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WAR DEPARTMENT

TECHNICAL MANUAL

COMMON-BATTERY TELEPHONE EQUIPMENT

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COMMON-BATTERY TELEPHONE EQUIPMENT

SECTION I
GENERAL

1. Purpose.—The purpose of this text is to acquaint the student with the basic fundamentals governing common-battery telephony.

2. Scope.—The general application of various circuits and combination of circuits used in common-battery telephony is discussed in this text. On the other hand no attempt is made to cover special application of the various circuits in specific equipment if the circuits employed are covered in existing technical manuals issued by the Signal Corps.

SECTION II
COMPARISON OF LOCAL-BATTERY AND COMMON-BATTERY SYSTEMS

3. Local-battery system.—The distance over which satisfactory telephone communication is possible is determined by the electrical characteristics of the circuit. These characteristics are, in some measure, affected by the type of outside plant construction, which, in turn, depends upon the number of subsets served and the expected life of the system.

a. Advantages.—The advantages of the local-battery system over the common-battery system are:

(1) The wire lines, usually called the outside plant, can be constructed more quickly and cheaply.

(2) For the local-battery system the switchboard is less complex, less delicate, and less costly.

(3) Transmission of speech is possible over long high resistance lines because the current in the line has a much smaller value.

b. Disadvantages.—(1) The life of a dry cell is short; it deteriorates even when standing idle, and the voltage varies radically between the time of installation and exhaustion. Hence, from an economic consideration, dry cells are one of the most expensive sources of electrical energy.

(2) As the voltage decreases, the output of the telephone will decrease, consequently, uniform service will not be obtained at any one subset.

(3) Checks must be made at each telephone set to test the batteries and replace exhausted cells. In commercial companies, this entails visits to the subset at perhaps isolated locations.

(4) In addition to the batteries, a means must be provided for the user to signal the operator. This is accomplished by a magneto (hand generator) which not only further increases the size of the set, but requires effort on the part of the user in turning the generator crank when signaling.

(5) Failure on the part of the person using this type of telephone to ring off, when through talking, increases the work of the operator. This necessitates monitoring by the operator to determine when to disconnect, and also reduces the availability of the circuits.

(6) If the switchboard drops are the manual restoring type, this further adds to the operator's work.

4. Common-battery system.—*a. Advantages.*—The use of the common-battery equipment overcomes all of the above disadvantages as follows:

(1) By furnishing all current from a centrally located battery, the drain on it is such to warrant the use of storage batteries which are easier and more economical to maintain. Recharging energy for a storage battery costs a great deal less than does the purchase of dry cells—the service requirements being the same.

(2) The talking current for the subsets is supplied from the storage batteries which hold their voltage constant, thus the output of the subset is not affected by battery deterioration.

(3) The battery supply being thus centralized, located at the telephone central office, eliminates the necessity of visiting subsets to test and renew batteries.

(4) The removal of the receiver or handset from the hookswitch allows a circuit to be completed for direct current which causes a lamp to light on the switchboard which signals the operator. (The operation of the component parts of the subset is discussed in detail in the next section.) Hence, the magneto is not required and with the elimination of the dry cells, the subset equipment is smaller and simpler.

(5) The operation of the hookswitch, when the receiver is removed—or hookswitch signaling—not only simplifies the routine for persons placing calls, but affords a prompt means of indicating completion of the conversation to the operator, resulting in reducing the operator's work.

(6) A single operator can handle many more lines on a common-battery switchboard than one at a local-battery switchboard and also give better service.

b. Disadvantages.—As compared to the local-battery system, the disadvantages of the system are:

(1) The outside plant must be of higher quality in order to reduce leakage from the potential standing on the lines.

(2) Any unbalance in the wire lines of the outside plant will seriously affect quality of transmission and distance over which transmission of speech is possible.

(3) The inside plant equipment is far more complex, expensive and delicate, therefore, a longer time is required for installation, and maintenance requirements are increased.

(4) The resistance of the loop or line to the subset limits the distance over which transmitter and signaling current may be supplied to a subset.

5. Application or uses of the two systems.—The common-battery system is used where there are a great number of subscribers located in a relatively small area and the local-battery system used where the subscribers are reasonably scattered. From the standpoint of quality of outside military plant (generally field wire), reliability of switchboard equipment, and quality of transmission over field wire, it has been found that common-battery equipment is not as well suited for *field* military telephone systems as is local-battery. Generally, the common-battery system will give better service where the local traffic is heavy and hence, is used by the army in higher headquarters where a number of subsets are concentrated in a relatively small area. The local-battery system is used where conditions do not permit the use of the common-battery equipment.

6. Questions for self-examination.—

1. Why are dry cells such an expensive source of electrical energy for a telephone system?
2. Give three advantages of a common-battery system over a local-battery system.
3. How does a common-battery subscriber signal the operator?
4. What components are there in a local-battery telephone which are not necessary in a common-battery telephone?
5. Under what conditions has a local-battery system advantages over the common-battery system?

SECTION III
THE COMMON-BATTERY TELEPHONE

Paragraph

7. Components of the common-battery telephone.—It was stated in section II that it is unnecessary to have a hand generator and a battery in a common-battery telephone. The other components of a local-battery subset, namely: receiver, transmitter, induction coil, ringer and hookswitch are all found in a common-battery subset. In addition to these five pieces of equipment, there is one other that is necessary in the common-battery subset, a capacitor. The usual common-battery subset, therefore, contains six component parts. The hookswitch, transmitter, receiver and ringer are identical with those used in the local-battery subset.

8. Common-battery induction coil.—Since the battery supply for talking is from a central source, the transmitter must be in series with the line instead of in an isolated circuit as in a local-battery telephone. The induction coil (an audio-frequency transformer) is used to electrically couple the secondary circuit to the primary circuit. Since the secondary circuit is a local circuit, it is unnecessary to pole the receiver. The resistance of the receiver is also removed from the primary circuit. There are two main types of common-battery induction coils. They are known as the sidetone and antisidetone induction coils. The sidetone induction coil has two windings and a typical example is the Western Electric 46-type coil. The resistance of its L_1–R (primary) winding is 14.7 ohms and the GN–C (secondary) winding is 9.5 ohms. The turn ratio of the primary to the secondary is 17 to 14, or approximately one to one.

a. Antisidetone induction coil.—The antisidetone induction coil has three windings and a typical example is the one used in the Automatic Electric Co., Monophone Type 40 subset. The resistance of its 1-2 (primary) winding is 28 ohms, the 3-4 (secondary) winding is 14 ohms, and 5-6 (tertiary) winding is 65 ohms. The turn ratio between the primary and secondary is approximately the same as in the sidetone induction coil, but this ratio will vary with the different makes depending on the requirements of the circuit in which they are used. The newer types of induction coils, such as the one just discussed, have closed magnetic paths. This gives them a greater degree of efficiency and they can be made more compact.

9. Capacitor.—The common-battery subset requires either one or two capacitors depending on the type of circuit used. The sidetone subset needs only one capacitor which performs two functions. It keeps direct current out of the ringer and also acts in the so-called booster circuit to increase the output of the subset. On the other hand, the antisidetone circuit requires separate capacitors to perform these functions.

10. Common-battery sidetone subset circuit.—The circuit of the common-battery subset may be developed in a logical manner. Battery for talking purposes is fed to the telephone from a central source so it may be assumed that battery is connected in some way to the terminals L_1 and L_2 of the telephone. The primary circuit of the subset, consisting of the transmitter and primary of the induction coil must be connected directly in series with this power source. Figure 1 shows a diagram of this circuit. The receiver is coupled to

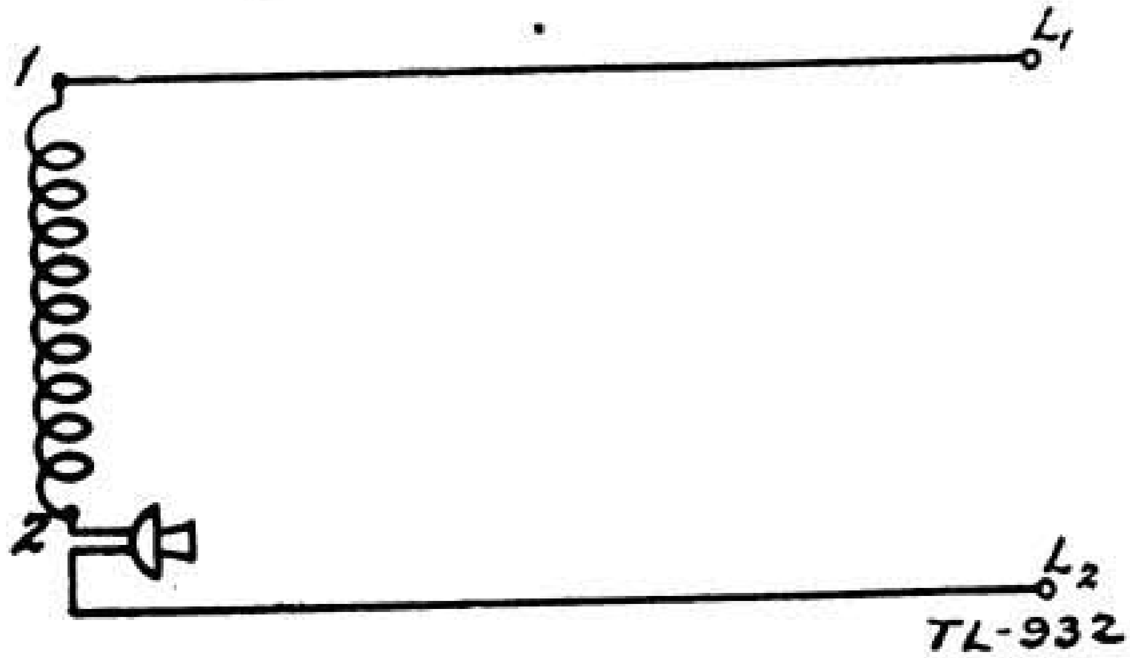

FIGURE 1.—Primary circuit.

the primary circuit by means of the secondary winding of the induction coil as illustrated in figure 2. This circuit is called the secondary circuit. The operation of these two circuits is as follows·

TL-933——

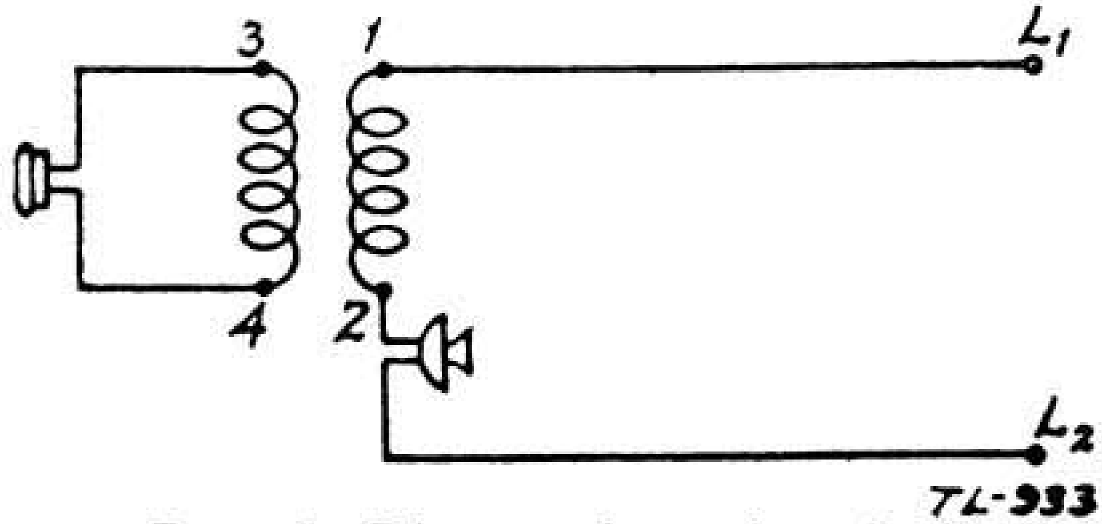

FIGURE 2.—Primary and secondary circuits.

There is direct current flowing in L_1, through the transmitter and out L_2, and the transmitter is able to vary this current by the action of its diaphragm on the carbon granules. This variable current in the primary causes a variable voltage to be induced in the secondary, which causes a corresponding variable current to flow through the receiver, giving an appreciable amount of sidetone. Sidetone may be defined as that sound heard in the receiver due to the sound picked up by the transmitter of the same subset. An incoming signal produced at the distant end of the line passes through the primary of the induction coil, the transmitter and back to its source. This signal, a varying current, induces a voltage in the secondary circuit which causes a current to flow through the receiver where it is changed to an audible sound. Since the operator is signaled in common-battery telephony by completing a path for direct current through the local subset, the necessity for opening hookswitch is inserted in the circuit as shown in figure 3. Since there is no direct current path through the secondary circuit, it is unnecessary to break that circuit.

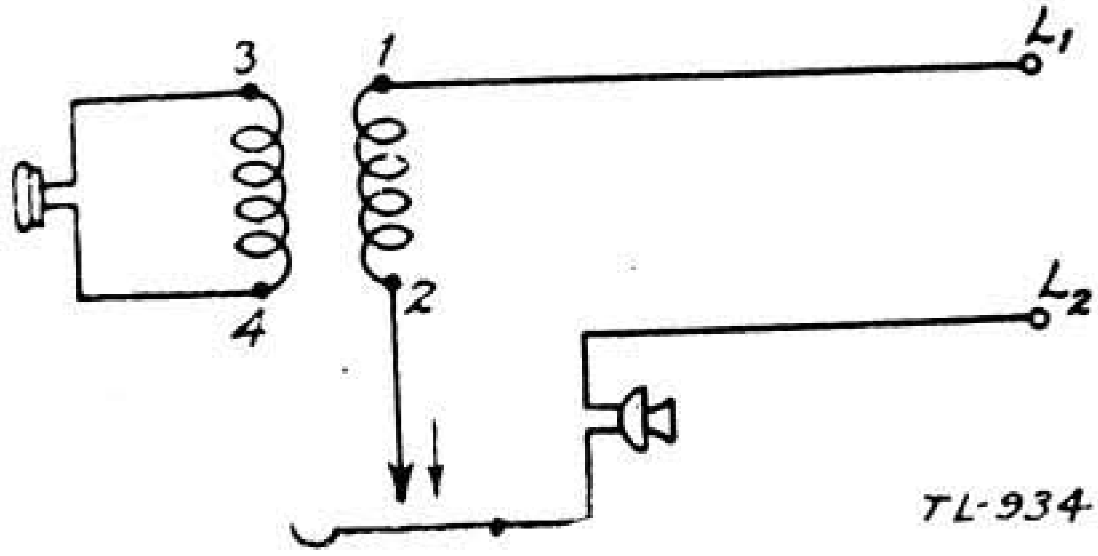

FIGURE 3.—Primary and secondary circuit with hookswitch added.

The local subscriber can now transmit and receive and he can also signal the operator, but the operator cannot signal the subscriber, so a ringer must be added for this purpose. The ringer must be across the line but it must not provide a direct current path. To accomplish this, a capacitor is placed in series with the ringer which allows 20-cycle ringing current to pass but blocks the direct current. Figure 4 illustrates the ringer circuit added to the telephone. This is a complete basic common-battery telephone circuit.

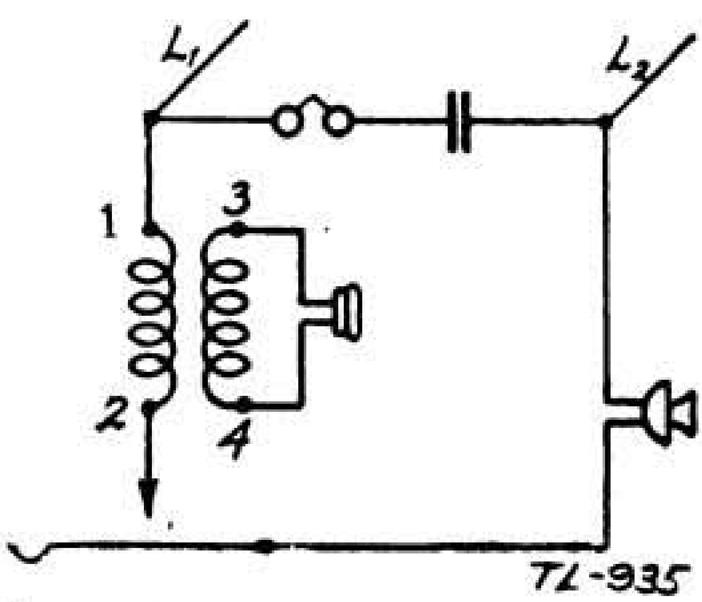

FIGURE 4.—Basic common-battery subset.

11. Booster subset.—Some years ago, the Western Electric Company developed a subset circuit which is a considerable improvement over that shown in figure 4. This circuit is known as the booster circuit and is now used in nearly all common-battery telephones. The same identical parts are used, but the capacitor and transmitter are also included in the receiver circuit. This is done by connecting terminal *3* of the induction coil to the point between

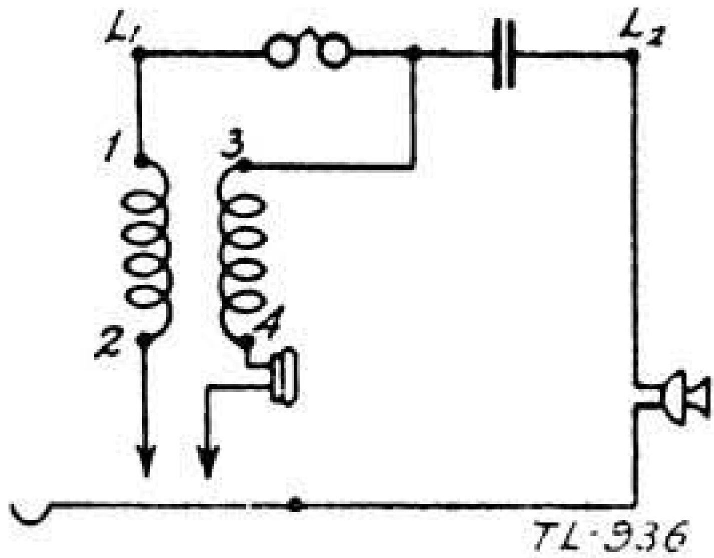

FIGURE 5.—Booster subset.

the ringer and capacitor and bringing one side of the receiver down to a hookswitch contact. Figure 5 shows a diagram of the booster circuit. By comparing figures 4 and 5 it can be seen exactly what changes in wiring are necessary to change from one to the other. With the circuit as shown in figure 5 it is necessary to open the receiver circuit also at the hookswitch, otherwise, there is a complete path for direct current from L_1 to L_2. This circuit is considerably more efficient in transmitting than was the one previously discussed.

12. Explanation of booster circuit.—The student should refer to figure 6 for this explanation. It is identical with figure 5 except

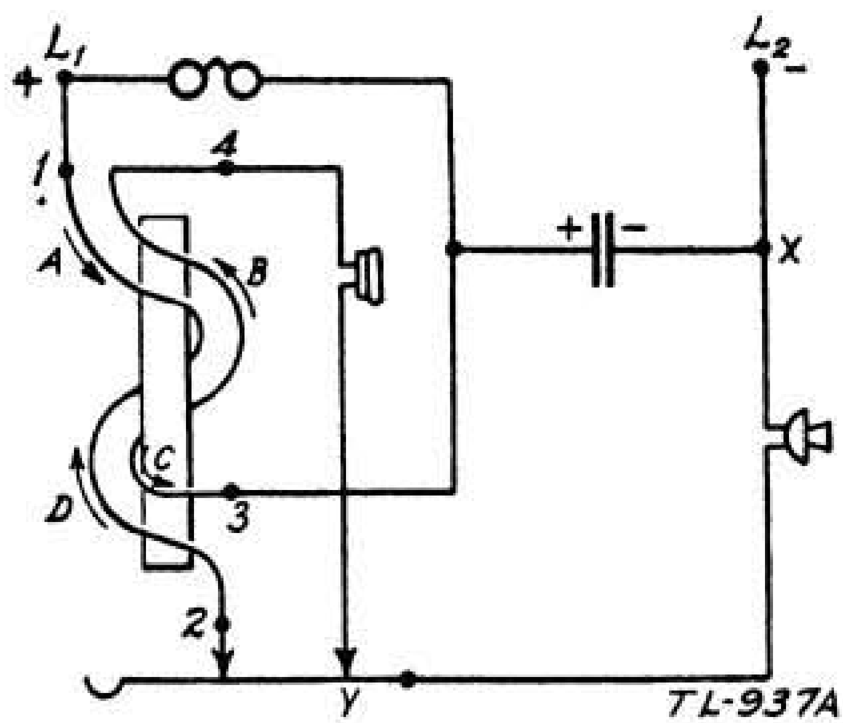

FIGURE 6.—Booster subset equivalent circuit.

that the induction coil windings are shown around the core in the direction they actually are in the coil. This makes it easier to understand how the circuit functions. Assume the transmitter is at rest. It has a certain normal resistance and direct current is flowing from the source, over the positive side of the line L_1, through *1-2* winding of the coil in direction of arrow *A*, hookswitch contact, transmitter, L_2, and back to source. Between the points *x* and *y* there is a certain voltage, the *IR* drop across the transmitter. The apacitor is charged by this same voltage with polarity as shown n the diagram

Now suppose some one speaks into the transmitter in such a way as to lower the resistance. This reduces the voltage between the points *x* and *y*, and demands an increase in the line current. This means that the capacitor can no longer hold its entire charge, so a discharge will take place from the positive side of the capacitor, through the *3-4* winding, receiver and transmitter to the negative side of the capacitor. The direction of this discharge is through the *3-4* winding as indicated by arrow *B*. This flow of current in the *3-4* winding in the direction of *B* will induce an electromotive force in the *1-2* winding in the direction of arrow *A*. Thus, the direction of this induced electromotive force in the *1-2* winding is such as to aid the transmitter at this instant in increasing the current in the line.

The next instant the resistance of the transmitter will increase. Thus the voltage between *x* and *y* increases and the line current must decrease. As the voltage between *x* and *y* has increased, current will flow to the positive side of the capacitor from *y*, charging the capacitor until the voltage across it equals that between *x* and *y*. This pulse of current is in the direction of arrow *C* through the *3-4* winding, inducing an electromotive force in the direction of arrow *D* in the *1-2* winding. Thus the induced electromotive force now aids the transmitter in reducing the line current. It will be seen that the current changes taking place in the telephone line are of much greater range than without the booster hook-up. The charge and discharge of the capacitor is made to aid the transmitter in changing the line current.

In receiving, the action of the circuit is simpler than for transmitting. As the resistance of the transmitter does not change, there is no charge and discharge of the capacitor. Assume an impulse coming in over L_1. It flows down through the *1-2* winding inducing an impulse upward in the *3-4* winding. This induced impulse flows around the receiver circuit, through the receiver, transmitter and capacitor, and produces the sound waves heard at the receiver. When the original impulse of current reaches the hookswitch, it finds a choice of two paths; one through the transmitter to L_2 and out, the other through the receiver, *3-4* winding, and capacitor to L_2. The impulse will divide in inverse ratio to the impedance of these two paths, much the larger part going through the transmitter. The portion which flows through the *3-4* winding is in the opposite direction to the induced impulse, weakening it to some slight extent. However, the gain in transmitting much more than offsets the loss in receiving.

13. Sidetone-reduction circuit.—Under certain conditions, such as noisy surroundings, it may become desirable to eliminate all possible sidetone. In modern telephones this is done by using an antisidetone circuit which bypasses the receiver with a balancing network without impairing the transmitting efficiency of the telephone. In the older types of telephones the reduction in sidetone is accomplished by neutralizing the booster circuit which reduces the transmission output of the telephone. The resulting circuit is known as the sidetone-reduction circuit. In this circuit the transmitter is shifted to a different location in the circuit as is shown in figure 7. This shift in the location of the transmitter reduces the sidetone but it completely destroys any action by the booster circuit. By inspection it may be seen that the capacitor is no longer in multiple with the transmitter and consequently it is no longer subject to a varying voltage.

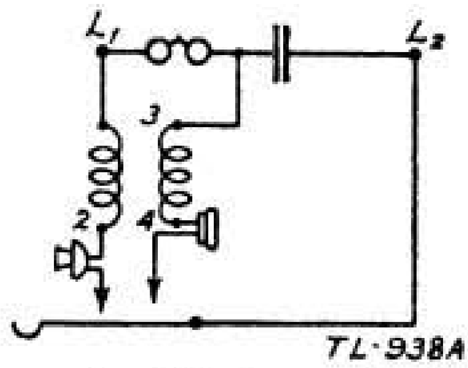

FIGURE 7.—Sidetone reduction circuit.

14. Combined hand telephone set TP–6.—*a.* Since the utilization of common-battery telephone systems in the higher units of the army, the Signal Corps has accepted as standard the type known commercially as the "combined hand telephone set." This telephone is known as the TP–6 and includes sets made by various manufacturers as follows:

Automatic Electric 40–AA–52
Western Electric 302–AW–3
Stromberg-Carlson 1212–ABZ
Kellogg 925 BA
North Electric 2–H4–SL–S

All working parts in these sets are combined in the handset and stand, thereby eliminating the use of a separate bell box. The mounting contains the switchhook, ringer, induction coil, and condensers. The specific design and method of connecting the parts into the telephone circuit varies with each manufacturer, therefore, several will be covered separately in this paragraph.

The handset is of the conventional type, consisting of a receiver of the watch case design and a non-positional transmitter, both of which are mounted in a plastic handle so shaped that when the receiver is held to the ear, the mouthpiece falls into the natural talking position. Due to the close mechanical coupling between receiver and transmitter, an antisidetone circuit is utilized to prevent howling. This circuit also allows an effective receiving gain by partially eliminating the local noises from the receiver; as side-tone is reduced, the user, hearing his own voice only faintly, tends to speak louder, thus also providing an effective transmission gain. A description of the sets follows:

b. Automatic Electric Co. Type "40–AA–52 Monophone."—The diagram below shows the fundamental circuit arrangement of the A.E. combined set and will be used for explanation.

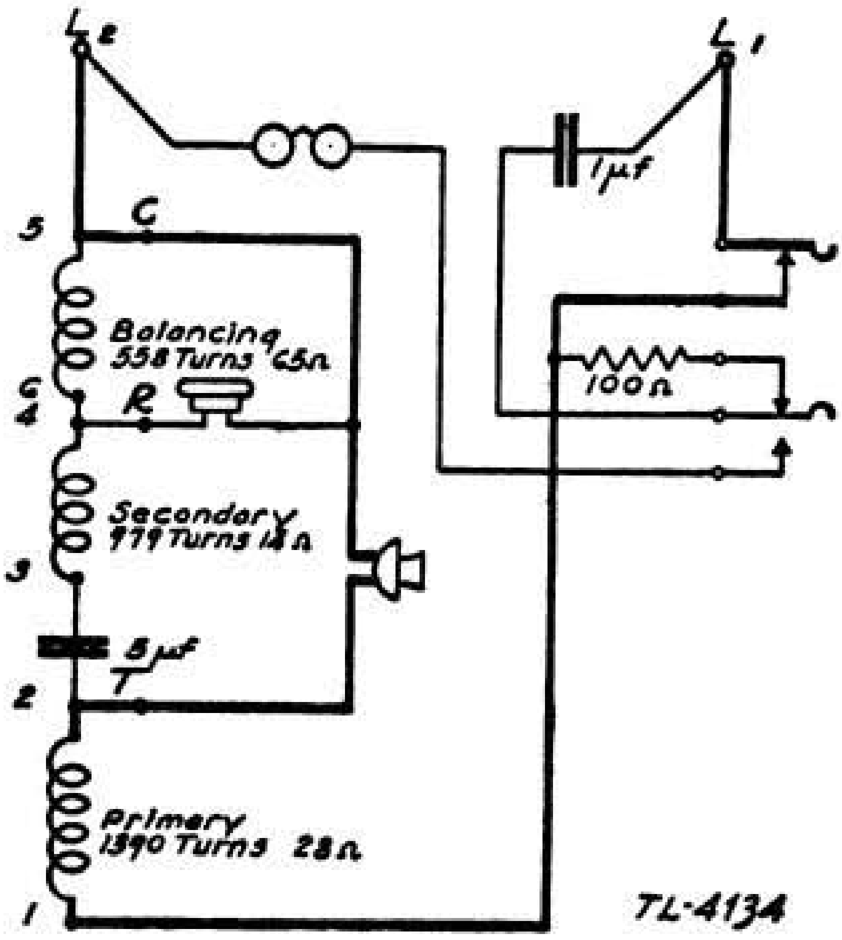

FIGURE 8.—Simplified circuit diagram of the Automatic Electric Co. Type 40–AA–52 Monophone.

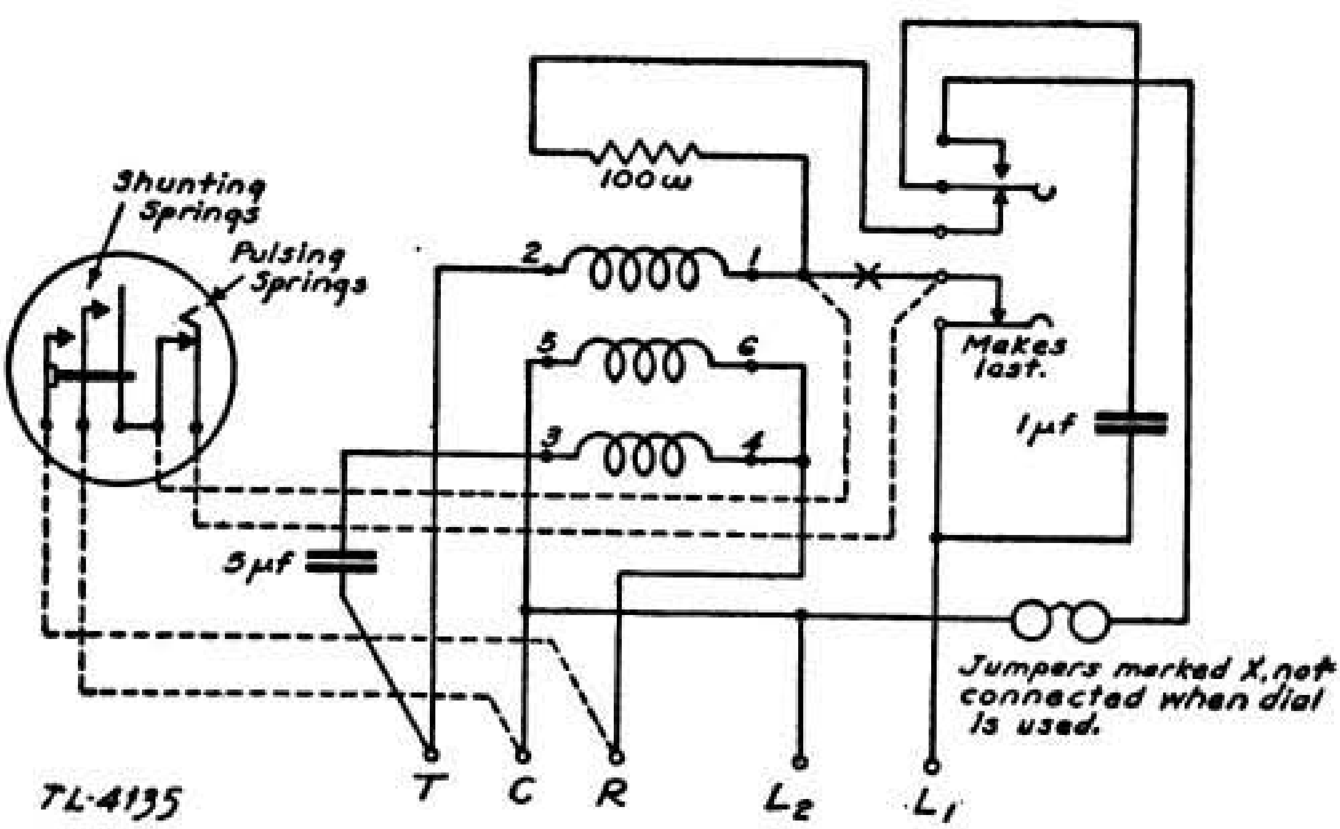

FIGURE 9.—Circuit diagram of the Automatic Electric Co. Type 40-AA-52 Monophone.

Figure 8 is a simplified diagram broken down so that the circuits can more easily be followed, while figure 9 is the conventional schematic diagram showing the various parts in their electrical and mechanical relationship.

The apparatus contained in the mounting functions as follows:

5-μf. condenser.—Part of the booster circuit to increase transmission output.

1-μf. condenser.—Keeps direct current from flowing through ringer. It also acts with the 100-ohm resistor as an arc suppressor across contact *X* and across the dial contacts when the dial is used.

Hookswitch.—Breaks the primary circuit and closes the ringer circuit when the handset is placed on its cradle.

100-ohm resistor.—Dissipates energy from the arc surge when the hookswitch contact is opened, or when a number is dialed.

Induction coil—1-2 winding.—This is the primary winding and is in series with the transmitter and line. It has 28 ohms resistance.

3-4 winding.—This is the secondary winding and has a resistance of 14 ohms. With the 5-μf. capacitor, transmitter and receiver, it forms the secondary or receiving circuit.

5-6 winding.—This is the tertiary or balancing winding and in this case is bridged directly across the receiver.

Ringer.—The ringer circuit, composed of the ringer and the 1-μf. capacitor, is completed through the hookswitch. This is done so that when the telephone is in use, the ringer is removed from across the line; also when used on dial systems, the bell cannot be activated while dialing.

The antisidetone feature is provided by the *5-6* section of the coil. The voltage induced in this coil section on transmission is opposite and equal to the *IR* drop in the coil and consequently the resultant voltage drop between terminals *C* and *R* is zero and no current will flow through the receiver. When receiving, the voltage induced in the *5-6* section of the coil is in the opposite direction and equal to the applied voltage on this coil, and consequently no current will flow through this coil, but it will all follow the alternate path through the receiver.

The dotted lines in the diagram show the circuit when the dial is used. In this case the jumper marked with an *X* is removed.

c. Western Electric Co. 302 Set.—It will be noted from the following diagram of the Western Electric 302 set that it has, with very few exceptions, the same circuit as the Automatic Electric Type 40 Monophone.

There are four major differences between this circuit and the A.E. Co. circuit:

(1) The ringer is not connected through the hookswitch, therefore, it remains across the line continuously.

(2) There is no separate resistance to absorb the arc across the hookswitch contacts. However, when there is excessive arcing across the pulsing contacts of the dial, a filter, consisting of resist-

ance and capacity may be connected into the circuit to absorb the arc.

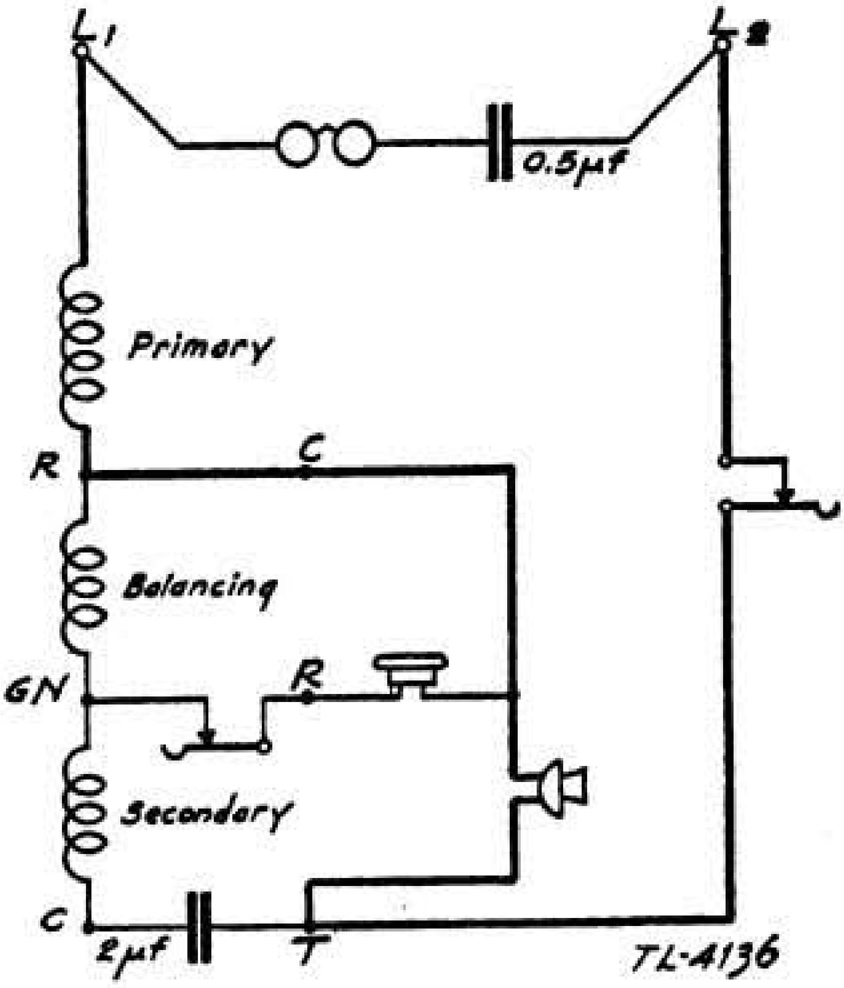

FIGURE 10.—Simplified circuit diagram of the Western Electric Co. No. 302 Set.

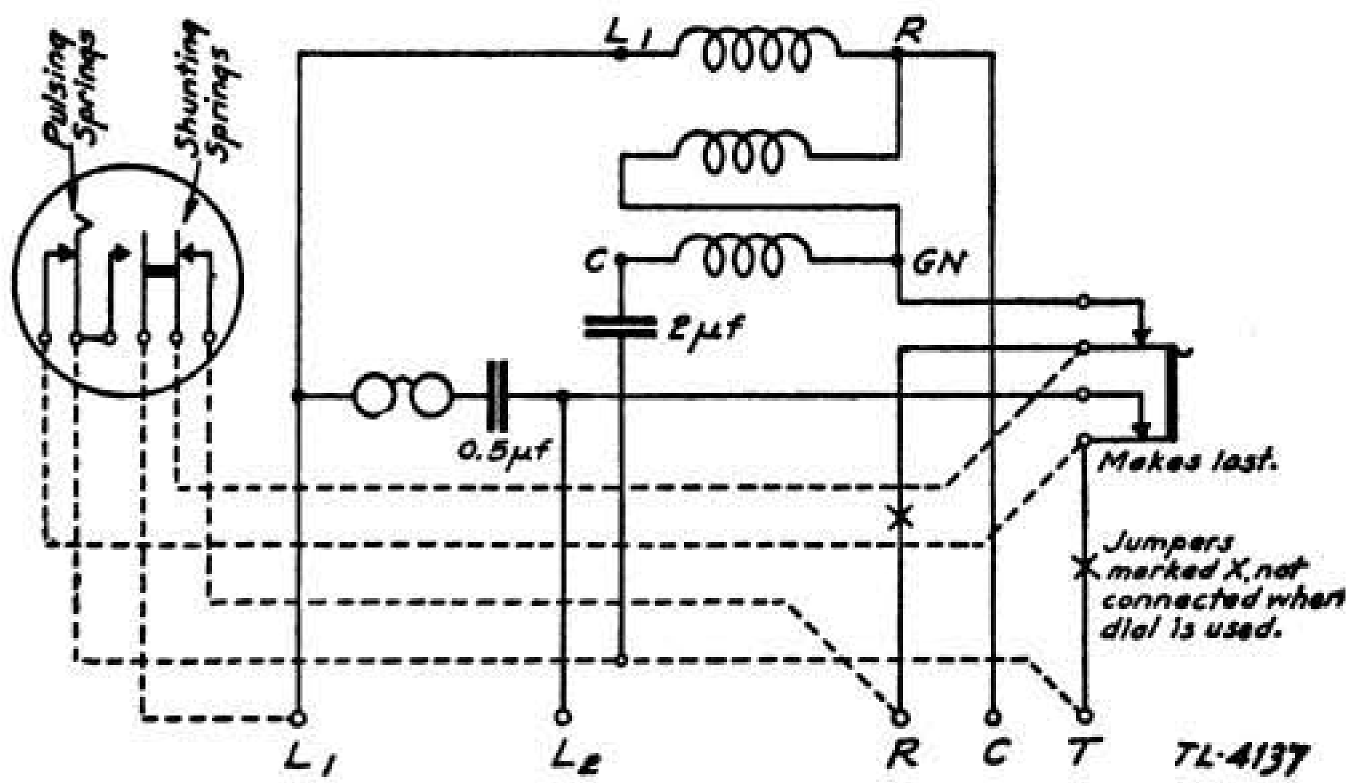

FIGURE 11.—Circuit diagram of the Western Electric Co. No. 302 Set.

(3) When the dial is used, the receiver circuit is opened during the dialing period instead of being shunted as in the A.E. set.

(4) By referring to the simplified schematic diagram figure 10 it will be noticed that the arrangement of the windings of the coil is different, but the way in which the balancing winding operates is exactly the same as was explained above under the Automatic Electric Co. telephone. Other than differences in design peculiar to the two manufacturers, the two telephones are, with the above exceptions, alike.

d. Kellogg Co. "Masterphone."—This telephone utilizes a different type circuit to suppress sidetone. The K. S. & S. Co. call it a Triad circuit.

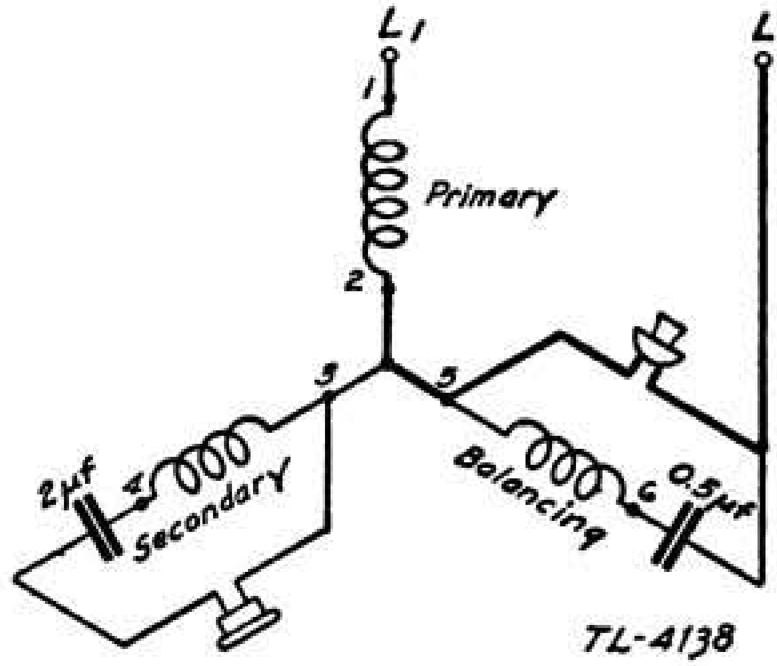

FIGURE 12.—Simplified circuit diagram of the Kellogg Co. "Masterphone."

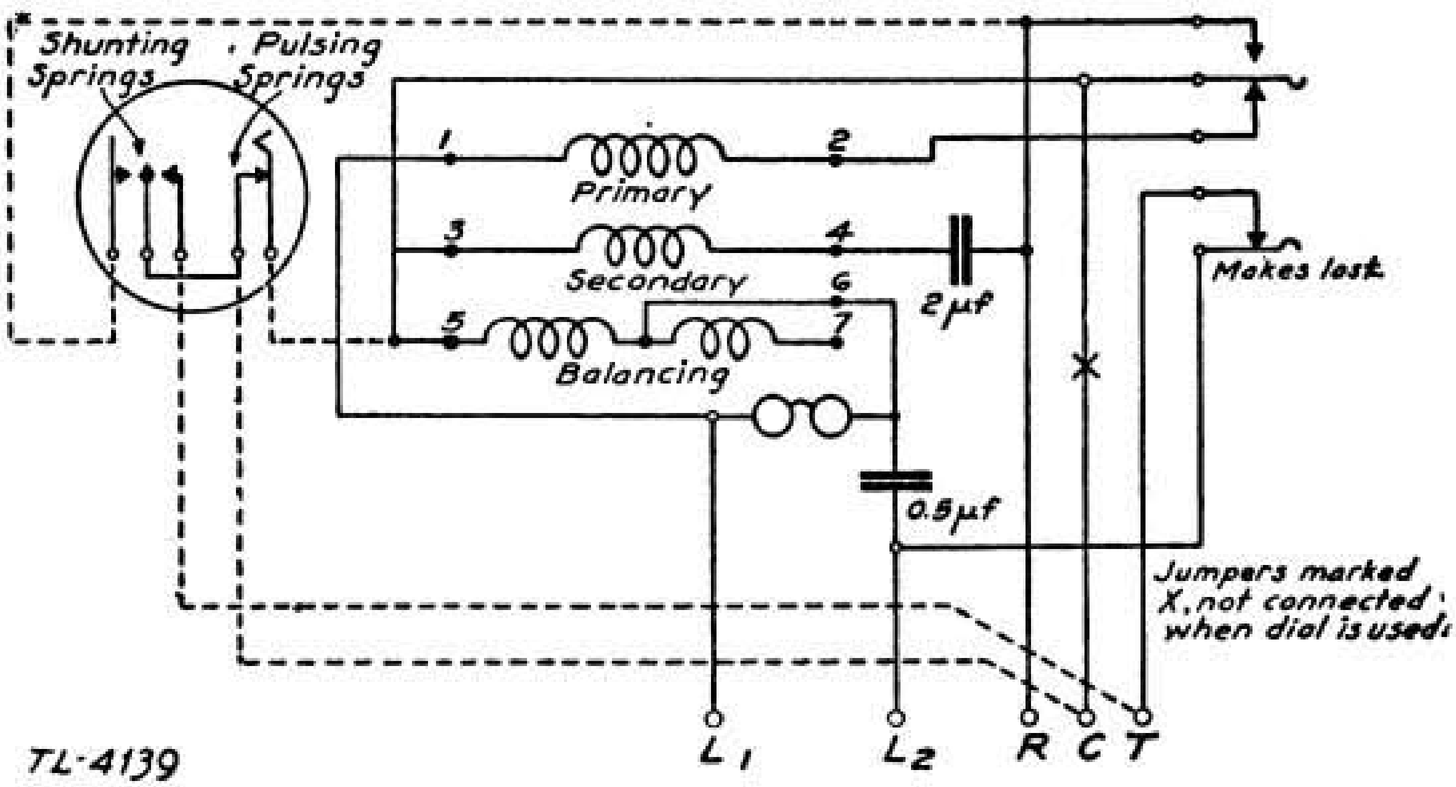

FIGURE 13.—Circuit diagram of the Kellogg Co. "Masterphone."

The 0.5-µf. condenser prevents the flow of direct current through the ringer, suppresses the arc across the pulsing contacts of the dial, when it is used on dial systems, and acts in the booster circuit to increase the transmission efficiency of the telephone.

The coil windings function as follows: *1-2* section is the primary winding; the *3-4* section is the secondary winding; and the *5-6* section is the balancing and booster winding.

In the following discussion refer to figure 12. The antisidetone circuit of this telephone is different from those previously discussed. When transmitting, we will assume that the transmitter diaphragm has just been depressed. A current increase will take place flowing from *1* to *2* in the *1-2* section of the coil, and the 0.5-µf. condenser will discharge, causing a current to flow from *6* to *5* through the *5-6* section of the coil. The voltages induced by these currents in the *3-4* section of the coil are opposite and cancel each other and as a result no current will flow in the receiver.

When receiving, it will be assumed that the instantaneous current flow will be from *1* to *2* in the *1-2* section of the coil. This current will induce a voltage in the *6* to *5* direction in the *5-6* section of the coil. This voltage is equal to the *IR* drop across the transmitter, consequently there is no voltage difference between the two sides of the 0.5-μf. condenser and no current will flow through the *5-6* section of the coil. As a result, the only voltage induced in the *3-4* section of the coil is that from the current in the *1-2* section and a strong current will flow through the receiver.

e. Stromberg-Carlson telephone 1212 ABZ.—The diagrams below show the circuit arrangement of this telephone, and by referring to them through the following discussion a better understanding will be obtained.

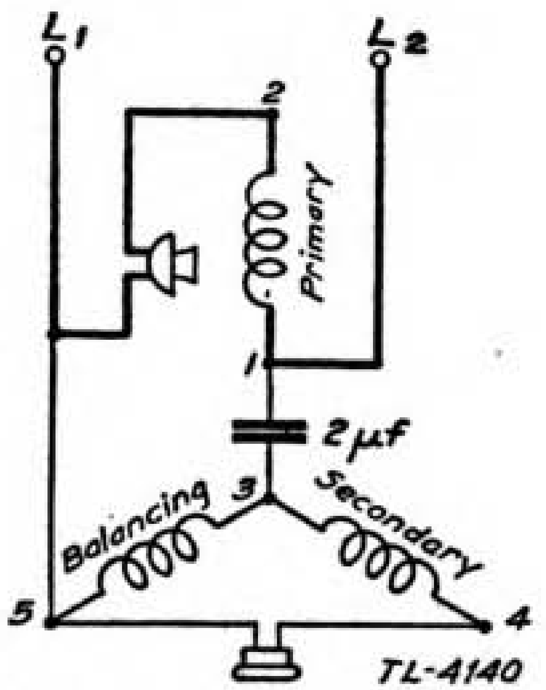

FIGURE 14.—Simplified circuit diagram of the Stromberg-Carlson telephone 1212 ABZ.

