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WAR DEPARTMENT

U.S. Dept. of Army

TECHNICAL MANUAL

LOCAL-BATTERY TELEPHONE EQUIPMENT

September 3, 1942

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TECHNICAL MANUAL No. 11-457

WAR DEPARTMENT,
WASHINGTON, September 3, 1942.

LOCAL-BATTERY TELEPHONE EQUIPMENT

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SECTION I

GENERAL

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

2. Scope.—The general application of various circuits and combination of circuits used in wire 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, because all such equipment and circuits employed are covered adequately in various technical manuals issued by the Signal Corps.

3. Advantages of telephony.—Telephony has certain advantages over telegraphy in that the spoken word can transmit more intelligence than the printed word, and the subject of the message can be discussed directly by the parties concerned without the formality of exchanging messages, and specially trained operators are not required for transmission and reception. Wire telephony, when available, also has certain advantages over radio telephony in that it is usually secret, it is not affected by static, and operation is not so critical.

4. Use of telephony.—Due to the reliability and ruggedness of the telephone equipment, telephone communication is used from the lowest unit in the field up to the highest. Since the members of a command are, as a rule, used to using the telephone as the primary means of communication, it becomes necessary, quite frequently, to re-educate them so that all of the means of communication will be used to their fullest capacity and greatest efficiency.

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Section II

THE LOCAL-BATTERY TELEPHONE

5. The components of the local-battery telephone.—The seven components of the local-battery telephone are the receiver, the transmitter, the battery, the induction coil, the hook switch, the hand generator and the ringer. Each of these parts will be described in detail, and the local-battery telephone circuit will be built up in steps from the simplest circuit to the final completed form.

6. The receiver.—*a.* The mechanical construction of a telephone receiver is shown in figure 1. The receiver contains a U-shaped permanent magnet which holds the diaphragm under a constant pull. The current at voice frequency passes through the coils which are wound around the pole pieces attached to the ends of the permanent

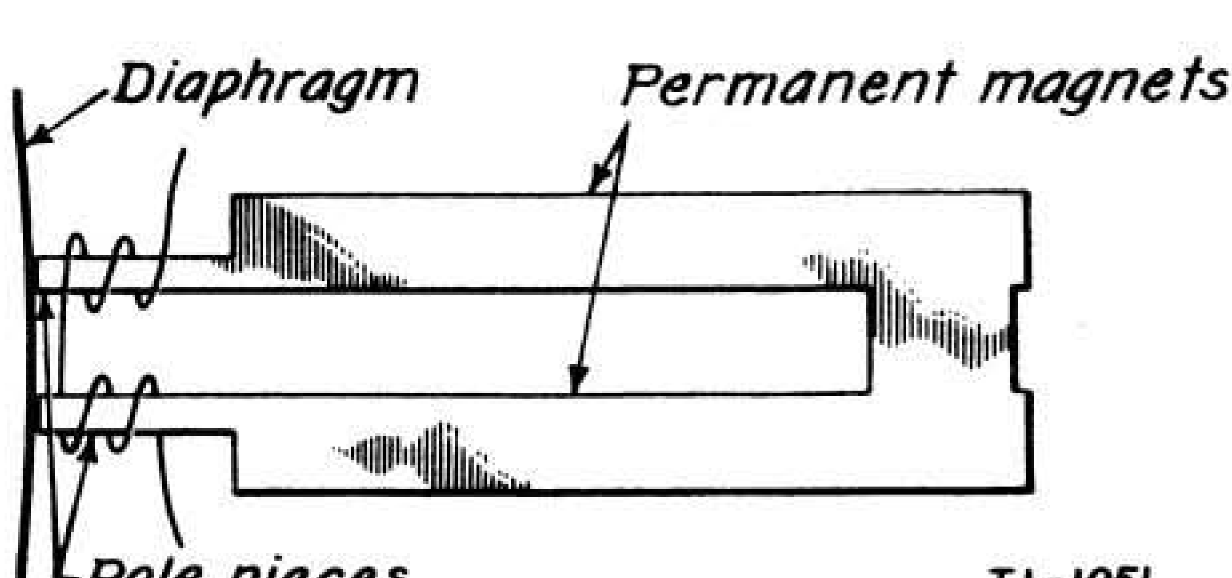

Figure 1.—Schematic diagram of a telephone receiver.

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magnet. The magnetic field produced by the voice currents alternately aids and opposes the field of the permanent magnet. Thus the pull on the diaphragm alternately increases and decreases, causing the diaphragm to vibrate in synchronism with the voice frequency current through the windings of the coils. The vibration of the diaphragm produces the sound waves.

b. All modern receivers are equipped with permanent magnets and it is important that this magnetism not be destroyed by jarring or other abuse. It is evident that a direct current could be put through the windings of the coils in such a direction as to destroy or impair the permanent magnet. The permanent magnet holds the diaphragm taut, making the receiver more sensitive. It also prevents the diaphragm from vibrating at twice the applied frequency.

c. Some of the troubles encountered in receivers are as follows: (a) bent diaphragm, (b) rust or dirt on pole pieces preventing motion of diaphragm, (c) incorrect clearance or gap between diaphragm and pole pieces, causing receiver to rattle on strong impulses, (d) loose diaphragm, (e) open winding, (f) open receiver cord.

d. Figure 2 is a cross-sectional view of the HA 1 receiver unit which is the present standard in the Bell System. This receiver which is of the bipolar permanent magnet type employs in its con-

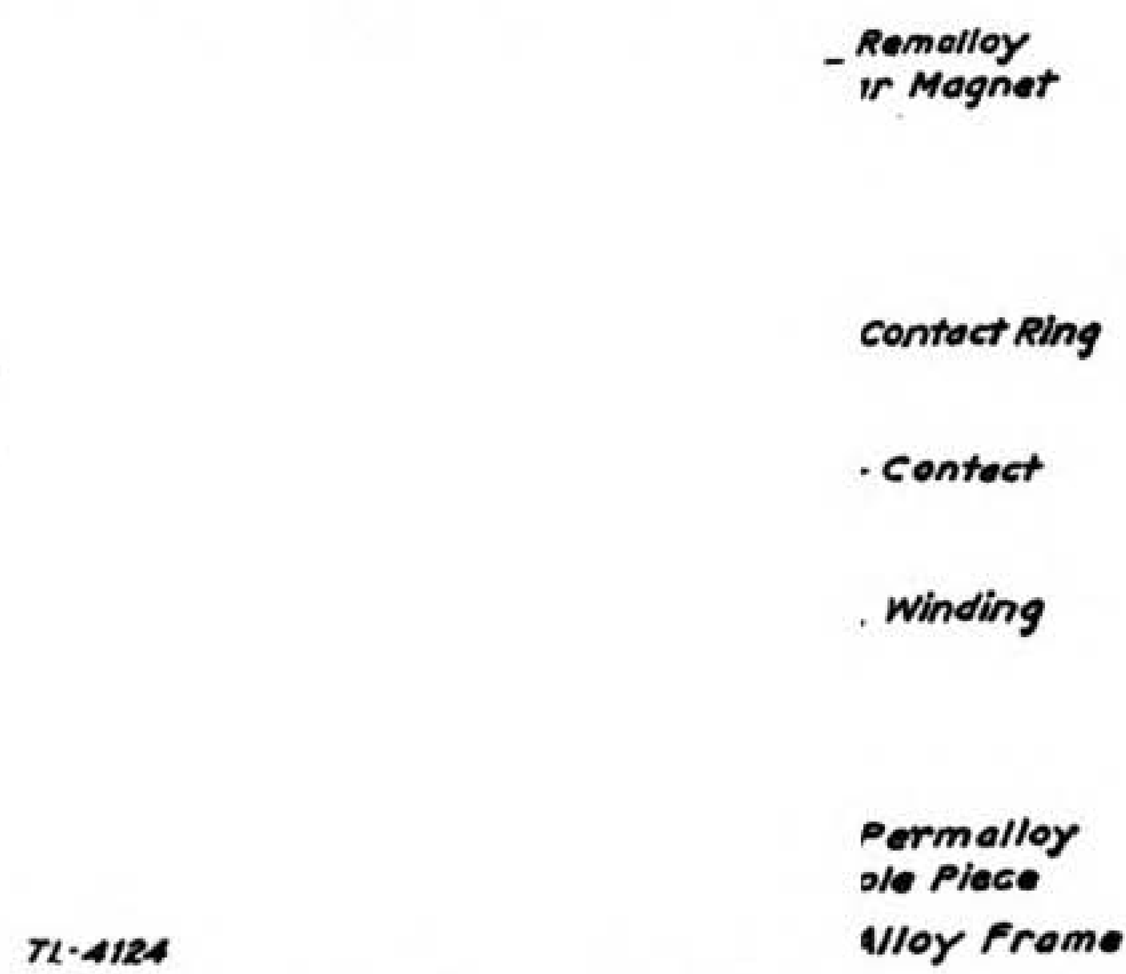

FIGURE 2.—Cross-section of a standard receiver unit.

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struction three comparatively new magnetic alloys with special magnetic characteristics. It is substantially more efficient than any previous design. It also differs notably from earlier types in the extent to which the motion of the diaphragm, which is made of vanadium-permendur, is affected by "acoustic controls." One acoustic control is directly behind the diaphragm, and the other is enclosed between the diaphragm and the inner surface of the receiver cup when the receiver unit is mounted in the telephone instrument. The former control consists of an air chamber with an outlet to the back of the receiver unit through a small hole covered with a silk disc. The latter consists of an air chamber which opens into the air through six holes in the receiver cap. These air chambers are designed to have "acoustic impedances" which match the "electrical impedances" of the receiver and improve its overall efficiency appreciably. The diaphragm, which is unclamped, rests on a ring-shaped ridge and is held in place by the pull of the magnet. By this method variations in receiver efficiency at different frequencies are practically eliminated within the voice range. The two permalloy pole pieces are welded to a pair of strong remalloy or cobalt-steel bar magnets, and the assembly is fastened to a zinc alloy frame. The whole unit is held together by a brass ferrule on the back of which are mounted two silver plated contacts for the electrical connections. Under no circumstances should direct current be passed through this type of receiver. Due to the small cross-sectional area and high concentration of magnetic flux in the magnets even a momentary flow of direct current may cause them to lose a large amount of their magnetism.

e. The original telephone as invented by Bell in 1876 consisted of a receiver which was used both as a transmitter and a receiver. The simplest form of telephone circuit, therefore, consists of two receivers connected by a pair of wires. The voice waves of the speaker cause the diaphragm to vibrate. This vibration changes the air gap of the magnetic circuit, thus varying the magnetic flux through the coils, and as a result, a voltage is induced in the coil windings. As the circuit is complete, talking current flows and operates the other receiver. It is easily seen that this current would be small and that this circuit is of little practical use except in cases of emergency.

