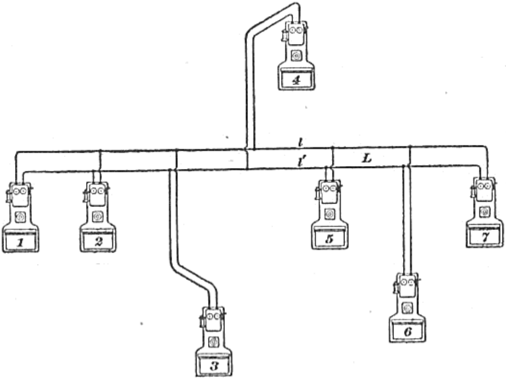



FIG. 38

use may not short-circuit or form serious leaks for the voice currents flowing between two stations in use. The higher the resistance of the line and the greater the number of telephones bridged across one line, the greater should be the resistance of the bells. The ringing current divides through all the bells connected across the line. The generator is usually provided with an automatic device that leaves the armature on open circuit when at rest and connects it directly across the line binding posts of the instrument while the generator is in use. Usually, the bells are connected permanently across the line binding posts, but in many instruments the bell is cut out when the receiver is removed from the hook. The bells are usually wound to 1,000, 1,200, 1,600, 2,500 and even as high as 5,000 ohms. The impedance of such bells to the high-frequency voice currents is so great that the voice currents are practically confined to the line and instruments at which the receivers are removed from the hooks.

**Party-Line Signals.**—On the party-line systems so far described, it is necessary to use a code of audible signals to enable the parties at the various stations to distinguish their calls from those of other stations on the same line circuit. These codes are usually made up of a various number of rings or various combinations of long and short rings, so that, by sound, a party may at once tell whether his attention is desired at the telephone.

There are other systems in which means are provided for ringing the bell of any one subscriber without disturbing any of the other bells on the same party line. They are termed *selective-signaling systems*, and may be divided into three classes:

1. Those employing step-by-step mechanisms operated by impulses of current sent from the central exchange in such a manner as to close the bell circuits at the subscribers' stations successively. This method has been used but little in actual practice because it is difficult to secure proper electrical contacts between the stationary and movable parts; also, the devices have been too complicated.

2. The second system applies to the harmonic, or reed, method of selecting, wherein currents of various frequencies are employed for actuating the different bells. The four-party selective-signaling systems devised by W. W. Dean come under this class. The four bell hammers on the same circuit are made so as to have different periods in which they will readily vibrate, and four different frequency currents and, in one case, slightly different voltages also, are used for ringing. In the system made by the American Electric

Telephone Company, alternating currents of two frequencies are used (20 and 60 cycles per sec.), while the capacity and inductance of the two bell circuits connected between the same two line wires are so proportioned that the lower frequency current will ring only one of the bells and the higher frequency only the other bell. By connecting two such bell circuits between each side of a complete metallic circuit and the ground, as is customary, any one of the four bells may be rung by connecting the proper frequency ringing machine between the proper line and the ground. A condenser is connected between each bell and the ground, so that neither line is actually grounded. When the receiver is removed from the hook, the telephone is connected across the two line wires; thus, a complete metallic circuit is used when conversing.

3. There is another system in which selective signaling is accomplished by changes in the direction of the current. A polarized relay or an ordinary polarized bell can be readily arranged to respond to current impulses in one direction only. Obviously, this in itself affords means for signaling either one of two stations on the same line circuit without disturbing the other. By attaching a spring to one end of the armature of an ordinary polarized bell, the hammer may be held normally against one gong. If direct but pulsating current flows through the bell coils in such a direction as to move the hammer against the other gong, the bell will ring, because the current impulses cause the hammer to hit one gong and the spring draws it back against the other gong between each impulse and while no current is flowing through the coils. A pulsating current in the opposite direction will not ring the bell, because the magnetism developed in the cores merely tends to pull the armature in the same direction as the spring and there is no tendency to move the hammer against the other gong. Another similarly polarized and wound bell may be rung by putting the spring on the opposite end of the armature and sending pulsating currents through the coils in the opposite direction. By connecting two such bells, wound to a high resistance, in parallel across a line, either bell may be rung. By

connecting two such bells between one wire of a metallic circuit and the ground and two similar bells between the other wire and the ground, any one of the four bells may be rung by connecting between the ground and the proper line wire one of two generators that will send pulsating currents in the proper direction. The circuits are arranged so that all conversations are carried on over the two line wires.

## TELEPHONE-EXCHANGE SYSTEMS

The ordinary form of telephone exchange for handling a large number of subscribers comprises a central office, from which the lines to the subscribers' stations radiate. The lines terminate at the central office in what is called a *switchboard*, which must contain apparatus for attracting the attention of the operator when one subscriber desires to talk to another; means for the operator to connect her telephone with the subscriber's line, in order to ascertain his wants; means for connecting his line with that of any other subscriber; means for calling the subscriber desired; and, finally, means for enabling either subscriber to notify the operator that their conversation is ended.

**Line Signals.**—The apparatus for attracting the operator's attention may be an electromagnetic annunciator, or a very small incandescent lamp whose circuit is controlled by a relay in the line circuit. Annunciators, or *drops*, as they are commonly called, are used on switchboards where the subscriber's set is equipped with a magneto generator, and relays controlling lamps are used in large central-energy, or common-battery, systems.

### SIMPLE MAGNETO SWITCHBOARD

The circuits of a *simple magneto switchboard* are illustrated in Fig. 39. The binding posts $L$ $L'$ are connected through line wires with the tip spring $t'$, $t''$ and the sleeve contacts $s'$, $s''$ of the spring jacks $J'$, $J''$, while the drops $D'$, $D''$ are connected between the contact spring $p'$, $p''$ and the sleeve side of the line circuit.

If subscriber *A* operates his generator *G′*, current flows through the line and drop *D′*, causing the shutter of the latter to fall, thereby attracting the operator's attention. The operator inserts the answering plug *P′* in the jack *J′*, thereby cutting out the drop and extending the line circuit to a flexible cord circuit, and restores the shutter of *D′* to its normal position. The tip *t* and sleeve *s* of the plugs are insulated from each other, but connect with wires *1*, *2*, and to the tip and sleeve of a jack when inserted therein. The

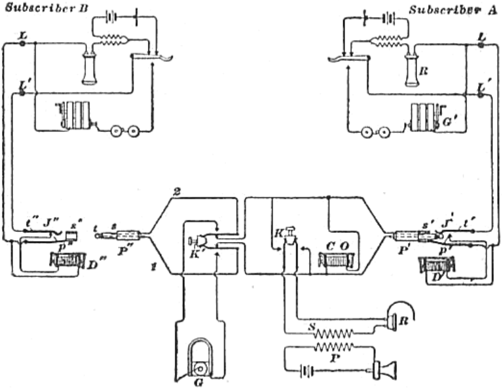



FIG. 39

operator depresses the listening key *K*, which connects the secondary circuit containing the head-receiver *R* and secondary *S* of the induction coil across the cord circuit. This enables the operator to converse with subscriber *A*, who has in the meantime taken down his receiver *R* and from whom is obtained the information that connection is desired with another subscriber, say *B*. The operator then inserts the calling plug *P″* in the jack *J″*, thereby cutting out the drop *D″* and establishing connection with the line wires of subscriber *B*. The operator then depresses the ringing key *K'*, thereby connecting the ringing generator *G* across the strands *1*, *2* of the calling side of the cord circuit leading to the calling plug *P''*, thus ringing the bell at station *B*. The ringing current cannot pass to station *A* because the depression of the ringing key *K'* disconnects the two cord conductors leading to the answering plug *P'*. When the operator releases the key *K'* and subscriber *B* removes his receiver from its hook, the talking circuit between the two subscribers is complete. After the conversation is finished, one or both of the subscribers should operate their generators, or "ring-off," as it is usually termed. This will send a current over the lines of the two connected subscribers, a part of which will find a path through the clearing-out drop *CO* and cause its shutter to fall. The operator, seeing the signal, should close the listening key, restore the shutter of *CO* to its normal position and inquire whether any further service is desired; if no response is received, the two lines should be disconnected by removing the two plugs from the jacks.

The line drop in a system of this kind should have about the same resistance as the subscriber's bell. In order that the clearing-out drop *CO*, which is connected across the circuit during the conversation, shall not form too low a leakage path between the two sides of the circuit, it is wound with a large number of turns to a high resistance (from 500 to 1,000 ohms). The inductance of the drop is increased by enclosing the core and coil in a tube of soft iron, which makes its impedance to the high-frequency voice currents very great, and, furthermore prevents cross-talk and other inductive disturbance between neighboring drops.

## CENTRAL-ENERGY, OR COMMON-BATTERY, SYSTEMS

Replacing all the transmitter batteries and the signaling generators at the subscribers' stations by a single source of current located at the central office has proved so successful that most of the new large exchanges are now operated on this plan. While there are many different systems in use, nearly all of them involve one of the following principles:

1. In the *Stone system*, the lines during a conversation, are connected through impedance coils with a common battery; that is, between one terminal of the common battery and one side of each circuit is connected an impedance coil, and between the other terminal of the battery and the other side of each circuit is connected another impedance coil. Thus, for each pair of lines connected together, there is a separate pair of impedance coils through which the battery supplies current for those lines. Therefore, each subscriber's station receives current from the central battery through a pair of impedance coils, which allows the battery current to flow, but confines the high-frequency voice currents to the line wires. These impedance coils may be made to serve as relays to give clearing-out or supervisory signals.

2. The *Hayes common-battery system* consists in connecting each side of two circuits in use through a repeating coil to the terminals of the common battery. The repeating coil is usually divided into at least four coils, constituting really two separate repeating coils. One coil connects one side of one circuit with one terminal of the battery, another coil connects the other side of the same circuit to the other terminal of the battery, and, similarly, the other half of the repeating coil connects the two sides of another circuit with the opposite terminals of the battery. This method of operation will be understood from the description to be given of the Bell central-energy exchange.

## LARGE SWITCHBOARD SYSTEMS

**Transfer Switchboards.**—When the number of subscribers connected with an exchange is larger than can be attended to by three operators, any one of whom can reach all the jacks, either transfer or multiple switchboards must be used. In the transfer system, auxiliary circuits, termed *trunk*, or *transfer lines*, run between the various sections into which the switchboard is divided, and means are provided by which the operator may connect one end of any one of these trunk lines with the line of a subscriber, while the operator at the other end, when instructed to do so by the first operator, can complete the action between her end of the trunk line and the line of the subscriber called for. Trunk lines thus serve as auxiliary connecting circuits between two subscribers' lines that cannot be connected together at any one section of the switchboard. A switchboard arranged to operate in this general manner is termed a *transfer*, or *express*, *switchboard*.