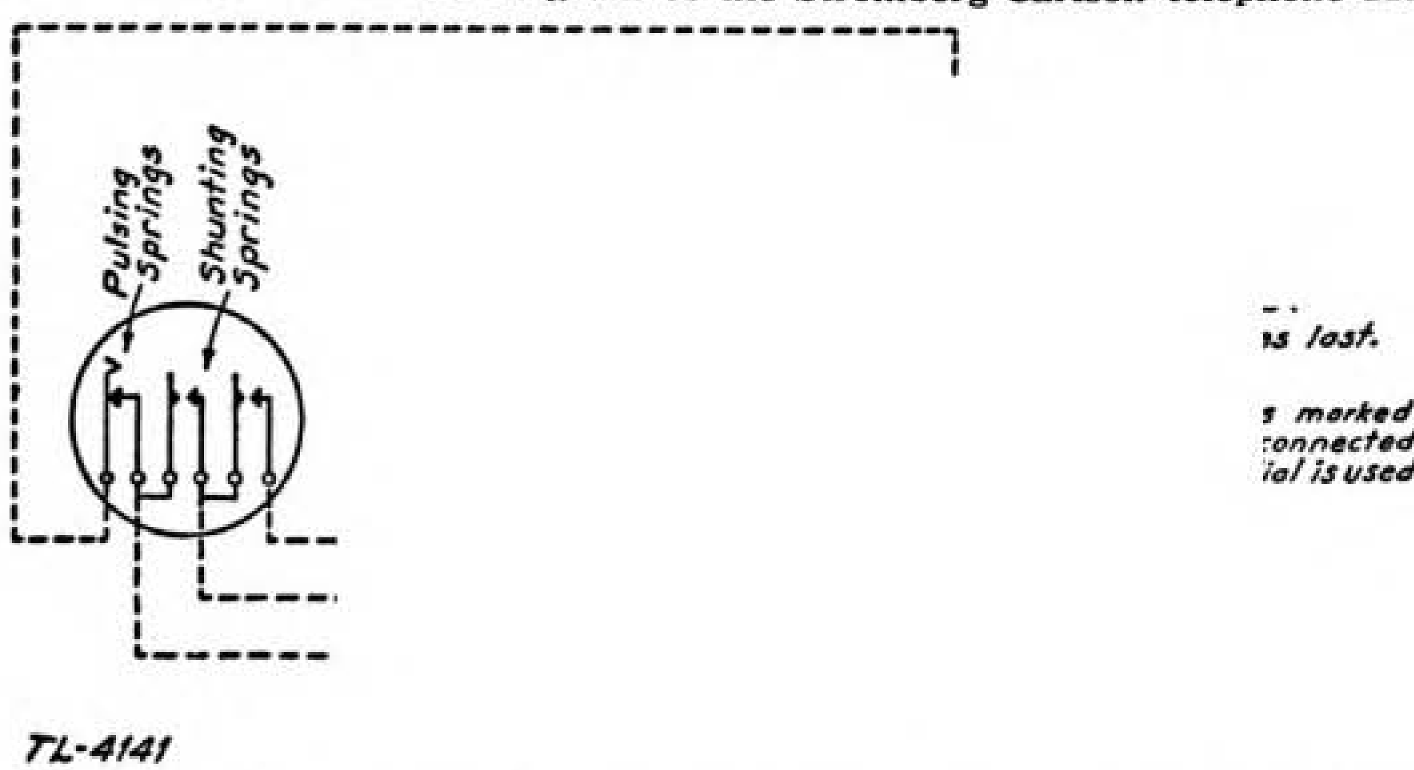

FIGURE 15.—Circuit diagram of the Stromberg-Carlson telephone 1212 ABZ.

The 1-μf. condenser serves merely to keep direct current from flowing through the ringer.

The 2-μf. condenser acts in the booster circuit and keeps the direct current out of the receiver.

The three windings of the coil function as follows: *1-2* is the primary winding, *3-4* is the secondary winding, and the *3-5* winding is the balancing winding for the antisidetone circuit.

Refer to figure 14. It will be seen that on transmission, when the resistance of the transmitter drops, current will increase in the *1-2* winding. Assume that this increase is in the *2* to *1* direction. At the same time the condenser discharges through the *3-5* winding in the direction *3* to *5*. These currents will induce a voltage in the *4* to *3* direction in the *3-4* winding. This voltage is equal and opposite to the *IR* drop across the *3-5* winding and as a result there is no voltage difference between terminals *4* and *5* of the coil and no current will flow through the receiver. When receiving, assume an instantaneous applied voltage which will cause a current to flow from *1* to *2* through the *1-2* winding. This current will induce a voltage in the *5* to *3* direction in the *3-5* winding and in the *3* to *4* direction in the *3-4* winding. In this case the two voltages are additive and cause a large current to flow through the receiver.

15. Types of common-battery telephones.—Common-battery telephones are made in four types: the wall, the desk stand, the hand-set, and the combined set. The wall type is a unit including all the parts except transmitter and receiver in one box. Desk stands are in two units; the bell box housing the ringer, induction coil and capacitor, and the desk stand containing the transmitter, the hookswitch and support for the receiver. Hand-sets are in three units: the bell box housing the ringer, induction coil and capacitor; the hand-set mounting containing the hookswitch; and the hand-set consisting of the transmitter and receiver. Combined sets are in two units; the base housing the ringer, induction coil, capacitors and switch, and the hand-set consisting of the transmitter and receiver.

16. Questions for self-examination.—

1. Name the component parts of a common-battery subset.
2. Does the receiver differ in any respect from the one used in a local-battery subset?
3. Is the receiver connected so that current from the central office battery flows through it? Why?
4. Does the transmitter differ in any respect from the one used in a local-battery subset?
5. From what source is the talking current obtained?
6. Why is an induction coil used in a common-battery subset?
7. How does this coil differ from the one used in a local-battery subset?

8. What is the turn ratio between the primary and secondary of the coil?

9. Would it be possible to use a common-battery subset in which the receiver and transmitter were connected in series with the line, using no induction coil? Why?

10. Why is a capacitor placed in series with the ringer in a common-battery subset?

11. What is meant by a "booster" circuit?

12. Is this circuit widely used?

13. Explain the booster action.

14. Is the transmission efficiency increased or decreased by use of the booster type of circuit? Why?

15. Is the receiving efficiency increased or decreased by the use use of the booster type of circuit? Why?

16. What is meant by "sidetone?"

17. Draw a diagram of talking circuit using a receiver, transmitter, and induction coil. Show the battery hooked across the line.

18. When no one is talking, what kind of current is flowing in the primary winding? In the secondary winding?

19. Assume one party talking; what kind of current is flowing in the primary winding? In the secondary winding?

20. What is the Signal Corps type number of the common-battery subset adopted by the Signal Corps?

21 What is the difference between the antisidetone and the sidetone reduction circuits?

22. What is meant by antisidetone circuit?

23. Does the antisidetone circuit effect the efficiency of the subset on transmission? On reception?

24. Is it necessary to have a hand generator in a common-battery subset?

25. What are the four types of common-battery telephones in general use?

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SECTION IV
SUBSCRIBER LOOPS

17. Definition.—The pair of conductors carrying the voice currents from the protectors at the central office is known as the subscriber loop. This loop may consist of drop wire, open wire, or cable pairs, each of different size wire and different type construction.

18. Station protectors.—*a. Air-gap protectors.*—In a discussion of subscribers loops, the first thing to be considered is the station protector. This usually consists of two 7-ampere fuses (will pass 7 amperes and blow out at 10½ amperes) in series with the line and a pair of carbon-block air-gap protectors to ground on the station side of the fuses. The air-gap protectors consist of two carbon blocks separated by approximately .003 inch. One of the two carbon blocks is connected to ground and the other one to the other conductor. A pair of blocks is used between each conductor and ground. These blocks then provide protection against high voltage to ground, such as lightning, which will arc across the gap. This arcing, however, will cause carbon dust to collect in the gap and this may cause trouble necessitating cleaning the gaps.

b. Fuses.—The fuses are of the long enclosed tubular type and are always located toward the exposed section of the line from the air-gap protector blocks so that if the exposure to a high voltage, which arcs across the air-gap protector, is prolonged the fuses will open the circuit should the current become excessive. One of the reasons for the fuses being rated at 7 amperes is because most constant-current series street-lighting circuits are automatically regulated to maintain their currents at 6.6 amperes. When a break occurs in such a circuit, the regulation causes the voltage to rise to high values in an attempt to maintain the current at this constant value. Should such a circuit be closed through the exposed line and fuse burn out the automatic regulation would build the voltage up to such a value as to maintain an arc across the gap. This would be a serious fire hazard. If the drop wire is very long, air-gap protectors may also be attached to the line at the cable terminal, otherwise the protection will be placed only at the station end of the drop wire.

19. Drop wire.—Connection must be made from the station protector to the cable or open wire line connected with the office. Leaving the open wire until a later discussion, it will be assumed that there is available a cable connected with the office. From the station protector the drop wire is run to a convenient cable pole. This drop wire consists of two copper conductors insulated from each other. A common type of drop wire has the conductors parallel to each other and a protective braid around the pair. Other types are twisted with individual braid over the insulation of each wire. The drop wire with its protective covering is designed to withstand exposure to the weather, and have good tensile strength as well as good conductivity.

20. Cable distribution.—At intervals along the cable there will be located cable terminal boxes. These terminals contain 10, 16, 26, or more pairs which are spliced into the cable in multiple with certain pairs in the cable. One pair in the cable may have connections brought out in several terminals. Another pair may have connections brought out in some of the same terminals that the first pair used and in addition some other terminals not used by the first pair. Each pair in a cable is numbered and a record is kept, and sometimes marked on the terminal. One terminal may have pairs 50 to 59 brought out in it while a second terminal may carry numbers 53 to 62 and a third 56 to 71, etc.

a. This plan is used for several reasons. It is impossible to tell in advance over a period of years how many telephone circuits are going to be required in the neighborhood of one terminal as compared with another terminal. Thus, a pair which might be idle if brought out to only one terminal, could readily be used if brought out in a second terminal also. This provides for greater flexibility.

21. Composition of cable.—The cables themselves may be made up of several diffierent size copper conductors, 19, 22, and 24 gage being the most common with 16 and 26 being used in some cases. There may be as many as 1818 or more pairs in a cable. These may be separated into groups of a hundred with all groups bound within the same sheath, or the pairs may be placed in layers from the center out with each layer twisting about the core in different directions. Some cables have each conductor wrapped in paper tape while others, particularly those using the smaller conductors, have the paper pulp molded on the wire. In each pair the conductors are twisted together after the insulation has been placed on the wires.

22. Open wire loops.—Occasionally, the subscriber loop will include a section of open wire construction. Here the drop wire is connected to a pair of open wires, the other end of which may connect into a cable with air gap protector blocks on the circuit at that point. The drop wire may, of course, be connected to the open wire at any pole. The open wire, usually bare and tied to glass insulators mounted on poles, may be of several sizes. Generally iron wire is used in subscriber loops, due to lower cost as compared to copper, having diameters of .083, .109, and .134 inch. Occasionally copper wire is used in which case .080 and .104 inch wire are most common. The larger the conductor, the less will be the loss through it, though the cost will be higher. Copper wire, of course, costs more than the iron but has much less loss.

23. Questions for self-examination.—

1. What is meant by a "subscriber loop"?
2. Of what does the station protector usually consist?
3. Of what are the air-gap protectors composed?
4. What is the function of the air-gap protector?
5. How much current will the station protector fuses pass without blowing out?
6. Since the telephone voice currents are so very small why not use fuses rated at one ampere instead of higher rating?
7. For what is drop wire used?
8. When are protectors placed at both ends of the drop wire?
9. Why are cable pairs brought out to more than one terminal?
10. What gages of wire are most common in cables?
11. What methods are employed in insulating the wires of a pair in a cable?
12. Where are protectors located when open wire is used in the subscriber loop?
13. What sizes of wire are most common in open wire subscriber loop construction?
14. Compare advantages and disadvantages of copper and iron wire.

SECTION V
TELEPHONE RELAYS

24. Definition.—In the simplest telephone systems all switching is done by the operator. As the telephone system becomes more complex the switching needs, as well as other requirements, make the use of relays necessary. Relays are electrically operated switches or keys and are widely used in the telephone plant.

25. Application.—There are several thousand types of relays which are 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, the order in which they operate, speed of operation, and current values required for operation. They may be used in control, signalling, supervision, or switching operations. The individual applications are as numerous as are the types of relays manufactured.

26. Construction.—*a. Characteristics.*—The different relays used in the telephone plant vary widely in design and characteristics according to the requirements of the circuit in which they are used. Some relays must operate quickly when energized and remain operated for some time after the circuit has been opened. Others operate slowly and release quickly. The combinations of springs and contacts are practically unlimited. The more precisely timed relays used in dial telephone systems will not be covered in this section. All relays treated in this section consist of an electromagnet, a moveable armature, and a spring and contact assembly.

b. Relay core.—The cores of relays are generally made of some material such as magnetic iron, silicon steel, or permalloy, that will become magnetized when a current passes throught the winding of relay yet will lose its magnetism rapidly when the current ceases to flow. The core must also be strong enough to function as a part of the frame of the relay and withstand the winding operation. Certain types of relays have laminated cores to increase the impedance of the relay windings to voice currents. These relays may be bridged across the talking circuit without greatly increasing the transmission loss. The shape of the relay core, in most cases, is a compromise between production cost and operating efficiency.

c. Armatures.—The magnetic path of any relay will be so constructed as to provide a low reluctance path for the operating flux but will have some arrangement to prevent the armature from actually touching the core and so completing a path through magnetic material for the operating flux. This consideration is important as it allows the rapid demagnetization of the relay when the current in the winding ceases to flow. This gap may be established by a small disk of non-magnetic material, referred to as "non-freezing disk", attached to either the core or armature, or may be adjusted by means of a residual screw in either the core or the armature. The travel of the armature depends upon several factors. A relay for use in a circuit where large currents are available to operate it can have a large unoperated gap and is not likely to be affected by small extraneous currents; a relay that must operate on small currents must have a small unoperated gap and so can not move springs a great distance.

d. Windings.—The winding is applied in evenly wound layers separated by a layer of thin insulating paper that keeps the winding even and so uses the available space more efficiently and also allows the use of less insulation on the wire, as the voltage drop across adjacent turns in the coil will be small. The insulation is usually enamel occupying very little space and is impervious to moisture. It will also stand up under higher temperatures without charring than will silk or cotton when overloaded. The winding or windings of a relay are arranged to meet the requirements of the circuit in which it is designed to operate (fig. 16). Many relays are wound with one of the windings noninductive. This winding is generally wound with half of the turns wound in one direction and the other half wound in the other direction. These relays are used in circuits where voice currents are present. The resistance of the noninductive winding is great enough to cause most of the direct current to pass through the operating winding while the high impedance of the operating winding to voice currents causes them to be bypassed through the noninductive winding. The relay may be wound with two separate coils, or concentrically with one coil wound on the top

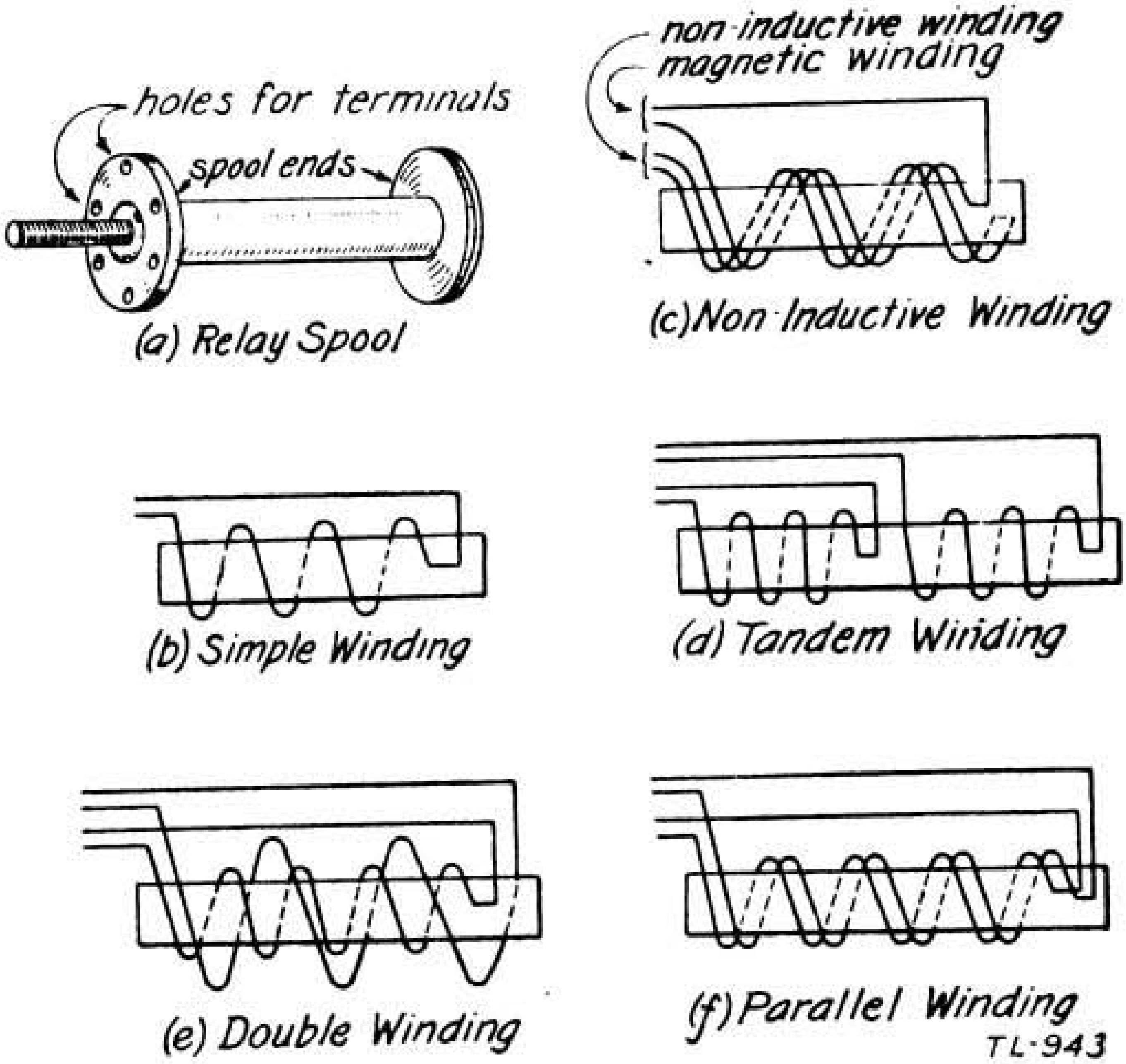

FIGURE 16.—Relay windings.

of the other, or with the two wires being wound on the core at the same time, but the important thing that should be kept in mind is that the same number of ampere-turns are required to operate a given relay regardless of the voltage available. It may be wound with a few turns of large wire to handle large currents or a great many turns of fine wire to operate from small currents.

e. Contacts.—When the armature of a relay moves from the unoperated to the operated position, contact springs are moved so as to open or close one or more circuits. The combinations of springs in a relay are practically unlimited. The only limit to the complexity of the combination lies in the power available to move the armature and so move the moveable contact springs. In relays having flexible contact springs the springs are constructed, and should be adjusted, so that the movement of the armature that causes the contacts to close is continued for a short distance. This continued movement of the contacts after they are closed causes a wiping action between the contacts which tend to make the contacts self-cleaning. In certain new types of relays the springs are split. This splitting of the springs and placing a contact on each half enables the contacts to function normally even if one of the pairs of contacts gets dirty. This reduces the chance of trouble due to dirty contacts to about one-fourth. Some of the simpler arrangements of contacts and their symbols are shown in figure 17.

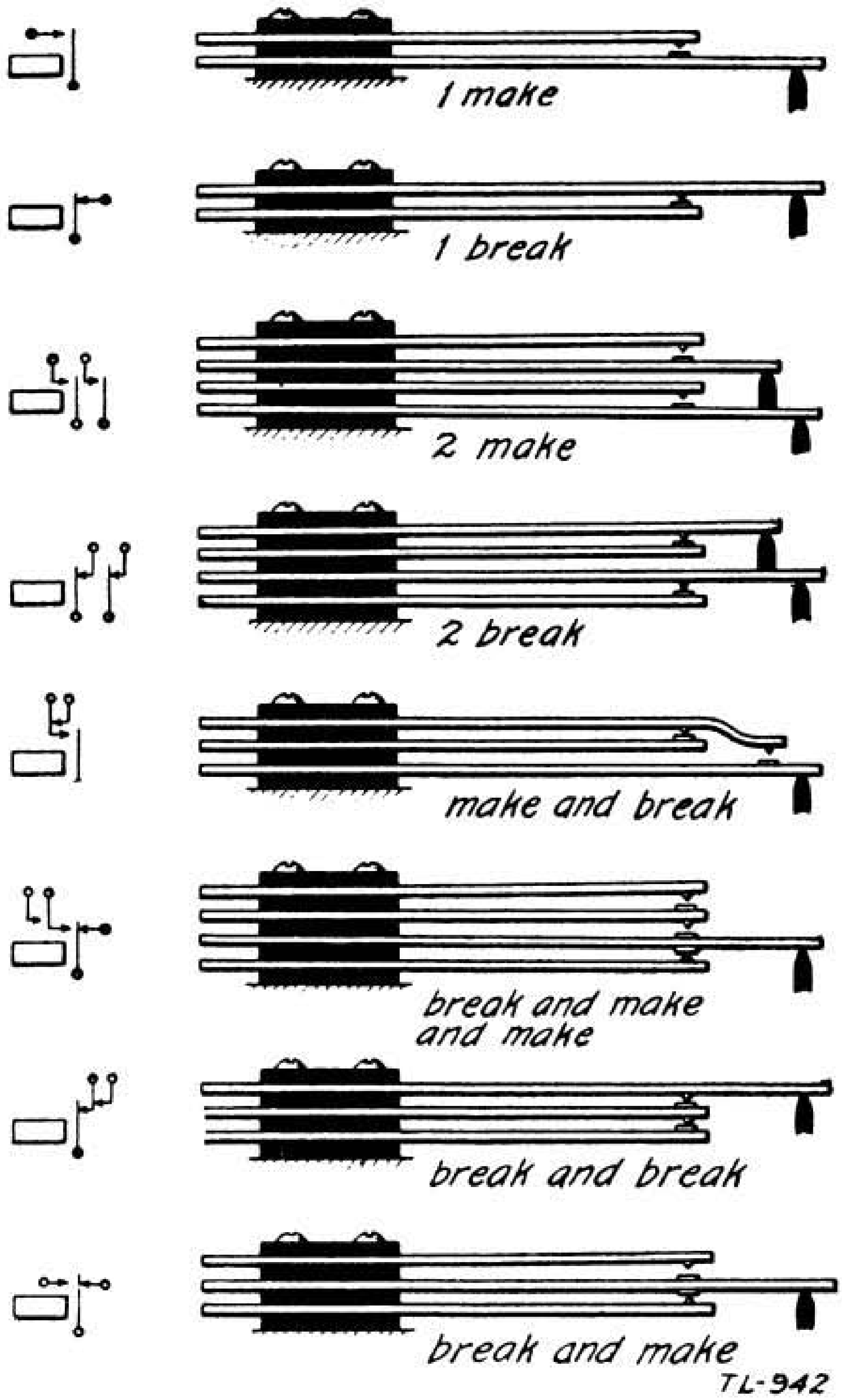

FIGURE 17.—Relay contacts.

f. Relay covers.—The covers of relays normally serve only to protect the relay from dirt and mechanical injury. Most relay covers are made of non-magnetic material so that they do not affect the operation of the relay, and may cover one or more relays. Relays having their windings in a talking circuit, and sensitive relays, have covers made of heavier magnetic material to shield the relay from stray magnetic fields. Because the magnetic force operating a relay may be affected by the shield of magnetic material, relays having covers that act as shields must be adjusted with the covers in place.

27. Marginal relays.—In referring to relays according to their manner of operation there are many different types. One of the most common is the marginal relay. For marginal operation, it is necessary to know both the operate, the nonoperate, and the release values of the relay current and to take advantage of them in arranging the circuit. A marginal relay will pull up when the current reaches a certain "operate" value, and will fall back and remain non-operated as soon as the current falls off to a certain "release" value, less than the operating value. It will not operate on the "nonoperate" value of current.

28. Polarized relays.—Relays designed to operate on current in one direction and remain non-operated on current in the opposite direction are called polarized relays. Polarized relays usually have a permanent magnet which exerts a force upon the armature. This permanent magnet is either aided (for operated relay) or opposed (for the nonoperated position) by the flux set up by the operating windings of the relay, depending upon the direction of the current through the winding. In some relays the permanent magnet is replaced by another winding acting in its place.

29. Slow acting relays.—Some circuits require a relay to be slow to operate, slow to release, or both. Usually these relays are used to obtain a certain sequence of operation in the circuit or to obtain a time interval in the circuit operation. This may be accomplished by proper adjustment of spring tensions, contact arrangements, air gap, or current in the relay windings. Another method is to use a very thick copper sleeve or slug around the core to act as a short-circuited one-turn winding. This is used extensively to make a relay slow acting. Generally the sleeve is placed on the armature end of the relay to make it slow to operate and on the heel end to make it slow to release. However, a relay using a sleeve for making it slow to operate will also be slow to release. Figures 18 and 19 show views of slow operating and slow releasing relays. When slower action in required than can be obtained by the methods outlined

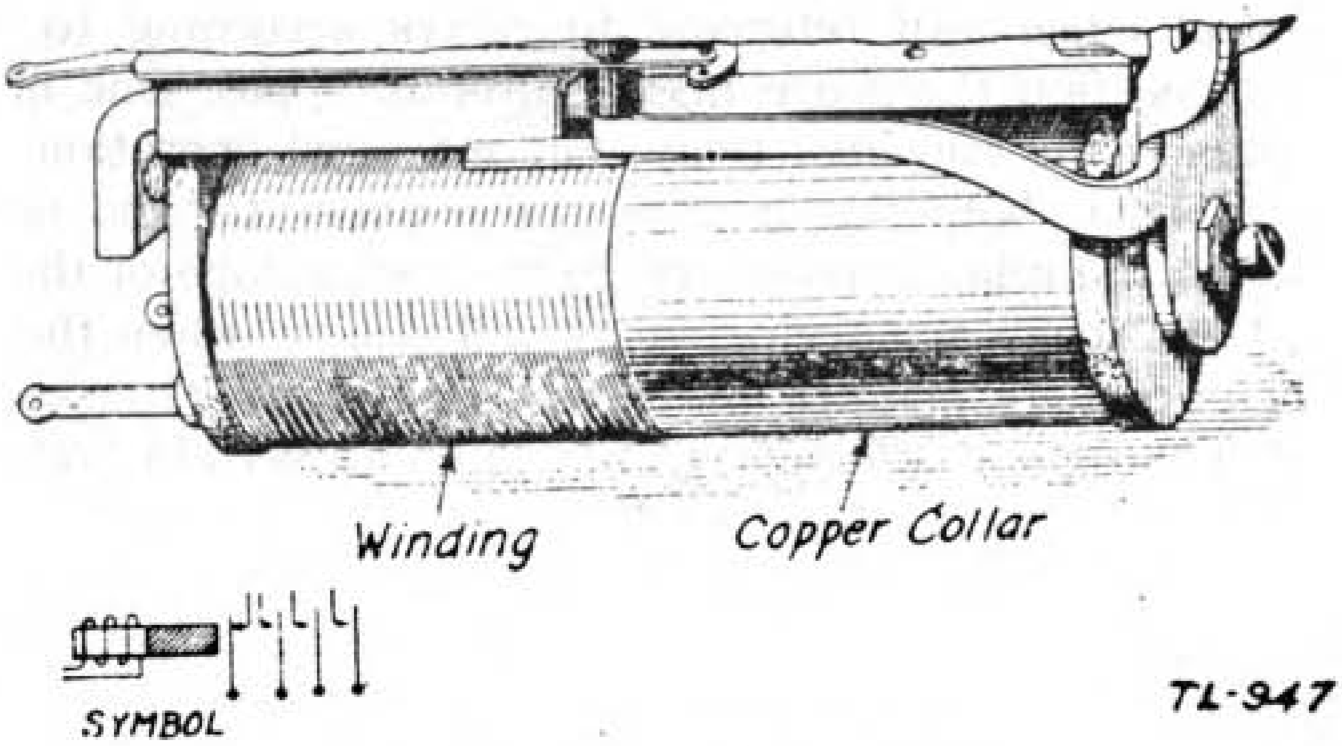

FIGURE 18.—Slow operating relay.

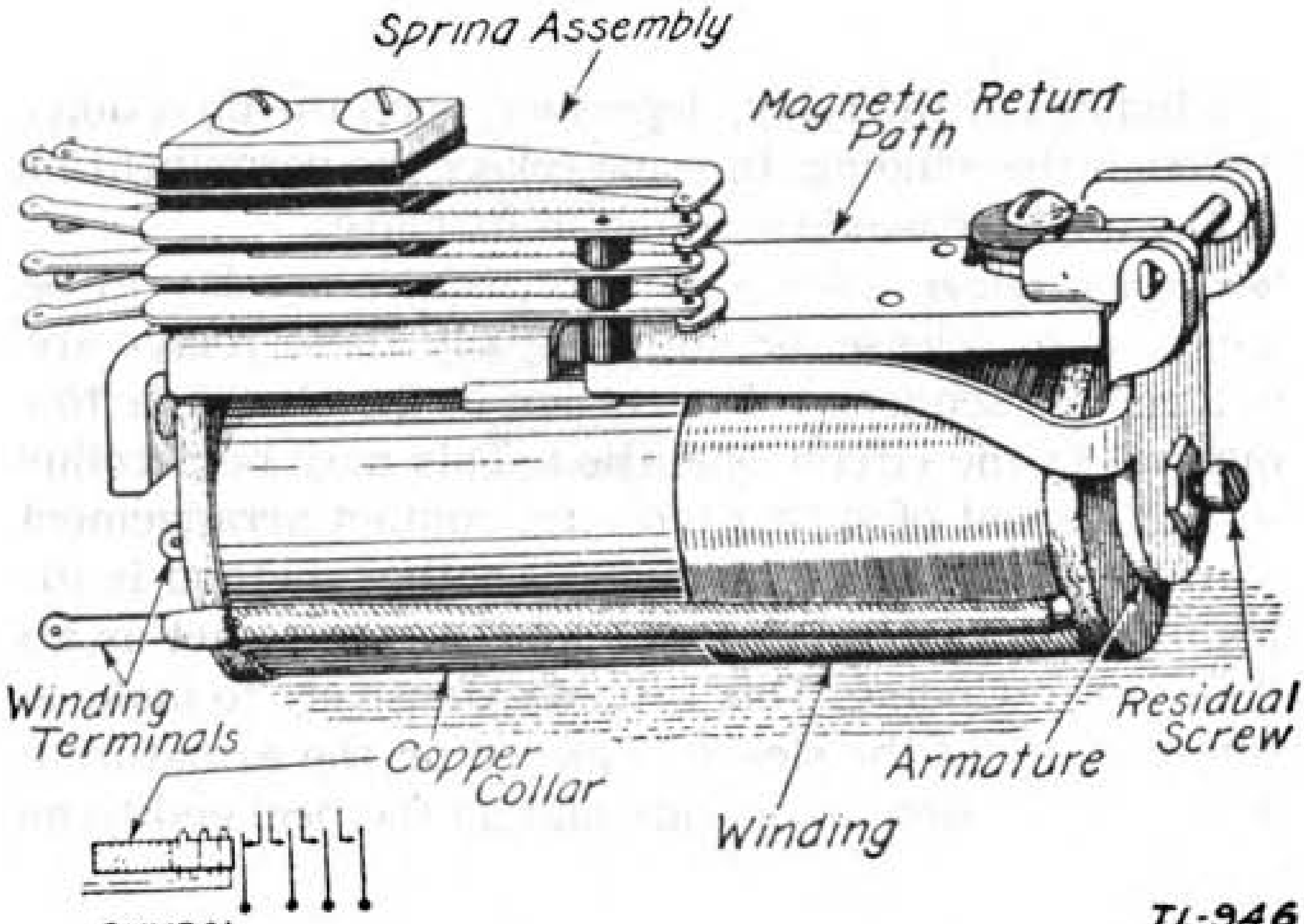

FIGURE 19.—Slow releasing relay.

above, a dash pot relay may be used. In a dash pot relay the armature also operates a piston in a cylinder filled with oil and the oil is forced through a small adjustable hole. The viscosity of the oil and the area of the hole govern the speed of operation.

30. Alternating-current relays.—The relays so far considered in this section have been designed to operate on direct current. Relays that must operate on alternating current must have some provision for holding the armature in the operated position while the alternating current passes through zero every half cycle. The most commonly used type of alternating current relay has the pole piece split and one-half of the pole piece is surrounded by a copper sleeve which acts as a one-turn short-circuited winding. This sleeve acts as the secondary of a transformer inasmuch as a current is induced in this winding. The zero value of this current does not come at the same time as the zero value of the operating current so that there is always enough magnetic force to hold the relay in the operated position. The same results may be obtained by using an armature with sufficient mass that it has enough inertia to prevent it from releasing as the current passes zero. Another method is the use of two windings on separate cores but both affecting the armature. The windings are connected into the circuit so that the current in one winding is out of phase with the current in the other winding.

31. Questions for self-examination.—

1. What is a relay?
2. Upon what basis may relays be classified?
3. What are the component parts of a relay?
4. What types of materials are used in the construction of relay cores?
5. Name three types of windings that may be used on a relay.
6. What limits the combinations of contacts that may be used on a relay?
7. Why are the contact springs adjusted so that there will be a continued movement of the armature after the contacts have been closed?
8. What are marginal relays? Polarized relays?
9. How may a relay be made to be slow acting?
10. How are alternating-current relays constructed?

SECTION VI
COMMON-BATTERY LINE CIRCUITS

Paragraph

32. Line jacks.—At a common-battery exchange each of the subscriber lines is connected to the springs of a jack on the switchboard. This is the same as in local-battery practice, except that the jack has one more contact. The contacts of a local-battery jack are tip and sleeve, while those of the common-battery jack are tip, ring, and sleeve. The tip and ring contacts are springs and the sleeve contact is tubular. See figure 20 which illustrates both simple and cut-

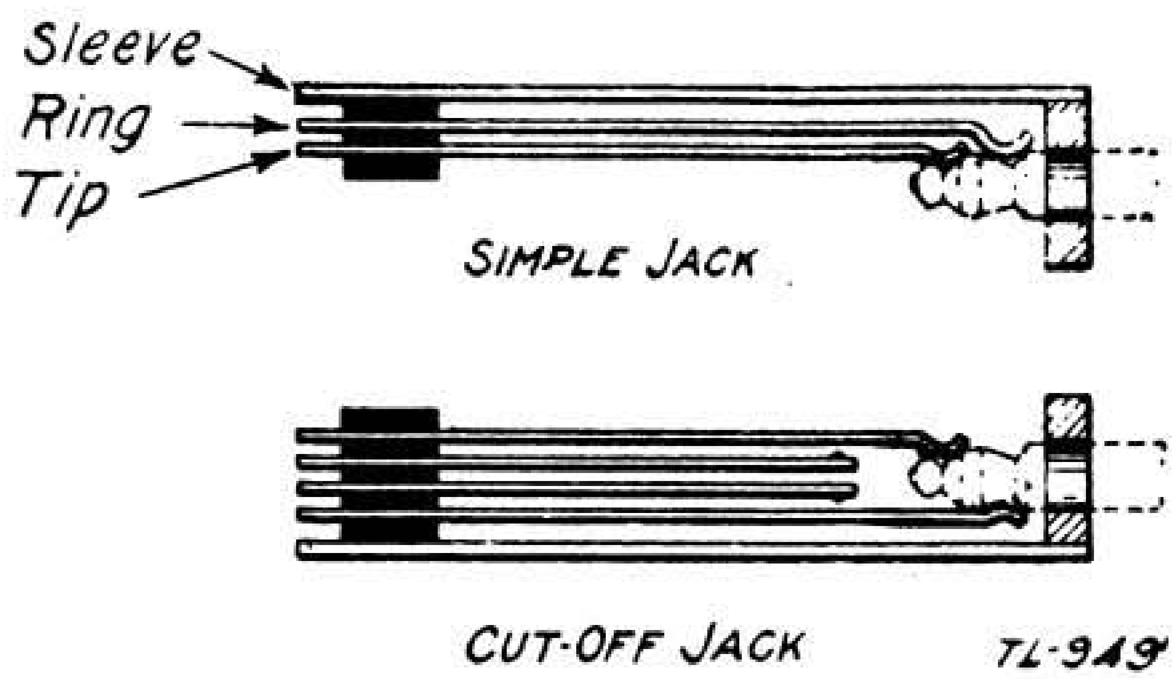

FIGURE 20.—Line jacks.

off jacks. Tip and ring springs in common-battery switchboards afford connection for the line, and the sleeve contact affords connection to certain auxiliary circuits. The simple jack is used when cut-off of signaling apparatus is not required or when cut-off is effected by relays; the cut-off jack is used when the cut-off is mechanical. Jacks are made in strips of ten or twenty, according to the switchboard in which used.

33. Line signals.—In a common-battery switchboard the line signal is usually a small lamp instead of a drop. This lamp is constructed as shown in figure 21. It has a small wooden block cemented to the end to support and insulate the filament terminals which are small metal plates extending along opposite sides of the tubular lamp bulb. These lamps are inserted in simple two-conductor jacks,

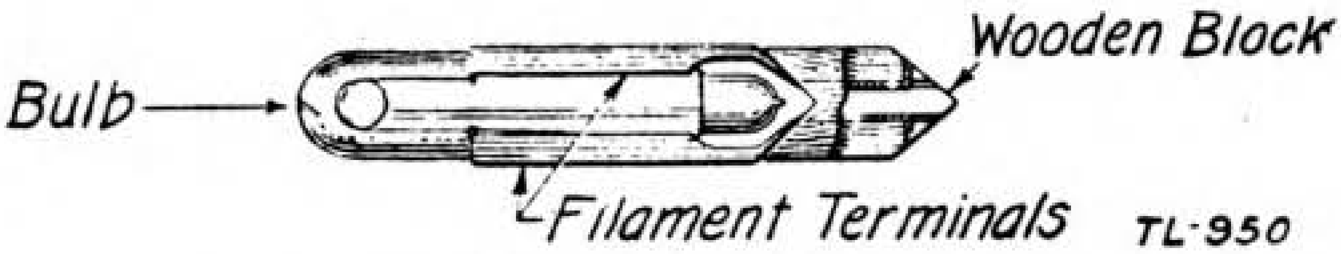

FIGURE 21.—Signal lamp.

known as lamp jacks, as shown in figure 22 and the mouth of the jack is closed with a glass lamp cap which may be one of a number of colors or markings to designate the class of service given the line, a matter which will be discussed later. Lamp jacks, too, are built in

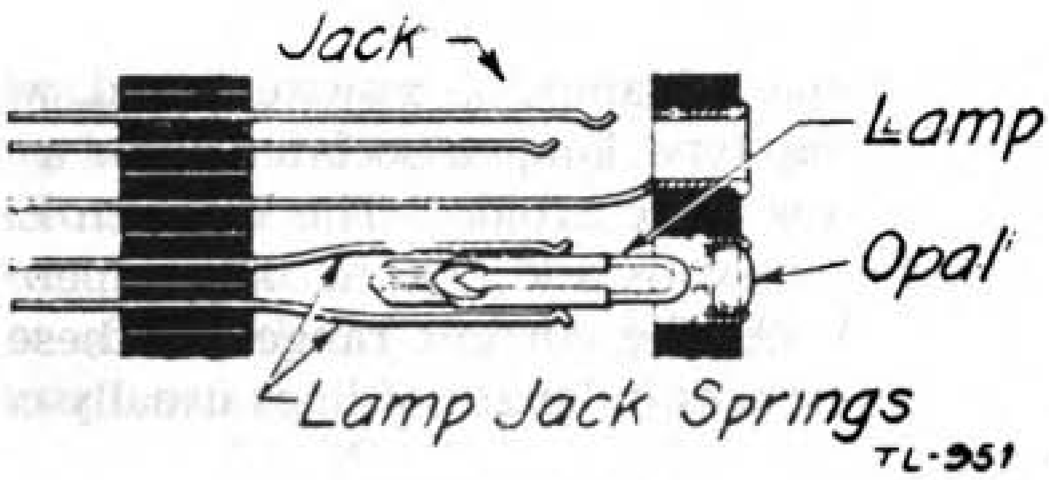

FIGURE 22.—Lamp jacks.

strips of ten or twenty and in the switchboard are mounted either directly above or below the line jacks with which they are associated.

34. Hookswitch control of signal.—The terminal voltage of the exchange battery is available at the hookswitch contacts of every idle telephone in a common-battery system. When a person desires to place a call, he removes the hand-set from the cradle, permitting current to flow from ground through the tip springs of the jack, the tip side of the line, the telephone, the ring side of the line, the ring springs of the jack, the line lamp, the battery and back to ground. This causes the lamp to light. A simple circuit by which this is accomplished is illustrated in figure 23. The battery shown in the diagram is the 24-volt exchange battery, *the positive side of which is*

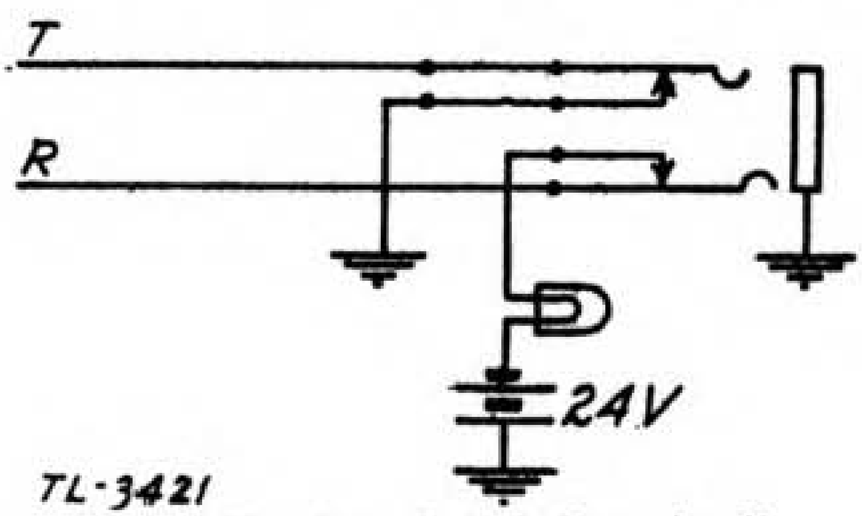

FIGURE 23.—Cut-off jack line circuit.

permanently grounded. This circuit is used exclusively in small switchboards which are designed to serve short lines of approximately equal length. The merit of the circuit lies in its simplicity and low cost. Its disadvantages are that the jack cut-off springs are not easily adjusted, because of their inaccessibility, and that it requires different kinds of lamps for different lengths of lines. The current in a lamp is governed by the resistance of the line with which it is associated. If the lamp designed for a long line were used on a very short line, the lower resistance of the line would cause such a heavy current to flow that the lamp would have a short life. Obviously, lamps of different operating current and requiring different voltages to light them are required. Such lamps are commercially available. For example, Western Electric "code 2" lamps are made in types ranging from the 2A requiring .17 to .21 amperes at 4 volts to the 2T requiring .025 to .035 amperes at 35 to 47 volts. A multiplicity of types of lamps on a switchboard, with the chance of getting the wrong type lamp associated with a line, complicates maintenance and is to be avoided. The Western Electric lamp code No. B2, rated at 18 volts and .036 to .048 amperes, is used on the switchboard BD-89. The current ranges of these lamps are suitable for the differences in length of lines usually connected to these switchboards. The line lamp of the BD-89 is protected by a varistor in parallel with the lamp as shown in figure 24. The varistor consists of two silicon-carbide discs. The resistance of the varistor is high at 24 volts and therefore does not materially affect the light-

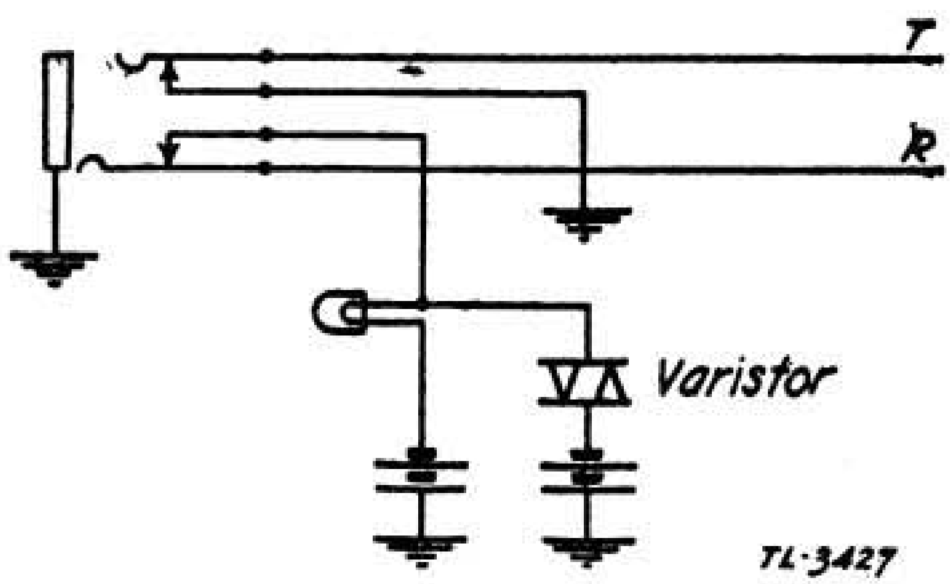

FIGURE 24.—Varistor protected line lamp.

ing of the lamp. When voltages higher than normal are induced in or connected to the line, the resistance of the varistor decreases, thus bypassing the excess current around the lamp.

35. Line circuit with line relay.—The circuit shown in figure 25 places a single wound relay (with one make contact) in series with the battery and has a local circuit controlled by the relay to light the lamp. This circuit requires only one type of lamp since the lamp circuit is entirely independent of the line. The margin of current

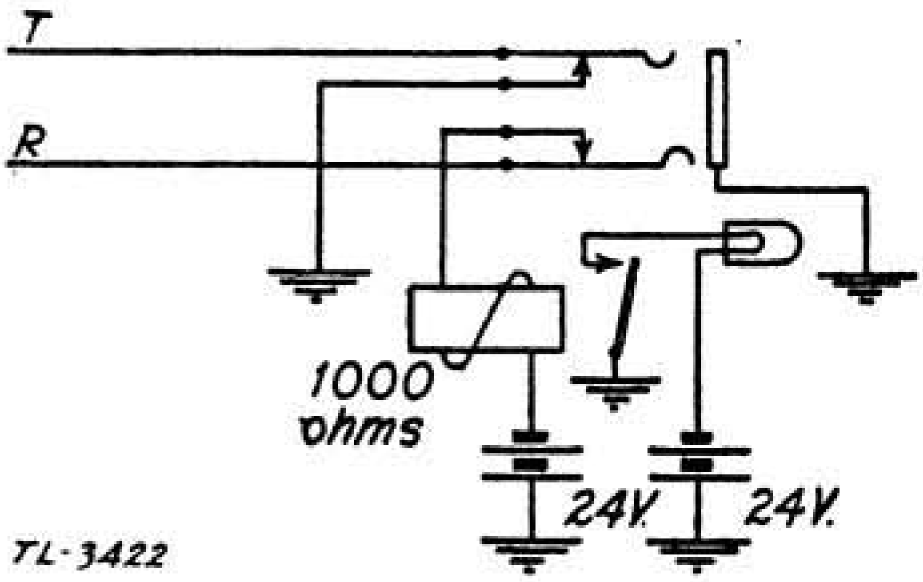

FIGURE 25.—Line circuit with line relay.

between that required to operate a relay and that which would burn out the winding can be made very large; hence, different types of relays are not required for different lengths of line.

36. Representing battery in diagrams.—It will be noted that there are five ground connections and two batteries shown in the figure 25, and this would seem to complicate the wiring of the circuit. As a matter of fact there is only one battery and one battery ground in the usual switchboard. The ground is connected to the positive terminal of the battery. In schematic diagrams it is common practice to show the negative terminal of a battery directly connected to each point which is wired to a lead to the negative terminal of the exchange battery, and to show a ground connection for each point which is wired to a lead to the positive terminal of the exchange battery.