7. The transmitter.—*a.* Although the principle of Bell's original telephone applies to the present day telephone receiver, it was ap-

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preciated in the early stages of telephone development that the electrical energy generated by a diaphragm vibrating in a magnetic field was insufficient for the transmission of speech over any considerable distance. The maximum energy available for such an instrument would be limited to the energy contained in the voice waves striking the diaphragm. One year after the invention of the original telephone, the Blake transmitter was introduced. It worked on the principle of a diaphragm varying the strength of an already established electrical current, instead of generating electrical energy by means of electromagnetic induction. By this method a large amount of electrical energy is controlled by the small amount of energy contained in the sound waves. Since the transmitter does not generate the electrical energy, an external source must be provided. This source, in practically all cases, is a battery.

b. The principle of the transmitter is that the contact resistance of carbon varies with the pressure of the contact. In nearly all modern transmitters carbon is used in the form of fine granules. These granules are contained in a cup, and the pressure is varied by means of a plunger or piston acting within the cup and mechanically connected to the diaphragm. The cup and piston with the granules is known as the transmitter button. Figure 3 is a schematic drawing of a transmitter which will give an idea of the electrical path through the transmitter and how the resistance of the path is varied.

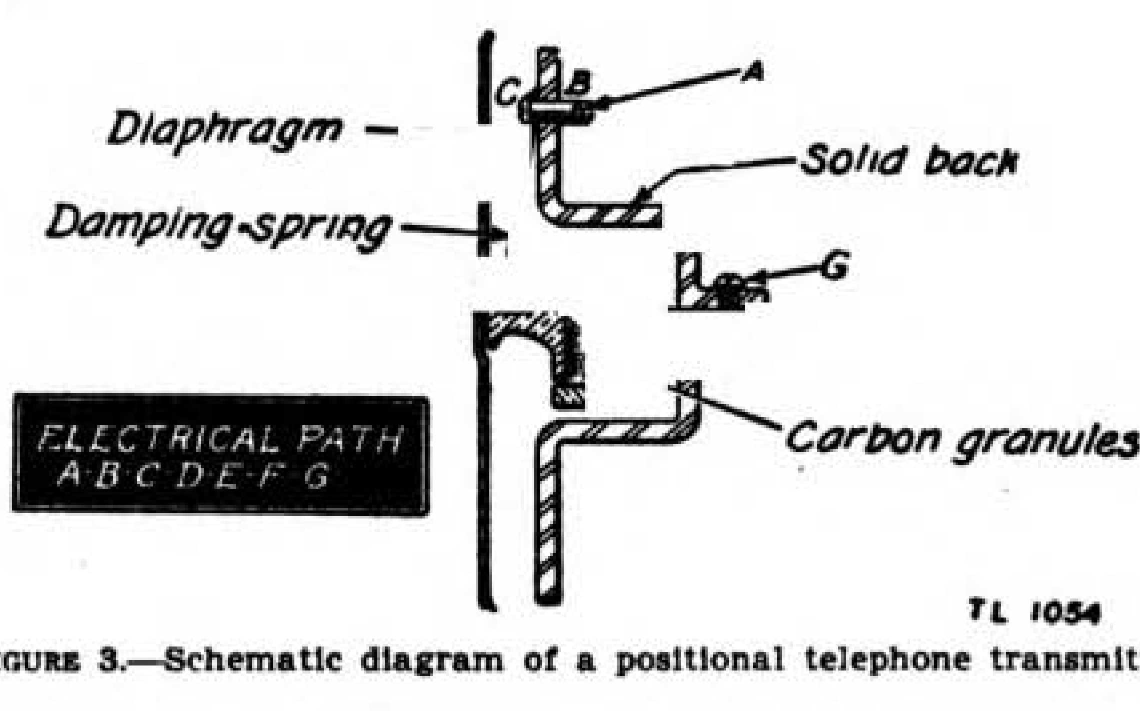

FIGURE 3.—Schematic diagram of a positional telephone transmitter.

c. Figure 4 shows in cross-section the nonpositional transmitter unit which is present standard for subscriber telephone sets. This transmitter is of the "direct action" type; that is, the movable element attached to the diaphragm, which actuates the granular

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carbon, is an electrode, and serves the dual purpose of contact and pressure surface. As the drawing shows this dome-shaped electrode is attached to the center of a conical diaphragm, and forms the front center surface of the bell-shaped carbon chamber.

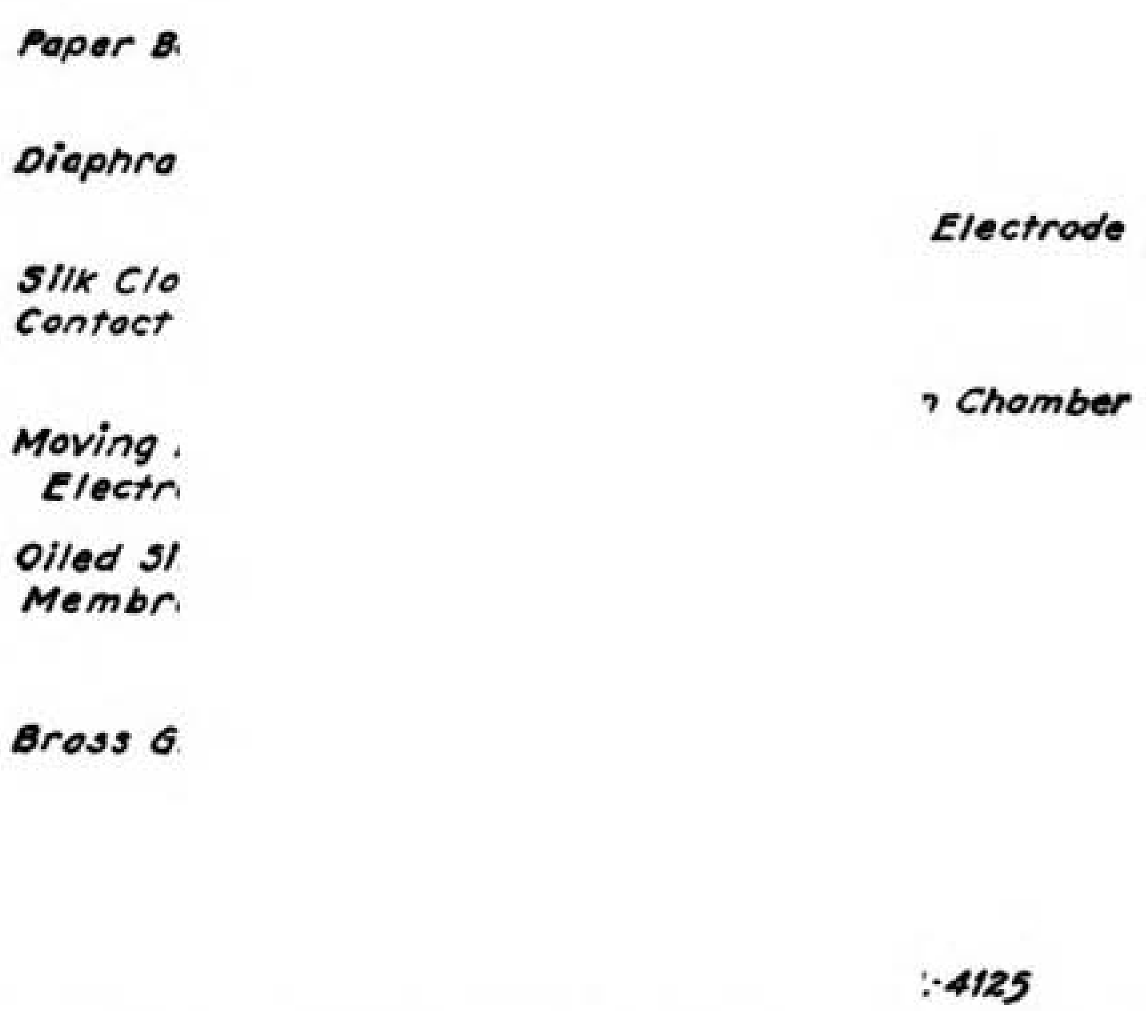

FIGURE 4.—Cross-section of a standard nonpositional transmitter unit.

d. The diaphragm is made of aluminum alloy 0.003 inch thick with radial ridges to increase stiffness. Paper "books," which consist of a number of thin impregnated paper rings, support the diaphragm at its edge on both sides. The carbon chamber is closed on the front side by a silk membrane clamped under the diaphragm electrode. A light spoked copper contact member, clamped under the diaphragm electrode, is the means of providing a flexible connection between this front electrode and the supporting metal frame. The fixed back electrode is held in place in a frame by a threaded ring and is insulated by a phenol fibre washer and a ceramic insulator which also forms one of the surfaces of the carbon chamber. The active surfaces of both electrodes are gold plated. A brass plate which is perforated with large holes protects the vibrating part against mechanical injury. Moisture is kept out of

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the working parts by an oil silk moisture-resisting membrane placed between the brass plate and the diaphragm. The shape of the electrodes and the carbon chamber provides sufficient contact force betwen the diaphragm electrode and the granular carbon in the zone of maximum current density so that this transmitter operates satisfactorily in any position. When new it has a resistance of around 30-40 ohms.

e. Transmitters made by various manufacturers may differ in constructional details but all of them work on the same fundamental principle.

f. Transmitter troubles can be classified as packing, heating, rattling and resonating. The last is a fault of design or construction and is rarely encountered. Rattling is caused by a loose diaphragm or loose contact within the transmitter unit. Heating is caused by passing too great a current through the transmitter causing pitting of the granules and giving rise to packing. Broken granules, the presence of dust and dampness also lead to packing. In a packed transmitter the granules are stuck together and vibrations of the diaphragm cannot vary the contact resistance.

g. The nonpositional transmitter may be used in any position, but the older types of transmitters must be held with the diaphragm vertical or nearly so. If it is held horizontal the carbon granules will fall away from one of the contacts and open the circuit. It should always be remembered that a transmitter will never generate a voltage, but is merely a variable resistor that can be used to control a flow of current from some other source.

h. The use of the transmitter greatly improved the simple telephone circuit as conceived by Bell. Figure 5 shows a diagram of a talking circuit using a transmitter, receiver, and battery at each station. This arrangement has two defects which must be overcome before it is of practical use: (1) it would require high battery voltage, especially on long lines, (2) the change in resistance of the

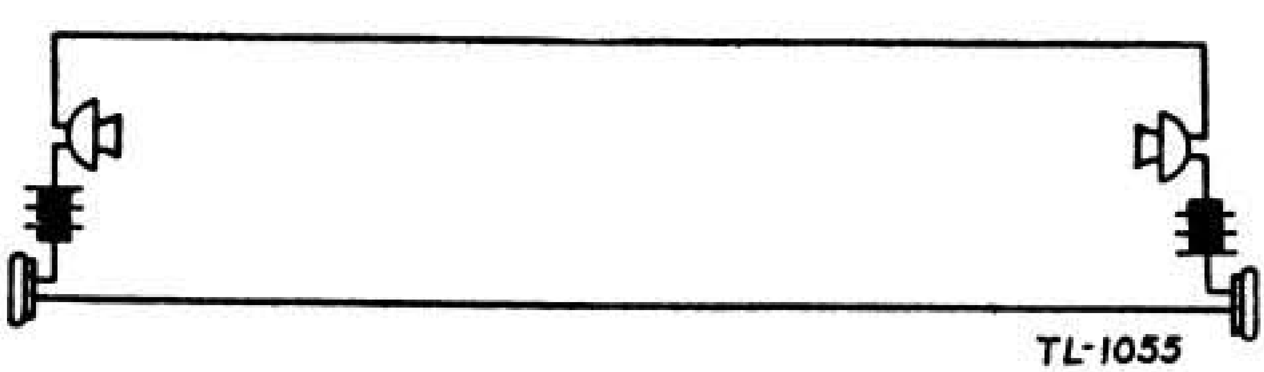

FIGURE 5.—Simple series telephone circuit.