**Multiple Switchboards.**—The primary object of the *multiple-switchboard system* is to so arrange the apparatus that any operator can connect the line of a calling subscriber with that of any other subscriber in the entire system without the assistance of another operator. The entire board is divided into sections, each usually containing the necessary apparatus and room for three operators. In each section are placed as many multiple jacks as there are lines in the exchange in addition to the line signals and answering jacks of the lines the calls from which are to be attended to at that section. Each operator can reach over one operator's position on each side of her. On some common-battery multiple switchboards, each operator attends to as many as 200 lines.

It is evident that the operator at one section will, unless special means are provided, have no way of knowing whether a line called for by a subscriber at her section is already connected with another line at some other section of the board. Should she make connections between one subscriber's line and another line already in use, three subscribers would be connected together and much confusion would result. In order to prevent an operator from making connection with a line that is already in use at another section of the board, there is provided a so-called *busy test*, which forms an essential feature of every multiple switchboard. The operator usually performs the test for a busy line by applying the tip of the calling plug to the sleeve or ring of the jack of the subscriber called for. If the line is busy, the operator will hear a click in her head telephone, while if it is free or not in use, silence will inform her of that fact. The details of the busy test will be explained in connection with the circuit of a central-energy multiple switchboard.

**Central-Energy Multiple Switchboard.**—The principal features of the *central-energy multiple-switchboard system* used by the licensees of the American Bell Telephone Company are shown in Fig. 40. The Hayes principle of utilizing repeating coils and one battery for all line circuits is employed. Two operator cords and three subscriber circuits are shown. Normally, the circuit between the line wires is closed only through the subscriber's bell and condenser. The alternating current from the ringing generator at the exchange can ring the bell through this circuit, but no battery current can pass through it on account of the condenser. In each cord circuit there is one repeating coil, which has four windings $w$, $x$, $y$, and $z$. In the answering, or left-hand, side of the cord circuit, there is one supervisory relay $AR$, controlling the answering supervisory lamp $AL$; and there is a similar arrangement in the calling, or right, side. So as not to impede the voice currents too much, the relays $AR$ and $CR$ are shunted by non-inductive resistances $Ar$ and $Cr$, which do not, however, interfere with the proper operation of the relays. When the resistance coil $u$ and lamp $AL$ are in series across the 24-volt battery $B$, the lamp will light, but it will go out when the 40-ohm resistance $v$ is connected in parallel with the lamp by the operation of the relay $AR$. For the sake of clearness several batteries are shown, but there is really only one battery. Normally, no current flows through the cut-off relay $CO_1$, and hence, the line circuit is closed between $a$, $b$ and between $m$, $i$.

When the subscriber at station *1* removes the receiver $R_1$ from the hook, the transmitter $T_1$ and one winding $P_1$ of the induction coil form a circuit across the two line wires of sufficiently low resistance to allow enough battery current to flow from $B_1$ to energize the line relay $LR_1$, thereby closing its local circuit and lighting the line lamp $LL_1$, which notifies the operator that her attention is desired on that line. The operator responds by inserting the answering plug (belonging to any one of the ten- or fifteen-cord circuits

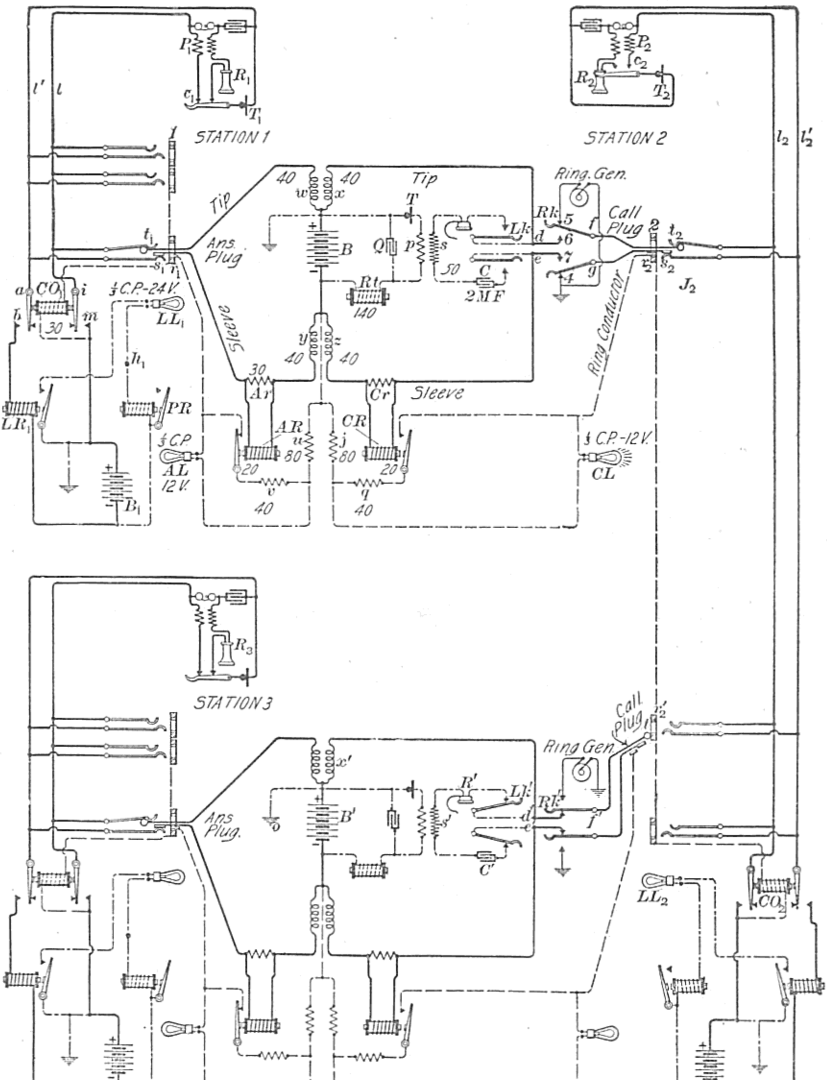

STATION 1
STATION 2
STATION 3
Tip
Sleeve
Ans. Plug
Call Plug
Ring Gen.
Ring Conductor
1/3 C.P.-24 V.
1/3 C.P. AL 12 V.
1/3 C.P.-12 V. CL
LL1
LL2
LR1
PR
CO1
CO2
B1
AR
CR
Ar
Cr
Rt
140
2 MF
J2
B
B'
Q
T
Rk
Lk
R1
R2
R3
P1
P2
T1
T2

Fig. 40

28552

that she has before her) into the answering jack belonging to line *1*, as shown. Enough current flows through $AR$ to close it, which prevents the lighting of $AL$. Current also flows through $CO_1$, thereby breaking the circuit at $b$ through the line relay $LR_1$, which causes the line lamp $LL_1$ to go out. The operator closes the listening key $Lk$, thereby connecting the receiver, secondary winding $s$ of her induction coil, and the condenser $C$ across the cord circuit. The operator's transmitter $T$, primary to winding $p$, and retarding coil $Rt$ are connected to the terminals of the battery $B$. The retarding coil not only limits the current through any one transmitter, but also enables current to be supplied to all the operators' transmitters from one battery without causing cross-talk. The condenser $Q$ improves the transmitting qualities, probably because it compensates more or less for the inductance of the retarding coil $Rt$.

If the subscriber at station *2* is wanted, the operator will make the usual busy test on that line, and if the line is not busy, she inserts the calling plug into the multiple jack $J_2$, opens the listening key, and closes the ringing key $Rk$. Current from the ringing generator flows through and rings the bell at station *2*. Current now flows through $B$–$CO_2$–$r_2$–$CL$–$j$, thereby lighting the supervisory lamp $CL$ and closing the relay $CO_2$, which prevents the lighting of the line lamp $LL_2$. When the subscriber removes his receiver $R_2$ from its hook, current flows from $B$ through the subscriber's circuit and the relay $CR$, thereby connecting $q$ in parallel with $CL$, which causes the latter to go out.

When the subscriber talks into the transmitter $T_1$, its resistance changes sufficiently to produce a variable current through the windings $w$, $y$, which induces an alternating current in the windings $x$, $z$. This alternating current, combined with the direct battery current, produces a current of variable strength in the line circuit of station *2*. This variable current in the winding $P_2$ of the induction coil induces an alternating E. M. F. in the other winding of the induction coil, thus producing an alternating current in the local circuit containing the receiver, transmitter, and condenser. It is also probable that the effect produced by this current is reinforced by some of the variable current. which may flow through the hook switch, receiver, and induction coil and assist in charging and discharging the condenser. When the conversation is finished, the lamp *CL* will light as soon as $R_2$ is hung up, and *AL* will light as soon as $R_1$ is hung up.

To explain the "busy" test, assume that the circuits are exactly as shown in Fig. 40; that is, that stations *1* and *2* are connected together, subscriber *2* not having removed his receiver from its hook, and that the call of subscriber *3* for connection with subscriber *2*, whose line is now busy, has just been answered by an operator at another section of the switchboard where the lower cord circuit is located. The latter operator makes the busy test as follows: Her listening key is already closed, so she merely touches the tip *t* of her calling plug to the ring contact $r_2'$ of the multiple jack in her section belonging to subscriber *2*. Current flowing from $+B$ through $CO_2$–$r_2$–$CL$–$j$ makes the potential of the ring contacts of all jacks belonging to this line different from that of the ground, and produces a click in the operator's receiver $R'$, for current then flows through $B$–ground–$o$–$x'$–$d'$–$f'$–$t$–$r_2'$ where it unites with current flowing through $B$–$CO_2$–$r_2'$, and the whole current flows through $r_2$–$CL$–$j$. Before touching $t$ to $r_2'$, the points $d'$, $e'$, and hence the terminals of condenser $C'$, had exactly the same potential difference as the terminals of battery $B'$; but now the current through $B$–ground–$o$–$x'$–$d'$–$f'$–$t$–$r_2'$–$r_2$–$CL$–$j$ has suddenly lowered the potential of $d'$, and hence the charge on condenser $C'$ has suddenly decreased, thereby producing a momentary current and click in the receiver $R'$, which notifies the operator that the line is already in use, or busy, as it is called.

If the line is not in use, that is, if there is no plug in any jack of this line, the tip *t* of the calling plug and the sleeve $r_2'$ of the jack will be at the same potential—the potential of the positive terminal of the common battery—and hence no click will be produced.

