CHAPTER XIII

TELEPHONE APPARATUS AND CIRCUITS

76. The Telephone Receiver

The next subject for consideration in our study of electricity would logically be that of the theory of alternating currents, but before going into that it may be profitable to devote a Chapter to some discussion of certain of the more common and relatively simple types of apparatus used in telephone work and to illustrate how apparatus units are connected together to form working circuits. It is obviously impossible, however, to describe more than a very few of the many different kinds of apparatus used or to analyze the operation of any large number of the variety of circuit assemblies, each designed to perform some definite function, that are standard.

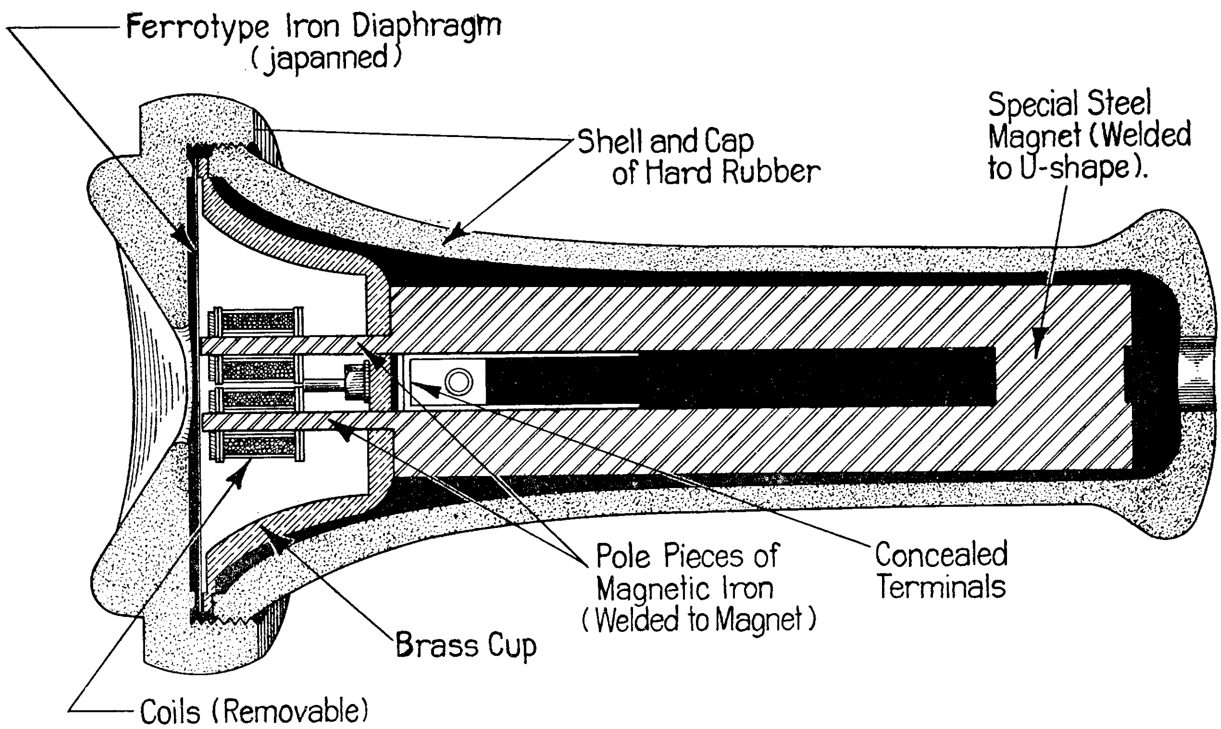


Fig. 143—Cross-Section of No. 144 Receiver.

As the first devised and perhaps most fundamental of telephone apparatus units, we may consider the telephone receiver. Figure 143 shows the mechanical construction of a modern type of receiver for substation use which has certain refinements in design that are marked improvements over earlier types.

The concealed binding posts eliminate the possibility of shocks to subscribers and protect the cord connection against shorts, opens and grounds. The hard rubber shell and cap are both changeable parts, being easily replaced. Since the brass cup is mechanically fastened to the magnets near the windings, the air gap between the pole pieces and the diaphragm is accurately gauged and a considerable part of the variation in this air gap due to contraction and expansion at different temperatures is eliminated. The brass cup also affords a dust proof case for the windings. The direct current resistance of the two windings (in series) is approximately 80 ohms.

In the manufacture of this instrument, the shell and cap are made of very hard rubber stock, and after being highly polished, are accurately gauged for the proper dimensions. The horseshoe magnet is made by welding two bars of special steel into the U shape. It is later inserted across two pointed metal pole pieces of a powerful electromagnet and given a high degree of magnetization. The coils are wound into longitudinally shaped spools and pressed on the magnet pole pieces. The brass cup is drawn from sheet brass by a punching and annealing process.

Other than the #144, the most important type of telephone receiver, which is used generally, is the #528 (watch case type) now standard for operators' telephone sets. It has a metal case with hard rubber cap. The operators' telephone sets, on the #4 type testboard, are equipped with a special high resistance receiver in a green finished metal case, which is coded #525 and is wound to a direct current resistance of about 500 ohms. It is used in connection with the testing circuit in preference to other types of operators' head set receivers since the high resistance permits it to be bridged across a talking connection without appreciable transmission loss.

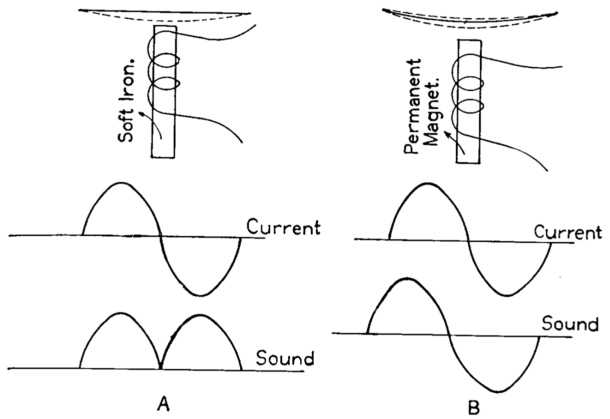


Fig. 144—Action of Receiver.

The above types of telephone receivers are equipped with permanent horseshoe magnets, and it is important that the magnetism should not be impaired by jarring or other abuse. A permanent magnet not only increases the amplitude of vibration of the diaphragm when the voice current is flowing through the windings, but prevents the diaphragm vibrating at twice the voice frequency.

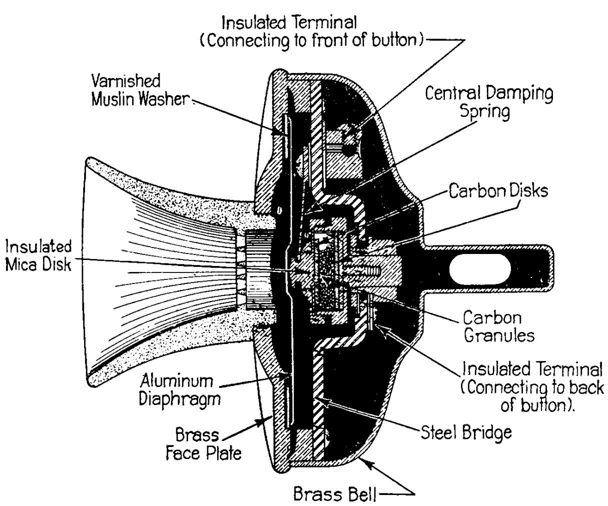


Fig. 145—Cross-Section of No. 323 Transmitter.

This principle is illustrated by Figure 144. When a piece of soft iron is held near an electromagnet, it is attracted by the magnet regardless of which direction the current is flowing through the windings. Thus, an alternating current through a winding having a soft core instead of a permanent magnet will assert an attraction during each half cycle, which in case of the receiver diaphragm will establish a vibration, with a frequency twice that of the current. If, on the other hand, a permanent magnet is used, the alternating current establishes a vibration of the same frequency by merely increasing or lessening the pull already exerted on the diaphragm.

77. The Telephone Transmitter

A cross-section of the working parts of a #323 type transmitter is shown in Figure 145. This instrument has certain improved transmission features over the #329, and differs from earlier types such as the #229 for general substation use in that it is an insulated type with no terminal grounded to the frame. This construction prevents shocks to the user and lessens the possibility of induction due to crosstalk from other lines. The top terminal shown in the figure engages the tip of one cord by means of a set screw, and connects to the front carbon disc of the transmitter button by means of the central damping spring which

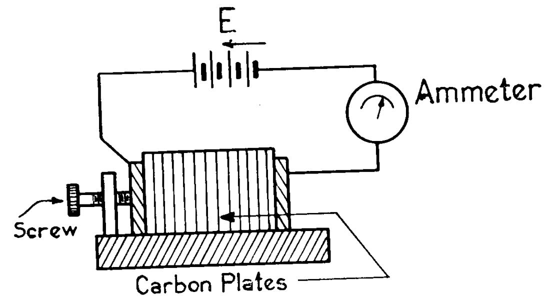


Figure 146

is held by an insulated screw through the steel bridge. The other terminal connects to the rear of the button through the button's mounting which is insulated from the steel bridge by means of mica. The vibration of the insulated diaphragm is transmitted directly to the front carbon disc through its pressure contact against the small piece of metal secured to the disc. This causes a variation in the pressure on the carbon granules which varies their resistance in a manner that may be better understood by referring to Figure 146. Here is shown a series of carbon plates in contact with each other and under compression by a screw clamp. If a battery E in series with an ammeter is connected across the group of plates, the current is seen to vary considerably with very small adjustments of the screw. This property of carbon is amplified in the transmitter button by using carbon granules between the carbon discs. The resistance of the carbon in the transmitter is approximately 50 ohms but decreases due to heating when the current is allowed to flow through the transmitter button for long periods.

A few other types of transmitters in use are the #232, a hanging type for testboards, the #234 which is the operator's breast transmitter, and the #266, especially designed for linemen's test sets.

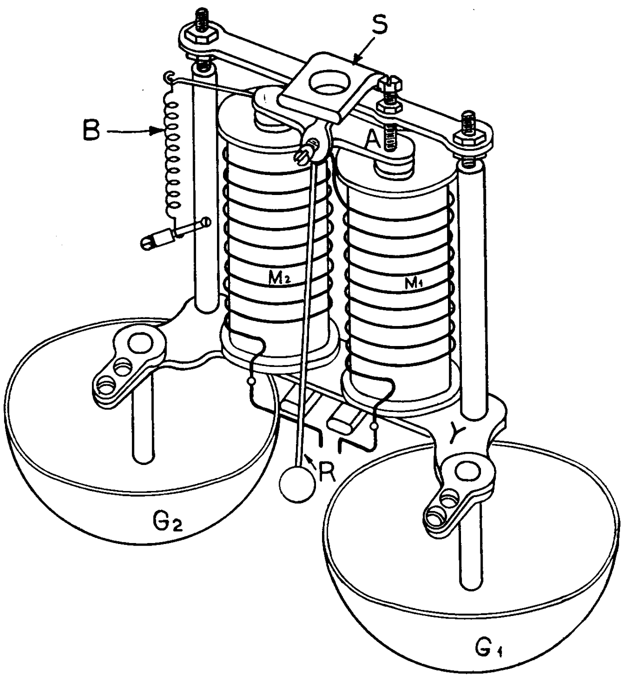


Fig. 147—Polarized Ringer.

78. The Polarized Ringer

The proper name for the substation telephone bell is "ringer". Figure 147 illustrates one type of ringer that is standard in the Bell System and is used on the majority of subsets. It is designed to operate on 20-cycle alternating current or on 20-cycle pulsating current when adjusted by means of the biasing spring. It consists of two electromagnets, M_1 and M_2, which are mounted on the soft iron yoke Y. The armature A is pivoted so as to give a slight air gap separation between its two ends and the respective cores of the magnets. The tapper rod R is securely fastened to this armature. One end of the permanent steel magnet S is mounted near the middle of the yoke Y, and the other, or north, end of the steel magnet is sufficiently near the armature that the magnetic circuit established by the permanent magnet is split at the north pole and carried through the armature and soft cores of the magnets to the soft iron yoke Y. The lines of force unite here and return to the south pole of the magnet which is secured to the center of the yoke. The electromagnets are in series and when an alternating current flows through their windings, the magnetism established by the permanent magnet will be strengthened during the first half cycle as it flows through one coil and weakened by an equal amount in the other. This will increase the attraction of the first core for the armature and decrease that of the second, thereby permitting the tapper to strike one gong. When the current reverses during the second half cycle, the attraction is reversed and the tapper strikes the other gong. Thus, the tapper will strike each gong 20 times per second.

If the biasing spring B is tightened (other than with slight tension to prevent tapping due to the rush of the direct current when the operator sticks the plug in the line jack), the bell will respond to pulsating current instead of alternating current, as explained in Chapter X.