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circuit which can be caused by talking into either transmitter is extremely small compared to the circuit resistance; hence the percentage change in current will be correspondingly small. To overcome these defects, induction coils are used at each station.

8. The local-battery induction coil.—A telephone induction coil is a transformer which is efficient over a wide range of voice frequencies. Figure 6 shows the fundamental talking circuit using induction coils. It should be noted that, with this arrangement, the resistance of the local transmitter circuit is relatively low, in fact, practically all of its resistance is that of the transmitter. The results are (1) a large current flows through the transmitter when a

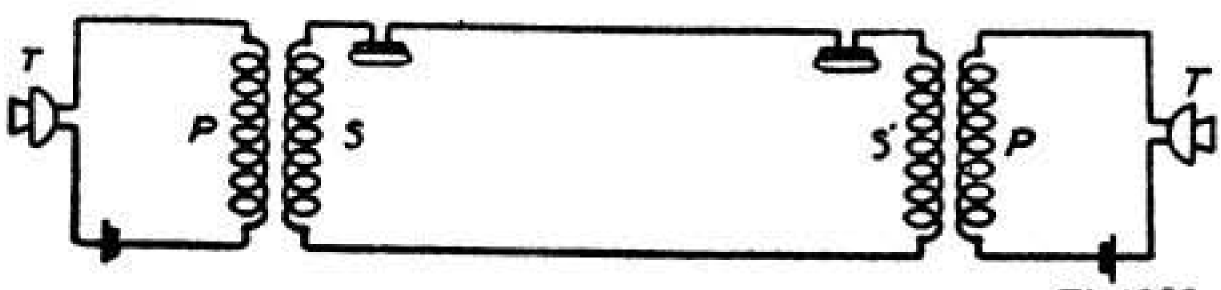

FIGURE 6.—Local-battery telephone circuit with induction coil.

comparatively low battery voltage (usually 3-6 volts) is applied, (2) a given resistance change in the transmitter causes a large percentage change in the current flow. A common type of induction coil used in local-battery telephony is the W. E. No. 13. The resistance of the primary of this coil is 1.8 ohms and the secondary resistance is 22 ohms. There are 400 turns in the primary and 1700 in the secondary; thus, it is a step up transformer of approximately 1 to 4 ratio. This gives an additional improvement in transmission by increasing the voltage and reducing the current in the secondary for a certain power transfer.

9. The hook switch.—*a*. The telephone circuit now set up has two definite disadvantages. There is no easy way to open the primary circuit and the battery would soon be exhausted. The secondary circuit is also continually across the line. This will not cause trouble in figure 6 but when the signaling circuit has been added it will shunt out the ringer and the bells will not ring. A solution of these two defects calls for a device that will open these two circuits when the telephone is not in use and close them when it is in use. The closing and opening of the primary and secondary circuits are accomplished by the hook switch, which is a spring return switch

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that breaks the two circuits when the weight of the receiver is on the hook. One form of this switch is shown in figure 7. It provides a place for hanging the receiver when the latter is not in use.

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FIGURE 7.—A telephone hook switch.

b. The hook switch is usually connected into the circuit as shown in figure 8. Insofar as transmitting and receiving are concerned the telephone circuit is complete, but a method is needed to signal the party at the distant end of the line when he is wanted on the line and to allow him to call the local party to the telephone.

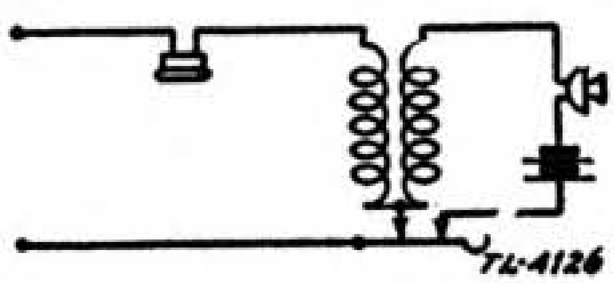

FIGURE 8.—Primary and secondary circuits of a local-battery telephone.

Permanent Magnets

Pole Pieces-

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FIGURE 9.—Magneto generator magnets and pole pieces.

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10. The hand generator or magneto.—*a.* The field of a typical hand generator consists of from two to five U-shaped steel permanent magnets arranged with like poles on the same side. These magnets are provided with cast iron pole pieces. This gives the arrangement shown in figure 9. A strong field exists between these pole pieces. End plates with bearings are secured across the ends of the pole pieces and in these bearings an armature is mounted. Figure 10 shows two views of an armature.

TL-1058

FIGURE 10.—Magneto generator armature.

b. The fewer the bars in the permanent magnet, the greater must be the number of turns in the armature winding, ranging from about 3000 for a 3-bar generator to about 1700 for a 5-bar machine. On one type of generator, one terminal of the winding is grounded to the armature core and the other is connected to a pin set into the axis of the shaft and insulated from the remainder of the shaft. Contact made with this pin by a flat spring gives one terminal of the generator, while connection to the generator frame gives the

FIGURE 11.—Magneto generator assembly without permanent magnets.

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other. Other types of magnetos have slightly different arrangements. Figure 11 shows the gear and crank arrangements for driving the magneto.

c. The crank turns a shaft extending all the way through the generator. Over this shaft is mounted a pointed sleeve *V* and to this sleeve is secured a large gear *S*. Pinned to the shaft is another sleeve *B* so notched as to engage the points of the sleeve *V*. A spring coiled about the shaft presses against the larger gear wheel and the collar *C* which is integral with the shaft; and this spring forces *B* to engage with *V*. As the crank is turned, the magnetic field tends to prevent the armature from turning, and this drag, through the gears, holds sleeve *V*. Rotation of the crank then causes the inclined face of *B* to ride up the face of *V* until the collar *C* jams against the hub of the gear *S*, which prevents further longitudinal movement of the shaft and causes the armature to rotate. The principal reason for this action is to cause the shaft to move endwise and operate a switch. This switch is of the break-one, make-one type. The make contact places the generator across the line and the break contact may remove the ringer from across the line as will be seen later. The pinion *P* is usually so connected to the shaft *A* that when cranking has ceased, the armature is free to rotate and aline itself with the field between the pole pieces. This lengthens the life of the permanent magnets. A magneto turned at normal speed will develop an electromotive force of about 85-90 volts at a frequency of 17-20 cycles.

11. The telephone ringer.—*a.* Figure 12 illustrates the ringer used in telephone instruments. This device operates on the 20-cycle alternating current put out by the hand generator.

b. The ringer consists of two electromagnets M_1 and M_2 which are mounted on a soft iron yoke *Y*. The armature is pivoted so as to give a slight air gap separation between its two ends and the cores of the respective magnets. The tapper rod *R* is securely fastened to the armature. One end of the permanent steel magnet *S* is mounted near the middle of *Y* and the other end is near the center of the armature. The two gongs G_1 and G_2 are mounted so that the tapper strikes first one and then the other as it vibrates between them.

c. The theory of the ringer can be better understood by referring to figure 13. In figure 13, *N* represents the north pole of the permanent magnet and is mounted very close to the center of the

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FIGURE 12.—Ringer assembly.

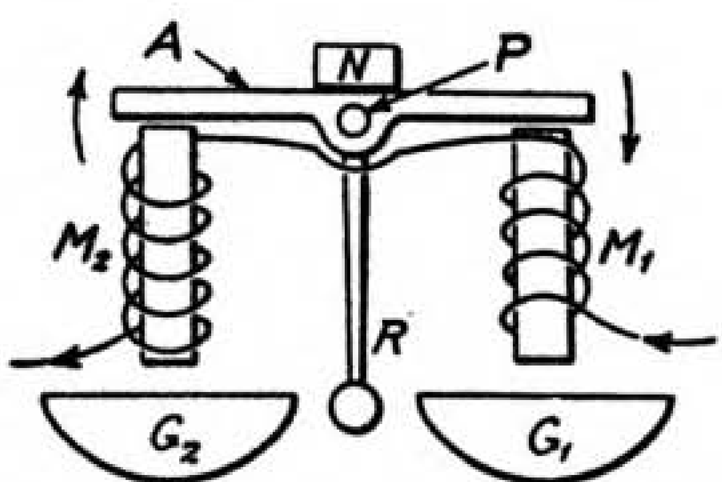

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FIGURE 13.—Schematic diagram of a ringer.

soft iron armature *A*. This induces an *S* pole at the center and an *N* pole at each end of the armature. Let us assume that 20-cycle ringing current is passing through the windings and that its direction during the present half cycle is as shown. This makes the

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upper end of M_1 an S pole and the upper end of M_2 an N pole. Thus the armature will rotate in the direction indicated about its pivot P, and the tapper will strike G_2. During the next half cycle the direction of current is reversed, so is the direction of armature rotation, and the tapper will strike G_1. Ringers of this kind having permanent magnets are called polarized ringers. They have resistances of from 1000 to 4250 ohms. The impedance of such a ringer to voice frequency currents is approximately 30,000 ohms, so it can be seen that a ringer across the line during conversation does not cause material transmission losses.

12. Ringing circuits.—*a*. In the two-way ringing circuit with standard generator, the ringer and line are so connected to the generator switch that when neither generator is being turned, the generators stand open and the ringers are connected across the line as shown in figure 14. But as soon as either generator crank is turned, that generator is connected across the line and the ringer at that sta-

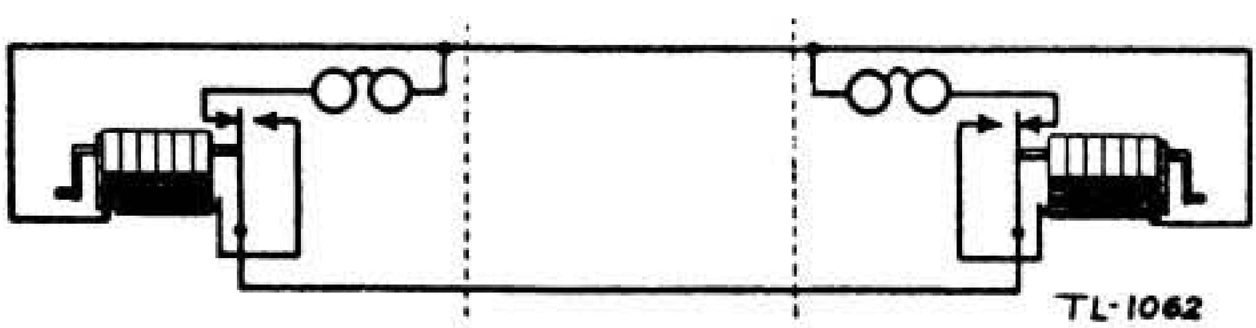

FIGURE 14.—Complete signaling circuit.

tion may or may not be disconnected from the line. Figure 15 shows a condition where the generator at *A* is being cranked and is sending current out to operate ringer at *B*. This diagram shows the ringer at *A* as having been disconnected from the line. Other hookups showing the ringer permanently across the line will be shown later. In figure 8 was shown the diagram of the talking circuit and

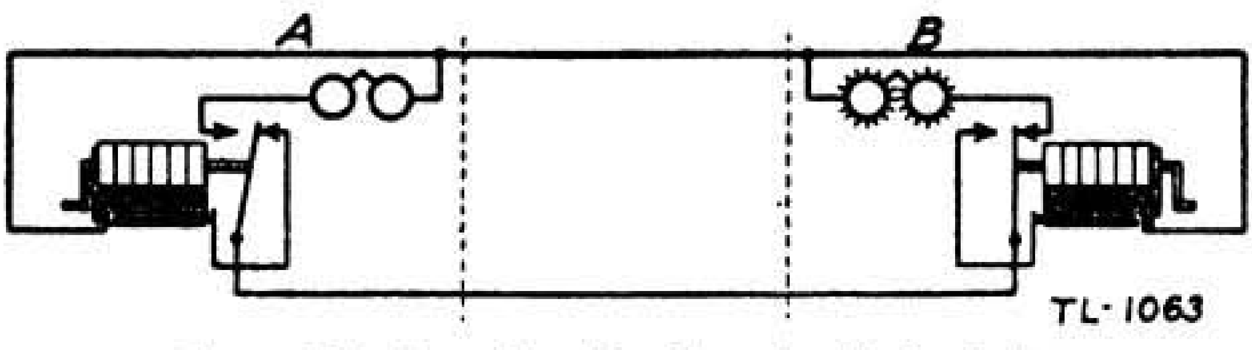

FIGURE 15.—Complete signaling circuit *A* ringing.

now in figure 15 there is shown the signaling circuit. There is no reason why the two cannot be combined, and then one pair of wires

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can be used for both talking and signaling. All this requires is the addition of a hand generator and ringer to each telephone as shown in figure 8. The result is shown in figure 16.