The circuits of all the line lamps at any one position are connected together at $h_1$, between which point and the battery is connected a line-pilot relay *PR*. This relay controls the circuit of a line-pilot lamp, which is not shown in this figure, but which lights every time any line lamp at that operator's position lights, and goes out when the line lamp goes out; that is, when the call is attended to by inserting a plug in the jack. A similar supervisory-pilot relay and supervisory-pilot lamp is associated with all the cord circuits at one operator's position. The supervisory-pilot relay is energized and the supervisory-pilot lamp lights when any answering supervisory lamp at the same operator's position is illuminated.

## AUTOMATIC TELEPHONE SYSTEMS

An *automatic telephone system* is one designed to supplant the telephone-exchange operator by automatic appliances. Switches located at a central office automatically connect two lines for a conversation and also disconnect them, this result being produced as a result of certain operations performed by the subscribers themselves. An automatic system usually consists of a telephone and selecting device at the subscribers' stations, the selecting device being used by the subscriber to select the line desired by sending a certain number of impulses over one or both line wires. At the exchange, a switch automatically connects the calling line to the line selected by the subscriber. Therefore, to establish connections between any two lines running to the same automatic exchange, no operators are required. Thus a large item of expense—operators' salaries—is saved in the cost of operation. Those favoring manually operated systems claim that more expert troublemen and switchboard men are required, which more or less offsets the saving in operators' salaries. Operators are generally employed, however, for toll service and trunking between different exchanges, even if both exchanges are automatic. The use and popularity of automatic systems are increasing and a large number of exchanges, both large and small, are now equipped with such systems. Automatic telephone systems are rather complicated, and, every new installation is likely to contain improvements over preceding systems; even a general description that would apply to one installation would require more space than can be devoted to it here. Such systems are fully described in the International Correspondence Schools' Telephone Engineering Course.

## TELEPHONE-PROTECTING DEVICES

A complete protector for telephone lines includes three forms of protective apparatus: (1) an open-space cut-out, designed to act as a spark gap and relieve the circuit from high-potential discharges by forming a non-inductive path to ground; (2) a thermal apparatus so designed that when an abnormal current of relatively low voltage appears, the thermal apparatus under the effect of the heat created by the extra current will operate in such a manner as to open or ground the side of the circuit toward the apparatus to be protected and ground the other, or line, side; and (3) a fusible cut-out of relatively large current-carrying capacity and extended across a long gap.

These three pieces of apparatus are known by the names *open-space cut-out lightning arrester* or *static arrester*, *heat coil* or *sneak-current protector*, and *fuse*. For the complete protection of a telephone line, it is usually considered desirable to place an open-space cut-out and heat coil on the distributing board to protect the central-station apparatus; to place a fuse wire on underground lines

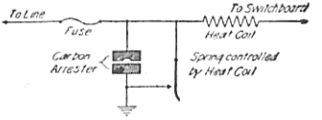


FIG. 41

where the cable to the central office joins open wire; and to place a second fuse and open-space cut-out and sometimes a heat coil at the subscriber's telephone substation.

Whenever the three elements—fuse static arrester, and heat coil—are used, the relation of the elements should be as shown in Fig. 41, the heat coil being connected on the switchboard side or, if at a subscriber's station, on the telephone side of the circuit. The first duty of protective apparatus is to prevent foreign currents from damaging central-office equipments; hence, the proper position for the fuse is between that part of the line circuit which can come into contact with a source of dangerous current and the office equipment. The term *exposed wiring* may be applied to such parts of the line as may ever come in contact with a source of dangerous current, while *unexposed wiring* may be applied to all parts of the line that are secure from such contact. Unexposed wiring includes underground cables cables formed of wires insulated with rubber, and wiring wholly within buildings. All other wiring may be considered as exposed to accidental contact with high-potential circuits. In this class, aerial cables having lead sheaths are included, because contact between such a cable and a high-potential wire very frequently causes an arc that destroys the sheath and allows current to enter the conductors.

**Lightning Arresters.**—Lightning arresters used on telephone lines usually consist of two blocks of carbon separated by silk, paper, perforated mica, or celluloid. At central stations, the separation is usually .005 in., and the same or a trifle greater (.008 in.) at the subscribers' stations. Where fuses are used, they are generally enclosed in long and nearly air-tight wooden or fiber tubes.

Fig. 42 (*a*) shows Cook's No. 10 protector for use on the terminal frame of an exchange. The carbons *c*, *e* of the lightning arrester rest on a grounded strip and are separated from the line carbons *b*, *d* by perforated or **U**-shaped pieces of celluloid .005 in. thick. The many small perforations in the celluloid are said to break up the discharge, thereby forcing it to pass through the arrester at many points and thus prevent particles of carbon from breaking off and short-circuiting the arrester. If an arc continues across *bc* or *de*, due to a cross with a high-voltage circuit, the celluloid will melt and allow the springs to press the carbon blocks together and form a dead ground; this will stop the arc, and if the current increases sufficiently, the fuses at the outer end of the line will melt and cut off the line circuit from the switchboard.

A low-voltage current that is large enough—if it persisted—to damage a switchboard, coil, or other device

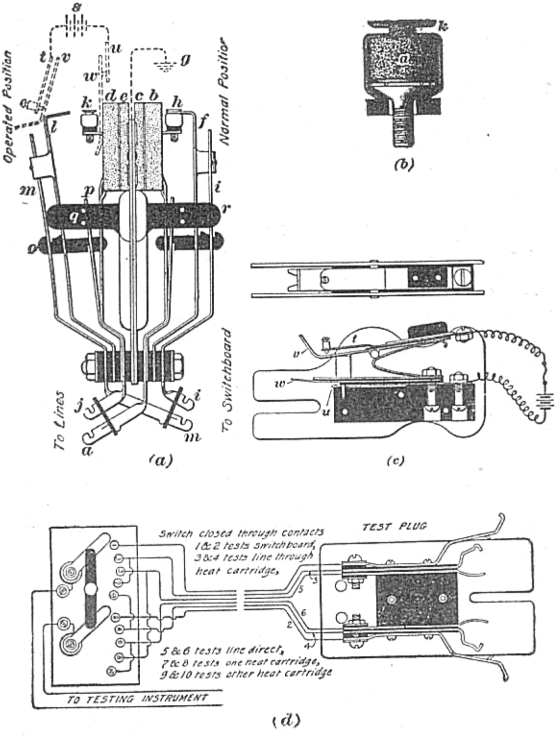

Operated Position
Normal Position
To Lines
To Switchboard
(a)
(b)
(c)
Switch closed through contacts
1 & 2 tests switchboard,
3 & 4 tests line through
heat cartridge,
5 & 6 tests line direct,
7 & 8 tests one heat cartridge,
9 & 10 tests other heat cartridge
TEST PLUG
TO TESTING INSTRUMENT
(d)

FIG. 42

will pass from line *a* through the heat cartridge *h*–springs *f*, *i*–switchboard–springs *m*, *l*–heat cartridge *k*–springs *j*, to line. An unusually large current will heat the graphite *a* packed in the cartridge [see Fig. 42 (*b*)], and, by the conduction of heat, a low-temperature-melting solder on the brass shell at *k* will become soft enough to allow the spring *m*, Fig. 42 (*a*), to pull the hard-rubber piece *o* and with it the spring *l* out of *k*. This also causes spring *p*, which is forked, to touch both metal pins *q* and thus close a circuit (not shown) containing a battery and an alarm bell. The cartridge, Fig. 42 (*b*), consists of a metal shell, enclosing a graphite composition that is insulated from the metal casing except on the upper and lower ends. Hard-rubber strips *r*, Fig. 42 (*a*), pass through the central grounded strip and keep the springs belonging to one line circuit alined and separated from adjacent springs.

To reset the heat cartridge, the resetting plug shown in Fig. 42 (*c*) is pushed between the springs, thereby connecting a battery *s*, Fig. 42 (*a*), between the springs *v*, *w* and pressing the springs *m*, *l* back toward their normal position. When *l* touches *k*, current flows through *k*, softens the solder, allows *l* to slip into place, and breaks contact between springs *t*, *v*, thereby stopping the current, which allows the solder to harden and hold the springs *l*, *m* in position. Should the cartridge be defective, the operation of resetting automatically indicates the fact, because the spring *l* cannot be reset properly. By inserting the test plug, Fig. 42 (*d*), between the springs of one protector, Fig. 42 (*a*), it is possible to test the various circuits, by the aid of the switch shown and the proper testing instruments.

**Combination Protector.**—The *D and W combination protector*, shown in Fig. 43, well represents the complete protection frequently used at subscribers' stations. Sometimes the heat coil is omitted and sometimes the fuse, depending on conditions and the opinion of the telephone man in charge of the system. The arresters almost invariably consist of two carbons similar to *a*, *b*, one of which is in contact with each line wire and separated from a grounded brass plate *e*, usually by means of a piece of silk, paper, or perforated mica, .008 in. thick. This thickness of mica will permit 350 or more volts to arc across the air gap, and thus allow the line to discharge to ground. Long, enclosed fuses, the center portion of which in this particular make runs through an air-tight capsule of gelatine *vu*, are used, and

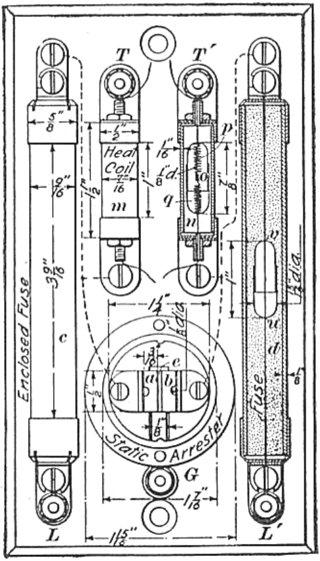



FIG. 43

the heat coils consist of spirals *p*, *q* of German-silver wire pulling away from each other. These spirals are held together, however, by a little solder at *o*, which melts when more than about .3 ampere flows through the line and the heat coil for 15 sec.

## INTERIOR SYSTEMS

In many factories, large houses, and institutions, telephonic communication between various departments without the aid of a central switchboard and operator is frequently desired. Intercommunication may be obtained by running at least one more wire than there are stations through all the stations, at each of which is provided a simple switch whereby the telephone instrument at that station may be connected with any other station. Such a system is variously known as an *intercommunicating*, *house*, or *speaking-tube*, *system*. There is practically no end to the various arrangements of apparatus and circuits used in house systems. In order to illustrate as many as possible, the description of each system will be very brief.