79. Plugs, Jacks and Cords

Plugs, jacks and cords are used in telephone work as a means of performing switching operations rapidly and with a maximum of flexibility. In addition to facilitating direct connections, jacks may be arranged for automatically accomplishing other

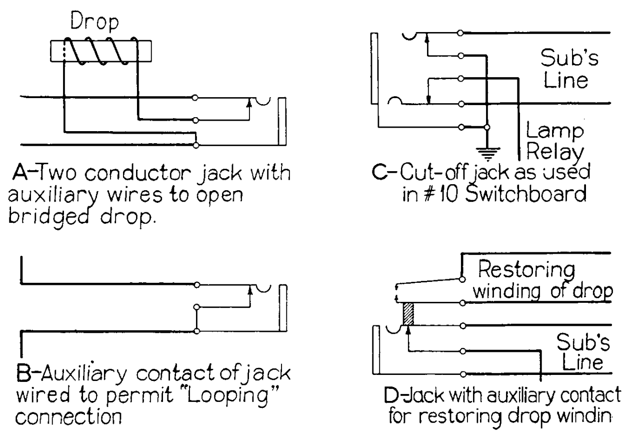


Fig. 148—Various Uses of Auxiliary Contacts of Jacks.

circuit operations by equipping them with auxiliary springs. A few such arrangements are shown by Figure 148. The simple manner in which the signalling drop of a line terminating at a telephone switchboard can be opened so as not to impair transmission when a plug is inserted in the jack is illustrated by Figure 148-A. Figure 148-B shows another use of the same auxiliary contact. Here a telegraph set terminated with a two-conductor plug may be looped in series with the wire at a single operation, or an ammeter connected to a cord may be inserted for measuring the current in the wire. Figure 148-C illustrates the use of normals for two springs of a three-conductor jack such as is used in connection with the #10 local switchboard to perform a function similar to that of the cut-off relay in the #1 switchboard. Figure 148-D illustrates another commonly used two-conductor jack which in this case is wired to operate a self-restoring drop in the same way as the three-conductor jack shown in Figure 112.

The mechanical construction of a few types of jacks used at the present time in connection with long distance service, is illustrated by Figure 149.

The #49 jack is mounted in strips of 5, 10 or 20 for use in the face of both local and toll switchboards. It takes the #110 plug. A smaller jack, coded as the #92, takes the #109 plug, and is used in the face of larger switchboards where the multiple must accommodate a greater number of lines than the toll or small local switchboard multiple. The #99 jack, illustrated in the same figure, is mounted in pairs in the switchboard key shelf to take a #137 plug, in which is terminated the operator's breast transmitter and head receiver. The remaining jacks in Figure 149 are those commonly used in the #4 and #5 toll testboards, and other testroom equipment requiring numerous combinations of auxiliary contacts. They can be mounted either singly or in pairs to accommodate single one or two conductor plugs such as the #116 and #47 or 2, 3 or 4 conductor plugs such as the #43, #241 and #137 types, respectively. Jacks of this type are made with a sherardized metal frame having a brass sleeve mechanically fastened to its front face. The channel shape readily permits the mounting of German Silver contact or auxiliary springs properly insulated from each other by bushings and washers.

Figure 150 illustrates both the mechanical and electrical features of various plugs and Figure 151 shows the construction of a commonly used type of switchboard cord. While this is only one of many cords in use, it represents the standard features and gives an insight into cord manufacturing processes.

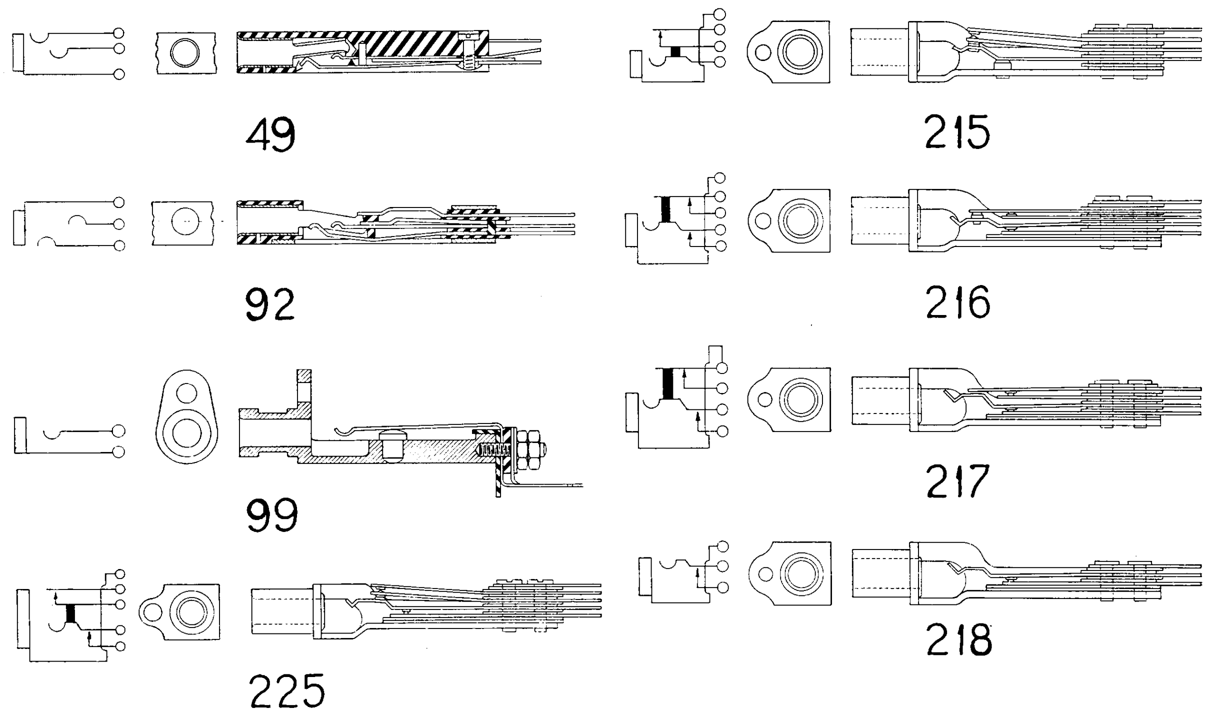


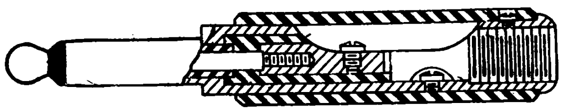
Fig.149—Jacks used in Connection with Long Distance Service.

80. Resistances

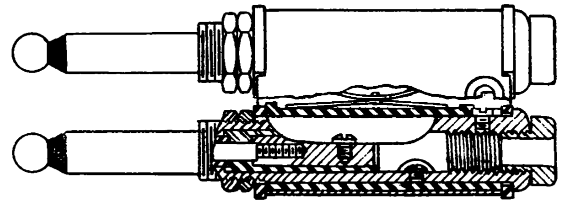
No single unit of apparatus is more fundamental than the resistance, several types of which have countless uses in the telephone plant. Testing apparatus, such as the Wheatstone bridge, ordinarily uses plain spool type resistances which consist of German Silver wire of suitable current carrying capacity (gauge) wound on a wooden spool, as in Figure 152. The resistance is made "non-inductive" (that is, will not induce potentials in adjacent spools or other electrical conductors) by winding simultaneously two conductors instead of one, with the two conductors short-circuited at one end and used as the resistance terminals at the other.

Two more common types of resistances which are used for such purposes as regulating the current from 24-volt battery at Central Offices to the proper value for operating and releasing relays, lighting switchboard lamps, etc., are illustrated by Figure 153. They are coded as #18 and #19, the #18-type being a single plain resistance, and the #19-type having a third connection to an intermediate point of the resistance winding. Both types are furnished with resistance values ranging from less than one ohm to a few thousand ohms. The accuracy is ordinarily within 5%, and the safe radiating capacity, which depends upon the mechanical design rather than the resistance value, is approximately 5 watts. On account of the flat shape, the winding is practically non-inductive. It consists of bare special high resistance wire covered with micanite. The ends of the wires are brought out to the metal terminals which give mechanical reinforcement to the edges. These terminals are 1-5/16 inches between centers, and are equipped with two clamping nuts and fibre washers for mounting on a standard iron mounting plate, which will accommodate from 10 to 40 resistances.

Figure 155 illustrates the Lavite resistance which has a very high resistance value for a comparatively few turns and for this reason is practically non-inductive. This type is made in units of 12,000, 24,000, 48,000 and 96,000 ohms. Its principal use is in connection with vacuum tube circuits such as telephone repeater potentiometers, etc.



47 A & B



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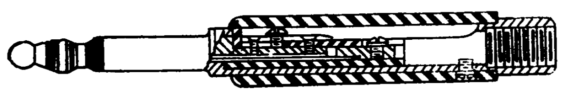

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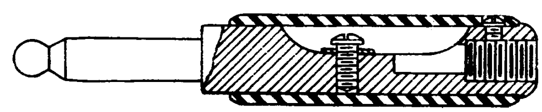

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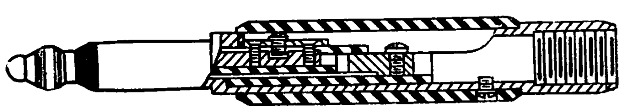

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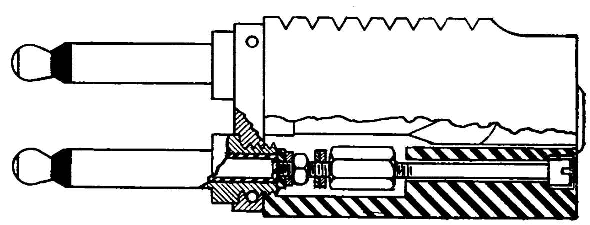

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Fig. 150—Plugs used in connection with Long Distance Service.

When it is necessary for a resistance to radiate heat energy greater than 5 watts, the vitrohm type is used in preference to the #18 or #19 type. Ordinarily these resistance units are equipped with an Edison base (lamp-socket screw) for mounting in receptacles on slate panels, as illustrated in Figure 154. The safe radiating capacity of this type is approximately 60 watts, or about 12 times that of the #18-type.

When a series of resistances is used in connection with adjustable dials, such as those of a Wheatstone bridge, it is not always necessary to have 10 separate units for each dial. Figure 156 shows several commonly used schemes of dial connections, one of which gives steps of zero to nine with only four spools. An adjustable dial, such as this or any one of the devices shown in Figure 157 for adjusting a resistance value, is called a rheostat". If a rheostat is connected as shown in Figure 158 so as to give an adjustable E.M.F., it is called a "potentiometer".

81. Switchboard Keys

A telephone key is a circuit opening or closing device or a special kind of switch adapted to telephone circuits. The way in which a simple six-spring key may perform the same circuit functions as the double pole, double throw switch, was illustrated in Figure 6. Just as plugs, jacks and cords provide more flexible and more complicated connections than can be provided with older type switchboards, the key has many advantages over the knife switch and facilitates additional features essential to telephone operation. Contacts to be made or broken may be delicately adjusted through the use of German Silver springs. These contacts, which are adequate for carrying the current values