37. Cut-off relay.—In both of the line circuits shown the jack cut-off springs enable the operator to open the lamp circuit and take battery off the line by the mechanical operation of inserting a plug in the line jack. This is a simple and inexpensive arrangement, but has the disadvantage that the whole strip of jacks must be removed for servicing, thus interfering with the operator. To obviate the necessity for the use of cut-off jacks, the circuit shown in figure 26 was developed. The circuit requires an additional relay, known as the cut-off relay, but it has the advantages that; the jacks are used solely for contact with the plug, the cut-off springs are on the relay, adjustment of contact springs is easily made and the

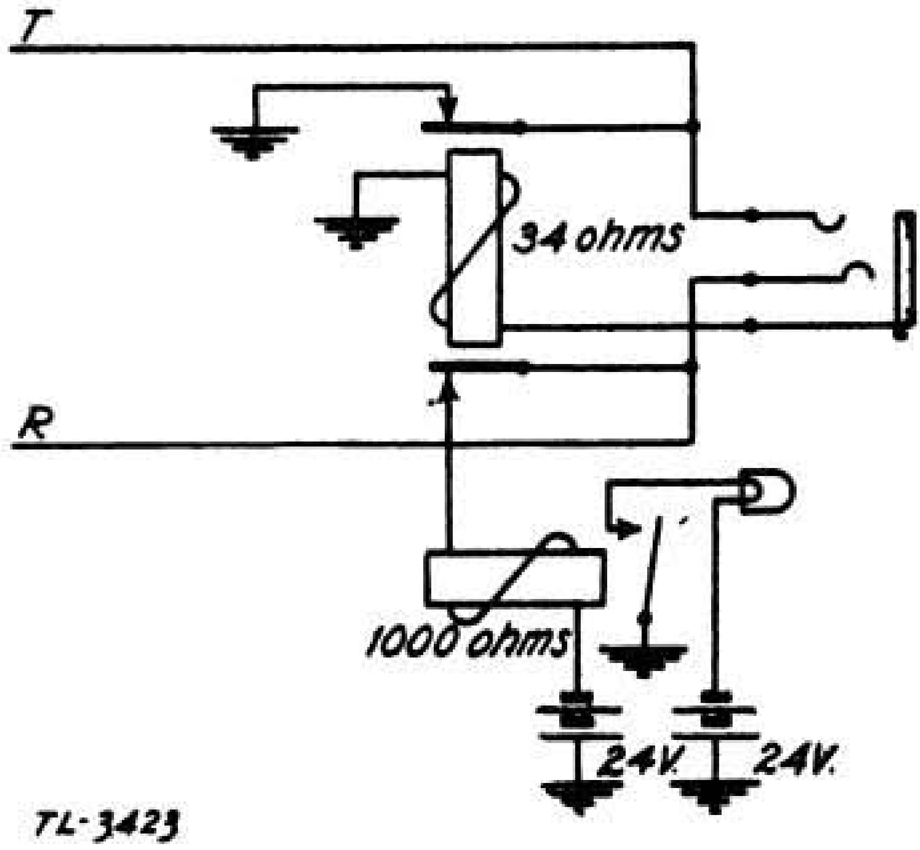

FIGURE 26.—Line circuit with cut-off relay.

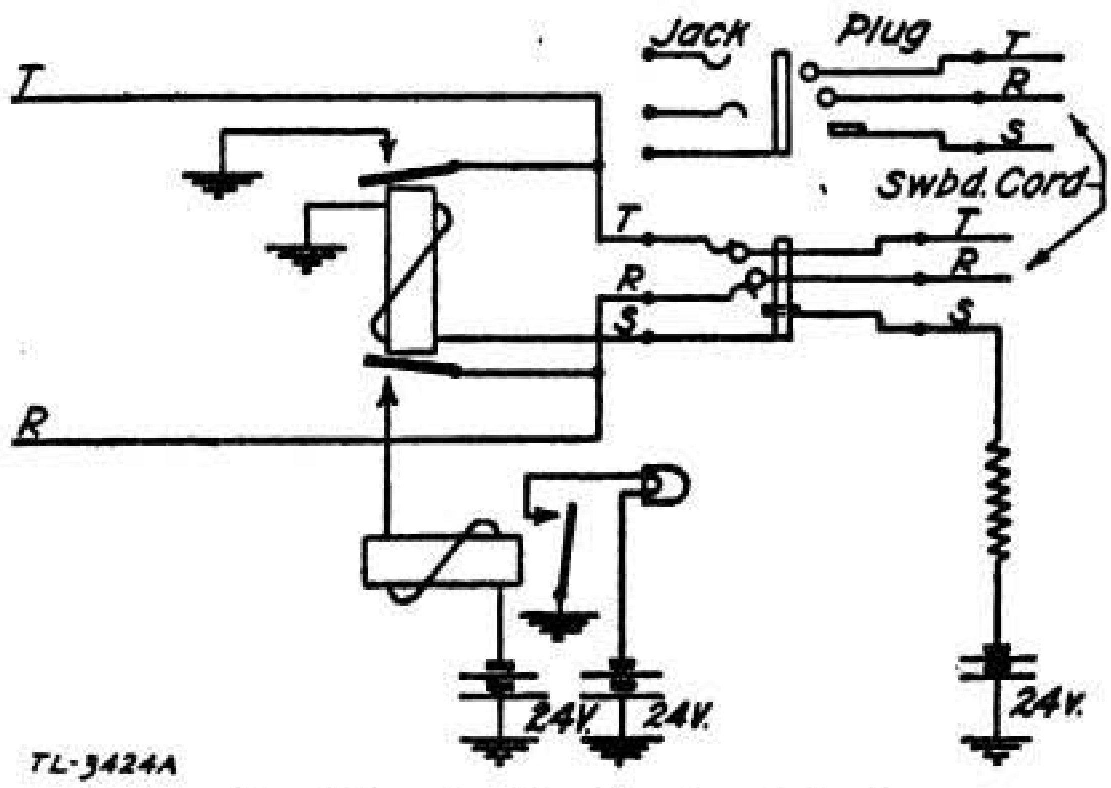

FIGURE 27.—Line circuit with plug in jack.

making of this adjustment does not interfere with the work of the operator. The cut-off relay is connected between the sleeve contact of the jack and ground. The line relay circuit is the same as with the cut-off jack, except that in this case it goes to the cut-off springs of the cut-off relay instead of to those of the jack; the operation of the line relay and lamp circuits is the same in both cases. However, in this circuit the insertion of the plug simply makes contact to tip, ring, and sleeve, of the jack. The sleeve contact of the plug is one end of a circuit which terminates as the negative pole of the battery, and when the plug is inserted in the jack, current flows to ground through this circuit and the cut-off relay, operating the relay and its cut-off springs. This removes battery and ground from the line and opens the line relay circuit which in turn opens the lamp circuit, extinguishing the line lamp as shown in figure 27.

Before the cut-off relay operates, the line may be noisy due to

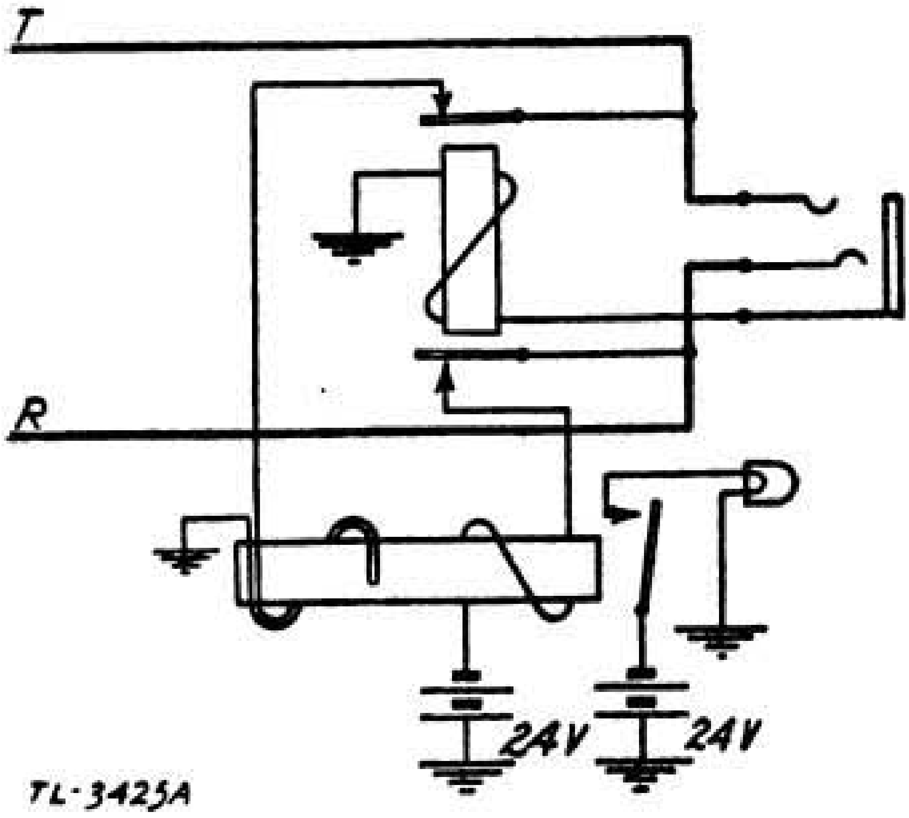

FIGURE 28.—Line circuit with double-wound line relay.

currents from line to ground. As may be seen from figure 26, voltages induced in the line by currents in a nearby line will cause current to flow to ground through the cut-off relay springs. The high resistance of the line relay will cause that part of the current on the ring side of the line to flow through the low resistance of the telephone to the tip side of the line and back through the relay springs to ground. A resistance, equal to that of the line relay, added between tip and ground will cause this current to divide equally to ground and not flow through the telephone. For a convenient place to mount the resistance, the line relay in this circuit is usually a double wound relay as shown in figure 28. The winding furnishing resistance to ground is a noninductive winding.

38. Long lines.—By a slight variation as shown in figure 29 the line circuit can be arranged for use on lines where the loops are too long for satisfactory common-battery operation. To prevent noise from leakage currents, no battery is connected to the line after the cord is plugged in. It is operated with a local-battery telephone.

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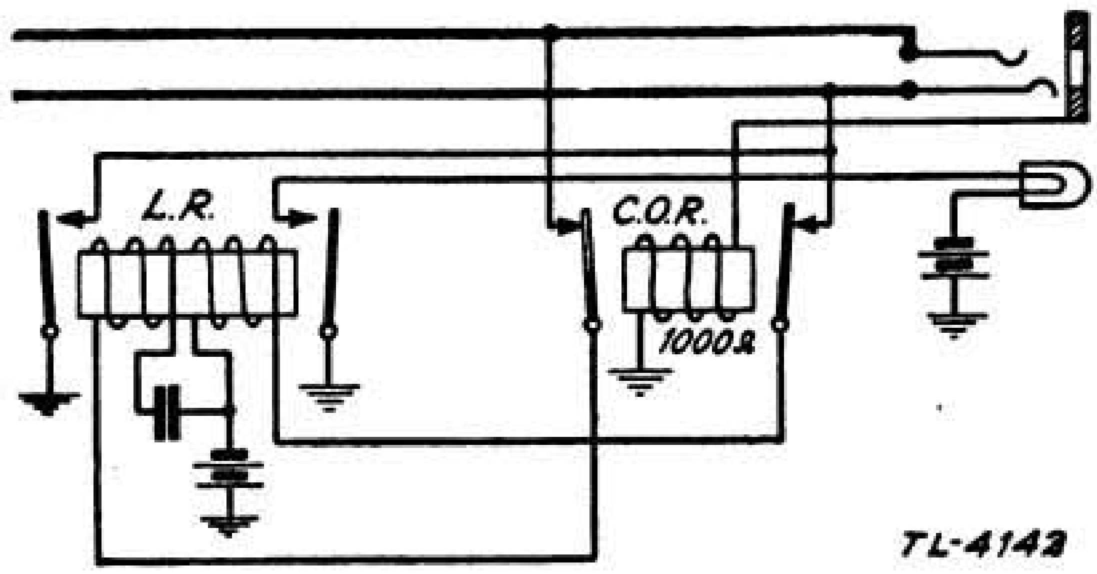

FIGURE 29.—Line circuit with ring-up line relay.

When it is desired to place a call, ringing current is put on the line. This current passes through the condenser so that the two windings on the line relay are in series and it closes its contacts. Current flows from ground through the left contact of the *LR* relay, through a contact on the cut-off relay, through one-half of the line relay winding, to battery and holds this relay operated after ringing current has stopped. Current flows through the other contact of the *LR* relay and lights the line lamp. When the plug is inserted into the jack, battery is placed on the cut-off relay. This removes the line relay from the line and opens the holding circuit which opens the lamp circuit and clears the line. The resistance of the cut-off relay is high enough to prevent operation of the cord circuit relay and no battery is fed to the line when the proper cord circuit is used.

39. Types of line circuits.—In summation, there are three types of common-battery line circuits. The first is the line circuit with cut-off jack and without line relay. It is used in small switchboards where the lines are short and of nearly uniform length. It is also found in army switchboards where the shock and vibration of transportation and the space required makes relays undesirable. The second is the one with cut-off jack and line relay. It is used in small switchboards and some larger switchboards where the lines are of unequal length and the load is not so heavy as to make maintenance of contacts and cut-off springs from the front of the board objectionable. The third is the line and cut-off relay type, which is used in all of the larger switchboards designed for serving the maximum load. The fourth circuit discussed is not a common-battery line circuit. It is an adaptation for connecting local-battery lines to a common-battery switchboard where the lines are too long for common-battery operation.

40. Line lamps and jacks.—It has been brought out that common-battery line jacks are three conductor jacks of either the cut-off or simple type. The connections are tip, ring, and sleeve. Line is connected to tip and ring and the sleeve is grounded. The switchboard apparatus of the line circuit is usually connected with ground on the tip and battery, through associated apparatus, on the ring. The line signals of common-battery switchboards are lamps and they are mounted in jacks and behind lamp caps in strips directly above or below the strips of line jacks so that each line lamp is adjacent to the jack of the line which it represents. Line lamps are available with various current and voltage characteristics.

41. Questions for self-examination.—

1. In what respect does a common-battery jack differ from a local-battery jack?

2. What kind of line signals are used on a common-battery switchboard?

3. What is necessary for the subscriber to do in order to bring in a signal on a common-battery switchboard?

4. Draw a diagram of a telephone connected to a line circuit which contains no relays.

5. What is the disadvantage of having the line lamp in series with the line as it is in the above diagram?

6. Name the three contacts on a common-battery line jack.

7. Draw a diagram of a line circuit containing a line relay and a cut-off jack.

8. What is the disadvantage of using cut-off jacks in line circuits?

9. Draw a diagram of a line circuit which overcomes this disadvantage by using a cut-off relay.

10. In answering the following refer to figure 28. Line relay coil $=1000\omega$, noninductive coil$=1000\omega$, cut-off relay coil$=37\omega$, lamp$=240\omega$. Operating values of relays, cut-off—.047 amperes, line—.0058 amperes.

a. What would be the effect of a cross between sleeve and ring?

b. Would the line lamp light if battery were placed on the tip?

c. Would the cut-off relay operate if ground were placed on the ring?

d. If the sleeve and lamp wires were crossed, how would the circuit be affected?

e. If the sleeve were crossed with the sleeve of another circuit, how would the operation of this circuit be affected when the other circuit was in use?

f. If the ring were crossed with the tip of another circuit, how would the trouble be indicated?

SECTION VII
COMMON-BATTERY CORD CIRCUITS

42. Description of cords and plugs.—The cord circuits of common-battery switchboards are fundamentally the same as those used in local-battery switchboards. However, there are many points of difference which are due to the centralization of the battery supply and to the automatic and continuous supervision. It has been noted that there is a difference in the jacks of the line circuits. This calls for corresponding differences in the cords and plugs. The cords of common-battery switchboards are of three conductors, instead of

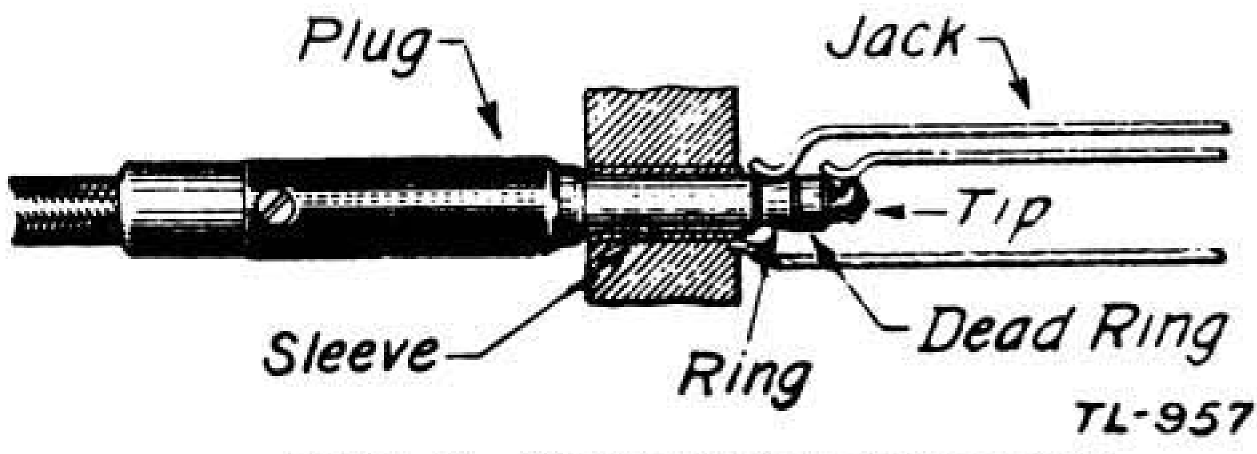

FIGURE 30.—Common-battery plug and jack.

two, and the plugs have three contact elements. Figure 30 shows a common-battery plug inserted in a jack. Observe the tip, ring, and sleeve making connection with the corresponding springs of the jack and note that there is a second ring of metal between the tip and the ring. This is called the dead ring and is required to reinforce the insulaton where it is increased in diameter to prevent possibility of short-circuiting the tip and ring contacts of the plug. Figure 31 shows a cross section of a common-battery plug.

43. Battery feed—battery bridged across line.—Perhaps the best way to understand just how a cord circuit functions in a common-battery board is to build up a circuit in a logical manner. This cord circuit must perform several functions, and in the common-battery system it must, in addition to all other functions, furnish current for talking purposes to every telephone in the system. This current must be furnished over the tip and ring of each plug since the pair of wires from the telephone is connected to the tip and ring of the jack. First, consider just the tip and ring conductors of the cord circuit and see how the 24-volt central office battery can be connected to them. The simplest way is to connect the battery

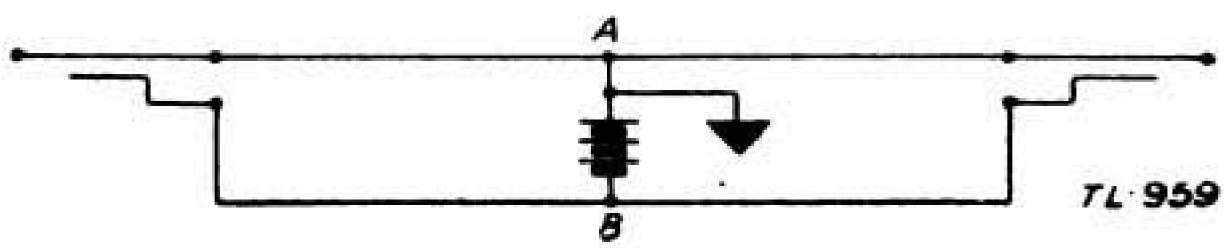

FIGURE 32.—Simplest common-battery cord circuit.

directly across the cord circuit as shown in figure 32. As shown in the diagram the positive side of the battery is always grounded and is the side connected to the tip, while negative battery is connected to ring. This arrangement will not work in practice. The reason for this may be seen by referring to figure 33. This merely shows two telephones connected by such a system of battery feed omitting all other equipment. Assume that (*a*) is speaking. When he talks he varies the direct current flowing through his transmitter. In order that (*b*) hear (*a*), these variations in current

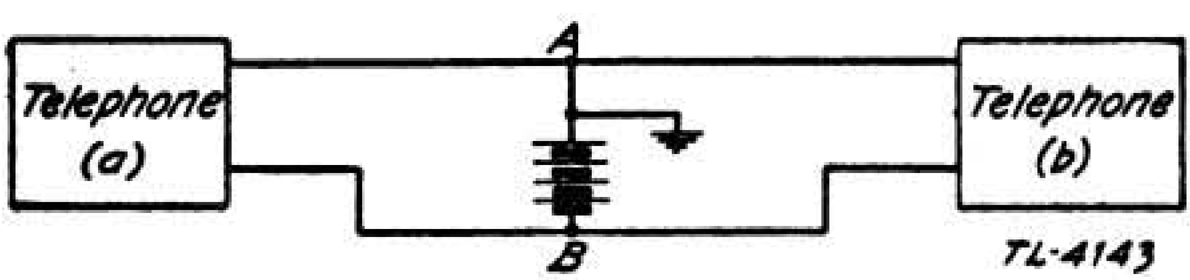

FIGURE 33.—Simple cord connecting telephones.

must reach (*b*)'s telephone. Instead of reaching (*b*) these variations in current pass through battery *AB*, because of the very low internal resistance of the battery. Another way of looking at it might be this. With no one speaking at either end, only direct current from the battery is flowing in both halves of the line. Now as soon as (*a*) speaks the current in his half becomes a pulsating current, or it could be considered as being two currents, a direct current originating at the battery and an alternating current of voice frequency originating at (*a*). So far as the alternating current is concerned the battery is a direct short, so all of it takes the path *AB* rather than the parallel path which is telephone (*b*).

44. Battery feed—retardation coil system.—*a. Single coils.*—To prevent the battery from providing a short circuit to voice frequency currents, an inductance must be put in series with the battery so that a high impedance is offered to alternating current and a low resistance to direct current. In telephone practice this inductance is called a retardation coil. In order to keep the line balanced the retardation coil is divided in two parts, one part in series with each battery lead. A cord circuit with a retardation-coil battery feed is shown in figure 34. Coils x and y are wound on the same core. One

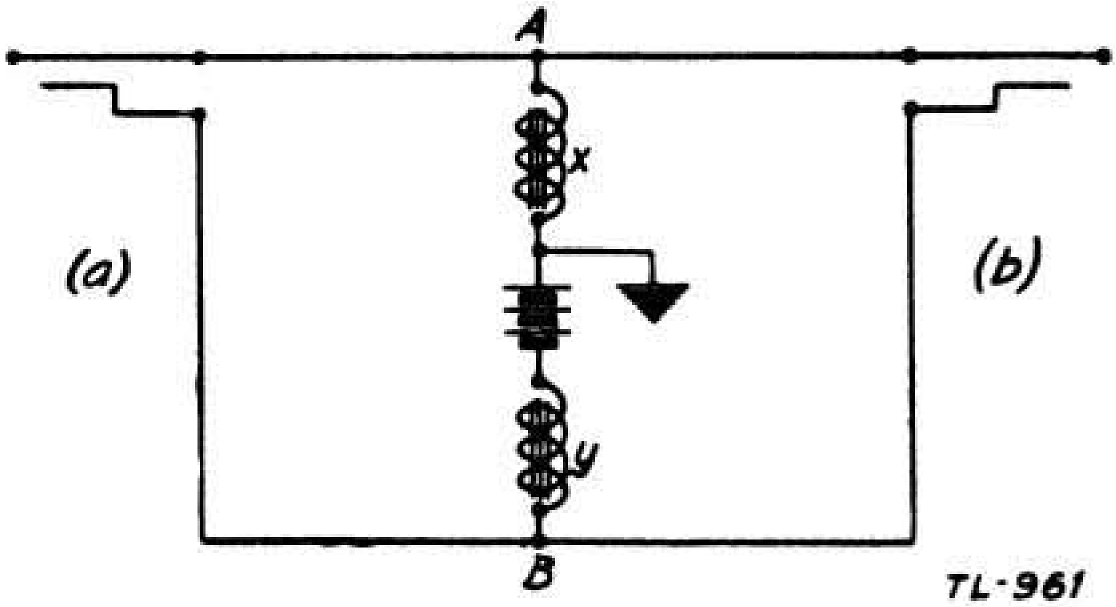

FIGURE 34.—Cord circuit with single retardation coil.

problem in connection with battery feed has been solved but another has been introduced. In figure 33 if the lines to (*a*) and (*b*) are of unequal length, the long line will draw less current than the short one; but it is to be noted that since the battery has very low resistance the current in one line is independent of the resistance of the other line. In figure 34 however, it may be seen that, since the retardation coil must have an appreciable resistance, the *IR* drop in the coil will be due to the current fed to both lines, and the current in one line is affected by the resistance of the other. The direct current flow through a subscriber's transmitter should be the same regardless of the line to which the connection is made.

b. Double coils.—If the battery is connected to each line through separate retardation coils as shown in figure 35, the current in one line is independent of any condition existing on the other half of the cord circuit. The capacitors shown are required to provide a low impedance path for voice currents through the cord circuit. Coils x

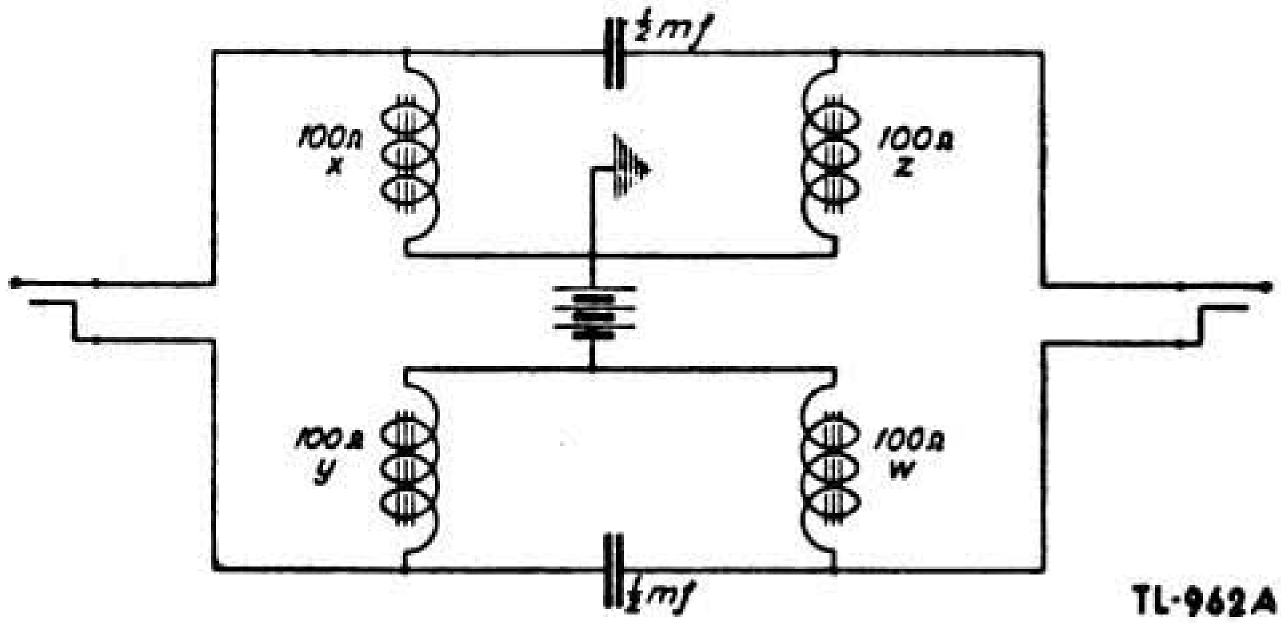

FIGURE 35.—Cord circuit with double retardation coils.

and *y* are combined on one core; *z* and *w* on another core. The resistance of the winding should be high enough to prevent excessive currents from flowing through short lines. A 48-volt system will naturally have higher values of coil resistance than a 24-volt system and this helps to maintain a more uniform direct current to all of its common-battery lines. It is to be remembered, however, that a high resistance line will always draw less transmitter current than a low resistance line. This is not serious if kept within proper limits.

c. Other features.—So far only the method of connecting the battery to the cord circuit has been considered. The cord circuit must accomplish several other things, too. The operator must have a means of talking with the subscribers, of signaling them, and also a means of supervision.

45. The operator's telephone—sidetone circuit.—The receiver circuit of the operator's set is placed directly across the cord circuit by means of a listening key just as in a local-battery cord circuit. The cord circuit with operator's set added is shown in figure 36. The receiver circuit is the same as a local-battery receiver circuit, except that it contains a capacitor. This capacitor opens the circuit to direct current, making it unnecessary to pole the receiver. It also insures proper supervision as will be seen later. The central-office battery is used in the primary or transmitter circuit. A high resistance choke is in series with the battery. This reduces the trans-

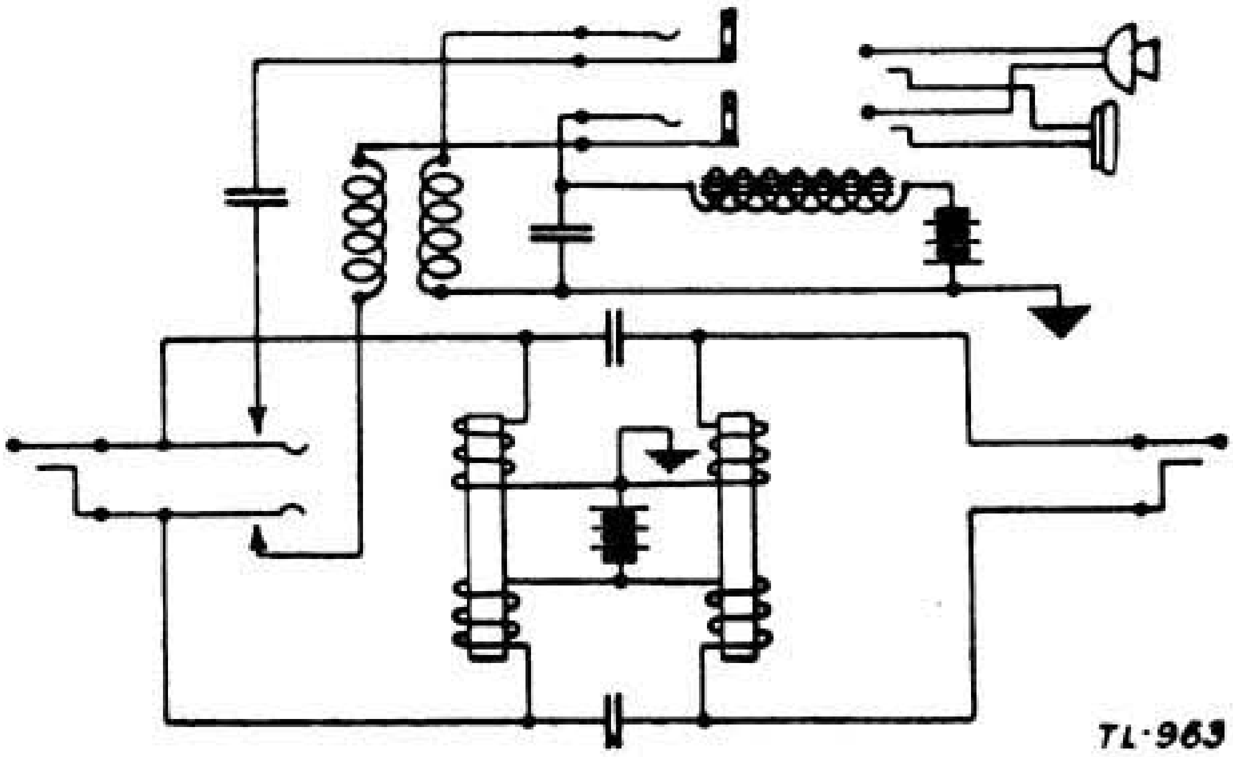

FIGURE 36.—Cord circuit with operator's telephone circuit.

mitter current to the proper value, and also prevents voice pulsations from passing through the battery. The capacitor is in the path provided for the voice frequency currents. The transmitter circuit is closed all the time that the operator's plug is in the jack. This may not always be the case, but it is common practice. Whenever the operator's plug and jack arrangement is used the transmitter is connected to the two tip contacts and the receiver to the two sleeve contacts; consequently it does not matter which way the plug is inserted in the jack. The operator's set shown employs the sidetone telephone circuit.

46. Signaling circuit.—Common-battery cord circuits will always have ringing keys, but usually will not be equipped with ring-back keys. However, the circuit may be equipped for two- and four-party signaling. This will be described later in a separate section. Figure 37 shows a circuit having the ringing key only. In figure 38 the cord circuit has both a ringing and ring-back key. Signaling current may be obtained from a ringing machine, in which case all the operator need do is to operate the ringing key.

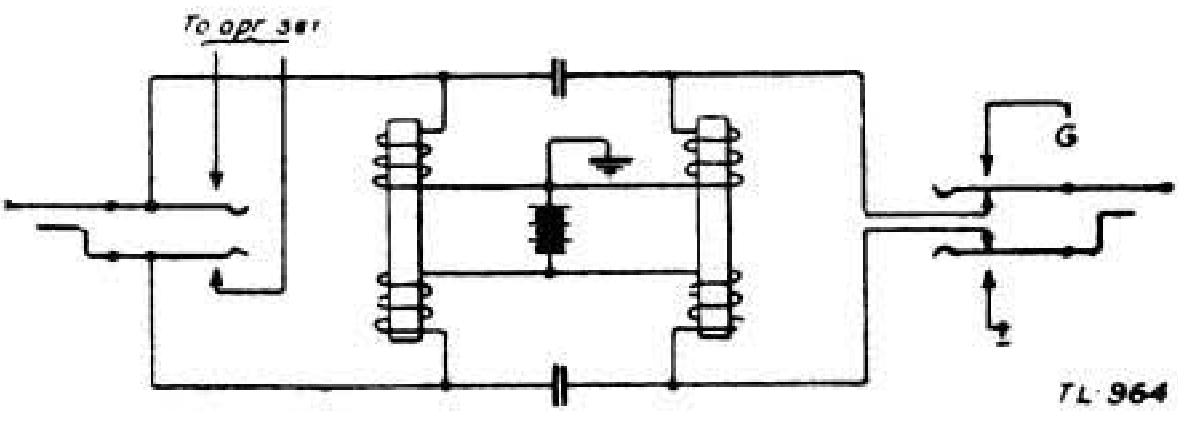

FIGURE 37.—Cord circuit with ringing key.

47. Supervision.—Supervision in a common-battery switchboard is given by two lamps on the plug shelf, one associated with the answering cord and the other with the calling cord. These lamps are extinguished when the hook of the telephone with which they are associated on a connection is up and they light when the hook is depressed. As soon as a party finishes talking and replaces the handset on the cradle the supervisory lamp associated with this party

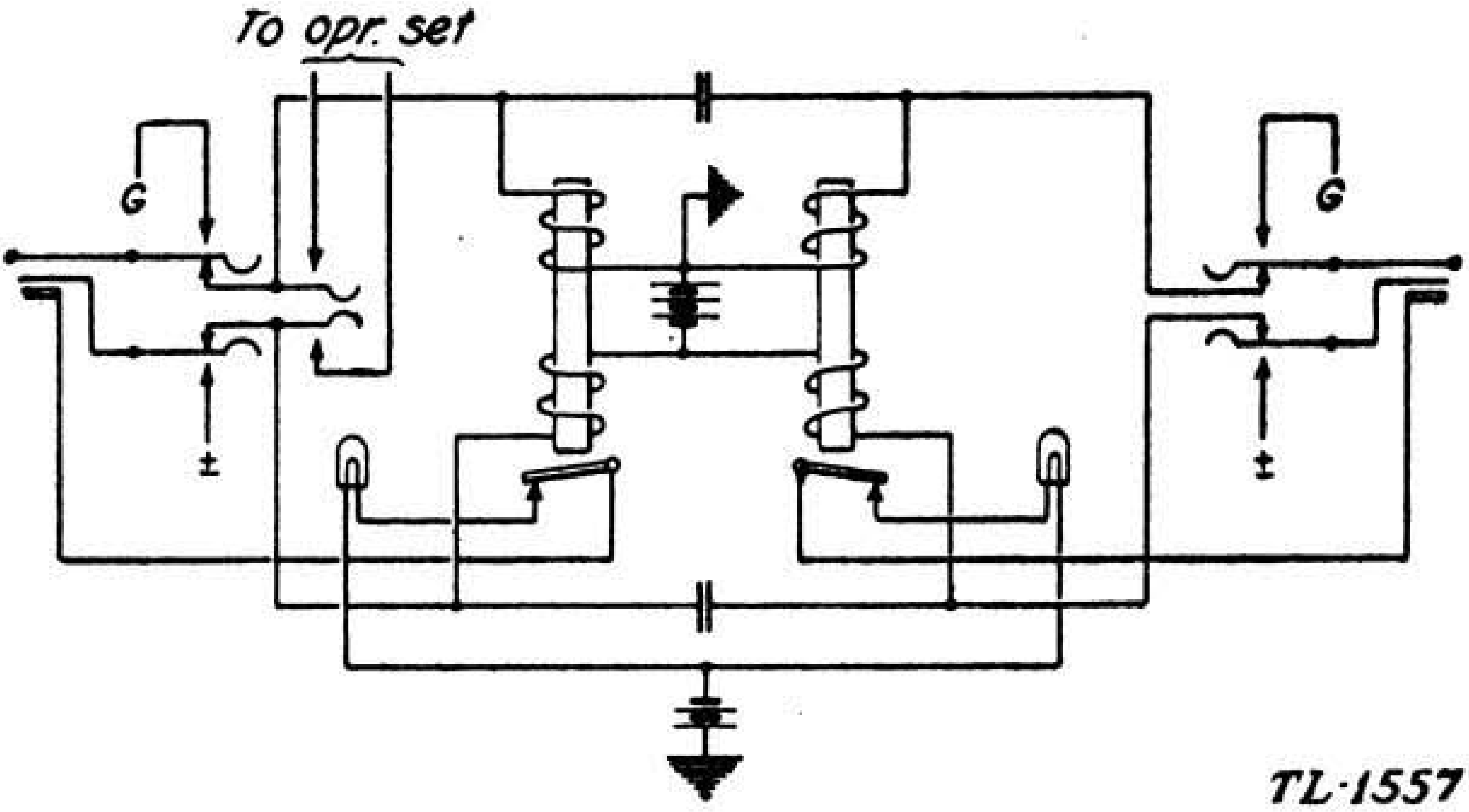

FIGURE 38.—Retardation-coil cord circuit.

lights. This is accomplished by grounding the sleeve of each line jack and placing battery on the sleeve of each plug through the lamp and the contacts of the combined retardation coil and supervisory relay. The cord circuit with this supervisory circuit added is shown in figure 38. In order to effect supervision each retardation coil is a tandem-wound relay with one break contact which is in the sleeve circuit of the cord. If one of the plugs is inserted in the jack of an idle line, current will flow through the sleeve circuit and light the supervisory lamp. Now if the receiver is removed from the hook, current will flow through the retardation-coil winding, causing the sleeve circuit to be opened at the relay contacts and the lamp to go out. If the receiver is replaced on the hook the supervisory lamp will light again. This is known as open-out supervision because it opens the lamp circuit. This retardation-coil cord circuit cannot be used with the cut-off relay type of line circuit, because as soon as the supervisory lamp circuit is opened, current would cease to flow through the cut-off relay which would release and connect ground to one side of the line and battery to the other. On a short loop this would bring in the line lamp giving a false signal. The circuit can, however, be modified slightly, as shown in figure 39, to give correct supervision. Sufficient current is put on the sleeve of the plug to hold the cut-off relay operated, but not enough to materially affect the lighting of the lamp.

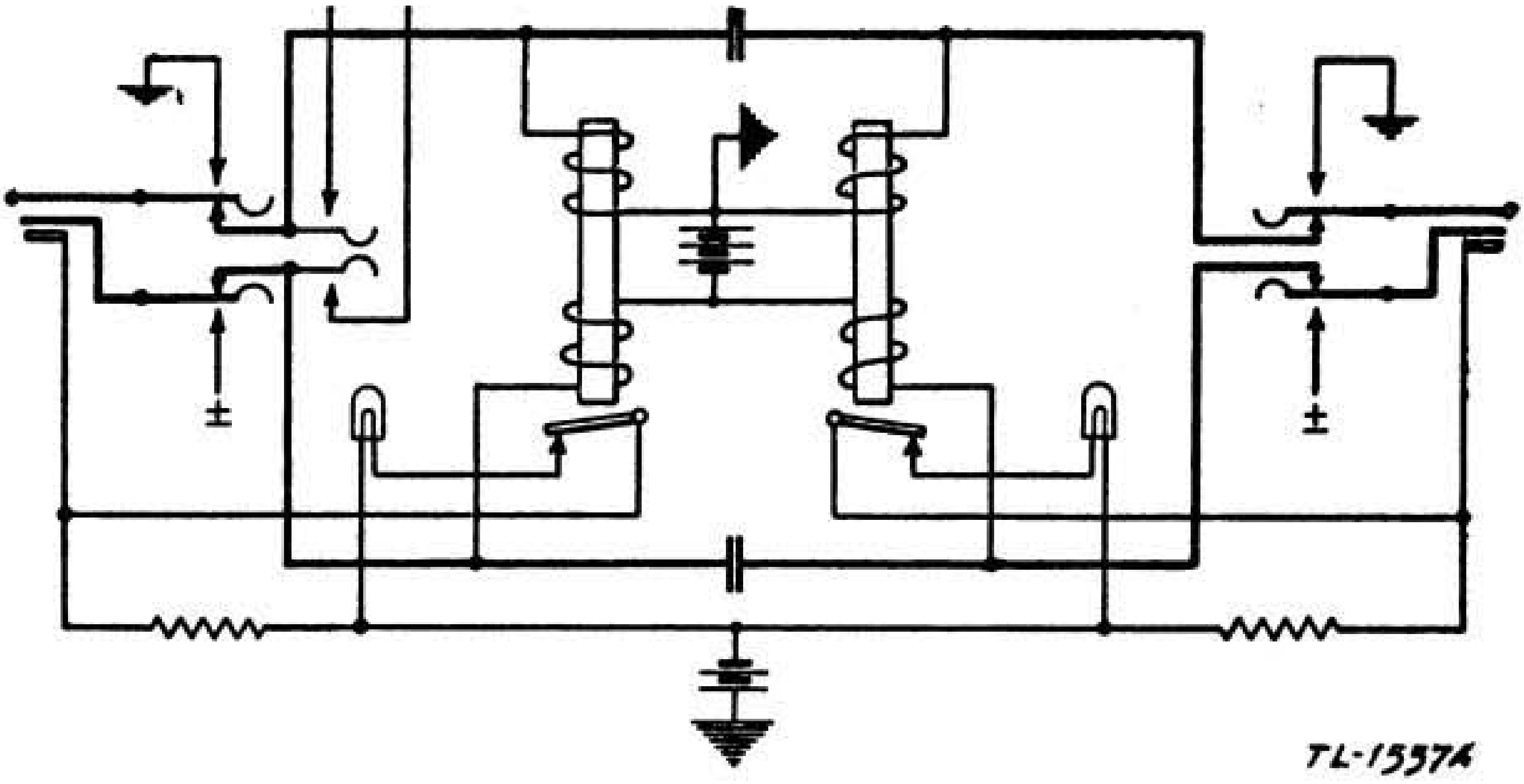

FIGURE 39.—Retardation-coil cord circuit with modified open-out supervision for use with cut-off relay.

Note.—The student should assume that the party on the left desires to place a call, and follow it through, noting just when certain lamps light and go out, when certain relays operate, etc.

48. The repeating coil.—*a. General.*—In nearly all of the large common-battery switchboards, a different type of cord circuit than that previously discussed is used. This is known as the repeating-coil type. Before going into an explanation of the circuit the characteristics of the repeating coil should be understood. A repeating coil is a very efficient one-to-one ratio, four-winding, transformer. The coils used in cord circuits differ somewhat from the repeating coils used for simplex and phantom circuits. The latter coils are efficient transformers of ringing frequency as well as voice frequencies, and are known as ring-through coils. In a cord circuit it is not necessary that the coil used repeat ringing frequency. Such a coil is called a non-ring-through coil, and differs from the simplex or phantom coil in that it has much less iron in the core.

b. Construction.—The core of Western Electric No. 25 repeating coil, which is widely used in cord circuits, is made up by winding a continuous iron wire in the form of a torus. The four windings, each of 21-ohms resistance, are then wound around this core. Figure 40 shows a schematic diagram of this arrangement. Since the core is

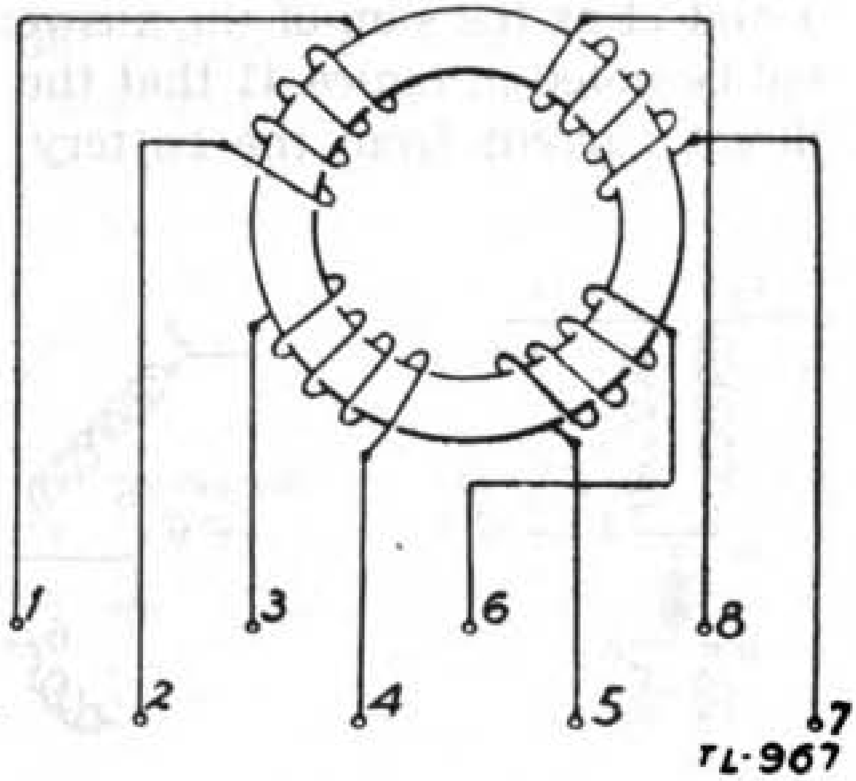

FIGURE 40.—Schematic diagram of a repeating coil.

constructed of one wire wound in the form of helix, air gaps are introduced in the magnetic circuit, preventing saturation. This construction is the equivalent of fine laminations; losses due to eddy currents are thus reduced to a minimum, making the repeating coil a highly efficient transformer over a wide range of voice frequencies. The core and its windings are placed in a pressed steel shell and the shell is filled with insulating compound. In the 25–A coil, two coils are mounted on a single wooden base about eleven by four inches and the ends of the windings brought out to lugs at one end of the base. In the 25–C coil lugs of each coil are at opposite ends. The wiring diagram of the coil is usually stenciled on the housing and the terminal lug numbers are stamped in the wood of the base.

c. Representation.—Figure 41 shows the wiring diagram and figure 42 the symbolic representation of the connections to the coil for use in cord circuits. They can be recalled by remembering
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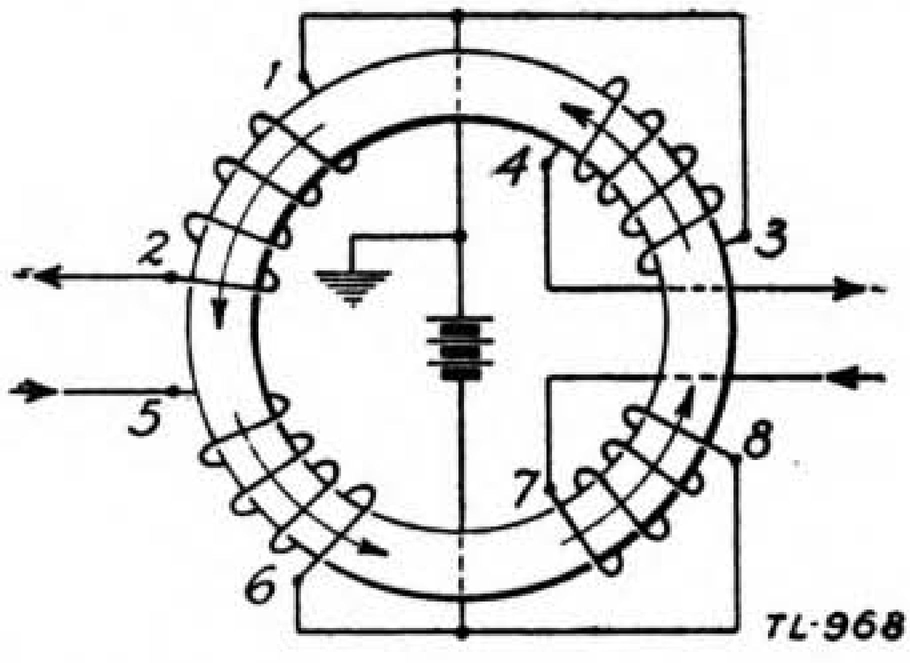

FIGURE 41.—Wiring diagram of a repeating coil for cord circuits.

the numbers 7 and 11 as the sum of the answering and calling cord numbers. It will be noted in figure 41 that the fields induced in the core by the direct current from the battery are all in the same direction.