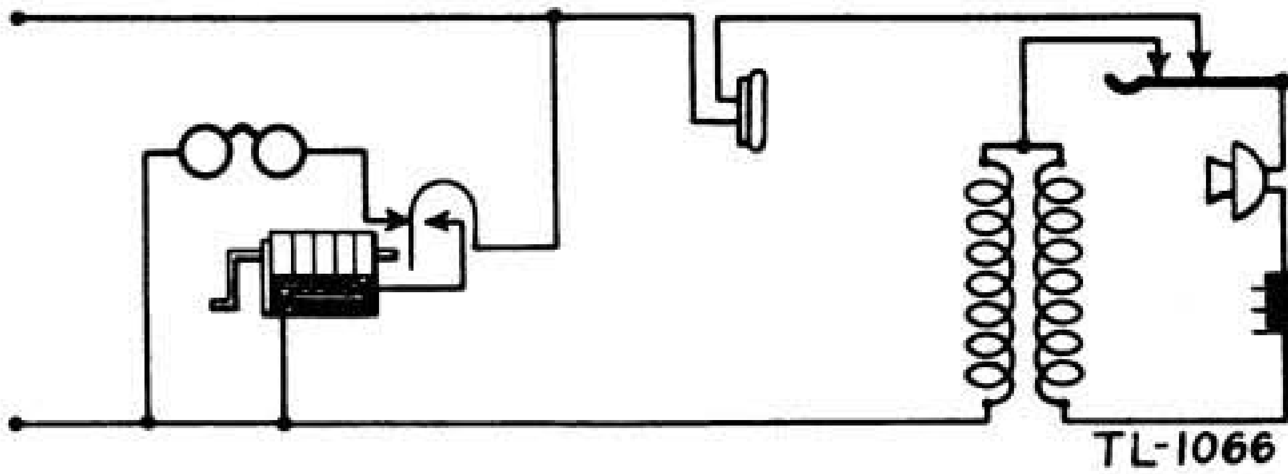

FIGURE 16.—Local-battery telephone complete.

b. The ringing circuit considered above is the Western Electric or open-out circuit. Another notable circuit is shown in figure 17.

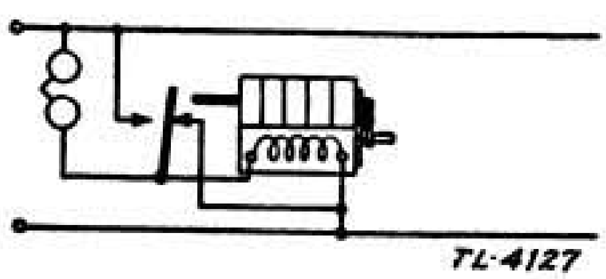

FIGURE 17.—Stromberg-Carlson or shunt-out signaling circuit.

By inspection it can be seen that the ringer and generator are shunted out when they are not supposed to operate. This circuit is known as the shunt-out or Stromberg-Carlson circuit. The same generator cannot be used for both circuits because the necessary terminals are not available.

13. The four fundamental circuits of the local-battery telephone.—These circuits are the primary, secondary, ringer and generator circuits. Figure 18 shows the primary circuit in heavy lines with the rest of telephone in light lines. The function of the primary circuit is to
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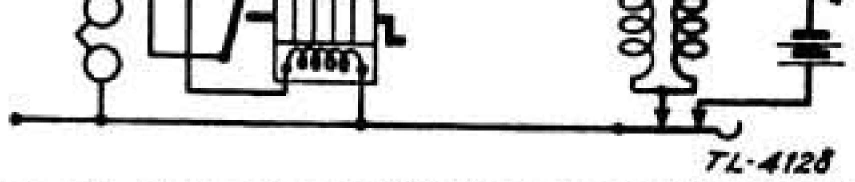

FIGURE 18.—Primary circuit of a local-battery telephone.

change sound impulses into electrical impulses and make them available to the secondary circuit. Figure 19 shows the secondary

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circuit of the same telephone. This circuit has a two fold function. It must place the electrical impulses from the primary circuit on

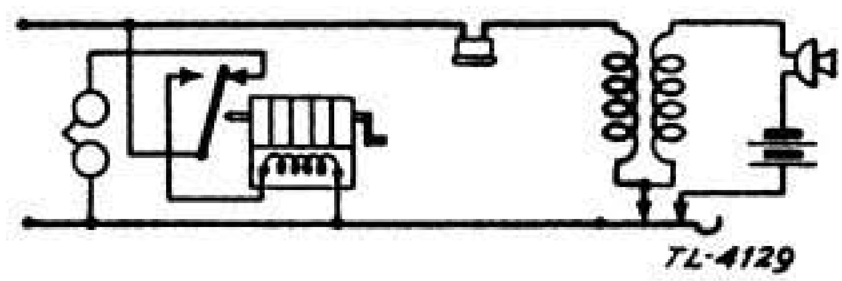

FIGURE 19.—Secondary circuit of a local-battery telephone.

the line and it must also change the incoming electrical impulses into sound impulses. The ringer circuit, as shown in figure 20, produces an audible signal when the subscriber is to be called to the telephone. When the local subscriber wishes to call the operator he

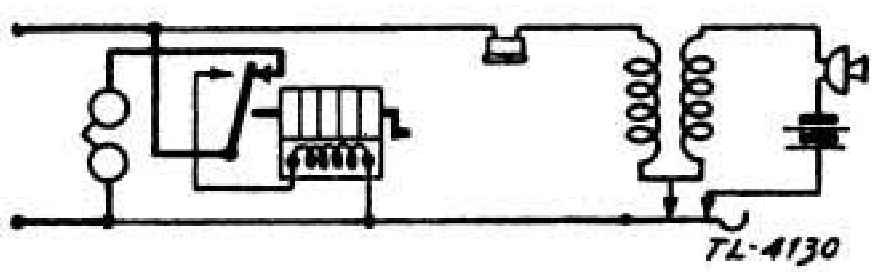

FIGURE 20.—Ringer circuit of a local-battery telephone.

must have some means of producing a strong signal at the distant end. This is accomplished by the generator circuit as shown in figure 21.

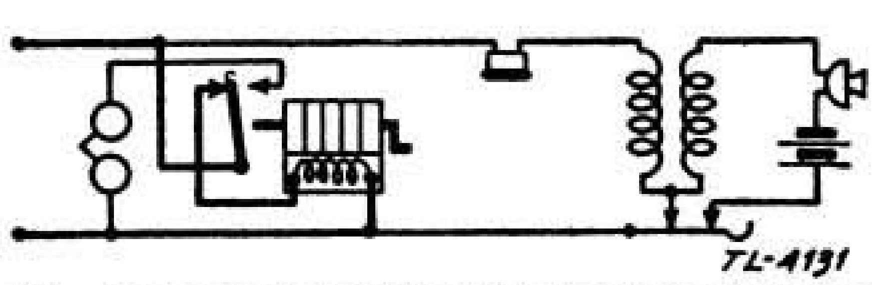

FIGURE 21.—Generator circuit of the local-battery telephone.

14. The local-battery antisidetone circuit.—*a. Definition.*—In the telephone circuits, thus far considered, the sounds picked up by a transmitter of one telephone were reproduced in the receiver of that telephone as well as in the distant receiver. This is called sidetone and becomes objectionable when the telephone is used in a noisy location. This local noise, picked up by the transmitter and reproduced by the receiver, tends to prevent the user from hearing the distant station. A circuit is used in modern telephones which substantially reduces this sidetone. This is known as the antisidetone circuit.

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b. Operation of circuit.—(1) *Transmitting.*—In the antisidetone circuit a different type of induction coil is used. The coil and circuit discussed here is taken from the EE-8-A telephone. This telephone uses an induction coil with one continuous winding tapped at terminals *2* and *3*, as shown in figure 22 so as to form the *1-2* section, *2-3* section and *3-4* section. When someone speaks into the transmitter the current through the *2-3* or primary section of the induction coil fluctuates with the change in resistance of the transmitter. These changes cause a voltage to be induced in the *1-3* or secondary section of the induction coil. For purposes of explanation, let us assume that an instantaneous current change in the direction *2* to *3* in the *2-3* section will cause a voltage to be induced in the *3* to *1* direction in the *1-3* section of the coil. The same current change will also induce a voltage in the *4* to *3* direction of the *3-4* section of the coil. Now consider that this induced voltage will cause current to flow out over the line and back to the point *C*,

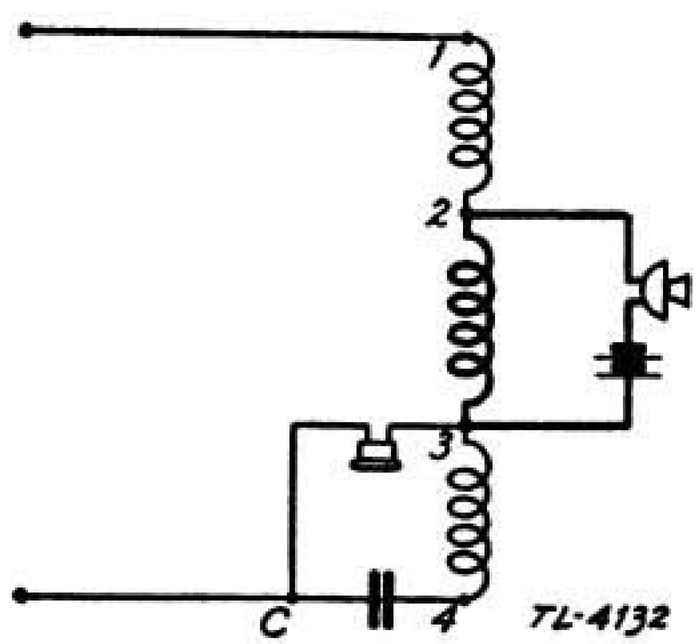

FIGURE 22.—A local-battery antisidetone circuit.

when the current reaches this point it has a choice of two paths. It can go through the receiver or through the *3-4* section of the coil. If it will be remembered the induced voltage in the *3-4* section was in such a direction as to aid this flow of current and if it is of such a value as to equal the *IZ* drop across the coil and condenser, there is no voltage drop between points *C* and *3*. Consequently no current will flow through the receiver. The condenser is not essential to the antisidetone circuit but its use makes possible a slightly better balance.