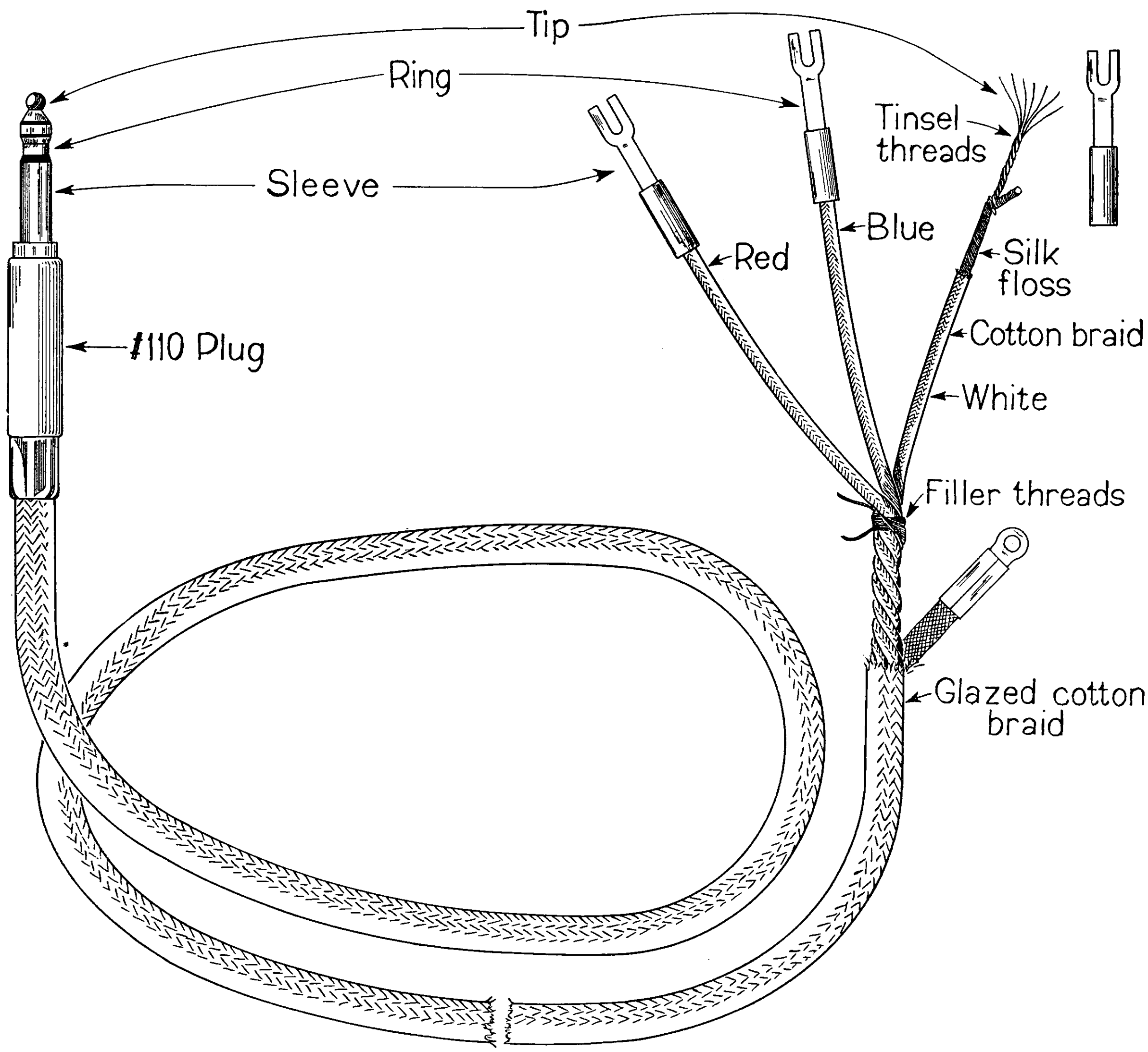


Fig. 151—Switchboard Cord.

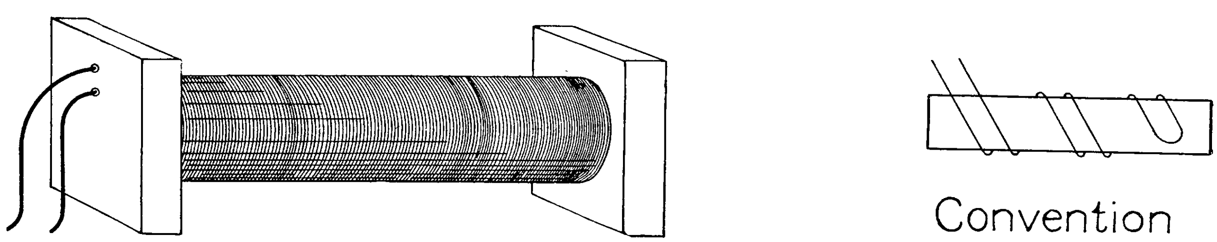


Fig. 152—Plain Spool Resistance.

ordinarily used by telephone circuits, are made through special contact metal welded to the German Silver springs, thereby preventing excessive resistances from being inserted in the sensitive telephone circuits. Auxiliary contact springs permit the operation of additional or more complicated circuit features which could not be easily provided on any other form of switch.

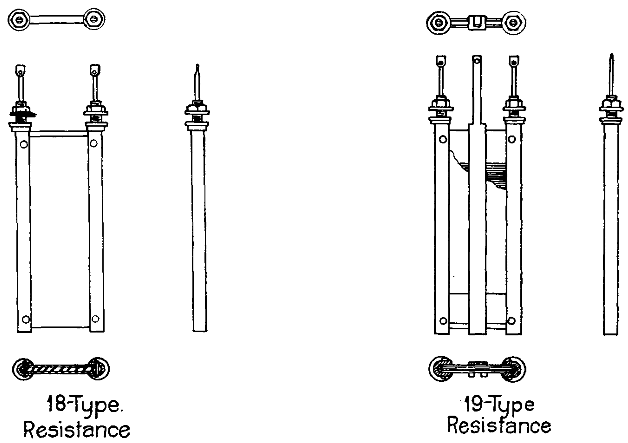


Figure 153

Figure 154
Vitrohm Resistance.

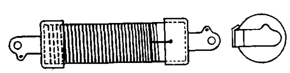


Figure 155
Lavite Resistance.

Figures 159 and 160 illustrate two designs of keys used in the operation of switchboard circuits which are especially important. Both are used in connection with the line position toll operator's cord circuit. As will be observed from the lever arrangement and the conventions showing the contacts, the two types are identical in so far as their operation and circuit features are concerned, but the #463-C key (Figure 159) differs from the #AIA key (Figure 160) in that it is an older type having a different arrangement of springs. The #AIA key was designed for use in connection with the universal key shelf and has the so-called "unit" construction. This permits one or more key spring units to be mounted, as illustrated, on a standard metal base which is equipped with a hard rubber top. Two types of spring units are provided, the lever type (Figure 160) and the push button type. The convenient manner in which individual units can be removed, and in which any key combination can be had by selecting various units for one standard base, has certain maintenance advantages.

82. Relays

A relay may be defined as an electrically operated switch or key. It gives one electrical circuit control over one or more other electrical circuits, or as in the case of the locking type relay, may have certain control over the same circuit. There are several thousand types of relays manufactured by the Western Electric Company and classified according to their mechanical construction features, number of windings, resistance of windings, number and kinds of contacts, whether contacts are made, broken or switched and the order in which they are made, speed of operation and current values required for operation. For our purposes, we may study a few general types of relays, remembering that minor changes in the electrical design of each type provide another of the same series which may be adapted to a widely different use.

Probably the earliest use of the relay was for telegraph circuits. A modern telegraph relay is illustrated by Figure 161. Its function is to operate a telegraph sounder connected to a local battery through its contact points, which requires more energy than is present in the telegraph line wire. It also permits some adjustment of the telegraph signals. This is effected by the retractile spring connected to the release armature and the air gap between the armature and pole pieces. These adjustments can be made by screws S_1 and S_2, respectively. Figure 162 shows a standard type of telephone relay, known as the "A" type, which is used as a line relay and as a "cut-off" relay for common battery subscribers' circuits (see Figure 113—Relays "A" and "B"). The mechanical construction of the "A" type relay is unique in several respects. In dimensions it is both small and narrow, thereby permitting a large number to be mounted in a comparatively small space, which results in a great saving of relay rack space in local central offices where a large number of line and cut-off relays are in use. The soft iron armature forms a loop which completes the magnetic circuit from the core through the two halves of the loop, and mechanically operates the contact springs. The winding is of enamel insulated small wire which aids in reducing the size of the relay. The "A" type is very quick in operation, and gives a "flashing line lamp" for more rapid moving of the hook-switch than was possible with earlier types. These relays are ordinarily mounted on complete strips of 20 and a single cover encloses the entire strip.

The "B" type relay, illustrated in Figure 163, is in many respects similar to the "A" type and is used as a supervisory relay (Figure 113—Relay "C" in the local cord circuit). Unlike the "A" type it has an individual cover and thus requires more mounting space.

A type of relay somewhat more elaborate than either the "A" or "B" but having in many respects similar mechanical construction, is known as the "E" series. It facilitates numerous combinations of contact springs and is adapted for very general use in telephone circuits. It is illustrated by Figure 164. It can be mounted either 10 per strip with individual covers or 20 per strip with an overall strip cover.

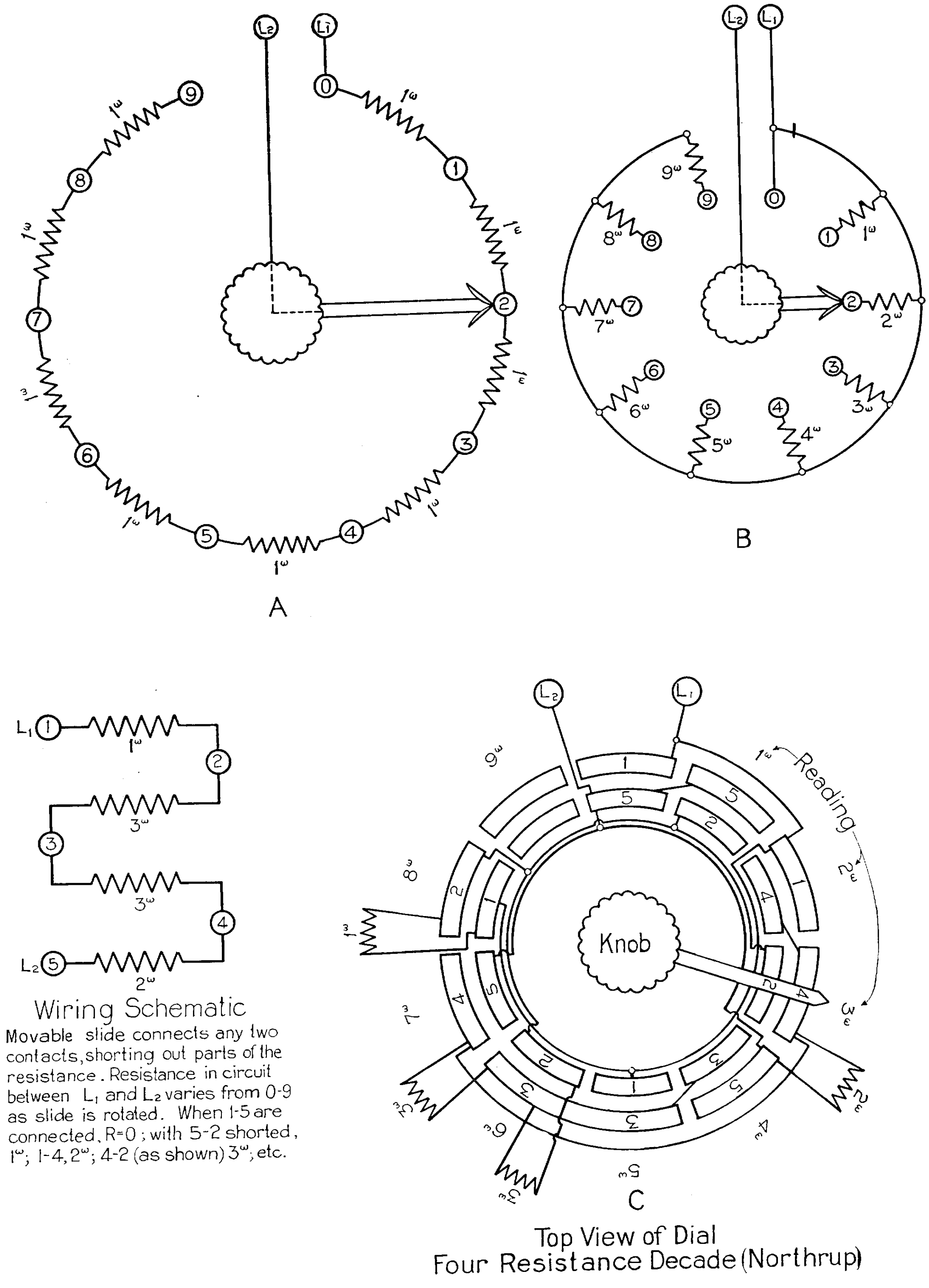
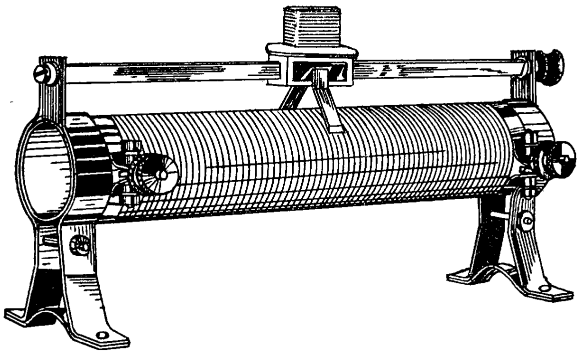


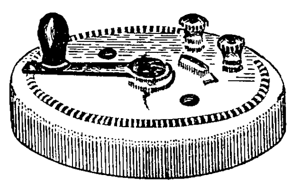
Fig. 156—Wheatstone Bridge Dials.

A type of relay still standard for certain telephone circuit uses, though of older design than the "A", "B" or "E" types, is coded as the #122-type and is shown in Figure 165. Its mechanical appearance is similar to the #178-type and with the exception of the number of groups of springs it is similar to the #125 (3 groups), #149 (one group) and #162 (one group). It has a spool winding and a laminated iron core with the magnetic circuit completed through the return armature and the soft iron framework at each end of the core. Relays of this design ordinarily have round caps which are fastened by means of a nut as shown in the figure.