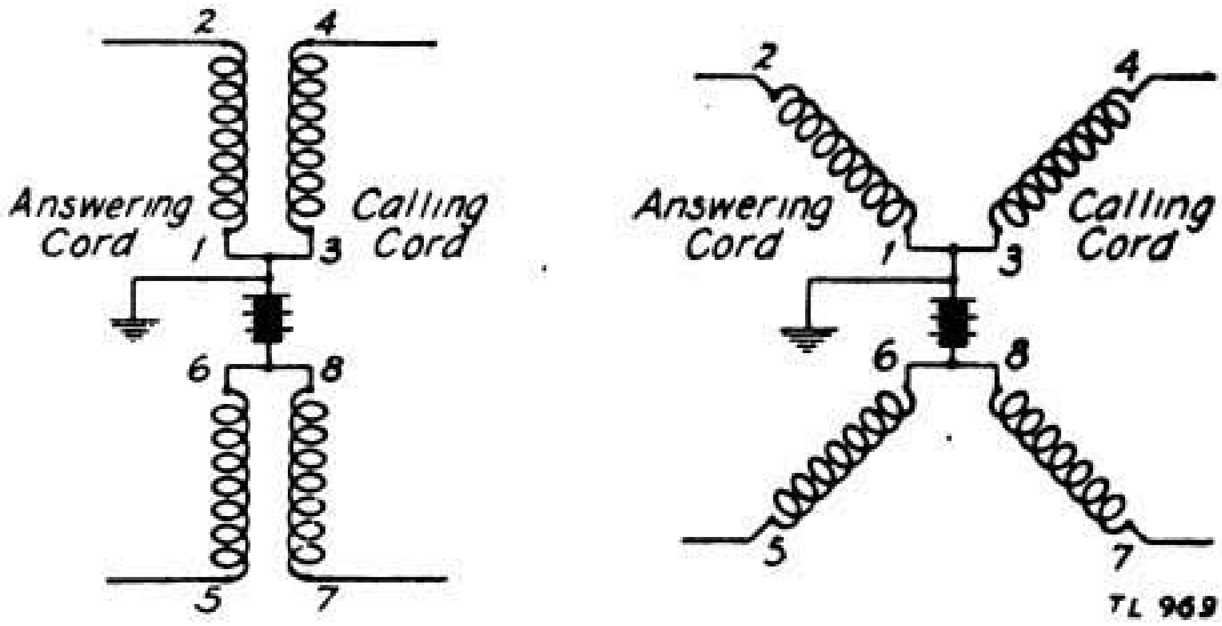

FIGURE 42.—Diagram of repeating coil connections.

49. Explanation of repeating-coil cord circuit.—*a. Repeating coil action.*—There are two ways of looking at the action of a repeating coil. Consider the schematic diagram in figure 43. This shows battery being fed to two telephones through a repeating coil just as it is when a connection is made using this type of cord circuit. As long as neither party talks, only direct current flows in each half of the circuit. We may think of the two halves of the circuit as being coupled together by a highly efficient one-to-one transformer. The *1–2* and *5–6* windings in a series make up one transformer winding

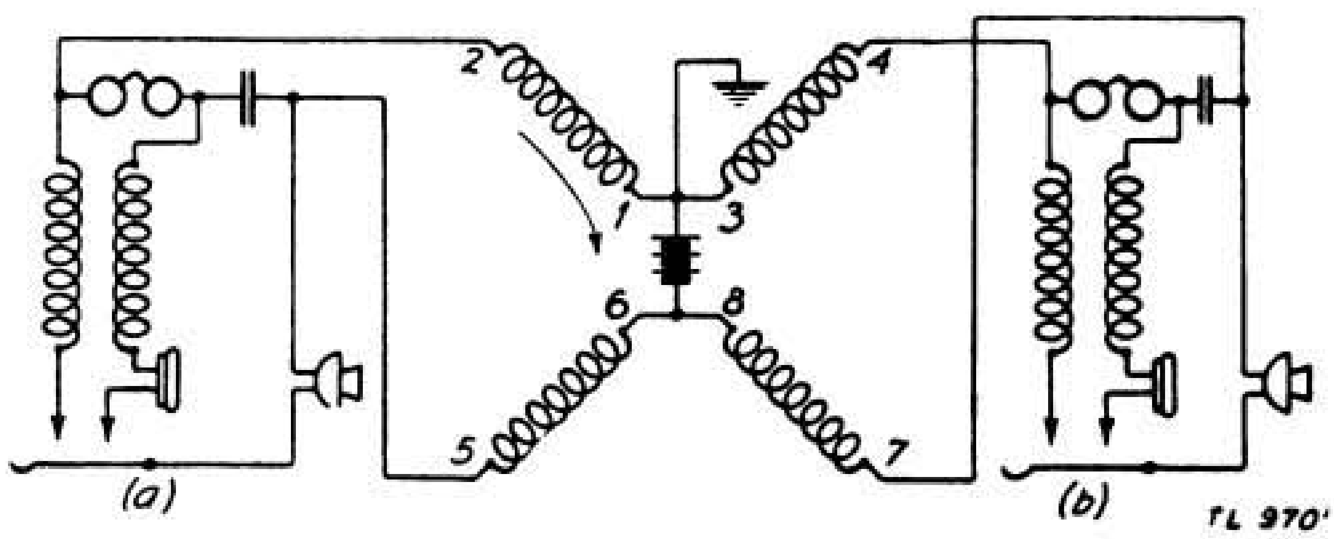

FIGURE 43.—Schematic diagram.

and the *4–3* and *7–8* windings the other. Now assume (*a*) speaks. This causes an alternating current of voice frequency to flow in that half of the circuit. Assume the first pulse of this alternating current be as shown in figure 43 (down through the battery). Then since s is a one-to-one ratio transformer and very efficient it will induce an opposite and equal impulse in the other transformer winding. This induced pulse will be up through the battery, hence, the resulting change in current through the battery is zero. Thus the alternating current in one-half of the circuit will cause a corresponding alternating current to flow in the other half, so one party will hear what the other says, yet the current through the battery itself, which is the part that is common to all cord circuits, remains unchanged.

b. Retardation coil action.—There is another way of looking at the action of a repeating coil. By referring to figure 41 it will be noted that the winding *2–1* is so wound with respect to *6–5* that they constitute a retardation coil. Similarly, *3–4* and *7–8* constitute another retardation coil. The effect of each of these coils is to prevent sudden changes in current flowing through them. But considering *1–2* with respect to *3–4*, and *5–6* with respect to *7–8*, each of these pairs combine to form the equivalent of noninductive winding, with no reactance to sudden changes in current. Now assume an impulse originating at telephone (*a*), figure 43. This impulse enters the repeating coil at *2*, but the retardation coil effect prevents it from returning by *5* while the noninductive effect allows it to leave by *4*. It passes through telephone (*b*) and back to *7* where the retard effect prevents it from going to *4*, while the noninductive effect allows it to leave by *5* and back to (*a*) where it originated. This second explanation agrees exactly with that given for the retardation-coil cord circuit. Thus, the repeating coil accomplishes exactly the same thing as was accomplished by use of two retardation coils and two capacitors.

c. Use.—The type of battery feed shown by figure 43 is sometimes called the Hayes system. Figure 44 shows a cord circuit using the Hayes system or repeating coil type of battery feed.

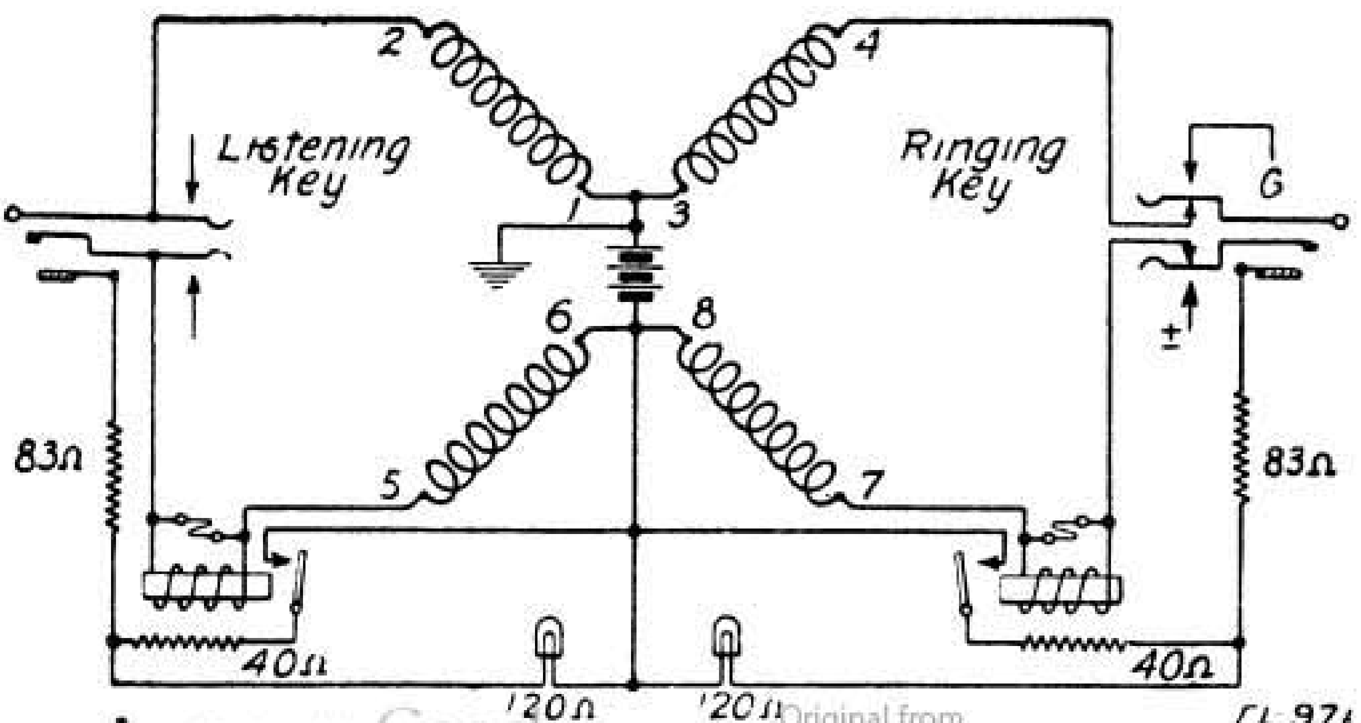

FIGURE 44.—Hayes system of battery feed.

50. Supervision on repeating-coil cord circuit.—It will be noted that the supervision in figure 44 is different from that considered previously. It is not possible to utilize the magnetic field of the repeating coil to operate armatures, hence, separate supervisory relays are required. Since the windings of these relays are in the talking circuit, it is necessary to furnish a bypass for voice frequency currents. This might be done by use of a capacitor, but this has the disadvantage that the reactance of a capacitor varies with the frequency and also this would add another piece of equipment. It is common practice to use a relay with a noninductive winding in shunt with the pull-up winding. The resistance of the noninductive shunt must not be so low as to bypass so much direct current that the relay will not operate. The relay has a make contact instead of a break. In the sleeve circuit there are two parallel branches, one containing the supervisory lamp, and the other the make contact and a 40-ohm resistor. There is an 83-ohm resistor in series with both, the purpose of which is, with the resistance of the cut-off relay of the line circuit, to limit the current through the lamp with the relay contact open. The purpose of the 40-ohm resistor is to reduce the current through the lamp, when the relay operates, to such a value that the lamp will be warm, but will not give off light. This type of supervision is known as the shunt-out type. It has advantages over the open-out type in that the lamp is kept warm and will therefore light to full brilliance in less time; also the sleeve is never opened and therefore, cut-off relay line circuits may be used with it. It can, of course, be used with any type of line circuit. It is also possible to use open-out supervision with a repeating-coil cord circuit, but this is seldom done.

51. Operator's telephone set, antisidetone circuit.—The operator's telephone used on a board equipped with repeating coil circuits may be of the same type already described, but usually it is a little more elaborate in that it uses an antisidetone circuit. A diagram of this operator's set is shown in figure 45. The primary circuit is the same as the one in the operator's set already described, except that the induction coil winding is really two windings in parallel. This causes a considerable increase in the alternating current over what it would be if the two halves of the coil were in series. Hence, a greater electromotive force is induced in the secondary. The important difference between this telephone and that previously studied is the manner of connecting the receiver. The receiver is placed across half of the secondary winding and a noninductive resistance of about 370 ohms. This value of resistance is taken as being that of the average subscriber loop. Assume the case where this resistance R exactly equals the resistance of the subscriber loop. Then speaking into the operator's transmitter or any noise in the switchboard room will not cause any current to flow through the operator's receiver. This is true because no matter what voltage is in-

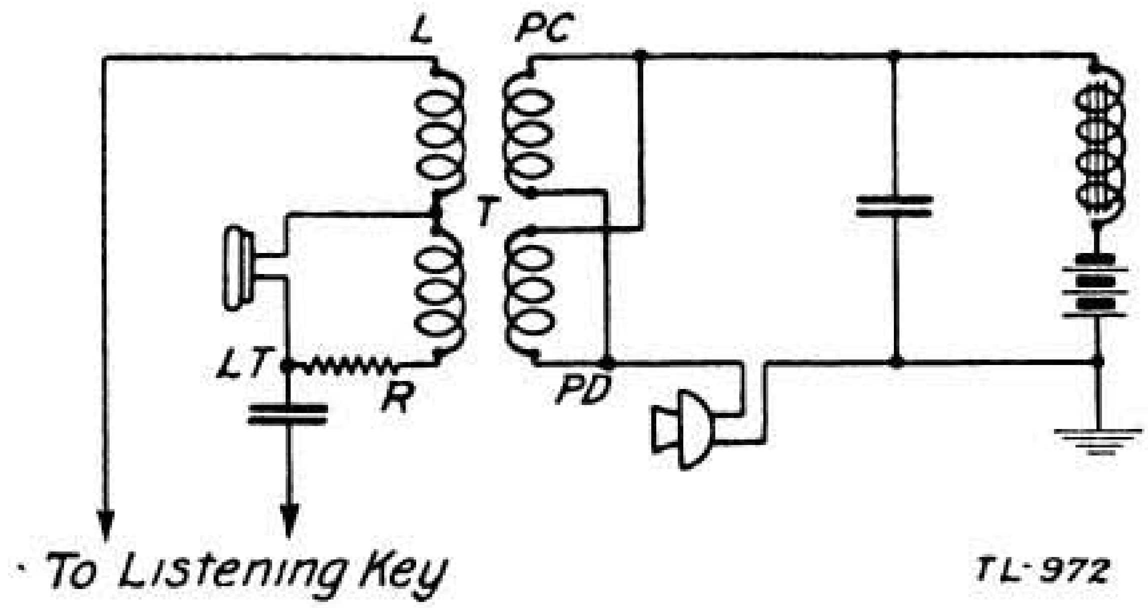

FIGURE 45.—Operator's telephone set.

duced in the secondary, the voltages induced in the two halves are equal and therefore the two receiver terminals are always at the same potential and no current flows through the receiver. This can be more easily understood from figure 46. To make the diagram simpler the voltages induced in the secondary have been shown by batteries. Since $E=E'$ and $R=R'$, the points A and B are always at the same potential. When the subscriber talks, the source of the alternating electromotive force is not the operator's primary circuit, but the subscriber's telephone and for this the operator's

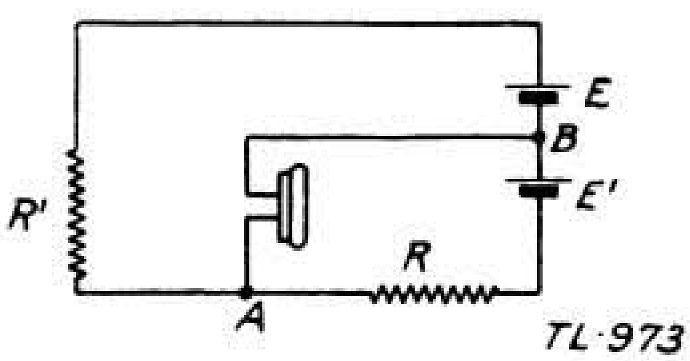

FIGURE 46.—Equivelant antisidetone circuit.

receiver is merely in parallel with half of the coil and R (about 370 ohms). As the resistance of the receiver is considerably below this, most of the alternating current flows through the receiver. This type of operator's set can also be used with the retardation-coil type of cord circuit.

52. Operation of the repeating-coil cord circuit.—Figure 47 shows two substations in an exchange served by a switchboard with repeating-coil cord circuits. Each subset is connected to a cut-off relay type of line circuit. Assuming that one of these subscribers desires to call the other, one may trace on the diagram the operations involved

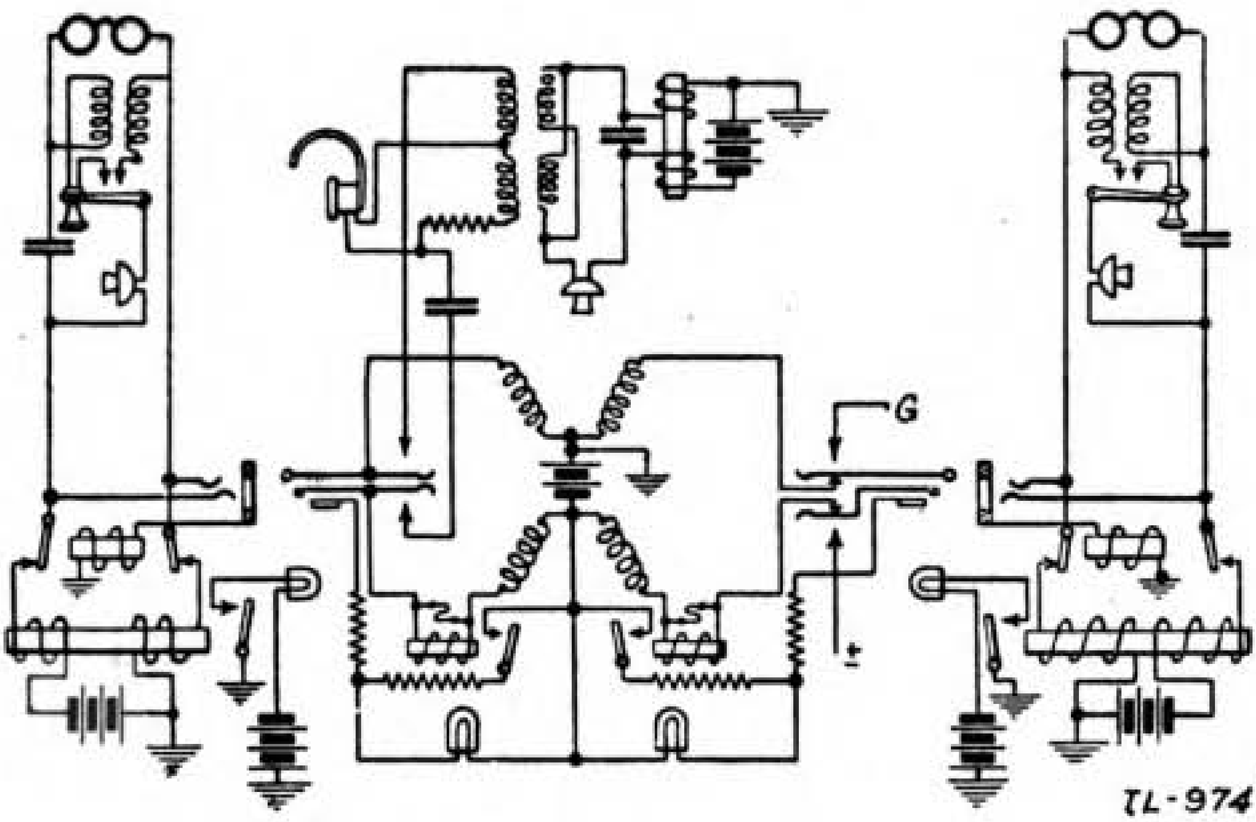

FIGURE 47.—Complete repeating coil cord circuit.

in completing the call, determining just which relays are operated and which lamps are lighted, etc., during each step of the complete operation.

53. **Universal cord circuit.**—*a. Need.*—On switchboards having both common-battery and local-battery lines it is necessary to have a cord circuit which will supply battery to the common-battery lines and not to the local-battery lines. It must also furnish a talking channel between two subscribers whether either or both lines are common-battery or local-battery. A cord circuit which will do this is called a universal cord circuit. In its usual form a full universal cord circuit uses eight or ten relays in each cord circuit. However, to conserve space and decrease trouble from relays a simplified circuit is used on army switchboards. Figure 48 shows the cord circuit used in the TC-1 and TC-2.

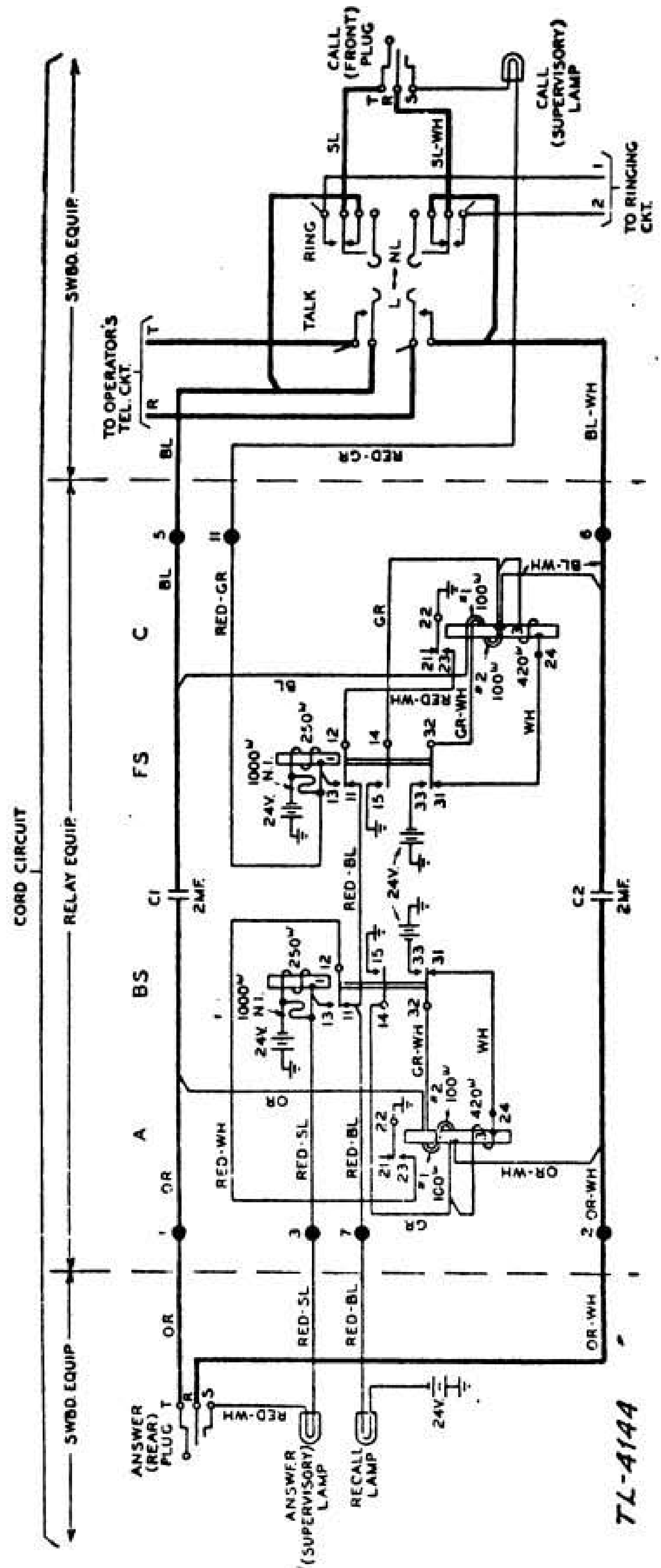

FIGURE 48.—Universal cord circuit.

b. Connection to local-battery lines.—(1) *Incoming calls.*—When the plug of the answering cord is inserted in the jack of a local-battery line circuit the *BS* relay does not operate since the sleeve circuit of the line jack is open. Under this condition the three windings of the *A* relay are connected series aiding and remain bridged across the tip and ring of the answering cord for ring-off supervision. The operator answers the call with the TALK key in the operated position.

(2) *Outgoing calls.*—When the plug of the calling cord is inserted into a jack of a local-battery line circuit the *FS* relay does not operate since the sleeve circuit of the line jack is open. Under this condition the three windings of the *C* relay are connected series aiding and remain bridged across the tip and ring of the calling cord for ring-off supervision. Upon the operation of the ringing key, ringing current is applied to the line. While the ringing key is not operated, the talking key is operated so that the operator may know when the call is answered at the distant end of the line, since no supervision is obtained when the call is answered.

(3) *Completion of conversation.*—When a conversation is completed, ringing current should be applied to the line by either telephone user in the case of a line-to-line connection or by the distant switchboard operator in case of a switchboard-to-switchboard connection. Ringing current over the line associated with the answering cord operates the *A* relay, and ringing current over the line associated with the calling cord will operate the *C* relay, causing the recall lamp to flash.

c. Connection to common-battery lines.—(1) *Incoming calls.*—When the plug of the answering cord is inserted in the jack of a common-battery line in response to a call, the *BS* relay operates, due to the ground on the line jack sleeve, and the supervisory lamp associated with the answering cord lights. The operation of the *BS* relay connects ground and battery respectively, to the tip and ring of the cord through the No. 1 and No. 2 windings of the *A* relay, thus providing for transmitter battery through the common-battery line circuit. The *A* relay operates since the circuit through its windings is completed at the distant telephone. The operation of the *A* relay short circuits the supervisory lamp, thus extinguishing the lamp by shunt-out supervision. The operator answers the call with the TALK key in the operated position.

(2) *Outgoing coils.*—When the plug of the calling cord is inserted in a common-battery line circuit jack the *FS* relay operates and the associated supervisory lamp lights in series with the *FS* relay. The operation of the *FS* relay connects ground and battery respectively, to the tip and ring of the calling cord through the No. 1 and the No. 2 windings of the *C* relay. Upon the operation of the ringing key, ringing current is applied to the line. When the called telephone answers, the *C* relay operates and shorts circuits the supervisory lamp, thus extinguishing the lamp.

(3) *Completion of conversation.*—When a conversation is completed the parties hang up and the circuit is broken at the telephone hook switch or lever switch in the telephone thus causing the *A* or *C* relay to release which in turn causes the associated supervisory lamp to light. Removal of the plug from the jack releases the *BS* or *FS* relay and extinguishes the supervisory lamp, thereby restoring the circuit to normal.

54. Questions for self-examination.—

1. What additional function must the cord circuit perform in common-battery telephony over those it performed in local-battery telephony?
2. Why is it that a circuit connecting two common-battery telephones with a storage battery only across its center will not give satisfactory transmission from one telephone to the other?
3. Why will not a system of battery feed in which both loops are fed through the same inductance coils work satisfactorily?
4. Draw a diagram of the retardation coil system of battery feed.
5. What is a repeating coil?
6. Explain the action of a repeating coil in a cord circuit.
7. Draw a diagram of the repeating coil system of battery feed.
8. What two keys are associated with each cord circuit?
9. What is the purpose of the two capacitors in the retardation-coil cord circuit?
10. What type of supervision is usually used on a retardation type of cord circuit?
11. What battery is used in the operator's telephone?
12. What is the purpose of the capacitor in the operator's primary circuit?
13. Why is the retardation coil placed in series with the battery?
14. What is the purpose of the capacitor in the operator's secondary circuit?
15. What type of supervision is usually used in the repeating-coil cord circuit?
16. Why is there a noninductive winding on the supervisory relay?
17. What is the purpose of the 40-ohm resistors in the repeating-coil cord circuit?
18. Explain the operation of the antisidetone operator's set.
19. Why is the primary coil split and the two halves placed in parallel?
20. What is the purpose of the resistor in the operator's secondary circuit?
21. What is a universal cord circuit?
22. How is battery fed to the common-battery lines?
23. What are the two principle functions of the *A* relay?
24. What is the function of the *FS* relay?

SECTION VIII
TRUNK CIRCUITS

55. Private branch exchanges.—There is need for interconnection between switchboards, whether they are exchange switchboards or are the smaller switchboards serving business houses, factories, and other plants requiring more than a few telephones. The latter switchboard is known as a private branch or *PBX*. In view of the similarity between the relations of these tributary switchboards to the exchange switchboards and the relations of army post telephone systems to commercial exchanges, the telephone company considers service to army switchboards as *PBX* service. The principal difference between army post systems and *PBX*'s is that the former are usually owned, operated, and maintained by the army, while the latter are rented from the telephone company and are maintained by them; and that where several army posts are close together, they are often interconnected by telephone lines.

56. Problems encountered in trunking.—In developing the circuits for terminating the lines interconnecting switchboards, which are known as trunks, the larger switchboard will be referred to as an exchange switchboard, and the smaller as the *PBX*. The problem in trunking is to provide for signaling and for supervision, without lowering efficiency of transmission and without requiring any departure at the exchange switchboard from the routine in handling service to subscriber lines. Trunk circuits vary in complexity with the conditions which must be met in solving the problem. The circuits on the exchange switchboard, the circuits in the *PBX*, the resistance and length of the trunk line and the nature of the service to be given over the trunk are some of the features causing the wide variety of circuits which are used.

57. Types of trunks.—There are two-way trunks and one-way trunks. The former are equipped with a signal at each end, while the latter have a signal at the switchboard on which they appear as an incoming trunk and have only a jack at the switchboard on which they appear as an outgoing trunk. Both classes may be automatic or may be ring-down and the two-way trunk may also be automatic one-way and ring-down the other. An automatic trunk is one which will bring in the signal as soon as the distant operator connects to it; and a ring-down trunk is one which requires that the distant operator send out ringing current to bring in the signal.

58. Two-way ring-down trunk.—Figure 49 shows a two-way ring-down trunk with ring-down drops as signals. The capacitors are cut in to avoid giving false supervision due to the bridging of the drop across the distant end of the line before the called switchboard answers. The two sides of the line are reversed so that the batteries at the two switchboards will be in series and not opposing each other. Were the batteries in opposition, no current would flow and there would be no supervision. With the batteries aiding each other, there are certain disadvantages. In the first place, the 48 volts of battery causes twice as much current as that for which the circuit was designed, unless the trunk is longer than the average subscriber loop. This is wasteful of battery energy, may burn out apparatus, and may cause saturation of repeating coil cores. If the grounds are not at the same potential, there will be unbalance of current in the line and this will probably cause noise. Figure 50 shows the method of using that circuit with the lamp type of signal. It is necessary to

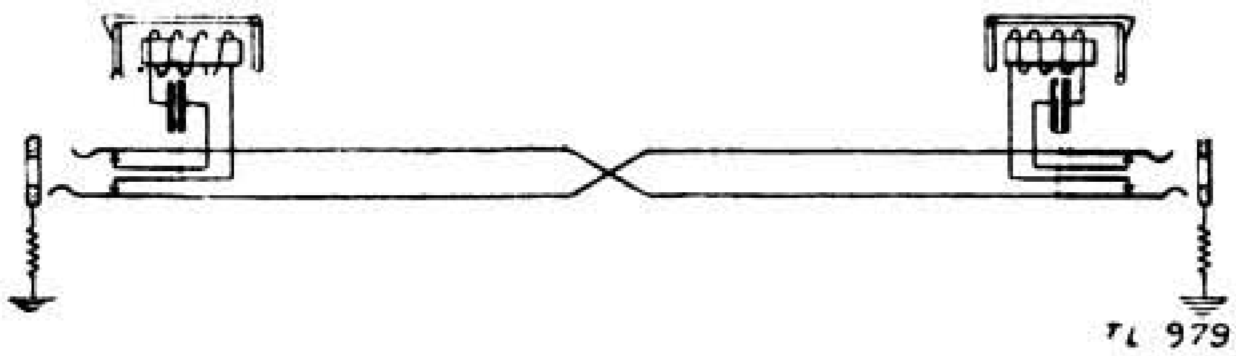

FIGURE 49.—Two-way ring-down trunk with drops.

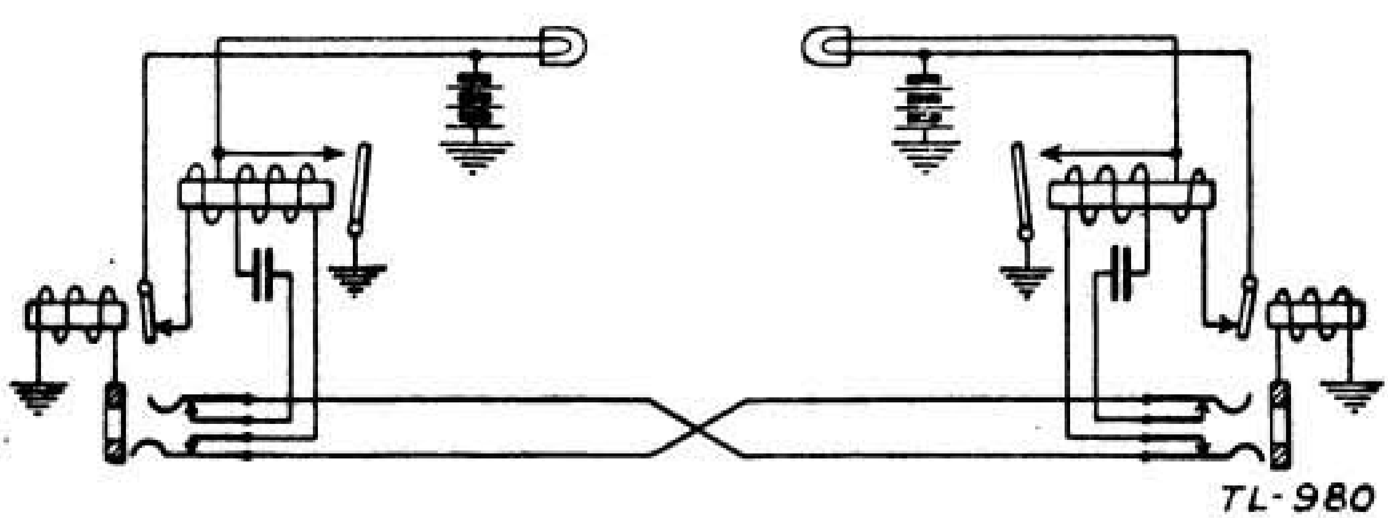

FIGURE 50.—Two-way ring-down trunk with lamps.

provide a holding winding on the lamp relay, and to enable current to reach ground through the sleeve to break the holding circuit. Cut-off relays could be used instead of cut-off jacks in this circuit.

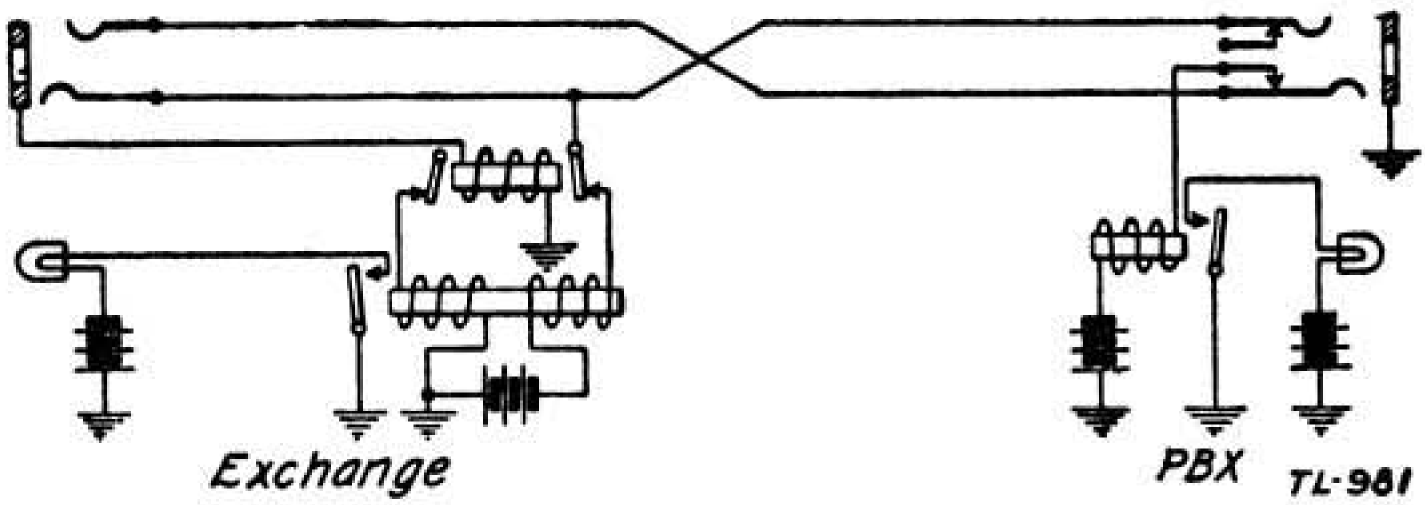

FIGURE 51.—Two-way automatic trunk.

59. Two-way automatic trunk.—Figure 51 shows the circuit of a two-way automatic trunk which is often used as an interposition trunk. As can be seen from the figure it is composed of two line circuits, with the ground removed from the cut-off contact. As shown, one line circuit is of the cut-off relay type and the other of the cut-off jack type, but the arrangement is applicable to any type of line circuit. This should not be used with a retardation coil cord circuit at either end, as it might give improper supervision.

60. One-way automatic, one-way ring-down trunk.—Figure 52 shows a trunk circuit which is automatic one-way and ring-down the other. The equipment at the exchange end is an ordinary line cir-

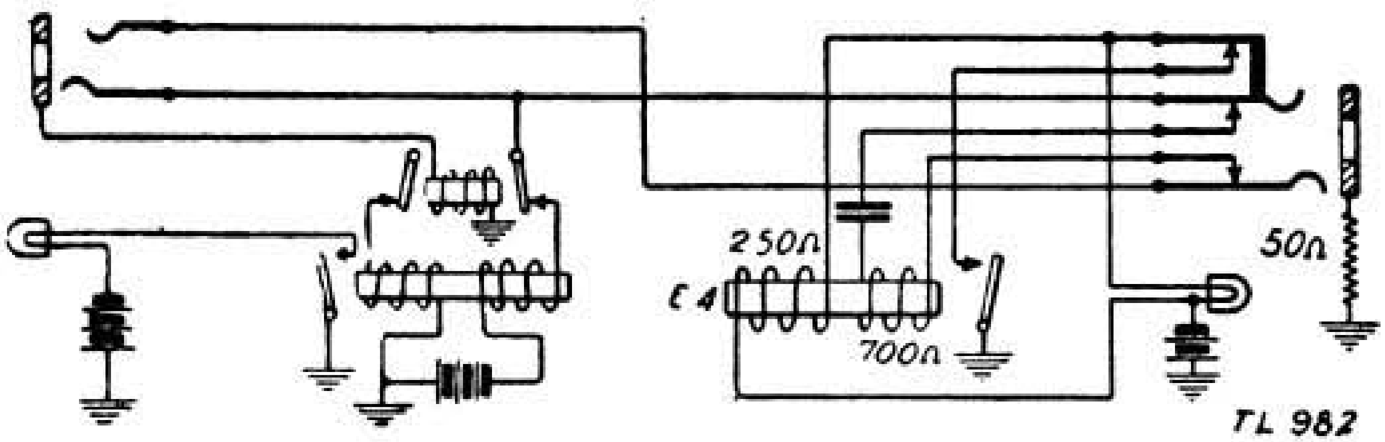

FIGURE 52.—One-way automatic, one-way ring-down trunk.

cuit. Some army post systems are connected to commercial systems by trunks similar to the above. They are automatic outgoing from the army board and ring-down incoming. The advantage of this lies in the fact that the operation at the commercial exchange end is the same as for a line circuit, and it is possible to group the army post trunks with the commercial subscriber lines. This secures better service than would be obtained if it were necessary to bring them in on a rural or other position; however a repeating coil cord circuit should be used at each end of this trunk.

61. Operation of the trunk.—When the exchange operator plugs in on this trunk to ring, her calling supervisory light comes in because the circuit through the *E-4* relay is open to direct current, due to the capacitor, but when she rings, ringing current passes through the capacitor and relay and rings up the armature. Closing of the relay contact permits current to flow through the relay contact, and the additional break contact on the jack, to a point where it divides and a portion lights the lamp, and the remainder holds up the relay by action of the 250-ohm holding coil. Thus the ringing brings in the signal and it is held in. When the army operator connects to the jack he opens the cut-off contacts, removing the *E-4* relay and capacitor from across the line and substitutes therefor the tip and ring conductors of his cord circuit; he also opens the additional break contact of the jack which releases the holding winding and opens the lamp circuit. The army exchange battery, poled to assist the exchange battery, closes out supervision at the exchange and holds out supervision at the army switchboard. When the conversation is concluded and the connection taken down at either end, supervision is brought in at the other end because the circuit goes open. When the army exchange initiates a call, the trunk equipment is cut off by plugging in and the line lamp is brought in at the distant exchange, without ringing

62. Repeating-coil trunks.—Every circuit thus far shown requires the proper poling of the circuit for additive connection of the battery and, as explained, there is a circuit unbalance if the grounds are of unequal potential. This inequality of potential may be quite pronounced near cities due to the power and traction systems. To avoid this condition, it is necessary to cut a repeating coil into the trunk circuit, which opens the line and destroys supervision unless some steps are taken to overcome this condition. The principle reason for more or less complex trunk circuits is the necessity for providing for separation of battery and at the same time retaining supervision. Figure 53 illustrates a one-way automatic one-way ring-down trunk circuit which accomplishes this. Before describing the operation of this circuit, the equipment involved in the circuit will be discussed. The jack required is a special jack with one make

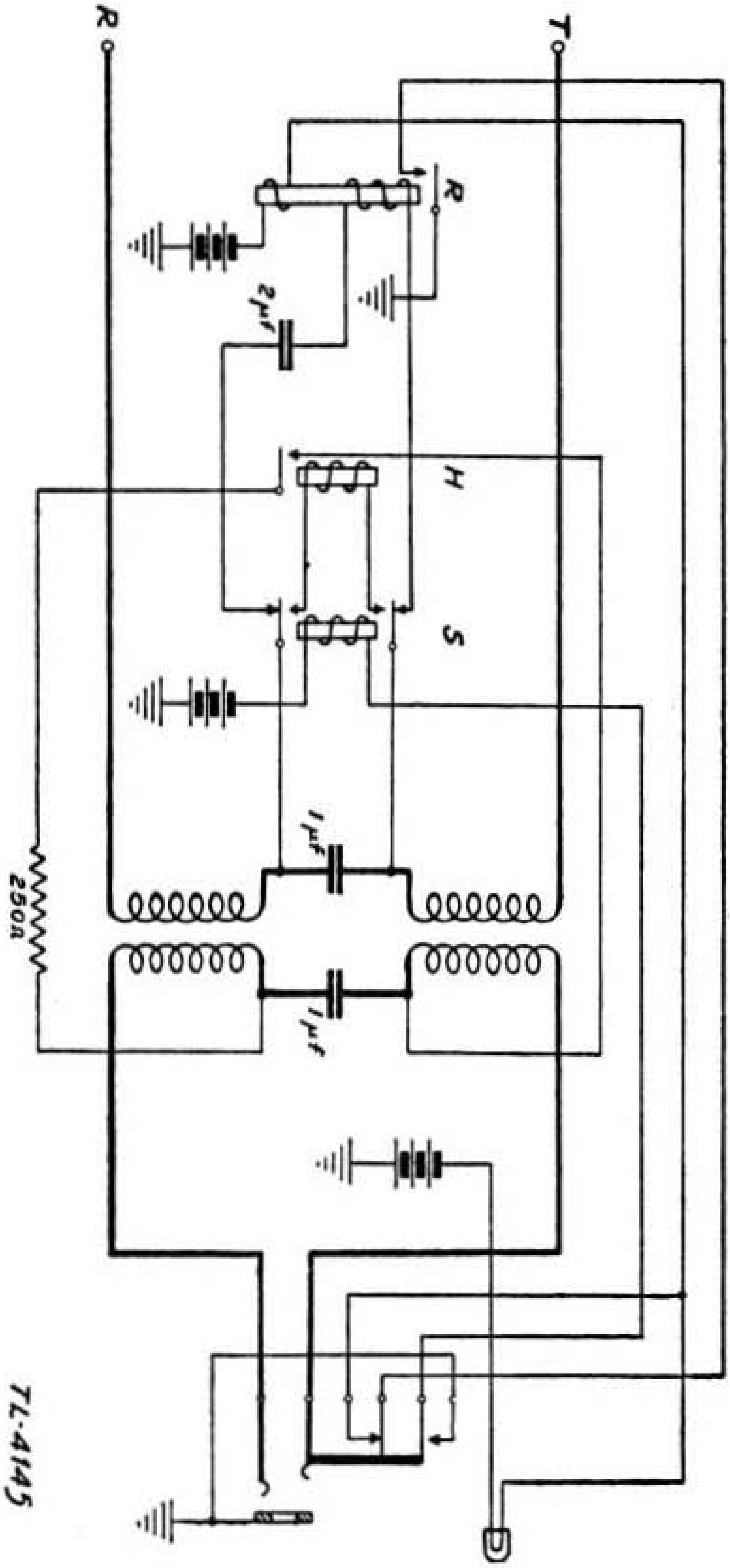

FIGURE 53.—Common-battery repeating coil trunk circuit.

contact and one-break contact. However, a relay with one make contact could be used in the sleeve circuit of the jack to accomplish the same thing if the cord circuit used at the local switchboard has shunt-out or modified open-out supervision. The *R* relay is a ring-down relay with one contact and a double winding. The extra winding acts with the contact to lock the relay in the operated position. The *H* (holding) relay provides a direct current path through the circuit for current from the distant switchboard and extends supervision to the local switchboard. The *S* (signaling) relay controls the current from the distant switchboard and by opening and closing the direct current circuit at the proper time it extends automatic supervision and signaling to the distant switchboard. The 1μf capacitors between the repeating coils provide a low impedance path for voice currents but offer relatively high impedance to ringing current, consequently ringing current will flow back around through the *R* relay and the 2μf capacitor. The 2μf capacitor opens the ring-down circuit to direct current so that relay *S* will have full control over signaling and supervision to the distant switchboard. When the repeating coil-type trunk circuit is used at the local switchboard it is, in all cases, connected directly to a common-battery line circuit. Under no circumstances should two trunk circuits of this type be connected together at opposite ends of a line.

63. Operation—incoming call.—Refer to figure 53 and assume that a subscriber connected to the distant switchboard desires to call a local subscriber. The distant operator answers the call in the usual way and then inserts the calling plug in the line jack connected through the line to the local trunk circuit and rings. The ringing current causes the *R* relay to operate and close its contact. This contact connects ground to the lamp and the holding winding on the *R* relay. The relay will now remain in the operated position and the signal light will burn until the holding circuit is broken. When the local operator inserts the plug in the trunk jack one contact is broken and another one is made. When the lower contact is broken, ground is removed from the lamp and the holding winding of relay *R*, extinguishing the lamp and allowing the relay to drop back to normal. When the upper contact on the jack makes, a ground connection is placed on the winding of relay *S* causing it to operate. When the *S* relay operates, a direct current path is provided through the *H* relay for current from the distant switchboard; thus the direct current loop is closed and the supervisory lamp on the distant switchboard is extinguished. This same current passing through the *H* relay causes it to operate, closing the local direct current loop through the 250-ohm resistor, and extinguishes the local supervisory lamp. The circuit is now completely set up and the local operator can determine what is wanted and proceed to complete the call.

64. Operation—outgoing call.—When the call originates locally the operation is slightly different. When the local operator plugs into the trunk jack, the make contact places ground on the winding of the *S* relay which operates, closing the direct current loop to the distant switchboard and lighting the line lamp at the distant switchboard. If the line circuit of the distant switchboard uses a line relay, the current from this source will not operate relay *H* so that the local supervisory lamp will remain lighted until the distant operator places the plug of the cord circuit into the line circuit jack. This will then operate relay *H*, extinguishing the local supervisory lamp and the circuit is ready for the conversation.