For systems requiring more than 20 or 30 stations, a private branch switchboard seems better. Plugs and spring jacks and, frequently, push buttons may be used, but the circuits can be most clearly shown in the figures by using strap switches. On each switch, the button bearing the same number as the station at which that switch is located is usually placed at the left-hand end, and is called the home button. All the switch levers normally rest on this home button. In practically all systems to be shown, the wiring is arranged so that the bells at any station can be rung from any other station, no matter on what button the switch lever may have been left, but before a conversation can be carried on, the switch at the station called should be returned to the home contact if not already there. This is usually the best arrangement, except for vestibule or apartment houses, because it cultivates the desirable habit of returning the switch to its home position.

A *complete metallic-circuit, intercommunicating, telephone system* is here intended to mean one that has a pair of wires for each station and, if necessary, one or more wires that may be used for signaling purposes in common by all the stations. All these wires run through all the stations. The object of using two wires, usually twisted to form a pair, for each station is to eliminate cross-talk. Where cross-talk to a moderate degree is not objectionable, systems using only one wire for each station, in addition to one or more common wires, are cheaper to install, simpler, and give good satisfaction. However, where the wires are run in cables, as is usually the case in first-class installations, and all cross-talk must be eliminated, it is almost imperative to use a complete metallic-circuit system—as here defined—of some kind. In systems having only one wire for each station, there is likely to be more or less cross-talk, due either to induction between line wires running parallel and close together or to the use of one common wire as a common return by all stations as a part of their talking circuits.

## MAGNETO-BELL SYSTEMS

A system using ordinary magneto generators, polarized bells, the necessary talking apparatus, and strap switches is shown in Fig. 44. To call station *1* from station *2*, turn $S_2$ to contact *1*, as shown, close the ringing key $K_2$ and turn the

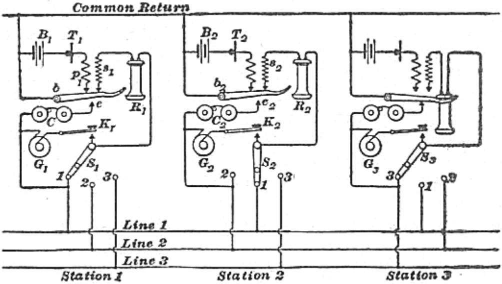



FIG. 44

ringing generator $G_2$, which will send a current through the bells $C$ and $C_2$. The generator may be so constructed as to automatically close its circuit when its handle is turned. When both receivers are removed from their hooks, the two parties may converse over line *1* and the common return wire.

If station *2* should desire to hold a consultation with both stations *1* and *3*, station *2* would first call up station *3*, request that the switch there be turned to button *1*, and then station *2* would call up station *1*. The three parties could then converse.

**Complete Metallic-Circuit System.**—To eliminate all trouble from cross-talk and interference from ringing currents, the wiring shown in Fig. 45 may be used. Two radial switch arms *c*, *d* are mechanically connected by

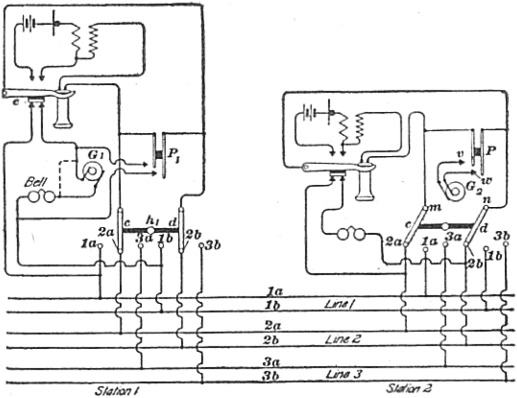



FIG. 45

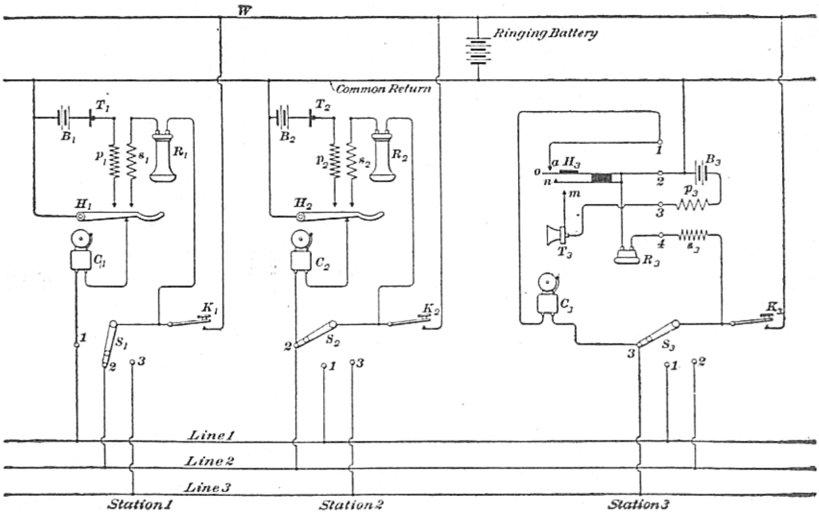
an insulating piece, to which one handle $h_1$ for controlling both arms is fastened. Of course, any other form of switch that will accomplish the same result may be used. To call a station, turn the switch to the number of the station desired, holding the double-contact push button $P_1$ closed while the handle of the magneto generator $G_1$ is turned. The piece *e* is insulated from the hook switch so that the ringing currents cannot interfere with other telephones in use, should the switch arm be left off its home position.

The bell can be rung no matter in what position the switch is left, but it must be on the home position at the station called before a conversation can be carried on. A series bell and generator are required with the wiring shown at station *1*, and the usual automatic shunt used in series telephones is necessary, as indicated by the dotted line around the generator $G_1$. However, the generator may be connected as shown at station *2*, that is, across the contacts *v*, *w*. In this arrangement, any suitable generator may be used and no automatic shunt or cut-in device is necessary; in fact, one terminal of the generator could then be permanently connected to *m* and a single-point push button used to connect the other generator terminal to *n* when using the generator. A generator having an automatic cut-in device could be connected across *m*, *n*, no push button being required. Either series or bridging bells may be used with the wiring shown at station *2*.

## COMMON RINGING-BATTERY SYSTEMS

**Common-Return Circuit.**—The *common ringing-battery system* is one in which one battery is used in common by all stations for signaling purposes only. Fig. 46 shows such a system. The means for signaling consists of an ordinary vibrating, or battery, bell and a push button at each station and one ringing battery conveniently located for ringing the bells. Stations *1* and *2* represent an ordinary wall set, and station *3* the wiring for a hand microtelephone set. The latter consists of a receiver and transmitter mounted in one handle, which contains a switch that can be readily held closed by the pressure of the hand that holds it to the mouth and ear. The bell at the station making the call does not ring.

**Complete Metallic Circuit.**—A good way to wire common-ringing battery telephone instruments for a system having two wires for each station is shown in Fig. 47. The wiring is shown more clearly at station *1*, but the practical arrangement of the hook-switch contacts is more accurately shown at station *2*. A centrally located battery *RB* is used for ringing ordinary battery bells $V_1$, $V_2$. At station *1*, a contact piece *e*



W
Ringing Battery
Common Return
$T_1$ $B_1$ $p_1$ $s_1$ $R_1$ $H_1$ $C_1$ $K_1$ $S_1$
$T_2$ $B_2$ $p_2$ $s_2$ $R_2$ $H_2$ $C_2$ $K_2$ $S_2$
$B_3$ $p_3$ $s_3$ $R_3$ $H_3$ $T_3$ $C_3$ $K_3$ $S_3$
o a n m
Line 1
Line 2
Line 3
Station 1
Station 2
Station 3


FIG. 46

is fastened to, but insulated from, the hook switch in such a manner as to close the bell circuit only when the receiver rests on the hook. To call up a station, the switch is turned to the proper buttons and the push button is then pressed.

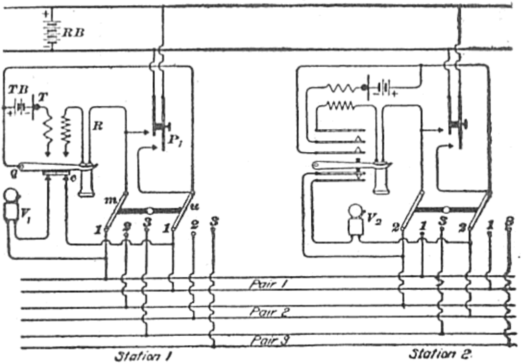



FIG. 47

The fact that the switch at the station desired may not rest on the home position does not prevent that station from being called from any other station. However, the switch at the station called must rest on, or be returned to, the home position before any conversation can be carried on.

## CENTRAL-ENERGY HOUSE SYSTEMS

Where batteries are not desired at each station, a *central-energy system*, one of which is shown in Fig. 48, may be used. The objection to most all central-energy intercommunicating systems is the liability to cross-talk. Cross-talk may be reduced by inserting a 25- to 50-ohm impedance coil *I* in series with each transmitter, as shown at station *3*. Current is supplied to the various transmitters, when in use, by the set of cells *ab*, and the cells *cd* are used for ringing the bells.

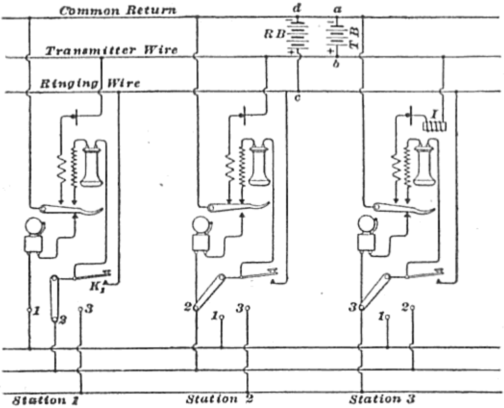

Common Return
Transmitter Wire
Ringing Wire
d
a
RB
TB
b
c
I
$K_1$
1
2
3
Station 1
Station 2
Station 3

Fig. 48

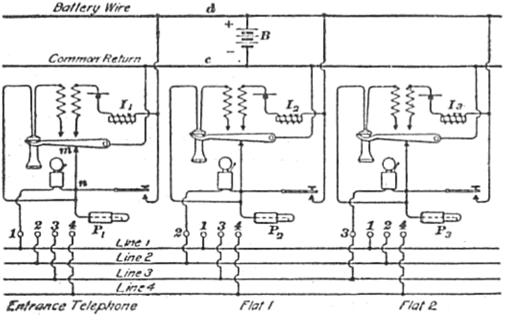

Battery Wire
d
B
Common Return
c
$I_1$
$I_2$
$I_3$
m
n
$P_1$
$P_2$
$P_3$
1
2
3
4
Line 1
Line 2
Line 3
Line 4
Entrance Telephone
Flat 1
Flat 2

Fig. 49

On a small system, where the same number of cells may answer for both transmitters and bells, one wire less may be used by connecting each transmitter to the ringing wire, the transmitter wire and battery *TB* being omitted.