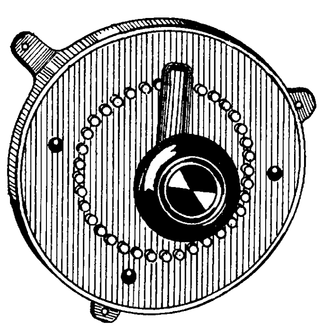
The relays thus far described are intended to operate only on direct current. There are a few other types that may be classified as alternating current relays, the more common of which are the "J" type, the #87-type, the #172-type, the #196-type, the #150-type and the #218-type.



Sliding Contact Tube Rheostat



Miniature Battery Rheostat



Motor Speed Rheostat

Figure 157

The "J" type relay is similar in appearance to the "B" type already discussed.

The #87-type which, while now obsolete, is still in use in many places, is designed to operate on 20-cycle ringing current, and to firmly close a set of contacts when so operated. It is illustrated by Figure 166. Its armature is made of a heavy block of soft iron pivoted near its center at an angle of about 30 degrees. When operated it becomes hori-

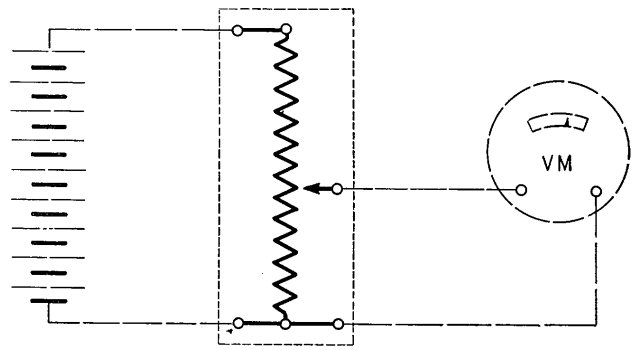


Fig. 158—Theory of Potentiometer.

zontal and is held so by the completed magnetic circuit through the core of the coil, the U-shaped framework and the armature itself. On account of its inertia, and on account of being pivoted so that it is nearly balanced, it is held in position by a pulsating magnetic pull, such as is given by the 20-cycle alternating current. The contact springs are specially designed to hold a firm contact in spite of the slight "quiver" of the armature that results from the alternating current operation.

The #172 and the #196 relays are not illustrated, but these more nearly resemble direct current types. The #172 is a toll line ringdown relay and the #196 is used for operating the toll line supervisory lamp of the toll cord circuit and in telephone repeater circuits designed for 20-cycle signalling.

The #150 and #218-type relays operate on 135-cycle alternating current and have a magnetic circuit similar to that of the polarized ringer. The #150-type relay is shown in Figure 167. The large permanent bar magnet establishes a split magnetic circuit through the cores of the two windings. The accurately adjusted reed between these two cores forms a return for the magnetic circuit. Just as alternating current in the winding of the relay will establish a vibration if it is in tune with the natural period of vibration of the reed, so when the reed is vibrating, the momentum of a contact spring with a weight on one end holds the contact open, except for an instant when the reed imparts a light blow to the spring. Ordinarily the winding of a second relay is in series with these contacts, and is operated by the contacts being open during the major part of the reed's period of vibration. The #150-type relay is used in composite ringer circuits and in connection with telephone repeaters designed for 135-cycle signalling. The #218-type is similar in construction and in use but is somewhat more sensitive. Also, it is equipped with a back contact so that the operation of the relay is positive, closing a contact.

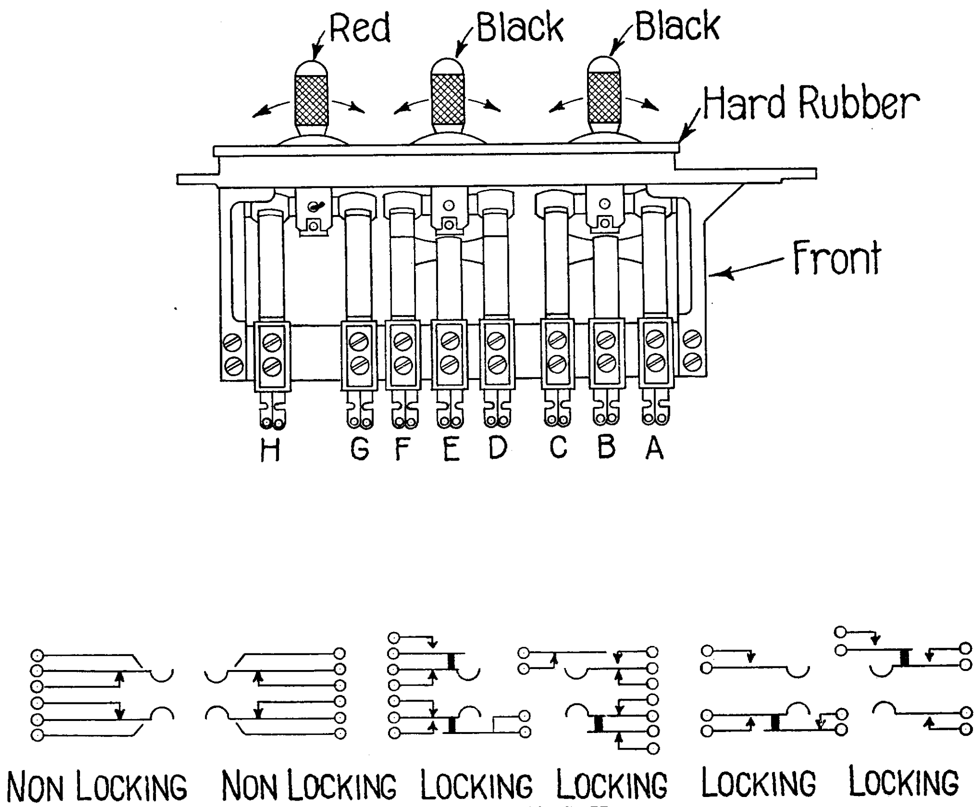


Fig. 159—No. 463-C Key.

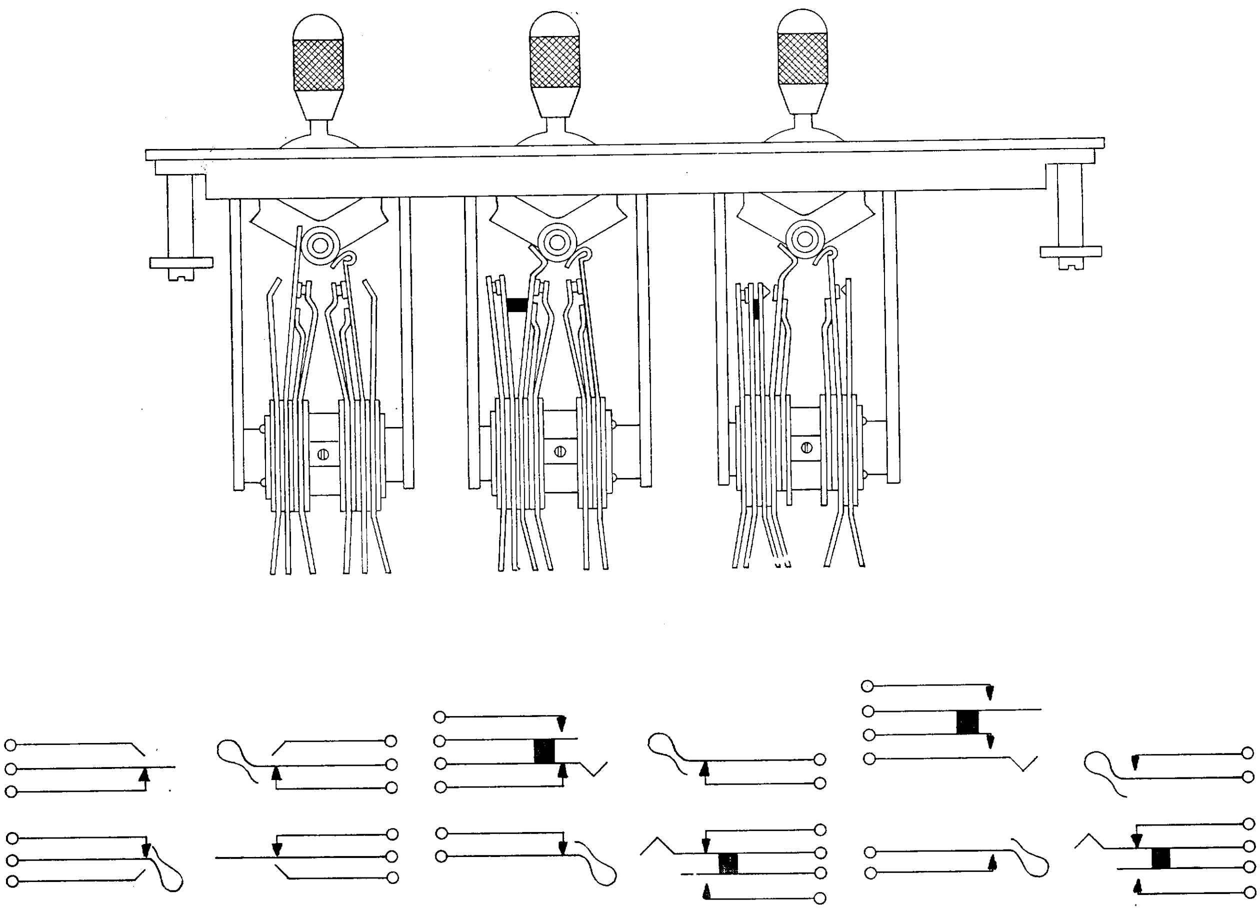


Fig. 160—A1A-Type Key.

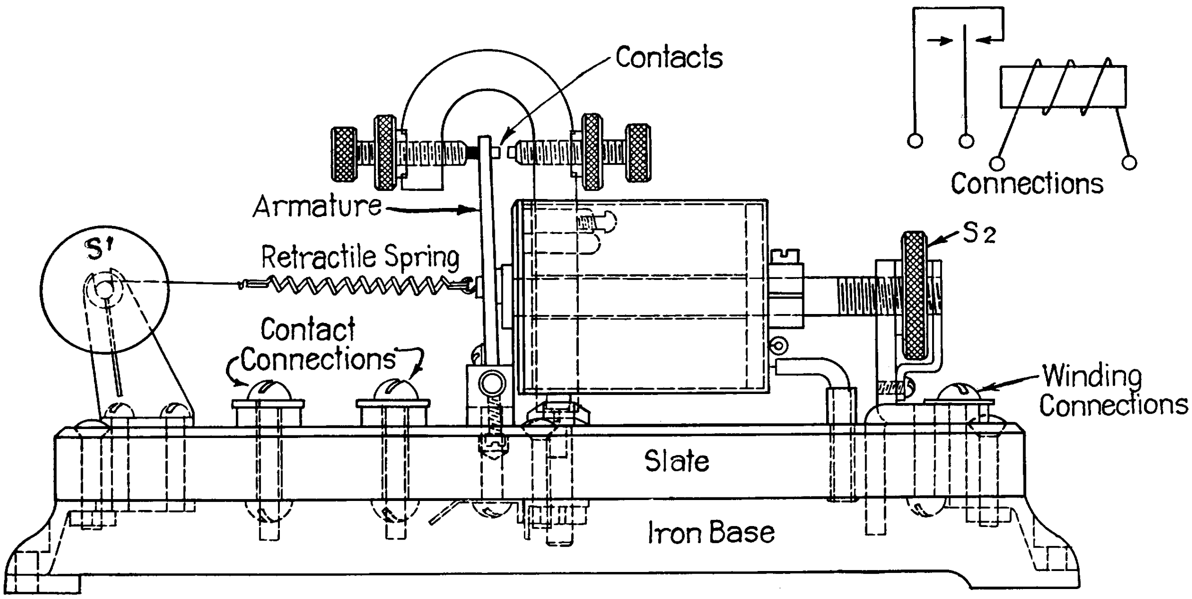


Fig. 161—21 Type Relay.

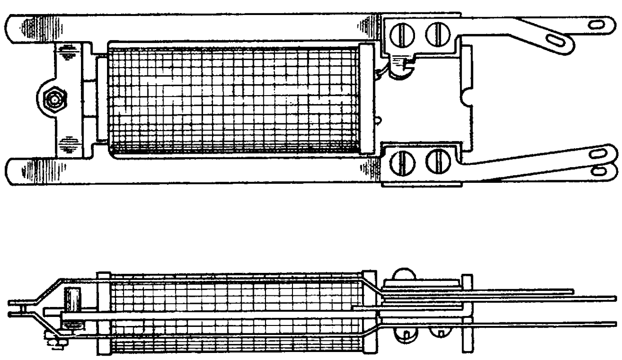


Fig. 162—A-type Relay.