65. Supervision.—When the distant operator disconnects from the line, the additional resistance of the line relay reduces the current to a value where the *H* relay will drop back to normal, opening the local direct current loop and causing the local supervisory lamp to light. When the local operator disconnects first, ground is removed from the winding of the S relay, allowing it to drop back to normal, opening the direct current loop to the distant switchboard and causing its supervisory lamp to light.

66. Variation of trunk circuits.—The trunk circuit just discussed is typical of one-way automatic one-way ring-down repeating-coil trunks, which are to be found on many switchboards, but it is subject to many variations and extensions. These variations may run from very complex circuits using six or more relays, to the very simple, using one relay and giving only one-way supervision. It is beyond the scope of this text to include a discussion of these many variations.

67. Questions for self-examination.—

1. What is a PBX?
2. What is a trunk circuit?
3. Explain the difference between a two-way and a one-way trunk.
4. Explain the difference between a ring-down and an automatic trunk.
5. Draw a diagram of a two-way ring-down trunk using drops as signals.
6. Could lamps have been used as signals in the above circuit?
7. Where are two-way automatic trunks often used?
8. Draw a diagram of two line circuits and connect them together to form a two-way automatic trunk.
9. What type of trunk is usually used between a large exchange and a PBX? Why?
10. Why are the tip and ring of the line connecting the two switchboards reversed in a two-way automatic trunk?
11. Is the same type of repeating coil used in the repeating-coil trunk circuit as is used in cord circuits?
12. Refer to fig. 53 for the following questions:

a. What is the purpose of the capacitor in series with the *R* lay?

b. Should it be larger or smaller than the capacitor in series with the repeating coil? Why?

c. Which piece of apparatus, by its operation, puts out the trunk lamp?

d. Explain the operation of this trunk circuit for an out-going call.

e. Explain the operation or the trunk circuit for an incoming call.

f. Which relay is a marginal relay?

g. Why must this relay be marginal?

SECTION IX
SELECTIVE RINGING

68. Party lines.—In army and commercial telephone systems it often becomes necessary, in order to conserve plant facilities, to connect two or more telephones to the same line. Such lines are called party lines. Commercial companies use two- and four-party lines extensively. Such subscribers are given a lower rate, because there are some disadvantages to party line service. If all substations are connected to the line in the ordinary manner and code ringing is used to designate which substation is called, each subscriber on the line must listen every time the bells ring and identify his calling code. Because of code ringing the work of the operator is increased and the subscriber answering time is longer. The frequent ringing of the telephone is annoying and disturbing. Because of the fact that several ringers are bridged across the line, transmission losses are increased. On such a line there is nothing to prevent any of the subscribers from listening to conversations of others. A subscriber on a party line can call or be called only when the line is not in use by other parties.

There are two general methods by which conditions on party lines as outlined above may be improved. The first is by use of a lock-out system and the second is selective signaling.

69. Lock-out systems.—A lock-out system makes the line available to only one subscriber at a time but the means to accomplish this must be complicated. Its cost and maintenance are so great that the saving effected in plant facilities is in general less than the cost of the equipment. For this reason such systems are very seldom used.

70. Selective signaling.—Lock-out systems afford absolute secrecy, but a selective ringing system provides a measure of secrecy by calling only one station without disturbing the others. Selective ringing requires only minor changes in substation equipment, and but little additional equipment at the central office. There are three different methods of selective ringing, namely: ringing to ground, pulsating ringing, and harmonic ringing.

71. Ringing to ground.—*a. Operation.*—This system is used extensively on two-party lines. Figure 54 shows the ringing key part of the cord and the way in which the two subsets are connected to the line for this method of signaling. One of the subsets is connected with L_2 to the tip side of the line and the other with L_2 to the ring side. One side of the ringer of each set, instead of being

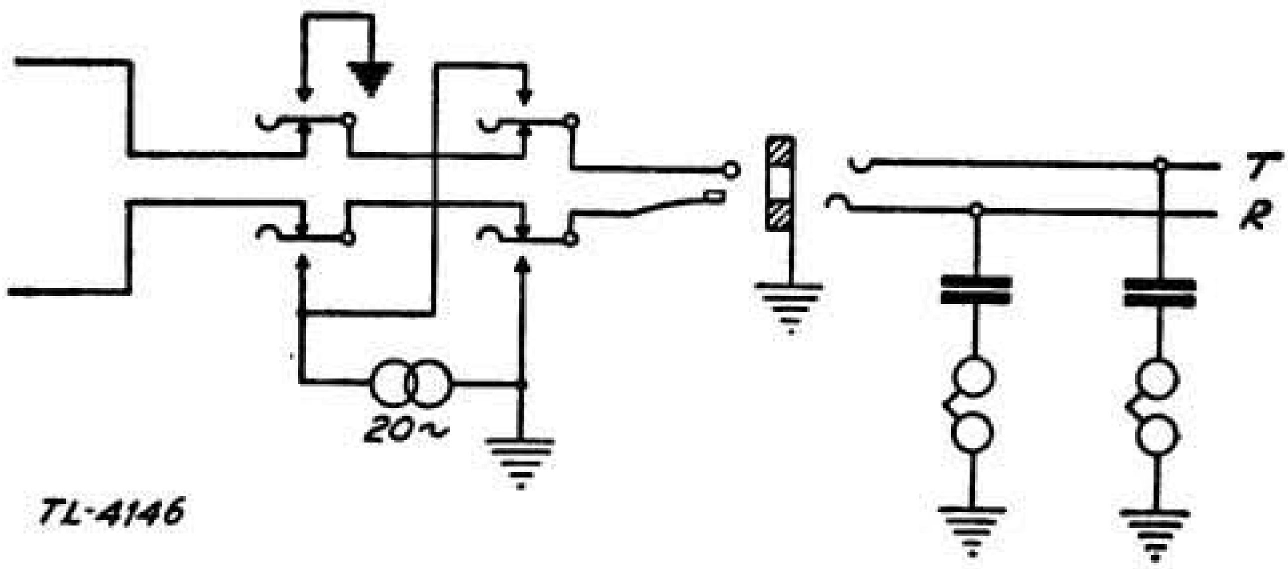

FIGURE 54.—Two-party ringing to ground.

connected to L_1, is connected to the ground terminal which is in turn wired to ground at the protector. At the switchboard, the ringing machine has one side grounded and the other side to the two ringing keys. The keys are arranged so that the one with the red handle will send current out on the tip side of the line, ringing one of the parties, and the one with the black handle will send current out over the ring side and ring the other party. The key with the black handle thrown in the opposite direction is the listening key. In Western Electric switchboards there is a device connected to the two ringing keys to show black when one key is operated and white when the other one is operated. This informs the operator at a glance which key to use to ring the party a second time.

b. Army boards provided with selective ringing.—The army boards BD-80 and BD-89 provide for ringing to ground over either the tip or ring side of the line. Normally the tip side of the line is connected to the grounded side of the 20-cycle supply. By reversing the master ring key the grounded side of the 20-cycle supply is connected to the ring side of the line.

72. Selective ringing with pulsating current.—*a. Biased ringers.*—Before explaining this method of selective ringing it might be well to show how an ordinary 8A ringer can be made to operate on pulsating current. This can be done by biasing the ringer, that is, by attaching a coil spring to one end of the armature as shown in figure 55. Assume the pulsating current to flow in the direction indicated. This current always continues in this direction, but varies in amplitude at regular intervals. Thus the polarity of the electromagnets would always be as shown in figure 55 and the end *A* of the armature would always be attracted and the striker would rest against gong G_2. But by using a biasing spring connected as shown, the tension of this spring can be so adjusted that during the interval when the current is small, the pull of the spring exceeds that of the electromagnets and the striker will hit G_1. The next instant the current increases and the pull of the electromagnets exceeds that of the spring, causing the striker to hit G_2. Thus it will be seen that by adding this biasing spring and adjusting it, the 8A ringer can be

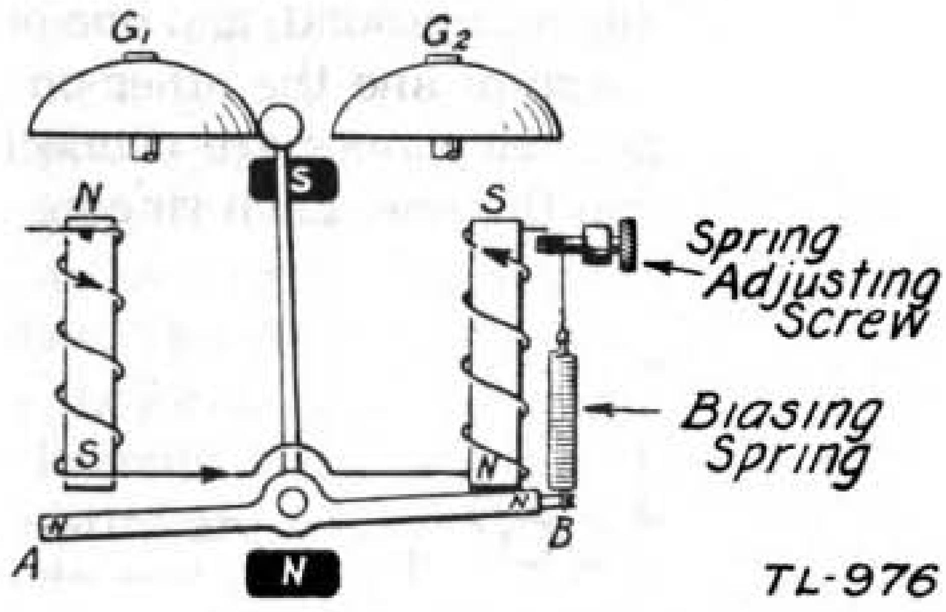

FIGURE 55.—Western Electric Co. 8A ringer.

made to operate on pulsating current.

b. Circuit operation.—Figure 56 illustrates the line and cord circuit arrangements for ringing with pulsating current. In this case both subsets are connected with L_1 to tip and L_2 to ring. Both ringers are biased and are connected between L_1 and ground in each case, but have their terminals interchanged so that one will respond to positive pulsating current and the other to negative. If the ringers were connected between ring and ground on common-battery systems, without a capacitor, direct current would flow from the ring side through the ringer to ground and bring in the line lamp permanently. It is impracticable to ring with pulsating current through a capacitor, so that four-party ringing can be used only on local-battery systems when this method is used.

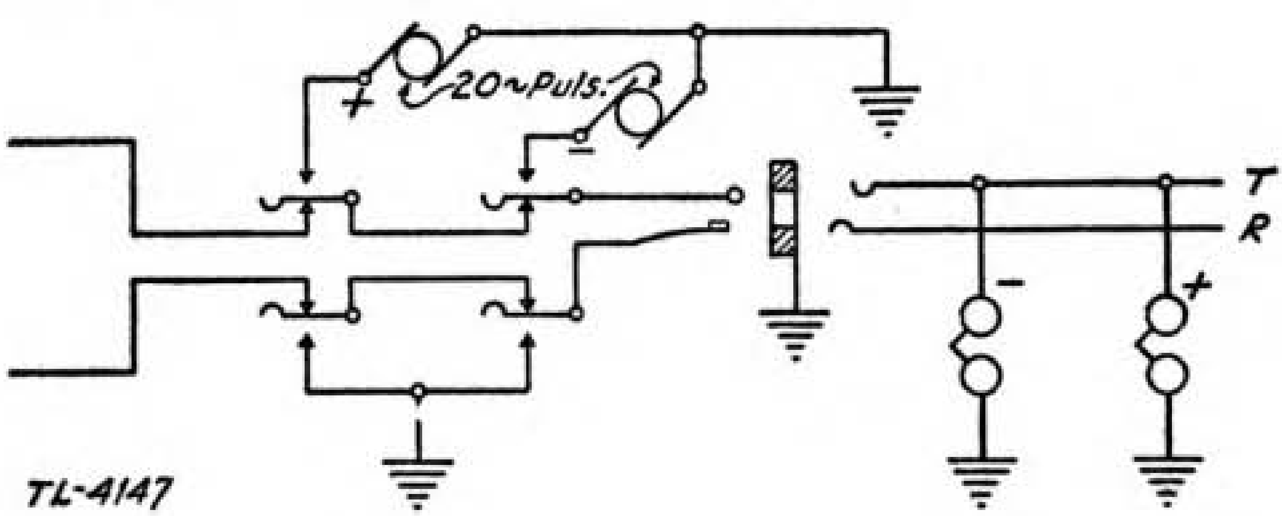

FIGURE 56.—Two-party ringing pulsating current.

73. Four-party selective ringing.—*a. Relays.*—Although four-party selective ringing is seldom seen in an army system it is used a great deal commercially. The four telephones are all connected with L_1 to tip and L_2 to ring. Each telephone contains a relay which is connected between the capacitor and L_1. This relay operates on alternating ringing current and has one make contact. This make contact is in series with the ringer. All ringers are biased. Two of the ringers are connected between tip and ground, one of these will operate on positive pulsating current and the other on negative. The other two ringers are between ring and ground, and one of these will operate on positive pulsating current and the other on negative. Figure 57 shows the way the four telephones are connected and the way ringing current is placed on the line. Each ringing key consists of a

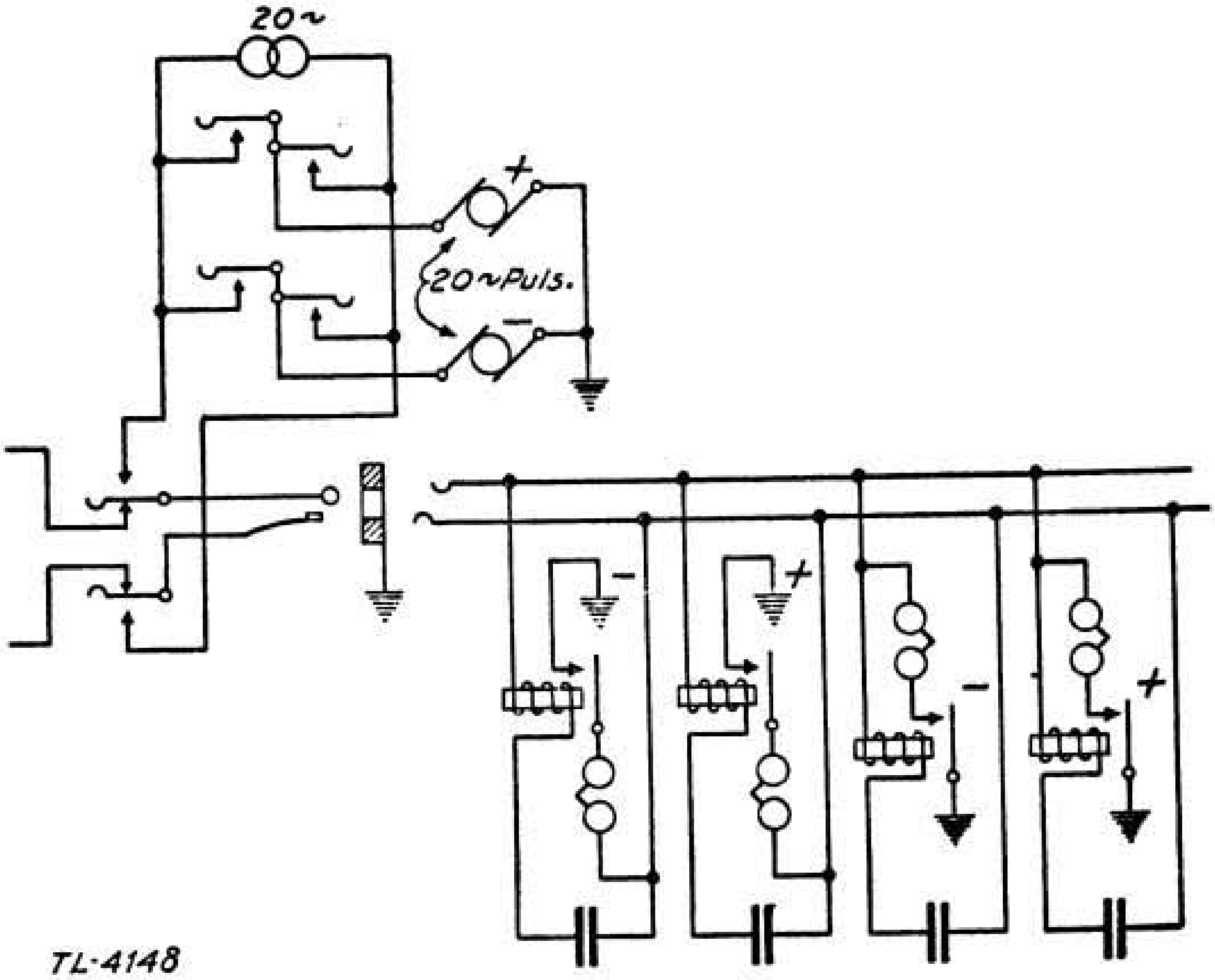

FIGURE 57.—Four-party ringing with relays.

master key and four plunger keys. These plunger keys are marked *W*, *R*, *J*, *M*, respectively, and when any one is depressed it locks and remain down until another is depressed. One button connects positive pulsating current to the tip contact of the master key; another negative pulsating current to the tip contact; another positive pulsating current to the ring contact; and the fourth, negative pulsating current to the ring contact. Alternating current is also connected across the tip and ring contacts of the master key. To call any party the operator presses the proper key which connects pulsating current of proper polarity to the proper side of the master key. The master key is then operated and this places alternating current through all of the relays causing the four to operate and make their respective contacts, but since pulsating current was applied to only one side of the line and that of only one polarity, only the one ringer will operate, the other three remaining silent. The grounding of the ring side of the line during ringing is not objectionable because the cut-off relay has removed battery from the line and the master key has removed battery from the calling cord. When ringing on a single-party line the alternating current operates the ringer instead of the relay.

b. Gas tubes—Four-party selective ringing.—A more recent development in four-party selective ringing employs a cold cathode, gas filled tube which replaces the relay and also eliminates the condenser in the ringing circuit of the subset. The tube is interchangeable with the relay and no change is necessary on the cord circuit at the central office. The 20-cycle a-c voltage applied to the line to operate the relay, however, is not required in this system. The tube contains three elements, a control anode, cathode and an anode, and its characteristics are such that a potential of 75 volts applied across the cathode and control anode will ionize the gas so that the tube will conduct current. The tube is also a rectifier since no current will flow between the anode and cathode except when the anode is made positive with respect to the cathode. Figure 58 shows a four-party line employing gas tubes in the ringing circuits. The tubes perform the same function as the relay in figure 57. When the gas in the tube is ionized, the ringer circuit is completed through the tube. The 150,000-ohm resistor in series with the control anode limits the current flowing between control anode and cathode. Pulsating voltage applied across either tip or ring and ground will ionize the gas of the tubes connected to that side of the line, and current will flow through the ringer circuit where the anode of the tube is made positive with respect to the cathode. Whether the anode or cathode of the tube is connected to the line or ground is determined by the bias of the ringers. One of the ringers on the tip side of the line will respond to negative and the other to positive current. Those on the ring side are also biased oppositely. The advantage in using the gas tube is that the tube requires no maintenance, has a long life, occupies less space in the subset, and is less expensive.

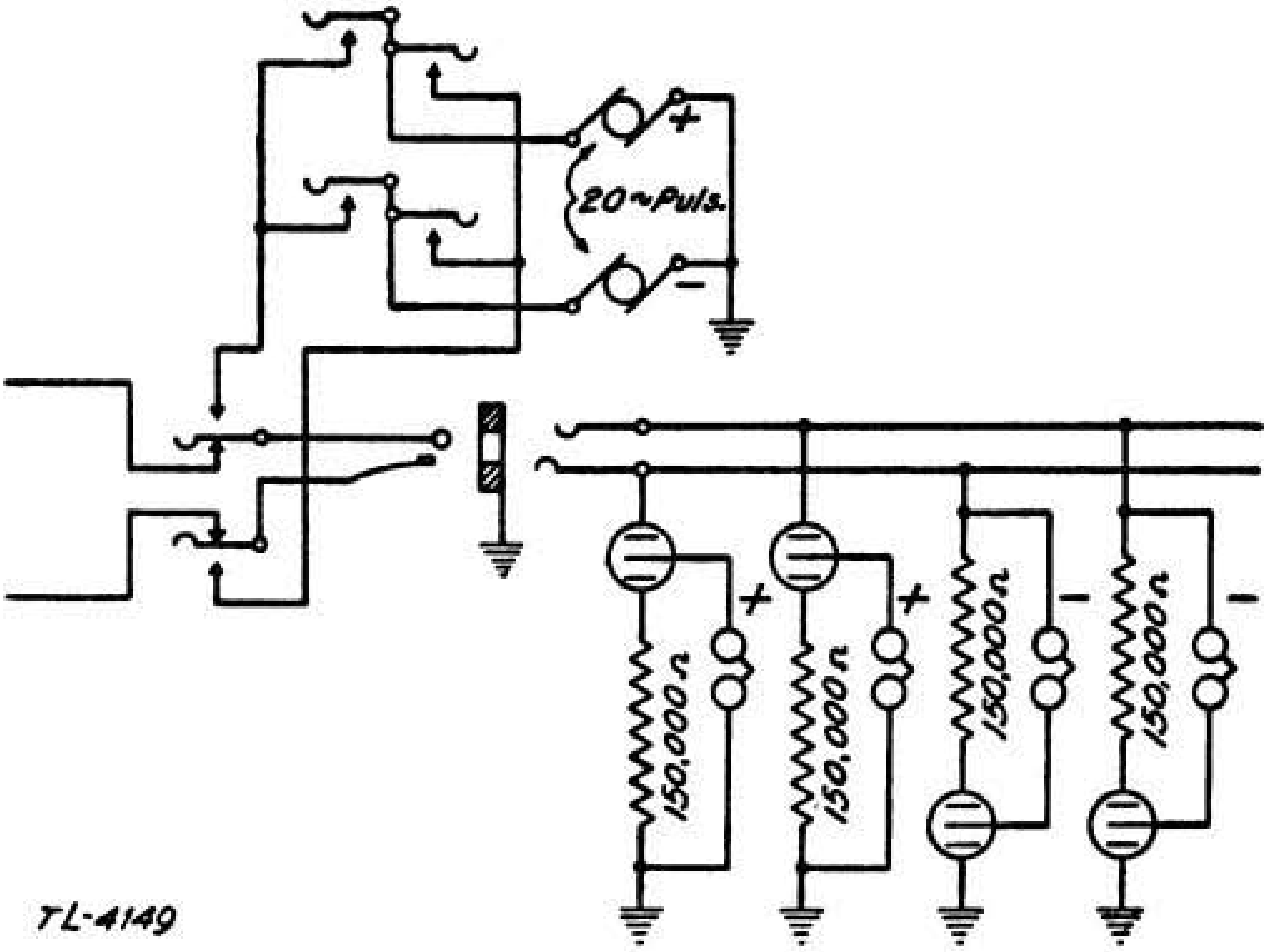

FIGURE 58.—Four-party ringing using gas tubes.

74. Harmonic ringing.—There is another four-party selective ringing system called harmonic ringing. The ringers of the subsets are connected across the line but these ringers are of a somewhat different design than that shown in figure 55. The armature, instead of being pivoted, can be moved only because of the spring in the clapper rod. This rod is mounted as a reed and each of the clappers for a given line has a different weight. The weight of each clapper is such that the frequency of vibration of the rod is that of one of the frequencies of alternating current generated, and the selection of frequencies for ringing is controlled by a key similar in design to that used in the four-party pulsating system. Instead of connecting ringing current to one side of the line only with the other side grounded, the key in this instance connects the ringing current across both tip and ring contacts of the master key. The frequencies are either 16.6, 33.3, 50, and 66.6 or are 30, 42, 54, and 66. All ringers receive ringing current each time the line is rung, but only that ringer which is tuned to the frequency connected to the line responds. Ringing machines and ringers with this system must be closely adjusted and maintenance is high.

75. Party lines in army systems.—In army practice party line service is usually only a temporary expedient, the necessity for which ceases when adequate plant facilities are available. By confining the party line service to unimportant and little used telephones, usually code ringing or ringing to ground will prove satisfactory.

76. Questions for self-examination.—

1. What is a party line?
2. What is meant by code ringing?
3. Give two disadvantages of code ringing.
4. Name two methods by which these disadvantages may be overcome.
5. What is a lock-out system?
6. Why are not lock-out systems in more common use?
7. What is meant by selective signaling?
8. Name three methods of accomplishing selective ringing.
9. Show by means of a diagram how you would connect two telephones to a line so as to obtain selective ringing using only alternating current.
10. Draw a diagram of the ringing key combination that will accomplish the above.
11. Draw a diagram of a polarized ringer, equip the ringer so that it will operate on pulsating current and show the direction of the current through the windings for proper operation.
12. Show by means of a diagram a schematic of the line and cord circuit arrangement for two-party selective ringing using pulsating current.
13. Why is it that you cannot ring through a capacitor with pulsating current?
14. Explain operation of four-party selective ringing employing relays in subset.
15. What are the advantages of the gas tube over the relay used in the subsets in four-party selection?
16. Explain operation of four-party selective ringing employing gas tubes in subsets.
17. What is harmonic ringing?
18. What is a serious disadvantage of harmonic ringing?

SECTION X
AUXILIARY CIRCUITS

77. Auxiliary circuits.—The circuits additional to those already described are called auxiliary or miscellaneous circuits. It will be noted that certain of these may be common to both small nonmultiple switchboards and larger multiple switchboards. Also these circuits are either in the nature of refinements in the case of nonmultiple boards or additions to multiple boards performing functions of a more complex nature.

The following is a list of the more general of these circuits:

Auxiliary circuit	*Generally used with*
Line-pilot circuit	Multiple or nonmultiple board
Supervisory-pilot circuit	" " " "
Night-alarm circuit	" " " "
Generator-switching circuit	" " " "
Battery-switching circuit	Nonmultiple board
Transfer circuit	Multiple or nonmultiple board
Conference circuit	" " " "
Order-wire circuit	Multiple board
Test-cord circuit	" "
Wire chief's order-wire circuit	" "
Fuse-alarm circuits	Multiple or nonmultiple board
Peg count	Multiple board
Position and master clock circuit	" "
Supervisor's circuit	" "
Monitoring circuit	" "
Busy-back circuit	" "
Trouble-tone circuit	" "
Howler-cord circuit	" "

78. Line-pilot circuit.—On a busy switchboard some of the line lamps are occasionally obscured by the cords to other lines. If one of these hidden lamps should come on, the operator might overlook it and thus delay service on the call. The line pilot lamp is arranged to light every time that any line lamp comes in and this prominently placed signal light informs the operator that some party desires to place a call. The circuit by which this is accomplished is known as the line-pilot circuit. Figure 59 shows one type of circuit, and examination of this circuit reveals the fact that the battery side of all line lamps is connected to battery through a line-pilot relay. This relay is energized all the time that any line lamp is lighted. The armature of this relay closes a circuit through the line-pilot lamp causing it to light.

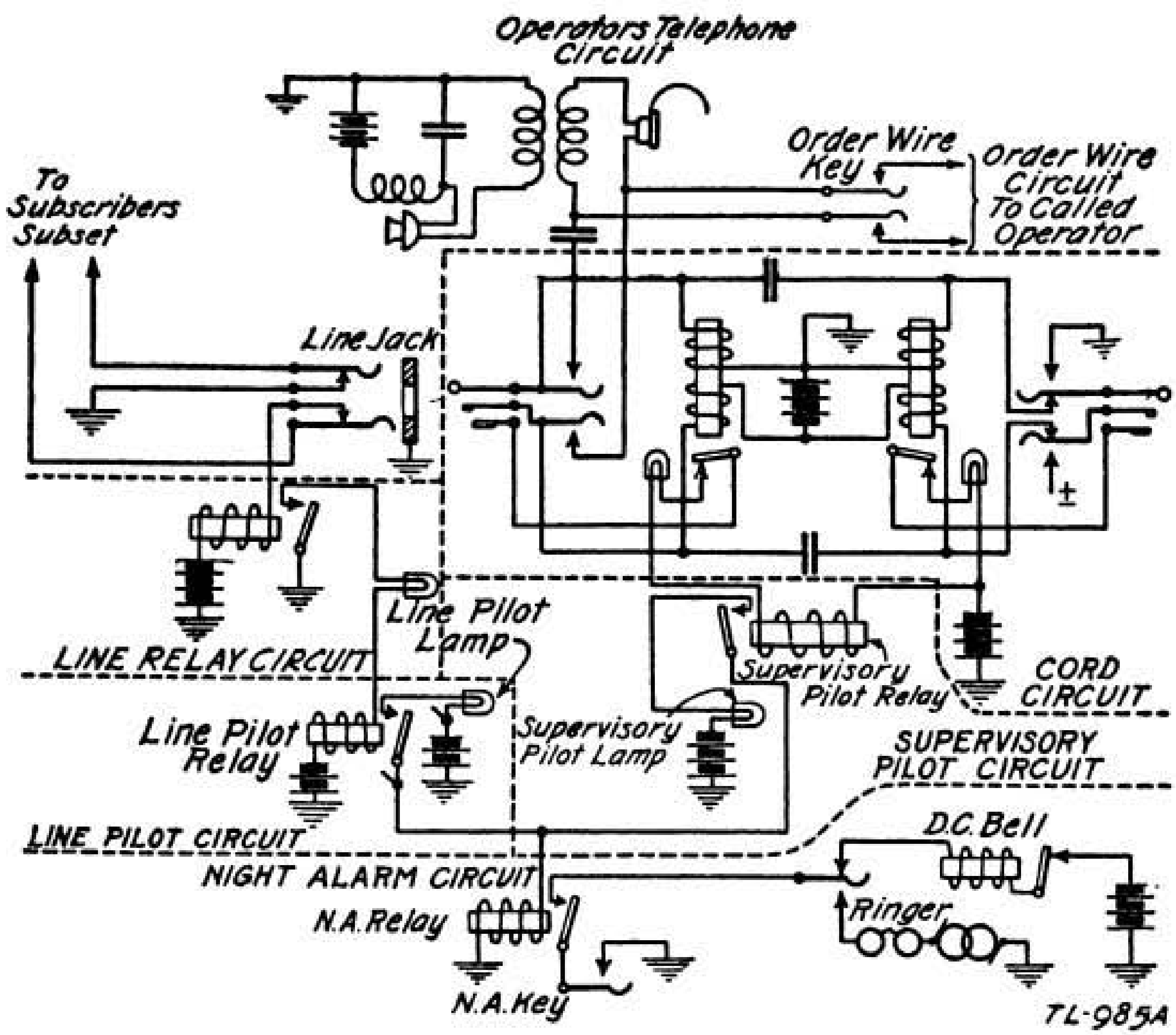

FIGURE 59.—Common-battery switchboard circuits.

79. Supervisory-pilot circuit.—When traffic through a switchboard is light, the operator is apt to overlook supervisory lights as they come in, and it is considered desirable to provide a pilot for those lights. Toll switchboards are generally arranged so that the pilot comes on when any supervisory signals come in, while in local switchboards it lights only when an answering supervisory light comes on. Figure 59 shows retardation type of cord circuit equipped with a supervisory pilot that will light each time an answering supervisory lamp is lighted. This pilot circuit is connected to the night alarm circuit which is common to the board. Shunt type cord circuits are not arranged for supervisory pilot circuits, because of the fact that if several cord circuits were up in connection, sufficient current would be flowing to hold the pilot relay operated, thus giving a false pilot signal.

80. Night-alarm circuit.—The flow of current to each pilot light is over a common lead which goes to ground through the winding of the night-alarm relay. Thus, this relay will operate and remain operated as long as either pilot lamp is lighted. This closes a circuit which contains a key and a signaling device in series across a source of electromotive force. When the key is open no current will flow to operate the signaling device, but when the key is closed the signaling device will operate. This night-alarm key permits the operator to silence the night-alarm signal while he is at the switchboard, and to arrange for it to ring and call him to the switchboard during periods when traffic is light and does not require his full time at the switchboard. It will be noted that there is a selector switch in the night alarm circuit shown in figure 59 and that this switch permits the operator to cut either a ringer or a vibrating bell into the night-alarm circuit as the signal.

81. Generator-switching circuit.—The generator-switching circuit of a common-battery switchboard serves the same purpose as on a local-battery switchboard. A key allows the operator to transfer the normal ringing power source to an emergency source. This emergency source may be another power ringing supply or a hand generator. Figure 60 shows a typical arrangement of a generator-switching circuit.

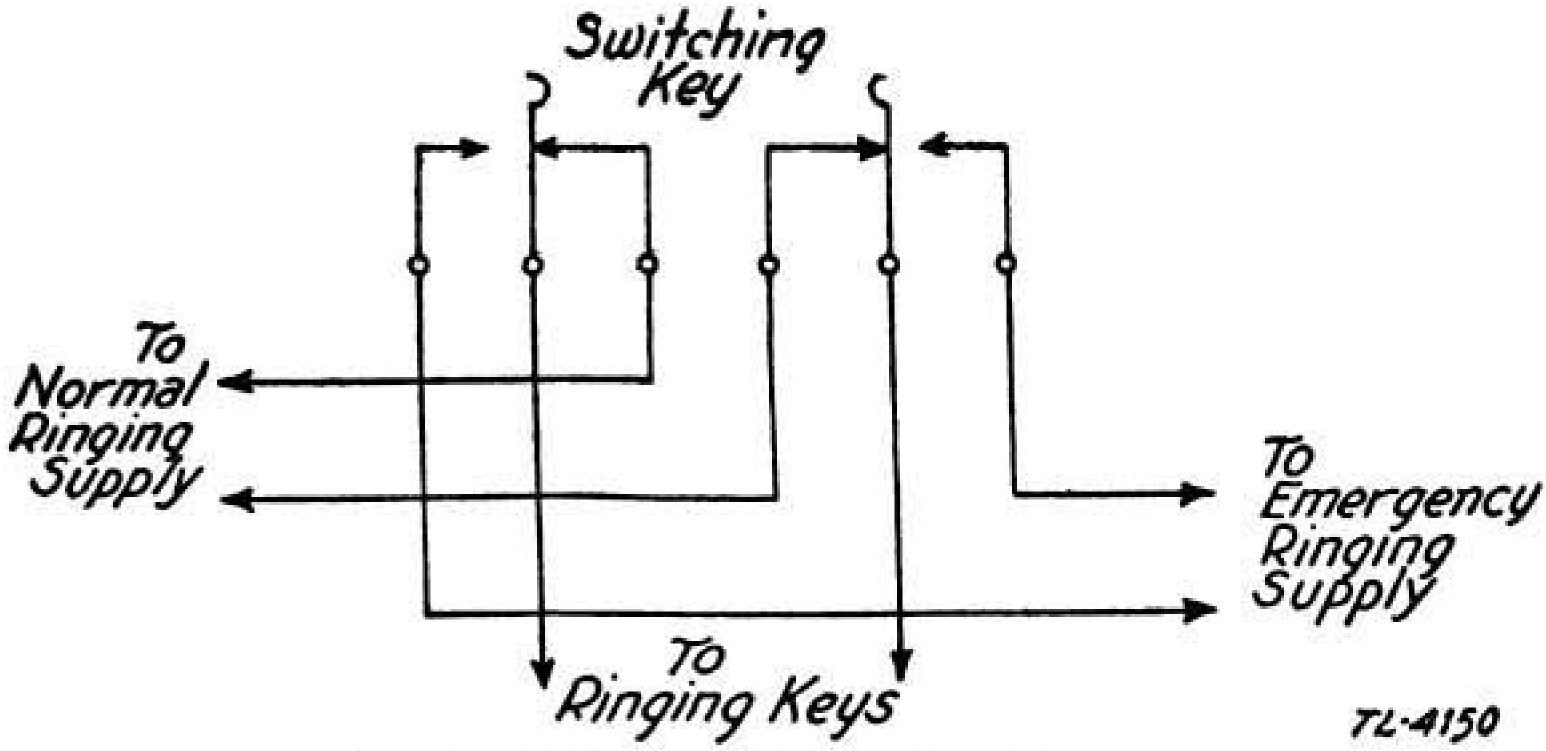

FIGURE 60.—Generator-switching circuit.

82. Battery-switching circuit.—Not all small switchboards are operated throughout the twenty-four hours of the day. Commercial PBX switchboards are usually equipped so that the operator can cut off battery and ground when taking the board out of service. The battery-switching circuit is not used on many army switchboards, unless they are installed as branch exchanges in office buildings or arsenals, etc.

83. Transfer circuit.—This circuit is for the interconnection of positions to enable several positions to be handled by one operator when the load is light. The circuit is similar to that used for the same purpose in local-battery switchboards. Throwing of the transfer key cuts the operator's telephone circuits together, enabling an operator on any one position to talk to subscribers over cords of the other positions.

84. Conference circuit.—If the type of service at a telephone central requires a circuit common to a calling party and two or more called parties, a switchboard with a conference circuit will be used. Figure 61 shows a typical conference circuit with five jacks. Such an arrangement would allow a conference between the calling party

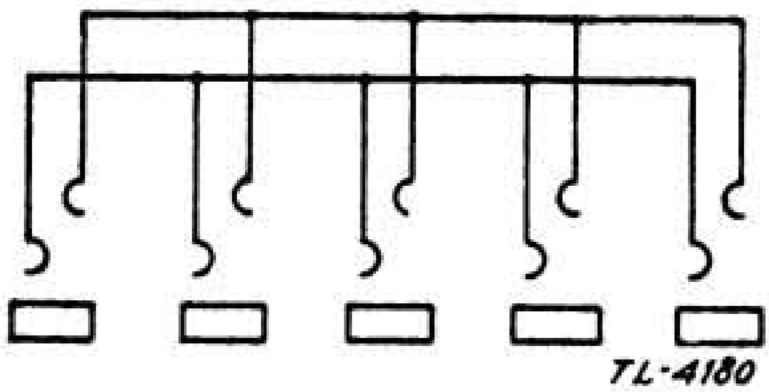

FIGURE 61.—Conference circuit.

and four called parties. All lines plugged into this circuit will be in parallel and therefore conversation is possible between all parties so connected. Army common-battery switchboards having conference circuits are BD-80 and BD-89.

85. Order-wire circuit.—An operator receiving a local call which must be trunked to another exchange for completing must make known to the operator at the other end of the trunk circuit the number desired by the calling party. If a separate means of talking between the two operators is to be provided, then auxiliary circuits are necessary. These circuits connect the telephone sets of

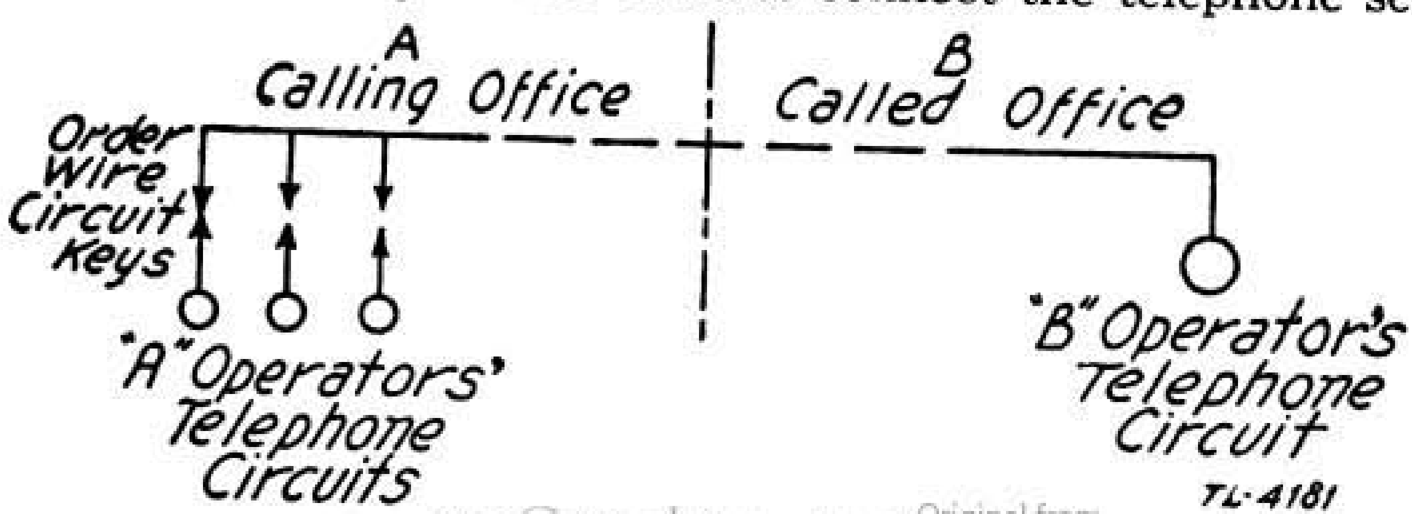

FIGURE 62.—Order-wire circuit.

the two operators together. Since one way trunking is more general, the order wire circuit is established by an order wire key at the switchboard of the calling office. Figure 62 is a schematic of a typical order wire circuit between exchanges *A* and *B*. It is to be noted that straight forward trunking, discussed in section XV, is superseding the order wire circuit for trunking operation. Similar order wire circuits may be used between operators of a multiple *A* switchboard, or between operators of an *A* board and a *B* board (see section XIV for usages of *A* and *B* boards).

86. Test-cord circuit.—A local exchange of any size will have a test board for testing local lines and line equipment.

It is necessary in this case that provision be made to connect any line appearing on the switchboard to the testboard for test purposes. The circuit for such connections is provided by one or more test cords at each of one or more positions on the switchboard. One end only of the test cord circuit appears in the form of a plug at the switchboard. The other end of this circuit terminates at the test board. Thus, at the direction of the person at the test board, any line circuit may be brought into the test board. It is now apparent that some means of communication between the test board and switchboard is needed. This need is filled by the wire chief's order-wire circuit which is taken up in the next paragraph.

87. Wire chief's order-wire circuit.—This circuit is similar to the one discussed in paragraph 85 as far as operation is concerned. The order wire key for completing the circuit is at the test board and there will be a key for each position which has test cords.

88. Fuse-alarm circuit.—When a fuse-alarm circuit is incorporated in a switchboard it is used to indicate a blown fuse on the battery supply line to cord circuits and other fused battery circuits. This alarm circuit is designed to close a common alarm circuit when any fuse blows. Thus the fact that a circuit has lost battery supply is indicated. Figure 63 shows a type of fuse-alarm circuit. Figure 73, paragraph 104, section XII shows the type of fuse used and the operation of the fuse in the alarm circuit.

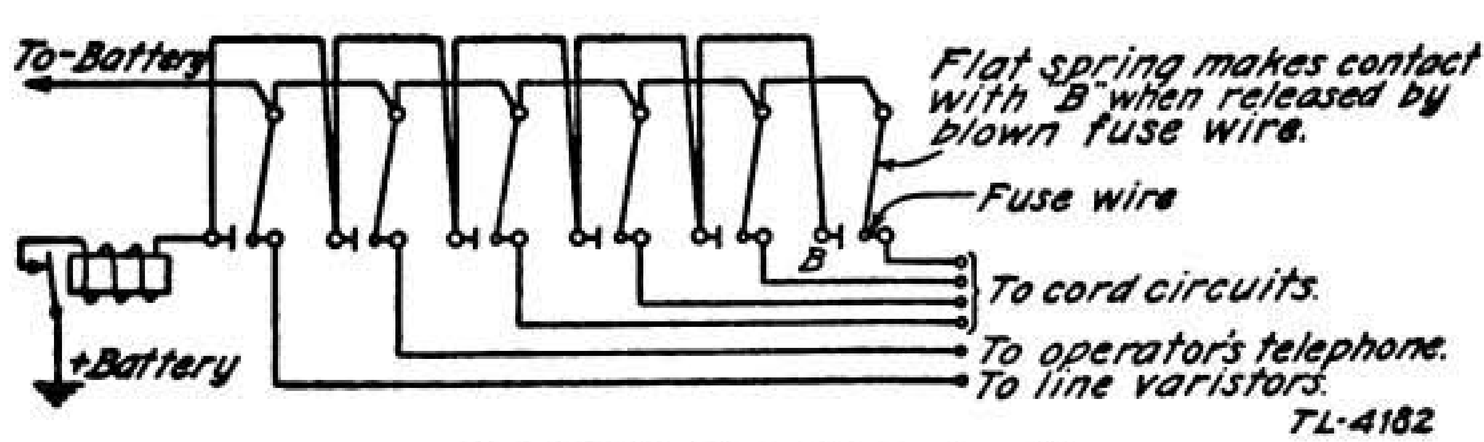

FIGURE 63.—Fuse-alarm circuit.

89. Other circuits.—The following list includes other auxiliary circuits which are beyond the scope of this text. (Brief mention is made of these in section XIV.)

Peg-count circuit
Position- and master-clock circuit
Supervisor's circuit
Monitoring circuit
Busy-back circuit

90. Questions for self-examination.—

1. What is an auxiliary circuit?
2. Name five auxiliary circuits usually found on a nonmultiple switchboard.
3. What is a line-pilot circuit?
4. What is the purpose of the above circuit?
5. What is the purpose of the supervisory-pilot circuit?
6. Do all switchboards contain a supervisory-pilot circuit?
7. Why is it not practicable to have a supervisory-pilot circuit on a switchboard with the shunt-out type of supervision?
8. Draw a diagram of a line circuit including line-pilot circuit and night-alarm circuit. Make your line circuit of the cut-off jack type.
9. Draw a diagram of a simple generator-switching circuit.
10. What is a transfer circuit?
11. What is the purpose of the conference circuit?
12. What is one method used to provide communication between calling and called office operators when a trunking connection is to be made?
13. What is a test-cord circuit?
14. Why would a person at the local test board require a wire chief's order-wire circuit?

SECTION XI
DISTRIBUTING FRAMES

91. Purpose of distributing frames.—In addition to the switchboard, a central office is equipped with facilities for permanently terminating the incoming lines and distributing them to the various jacks. It is the purpose of this section to give a description of the distributing frames found in various size offices. It is important that the functions of these frames be thoroughly understood. The principal function is to provide means for terminating the outside lines and also the switchboard lines in a permanent and orderly manner, and at the same time provide facilities for changeably interconnecting these permanently terminated lines among themselves by means of jumpers or cross connecting wires. The MDF (main distributing frame) is a natural dividing point between the outside plant and inside plant or between the outside lines and the switchboard lines. Therefore the MDF is the logical location of the central office protectors, to be discussed in a later section, which guard the inside plant from all outside hazards. The fact that all outside lines and all inside lines are permanently terminated on the MDF in such manner as to be readily identified and easily accessible, without disturbing any of the permanent wiring, makes the main frame the most convenient point from which to conduct many of the tests that are required both on the outside and inside lines. Finally, the use of another type of distributing frame makes it possible to shift the load of different operators and to change subscriber's numbers. This may not seem very important in a small office with one nonmultiple board, but in a large exchange with a multiple board it is of utmost importance. In fact without the use of such frames the wiring in a large central office would be a hopeless tangle.

92. Distributing frames for small offices.—Distributing frames are divided into two classes; wall and floor frames. In most small offices the wall-type frame is used; however, this will vary with local conditions such as probability of expansion, type subscriber served, etc. In small army exchanges that use the switchboard BD-80 or BD-89, floor type frames are used. For the very small commercial installations with 80 or less lines, the wall frame is built up of units each one of which will take care of 20 pairs. This is the simplest form of frame and consists of two terminal blocks. The pairs from the outside are fastened to contacts on one block and the pairs running to the board are fastened to the other block. The two blocks are then interconnected by wires called jumpers, which can be fastened to any desired set of terminal lugs on either end. These jumpers are run through rings in order to make a neat and orderly arrangement and to aid in tracing out circuits. All connections are made by soldering. In actual practice protective devices are mounted on either one or the other of these terminal blocks. By the use of such a simple frame a place is obtained for mounting protective devices and also a convenient place to open the circuits for testing purposes. Schematically the circuit through the frame is as shown in figure 64.

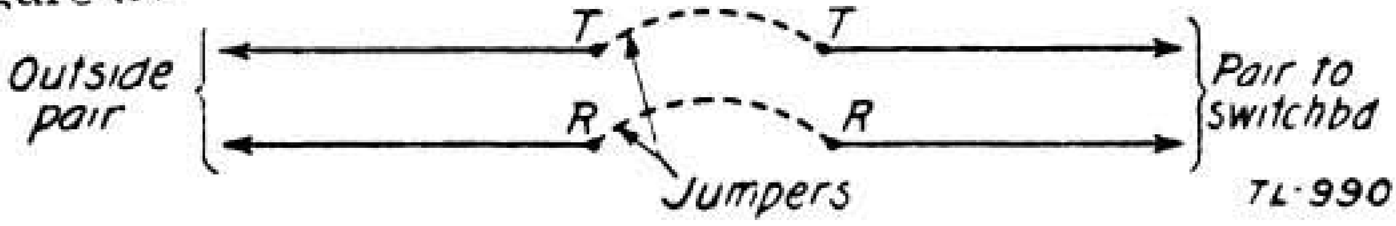

FIGURE 64.—Connections through a distributing frame.