**Apartment-House System.**—In Fig. 49 is shown a more suitable arrangement for communication between the vestibule and the various flats in a modern apartment house, as the plug does not have to be returned to its home jack or be removed from any jack in order that the parties may converse. Any station may be rung, regardless of the position of its plug. At each station there is an impedance coil $I_1$, $I_2$, $I_3$ to reduce the cross-talk and a plug $P_1$, $P_2$, $P_3$ to make connections through one of the jacks *1*, *2*, *3*, *4* with the desired telephone. This arrangement may be used to provide communication between the tenants, between the tenants and callers, and between the tenants and the janitor, in whose quarters a telephone set may be located. The common battery *B* may also be placed in the janitor's quarters. An objection to this system is that, if any two stations are connected, and a third station calls either one of the first two, the bells of the first two stations will both ring if the receivers are on thei- hooks. In many cases, no bell would be required in the entrance telephone and the circuit *m–n–1* would be omitted.

**Simple Plug-Switch System.**—In Fig. 50 is shown a very simple central-energy intercommunicating system, described in the Telephone Magazine by James V. Crecelius, who says that he has found it more satisfactory, where the longest line does not exceed 1,000 ft., than many other more complicated systems. Provided the receivers are hung up when not in use, no bell except the one desired will ring even though the plugs are accidentally left in any jack. To call station *2* from station *1*, insert the plug $P_1$ in jack *2* at station *1* and press the push button $K_1$. Very little of the ringing current passes through the transmitter $T_2$, because the bell $W_2$ has very much less resistance. Although it has not been found necessary, the arrangement shown only at station *3*, in which the transmitter circuit is normally open and therefore not in parallel with the bell, could be

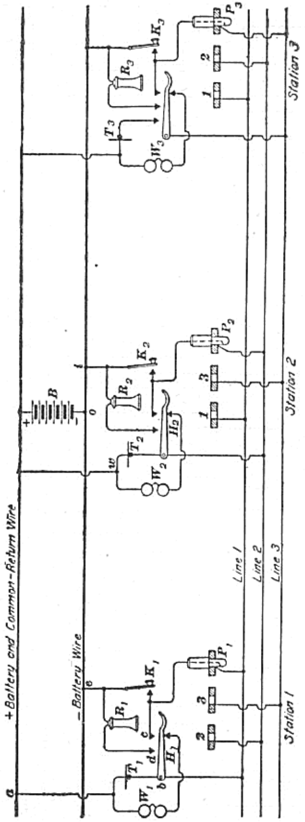

+ Battery and Common-Return Wire
– Battery Wire
Line 1
Line 2
Line 3
Station 1
Station 2
Station 3

Fig. 50

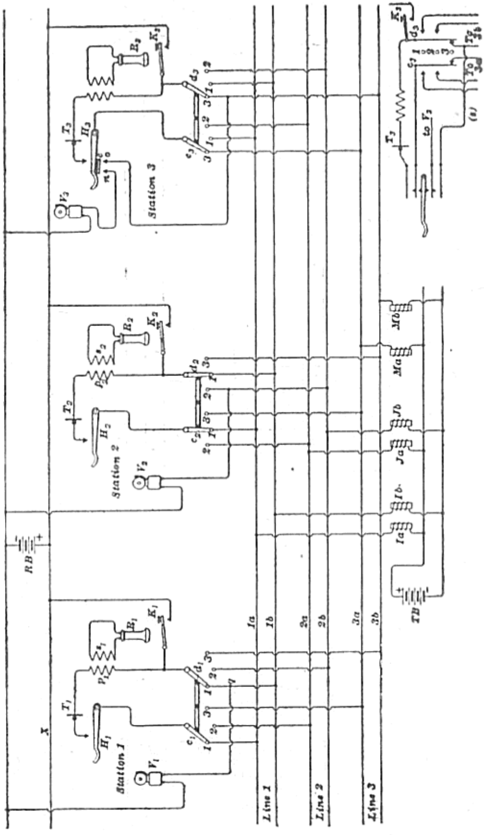

Station 1
Station 2
Station 3
Line 1
Line 2
Line 3
1a
1b
2a
2b
3a
3b
RB
TB
X
Ia
Ib
Ja
Jb
Ma
Mb

FIG. 51

used at all stations. The receiver must be connected in the proper direction in the circuit and the plugs should always be withdrawn at the end of a conversation, because otherwise there is a chance for cross-talk should four or more people be talking at the same time. For the battery $B$, use enough dry cells to give from 6 to 9 volts.

**Complete Metallic Circuit.**—A central-energy intercommunicating circuit that is suitable for a large system because it is free from cross-talk, is shown in Fig. 51. There is one battery $RB$ for signaling purposes and another $TB$ for supplying current to all the transmitters. Each pair of line wires is connected through two coils of high inductance to the talking battery $TB$. The transmitter is connected in series with the primary of an induction coil, and the receiver in series with the secondary and in a permanently closed local circuit. At station *3*, the bell $V_3$ is disconnected from the circuit at the hook switch while conversing; this prevents the possibility of interference while talking, due to charging and discharging currents and to leakage through the bell and the wire. However, it is very doubtful whether this would usually be serious enough to warrant the use of the extra contacts *n*, *o*, *c* thereby required. The bell at any station can be rung from any other station, even if the switch has not been returned to its home position, but the conversation cannot be held until the switch at the station called is returned to its home position.

## CONNECTION BETWEEN INTERCOMMUNICATING AND EXCHANGE TELEPHONES

It is often very desirable to be able to connect a telephone belonging to a city exchange with an intercommunicating system. Intercommunicating systems are being used for this purpose in place of small private branch switchboards. Whether such connections can be made, depends on whether the local exchange company will allow it, and, furthermore, intercommunicating telephones should be so arranged as not to interfere with the proper operation of the exchange telephone and the switchboard signals.

**Kellogg System.**—In Fig. 52 is shown the central-energy intercommunicating system made by the Kellogg Switchboard and Supply Company. It is a complete metallic-circuit system. The battery bell has two gongs, which give it the appearance on the outside of a polarized bell. Two sets of dry batteries are required, one *TB* for talking and another *RB* for ringing the bells. For five to ten stations with 1,000 ft. of cable, the talking battery should contain three cells and the ringing battery six cells; with 2,000 ft. of cable, the talking battery should contain four cells and the ringing battery seven cells; for eleven to twenty stations with 1,000 ft. of cable, the talking battery should contain six cells and the ringing battery six cells; with 2,000 ft. of cable, the talking battery should contain eight cells and the ringing battery seven cells.

Two classes of telephone instruments—one called the major and the other the minor—are made for the Kellogg system. The major has a receiver and condenser in series, the two being connected in parallel with an impedance coil, as shown at station *2*. The minor instruments have the same apparatus, but the condensers and impedance coils are omitted, the transmitters being connected simply in series with the receiver, as shown at station *1*. The impedance coil in a major instrument forms a path of low resistance for the battery-transmitter current, which the condenser excludes from the receiver, while the fluctuating currents, since they pass through a condenser more easily than through an impedance coil, readily flow through the receiver-condenser circuit.

At station *1* is shown a minor desk-stand set; at station *2*, a major wall set; and at the answering station, a major desk-stand set equipped as an answering station. The answering station is provided with two trunk jacks *Jt* instead of one, as at the regular intercommunicating stations; an extra plug *P* for holding the exchange trunk line; and an extra box in which is mounted the holding coil *H*, a polarized bell *E* and condenser *C*, the bell and condenser being bridged, as an ordinary extension-bell set, across the exchange trunk line, to serve as a signal from the exchange to the answering station.

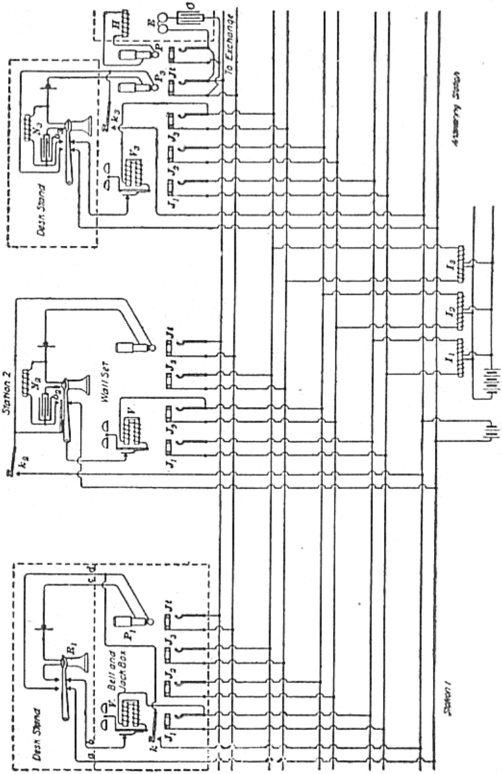

Desk Stand
To Exchange
Station 2
Wall Set
Bell and Jack Box
Desk Stand
Station 1
TB
RB

FIG. 52

The plug may be left in any jack or out of the jacks altogether, and yet the station desired can be called without ringing any other than the desired bell. All incoming calls from the city exchange are answered by the party at the answering station, who inserts the plug associated with this talking circuit into one of the trunk jacks *Jt* after a signal is received from central. After learning what department is wanted, the answering party inserts the plug *P*, across whose cords is connected the holding coil *H*, into the second jack of the trunk line, withdraws the regular talking plug from the other jack of the trunk line and inserts the same into the jack corresponding to the party with whom the party on the trunk line wishes to talk, and presses the ringing button, which rings the bell of the called party. As soon as the called party answers, he is notified by the party at the answering station to answer on the exchange line; the called party takes the plug out of the intercommunicating jack and inserts the same into the trunk jack, and the answering party withdraws both plugs from the jacks, restoring this station to its normal condition. When through talking, the receiver is hung up, which automatically gives the disconnect signal at central. To talk with an exchange subscriber, the intercommunicating subscriber merely inserts the plug into the trunk jack and takes down the receiver; this operates the exchange line signal and the exchange operator connects this line with the exchange subscriber desired in the usual manner.