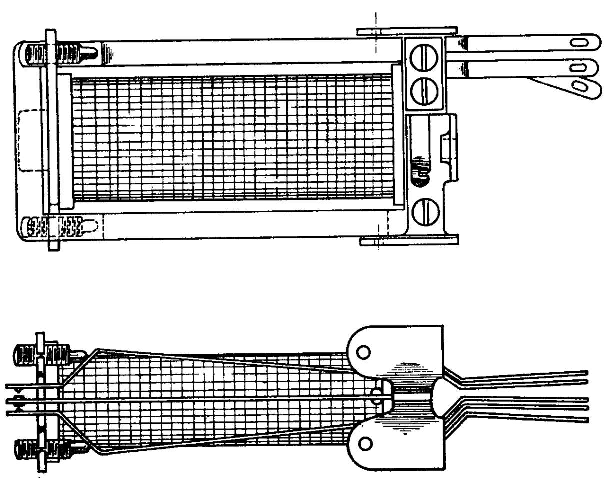


Fig. 163—B-type Relay.

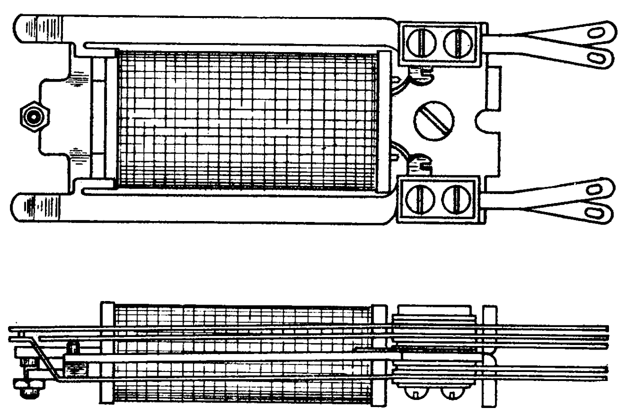


Fig. 164—E-type Relay.

83. Operation of Toll Central Office Circuits in Establishing a Long Distance Connection—No. 1 Switchboard.

We may now observe how various apparatus units are connected together and made to perform specific functions by following through, as an example, the operation of the circuits used in establishing a typical long distance connection over an open wire toll circuit terminated in No. 1 type switchboards. Figure 168 shows these circuits, the several distinct circuit units being grouped in blocks separated from one another by the cross-hatched lines.

To examine the operation of these circuits let us assume that a long distance connection is to be established using the standard single ticket method of operating. We may begin the analysis by considering that an outward line operator in the city

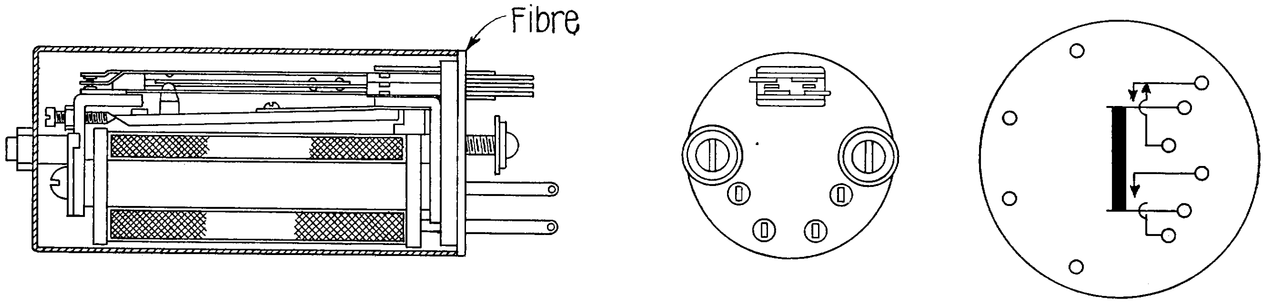


Fig. 165—122 Type Relay.

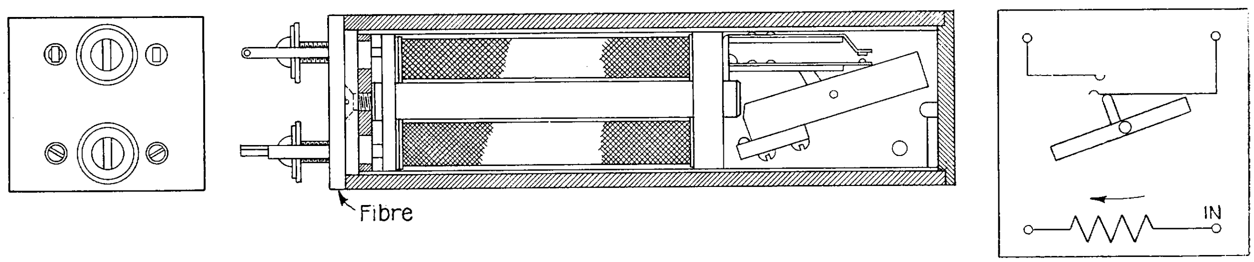


Fig. 166—87 Type Relay.

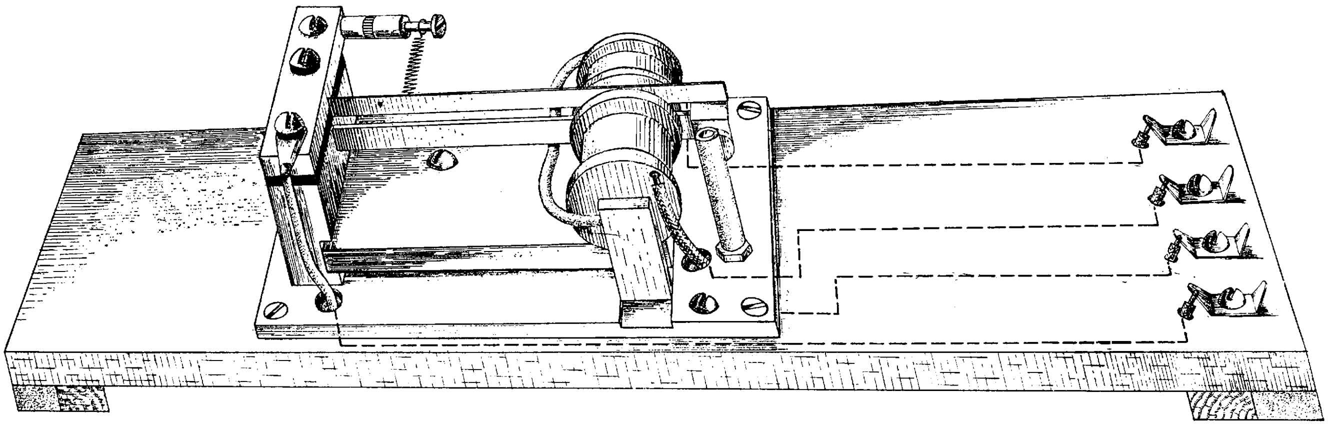


Fig. 167—150 Type Relay.

where the calling subscriber is located has received the toll ticket and is ready to begin work on building up the desired connection. Her first operation will be to connect the proper plug of a toll cord circuit to the outward jack of the toll line circuit. When this is done, a current will flow from the 24-volt battery connection through the 113 ohm winding of the E-156 relay of the cord circuit, through the sleeve of the cord itself to the sleeve connection of the toll line circuit multiple, through the 60 ohm winding of the E-702 relay of the toll line circuit, to ground, thus operating the E-702 and the E-156 relays. When the E-702 relay is operated one of the two springs connected to its armature breaks a contact which normally bridges a 172-B relay across the toll line, and the other makes a contact with a 24-volt battery connection that operates all the busy signals of the multiple, thereby notifying all other long distance operators that the particular toll line circuit is in use. The operation of the E-702 relay also disconnects the 24-volt battery from the winding of the E-28 relay for reasons to be given later. When the E-156 relay operated, it connected the 24-volt battery to the 162-B relay which operated it but did not light the supervisory lamp.

The long distance operator then rings over the toll line by depressing her ringing key, which is designated as key No. 3, in a direction which will operate the set of springs designated as F. These springs disconnect the toll cord from the toll cord circuit proper and connect it to energized ringing leads of 20-cycle frequency, one side of which is grounded. (This 20-cycle ringing current, however, will not be transmitted to the distant end as such if the long distance circuit is used for telegraph as well as telephone service and equipped with a composite set as shown. The 20-cycle ringing current being so nearly similar in its characteristics to the telegraph currents will interfere with telegraph operation and, in addition to this, be greatly weakened when passing through the composite set which is designed to separate telephone from telegraph currents. It is, therefore, necessary in the test and telegraph room to have special equipment installed that will convert the 20-cycle ringing current into a current of higher frequency which will flow through the composite set in the same way that the voice current does and which will, furthermore, not interfere with proper telegraph operation. This is accomplished by means of a "composite ringer set", which is inserted in the circuit. The composite ringer set at the distant end will, in turn, receive the higher frequency ringing current, or the 135-cycle ringing current, and convert it into a 20-cycle ringing current similar to that originally sent out by the long distance operator.)

Now, assuming that the long distance circuit at the distant end is terminated in a "toll line circuit" identical to that in which it is terminated at this end, the incoming 20-cycle ringing current will flow through the winding of the 172-B relay, which is bridged across the distant end of the circuit since no operator at the distant end has a plug in the multiple. This 172-B relay is designed for operating on 20-cycle alternating current and the ringing current will, while flowing, close its armature contact. This closes the winding of the E-28 relay to ground, thereby permitting current to flow from the 24-volt battery connected through the unoperated contact at the E-702 relay to its winding. The operation of the E-28 relay in turn, operates the E-280 relay through its 250 ohm winding. The E-280 relay closes two sets of contacts, one of which permits current to flow through its 700 ohm winding, thereby "locking" it, that is, this relay will remain operated even after the ringing signal ceases and the 172-B relay contacts are open and the E-28 contacts are open, because current will flow from the 24-volt battery connection at the non-operated contact of the E-702 relay through this contact of the E-280 relay and through its own 700 ohm winding. Thus its contact will remain made as long as this current flows and this current will flow as long as this contact is made, unless the E-702 relay is operated.

In addition to locking itself, the E-280 relay closes another contact which operates the busy signals of the toll line multiple thereby notifying all other of the long distance operators at the distant end not to use the line because the operator at this (the near) end is using it to call an inward operator at the distant end. It also closes a third connection at its locking winding contact, through a non-operated contact of the E-651 relay, through a night transfer key to a line lamp at some one of the inward positions and through an auxiliary lamp relay to ground, thus lighting the line lamp. Two inward positions are ordinarily equipped with line lamp sockets, and in this drawing two line lamps are shown. This need not be confusing, however, as the second lamp socket is provided merely to give flexibility in the operating loads of the inward operators without making any cross-connections or other complicated changes.

The inward operator at the distant end then answers this lamp by inserting the toll plug of her toll cord circuit in the inward jack and connecting her head set to this cord circuit by throwing key No. 1 so as to operate the springs designated as B which gives a direct bridging connection for her head set across the cord circuit, and also opens a set of auxiliary spring contacts that are provided for a special feature of the cord circuit to be discussed later. The operator has a standard operator's telephone circuit, which consists of a 528 receiver and a 234 transmitter. The receiver is connected through contacts of a non-operated E-106 relay to the terminals of a #65 induction coil designated 2 and T. The transmitter is connected to a 24-volt battery tap in series with a 12-AB retardation coil and the primary winding of the induction coil, which is in reality two windings in parallel. The 12-AB retardation coil tends to steady the transmitter current flow in the 24-volt battery, thereby reducing noise and compelling the fluctuations (which are in effect a superimposed alternating current) to flow through the 21-E bridged condenser in series with the primary of the induction coil instead of through the 24-volt battery. This tends to give the effect of a lower voltage battery, which is preferable for the operator's transmitter in that it prevents both loud clicks and other disagreeable loudness being heard in the receiver as side tone.

The talking current is induced from the primary of the 65-induction coil to the secondary winding, and in order that its full strength will not be heard in the receiver as side tone this winding has resistance in series with one-half of the winding which, together with the winding, gives a resistance of 500 ohms. However, the induced current, although weakened to some extent by this resistance, will flow over the connections to L and 2, through a 2 mf. condenser, to the contacts of the cord circuit talking key designated as B.

The distant toll operator not only connects her head set to the cord used in answering, but upon plugging into the inward jack establishes a sleeve connection through the E-156 relay of the toll cord circuit to the sleeve of the inward jack (which is different from the sleeve of the multiple jack) through a contact of the E-651 relay, through the winding of the E-702 relay, thereby operating the E-702 relay. This operates the busy signals for all jacks of the multiple in the same way as explained in the foregoing for the near end of the circuit, and in addition, breaks the 24-volt connections to the E-28 relay and to the locking winding of the E-280 relay. This unlocks the E-280 relay and opens its second winding at the same time, which releases its control over the busy signals, now taken up by the E-702 relay, and also breaks the circuit through the line lamp which is no longer necessary since the operator has answered the call and the lamp need not burn thereafter. The E-702 relay also disconnects the bridged 172-B relay which received the original signal in order that this relay shall not weaken the voice current by forming a shunt during the conversation.