(2) *Receiving.*—The line current flowing through the *1-3* section of the induction coil induces a voltage in the *3-4* section in such a

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direction as always to oppose the flow of this current through the *3–4* section of the coil and as a result the received current will take the alternate path through the receiver.

15. Questions for self-examination.—

1. Draw a schematic diagram of a receiver showing permanent magnets, pole pieces, windings and diaphragm.

2. What are the component parts of a local-battery telephone?

3. What is the function of a receiver?

4. Why is a permanent magnet used in a receiver?

5. Should direct current ever be passed through a modern receiver? Why?

6. Will a receiver act as a generator?

7. What are some of the troubles encountered in a telephone receiver?

8. Draw a schematic diagram of a telephone transmitter, show the electrical path through it.

9. Name some of the troubles inherent in a telephone transmitter.

10. Can a transmitter be used to generate a voltage? Why?

11. What is the approximate turn ratio of a local-battery induction coil?

12. What is the resistance of each winding?

13. What is the principle function of the induction coil?

14. When no one is talking what kind of current flows in the primary circuit? In the secondary circuit?

15. When someone is talking in the transmitter what kind of current flows in each case in question 14?

16. Explain the operation of a polarized ringer.

17. What kind of current will operate the ringer?

18. What is the resistance of an ordinary ringer?

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19. Are the two windings in series or parallel?

20. Is it possible to leave a ringer bridged across a line during conversation? Why?

21. Draw a schematic diagram of a telephone magneto generator.

22. What is the frequency and voltage put out by a telephone generator?

23. What is the function of the ringer?

24. What is the function of the generator?

25. What is the function of the hook switch?

26. Draw a diagram of the local-battery telephone.

27. Name the four fundamental circuits of the local-battery telephones.

28. What is the battery voltage used in local-battery telephones?

29. Explain the operation of the antisidetone circuit.

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SECTION III

THE LOCAL-BATTERY SWITCHBOARD

16. The need for switchboards.—Thus far two telephones connected by a pair of wires have been considered. This pair of wires might be called a line circuit. This system would work perfectly if each of these parties never wanted to talk to any one but the other party. However, ordinarily a man wants to be able to talk to any one of several people, perhaps one of hundreds or thousands. Consider the diagram shown in figure 23. This diagram shows four people

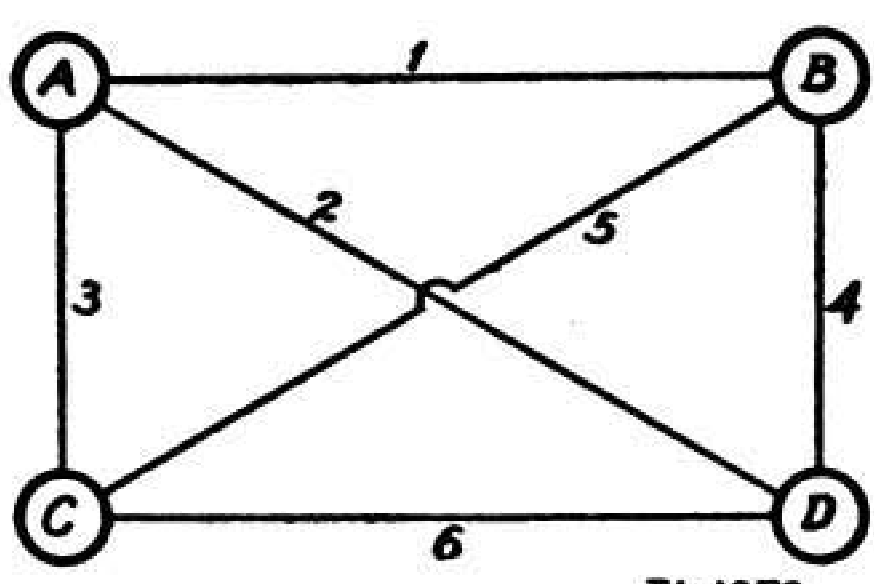

FIGURE 23.—Telephone net without switchboard.

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A, *B*, *C*, and *D*, and each one desires to be able to talk to any one of the other three. Several disadvantages to such a hook-up are at once evident. In the first place, it requires six line circuits, and this number increases rapidly as the number of interconnected parties is increased. For example, five parties would require ten line circuits, six parties fifteen line circuits, etc. Thus, it would soon grow to be a very complex network, also a very expensive one. In the second place each of the parties shown in figure 23 must have three telephones, one for each line, or he must connect all three lines to one telephone. If he has three telephones, there is the cost to consider. Also, he must have a different sounding ringer on each, or he will not be able to tell which one is ringing unless the ringers are mounted a long distance apart. If he puts all three line circuits on one telephone he must use code ringing because every time he cranks his generator he will ring all three of the other parties' telephones. The result is loss of secrecy; if *A* and *B* were talking, *C* and *D* could overhear everything that was said. Thus it can be seen that without using a different scheme, even a small telephone system would be costly and complicated. There is one way of avoiding all this difficulty, and that is by the use of an additional piece of equipment called a switchboard. One line circuit is run from each telephone to this switchboard as shown in figure 24. The switchboard is located at the central office. An attendant, called the operator, is on duty at the switchboard, and it is this operator's job to make connections between these line circuits that come into the board. In order to do this several things are necessary. Assume that *A* wishes to talk to *D*. The following must be possible:

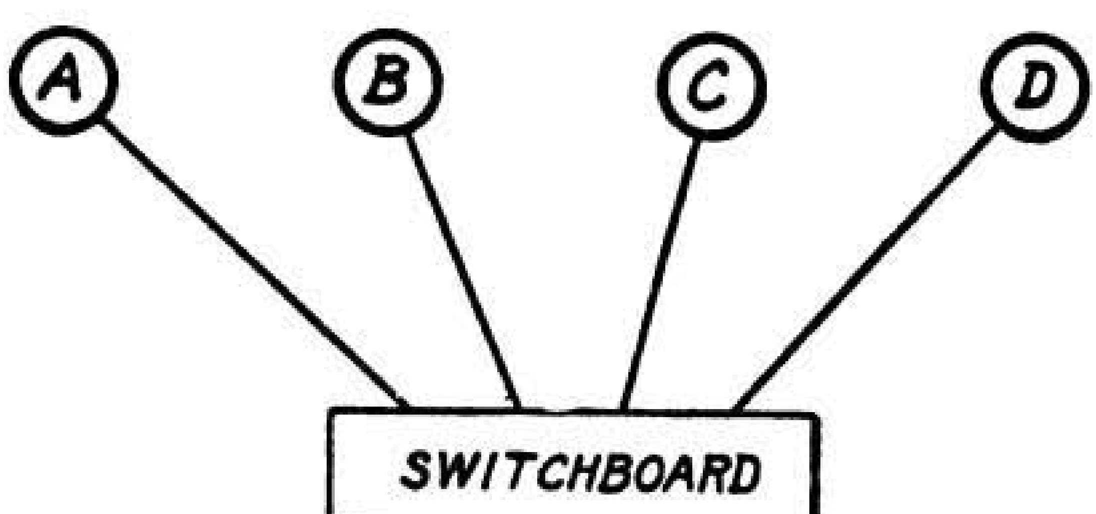

FIGURE 24.—Telephone net with switchboard.

a. *A* must be able to signal the operator.

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b. A must be able to let the operator know that it is *D* with whom he wishes to talk.

c. The operator must be able to signal *D.*

d. The operator must have means available at the switchboard so that he can easily interconnect *A* and *D* without the loss of time.

e. The operator must be able to determine when *A* and *D* have ended their conversation so that he can take the connection down.

17. The switchboard drop.—As stated above, the first thing the subscriber or telephone user must do when he wishes to talk to someone is to secure the attention of the operator. To do this he turns his generator crank and sends out 20-cycle ringing current. Because of the bulk of ringers and also the confusion that would result from attempting to locate the calling line, the use of ringers at the central office is impracticable. The situation calls for a small compact device, which, when energized by the ringing current, operates and displays a signal until such time as the operator answers the call. This device is called a drop and is a small electromagnet with a hinged armature. When ringing current is put through the magnet winding, the armature is attracted and a shutter is released on the face of the switchboard, giving visual indication to the operator that the line associated with that drop has signaled the central office. The schematic diagram of a switchboard drop is shown in figure 25 with the various parts named. Such a drop might not operate on weak signals because of leakage of the magnetic flux. In order to avoid this, some sort of return

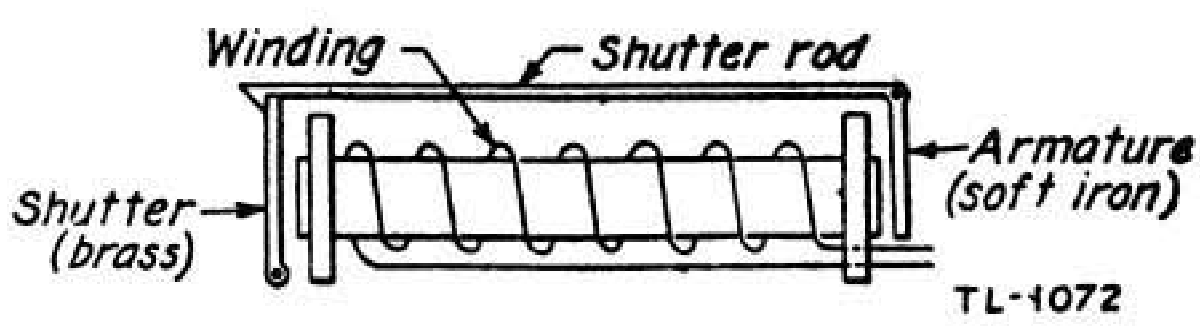

FIGURE 25.—Schematic diagram of local-battery switchboard drop.

path for the lines of force must be provided. This can be done by winding the magnet on two spools or by providing a soft iron bar for the return path. However, two spools make a bulky switchboard drop and the bar return path still allows much flux leakage. To eliminate these difficulties, the form of drop most commonly used consists of a single spool which is placed in a soft iron cup or

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tube. This cup provides a magnetic return path and also prevents any straying or leakage of magnetic lines of force. Figure 26 shows side and end views of a drop of this type.