93. Types of floor frames.—In general floor frames are of three classes:

(1) Those that have two vertical sides as the *FM-19* (TC-1) and BE-79 (TC-2). This type frame is used in small army exchanges.

(2) Those that have one side vertical and the other side a combination horizontal and vertical. This type is used in larger army exchanges and will be discussed later.

(3) The other type of floor frame is the standard frame that has one side vertical and the other horizontal. On all floor-type frames the two sets of terminal blocks are on opposite sides of the frame. Usually they are arranged in vertical rows on one side and horizontal rows on the other. These two sides are then referred to as the vertical and horizontal sides respectively. Figure 65 shows part of a typical distribution frame. The protectors are mounted on the vertical side. On the horizontal side are found the terminal blocks; each mounted in a horizontal position. When the vertical side is the switchboard side the frame is known as type *A* frame. With the horizontal side connected to the board, it is known as type *B* frame. The bridle rings are to assist in an orderly running of jumper wires between protectors and terminal blocks.

94. Distributing frames for large exchanges.—In large exchanges where all switchboards are of the multiple type, there is a great increase in the amount of central office wiring necessary. Thus a more elaborate system of distribution is required. To accomplish this it is common practice to use two distributing frames and, to distinguish between them, they are known as a main frame and intermediate frame. Each of these frames has a vertical and a horizontal side. The protectors are mounted on the vertical side of the main frame and it is to this side that the outside pairs are attached. Figure 66 shows the manner in which connections are made through the two frames.

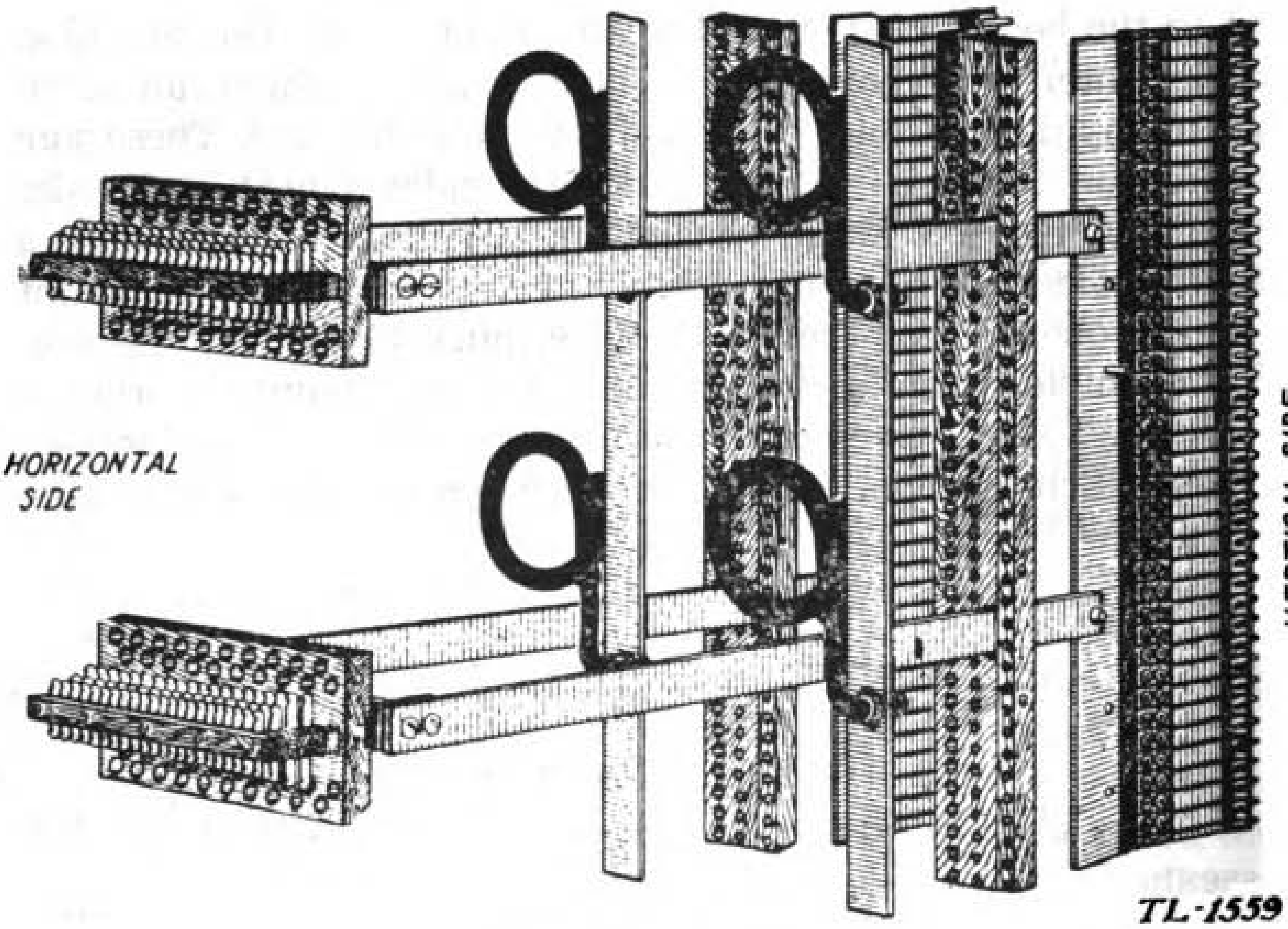

FIGURE 65.—Floor frames.

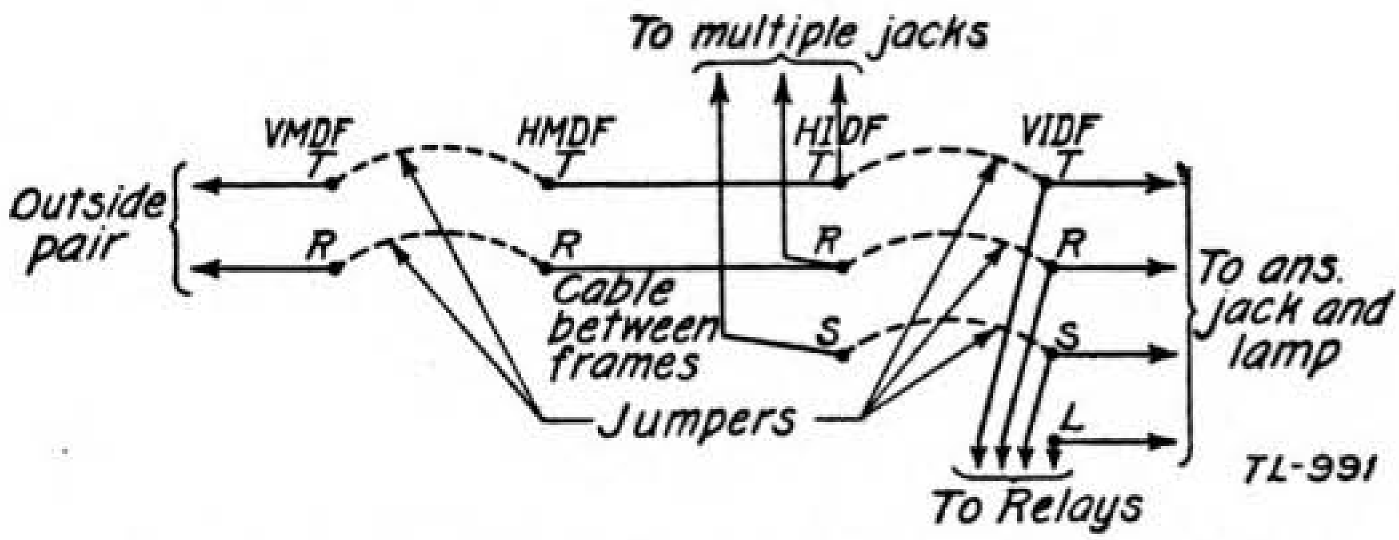

FIGURE 66.—Connections through standard MDF and IDF.

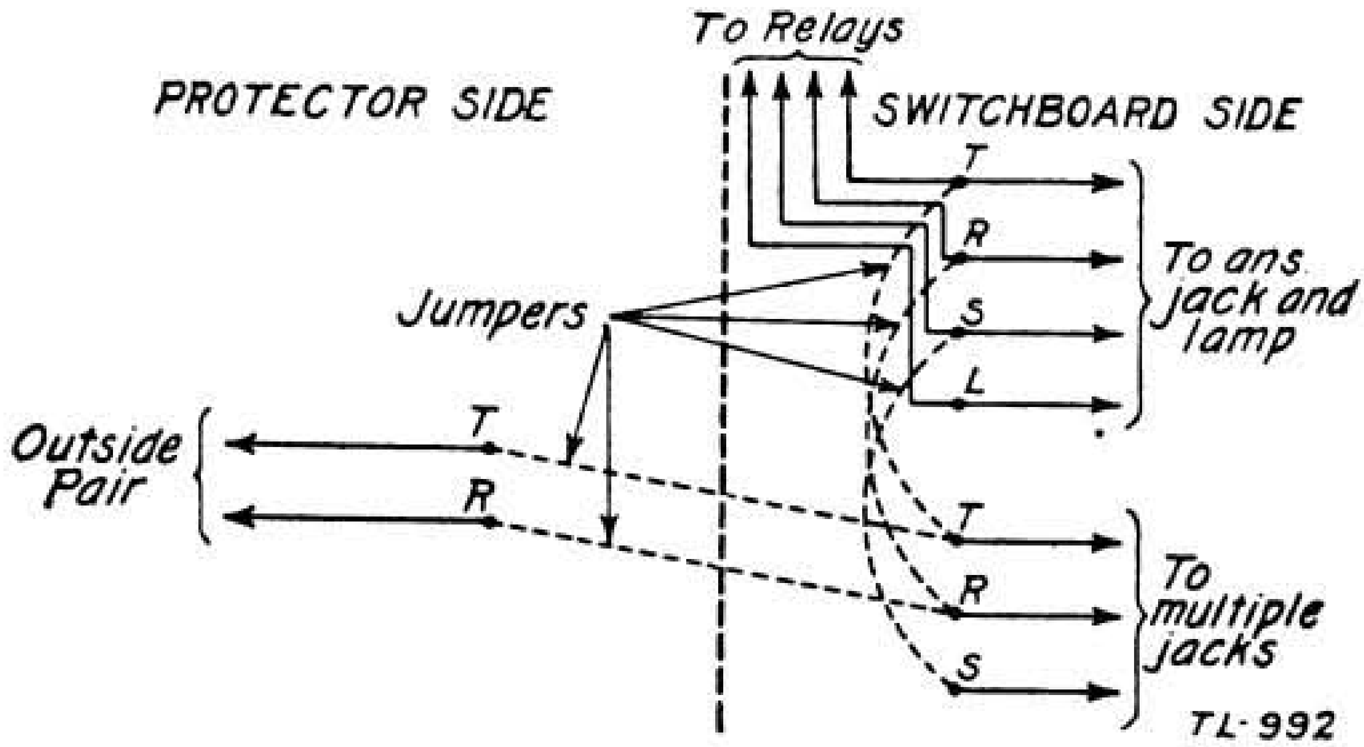

FIGURE 67.—Connections through combination MDF and IDF.

In the diagram, *VMDF* means vertical side of main distributing frame, etc. It will be noticed that two-wire jumpers are used on the main frame and three-wire jumpers on the intermediate frame. Since the telephone number is determined by the multiple jack to which the telephone is connected, the numbers of telphones are changed by shifting jumpers on the main frame. The load of the operators can be varied by shifting jumpers on the intermediate frame. The above means of distribution is used in all large commercial exchanges.

95. Distributing frames for larger army exchanges.—In some of the larger exchanges in the service which use multiple boards, a means of distribution is used which differs somewhat from the system described above. One frame known as a combined frame is used instead of the two. This method, of course, costs less but also some of the advantages of having the two frames are lost. The protectors are mounted on the vertical side of this frame as before and the outside pairs terminate on this side. The other side of this frame is a combination horizontal and vertical side, the lower half being horizontal and the upper half vertical. The lower half corresponds to the *HMDF* and *HIDF*, thus doing away with the cable that was used between frames and shown in figure 66. The upper half corresponds to the *VIDF*. Thus the two sets of jumpers are used on the one frame. Figure 67 shows a schematic diagram of this arrangement.

96. Switchboard cables.—From the distributing frame it is universal practice to conduct the lines to the switchboard in switchboard cables. With 100-line and smaller boards, it is not uncommon to use a single cable to carry all the pairs. With some small boards and all larger ones, it is common practice to use as many 20-pair cables as may be required. These cables are usually a flat oval in cross section, so that they will pile evenly and maintain their place on the cable rack. The pile of cables is laced together and to the cable rack which supports it. This same type of 20-pair cable is used between the *HMDF* and *HIDF* in all large exchanges.

97. Cables from outside plant.—The cables of the outside plant are usually more easily introduced from below to the distributing frame. If the plant is underground construction, the entrance will be made from the cable vault, and if the plant is aerial, the entrance will usually be made through iron pipes which are brought down the office pole and come up beneath the distributing frame. In a small office with a wall frame aerial cables are often brought to the office by means of a cable rack extending from the building to the office pole.

98. Questions for self-examination.—

1. What is a distributing frame?
2. What is the purpose of using a distributing frame in a central office?
3. Describe the wall type of frame.
4. What type frame is used in a small office?
5. How is a jumper connected to the terminal contacts?
6. What type of main frame is used in a large exchange?
7. What is the difference between a type *A* main frame and a type *B*?
8. Upon which side of a main frame are the protectors mounted?
9. Under what conditions is it most practicable to use a separate main and intermediate frame?
10. When is it practicable to use a combined *MDF* and *IDF*?
11. How many conductors are there in an *MDF* jumper?
12. How many conductors are there in an *IDF* jumper?
13. Draw a diagram tracing a circuit through separate *MDF* and *IDF*. Show which leads go to the multiple, the jack, and the outside pair.
14. By what means is the *HMDF* connected to the *HIDF*?
15. How are outside cables usually brought in to the main frame?
16. Draw a diagram tracing a circuit through a combined *MDF* and *IDF*.

SECTION XII
CENTRAL OFFICE PROTECTION

99. Types of hazards.—*a. General.*—Telephone apparatus must be protected against electrical hazards which may be due to either natural or artificial causes. Lightning is the only noteworthy example of a natural hazard. Artificial hazards may be created from sources outside the telephone plant, such as excessive voltages or currents induced in the telephone wires from electrical systems and high power radio sending apparatus, being in close proximity to telephone lines; or from sources within the telephone plant, such as the accidental flow of current from the plant power supply in unexpected channels or in abnormal quantities.

Protective equipment must be provided to safeguard persons and property against all such hazards. All protective devices are designed so as to function properly before any damage to plant occurs, but they must not be be so sensitive as to cause unnecessary interruptions to service.

b. Classification of protective equipment.—Practically all outside telephone plant, except such conductors as are completely underground from terminal to terminal, may be exposed to one or more of these foreign hazards. Therefore whenever exposed wires are led into a central office or subscriber station, they are connected first through certain protective devices. The particular protective units employed and the manner in which they are connected into the telephone circuits vary somewhat with particular situations, but in general protective devices are classified as to the type hazard they are intended to guard against:

(1) Those forming a protection against small currents which become a hazard only when flow continues for an appreciable length of time. The heat coil is an example of this type.

(2) Those forming a protection against excessive currents. The fuse is an example of this type.

(3) Those forming a protection against excessive voltages. The air-gap arrestor is an example of this type.

In large exchanges where incoming cable is all underground, it is the practice to omit protector blocks and heat coils and to replace them with dummy apparatus. The only function the protector mounting serves in this case is to provide means for opening the lines for test purposes.

100. Heat coils.—*a. Common type.*—A heat coil consists of a small coil of resistance wire wound around a metal collar to which one end of the wire is soldered. The collar in turn is fastened by a low melting point solder to the cord. The whole is contained in a fibre shell for mechanical protection and heat insulation.

Heat coils are designed to protect against low potential currents. They operate on a small amount of excess current supplied over a period of time. The accumulated heating effect of the small current passing through the winding finally melts the low melting point solder and allows the core and the collar of the device to move with respect to each other. A Western Electric heat coil is installed with one end of the core pressing against a spring and when the coil operates, the core presses this spring in until it makes contact with ground. Thus, a heat coil in operating does not open the circuit but grounds the line. The Western Electric heat coil has a resistance of about 3½ ohms and operate on ½ ampere in less than 3½ minutes. Figure 68 shows a diagram of that coil (with the shell cut away) and the springs between which it is mounted. The coil is mounted

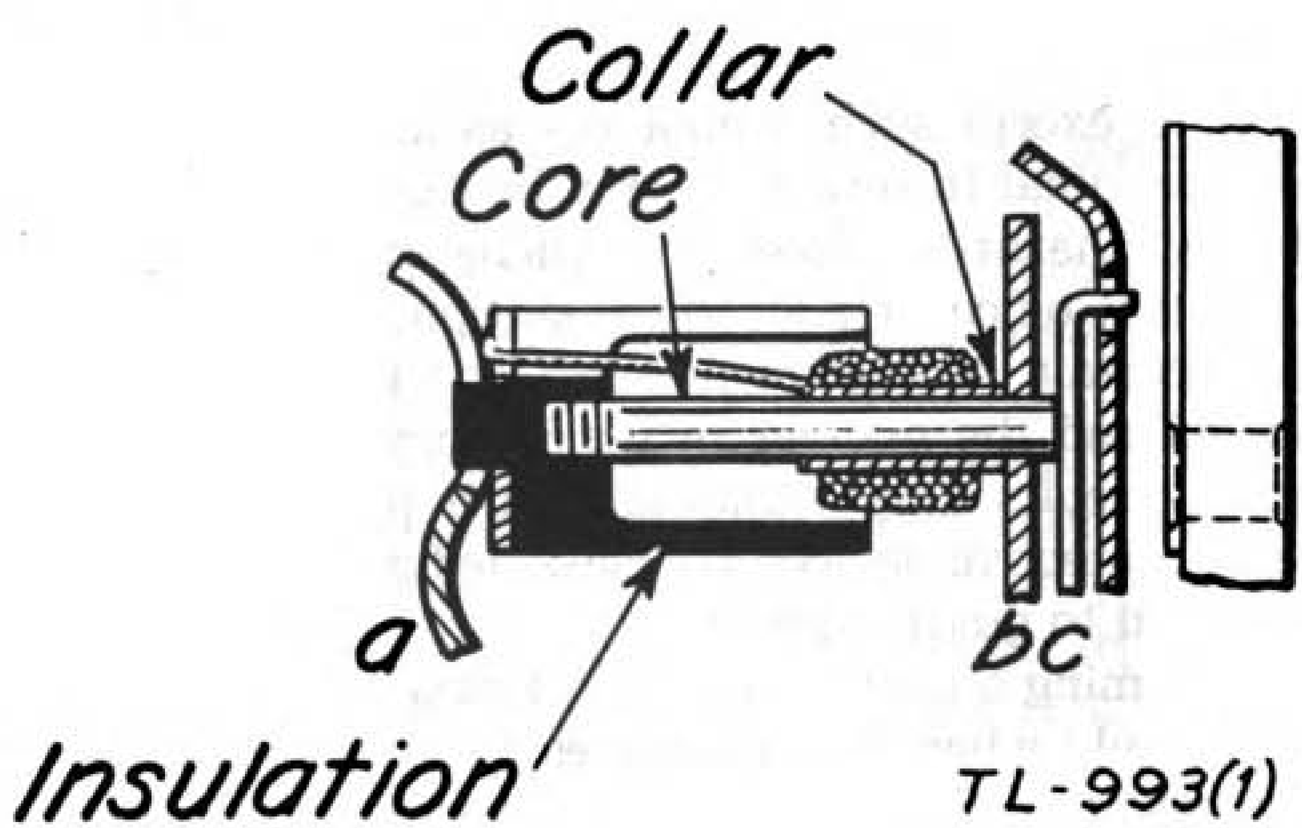

FIGURE 68.—Heat coil.

as shown between springs *a* and *b*, *b* is held rigidly while *a* exerts a pressure on the coil at all times in the direction of *b*. When the coil operates the pressure of *a* forces the core to move through the collar, pushing spring *c* against ground and thereby grounding the line. Thus, low potential current which might have gone through central office equipment and injured it has been provided with a direct path to ground.

b. Self-soldering type.—There is another type heat coil known as the "self-soldering" type. It derives this name from the fact that upon cooling after operation, it resolders itself so as to be again usable by a mere change of position in the protector mounting.

The most widely used coil of this type is shown in figure 69. The coil is provided with a ratchet on its outer edge, one of the teeth of which serves as a detent for the movable arrestor spring as long as the coil is prevented from rotating by the solder. When, however, the solder is melted, the ratchet is allowed to turn thus releasing the spring. These protectors are reset by merely placing the controlling spring in engagement with another tooth of the coil after

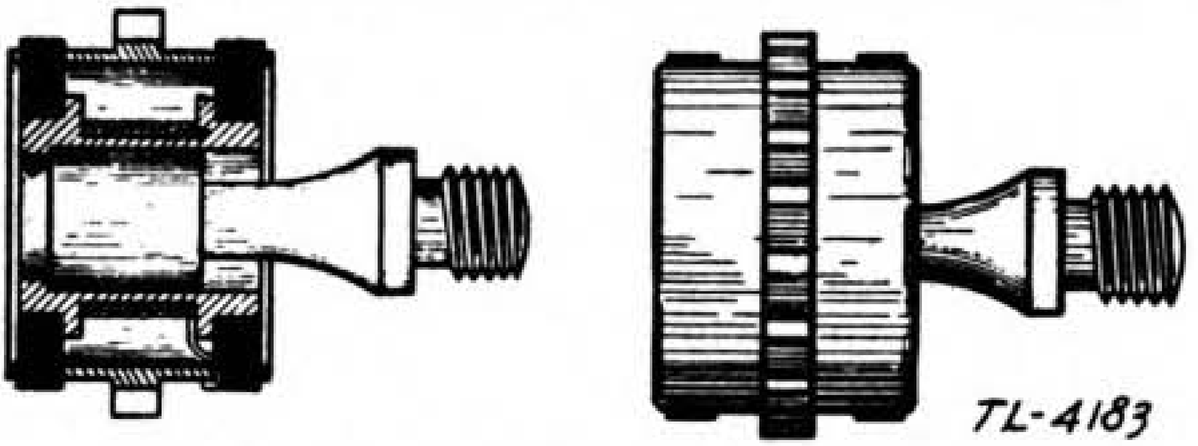

FIGURE 69.—Cook self-soldering heat coil.

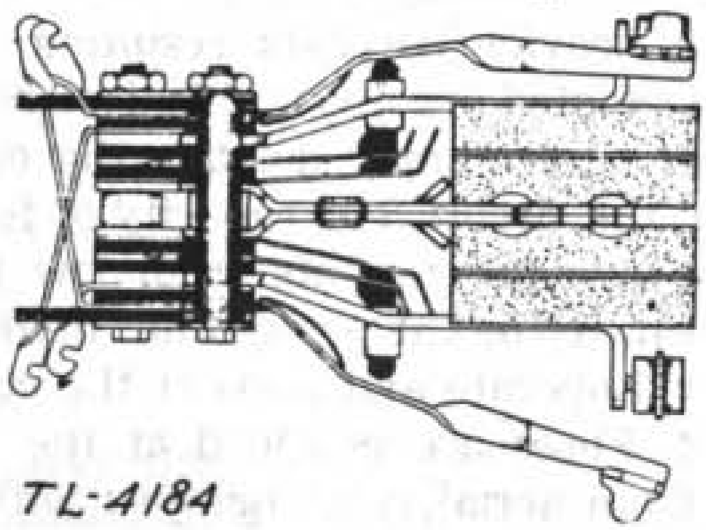

FIGURE 70.—Cook central-office protector.

the solder has again hardened. As shown in figure 70 the protector on top is in its normal position, the ratchet on the heat coil holding the long movable spring in its flexed position. When so held, the circuit from the outside to the inside line wire is completed through the heat coil. Also, by means of the insulating plunger engaged by the mid-portion of the movable spring, the two short inner springs are held out of engagement with the line spring.

The lower side of the protector in figure 70 is shown in the operated position. The solder has melted to the point where the ratchet has turned and released the long outer spring, thus opening the line circuit. Also by releasing the pressure on the insulating plunger, the two shorter springs are allowed to engage the spring forming the terminal of the outside line. The inner one of these short springs is seen to be in permanent connection with the ground plate and it thus serves to ground the outside line. The other one of the short springs also becomes grounded by engaging the now grounded line spring. It forms the terminal of an alarm circuit, which is thus energized to sound an alarm whenever any heat coil operates. This heat coil will operate in less than 210 seconds on 0.5 amperes and will carry 0.35 amperes for 3 hours with a room temperature of 68° F. As heat coils are used in conjunction with open space cut-outs in the central office, their location and the way in which they fit into the circuits will be shown later.

101. Fuses.—When a telephone conductor is grounded by operation of a protector, current will continue to flow through the telephone conductor to ground so long as the exposure continues. The current may be large enough to damage the telephone conductor or the protective apparatus itself. Accordingly it is necessary to insert in the conductor on the line side of the protector, a device which opens the conductor when the current is too large. Fuses are used for this purpose. Fuses designed for protection of telephone lines are tubular shells about 4 inches long inclosing a fusible wire of from 1 to 7 amperes capacity. Heat coils, of course, will function on the heavier currents resulting from high potential (class 3), but as pointed out above this does not open the circuit so that this heavier current may damage the cable unless a fuse is provided to open the circuit. The capacity of fuses is relatively high to prevent burn-outs on currents from low potentials which are insufficient to damage the cable and other material. In this case, the heat coil only will operate and prevent the current from reaching the switchboard. Fuses are provided at the central office for all wires entering from aerial cable or open wire but not for underground cable. In the latter case, it was formerly the practice to install fuses at the point where aerial plant went underground. Now it is common to use a section of smaller gage cable such as #24 or #26 at this point, which accommplishes the same result as if fuses were used.

102. Lighting arrestors or open space cut-outs.—Open space cut-outs are designed to protect against lighting or other extra high potential by affording a path for it to arc to ground. Figure 71 shows a standard arrester in use today. The upper block is of porcelain. Imbedded in it and held in place by glass cement is a small rectangular block of carbon. The lower block is a solid piece of carbon. When mounted in the protector as shown in figure 71 there is a small air gap between the two carbon blocks. The right hand drawing of figure 71 gives a cross section through the two blocks and clearly shows this air gap. This gap forms the protection against high potentials existing between a line and ground. A lightning discharge across the gap will not usually cause a permanent grounding of the line, but, if a high potential exists long enough to maintain an arc for an appreciable length of time, the heat created will cause the glass cement to melt and allow the protector spring to force the smaller carbon block against the larger one. This will create a permanent ground.

The air gap space between the blocks is designed so that the operating voltage of the protector will be less than the break down voltage of the weakest point of the circuit which it is designed to protect and greater than the maximum working voltage of the circuit. The average operating voltage of the open-space cut-outs used at subscriber's stations and in central offices is about 350 volts.

The older type of lighting arrestor consisted of two rectangular carbon blocks separated by one thickness of U-shaped mica. The inner face of the grounded block has a fusible metal slug imbedded in it. An arcing current melts this slug and causes it to form a permanent path to ground. When mounted, the gap in the mica should be downward to prevent dust collecting in the gap between the carbons.

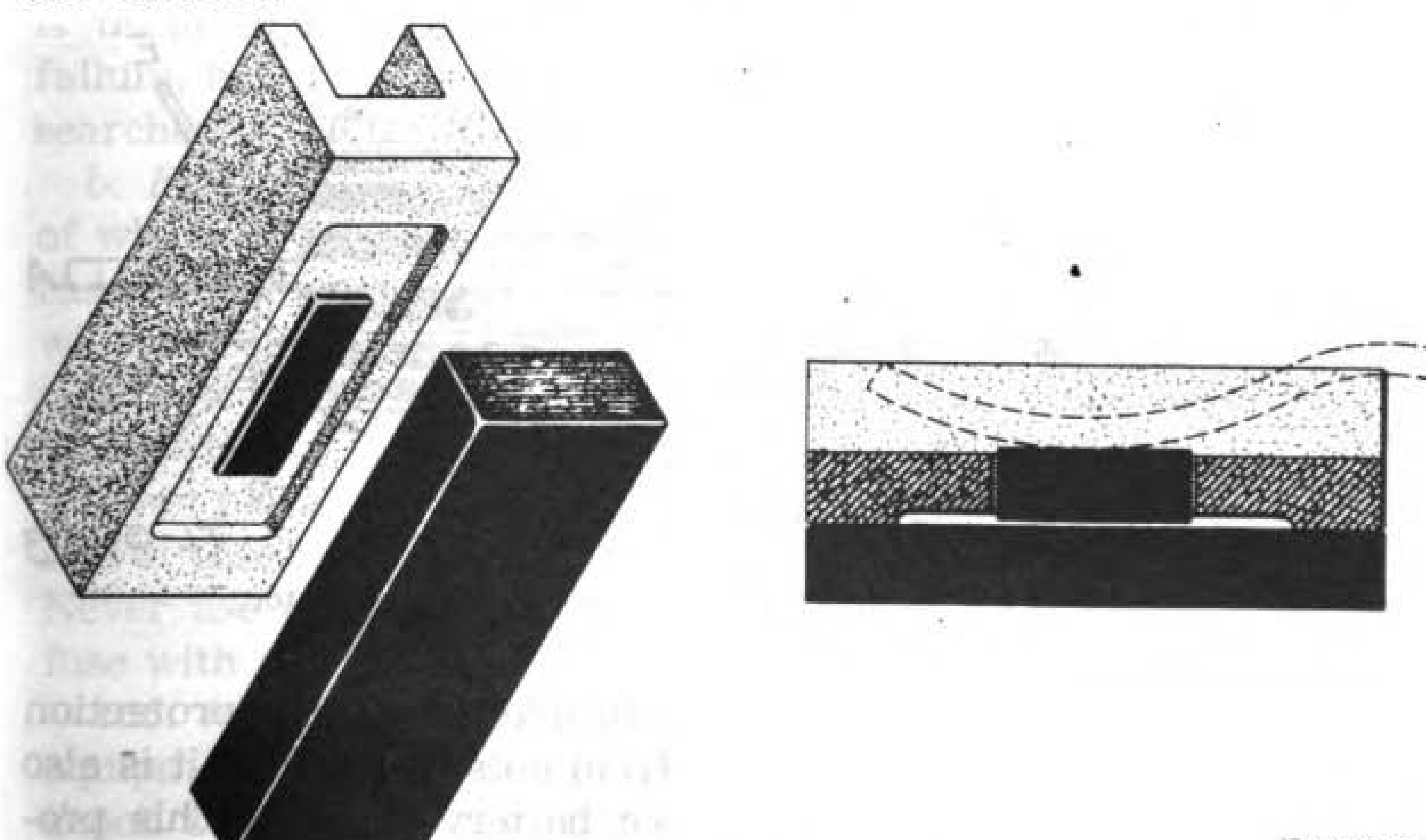

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FIGURE 71.—Open space cut-out.

103. Protectors.—Lightning arrestors and heat coils are used together in a central office and the two combined are ordinarily called a protector. This protector is ordinarily referred to as a high potential sneak current protector. This is the protective device that was mentioned in the section on distributing frames. These protectors are in strips of 20 and are mounted on the vertical side of the main frame. As will be remembered there are two types of frames, *A* and *B*. The protectors for these two types differ slightly in their construction only. Figure 72 shows a *B* frame protector. *A* is a heavy metal center piece by means of which the protector is connected to the distributing frame and thus to ground. The outside pair (which is connected to the protector in a type *B* frame), is connected to *B* and *E*. The jumpers connect to *C* and *D* which are bought out on the same side of the center piece. The jumper is never split. This is always true whether the frame is of the *A* or *B* type. It should be noted that when the protector is used in line circuits, as in the case of conductors entering a central office, the heat coil is mounted on the office side of the open-space cut-out. In this position the heat coil wiring aids the operation of the open-space cut-out by presenting a considerable impedance to suddenly applied voltages such as are produced by lightning discharges.

The only difference between the *A* frame protector and figure 72 is in the arrangement of the spring assembly. The switchboard pairs connect to the protector in this case and are split, but the jumper is not. At the same time, the heat coils must be on the unexposed side of the arrestors.

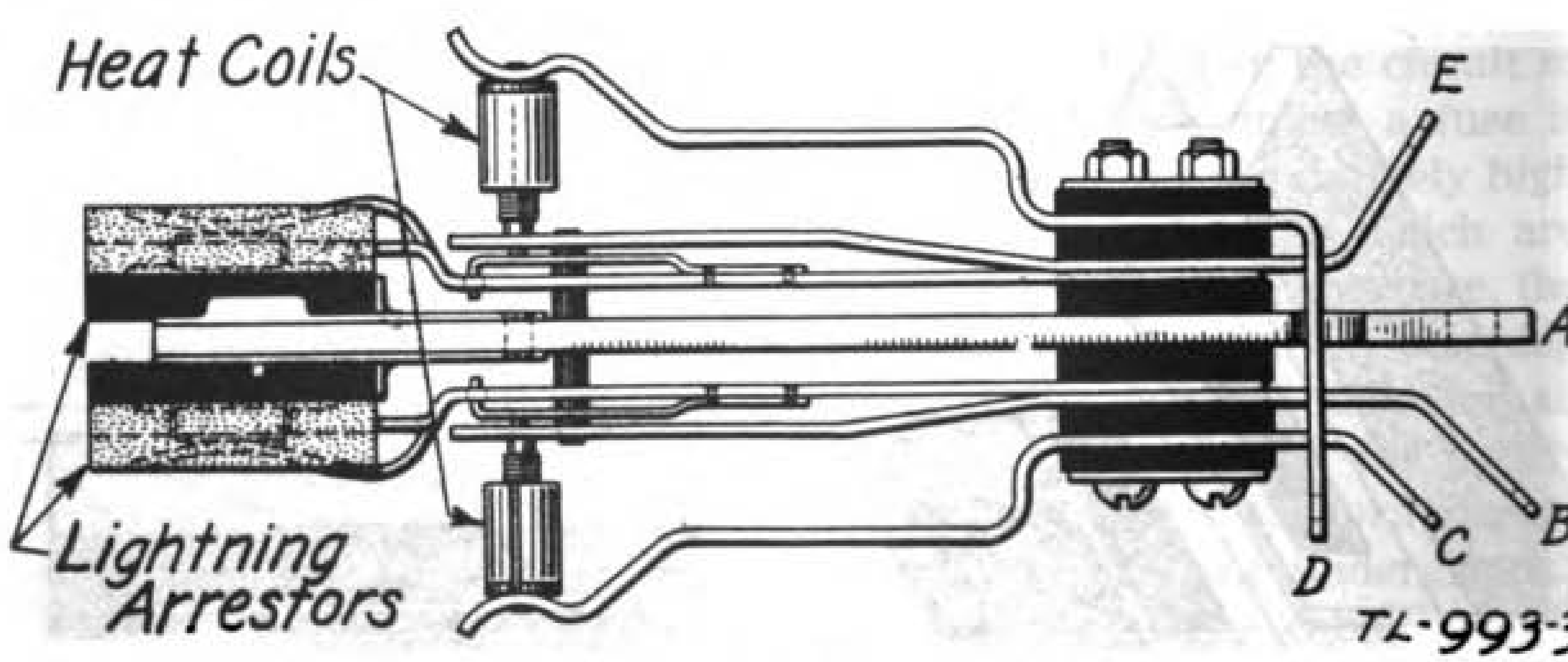


FIGURE 72.—Western Electric Co. central-office protector.

104. Switchboard fuses.—*a. Types.*—In addition to the protection afforded the switchboard apparatus from outside hazards, it is also protected from damage from its own battery current, This protection is provided by small fuses in each group of circuits. In a large central office there are hundreds of these fuses. For continuity of service it is necesary for the office maintenance force to know the instant a fuse blows and to be able to locate it quickly. For this reason, indicating fuses as shown in figure 73 are used. As shown, the fuse is mounted outside between the battery bus and the stud on which the circuit (or group of circuits) fused by it terminates; and between these mountings is a thin bus bar which connects to ground through a pilot light and alarm bell. When any fuse blows both springs are released. The coil spring throws the glass bead out of line so that it can easily be seen and the flat spring makes contact with the fuse alarm bus, putting battery on that circuit. The ringing of the bell calls the attention of the attendant

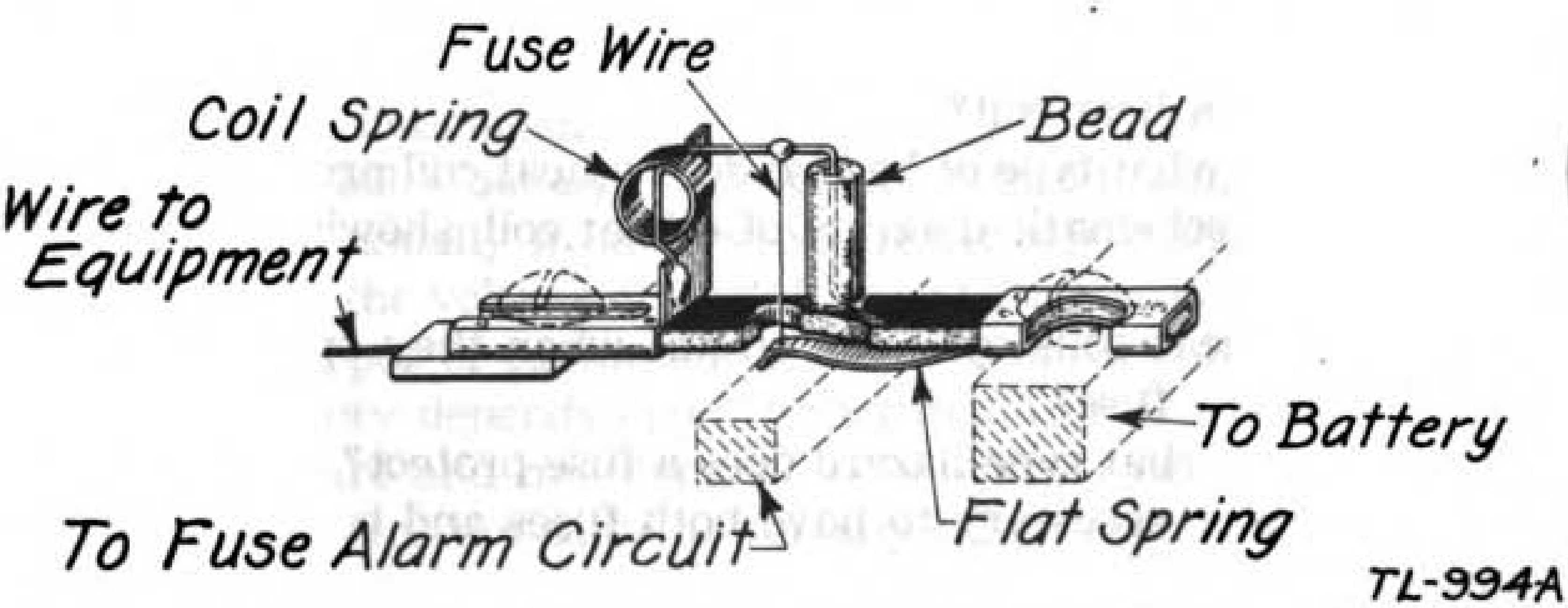


FIGURE 73.—Western Electric Co. 35-type alarm fuse.

and the particular pilot lamp burning shows him on which panel the blown fuse is located. By inspection of the panel for a fuse with the bead raised out of line the particular fuse is easily located. It is usual to replace one fuse without investigating the cause of failure, but if the second fuse goes out the cause of the trouble is searched out and cleared.

b. Fuse sizes.—Switchboard fuses are available in various sizes of which ½, 1⅓, 2, and 3 ampere capacities are most common. Th fuse circuit prints will show which size to install in each case, an when replacing fuses the capacity of the fuse removed will show th size to use for replacement. To aid in the identification of the fuses and particularly to prevent a fuse of the wrong rating being used in a given place, the glass beads are variously colored. If the proper size of fuse is not available, use a piece of fuse wire of proper size. Never use a copper wire in place of a fuse, and never replace a fuse with another of larger capacity.

105. Acoustic shock reducer.—There is another piece of protective equipment found in the switchboard. This is a varistor-type acoustic shock reducer that is used in the operators circuit. In use, the varistor is bridged on the receiver branch of the operator's telephone set, usually being wired across the receiver leads to the telephone jacks in the switchboard.

When the varistor has applied to it the relatively low voltages due to speech at ordinary levels its impedance is high (about 30,000 ohms at 0.1 volt) and it shunts from the receiver only a small amount of current. When relatively high voltages are impressed on the operator's telephone circuit the impedance of the varistor drops to a low value (about 15 ohms at 1.5 volts) and causes most of the current to be shunted from the receiver, thereby greatly reducing the intensity of acoustic disturbances.

106. Questions for self-examination.—

1. What is meant by a hazard?
2. Name three types of hazards to which telephone plant is exposed.
3. What is a heat coil?
4. Against what type of hazard does a heat coil protect?
5. Draw a schematic diagram of a heat coil, showing the circuit through it.
6. Do all heat coils open the circuit when they operate?
7. What is a fuse?
8. Against what type hazard does a fuse protect?
9. Why is it necessary to have both fuses and heat coils in the same circuit?
10. Is underground cable fused as it is brought in to the central office? Why?
11. What is an open-space cut-out?
12. Against what type hazard does an open-space cut-out protect?
13. What type open-space cut-out is used considerably in army exchanges?
14. Describe the older type cut-out containing the two carbon blocks.
15. What two protective devices are combined and called central office "protector"?
16. Where is this protector mounted?
17. Upon which side of the open-space cut-out should the heat coil be in this protector? Why?
18. Are the protectors used on *A*- and *B*-type frames identical? Why?
19. What type of fuse is used to protect central office equipment from the central office battery?
20. Why is this type of fuse used?
21. What is the purpose of the acoustic shock reducer?
22. Describe the operation of this acoustic shock reducer?

SECTION XIII
POWER EQUIPMENT

107. Central office battery.—The direct current source in a telephone office is usually a battery of the regular lead-acid type. In most instances the voltage of one of these batteries is 24 volts, however, certain types of equipment require 36 or 48 volts. The capacity of the battery depends upon the normal load of each individual installation. Care and maintenance of telephone central office batteries is in general the same as for any other battery of the same type and detailed instructions may be found in TM 11-430, Storage Batteries for Signal Communication.

108. Charging equipment—general.—As telephone central office batteries are in use almost continuously it is necessary to charge them while they are in use. This necessitates a uniform and ripple-free charging source, of adequate capacity to provide the charging current plus the normal exchange current load. There are many different types of charging equipment, to be used according to local conditions.

109. Motor-generator sets.—When an electric motor drives an electric generator, the combination is referred to as a motor-generator set. A set of this type is probably the most efficient charging equipment to use, where the charging rate is greater than fifty amperes. If the motor and generator of such a set are combined in one housing with a single rotor and the input and the output paths are conductively separate, they are known as dynamotors, however, when the input is alternating current and the output is direct current and the windings are conductively identical the machine is a rotary converter. When these sets are to be used as charging equipment, the generators should be designed to insure a minimum of commutator ripple.

110. Rectifiers—general.—A rectifier is commonly defined as a device for converting alternating current to direct current. Motor-generator sets first convert electric energy to mechanical energy, then to the desired type of electrical energy, and are not called rectifiers. Accordingly a rectifier may be somewhat more precisely defined as a device for converting a-c energy to d-c energy directly, or without an intervening step. All rectifying devices depend for their operation upon the characteristic of permitting electric current to flow through them freely in only one direction. They include a variety of vacuum and gas-filled tubes such as the older mercury-arc tube and the newer mercury-vapor tube, and the Tungar tube. In addition there are the dissimilar metal rectifiers, as the copper-oxide, and the selenium types.

111. Gas tube rectifiers.—Tubes of this type are commonly used as rectifiers when a power output of less than fifty amperes is desired. In this respect they function as "converters" of alternating current to direct current power. Very efficient rectifiers may be secured by admitting a small amount of certain gases at controlled pressure into the vacuum of a tube. In this case flow of electrons between the cathode and plate ionizes the gas by the electrons colliding with the gas molecules. The collision between an electron and a gas molecule knocks some electrons out of the molecules, thereby separating it into a positive ion and one or more electrons. The electrons, being negative, are attracted to the positive plate, and the ions being positive travel to the cathode. The positive ions neutralize the negative space charge that would otherwise exist near the cathode, thus greatly facilitating the escape of additional electrons. The net result is that the opposition to the space current flow is reduced, which permits the current to increase to a value limited primarily by the external resistance in the plate circuit. Mercury vapor and argon are the two gases most commonly used in these tubes.

112. Half-wave rectification.—Figure 74 illustrates schematically a general type circuit, as used in half-wave rectification, for a two-electrode gas tube. In the particular tube illustrated, the cathode is of the filament type and is heated by a low voltage current. In

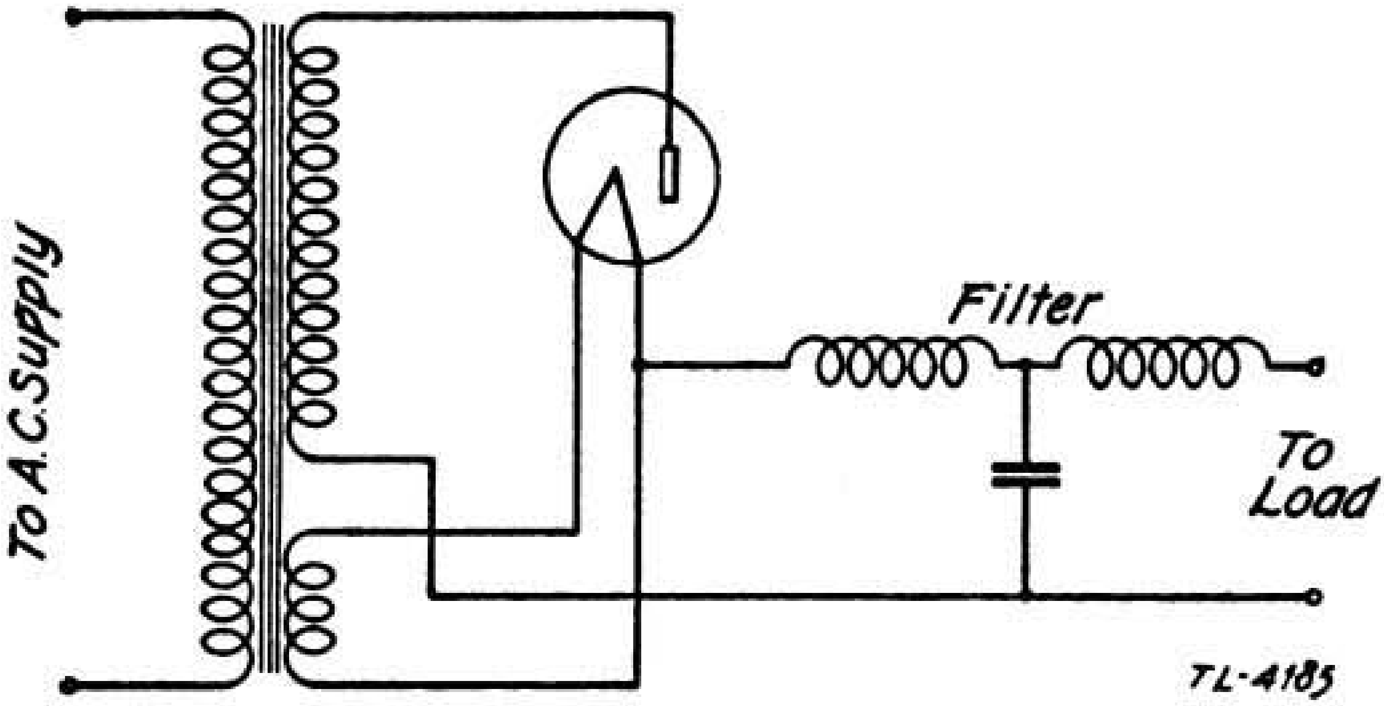


FIGURE 74.—Half-wave rectifier.

figure 74 the alternating voltage in the secondary side of the transformer is impressed across the plate and cathode of the tube. The flow of space current, of course, occurs only during the time the plate is positive with respect to the cathode. This means that during the positive half-cycle there is a current flow between the cathode and plate which gives the effect of closing the circuit or connecting the filter and load to the transformer. During the negative half-cycle (plate negative with respect to the cathode) there is no space current and the tube may be considered as opening the circuit. The output current from the half-wave rectifier flows in one direction, but its magnitude varies as the positive half of the impressed wave and is therefore of a pulsating character. By adding a filter in the output containing series inductance and shunt capacitance, this pulsating current is smoothed out into a more even direct current.