We now have the outward long distance operator at the near end of the circuit in communication with the inward long distance operator at the distant end of the circuit, and assuming that the distant operator succeeds in getting the called party on the line, she will throw her talking key to normal after telling the called party that the distant operator (that is, the operator at this end) is calling. This leaves the procedure in connection with handling the call entirely up to the outward operator at this end, with the exception of pulling down the connection at the distant end when the conversation is finished, which is merely a matter of disconnecting the plugs when that operator finds the supervisory lamps associated with her cord circuit burning.

The outward operator at this end now having the called party on the line presses a call circuit key (indicated but not shown on the drawing) which will connect her head set directly to the B-board operator at the local central office. Upon giving the B-board operator the number of the subscriber who placed the call and receiving from the B-board operator the number of the "toll switching trunk" which is to be used for the connection, the long distance operator will plug the other end of her toll cord circuit into the toll switching trunk multiple of trunk No. 10, for example, and upon so doing will close a sleeve circuit to ground through a 500 ohm resistance connected to the toll switching trunk multiple sleeve. This will operate the B-261 relay in series with the E-1466 relay and the 12 ohm winding of the E-156 but will not operate the E-1466 relay on account of the current being too weak. The E-24 relay is next closed and its armature closes the talking connection from the cord circuit keys to the talking conductors of the plug and disconnects a busy test feature of the operator's telephone set circuit.

This busy test feature would have given the toll operator a "click" in her receiver if she had attempted to plug into a busy toll switching trunk instead of the one assigned her by the B-board operator. This click would have been caused by the operation of the B-86 relay which permits a rush of current from the 24-volt battery through one winding of the 20-G repeating coil to ground. This repeating coil is associated with the 65-induction coil. But assuming that the operator plugs into the proper trunk, if the line of the subscriber who has placed the long distance call is not busy, the local B-board operator will connect the plug of the incoming trunk circuit to that line in the B-board multiple. If the line is busy, upon attempting to make this connection, the B operator will get a click in her receiver by a busy test feature associated with the trunk similar to that connected to the toll cord circuit, and instead of plugging the trunk into the subscriber's line she will plug it into one of a special group of jacks which are connected with an interrupter that sends back to the toll operator over the trunk a signal known as the "busy back".

But assuming the line is not busy and that the connection is made, the E-122 relay of the trunk circuit will be operated by closing a 24-volt battery circuit through its winding, through the sleeve of the B-board multiple, through the cut-off relay (A-26) of the subscriber's line circuit to ground. The operation of the E-122 relay in addition to disconnecting the "B" operator's busy test will, through other contacts, connect a guard and disconnect lamp associated with the cord of the incoming trunk to the contact of the 124-F relay and disconnect it from the contact of the B-15 relay and the 30 ohm winding of the E-126 relay. If the B-board operator finishes her connection to the subscriber's line before the outward long distance operator finishes her connection with the trunk, this signal will burn but as soon as the outward long distance operator finishes her connection, this signal will go out. This assures the B-board operator that the long distance operator has understood the trunk number assigned and has plugged into this particular trunk.

The reason this guard and disconnect signal goes out is the operation of the 124-F relay, which breaks the lamp connection, and in turn, closes a connection to the 30 ohm winding of the E-126 relay but does not operate the E-126 relay on account of the other side of this winding being open. The 124-F relay is operated due to the toll operator's cord circuit forming a shunt and a current from the 24-volt battery tap flowing through a 500 ohm winding of this relay to the contact of the E-126 relay, through one winding of the 25-S repeating coil, over one conductor of the trunk to the long distance office, over one conductor of the toll cord circuit to the bridged connection of a 44-D retardation coil (between the splitting and ringing keys), through the windings of the 44-D retardation coil, through the contact of the E-1466 relay, and through the winding of the B-43 relay to the other side of the cord circuit and back over the trunk to the other 500 ohm winding of the 124-F relay, thus operating it. (The resistance shown in series with the 500 ohm windings of the 124-F relay and designated as "X" is adjusted in value to compensate for different lengths of trunk circuits.)

We now have the connection established, the 124-F relay operated, and the lamp not burning at the B operator's position, telling her that the trunk is in use, needs no attention and must not be disconnected. The same current that operated the 124-F relay of the trunk circuit in flowing through the B-43 relay of the toll cord circuit operated it as well and lighted the trunk and toll line supervisory signal of the toll cord circuit, thereby signifying to the operator that she must ring the subscriber. She rings the subscriber by depressing her ringing key in such direction as to operate the springs designated by E which send 20-cycle ringing current over the toll switching trunk to the local office. This causes the 87-A relay, during the interval that the ringing current is flowing, to connect a ground to the E-122 relay which, in turn, sends ringing current to the subscriber's telephone. Incidentally this ringing current flows through contacts of a special key so wired that it can be set to reverse the ringing connection and permit "party line ringing" from the toll cord circuit. This key is set at the same time the trunk is plugged into the B-board multiple, in case the long distance operator passes a number to the B-board operator having a "J" or "W" associated with it.

We thus have the ringing current properly relayed at the local office and when the subscriber answers, a 48-volt battery current will flow through the winding of the B-15 relay, through the 40 ohm non-inductive resistance and one winding of the 25-S repeating coil, over the subscriber's line and back to ground, through the other winding of the 25-S repeating coil and a second 40 ohm non-inductive resistance. This 48-volt circuit is, of course, the subscriber's battery supply and is used in connection with toll switching trunks to improve the subscriber's transmission over long subscribers' loops. The 40 ohm resistance in series with the repeating coil prevents, however, the current being too great on very short loops. Neither this resistance nor the winding of the B-15 relay can appreciably weaken the voice current on account of a condenser being bridged between the terminals 3 and 8 of the 25-S repeating coil; likewise, the winding of the 87-A relay between terminals 1 and 6 does not weaken the voice current on account of the bridged condenser between 1 and 6 of the other side of the repeating coil.

When the B-15 relay operates, due to the subscriber taking his receiver off the hook, its armature contact closes the 200 ohm winding of the E-126 relay through a 600 ohm resistance, through the 30 ohm winding of the same relay to the ground connected to the armature of the 124-F relay. This operates the E-126 relay which disconnects the 124-F relay from the bridge of the long distance operator's cord, but connects one winding of it to ground, which will hold it operated and keep the disconnect signal from burning. This interrupted flow of current through the toll cord circuit bridge releases the B-43 relay of the toll cord circuit, putting out the trunk and toll line supervisory signal, thereby notifying the long distance operator to cease ringing since the subscriber has answered. She then, having her talking key depressed, notifies the subscriber that she is "ready on his long distance call". After this she throws the key lever of her talking key in the other direction, which operates springs A instead of springs B and this disconnects her telephone circuit but connects the 27-F repeating coil and operates the E-106 relay. The E-106 relay switches the telephone receiver from the head set circuit to terminals 7 and 8 of the 27-F repeating coil circuit, thereby permitting the operator to listen, in such a manner as not to seriously affect the subscriber's transmission.

As soon as the subscriber starts talking, the operator stamps the ticket and sets key No. 1 normal, which disassociates her head set from the connection altogether, unless for some reason it is desirable to continue monitoring.

When the E-106 relay is operated it establishes contacts other than those for switching the telephone receiver from the head set circuit to the 27-F repeating coil. These additional contacts are associated with monitoring taps which connect the operator with the service observing board, thereby permitting the service observer to listen in on the circuit either when the operator is talking or monitoring.

When the subscriber has finished talking and hangs up the receiver on the hook the B-15 relay of the toll switching trunk circuit is released which, in turn, releases the E-126 relay, and this relay again connects the 124-F relay over the trunk to the bridge of the toll cord circuit and operates the B-43 relay which lights the trunk and toll line supervisory signal, thus notifying the long distance operator that the subscriber has hung up. After stamping the ticket she pulls down the connection with the toll switching trunk, releasing the 124-F relay and in doing so lights the guard and disconnect signal in front of the B operator. This time the B operator knows that the burning lamp means "disconnect" and pulls down the cord. This releases the E-122 relay which lets the guard and disconnect signal again go out, telling the B operator that the trunk is not in use and no further attention is needed. The long distance operator again rings the long distance inward operator at the distant end, but this time the signal does not display a lamp associated with the toll line circuit on account of the inward operator's toll cord circuit being connected. Instead, the signal is displayed by means of the ringing current operating the 196-A relay which is bridged across the cord circuit and which, in turn, releases the 162-B relay, permitting the toll line supervisory signal to light on account of the 24-volt connection through the contacts of the E-156 relay, the contact of the 162-B relay as well as the locking contacts of the 162-E relay and the auxiliary contacts of the talking key through the auxiliary signal relay indicated but not shown. This is a signal for the inward operator to clear the circuit and is additional to the signal she will receive when the distant party hangs up.

Both the toll line circuit and the toll cord circuit have features which were not explained in connection with this particular call. One feature of the toll line circuit is the night transfer key which permits grouping the inward signals. One night operator will handle as many incoming toll circuits as several inward operators handle during the day. Another feature is the use of non-locking keys associated with lamps at the inward position, which

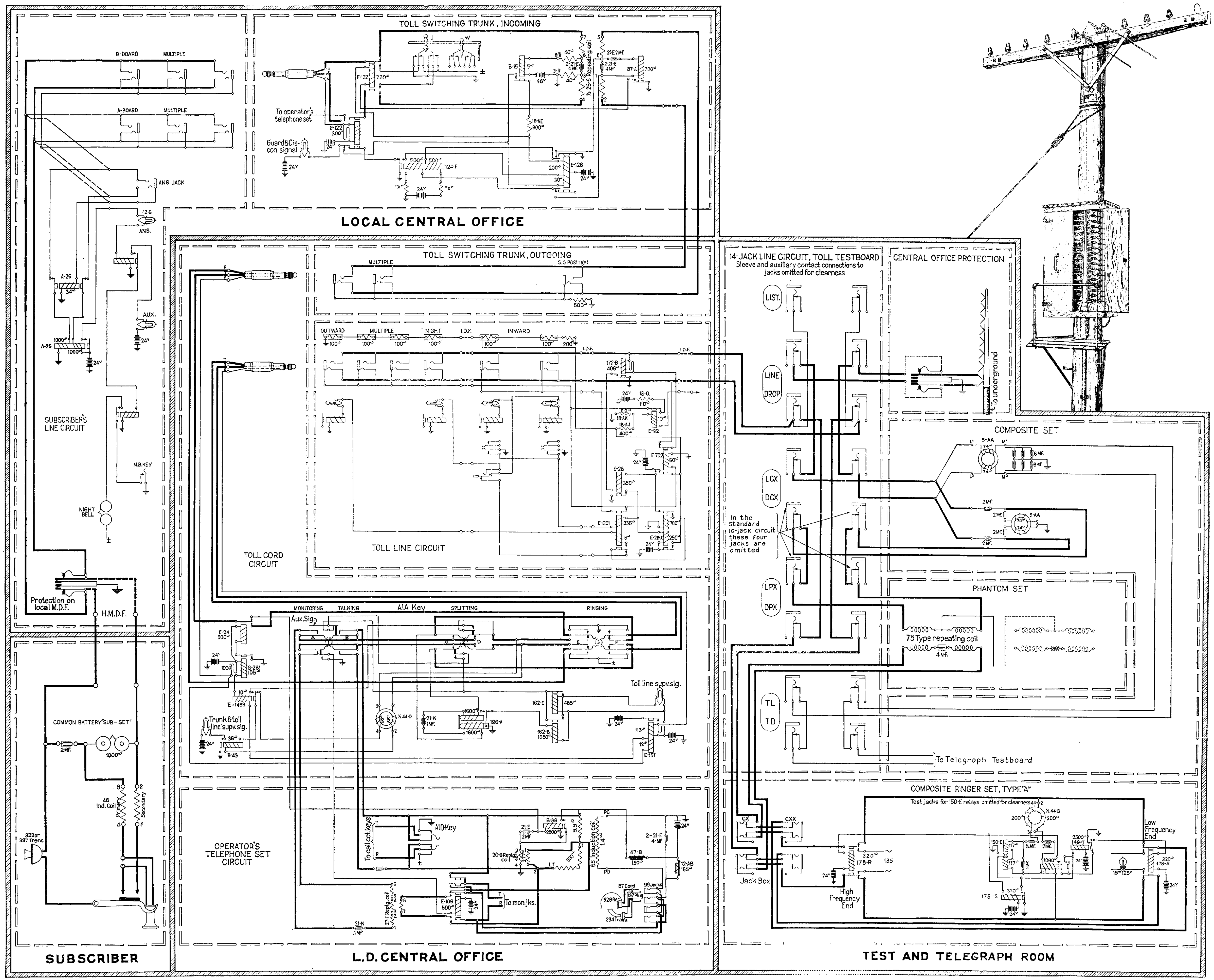


Fig. 168—Typical Long Distance Terminating Connection. Open Wire Circuit—No. 1 Switchboard.

when pressed by the inward operator will transfer a call from the distant office to an outward operator by extinguishing the inward line lamp and operating the E-651 relay which will burn the outward line lamp. This is for use where the method of operation is such as to require that tickets be made at both ends of the circuit or for delayed traffic where the distant office's outward operator will make all subsequent attempts to locate the called party.