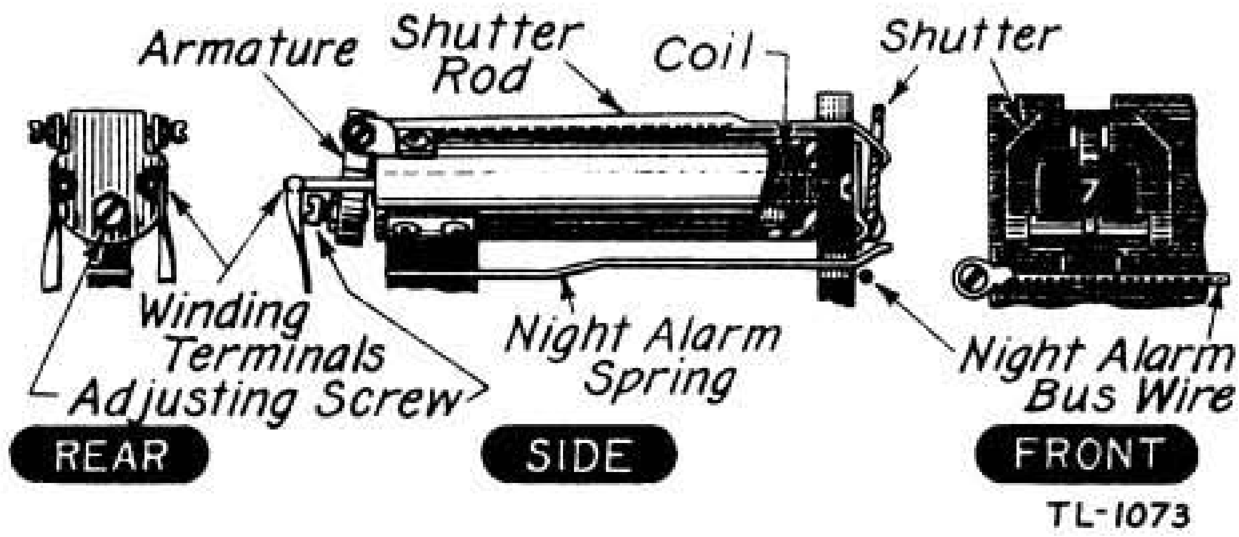

FIGURE 26.—Local-battery line drop.

There are several features of this drop that should be noted:

(1) The armature hangs between pointed pivot screws provided with lock nuts, and by means of these, the play can be taken out of the bearing.

(2) The terminals are at the rear of the device, permitting the armature to be adjusted, or wire connections to be resoldered, without disturbing the operator.

(3) The armature when attracted cannot make contact with the magnet core; thus it will not stick in the operated position due to residual magnetism of the core.

(4) The shutter rod is slightly bent near its hooked end where it passes through a hole in the shutter, so that when the armature is attracted, the inclined upper face of the rod strikes the upper edge of the hole in the shutter forcing the shutter outward and accelerating its fall. This makes the shutter operation positive in spite of any slight binding at the bearing or any small inclination of the axis of the drop. When a drop of this type falls, it must be rsetored manually by the operator.

18. The switchboard jack.—*a*. In the preceding paragraph the means by which a subscriber can signal the operator was discussed. The next step is to determine how the operator can make connection to the different lines. One method would be to bring the lines in on binding posts and provide the operator with clips for making the contacts. There are many systems that could be used, but the method that has been adopted as the quickest and most convenient

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is to terminate each line circuit in a jack. Connections are then made to these jacks by means of plugs. These plugs and the circuit that goes with them will be discussed at greater length later. Figure 27 shows a diagram of one type of jack with a plug in it. Right below is shown the symbol of each. It will be seen from the diagram

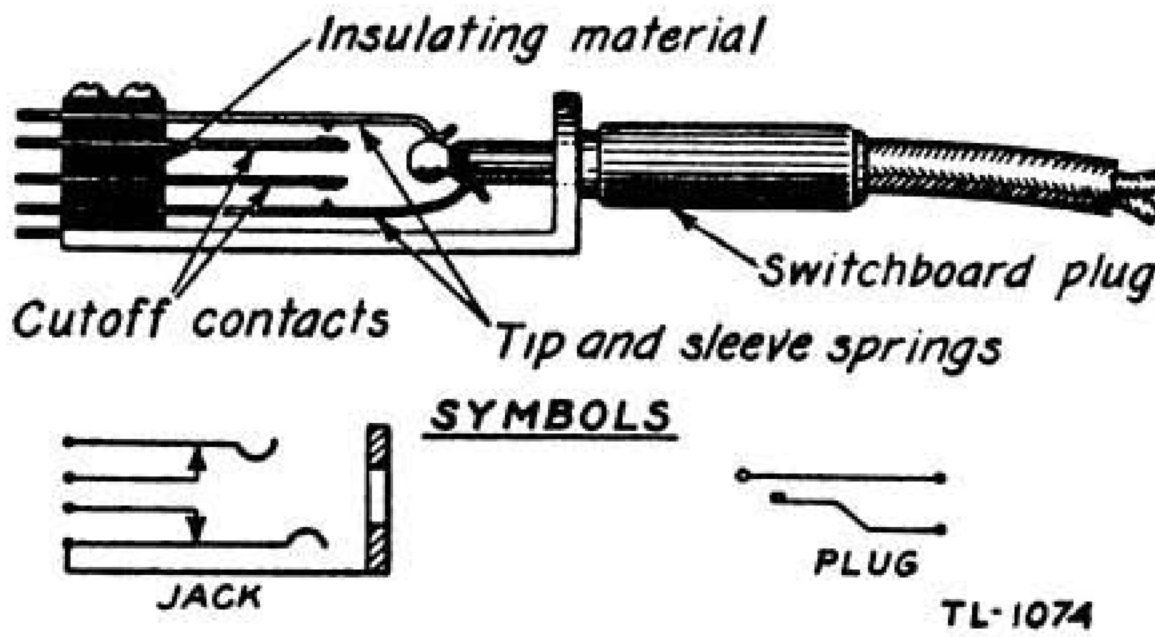

FIGURE 27.—Two-conductor plug and jack.

that the tip of the plug makes contact with the tip spring of the jack and that the sleeve of the plug makes contact with the sleeve spring of the jack. By variations in the number and arrangement of springs a jack can be made to perform simple switching operations when the plug is inserted.

b. Figure 28 shows a number of jacks that are used, with a statement of the function each performs. The jacks used in a local-battery switchboard are usually of the break-one or break-two type, and when the break occurs from the tip or sleeve springs they are called the single cut-off or double cut-off jacks.

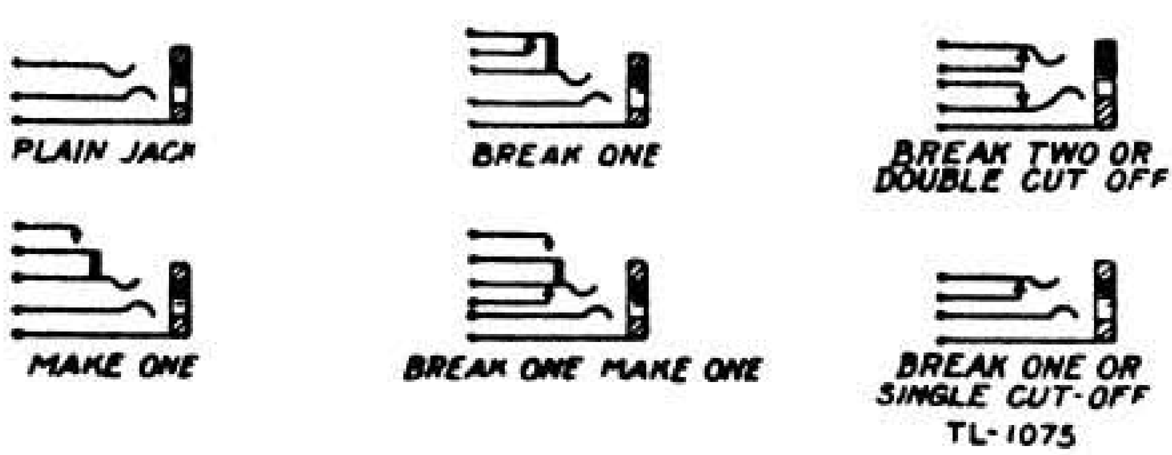

FIGURE 28.—Schematic diagrams of jacks.

19. Combinations of drops and jacks.—The jack is so closely associated with the drop in a line circuit that it is common practice to build them in one unit, known as the combined drop and jack. This has the following advantages:

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(1) The jack is close to the signal with which it is associated.

(2) The wiring of the switchboard is simplified by shortening to a fraction of an inch, the leads connecting drop and jack.

(3) The drops may be made self-restoring, thereby speeding up switchboard operation.

Figure 29 shows a combined drop and jack and the leads to the telephone. It can be seen from the figure that the circuit through the drop winding is complete from the telephone, so that when the subscriber cranks his generator, ringing current passes through this winding and causes the armature to be pulled up. This allows

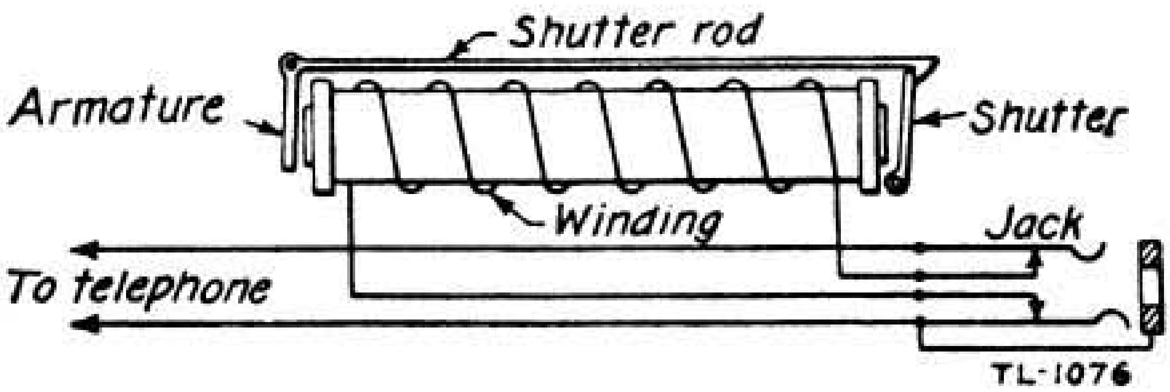

FIGURE 29.—Local-battery line circuit

the shutter to fall and the operator knows that the subscriber has signaled the central office. When the operator inserts the plug in the jack, the drop is disconnected from the line. Just how the operator is able to talk with the subscriber and determine what number or party the subscriber desires to talk to will be discussed later.

Figure 30 shows a picture of a Western Electric combined drop and jack with a self-restoring device; *a* shows the operated position with the shutter down and *b* shows how the shutter is restored when the plug is inserted. The night alarm spring is shown in figure 26. When the shutter is down the circuit between this spring

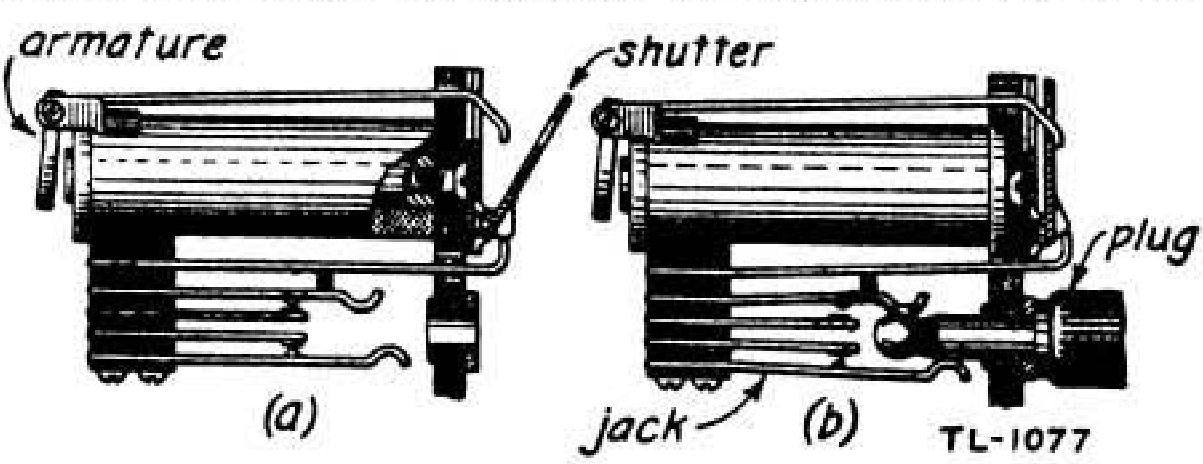

FIGURE 30.—Self restoring line drops.

and the night alarm bus is closed, and the circuit is open when the shutter is up in the normal position. These are the night alarm

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contacts, the function of which will be discussed later in connection with the miscellaneous circuits of a switchboard. The night alarm spring has been omitted from figure 30.