113. Full-wave rectification.—Many commercial companies manufacture full-wave rectifiers of the type shown in figure 75. There are of course slight modifications by each manufacturer, of which the tube is the most outstanding. In figure 75 the tube has two separate plates, to which are connected the terminals of the trans-

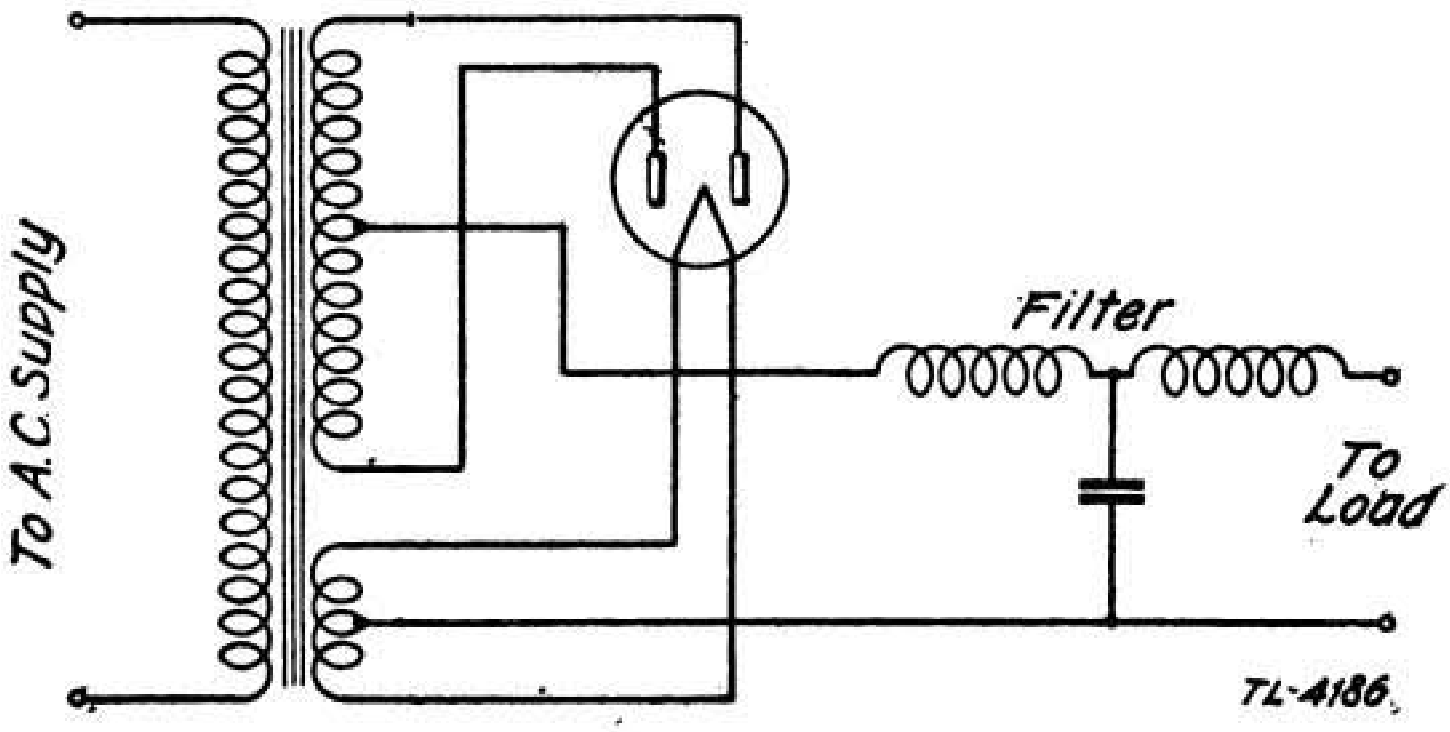


FIGURE 75.—Full-wave rectifier.

former secondary winding. It can be seen that when a voltage is impressed on the primary one of the plates will always be positive with respect to the cathode. This means there will be current flowing in the same direction in the output (filter and load) during both positive and negative half cycles, or the rectifier is said to be full-wave. As the full-wave rectifier uses both halves of the cycle, its power output is approximately twice that of the half-wave rectifier, and the filtering requirements are less severe, i.e., done more easily.

114. "Tungar" tube rectifiers.—Of all the various gas-filled tubes used for rectification the "Tungar" is probably the best known and most widely used in the army. This tube is manufactured by many different firms, and consists of a single carbon plate and an ordinary tungsten filament within a gas filled (usually argon) tube. Operation is basically the same as for any tube rectifier; however, as there is but one anode in each tube, two tubes must be utilized for full-wave rectification. Figure 76 is a schematic diagram of one way in which these tubes may be connected for full-wave operation.

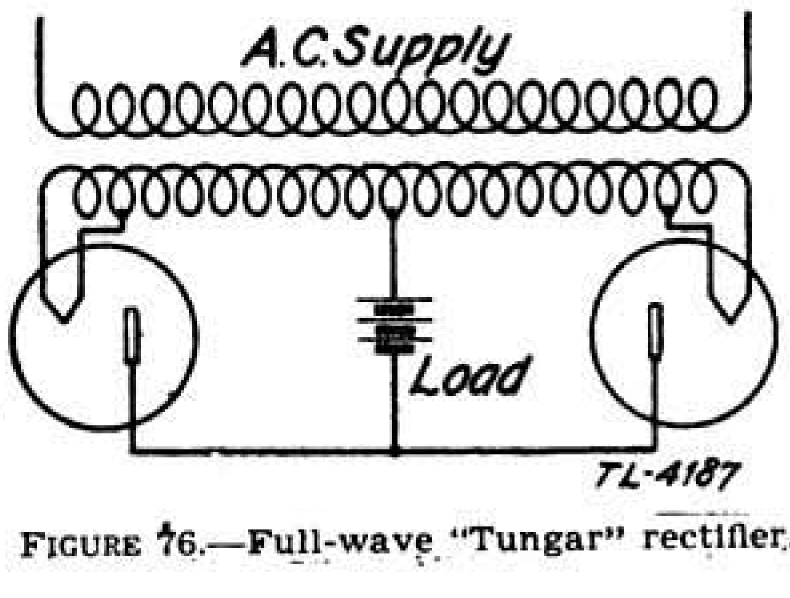


FIGURE 76.—Full-wave "Tungar" rectifier.

115. Mercury-arc rectifier.—The mercury-arc rectifier is a pear-shaped glass bulb, evacuated of air and having in the bottom a little mercury. Into the glass bulb penetrate four iron terminals, iron being used because mercury does not amalgamate with it. In figure 77 three of the terminals are *C*, *D*, and *F*; the fourth is just beneath the pool of mercury at *E*. In the figure is shown connected the alternator whose current is to be rectified; the battery between *E* and *J* is to be charged by the rectified current. The inductances *G* and *H* are auxiliary apparatus necessary to the functioning of the rectifier.

a. Mercury vaporizes very little at ordinary temperatures and pressure, hence the gas pressure within the bulb is low, and once the gas is ionized it will conduct very well. To start the rectifier, the bulb is tipped to the left allowing the mercury to short circuit terminals *E* and *F*. This would be a short circuit upon the alternator were it not for the resistance, *R*, connected in to limit the current to a reasonable value. When the bulb is righted, the mercury runs back to *E*, breaking the circuit. But the inductance of the circuit causes an arc to form at the break of the mercury stream and some of the mercury is ionized by the arc. Let us suppose that

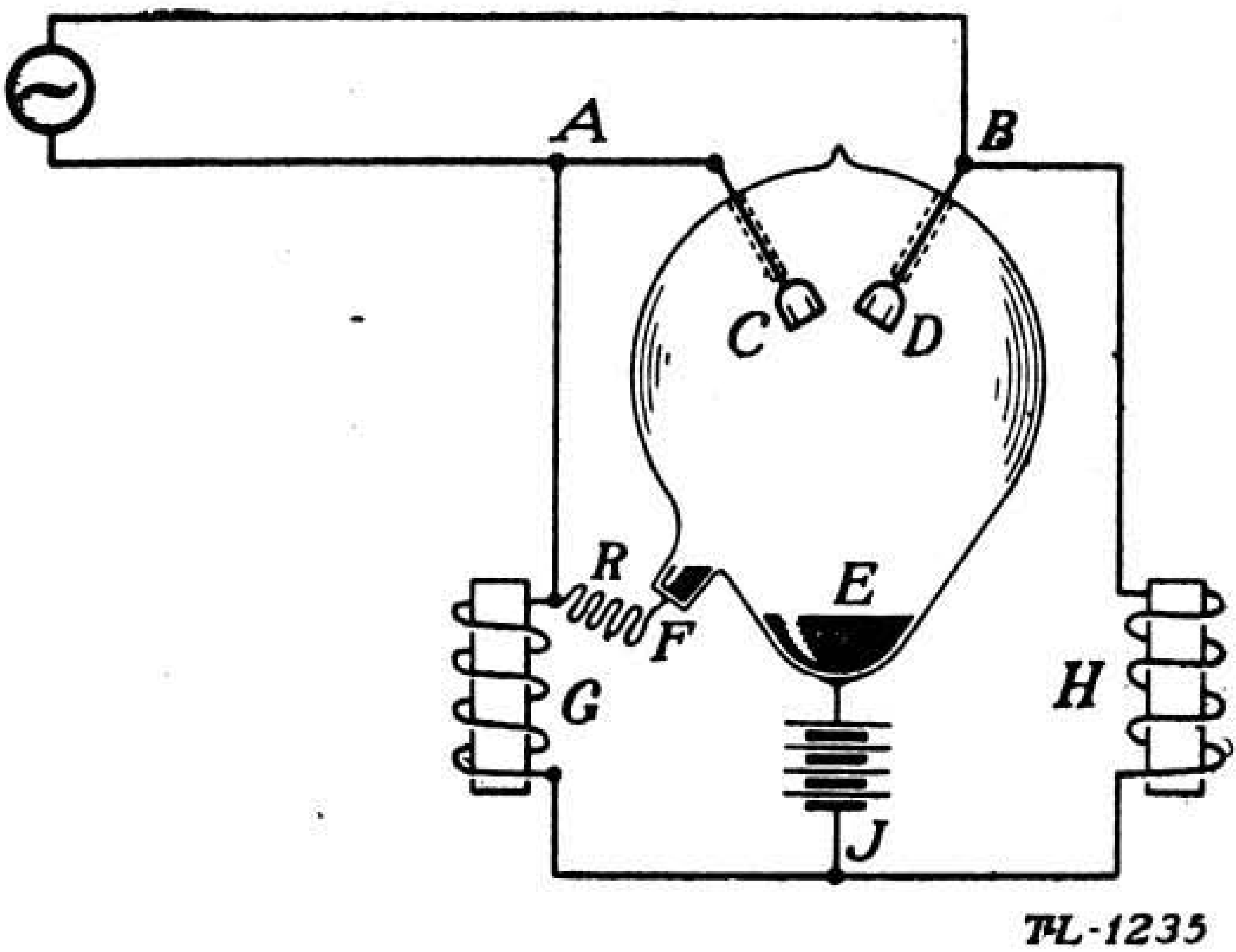


FIGURE 77.—Mercury-arc rectifier.

at this instant the emf of the alternator is acting from the alternator towards *A*. Then *C* is at a higher potential than *E* which is connected to the other terminal of the alternator. The positive ions will be attracted to *E* and the electrons to *C*; there is a current flow from the alternator through the path *ACEJHB*. This current is conducted within the bulb by the stream of ions and electrons.

b. The emf of the alternator dies down preparatory to reversing its direction, but the current does not begin its decrease as soon as the emf because the inductance *H* causes the current to lag behind the emf. When the current does decrease, *H* opposes this decrease by an induced emf acting in the direction of current flow. This induced emf acts from *J* to *B*, making *D* of a higher potential than *E*. Thus, before the alternator has made *D* positive with respect to *E*, current has begun to flow from *D* to *E* because of the discharge of *H*'s energy. The induced emf acting from *J* to *D* outside the bulb, because of the inductance *H*, lasts only an instant but it is long enough for the alternator to have built up towards *B* a sufficient voltage to maintain the current flow through the bulb. When the emf of the alternator again reverses direction, *G* plays the same part as that just played by *H* in maintaining the current flow and ionization within the bulb until the alternator has begun to build up in the new direction. In the part of the circuit *E* to *J*, it is seen that the direction of current flow is always the same. Hence, a battery placed there may be charged, or there may be connected between *E* and *J* any load requiring direct current. As the output of the rectifier is pulsating a filter must be added between *E* and *J* to smooth out the output for use in a telephone central office.

116. Copper-oxide rectifiers.—There is a rectifier that has no moving parts and does not use a gas-filled tube. It operates on the principle that if two dissimilar metals are in contact, current can flow more easily in one direction than in the other. Notable in this category are the selenium rectifier and the copper-oxide rectifier. As the only difference in these units is the metal used in the individual rectifying element, a discussion of the copper-oxide rectifier will suffice for the elements made of other metals. Copper and copper-oxide are used in the same manner as two dissimilar metals, to form the element of the copper-oxide rectifier. This combination offers low resistance to current flowing from the copper-oxide to the copper, but offers a comparatively high resistance to the flow of current from the copper to the copper-oxide. Thus it becomes of value for the rectification of alternating currents.

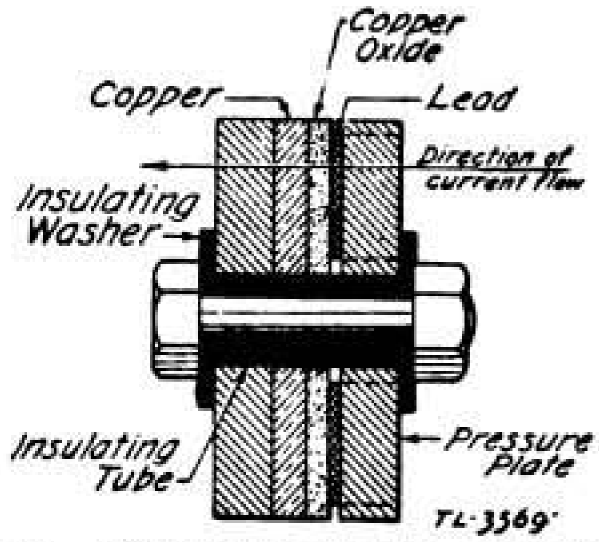


FIGURE 78.—Rectifying element arrangement.

a. Assembly.—Good electrical contact to the oxide is secured by pressing it into a lead washer. Several elements as shown in figure 78 can be placed together in a series or parallel arrangement to build rectifiers of the desired capacity or characteristic. The assembling is held together by means of heavy pressure plates secured by bolts. For best operation, the pressure should be between 500 and 2000 pounds per square inch. Figure 79 shows a copper-oxide rectifier unit.

b. Aging.—The resistance of a copper-oxide rectifier increases during the first two to three months it is in use. This is known as "aging" and will cause the resistance to increase about 25%. Heating both hastens and increases the effect of this aging. Units should not be run with an overload. Various methods have been devised to overcome the effect of aging and two of the most common means are: plating the lead washer with tin, and coating the oxide with graphite.

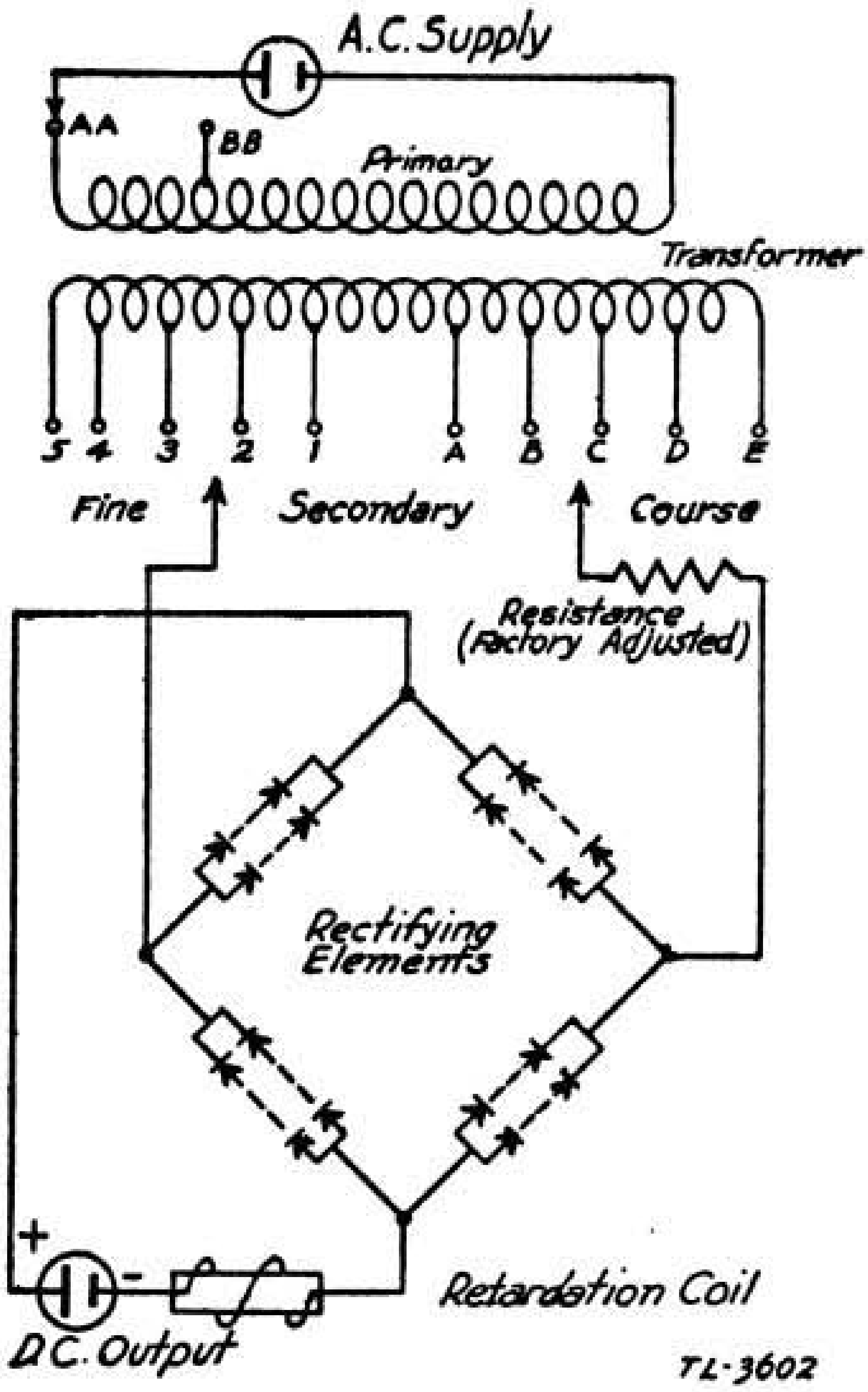


FIGURE 79.—Copper-oxide rectifier.

c. Adjustments.—Ordinarily there is a transformer in the input which is provided with taps in order to regulate it to the required potential. Resistances are provided in some cases to compensate for variations in the rectifier output due to manufacturing variations or variations in line regulation. On copper-oxide rectifiers, that are used to charge storage batteries used in telephone systems, a retardation or choke coil is provided to smooth out the rectified current. This coil must always be provided in order to prevent noise in the voice frequency range from entering the battery.

117. Ringing machines—general.—Many different frequencies are used for ringing in telephone work, 16⅔, 20, 33⅓, 50, 66⅔, 1000 cycles etc.; however, most of these are for special cases, i.e. harmonic ringing, carrier use, etc. Of all these frequencies 20 cycles is used most frequently. As in the case of charging equipment a motor-generator may be used as the power source, in which case it provides a number of things, i.e., busy signal, dial tone in automatic exchanges, etc. Motor magnetos are also in use, although mostly in old installations, and are being replaced with newer equipment. Many manufacturers make very compact and efficient ringing machines to fill the need of the small central office in a more efficient manner than is possible with the above equipment. The following ringing machines of this type have been generally adopted as standard:

a. The "Telering."

b. The "Sub-cycle" static frequency converter.

c. The vibrating pole changer.

The output of each machine is isolated from battery and power circuits, allowing the ringing current supply to be connected to battery or used to ring directly to ground at the telephone exchange equipment.

118. The "Telering."—This instrument was devised to produce a 20-cycle ringing current from a 110-volt 60-cycle power input. It is included as part of the Telephone Central Office Sets TC-1, TC-2, and TC-4. The principal of operation of the Telering is the utilization of two frequencies to produce a beat frequency. This beat frequency is the difference between the 60-cycle input and the resonant frequency of a vibrating reed. Figure 80 is a schematic diagram of the model "H" Telering. Fundamentally, it has the same circuit as other models. Referring to figure 80, let us assume that the instant the circuit is closed, current is flowing in at *L-1*, through the fuse and the primary of the transformer and through the other fuse to *L-2*. A voltage is induced in the secondary of the transformer in the direction of the arrow to point *A*. Here it divides, part flowing through the fifty-watt lamp and the output load, and part through the 2000-ohm resistor and the winding of the motor coil. The current flows through these two circuits and joins at the vibrating reed. From the vibrating reed it flows through the *R.F.* choke and back to the secondary of the transformer. As long as the circuit is closed between the vibrating reed and its contact, current will flow through the output load. This first half-cycle, or alternation, through the motor coil, causes the reed to sweep toward the motor coil, opening the circuit. The circuit being opened,

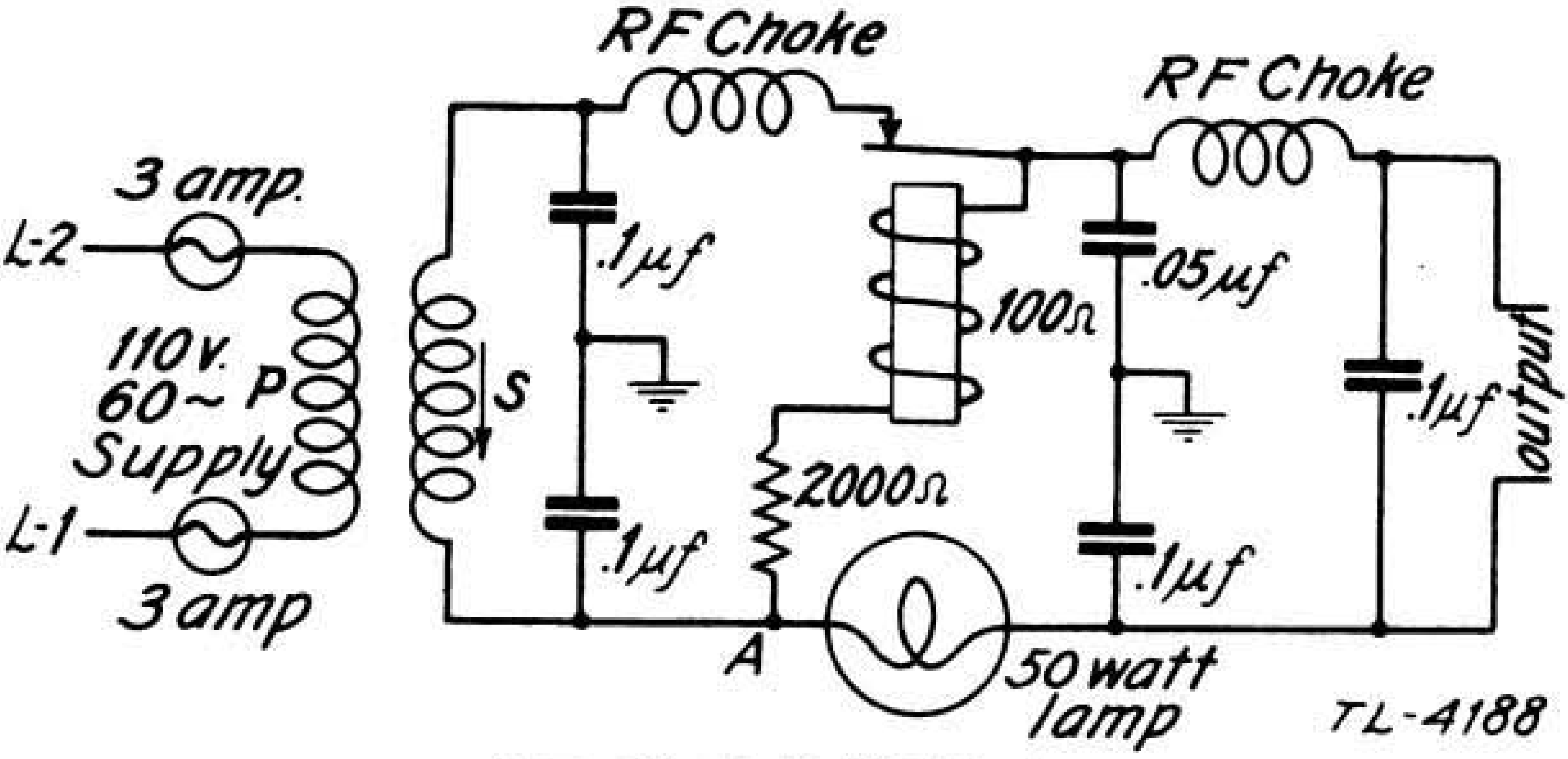


FIGURE 80.—Model "H" Telering.

the motor coil de-energizes and the reed sweeps back and closes its contact. In this manner, the reed is kept vibrating continuously. The contact at the reed, being common to both the motor coil and the output, allows an impulse to go through the fifty-watt lamp to the output each time the contact is closed. Due to the characteristics

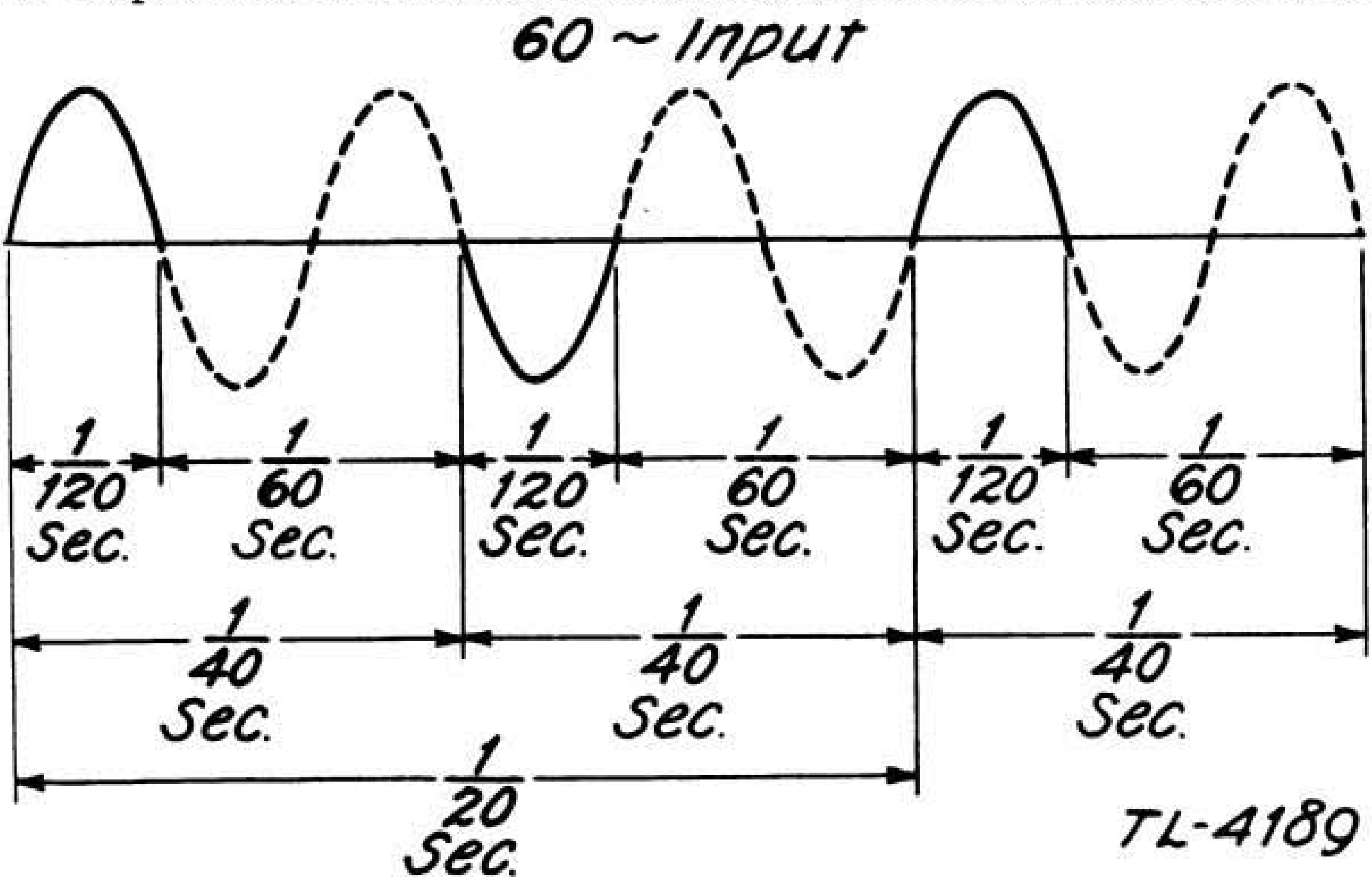


FIGURE 81.—20-cycle output of the "Telering."

of the tuned vibrating reed, the contact is closed for $1/120$ of a second and open for $1/60$ of a second. The input is 60 cycles, or 120 alternations per second; therefore, each alternation takes $1/120$ of a second. When the contact at the reed is closed for $1/120$ of a second, one alternation is permitted to flow through the output. The contact is then opened for $1/60$ of a second and two alternations of the input are missed and not allowed to flow through the output. It can be seen from figure 81 that 40 alternations or 20 cycles are selected per second, and allowed to flow into the output.

119. The "Sub-cycle" static frequency converter.—This apparatus is a frequency reducing device which furnishes ringing power at a sub-multiple of the power supply frequency. The Sub-cycle does not use any moving parts while operating. They are available for operation on 115-volt 60-cycle and for 115-volt 50-cycle power. For other commercial voltages at these same frequencies, a transformer is inserted between the converter proper and the power supply line, so as to bring the input voltage within the rating of the device, as given on the name plate. The output frequency of the Sub-cycle is one-third of the input frequency. The maximum output is 20 watts which is sufficient to operate 25 ringers simultaneously with average line conditions. The output voltage at no load is 90 volts across the secondary winding. From no load to full load, the output voltage drops no more than eight volts.

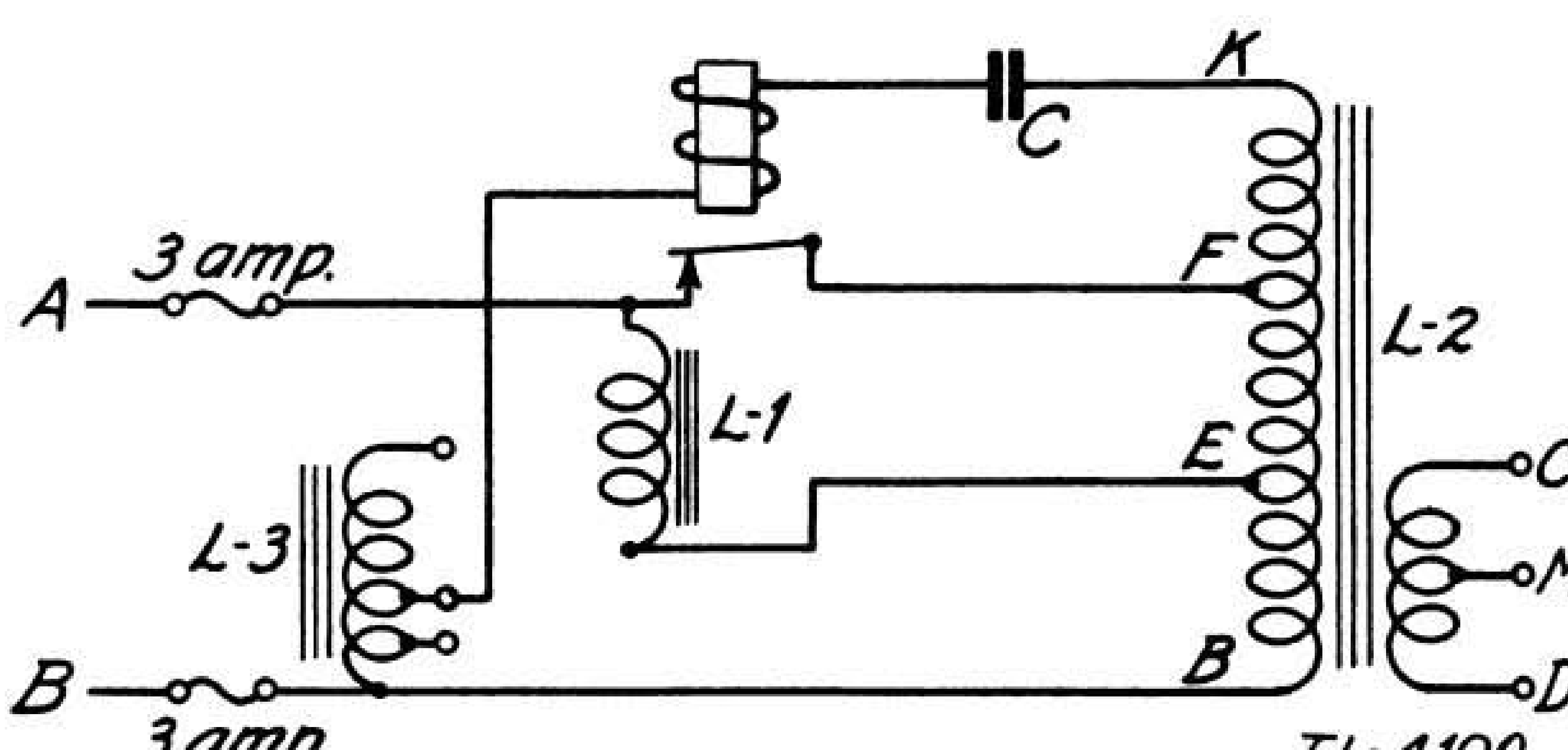


FIGURE 82.—"Sub-cycle" static frequency converter.

a. Starting.—The 115-volt 60-cycle supply is applied to points *A* and *B*, figure 82, through the three-ampere fuses. With the relay at normal, the input supply is connected to the winding *FB* of transformer *L–2*. The transformer operates as a 60-cycle auto-transformer at this time, stepping up the voltage to approximately 440 volts across its winding *KB*. This high voltage is applied to the 8 μf capacitor *C* through *L–3* and the relay winding. The resistances of *L–3* and the relay winding are approximately 2 ohms each and have a negligible effect on the charging current of the capacitor. A large charging current rushes into the capacitor, energizing the relay. The operating time of the relay is such that it operates about the time capacitor *C* has charged to the peak value of the 440 volts. The operation of the starting relay allows the charge stored on the capacitor to discharge through winding *KB* of transformer *L–2* causing a starting current to flow through series inductance *L–1*. Thus, the resonant circuit formed by inductance *L–3* and the capacitor *C* coupled by the transformer *L–2* is started oscillating at its resonant frequency of 20 cycles per second. In this particular case, choke coil *L–1* is a low resistance inductance which saturates sharply with voltages greater than 115 volts at 60 cycles.

b. Operation.—While the 20-cycle circuit is oscillating freely, there will be successive times when the potentials of the 60-cycle supply and the 20-cycle oscillations counteract current flow through *L–1* and other times when they do not. For the former condition *L–1* will have a high impedance, but for the latter condition *L–1* will saturate and have a low impedance. Thus, a large current flows from the 60-cycle source when in a direction to aid the flow of the 20-cycle current; but a very small current from the 60-cycle source flows at all other times due to the high impedance of *L–1* when not saturated.

c. Restarting.—In case of a momentary overload, the external load requires so much power that the circuit will be unable to maintain the 20-cycle oscillations. As soon as the oscillations through capacitor *C* and winding *KB* stop, the relay will release and automatically restart the converter. In case of a prolonged overload, the capacitor *C* will be repeatedly charged by the automatic restart operations of the relay. The successive large charging currents will burn out the three-ampere fuses to protect the machine. The relay has no function in the normal operation of the converter, but plays an important part in automatically starting and restarting the machine. The Sub-cycle requires only 20 watts no-load power, which demonstrates its economy of operation, even where continuous operation is necessary. Stability of the converter is not affected by relatively wide variations in either the frequency or the voltage of the commercial a-c supply. A self-regulating characteristic maintains better voltage regulation of the output than any attempt at regulation of the input voltage.

120. The vibrating pole-changer.—This unit has been designed for use as a source of ringing power, where direct current is to be used for power. There are several different types of interrupters designed to fill the needs of various ringing requirements. The output may be either or both polarities of pulsating direct current, or alternating current, and the input may be one of several voltages, according to the individual central office. As the Western Electric type 84 interrupter is a component part of the TC–1 and TC–2, it will be used as an example. This interrupter, as used in the TC–1 and TC–2, operates on the regular central office storage battery, and puts out 20-cycle alternating current as ringing power.

a. Starting.—Figure 83 is a schematic representation of the circuit of the type 84–F interrupter, as used in the TC–2, while at rest. When the power is turned on current flows from the positive (grounded) side of the input through the break contact on the vibrator, through the motor coil, and returns to the negative side of the input and back to its source. As soon as the motor coil is energized, it attracts the vibrator and makes the contact at *B*. As the key is closed there is now a complete circuit from point *A* through *B* and the key and then through the lower half of the primary of the repeating coil, to ground and back to its source. During the time this current is flowing an emf is induced in the secondary of the repeating coil thereby allowing the first half cycle to flow to the output.

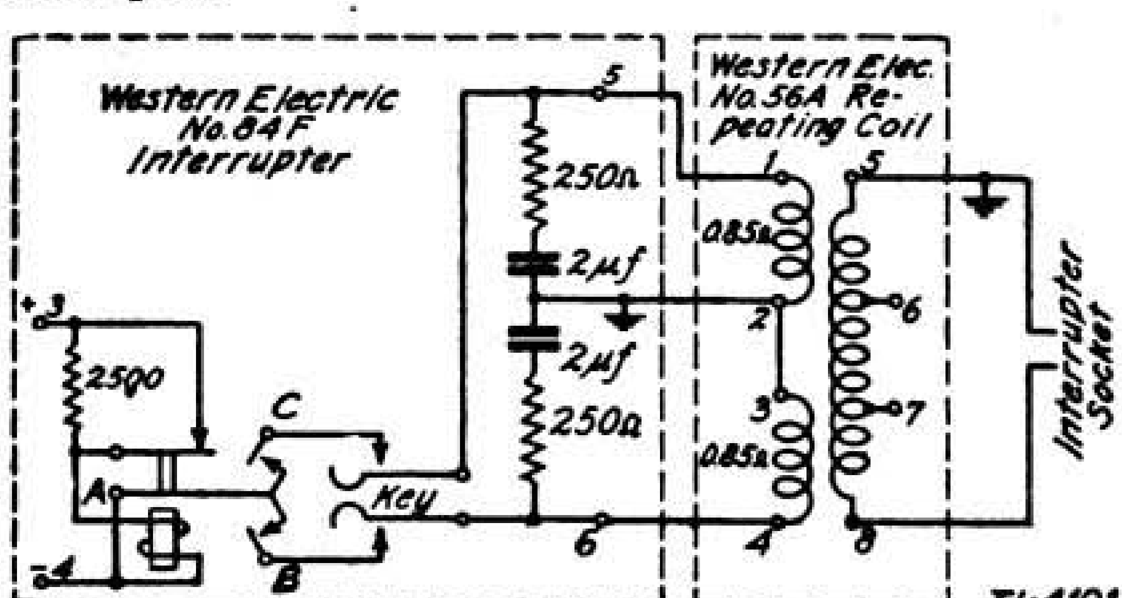


FIGURE 83.—Circuit diagram of the 84–F interrupter.

b. Operation.—As soon as the motor coil operates, the break contact on the vibrator is broken causing the circut to open and de-energize the motor coil. That allows the vibrator to swing back and close the vibrator contact and allows current to flow to point *A*, through *C* and the key and thence through the upper half of the primary of the repeating coil to ground and back to its source. An emf is now induced into the secondary in the opposite direction as before, causing the second half-cycle to flow through the output.

It can be seen that the input direct current has been changed to alternating current at the output. The frequency is controlled by the vibrator, in this case to allow the output to be 20 cycles. The 2500-ohm resistance is across the vibrator contacts and prevents excessive sparking. The two 250-ohm resistors, and the 2μf capacitors that are across the primary of the repeating coil, act as a filter for the output.

121. Questions for self-examination.—

1. What type of storage battery is used in a central office?
2. What voltage is usually used?
3. What two general types of equipment are used for charging telephone batteries?
4. What is a rotary converter?
5. What is a dynamotor?
6. Define rectifier.
7. What is a full-wave rectifier? A half-wave rectifier?
8. What type of rectifier is generally used in the army for battery charging?
9. What type of gas is usually found in the tungar tube?
10. Explain the operation of the copper-oxide rectifier.
11. What is "aging" as applied to copper-oxide rectifiers?
12. What is the frequency of the ringing current most often used?
13. What types of ringing machines are generally found in small exchanges?
14. Explain the operation of the Telering machine.
15. Explain the operation of the Sub-cycle ringing converter.
16. Where and when is the vibrating pole-changer used?

SECTION XIV
NONMULTIPLE AND MULTIPLE SWITCHBOARDS

122. Nonmultiple army exchange switchboards.—The circuits described in the foregoing sections complete the requirements for a nonmultiple common-battery switchboard. The army uses many different types and sizes of these small switchboards which are manufactured for use as commercial branch exchanges but when installed in small army posts they are used as the main exchange switchboards. In some of the larger posts they are used as branch exchanges for hospitals or other centralized activities. These switchboards are housed in oak or mahogany cabinets similar in design to those used in local-battery switchboards. They are not so tall as local-battery boards because the substitution of lamps for drops has reduced the vertical space requirements. Common-battery switchboards are, however, slightly deeper than local-battery switchboards because some of the relays, condensers, and other circuit equipment are mounted in the back of the cabinet. Since the greatest part of the cost of any switchboard is the cost of the circuit equipment, it is the general practice to provide a cabinet of sufficient capacity to serve the ultimate requirements or the maximum load of a single operator. The switchboard is usually wired for the full capacity of the framework, but only those circuits which are actually required are equipped initially. It is possible thus for a switchboard to be wired for 100 lines, 15 trunks, and 15 cord circuits and equipped for only 40 lines, 8 trunks, and 10 cord circuits. When the load increases beyond the capacity of the initial equipment of such a board, it is an easy matter to remove the apparatus blanks and install additional equipment. For details of the circuits employed in these switchboards refer to the sections covering line circuits, cord circuits, and trunk circuits.

123. Limitations of nonmultiple switchboards.—Two single-position switchboards may be placed side by side to handle traffic up to the operating capacity of two operators. An operator at one position will have no difficulty in reaching across the other position to establish a connection between two lines appearing on different positions. When traffic volume becomes too great to be handled by two operators, the addition of a third position does not always afford a satisfactory solution. The operator at the end positions cannot easily reach the jack field of the other end positions. The use of interposition trunks (trunks connecting two positions of the same switchboard) enables any operator to give connection to lines appearing on the distant positions. This is a practical scheme where there are not more than three or four positions in the exchange, but the slight increase of time in placing each trunk call is usually considered objectionable. When the exchange is of five or more positions the system of interposition trunks becomes quite complex, and the errors in trunking further lower the efficiency of the service rendered. The provision of a multiple-type switchboard is advisable, in most cases, when the estimated ultimate requirements are three or more positions.

124. The multiple switchboard idea.—The width of jack field over which an operator may comfortably reach is about six feet, and within such a width not more than three operators can comfortably work. When more than three operators are required the multiple switchboard meets this space problem by the simple expedient of placing a complete appearance of jacks (one for each line) within a unit jack field small enough so that all jacks are easily reached by one operator. This unit jack field is then repeated along the length of the board so that each operator has within easy reach a multiple jack for each subscriber line in the office. A sufficient number of positions is provided to accommodate the number of operators required to take care of the traffic during the busiest period at the desired level of efficiency. The jacks in these fields that are repeated at regular intervals along the boards are termed "multiple jacks" and the entire aggregation of them with their connecting wiring is referred to as the "multiple." Various types of multiple schemes are discussed in following paragraphs.

125. Branch multiple.—The common-battery line circuit using cut-off relays for signaling may be arranged as shown in figure 84 with several jacks, all having their tip, ring, and sleeve contacts connected in parallel. The signaling equipment will be disconnected by sleeve current if a cord circuit plug is inserted in any of the jacks. This arrangement is known as a branch multiple. It should be noted that the equipment of the line circuit is in five groups,

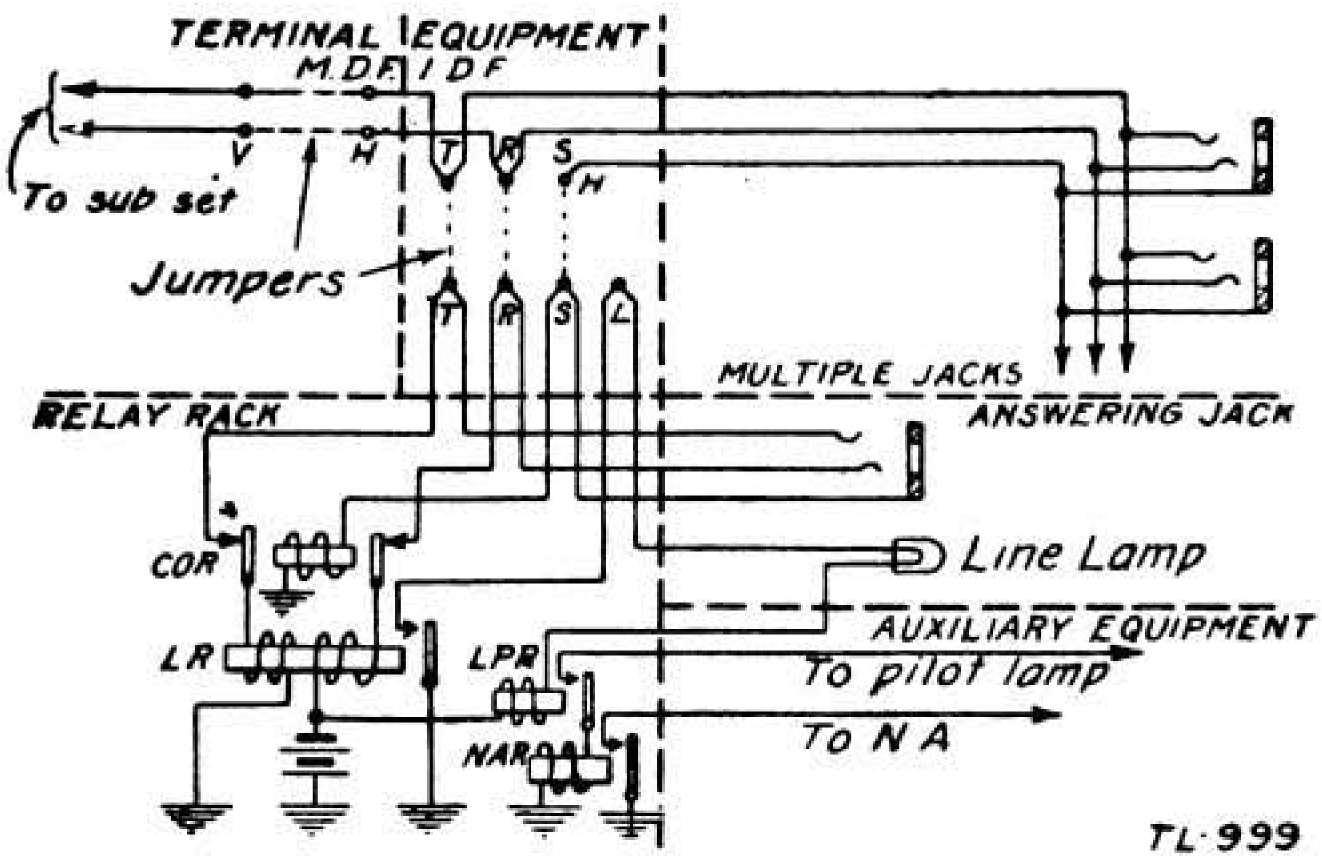


FIGURE 84.—Multiple circuit.

namely, terminal equipment, answering jack equipment, multiple equipment, relay equipment, and auxiliary equipment. The last mentioned is common to all lines appearing on a single position. The answering equipment consists of the line jack and associated line lamp and is fed from the terminal equipment. Likewise, the multiple equipment is fed from the terminal equipment. The relays too are connected to the terminal equipment. The advantages of this arrangement are simplicity, ability to segregate the relay equipment on a framework outside of the switchboard cabinet and obtain a higher order of flexibility.

126. Equalization of traffic load.—The calling number of any subscriber depends upon the number of the jack with which his line is associated in the multiple. It is possible to change the calling number of any line, by changing the jumper on the main distributing frame. Numbering in the multiple cannot be rearranged because the jacks must be placed in numerical sequence to enable any operator to locate quickly the jack of the line called. This however is not the case with answering jacks, since they are never used for outgoing calls on this type of commercial switchboard. Answering jacks on each position are numbered from "0" upward.