A special feature of the toll cord circuit is the E-1466 relay which is "marginal" and operates on the current which flows when the plug is connected to another toll line circuit. The operation of this relay opens up the direct current supervisory bridge through the B-43 relay, eliminating its shunting effect upon transmission in case the toll cord circuit

nated as a "14-jack line circuit" in the toll testboard. In present installations a 10-jack line circuit is used instead of the 14-jack circuit but many 14-jack circuits remain in use and it is accordingly selected for our example. Figure 169 shows diagrammatically the order in which these circuits are connected with respect to the 14-jack line circuit and may be helpful in following the connections shown by Figure 168. In either figure if we trace carefully the long distance circuit from the long distance operating room to the underground cable, we shall find it first connected to the drop jacks in the testboard line circuit by means of cross-connections at an intermediate distributing frame. In order that the busy test feature may apply to the testboard circuit as well as the long distance switchboard multiple, a third conductor is used which connects to the 14-jack line circuit.

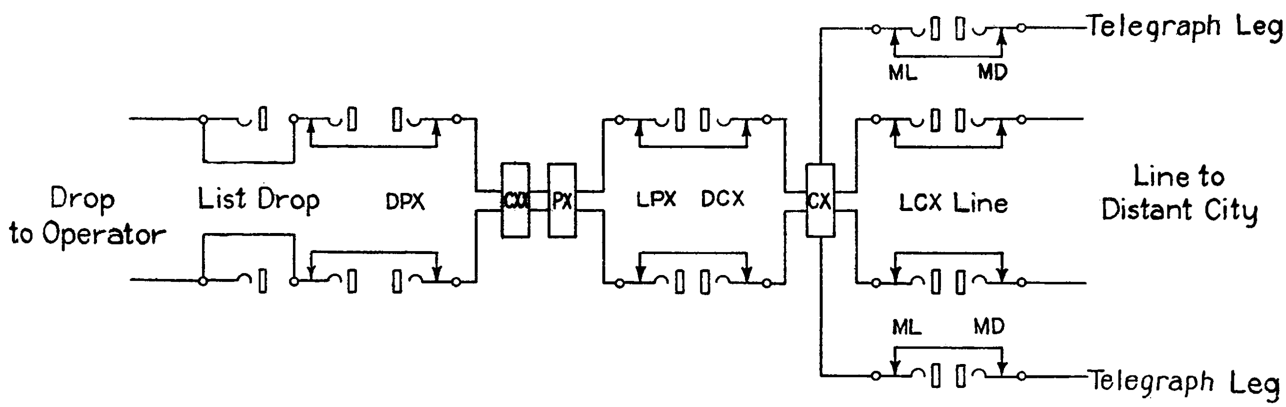


Fig. 169—Line Circuit Jack Connections at Toll Test Board.

is used for a switching connection, that is, when two toll line circuits are connected together instead of one toll line circuit connected to a switching trunk. Another feature is the splitting key, which permits the operator to talk on one end of the circuit without the party at the other end hearing; thus she can communicate with the calling party or the called party at will. Auxiliary contacts of the splitting key have special relay connections whereby she will receive an incoming signal on the other end of her cord circuit in case the splitting key is thrown. A special feature of the operator's telephone circuit is a ringing key associated with the call circuit keys which permits ringing on call circuits at night or in other cases where the B-board operator "answers in" on call circuit signals instead of having a head set permanently connected to a group of call circuits.

We have mentioned the functions of the circuits shown associated with the long distance connection in the test and telegraph room and we may now direct our attention to their operation in detail. For the open wire terminating circuit illustrated in Figure 168 three distinct apparatus circuits are shown, namely, the composite set, phantom set and composite ringer set, which represent apparatus units installed on relay or coil racks and cabled in this case to a single group of fourteen jacks, desig-

This and all of the auxiliary contact wiring is omitted for the sake of clearness, and we may consider only the talking conductors that terminate on the tip springs of the two jacks designated as "drop". If the #241 plug of the testboard man's testing circuit is inserted in these jacks, the testing circuit will be connected with the toll switchboard, and all other equipment in the test room, as well as the line itself, will be disconnected on account of the tips of the plug operating the springs of these jacks and opening the contacts shown. When the plug of the testing cord circuit is not inserted, however, the toll circuit is merely looped through the drop jacks and thence to contacts of two similar jacks designated as DPX, an abbreviation for "drop side of phantom set". The plug inserted here will likewise open up the circuit but will pick it up in the other direction, "looking" toward the line through all of the associated equipment in the test room with the long distance office disconnected instead of "looking" toward the long distance office with the other direction disconnected.

Leaving the DPX jacks the circuit is looped through other jacks at a composite ringer jack box and is connected to the armature springs of a 178-S relay at the low frequency end of the composite ringer set. When this relay is not operated the circuit continues but has bridged across it the composite ringer signalling apparatus and is connected to the outer contacts of the 178-R relay at the high frequency end of the composite ringer set. Continuing, it again loops through the composite ringer jack box and is carried by means of cable conductors to the drop winding of one coil of a phantom set. The line winding of this phantom set is connected to springs of two other jacks of the testboard circuit designated LPX, which is an abbreviation for "line side of phantom set". A plug inserted here will open the long distance circuit and pick up the central office end through the phantom coil and the composite ringer. With no plug inserted the circuit merely loops through these jacks and straps to contacts of other jacks designated as DCX, meaning "drop side of composite set". Leaving the springs of these jacks, the circuit is carried through the talking branch of the composite set, returning to the testboard and terminating on the springs of the LCX jacks or the "line side of the composite set" jacks. The DCX and LCX jacks permit the testboard man to pick up the circuit on either side of the composite set in the same manner that he can pick it up on either side of the repeating coil in tandem with the composite ringer. The contacts of the LCX jacks are strapped with the contacts of the line jacks and the circuit is carried from these through cable conductors to the horizontal side of the main distributing frame and by means of a cross-connection is connected to the protection associated with the underground cable conductors.

The operation of the composite ringer set is as follows: A 20-cycle ringing current from the long distance operator's ringing key reaches the bridged apparatus from the low frequency end of the circuit and flows through a 200 ohm winding of the 44-B retardation coil in series with a 2 mf. condenser and a J-1 relay. This operates the J-1 relay. Ground through the armature of the 149-T relay which is normally operated when the circuit is not receiving a signal from the distant end, is connected to both the winding of the 178-R relay at the high frequency end and the 178-S relay. The 178-R relay operates and switches the line side of the circuit from its drop connection to the ringing leads from a 135-cycle ringing generator. This 135-cycle high frequency current will pass through the composite set to the line side of the circuit.

The same composite ringer set not only "arrests" the 20-cycle ringing current and substitutes in its stead an outgoing 135-cycle current but reverses the operation on an incoming ring from the distant end. In this case the 135-cycle high frequency current flows through a second bridge consisting of one winding of the 44-B retardation coil in series with a one-half mf. condenser and the winding of the 150-E relay in parallel with a 1 mf. condenser. The operation of the 150-E opens a connection to ground, permitting the armature of the 149-T relay to fall back and this connects the winding of the 178-S relay at the low frequency end to ground, thereby operating it and connecting the drop of the toll circuit to 20-cycle ringing leads which operates the 172-B relay of the toll line circuit. There are special precautionary features of the composite ringer set which prevent temporary impulses that may for an instant open the 150-E relay. These hold the 149-T relay from giving false rings. Such impulses ordinarily come from condenser charges incidental to 20-cycle ringing or harmonics of the 20-cycle ringing current. The second armature of the J-1 relay shunts the winding of the 149-T relay when the ringer circuit is operating in the other direction. The armature of the 178-S relay likewise forms a shunt which is not as rapid in its action but makes a steadier contact.

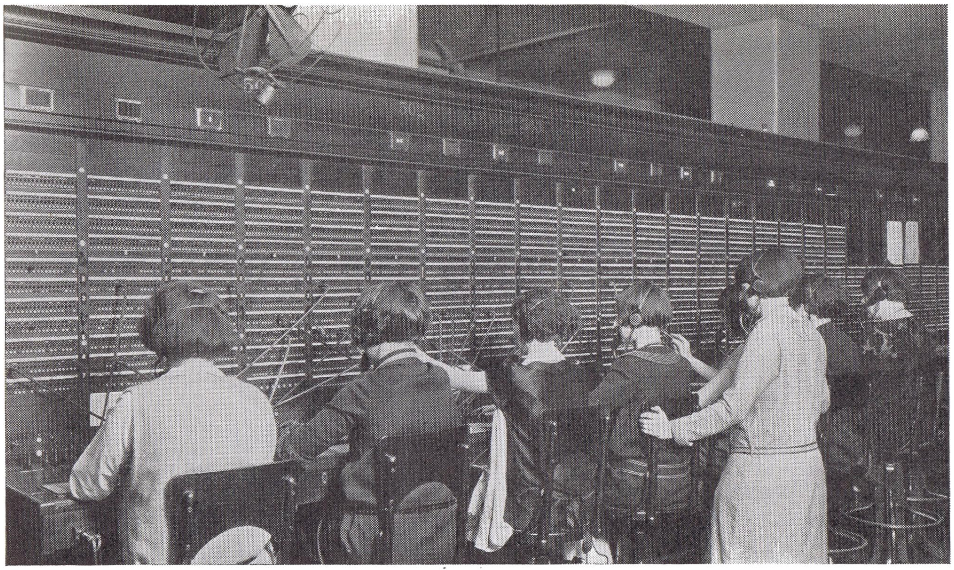
84. Operation of Toll Central Office Circuits in Establishing a Long Distance Connection—No. 3 Switchboard.

As a further example, Figure 168-A shows the circuits and apparatus provided to establish a connection to a four-wire cable circuit terminated in the more recently designed No. 3 switchboard. It may be interesting to compare the operation of this circuit with that which we have just been over. The principal point of difference between the No. 3 and No. 1 switchboards is that in the former all apparatus except one relay and the necessary keys is removed from the cord circuit proper and connected either in the toll line or outgoing switching trunk circuit or in a special circuit which may be used in common with any of the cords in a position, known as the operator's position circuit. This arrangement reduces quite materially the amount of apparatus mounted in the switchboard position and effects a large reduction in maintenance difficulties. There is also a change in the signalling circuits which, when it has been more completely adapted to existing plant, will introduce substantial economies.

Let us briefly follow through the operation of the circuits of Figure 168-A in the same way that we did those of Figure 168. When the outward operator connects one end of her cord to the toll line jack a connection is established from battery through the supervisory lamp of the cord circuit and the cord sleeve to the winding of the B-1019 relay in the toll line circuit. This relay operates but due to its relatively high resistance (1800 ohms) the current flowing is too weak to light the supervisory lamp. The operation of relay B-1019 is followed by that of the R-897 relay which operates the busy signals.

The operator now signals on the circuit by operating the ringing key in the proper direction which connects 24 volt battery in series with 28 ohms to the tip of the cord. This establishes a current through one winding of the 54-L retard coil and the winding of relay R-856 in the toll line circuit, which in operating connects 20 cycle ringing current to the outgoing line. This ringing current is converted to a higher frequency for transmission over

PLATE V



TOLL OPERATING

Above — Through or "Rx" switchboard where switched connections between distant cities are established.

Above—Line switchboard where outgoing toll calls are handled.

Left—Close-up of line switchboard position. The operator is connecting one end of a cord circuit to a toll switching trunk, the other end being already connected to a toll circuit.

the toll line but is received at the distant switchboard as 20 cycles again, where it passes over the signalling bridge and operates the 196-A relay in the line signalling equipment circuit. This releases the normally operated 162-B relay connecting ground to the 300 ohm winding of the R-854 relay in the toll line circuit through a non-operated contact of the R897 relay. One armature of the former in closing operates the busy signals and through the other closed armature contact, the relay is locked up through its 475 ohm winding under control of the R-897, and battery is connected through non-operated contacts of the R-897 and R-855 relay to the signal lamps at the inward multiple.

The inward operator recognizes the signal by connecting one end of a cord to the jack which permits current to flow through the sleeve to the B-1019 relay operating it and in turn the R-897. The latter opens the battery connection to the line lamps and releases the locked up R-854. The operator answers on the connection by throwing her Talk key which through the resultant operation of the R-857 relay in the cord circuit and certain other relays in the operator's position circuit to be discussed later, connects her telephone set circuit across the line. The telephone set circuit differs in minor detail only from that described in connection with Figure 168.