**Stromberg-Carlson System.**—In Fig. 53 is shown the central-energy intercommunicating system made by the Stromberg-Carlson Telephone Manufacturing Company and the way in which it may be connected to a telephone instrument belonging to a magneto-exchange system. A person may communicate from any station on the intercommunicating system with outside parties, but the central exchange cannot be called, nor can the central-office operator ring the bell of any telephone belonging to the intercommunicating system only. It is necessary to place one intercommunicating telephone, which is termed the answering station, near the exchange telephone or an extension bell connected to it,

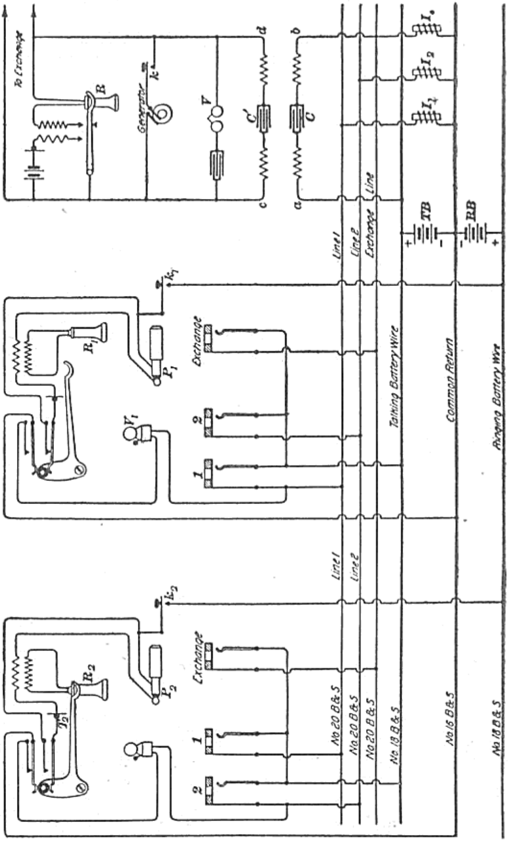

To Exchange
Generator
Station 1
Station 2
Exchange
Line 1
Line 2
Line
Talking Battery Wire
Common Return
Ringing Battery Wire
TB
BB
No 20 B&S
No 18 B&S
No 16 B&S

FIG. 53

so that the party that answers the exchange telephone may signal the intercommunicating station desired and also the exchange operator when some one at another intercommunicating station calls up and requests the answering station to do so. If the plug is not in the home, or left-hand, jack, where it should be placed after any conversation, the bell can still be rung but nothing can be heard at the station called until the plug is inserted in the home jack. The exchange telephone is connected to the intercommunicating system by means of the repeating coil *abcd*. The condenser *C*, connected in the middle of the winding *ab*, prevents a constant waste of current from *TB* through this winding, and the condenser *C′* is necessary to avoid short-circuiting the ordinary 1,000-ohm polarized bell *V* in the exchange telephone instrument.

**Holtzer-Cabot System.**—In Fig. 54 is shown one way in which local-battery telephone instruments of an intercommunicating system may be connected with the instrument located at station *3*, which is supposed to be connected with a central-energy city-exchange system. No change whatever is made in the wiring of the central-energy instrument, which is located at station *3*, the line wires simply being connected from the binding posts *a*, *b* to the pair of wires *3* running through all the stations in the intercommunicating system. At station *1* is shown the plan of wiring used by the Holtzer-Cabot Electric Company in connection with its Ness automatic intercommunicating switch. The two levers *w*, *v* are insulated from each other, but are mechanically connected together, so that moving *w* by its handle moves both levers. Pressing the lever *w* by its handle against the strip *d* allows current to flow from the ringing battery *RB* through the contact button and line wire to which *w* is turned.

At station *2* is shown practically the same arrangement, except that an automatic switch is not necessary and a push button *P* is used in place of the ringing strip *d* in the Ness automatic switch. If the city-exchange instrument is operated on the central-energy plan, the resistance of the secondary $s_1$ and the receiver $R_1$ must be of approximately

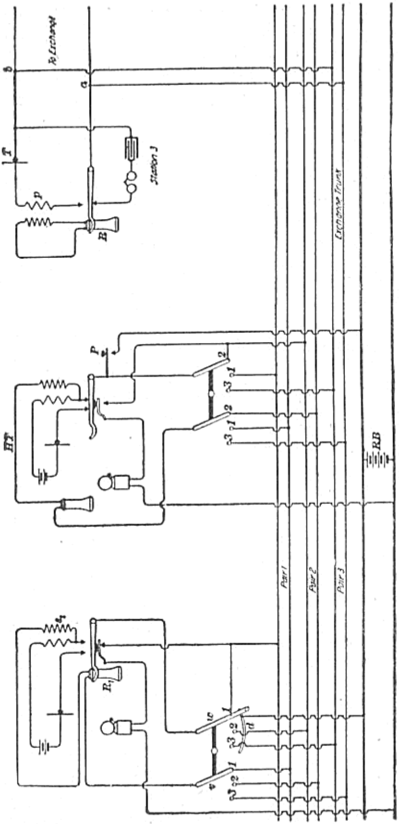

To Exchange
Station 3
Exchange Trunk
Station 2
Station 1
Pair 1
Pair 2
Pair 3
RB

FIG. 54

the same resistance as that of the transmitter *T* and primary coil *p* in the central-energy system, in order that hanging up and taking down the receiver at the intercommunicating telephones will properly operate the signals at the central-energy exchange. The central-energy exchange may be called up from any instrument on the intercommunicating system by turning the intercommunicating switch, in this case to contact *3*, and taking the receiver off the hook. It is impossible (and not usually necessary) for the exchange to ring the bell at any of the intercommunicating telephones, and for this reason one of the intercommunicating instruments must be placed alongside the exchange instrument. The party that answers the exchange instrument at station *3* must call up the proper intercommunicating station, and, by means of the intercommunicating instrument alongside it, inform the party that answers to turn his switch so as to connect the instrument with the trunk line running to the city exchange, then hang up the receiver *R* of the exchange telephone and also the receiver belonging to the intercommunicating instrument at the answering station.

## AUTOMATIC-SWITCH SYSTEMS

With the original house systems it was absolutely necessary for the calling party to return the intercommunicating switch to the home position when through with a conversation, in order to avoid leaving the station cut out so that no other station could ring it up; with more modern systems this is not the case, but it led to the development of automatic-return switches and systems. An *automatic intercommunicating switch* is one that automatically restores all connections to their normal positions when the receiver is hung on the hook switch.

**Holtzer - Cabot Automatic System.**—The Holtzer - Cabot automatic central-energy house system, which has all batteries located at some one convenient place, is shown in Fig. 55. Only two stations in a three-station system are shown, but the switches are made for any number of stations up to twenty. The current for all the transmitters is supplied by the battery *TB*; for ringing the bells, current is supplied from both the batteries connected in series. Normally, the switch $S_1$ rests upon the home button and does not touch the strip *d*. To call up station *2*, for instance, the switch $S_1$ is turned to contact *2* and the handle is pressed down, so as to touch the strip *d* as well as button *2*, thereby ringing the bell $V_2$. When both receivers are removed from

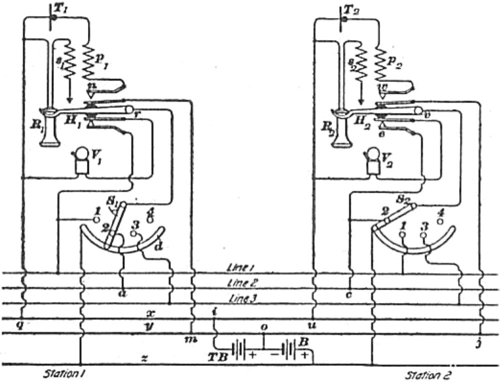



FIG. 55

their hooks, current flows through $TB$–$o$–$m$–$n$–$p_1$–$T_1$– $q$-line $x$–$i$, and also from $o$–through $j$–$w$–$p_2$–$T_2$–$u$–$i$. The voice currents flow from $s_1$ through $R_1$–$q$-line $x$–$u$–$R_2$–$s_2$–$H_2$–$v$–$S_2$–contact *2*–$c$–line *2*–$a$–contact *2*–$S_1$–$r$–$H_1$–$s_1$. When receiver $R_1$ is hung up, an automatic device restores the switch $S_1$ to the home contact.

## TELEPHONES FOR APARTMENT HOUSES

In the vestibules of modern apartment houses, or flats, there is usually a row of push buttons that ring bells in the different apartments and a row of speaking tubes for communicating with the tenants. Telephone systems may be used to advantage in place of the speaking tubes. The telephone systems for such cases should be very simple, and all batteries should be located preferably in the janitor's quarters. Callers should be able to communicate with any tenant and any tenant with the janitor. In addition, it is sometimes desirable to arrange for communication between the tenants. It should only be necessary for a caller to

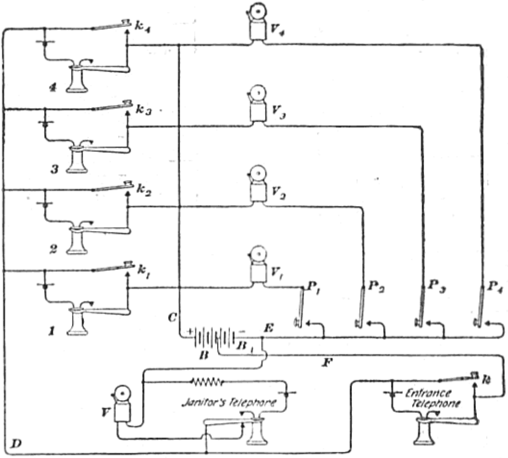



FIG. 56

press one push button associated with the telephone of the desired tenant and to take down the receiver. No system requiring the manipulation of a switch of any kind by the caller, who may not be familiar with such a system, is admissible.