20. Constructional features of drops and jacks.—The magnet coils for drops are wound to a total resistance of from 80 ohms to 1600 ohms, the latter being the more sensitive. The core is of solid soft iron and the spool ends are usually of fibre about $\frac{1}{16}$ inch thick. The spool is usually about $\frac{1}{2}$ inch in diameter and about $2\frac{3}{4}$ inches long and is so mounted that the armature cannot make contact with the core. The combined drops and jacks are screwed to metal plates mounting from five to ten in a group and these plates are secured in the face of the switchboard. Thus the drop shutters appear in horizontal rows across the face of the switchboard and below each shutter is its associated jack.

21. Purpose and description of cord circuits.—Line circuits always terminate on jacks in the switchboard. A drop is immediately associated with each jack. The use of jacks for terminating line circuits furnishes an easy and rapid method of making connection to the line circuits. For making this connection, plug-ended circuits are used. These circuits are called cord circuits and ordinarily are terminated by a plug at each end. The plug consists of three main

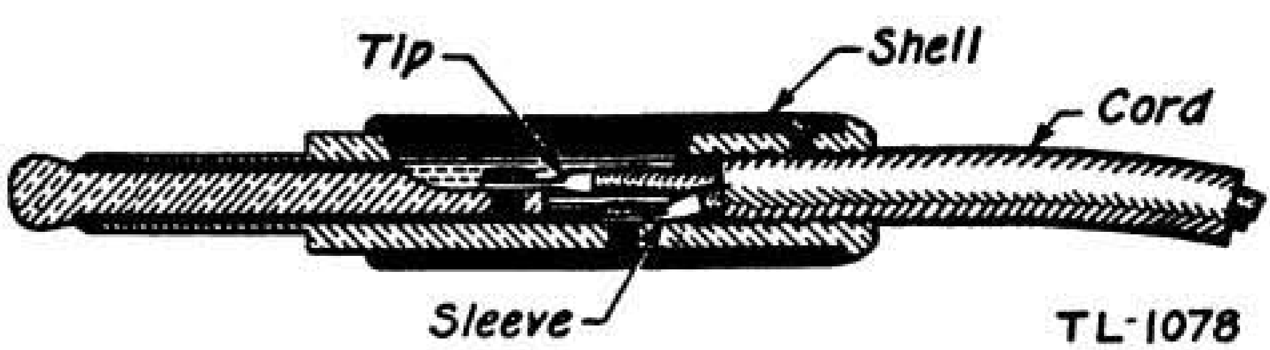

FIGURE 31.—Two-conductor switchboard plug.

parts; namely, a rod terminating in a ball, a tube fitting over the rod and insulated from it, and a shell which covers the rear end of the rod and tube and protects the connections of these parts to the cord. Figure 31 shows a plug in cross section. The ball is known as the tip and makes contact with the shorter or tip spring of the jack, while the tube is known as the sleeve and makes contact with the longer or sleeve contact of the jack. Refer also to figure 27.

22. The patching cord.—The simplest form of a cord circuit consists of a pair of conductors with a plug at each end. This type is known as a patching cord. Figure 32 shows a diagram of two lines

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connected by such a cord. The two parties connected as shown above can converse perfectly over such a cord circuit, after the connection is once established. But so far there is no means by which the calling party (the one who places the call) can talk to the operator and tell him with whom he wants to talk. There is also no means by which the operator can signal to any party, nor is there any means which will tell him when the two people are through talking.

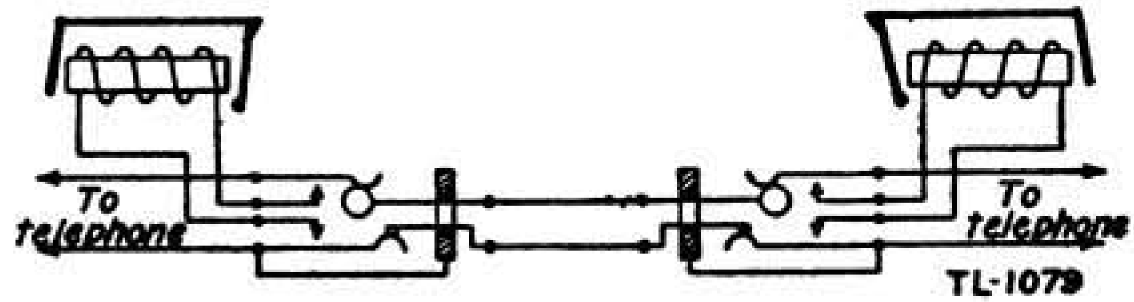

FIGURE 32.—Patching cord circuit.

23. The operator's telephone.—The first thing to do is to provide the operator with a telephone set so that he can talk to the subscriber and hear what the subscriber says. In order to obtain this two-way conversation when we use two telephones, it is necessary that:

(1) A receiver and secondary in series be placed across the line, and

(2) A primary circuit consisting of a transmitter, battery and primary of the induction coil be complete and coupled to the line by means of the induction coil. If we make this addition to the simple cord circuit it will look like figure 33. Now if a party places a call by ringing, the drop falls, calling attention of the operator,

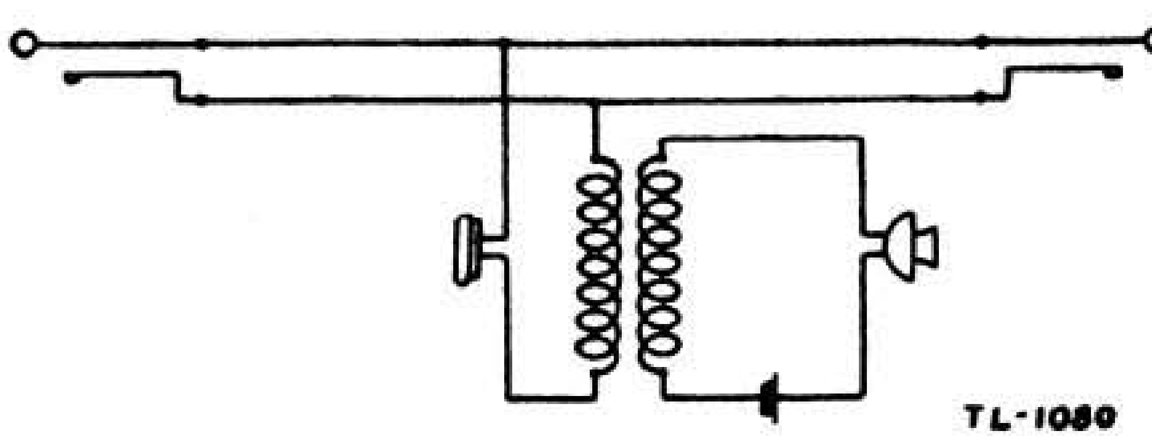

FIGURE 33.—Patching cord with operator's set.

whereupon the operator may place one of the plugs in the jack and can then talk with the subscriber, and the subscriber can tell the operator the number or party he wants. If the operator's telephone

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were to be connected exactly as shown in figure 33, it would have some defects. In the first place, the telephone is permanently connected to the cord circuit. This is not desirable, as will be seen later, so there should be some means of connecting and disconnecting the telephone from the cord circuit at will. Secondly, the primary circuit is closed at all times; therefore current is flowing whether the operator's telephone is in use or not. To overcome these disadvantages a switching device called a listening key is used. Figure 34 shows a schematic diagram of two listening keys. Spreading the two center springs causes the contacts to make. A key of

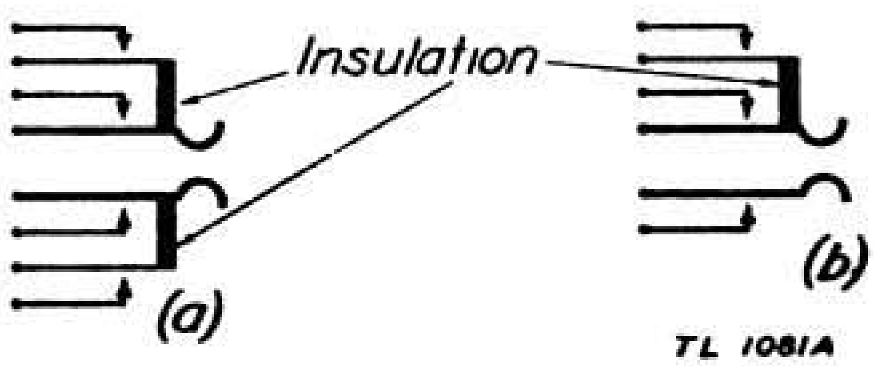

FIGURE 34.—Types of listening keys.

type shown in figure 34a is placed in the cord circuit as shown in figure 35. As can be seen from figure 35, operating the listening key will connect the operator's set to the cord circuit. It will be noticed that there are two unused contacts of the key. It is common practice to make keys as shown, but in this type of cord circuit, two of the contacts are useless.

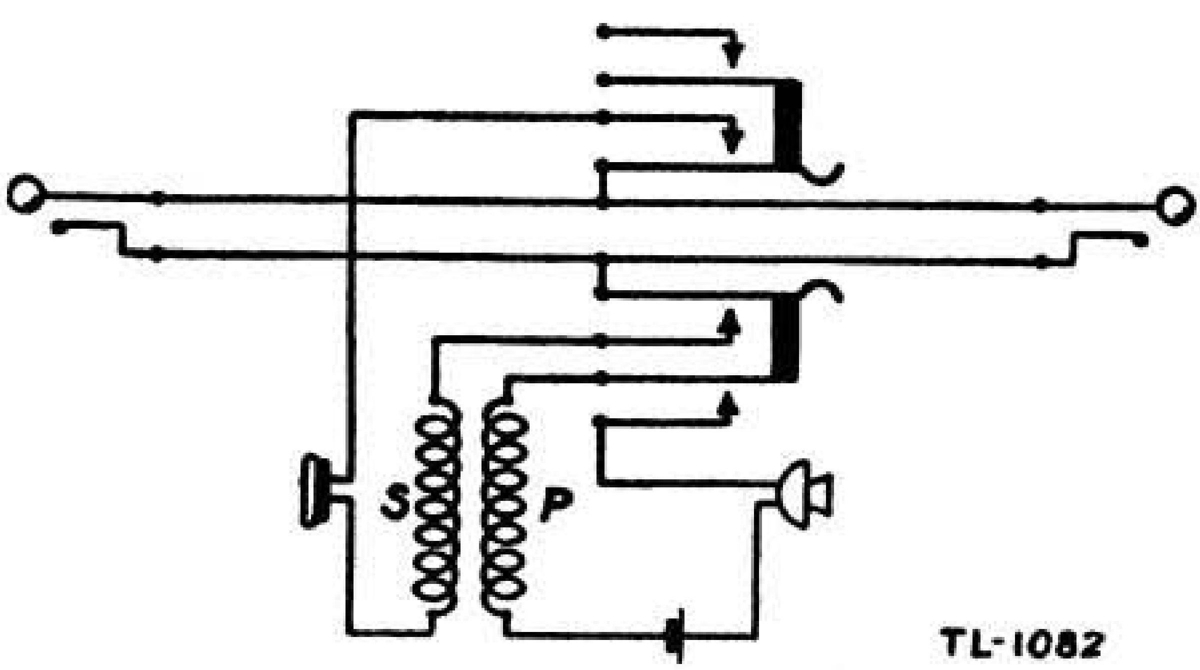

FIGURE 35.—Cord circuit with listening key.