When the other end of the cord circuit is connected to the switching trunk, a sleeve connection is closed through the B-199 relay in the outgoing end of the trunk, operating it. This closes a circuit through the winding of the B-1009 relay over the trunk and through the windings of the 124-F relay, operating both relays. The circuit of the incoming end of the trunk is identical with that of Figure 168 and functions in exactly the same manner. The operation of the B-1009 relay connects the 85 ohm winding of the B-199 relay in parallel with its 1800 ohm winding to the sleeve wire, the resultant reduction in series resistance permitting sufficient current to flow to light the cord circuit supervisory lamp. The toll operator then operates her ringing key which connects battery to the tip wire and so operates the E-65 relay in the trunk. This connects 20 cycle ringing current to the trunk which causes the operation of the 87-A relay followed by that of the E-122 which connects ringing current to the subscriber's line. When the subscriber answers, the B-15 and E-126 relays are operated in that order, the latter opening the circuit through the winding of relay B-1009 putting out the signal lamp.

Upon completion of the call, the outward operator rings on the toll line. The incoming signal at the distant end operates the 196-A relay in the line signalling circuit which releases the 162-B, grounding the lead to the toll line circuit. Due to the cord being connected to the circuit, however, the R-897 relay is now operated so that the grounded lead is now connected through its operated contacts to the winding of the B-1020 relay thence through contacts of relay E-6485 to the sleeve. The low resistance B-1020 relay now connected in parallel with the B-1019 reduces the sleeve wire series resistance to about 80 ohms permitting the cord circuit supervisory lamp to flash. The operation of relay B-1020 connects battery to one end of the winding of relay E-6193, the other end of which is connected to interrupted ground. This relay then operates intermittently causing a similar operation of relay E-6485 which, in turn, intermittently opens the connection of relay B-1020 to the sleeve circuit. The B-1020 is held operated, however, by battery supplied through the operated contacts of the E-6485 to one end of its winding, the other end being grounded through a pair of its own operated contacts. The net result is to cause the cord circuit signal lamp to flash intermittently, and this will continue even after ringing stops until the inward operator either pulls down the cord or answers in on the circuit.

The inward operator may answer by throwing the talking key in her cord which disconnects the sleeve wire from the lamp circuit and connects it to battery through the windings of the B-1022 and B-1023 relays in the operator's position circuit in series. The combined resistance of these two relays is about 600 ohms, a value sufficiently high to so reduce the current flowing in the sleeve wire that the B-1020 relay, which is marginal, is released. This breaks the connection to the E-6193 and E-6485 relays, stopping their action and also increases the sleeve resistance to 1800 ohms. The B-1022 relay in the operator's position circuit is also marginal and does not operate but the B-1023, and following it, the R-1084 are operated. The operation of the talking key also establishes a circuit through a non-operated contact of the 149-BL relay in the position circuit and the 175 ohm winding of the R-857 relay in the cord circuit operating it. This breaks the direct connection between the two ends of the cord and connects them to the splitting key from which they are connected to the telephone set circuit through closed contacts of the two R-1084 relays which are both operated if both ends of the cord are connected to jacks.

The operator's position circuit is, as its name implies, common to all the cord circuits at a position. This means that each wire shown in Figure 168A as connecting from this circuit to the cord circuit is also connected in the same way to every other cord circuit in the position. It may be noted that with the monitoring and talking keys of the cord normal, every one of these wires is open at one end or the other. When the position circuit is connected to a cord by operation of the talking key, the cord may be split for talking in either direction by operation of the splitting key in the position circuit.

If, when the talking key is operated, a ringing signal is received over the line, it will operate the relays in the signalling circuit and connect ground through the operated contacts of the R-897 relay, the winding of the B-1020, non-operated contacts of the E-6485 and thence over the sleeve wire and through contacts of the talking key and the windings of the B-1022 and B-1023 relays to battery. The current set up will not be great enough to operate the B-1020 relay but due to the connection of the B-1020 in parallel with the B-1019 in the sleeve circuit, the current will be of sufficient value to operate the marginal B-1022 relay in the position circuit. Its operation will reduce the resistance of the circuit of the cord circuit supervisory lamp, which may be traced through contacts of the talking key, from 1800 ohms to 80 ohms by connecting an 85 ohm resistance in parallel with the 1800 ohm resistance already connected to the lamp and grounded through a closed contact of the R-1084 relay, and permit the lamp to light.

Similarly a switch-hook signal from the subscriber, when the talking key is operated, will operate the B-1009 relay in the trunk circuit which will connect the low resistance winding of the B-199 relay into the sleeve reducing its net resistance and so allowing the B-1022 relay associated with that end of the cord to operate and light the other signal lamp.

The position circuit is so designed that if the talking keys of two cords are operated, only the cord whose key was thrown first will be connected to it. This is effected by means of the 149-BL relay which when it operates following the operation of the R-857 relay in the cord circuit whose key is thrown first, opens the ground connection to the 175 ohm winding of the R-857 and replaces it with a ground connection through another pair of contacts in the talking key and auxiliary contacts of the R-857 to its own 700 ohm winding. This holds the R-857 relay in the first cord operated but makes it impossible for the R-857 in any other cord to operate even though its talking key is operated because both windings will be opened, one by its own non-operated contacts and the other by the operated armature of the 149-BL.

It is possible, on the other hand, to monitor on two or more cords at the same time by operating the monitoring keys. It is possible also to talk and listen on two cords simultaneously by operating the talking key of one and the monitoring key of the other. In this case only the cord whose talking key is thrown is connected through the position circuit for splitting or transferring but the operation of the R-506 relay connects the monitoring leads from the second cord to the leads running to the telephone set circuit through two 2 mf. condensers.

The position circuit of Figure 168-A is arranged for transferring an incoming call from the inward to an outward position. The circuit may also be arranged for transferring from inward to through or, by adding another relay in the toll line circuit, for transferring from inward to through and outward. The transfer from inward to outward is accomplished by operating the transfer key shown in the circuit. This connects battery through 84 ohms to the ring wire of the cord permitting current to flow over this wire and through the 1-2 winding of the 54-L retard coil to the 165 ohm winding of the R-855 relay in the toll line circuit. Its operation opens the sleeve connection from the inward jack, thus releasing the B-1019 and R-897 relays. The simultaneous establishment of a ground connection to the 300 ohm winding of the R-854 relay, however, causes it to pull up and hold the busy signals operated. The closing of the R-854 and R-855 relays also establishes a connection from battery at the now opened contacts of the R-897 relay through a closed contact of the R-854 and the 7 ohm winding of the R-855 to the lamp signals at the outward positions. The R-854 and R-855 relays are locked up through their 475 ohm and 7 ohm windings respectively, so that the lamps at the outward positions remain lighted until the outward operator plugs into the jack even though the inward operator restores the transfer key to normal and pulls down her cord. When the outward operator answers, the operation of the B-1019 and R-897 relays due to the sleeve connection, breaks the battery connection to the signal lamps and the R-854 and R-855 relays, allowing them to return to their normal non-operated position.

From the switchboard, the line circuit is led through three pairs of jacks at the secondary testboard. There the circuit may be monitored by the testboard man and patches involving the drop circuit and the drop side of the four-wire terminating equipment can be made. An artificial line or pad is inserted between the HYL jacks at the secondary testboard and the four-wire terminating set, the primary purpose of which is to effectively lengthen the two-wire line circuit and so make possible a better balance between this line and the network associated with the terminating set. In cases where the equivalent of cord circuit repeater operation is desired a second pad having a 3 db loss is also inserted at this point and is so arranged that it will be cut out when the circuit is connected at the through switchboard to another similarly arranged circuit, the net effect being to give the equivalent of a 6 db repeater gain.

The four-wire terminating circuit is a device for breaking the circuit into two parts, a transmitting and a receiving circuit, each requiring a pair of wires. It consists of two 82-C repeating coils connected in the bridge transformer arrangement to be discussed in a later Chapter. A terminal composite ringer is bridged around the terminating set and the pad. This converts the 20 cycle signal coming from the drop to 135 or 1000 cycles for transmission over the toll line and likewise converts incoming high frequency ringing signals to 20 cycles for operating the signal receiving circuits at the switchboard. The two relays shown associated with the terminating set function in connection with the operation of the terminal ringer.

From the terminating set, the transmitting and receiving circuits pass through four jack circuits in

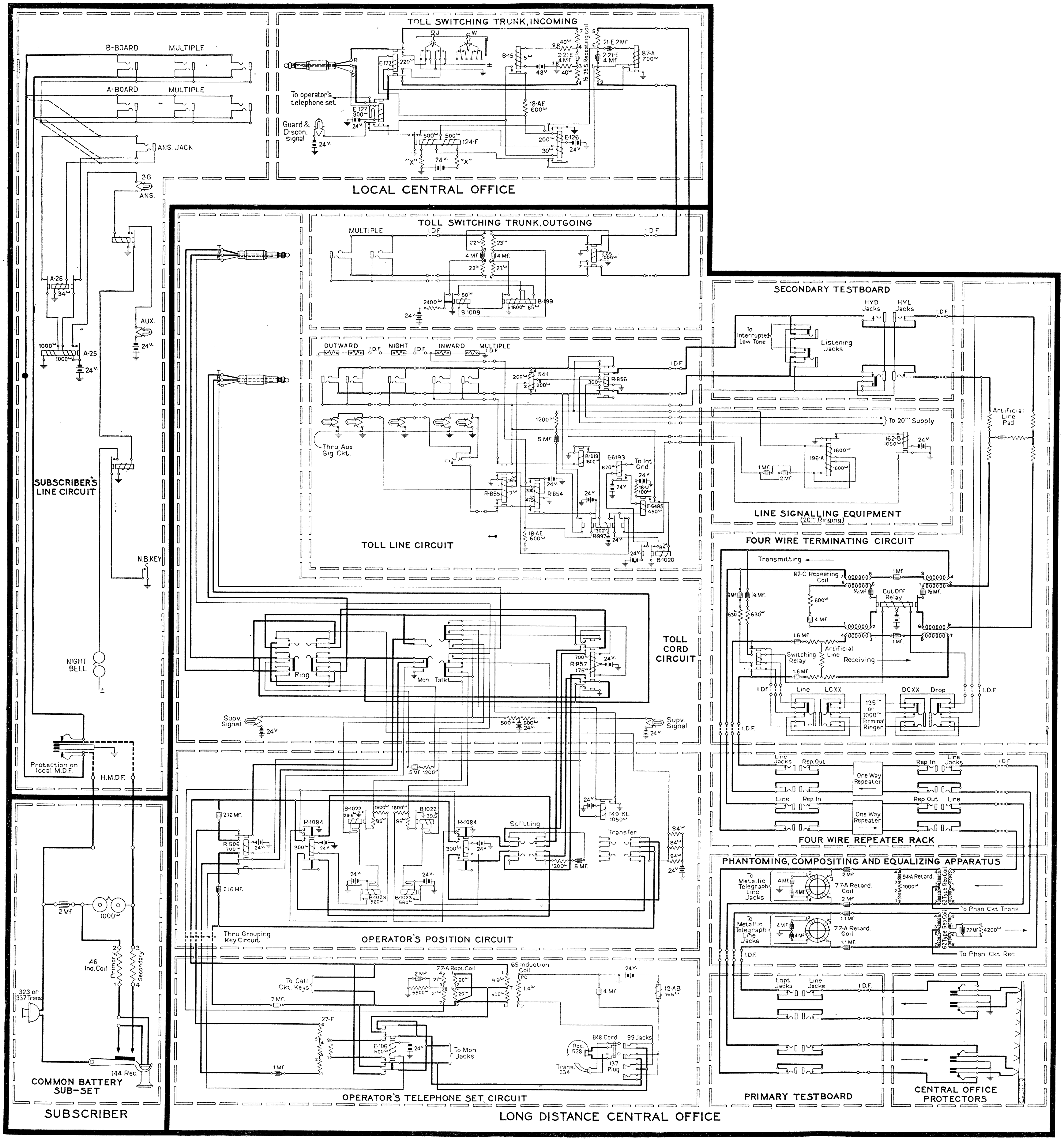


Fig. 168A—Long Distance Terminating Connection Four Wire Cable Circuit—No. 3 Switchboard and out of the terminating amplifiers or repeaters, indicated by blocks in the drawing, and from thence to the line equipment. This consists of the composite sets, equalizing equipment and phantom sets which are connected directly together instead of being brought out separately through jacks at the testboard as in Figure 168. The composite sets shown in Figure 168A are arranged for metallic telegraph circuits and differ in detail but not in principle from those that have been previously examined. Equalizing apparatus consists of arrangements of resistances, inductances and capacities connected across the line on the line side of the phantom repeating coil in the transmitting circuit and in series with the drop windings of the repeating coil in the receiving circuit. The purpose of this is to broaden the band of frequencies through which transmission over the circuit will be practically uniform.

For line testing purposes and for patching the equipment, the line circuits are next connected through four-jack circuits at another testboard position called the primary testboard where a large number of cable pairs may be terminated conveniently since each pair occupies only a relatively small space in the testboard jack panels. From the line jacks here the circuits are connected to the distributing frame again and thence through protectors to the toll cable itself.