**Push-Button Bell System.**—Fig. 56 shows a system suitable for apartment houses and it can be installed where push-button bell circuits have been used. The original bell circuits include the push buttons $P_1$, $P_2$, $P_3$, $P_4$ at the entrance, the bells $V_1$, $V_2$, $V_3$, $V_4$ in the various apartments, the common-return wire $C$, and a battery. It will usually be necessary to run a third wire $D$ or to use a ground return in its place. In each apartment, there is a simple telephone with a transmitter and receiver in series, a push button and a battery bell. One terminal of the entrance telephone is connected to an intermediate point in the battery, in order that it

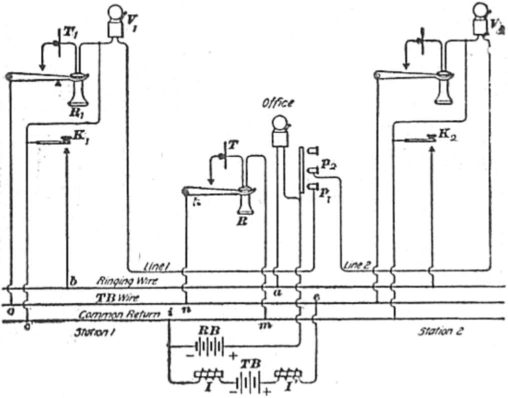



FIG. 57

may be used to talk with either the janitor or any tenant. In most cases, the entrance telephone would be nearer the janitor's telephone than any tenant's telephone; hence, a fewer number of cells would be required in $B_1$ than in $B$, while the entire battery would be required for conversations between the janitor and tenants. The push buttons $k$, $k_1$, $k_2$ etc., when pressed, ring the janitor's bell $V$.

**Couch & Seeley Speaking-Tube System.**—Fig. 57 shows a central-energy speaking-tube system made by the Couch & Seeley Company. It is suitable for a house, flat, or building requiring only three or four telephones and where communication between a central office and the stations only is required. The battery *TB* supplies the current for the transmitters, and the battery *RB* the current for ringing purposes. Impedance coils *I*, *I'* are connected between the battery *TB* and the two wires, over which flows the current for all the transmitters. To call up the central office from station *1*, for example, it is simply necessary to press the push button $K_1$. When the central office wishes to call a substation, say station *1*, the push $p_1$ is pressed.

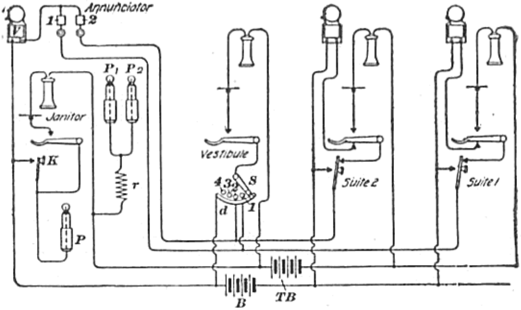



Fig. 58

**Holtzer-Cabot Apartment-House System.**—Fig. 58 shows what the Holtzer-Cabot Electric Company terms its *vestibule system* for apartment houses. In the vestibule is placed a telephone, equipped with an automatic switch, for calling and talking to any tenant. In the janitor's apartment is an annunciator provided with one signal, and immediately below it a jack for each suite, or apartment, one bell *V* through which all annunciator circuits return to the battery *B*, one plug *P* for answering ordinary calls by inserting it in the jack under the displayed signal, and a push button *K* for ringing, through plug *P* and the proper jack, the bell in any apartment. A pair of plugs $P_1$, $P_2$ may also be provided for connecting together any two apartment telephones by inserting them in the proper jacks. Each suite is provided with a telephone, bell, and push button; by means of the latter the annunciator and bell in the janitor's apartment may be operated. To call any suite from the vestibule, the switch *S* is turned to the desired number and pressed to make contact with strip *d*, which will cause the desired bell to be rung with current from *B*. When the two receivers are taken down, the talking battery *TB* is connected in series with the two transmitters and two receivers. Hanging up the receiver in the vestibule restores the switch to its normal home position.

## HOTEL TELEPHONE SYSTEMS

In a hotel, almost any switchboard system can be used, but it is customary to install only central-energy systems with very simple instruments in the guests' rooms. In most cases, only communication between the stations and office is required, but sometimes communication between the stations is afforded by means of simple jacks and plugs at a central-office switchboard. Very often a telephone system is to replace or to be added to an annunciator system, the wiring for which is already installed. In such cases, the same wires between the various stations and the office can, and generally must, be used for the telephone system. In large city hotels, it is becoming quite customary to install a private-branch switchboard, so that the telephone in any room may be connected to any other telephone in the hotel or in the entire city-exchange system.

### ANNUNCIATOR TELEPHONE SYSTEMS

Fig. 59 shows a Couch & Seeley *automatic switch system* suitable for a small hotel. The office is equipped with a telephone, an annunciator, automatic switch, a talking battery *TB*, two impedance coils *i*, *j*, and a ringing battery *RB*. To call station *2* from the office, press in button *2* (which will remain in until the office receiver *R* is taken down and hung up, and also press the ringing push button *p*.

thereby ringing the bell $V_2$. When both receivers have been taken down, the transmitter circuits of the two telephones are in parallel, both being supplied with current from the battery *TB* through the impedance coils *i j*. To call the

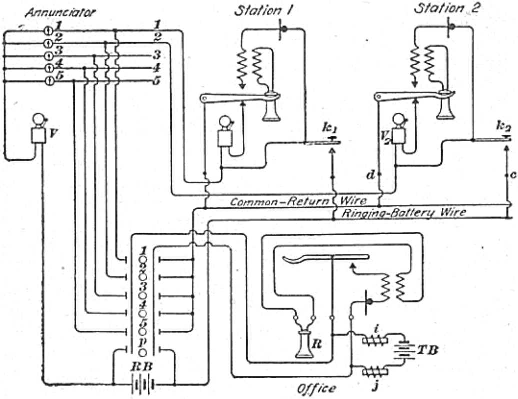



FIG. 59

office from station *1*, press the push button $k_1$, which will operate the annunciator *1* and bell *V* in the office. The office attendant pushes in the corresponding button *1* on the automatic switch, restores the annunciator, takes down the receiver, and attends to the call.

## HOTEL-SWITCHBOARD SYSTEMS

**Communication Between Office and Substations Only.** In Fig. 60 is shown a simple *hotel-switchboard system* that admits of communication between the office and any substation and vice versa, but does not admit of cross-connecting between any two substations. $D_1$ and $D_2$ represent ordinary annunciator electromagnets, and $J_1$ and $J_2$ the spring jacks of a simple plug switchboard. The talking battery *TB*

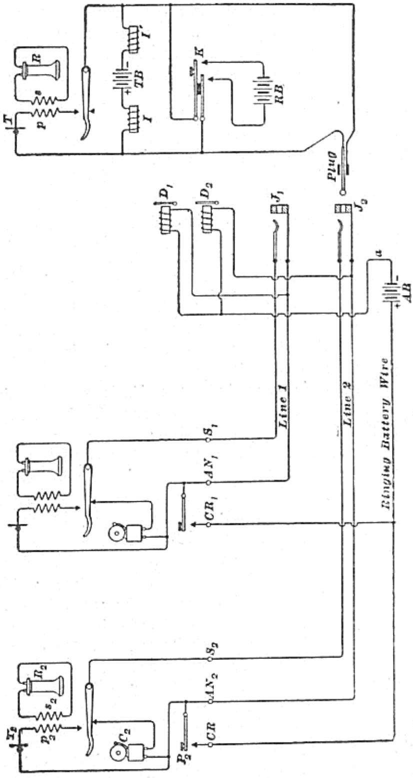

R
T
p
TB
I
I'
K
RB
Plug
$D_1$
$D_2$
$J_1$
$J_2$
a
AB
Line 1
Line 2
Ringing Battery Wire
$S_1$
$AN_1$
$CR_1$
$S_2$
$AN_2$
CR
$R_2$
$s_2$
$p_2$
$C_2$
$P_2$

FIG. 60

supplies all the current for talking purposes. The substation instruments can be simplified and cheapened by connecting the receiver and transmitter directly in series, omitting the induction coil. The spring jacks and plug may be replaced by a simple, or automatic, two-wire intercommunicating switch.

Any substation calls the central office by merely pressing a push button, and it makes no difference whether the substation receiver is on or off the hook. The office attendant inserts the plug in the spring jack corresponding to the drop shutter that has fallen, and takes the office receiver $R$ off its hook. To call up any substation, the office attendant inserts the plug in the proper jack and closes the ringing key $K$, thereby ringing the substation bell. When both substation and office receivers are removed from their hooks, the two parties can converse. $RB$ and $AB$ may be the same battery, and, if desired, a bell or buzzer may be included in the circuit at $a$, so that it will ring whenever any drop is operated.

**Communication Between Any Two Stations.**—The simple system shown in Fig. 61 allows communication not only between the office and any substation, but also between any substations through the office plugboard; this is a system designed by Couch & Seeley Company for ordinary hotels. All batteries are located in or near the central office, where an ordinary annunciator, plug board, connecting cords, and plugs are also provided. This system is not intended for use where more than two substations would need to be connected together at any one time, although there could be two or more listening jacks and two or more pairs of connecting plugs. Only three impedance coils $I$, $I'$, $I''$, one talking battery $TB$, one bell battery $RB$, one annunciator battery $AB$, one office bell or buzzer $C$, one listening jack, one operator's plug, and one pair of connecting plugs would be required, no matter how many substations there may be on a small system, for which this arrangement is only intended.

The removal of a receiver at a substation is all that is necessary to call up the office. To answer a call, the

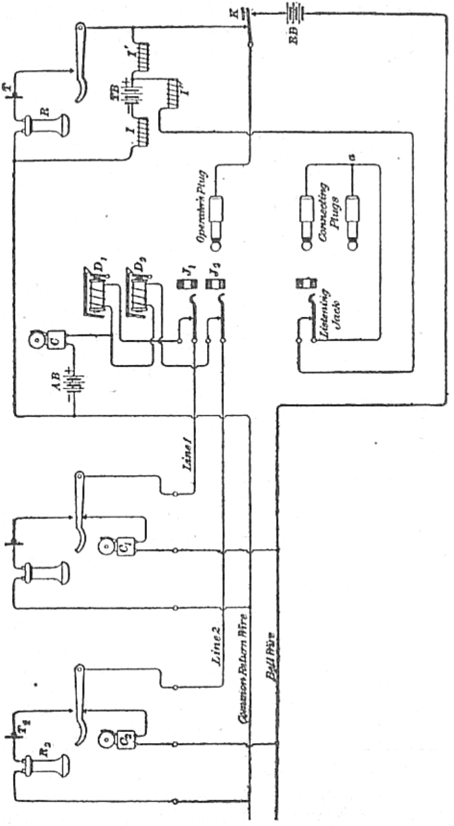

K
BB
TB
Operator's Plug
Connecting Plugs
Listening Jack
Line 1
Line 2
Common Return Wire
Bell Wire
AB

FIG. 61

office attendant inserts the operator's plug in the jack corresponding to the drop whose shutter has fallen. To call up a substation, the operator's plug is inserted in the jack associated with the substation desired and the key $K$ is closed to ring the bell. To connect together any two substations, the connecting plugs are inserted in the corresponding jacks. The office attendant must insert the operator's plug in the listening jack to determine, by listening, when the conversation is completed.