The branch multiple system enables any answering jack and associated relay equipment to be connected to any multiple number by the changing of a three-wire jumper on the intermediate distributing frame. This makes it possible to shift the answering jack assignment of any line from one position to another, without changing the calling number, and facilitates the equalization of the traffic load on all positions without change of directory listings.

127. Lamp associated multiple.—There are multiple installations where each multiple jack has a line lamp associated with it as shown in figure 85. In this case there is no separate answering jack, and when any line calls, all lamps light simultaneously. The first available operator plugs into the multiple and answers the call, extinguishing all lamps. This arrangement effects an automatic distribution of load, but it reduces the capacity of the switchboard considerably, increases battery drain and is likely to result in two or more operators answering the same call. It is known as the lamp associated multiple system. It is coming into wide use in small commercial exchanges.

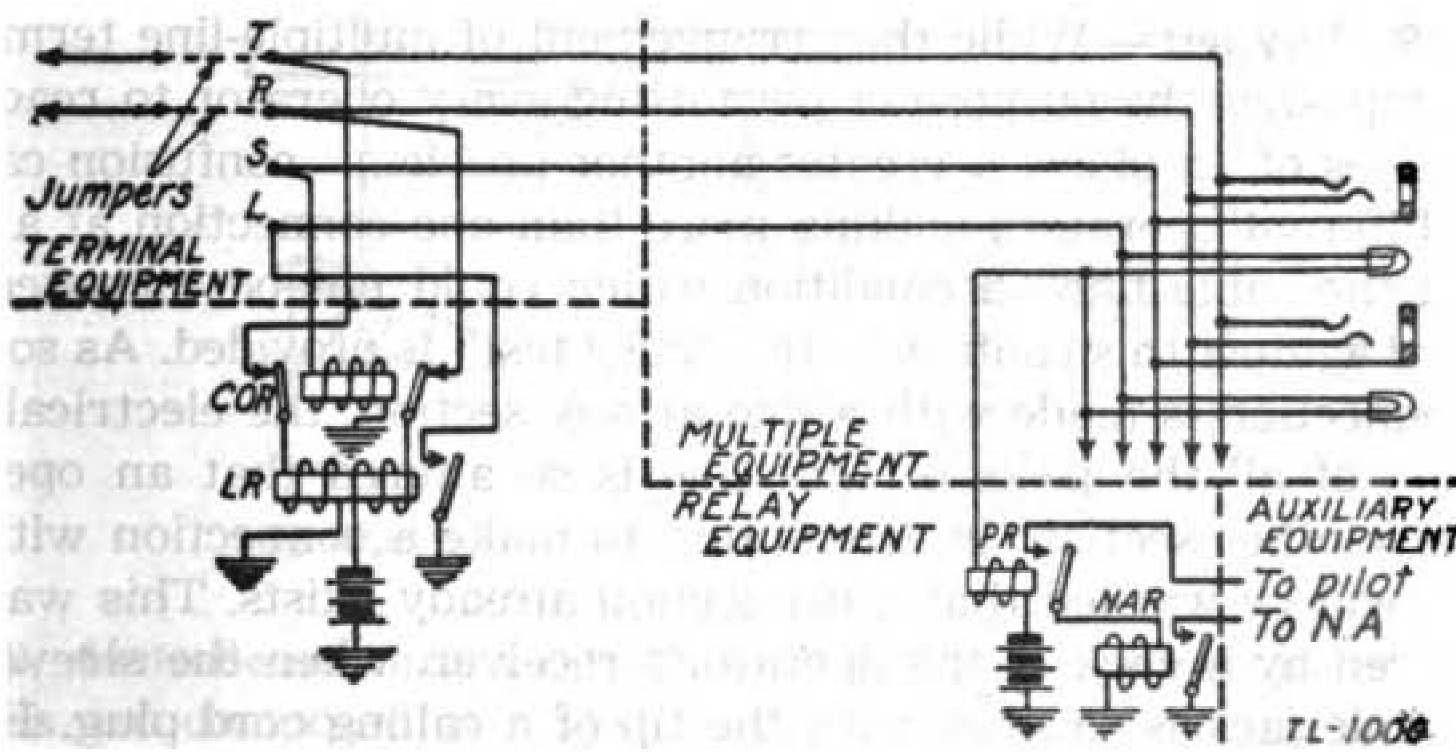


FIGURE 85.—Lamp associated multiple circuit.

128. Series multiple.—Another type of multiple jack arrangement as used in the Signal Corps switchboard BD-80-A is shown in figure 86. In this multiple arrangement the jacks are connected in series through cut-off springs and contacts in each jack. Since cut-off jacks are used instead of relays to operate the line lamps, this series arrangement of multiple jacks is necessary in order to extinguish the line lamp when a cord plug is inserted in a multiple appearance jack. On this switchboard the answering appearance is also used for outgoing calls since it is the only appearance of the line on that position of the board. The switchboard BD-80-A does not require an intermediate distribution frame. The multiple connections are made by a standard cable arrangement.

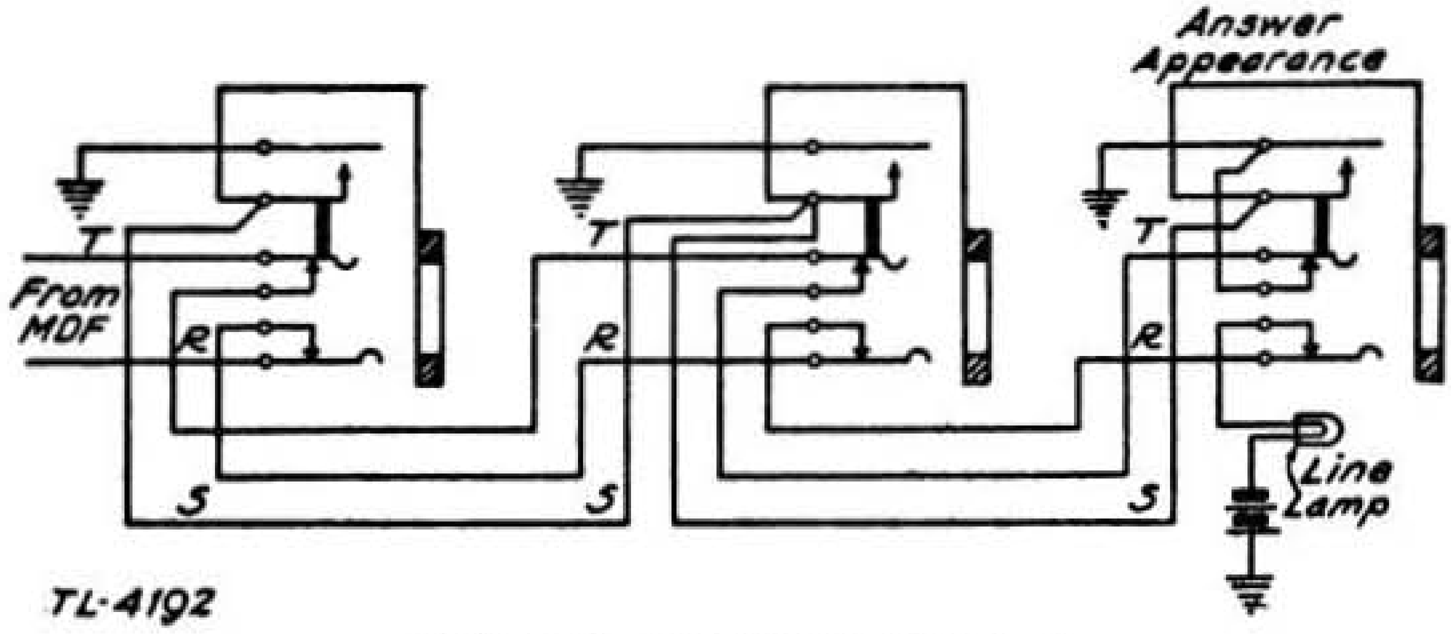


FIGURE 86.—Series multiple circuit.

129. Busy test.—While the arrangement of multiple-line terminals accomplishes the purpose of permitting every operator to reach all the lines of an office, it creates another problem—confusion caused by different operators making more than one connection at a time with the same line—a condition which could not be tolerated. To guard against this confusion, the "busy test" is provided. As soon as a connection is made with a line at any section, the electrical condition of all the jacks of that line is so altered that an operator at any other section, in attempting to make a connection with the line, will be warned that a connection already exists. This warning is given by a click in the operator's receiver, when the sleeve of a multiple jack is touched with the tip of a calling cord plug. Figure 87 shows a simple schematic diagram of how this busy-test connection is established.

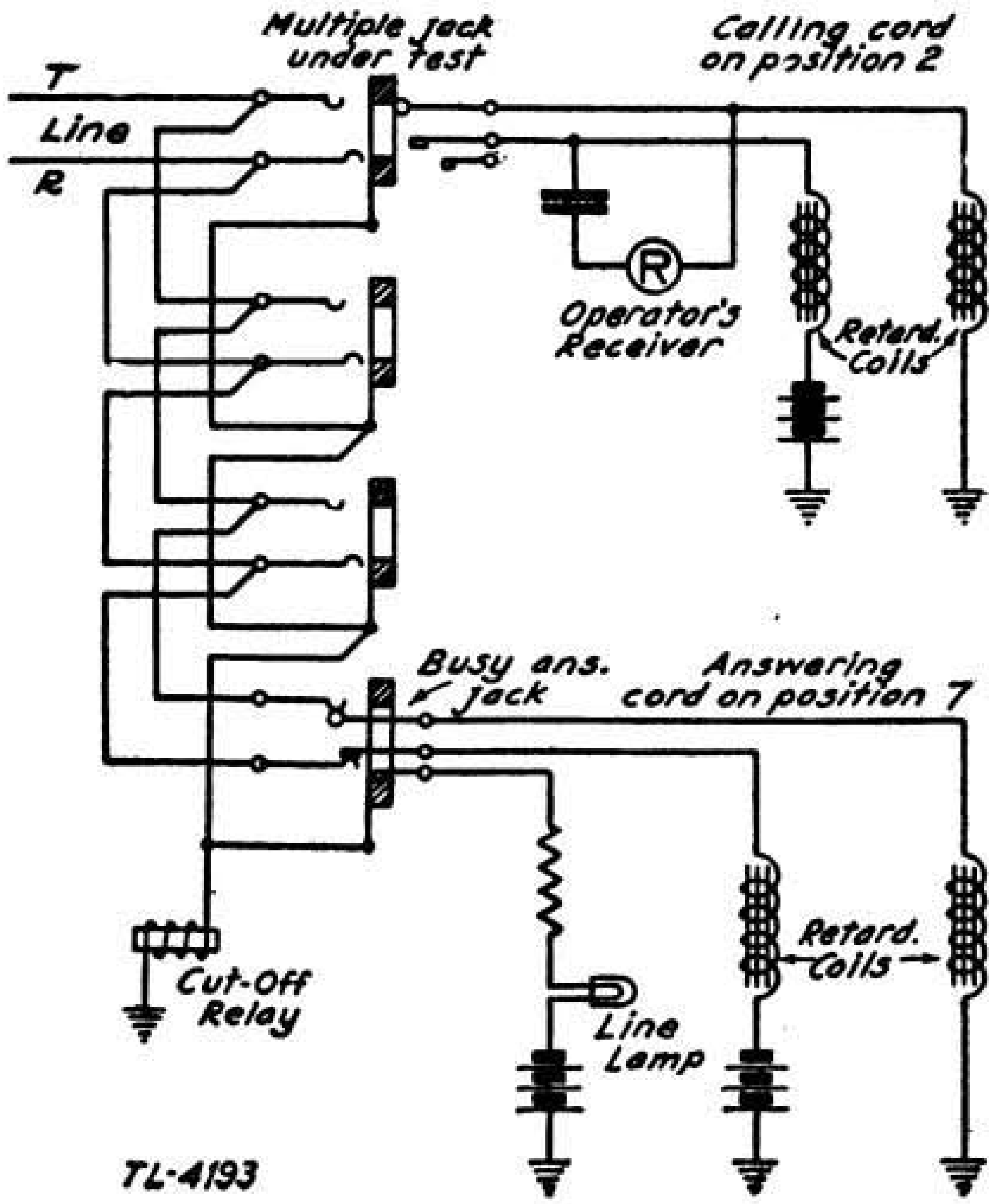


FIGURE 87.—Busy-test circuit.

130. Switchboard circuits.—Both multiple and nonmultiple switchboards are composed of a systematic and efficient arrangement of essential circuits, depending upon the kind and extent of service the board provides. The various types of line circuits, trunk circuits, cord circuits, and operator's telephone circuits employed in switchboards are taken up in other sections of this text.

131. Miscellaneous circuits.—In addition to the main communication circuits provided by switchboards, there are miscellaneous circuits on both muluiple and nonmultiple switchboards which perform auxiliary or supplementary functions. The following is a list of some of the more common miscellaneous circuits with a brief mention of their purpose:

Auxiliary relay.—To operate pilot lamp when any line lamp lights.

Pilot lamp.—To notify operator that a line lamp is lighted.

Fuse alarm.—To provide an audible signal when certain circuits are open due to blown fuses.

Night alarm.—To provide an audible signal when an incoming call appears on the switchboard.

Transfer key.—To group positions.

Ringing mains.—Wiring of ringing power to each position.

Emergency ringing.—Wiring of reserve ringing power.

Peg count.—To cut in meters to measure operator's load.

Position clock.—To operate clocks on each position.

Master clock.—To synchronize position clocks.

Supervisors.—To enable supervisors to check operators.

Monitoring.—To enable chief operators and others to check operator's work.

Busy-back.—To put a busy-back signal on plug-ended trunks.

Trouble tone.—To put a special tone on circuits which are out of order.

Howler.—Wiring of apparatus to generate howler tone.

Howler cord.—To provide for putting howler tone on a line to cause restoration of receiver.

Coin collect.—To enable operator to control pay stations.

There are many circuits available for any one make and type of switchboard, and any one installation will usually employ several of them. The number of different circuits required in any switchboard will vary with operating and service conditions. Each installation is covered by a specification, which makes reference to all drawings and wiring diagrams forming a part of it and covering the details of the circuits involved.

132. Western Electric 1–D switchboard.—Many present Signal Corps common-battery multiple switchboards are of the Western Electric 1–D type. On this switchboard it is usual to repeat the multiple every three positions; or, in other words, to wire the board with sections of three operator's positions each. Each section will then have 6 panels and will contain one complete appearance of calling jacks for all subscriber lines. On this form the switchboard has a capacity of 3000 lines and 300 trunks, each panel having an ultimate capacity of 120 answering jacks in strips of 10, or 160 in strips of 20. The 1–D board is very flexible, and it is often wired so as to repeat the multiple every two positions, resulting in four panel sections. With reduced sections the answering jack capacity of each panel is often reduced to 40, thus giving each operator 80-answering jacks to handle.

When the 1–D switchboard is wired with lamp associated multiple, with six panel sections, it has a capacity of 3000 lines and 60 trunks. The slight decrease in capacity is caused by the space required for the additional lamp jacks. With this arrangement there is the advantage of self-equalization of load and slight increase in speed of service, but as explained the lamp maintenance is higher and there is a greater drain on the battery.

133. Constructional features.—A section is a grouping of positions to secure one complete appearance of the multiple. It is the minimum initial installation of a multiple switchboard. A position is the subdivision of a switchboard designed to be handled by a single operator. A panel is a subdivision of the face equipment of a position, and has a width of one strip of jacks.

134. Arrangement of the multiple.—Figure 88 illustrates the panel arrangement of a multiple switchboard. Each section contains calling jacks of all lines served by the switchboard, the ultimate capacity in this instance being 7700 subscriber lines. There are seven panels and three operator's positions for each section. There must be sufficient operator's positions to allow each answering jack to appear once on the entire switchboard face. Should there be but four panels per section the capacity of the board would be 4400 subscriber lines. Such a decrease in the number of panels per section reduces the distance an operator will have to reach in completing a connection.

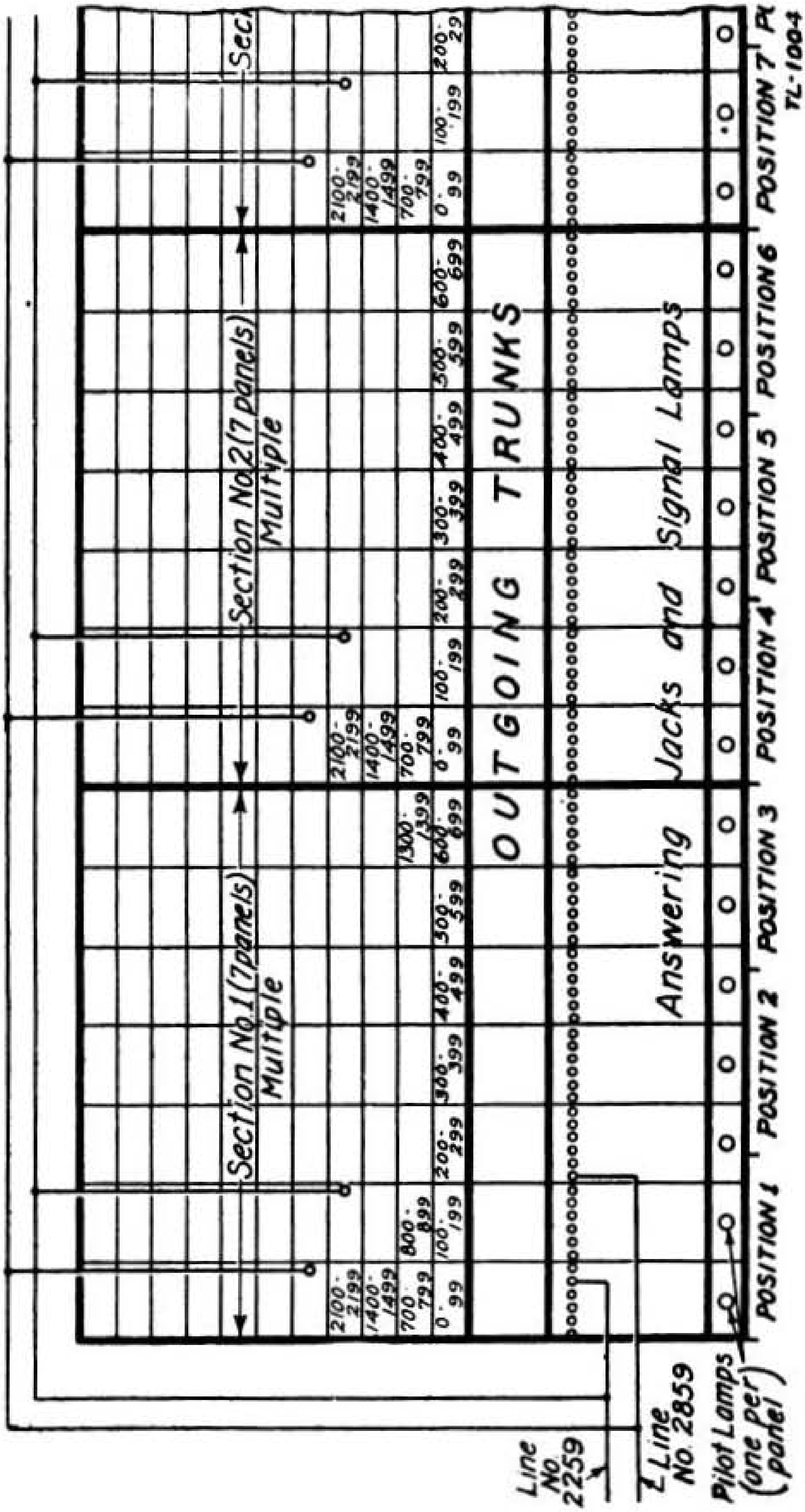
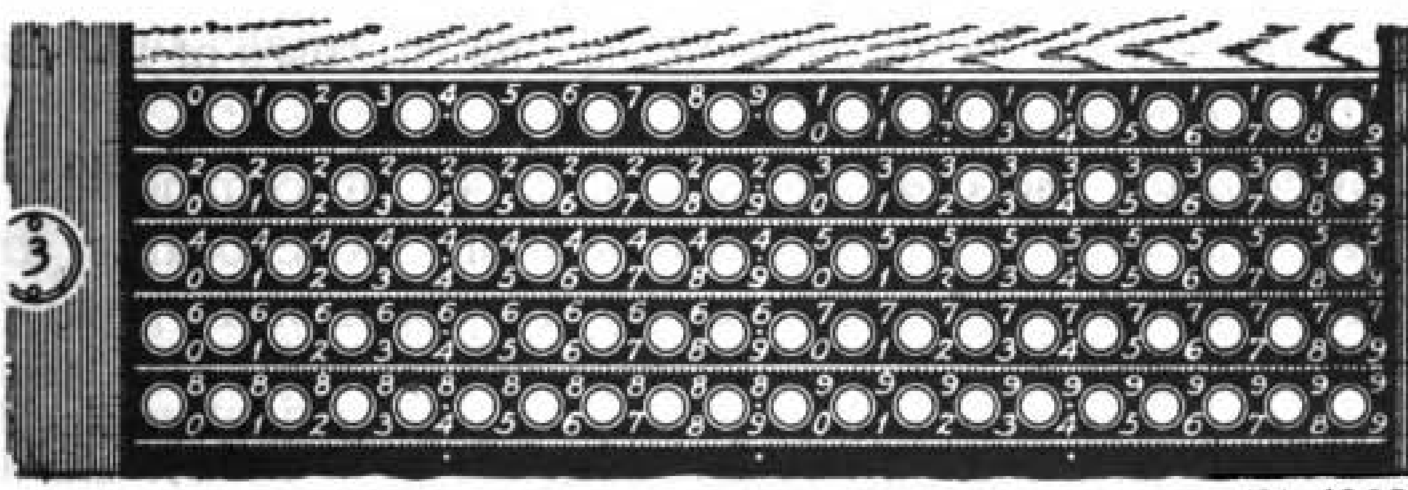


FIGURE 88.—Multiple panel arrangement.

135. Arrangement of jacks.—Answering jacks are usually in strips of 10, while multiple jacks on branch multiple switchboards are in strips of 20. The answering jacks are arranged for individual removable number plates to appear beside each jack. As has been mentioned, the numbering of the answering jacks is not consecutive, since the lines are shifted around so that approximately the same load is placed on each operator. The bottom position of the face equipment of each panel is occupied with answering jacks and line lamps. Next above them are the trunk multiple jacks numbered consecutively. To the left of each strip of trunk jacks there is a number plate in the stile strip, and above the jacks is a designation strip on which may be indicated the name of the exchange with which they afford connection. The remainder of the face of the panel is taken up with multiple jacks.

136. Multiple jacks.—Multiple jacks are grouped in banks of five strips or 100 jacks, as shown in figure 89. Each bank has a number plate in the stile strip to the left of it to indicate the number of the



TL-1005

FIGURE 89.—Multiple jack arrangement.

bank, and each bank is separated from the bank above and below by a 1/16 inch strip of holly wood to segregate the bank. Strips of multiple jacks are inserted in the panel from the rear and are secured in position by discs known as jack fasteners.

137. Typical installations.—In numbers of positions and in positional equipments multiple switchboard installations will vary with the size of the post and the nature of the service. The number of answering jacks varies largely with the number of lines served. The number of multiple jacks varies with the number of answering jacks and the number of sections of the multiple. The number of trunks varies with the service requirements which are governed by several factors among which are: number of subscribers, size of system or system with which trunking is handled, number of exchanges to which trunk service is provided, amount of business which subscribers transact with those of connected exchanges, service of connected exchanges and the rate charged for trunks. The type of trunks used and the circuits employed vary with the nature of the service given over them (subscriber, interoffice or toll), length of the trunk circuits and the type of equipment to which connected at the distant exchange.

138. Relay rack.—In larger installations there is little room in the switchboard positions for mounting relays. In such cases relay racks are provided for mounting the line and cut-off relays. The individual relays are mounted in groups of 10 or 20 on mounting plates of uniform length and these plates are bolted to a vertical channel iron framework known as a relay rack. The line and cut-off relays mounted on the relay rack are connected to terminals on the vertical side of the IDF (intermediate distributing frame) through switchboard cable. These same terminals of the IDF are cabled to the answering jack and lamp on the switchboard position. Thus, each answering jack and lamp is permanently associated with the relay-rack line equipment. This centralization of equipment provides a convenient place to introduce battery and ground. In modern practice one 24-volt battery lead is provided for each group of 120 line relays at the relay rack. Battery is fed to fuse panels and from there distributed through alarm fuses of the proper capacity to the various circuits.

139. Switchboard markings.—*a.* In all types of common-battery exchanges, particularly those with multiple switchboards, there are certain devices employed to assist the operator in giving the proper service. For example, lamp caps are obtainable in several different colors, and with many different markings engraved in the opal and filled with opaque paint. The different caps are used on the line and trunk lamps to distinguish between various classes of service. For example, a certain cap may be used to indicate that priority is to be given to the lines on which it is used, another type of cap may be used on lines denied trunk service, another on those denied toll service, another on those lines to be used for fire alarm service only, and so on for many other classes or combinations of classes of service.

b. Where lines are permanently disconnected or for one reason or other are temporarily out of service, it is desirable to be able to prevent an operator from plugging into the multiple jack. This is accomplished by inserting a signal plug in the appearances of the number in the multiple, and by using a proper color, it is possible to inform the operator why the line is not in service. In case of changes of subscriber's number the new number is marked on the signal plugs, and the old number is not used for another line until a new directory has been published.

c. There are four small holes around each multiple jack and by the use of certain colors of paint and combinations of holes, it is possible to mark the multiple jacks to indicate a wide range of outgoing service conditions. To mark a series of jacks any one of which is available under the same calling number, such as a group of trunks to a branch exchange, a line of selected color is drawn below the entire group of jacks.

140. Questions for self-examination.—

1. In nonmultiple switchboard installations, how is future expansion provided for?
2. For what types or kind of installations are nonmultiple switchboards suitable?
3. What are the general limitations of nonmultiple switchboards?
4. What is meant by the term "multiple jack"?
5. What is the advantage of a multiple board?
6. Draw a diagram of a branch multiple showing the answering jack and at least one multiple jack with all equipment immediately associated with it.
7. What determines the subscriber's telephone number?
8. What change in wiring is made in a central office to change a subscriber's number?
9. What change in wiring is made to equalize the traffic load between operators' positions?
10. What is meant by a lamp associated multiple?
11. How is distribution of load effected on a lamp associated multiple switchboard?
12. By means of a diagram describe a series multiple arrangement.
13. In the series multiple why are cut-off springs used?
14. By means of a diagram explain the busy test used on a multiple switchboard.
15. Name six miscellaneous circuits found on a multiple switchboard.
16. Describe the arrangement of jacks in a multiple.
17. What is a relay rack?
18. What is the purpose of line lamp cap markings on a switchboard?

Section XV
COMMERCIAL MANUAL SWITCHING

141. Multioffice exchange, A and B switchboards.—Where the number of lines in an exchange exceeds the number which can economically be brought to a single switchboard, additional offices are established. In each office of such a multioffice exchange, there is an *A* switchboard to serve calls originating within the office area and a *B* switchboard to serve calls to subscribers within the office area which originate in other office areas of the exchange area, or in offices in other exchange areas. These calls may be routed to the called *B* switchboard either over direct trunk connections or via a centralized switching point. This switching point is known as a tandem office or, in cases of very long haul calls, a long distance office. An *A* switchboard is of the multiple type previously described and has outgoing trunks to all other offices within the exchange. These trunks are incoming to the *B* switchboard where they appear as plugs. A *B* switchboard is a trunking switchboard exclusively and has no cord circuits. In front of the operator appears the multiple of every subscriber in the office area, and on the cord shelf are plug-ended trunks from all other offices in the exchange.

142. Straightforward trunking.—On a call routed directly from the *A* switchboard in the calling office to the *B* switchboard in the called office, the usual method is by straightforward trunking. Take, for example, a call from Pershing 1872 to Cathedral 2536. The Pershing *A* operator answers the call and is given the number Cathedral 2536. She selects an idle trunk to the Cathedral office. This selection is made by means of the busy test–running the tip of the calling plug along the strip of jacks—or by observing a lighted lamp associated with an idle trunk. When the trunk is selected, the lamp associated with the next idle trunk lights. Connection to the selected trunk lights the lamp associated with the trunk at the Cathedral *B* switchboard. In response to the lighted lamp, the *B* operator connects to the trunk by manually depressing an assignment key or is automatically connected to the trunk by a relay in the trunk circuit. An order tone consisting of two short impulses of high pitch called zip tones, is transmitted to the Pershing *A* operator. This advises the *A* operator that she may continue with the completion of her call, which she does by saying 2535 in this case. The Cathedral *B* operator than tests the line called and, if it is idle, connects to it. On connection to this multiple jack of the called subscriber, machine ringing is provided from the *B* board. The *B* operator's telephone is now disconnected from the incoming trunk by a relay in the sleeve of the trunk circuit. Supervision on calls trunked through *B* boards is of the through type and is returned to the *A* operator. It is the duty of the *A* operator to time this connection and to take it down in accordance with the signals of the supervisory lamps at the position. If the *B* operator finds the called line busy, the trunk plug is inserted into a jack which connects an interrupted tone, known as the busy-back, across the trunk line. The plug is left in the jack until the *A* operator takes down the connection as shown by the lighting of the supervisory lamp at the *B* switchboard.

143. Hundred-percent trunking.—In very large exchanges, the interoffice trunks take up so much room that the answering jack and multiple capacity is reduced below an economical figure. In this case 100-percent trunking is used and the subscriber multiple of the *A* board is removed, and in its place there is only the trunk multiple. In this case all calls are handled by both an *A* and a *B* operator. The *A* board here is exclusively an outgoing trunking board and the *B* board, as before, is exclusively an incoming trunking board.

144. Tandem offices.—Where the exchanges are so large that there is not room in the *A* board multiple for all of the *B* board trunks, or where it is uneconomical to establish groups of direct trunks between the offices involved, there is no direct connection between *A* and *B* boards. The tandem office is only a switching point used to connect one local exchange office with another, and serves the same purpose as an isolated switching central in military systems. When an *A* operator receives a call for a subscriber at an office to which she has no trunk, she routes it to the tandem office with which she is connected, and receives a series of three zip tones when the tandem operator comes in on the trunk. The *A* operator then gives the name of the called office. The tandem operator tests for an idle trunk to this office and puts the connection on through to the office of destination. When the called *B* operator comes in on a trunk to the tandem, there is a series of two zips and the *A* operator responds with the number of the station called. This routine sounds quite complex, but as a matter of fact it consumes but little time and has a high degree of accuracy, although each such call is handled by three operators.

145. Toll service.—Service between substations within an exchange is usually on a flat rate basis and is known as local service. Service between substations of different exchanges is handled on a charge per call basis and is known as toll service. This latter service is divided into two classes. The first class, used for traffic between exchanges which are generally not more than 50 miles apart, is is known as A-B Toll traffic. The second class, known as "long distance service", is used for traffic between more widely separated exchanges. For long distance service the toll board method is usually employed. A calling subscriber asks for "long distance". His local *A* operator then connects him to an outward operator at a toll switchboard over a recording trunk. This toll switchboard is one that handles long distance calls for a designated group of local offices. The outward operator fills out the toll ticket and secures a connection to the inward toll operator at the distant toll switchboard via a toll line. The outward operator then secures a connection to the calling party over a switching trunk to his local exchange. The switching trunk is a high grade circuit, and also provides 48 volts instead of 24 volts to the subscriber's telephone. These factors greatly improve transmission quality. The recording trunk over which the calling subscriber secured the original connection to the outward operator is then released. At the distant toll office the inward toll operator secures a connection to the called party via a toll switching trunk to her local exchange. The outward operator at the originating toll switchboard supervises and times the call. When the conversation is completed she takes down the connection and completes the toll ticket.

146. Questions for self-examination.—

1. What is an "A" switchboard?
2. What is a "B" switchboard?
3. Describe a call being placed between an "A" and a "B" switchboard.
4. What equipment appears on the face of a "B" board?
5. What equipment appears on the face of an "A" board?
6. What is meant by straightforward trunking?
7. What is meant by 100-percent trunking?
8. What is the advantage of 100-percent trunking?
9. What is a tandem office?

APPENDIX I
INDEX TO TECHNICAL AND FIELD MANUALS

(See FM 21–6 for complete list)

TM 11–302	Charging Set SCR–169
TM 11–330	Switchboards BD–71 and BD–72
TM 11–331	Switchboard BD–14
TM 11–332	Telephone Central Office Set TC–4
TM 11–333	Signal Corps Telephone EE–8–A
TM 11–335	Telephone Central Office Set TC–1
TM 11–340	Telephone Central Office Set TC–2
TM 11–345	Cabinet BE–70–( ), Wire Chief's Testing Cabinet
TM 11–351	Telegraph Sets TG–5 and TG–5–A
TM 11–353	Installation and Maintenance of Telegraph Printer Equipment
TM 11–354	Teletypewriter Sets EE–97 and EE–98
TM 11–360	Reel Units RL–26 and RL–26–A
TM 11–361	Signal Corps Test Sets EE–65 and EE–65–A
TM 11–362	Reel Unit RL–31
TM 11–363	Pole Line Construction
TM 11–430	Storage Batteries for Signal Communication, except those pertaining to aircraft
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TM 11–457	Local-Battery Telephone Equipment
TM 11–900	Power Units PE–75–A and PE–75–B
TM 11–901	Power Unit PE–75–C
FM 1–45	Signal Communication; Air Corps
FM 5–10	Communication, Construction, and Utilities; Engineer
FM 11–5	Missions, Functions, and Signal Communication in General; Signal Corps
FM 24–5	Signal Communication

APPENDIX II

GLOSSARY OF TERMS

The following definition of words and terms apply only to their usage in this text.

Alternating current—Current that periodically reverses in direction.

Alternator.—An a-c generator.

Ammeter.—A current meter with a scale calibrated in amperes.

Amplifier.—A device which, under control of a current or voltage of given characteristics, produces a larger current or voltage of similar characteristics.

Amplitude.—In connection with alternating current or any other periodic phenomena, the maximum value of the displacement from zero position.

Anode.—The terminal or electrode from which electrons leave an electron tube.

Antisidetone circuit.—A telephone circuit that materially reduces sidetone without reducing the output of the telephone; *without detone.* (See Sidetone.)

Armature.—The rotating assembly of a d-c motor or generator; so the movable iron part which completes the magnetic circuit certain apparatus.

Attenuation.—The decrease in amplitude of electrical energy as it passes through a device or circuit.

Attenuator.—A device for producing attenuation; usually calibrated to produce known amounts of attenuation.

Battery.—A device for converting chemical energy into electrical energy; one or more cells.

Bell.—A device which will operate on either alternating or direct current (a-c or d-c) and give continued striking of a gong, producing a clear ringing sound.

Bias.—*Line bias.*—The effect on the length of telegraph signals produced by the electrical characteristics of the line and equipment. If the received signal is longer than that sent, the distortion is called marking bias; if the received signal is shorter, it is called spacing bias.

Applied bias.—A force (electrical, mechanical, or magnetic) exerted on a relay or other device which tends to hold the device in a given electrical or mechanical condition.

Break contact.—That contact of a switching device which opens a circuit upon the operation of the device.

Bridge.—A shunt path; a device used in the electrical measurement of impedance, resistance, etc.

Buzzer.—An electrical device producing a buzzing sound, usually by use of a vibrator.

Bypass.—A shunt path around some element or elements of a circuit.

Capacitance.—The ability or capacity to receive an electrical charge.

Capacitive reactance.—The effect of capacitance in opposing the flow of alternating current.

Capacitor.—A device for inserting the property of capacitance into a circuit; two or more conductors separated by a dielectric.

Carrier current.—A current used in the transmission of intelligence impressed upon it.

Carrier frequency.—The frequency of the carrier current.

Cathode.—The negative terminal or electrode in an electrolytic cell, vacuum tube, or other electrical apparatus, from which electrons flow.

Cell.—A combination of electrodes and electrolyte which converts chemical energy into electrical energy.

Channel.—A band of frequencies or a circuit within which communication may be maintained.

Characteristic.—A d stinguishing trait, quality, or property.

Circuit.—A closed path or mesh of closed paths which may include a source of emf.

Commutation.—The mechanical process of converting alternating current, which flows in the armature of d-c generators, to direct current as furnished to the load.

Commutator.—The part of d-c rotating machinery which makes electrical contact with the brushes and connects the armature conductors to the external circuit and accomplishes commutation.

Commutator ripple—The small pulsations which take place in the voltage and current of d-c generators.

Component.—A part of the whole; e.g. pulsating direct current (the whole) consists of an a-c component (one part) and a d-c component (another part).

Condenser.—Same as capacitor.

Continuity.—A condition of a circuit where a closed electrical path is obtained.

Contactor.—A device for closing and opening electrical circuits remotely; a magnetically operated switch.

Coupling.—Term used to represent the means by which energy is transferred from one circuit to another.

Cross.—A type of line trouble in which one circuit becomes connected to one or more other circuits.

Crossfire.—A condition where telegraph signals on one circuit cause interference in other telegraph or telephone circuits.

Crosstalk.—A condition where conversation on one circuit causes interference in other telephone circuits.

Current.—A flow of electrons in a circuit.

Cycle.—In a periodic phenomena, one complete set of reoccuring events.

Decibel.—A unit of transmission expressing a relation between input and output power; equal to ten times the common logarithm of the ratio of input to output power.

Demodulator.—A nonlinear device for removing the modulation component (usually voice frequency) from a modulated carrier wave.

Density.—Concentration of anything; quantity per unit volume or area.

Direct current.—Current which is constant in direction.

Differential.—Pertaining to, or involving, a difference; i.e., a differential current device is one which operates upon the basis of a difference in two current values.

Distortion.—An alteration or deformity of a wave form.

Drop.—*a. Switchboard drop.*—An electrically operated mechanical device on a switchboard line circuit which is used to indicate an incoming call.

b. Drop side of a circuit.—That side of the circuit toward the switchboard drop.

c. Drop wire.—The overhead wire connecting a subscriber station with either open wire or cable.

Electrode.—The solid conductors of a cell or battery which are placed in contact with the electrolyte; a conductor which makes electrical contact with a liquid, gas, or an electron cloud.

Electrolyte.—A solution in which, when traversed by an electric current, there is a liberation of matter at the electrodes, either an evolution of gas or a deposit of a solid. Usually refers to the solution in a battery.

Electromagnet.—A core of magnetic material, such as soft iron, which is temporarily magnetized by passing an electric current through a coil of wire surrounding it, but loses its magnetism as soon as the current stops.

Electromotive force.—*emf*—Difference of electrical potential or pressure measured in volts.

Electron.—One of the negative particles of an atom.

Energy.—That capacity for doing work.

Equalizer.—A network having an attenuation complementary to that of a telephone line, for the purpose of equalizing the attenuation at the frequencies used.

Field of force.—Region in space within which a force is effective.

Filter.—A device for preventing the passage of current of certain frequencies while allowing currents of other frequencies to pass.

Flux.—The magnetic lines of force.

Force.—That which tends to change the state of rest or motion of matter.

Frequency.—In periodic phenomena the number of vibrations or cycles in unit time; in alternating current the number of cycles per second.

Function.—The duty or job performed by a device.

Fundamental.—A primary or necessary principle; basis; the lowest frequency component of a complex wave.

Fuse.—A circuit protecting device which makes use of a conductor which has a low melting point.

Gain.—The amount of amplification; negative attenuation.

Generator.—A device for converting mechanical energy into electrical energy.

Ground.—The contact of a conductor with the earth; also the earth when employed as a return conductor.

Grouping circuits.—Circuits used to connect two or more switchboard positions together so that one operator may handle the operation of those positions from his own operator's set.

Handset.—A telephone in which the transmitter, receiver, and a connecting handle form a single piece.

Harmonics.—Frequencies of exact multiples of a fundamental frequency.

Heat coil.—A protective device consisting of a coil of wire wound around a copper tube inside of which a pin is soldered. It is so designed that if an excessive current passes through it for a period of time the heat generated will melt the solder, releasing the pin, and grounding the line.

Holding coil.—A separate coil of a relay which is energized by the operation of the relay and holds the relay operated after the original operating circuit is deenergized.

Howler.—An electromechanical device for the production of an audio-frequency tone.

Hybrid coil.—A multi-winding transformer designed to be used in a circuit where currents in one portion of the circuit induce voltages in all branches except certain designated ones in which no voltage is induced.

Impedance.—The total opposition to the flow of current, consisting of resistance and reactance.

Inductance.—Property of a circuit which opposes a change in current.

Induction.—The act or process of producing voltage by the relative motion of a magnetic field and a conductor.

Inductive reactance.—The opposition to the flow of alternating or pulsating current due to the inductance of the circuit.

Instantaneous value.—When a value is continually varying with respect to time the value at any particular instant is known as the instantaneous value.

Insulator.—A medium which will not conduct electricity.

Intermediate distributing frame.—A frame upon which the circuits from a switchboard and other apparatus are brought out to terminals.

Interposition trunks.—Trunks between different positions of a switchboard.

Jack.—In combination with a plug, a device by which connections can readily be made in electrical circuits.

Key.—A hand operated device for the rapid opening and closing of a circuit or circuits.

Leakage.—Term used to express current loss through imperfect insulation.

Level.—The amplitude of a signal as compared to that of a signal chosen as reference; in telephony, reference level is considered as that signal producing one milliwatt of power in a 600-ohm load; usually measured in decibels (db) above (+) or below (−) a reference level.

Lines of force.—A path through space along which a field of force acts. (Shown by a line or lines on a sketch.)

Loading coil.—A coil designed to be inserted in a line to add inductance to the line.

Loop.—*a. Subscribers loop.*—The pair of conductors connecting a subscriber's telephone with the main frame of the central office.

b. Loop mile, resistance of.—A pair of conductors between two points one mile distant, the resistance of the conductors connected in series.

Magnetic pole.—Region where the majority of magnetic lines of force leave or enter a magnet.

Magnetism.—The property of the molecules of certain substances, as iron, by virtue of which they may store energy in the form of a field of force, due to the motion of the electrons in the atoms of substance; a manifestation of energy due to the motion of a dielectric field of force.

Magnetomotive force.—*mmf*—The force which is necessary to establish flux in a magnetic circuit or to magnetize an unmagnetized specimen.

Main distributing frame.—A frame upon which are brought out the incoming cable or open wire lines to terminals and protectors.

Make contact.—That contact of a device which closes a circuit upon the operation of the device.

Megohm.—A unit of resistance; equal to one million ohms.

Microfarad.—Practical unit of capacitance; one-millionth of farad.

Milliampere.—Unit of electric current; equal to one-thousandth an ampere.

Milliammeter.—Current meter with a scale calibrated in milliamperes.

Modulator.—A nonlinear device for changing the amplitude (or frequency) of a carrier wave at a rate corresponding to the signal to be transmitted.

Multiple.—Parallel connection whereby any number of identical pieces of equipment may be connected into the circuit.

Mutual inductance.—Inductance associated with more than one circuit.

Network.—An electrical circuit made up of series or shunt impedances or combinations of series and shunt impedances.

Noise.—An electrical disturbance which tends to interfere with communication over the circuit.

Ohm.—Fundamental unit of resistance.

Ohmmeter.—A direct reading instrument for measuring resistance, calibrated in ohms.

Oscillator.—A device for producing electrical oscillations; an electrical circuit for converting direct current into alternating current.

Pad.—A network, consisting of resistance, connected so as to have a given amount of attenuation at all frequencies; usually symmetrical.

Parallel circuit.—A circuit in which one side of all component parts are connected together to one line while the other side of all components are connected together to another line.

Patching.—Temporarily connecting together two lines or circuits by means other than switchboard cord circuits.

Patching cord.—A cord terminated on each end with a plug, used in patching between circuits terminated in jacks.

Period.—The time required for the completion of one cycle.

Permanent magnet.—A piece of steel or alloy which has its molecules lined up such that a magnetic field exists without the application of a magnetomotive force.

Phantom circuit.—A telephone circuit which is superimposed upon two other circuits so that the two conductors of one circuit act combined as one conductor for the phantom circuit, and the conductors of the second circuit act as the other phantom conductor.

Plug.—In combination with a jack, a device by which connections can readily be made in electrical circuits.

Potential difference.—The degree of electrical pressure exerted by a point in an electrical field or circuit in reference to some other point; same as electromotive force or voltage.

Private branch exchange (P.B.X.).—A small private exchange acting as a branch of the main exchange for a subscriber with a large number of telephones between which considerable traffic is handled.

Protector.—A device to protect equipment or personnel from high voltages or currents.

Protectors, open-space cut-out.—A device consisting of two carbon blocks, one connected to one side of a line and the other to ground, separated by a narrow gap, designed to provide a path to ground for high voltages such as lightning, etc.

Pulsating current.—Current of varying magnitude but constant direction.

Receiver.—An electromechanical device for converting electrical energy into sound waves.

Rectifier.—A device for changing alternating current to pulsating current.

Reflection.—The returning of a portion of an electrical wave to the sending end of the circuit.

Relay.—A device for controlling electrical circuits from a remote position; magnetic switch.

Repeater.—A device for the retransmission of a signal, usually with amplification.

Repeating coil.—An audio-frequency transformer for transferring energy from one electrical circuit to another, usually one-to-one ratio with one side (line connection) arranged so that a center tap may be obtained for simplexing.

Resistance.—The opposition offered by a conductor to the passage of either direct or alternating current. That portion of impedance which causes power loss.

Resonance.—The condition of a mechanical device or electrical circuit adjusted to respond to a certain frequency.

Retardation coil.—A coil offering high impedance to voice frequency currents but low impedance to direct current.

Rheostat.—A variable resistance for limiting the currents in a circuit.

Ringer.—An audible signaling device which will operate only on alternating current to give a clear ringing sound.

Rotor.—The rotating part of an electrical device.

Self inductance.—Inductance associated with but one circuit.

Series circuit.—An electrical circuit in which the component par are placed end-to-end and form a single continuous conductor; op posite of parallel.

Short.—A type of line trouble in which the two sides of a circuit become connected together.

Shunt.—A parallel or alternate path for the current in a circuit; usually with some impedance other than zero; not used with reference to trouble. (See Short.)

Side-band.—The band of those frequencies equal to the carrier plus the voice frequencies (upper side-band), or carrier minus the voice frequencies (lower side-band).

Sidetone.—That portion of the signal from a transmitter in a telephone which is returned to the receiver of that telephone.

Signal to noise ratio.—The ratio of the signal level on a circuit to the noise level of the same circuit.

Simplex.—A method of obtaining a telegraph channel by use of repeating coils or bridged impedances.

Singing.—Oscillations produced by feed-back in a circuit, especially in repeaters.

Space charge.—An electrical charge distributed throughout a space; such as a charge between the filament and plate of a vacuum tube.

Stator.—That part of an electrical device which remains stationary when in use.

Sub-cycle generator.—A frequency reducing device which furnishes ringing power at a sub-multiple of the power supply frequency.

Subscriber.—A person or organization to whom service is extended.

Subset.—The complete telephone equipment including handset, ringer, and other associated parts located at a subscriber station, exclusive of protective equipment.

Supervision.—The process of watching over the condition of a connection at a switchboard to determine when subscribers are through using the connection.

Switch.—A device for opening, closing, or rerouting an electrical circuit.

Switchboard.—A board containing apparatus for controlling or connecting electrical circuits.

Synchronism.—The state of being synchronous.

Synchronous.—Having the same period and phase; happening at the same time.

Tandem office.—A telephone office handling connections between smaller offices located in a group around it. It handles no direct connections to subscribers but serves only to connect one telephone office with another.

Telephone.—An instrument for the converting of speech into electrical waves for transmission and converting electrical waves to sound waves for reception.

Telering.—A frequency selector device for the production of ringing power; for the production of 20-cycle ringing power from a 60-cycle source it selects every third half-cycle of the input to be used as a half-cycle of the output frequency.

Terminal.—One end of an electrical circuit.

Transfer circuits.—Same as grouping circuits.

Transformer.—A device for raising or lowering a-c voltage.

Transmission.—The passing of energy through a conductor.

Transmitter.—Tnat part of a telephone which converts the sound waves into electrical waves; usually consists of a diaphragm operated by the sound waves to compress a container of carbon granules, causing a change in resistance and thus in currents to correspond to the sound waves.

Transposition.—A rearrangement of the relative position of adjacent wires, to prevent losses or interference by induction.

Trunks.—A circuit between two switchboards, central offices, switchboard positions or other parts of a telephone plant, but not to any subscriber.

Varistor.—A combination of dissimilar metals in contact which give a nonlinear impedance.

Voice frequencies.—Those frequencies covered by the range of human voice.

Volt.—Unit of potential, potential difference, emf, or electrical pressure.

Voltmeter.—An instrument for measuring potential difference or electrical pressure, calibrated in volts.

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