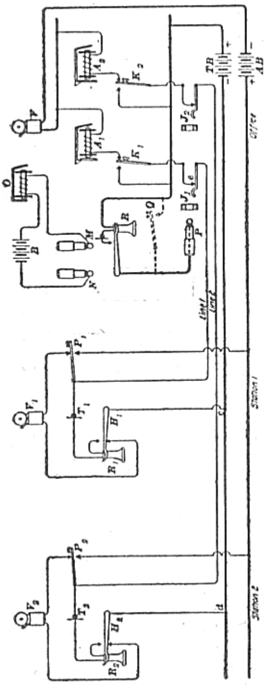


FIG. 62

**Return-Call Annunciator-Telephone System.** In Fig. 62 is shown a Holtzer-Cabot telephone system, suitable for a hotel. Since exactly the same line wires are used as in the Holtzer-Cabot return-call annunciator system, it is a simple matter to convert their return-call annunciator system into this telephone system. If the push button $K_1$ is pressed, the bell $V_1$ at station *1* rings. When the plug $P$ is inserted in the jack $J_1$ and the receivers $R$, $R_1$ are removed from their hooks, the office and station *1* may converse, the talking battery $TB$ supplying current for both transmitters. To call up the office, the push button is pressed at the substation, thereby causing the shutter of the corresponding annunciator to fall and the bell $V$ to ring. The central-office attendant responds by inserting the plug $P$ in the corresponding jack, and restores the annunciator. If, for instance, the party at station *2* desires to communicate with station *1*, the operator will remove the plug $P$ from jack $J_2$ and insert the plugs $M$, $N$ in the jacks $J_1$, $J_2$.

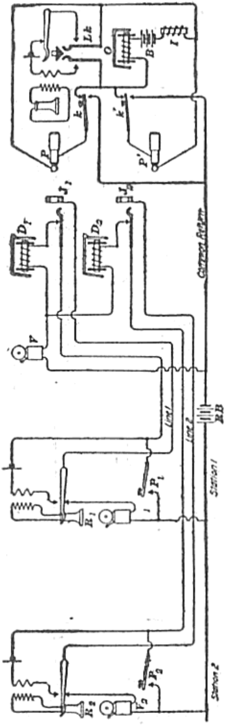


FIG. 63

The *Holtzer-Cabot hotel-switchboard* or *school system* is shown in Fig. 63. It has a centrally located switchboard, centralized talking and ringing batteries, and connecting cords for intercommunication between the various stations. In the common connection of the annunciator drops is the bell $V$, which therefore rings whenever any annunciator shutter falls. The operation of this system is very simple and only a brief explanation is necessary. When two parties are conversing, the battery $B$ supplies current for both transmitters and also energizes the clearing-out drop $O$. When both receivers are hung on the hooks, the clearing-out drop releases its shutter, which signifies that the conversation is completed, and both plugs should be withdrawn from the jacks. The impedance coil $I$.

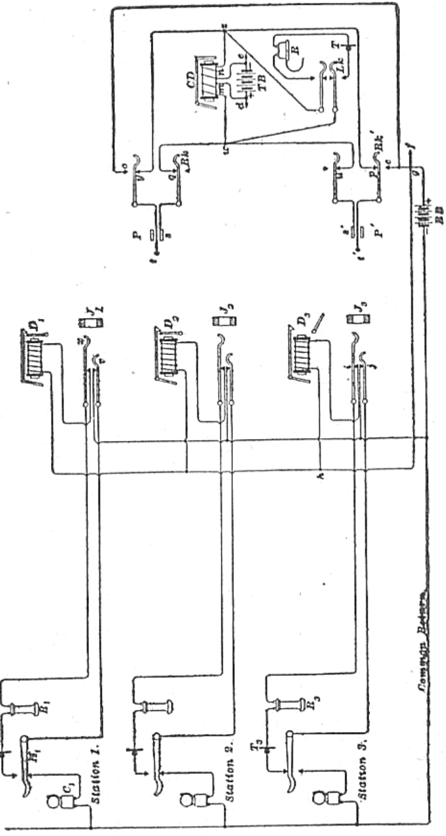



FIG. 64

having the same resistance and inductance as the clearing-out drop $O$, causes the system to be evenly balanced.

The *Couch & Seeley Company's hotel-switchboard system*, shown in Fig. 64, allows communication not only between the office and any substation, but also between any two substations through the office switchboard. As this system is more elaborate and complete, it is suitable for a larger hotel than the one illustrated in Fig. 61. It is a central-energy system, the talking battery $TB$ being connected through two impedance coils $m$, $n$ across each cord circuit. The two impedance coils in each cord circuit are so arranged as to constitute a clearing-out drop $CD$ for that cord circuit. There is one listening key $Lk$ and two ringing keys $Rk$ and $Rk'$ for each cord circuit. There is a separate battery $RB$ for ringing the subscribers' bells and operating the line drops $D_1$, $D_2$, and $D_3$. There may be as many cord circuits and clearing-out drops as required. One operator's set may be connected to each listening key; the lead $f$ runs to contacts $o, e$ on each ringing key, and leads $c, d$ to each clearing-out drop.

If the receiver $R_3$ is removed from the hook, the shutter of $D_3$ drops. The operator inserts one plug, say $P'$, into the corresponding line jack $J_3$, and closes the listening key $Lk$; this bridges the battery $TB$, through the coils $m$, $n$ of the clearing-out drop, across the cord circuit and also across the operator's receiver $R$ and transmitter $T$, thereby supplying both the substation and the operator's set with current. Furthermore, the shutter of the clearing-out drop is raised. If station *1* is desired, the operator will insert the other plug $P$ of the same pair in jack $J_1$ and close the ringing key $Rk$, thereby ringing the bell $C_1$. When both receivers are hung up, the shutter of the drop $CD$ falls. The shutter remains up only while one or both receivers are off the hook.

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## TELEPHONE RELAYS

The *telephone relay* suggested itself almost contemporaneously with the appearance of the telephone, and probably thousands of devices have been brought out having for their object the accomplishment for telephony what the telegraph relay has done for telegraphy. A telephone relay may be defined as an arrangement of apparatus and circuits whereby the usual telephone current traversing a line of usual length may, by passing through the telephone relay, cause a telephone current of similar characteristics to be transmitted by the aid of another battery through another section of the line. One of the first methods suggested was to attach a transmitter to the diaphragm of a receiver located at an intermediate station, the transmitter operating the second section of the line. This did not prove satisfactory, however, and it was found better to replace such a telephone relay by a continuous line. An efficient repeater should increase the loudness without decreasing the clearness.

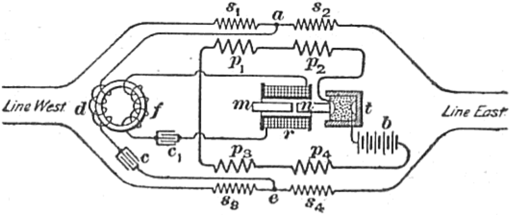


FIG. 65

In 1883, Edison patented a telephone relay that did not prove successful, but recently a slight modification of the circuit and improvements in the construction of the apparatus were made, and this same arrangement of apparatus seems to be successful in the hands of the American Telephone and Telegraph Company. The arrangement is shown in Fig. 65, in which $d$ is a special repeating coil with two equal windings; $c, c_1$ are condensers; $s_1, s_2, s_3, s_4$ one winding and $p_1, p_2, p_3, p_4$ the other winding of a repeating coil; and $r$, a so-called receiving magnet, having a permanent magnet as a core $m$ and a light piece of soft iron running part way inside the coil and having the carbon button of a White solid-back transmitter fixed to one end. The transmitter $t$

has the solid back electrode firmly fixed in position. The east and west lines must be equal in resistance and probably also in capacity and inductance; if not, they must be made so artificially, that is, by the insertion of resistance, capacity, and inductance.

Imagine a current originated in the west line; it passes through the windings $s_1$ and $s_3$ in reaching the points $a$, $e$. Here, this current subdivides, a portion passing on to the east line and a portion passing through one winding of the repeating coil $d$ and condenser $c$. The current passing through $d$ induces a current in the winding $f$ that causes the coil $r$ to vary the pull of the permanent magnet $m$ upon the soft-iron core $n$, thereby varying the resistance of the transmitter $t$, and the current passing through it in unison with the current in $d$ and in $s_1$, $s_2$, $s_3$, $s_4$. This fluctuating current thus produced in $p_1$, $p_2$, $p_3$, $p_4$ induces in $s_1$, $s_2$, $s_3$, $s_4$ a current that it superimposed upon that flowing in these coils from the west line, and thus produces in the east line a stronger current so near the same form as to give stronger and sufficiently articulate sounds in the receiver at the end of the east line. The condensers $c$, $c_1$ are probably proportioned to neutralize the self-induction of the coils $d$, $f$, and thus eliminate any difference in phase between the currents in the line and in $d$, $f$, $r$, and in $p_1$, $p_2$, $p_3$, $p_4$. All moving parts of the transmitter are as light as practicable, in order to reduce the inertia as much as possible. This repeater will evidently repeat equally well in either direction.

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## NATIONAL ELECTRICAL CODE

When electric lights first came into use, the insurance companies discovered that there were many fires of electrical origin. Therefore, the various associations of underwriters formulated rules in accordance with which they required that all wiring be done, or they would not insure buildings containing it. These rules are reduced to a uniform code, known as the *National Electrical Code*, which has received the indorsement of practically all the fire-inspection bureaus throughout the United States, besides that of many other organizations. A few cities have rules of their own that differ slightly from this code. Every wireman should be supplied with a copy of the latest edition of the National Electrical Code, and do work in compliance with those rules, whether additional laws exist or not. Copies of the code and of all other information published by the Underwriters' Association, for the sake of reducing the fire hazard, can be obtained from the National Board of Fire Underwriters, Chicago, or by applying to the nearest Underwriters' Inspection Bureau. The rules are revised as often as changes in the electrical art make such revision necessary.

In addition to this code of rules, about every year, the National Board of Fire Underwriters publish a list of approved fittings for use in connection with the code. This list contains the names of articles that have been found entirely satisfactory, together with the names of the manufacturers. This publication, however, does not contain all fittings that will pass inspection, and many good articles are not listed in its pages.