24. Ringing keys.—The next thing that must be added to the cord circuit is a device so that the operator can ring the called party (the one with whom the calling party desires to talk). An ordinary

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hand generator can be used as the source of ringing current, but it must be connected in such a way that ringing the called party will not ring in the ear of either the operator or the calling party. To accomplish this end a ringing key is used. Such a key is shown in figure 36. This key is of the break-two, make-two type. Some local-battery cord circuits use two of these keys in each cord circuit, one associated with each plug so that the ringing current may

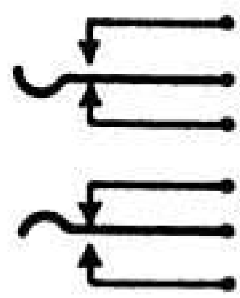

FIGURE 36.—Ringing key.

be put out from either plug. Figure 37 shows how these two ringing keys are placed in the cord circuit. From the diagram it can be seen that operating either ringing key and cranking the generator puts ringing current out through that key's associated cord and plug, for the ringing key opens the circuit to the other cord by means of its break contacts.

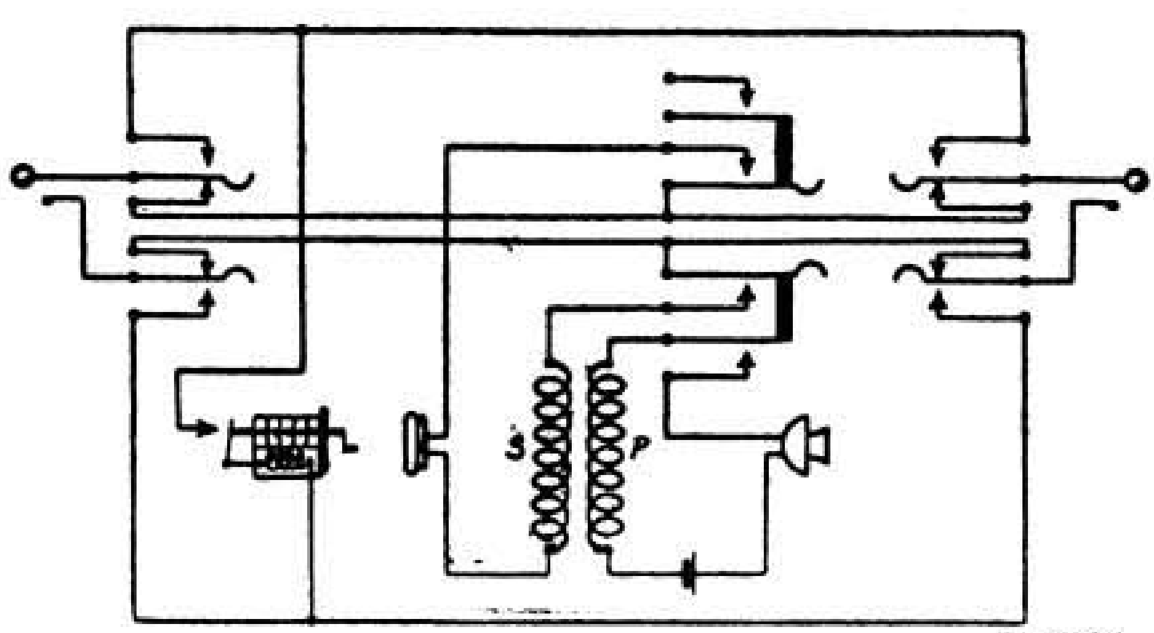

FIGURE 37.—Cord circuit with ring and ring-back keys.

25. Supervision.—There still remains one more addition to be made to the cord circuit, and that is a device to indicate to the operator when two people have finished a conversation. The simplest way to do this is to bridge a drop, similar to the ordinary line drop, across the cord circuit. When a conversation is finished, the subscribers should ring off. This will operate the drop, which is called

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a clearing out or supervisory drop, and let the operator know that the conversation is completed. Figure 38 shows the cord circuit with this supervisory drop added. The diagram is a typical local-battery cord circuit. The operator would be unable to tell which party had rung off, but he should throw his listening key and challenge before taking down the connection. Then if one party is trying to place another call, the operator can ask and find out which one it is. This method of using just one supervisory drop for each cord circuit is called single supervision. There is another method called double supervision in which two supervisory drops are used with each cord circuit, but this is not so common as single supervision.

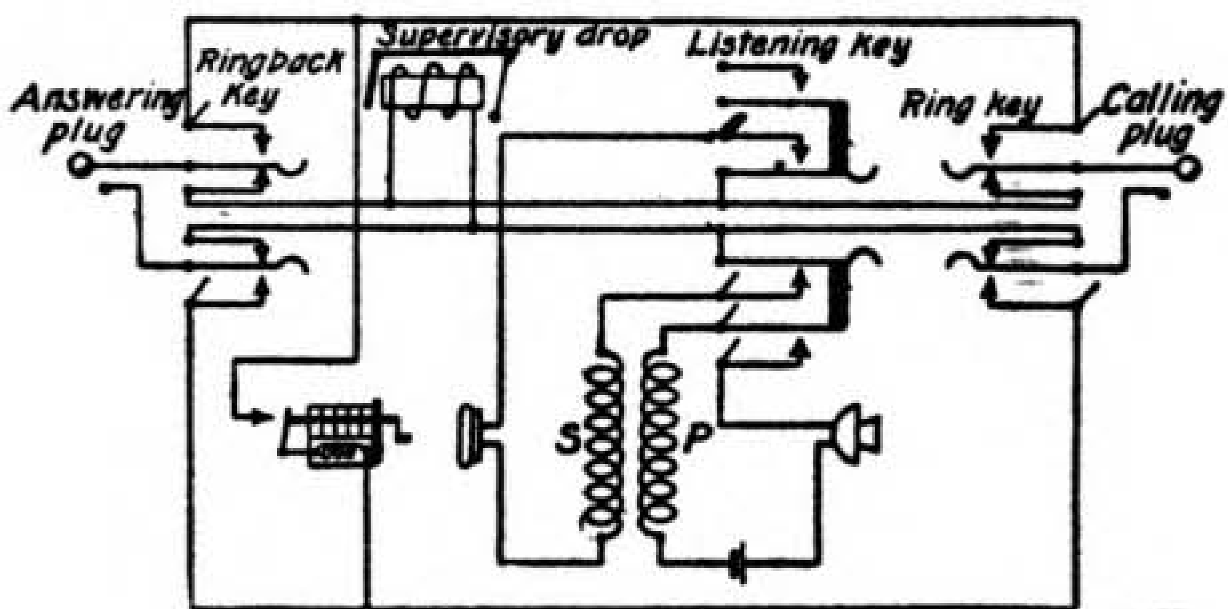

FIGURE 38.—Local-battery cord circuit complete.

26. Location of cord circuit parts in switchboard.—The next thing is to find out just where the various parts of the cord circuit appear

FIGURE 39.—Switchboard key shelf, side view.

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on the switchboard. The two plugs which are the ends or terminals of each cord circuit are located in plug seats on the key shelf of the board. One plug is directly in front of the other. Next and right in line with the two plugs appear the two key levers. On the face of the board and directly in line with the keys and plugs is the cord circuit supervisory drop. This drop is usually in a row below the line drops and can easily be distinguished from a line drop in that it has no associated jack. Figure 39 indicates more clearly the location of this equipment on the switchboard. The plug farther from the operator (one nearer panel of board) is the answering plug. This is the plug the operator uses to answer a calling subscriber. The ringing key associated with the answering plug is the ring-back key. The front plug of a pair (the one nearer the operator) is the calling plug and its associated key is the ring key or ringing key. These parts are labeled in figure 38. It is common practice in local-battery switchboards to associate two of the three keys together so that the two can be controlled by one lever. In many switchboards the listening and ring keys are associated together; pushing the lever away from the operator closes the listening key (lever locks in this position) while pulling the lever toward the operator puts ringing current out through the calling plug. Figure 38 shows these two keys controlled by one lever. In some switchboards the ring and ring-back keys are associated together.

27. Double supervision.—It was mentioned in a preceding paragraph that most local-battery switchboards are of the single supervision type. This is true of nearly every board, but it might be well to show how double supervision could be obtained. Figure 40 shows a cord circuit with this type of supervision. The ringing and listening keys are omitted from the diagram. The capacitors offer a great deal more opposition to ringing current than to voice frequency currents. By means of such a circuit the operator can tell when either or both parties ring off. However, it does have two disad-

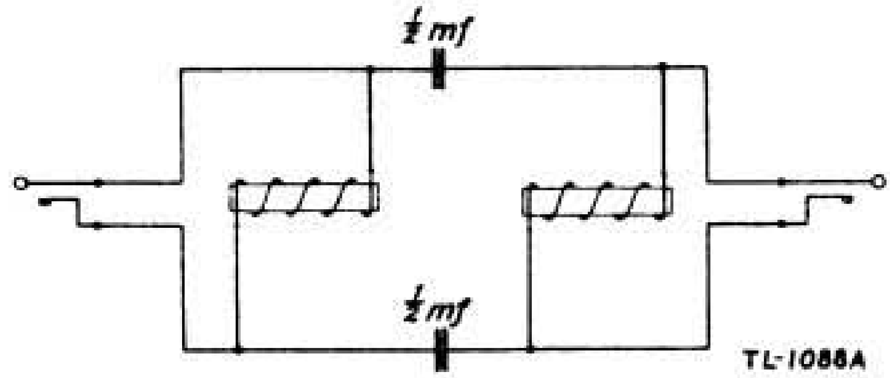

FIGURE 40.—Partial cord circuit showing double supervision.

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vantages and is, therefore, seldom used in practice. In the first place there is the added equipment, and ordinarily this is not worth while on a local-battery switchboard. Secondly, the capacitors in series with, and the two drops bridged across the line cause transmission loss in the circuit.

28. Repeating coil cord circuit.—Sometimes line circuits are composed of only one metallic conductor, ground being the other side of the circuit. In making connections at a switchboard where either or both lines are of this type, it is often desirable to keep the lines physically separate. In doing this the noise will be reduced to a minimum. To accomplish this a repeating coil cord circuit is used. The two halves of the cord circuit are physically separated but inductively coupled to each other. The repeating coil is a special type of transformer with four windings, but for this discussion it can be regarded as a highly efficient one to one ratio transformer. A diagram of such a cord circuit (omitting keys) is shown in figure 41. This circuit is of the single supervision type.

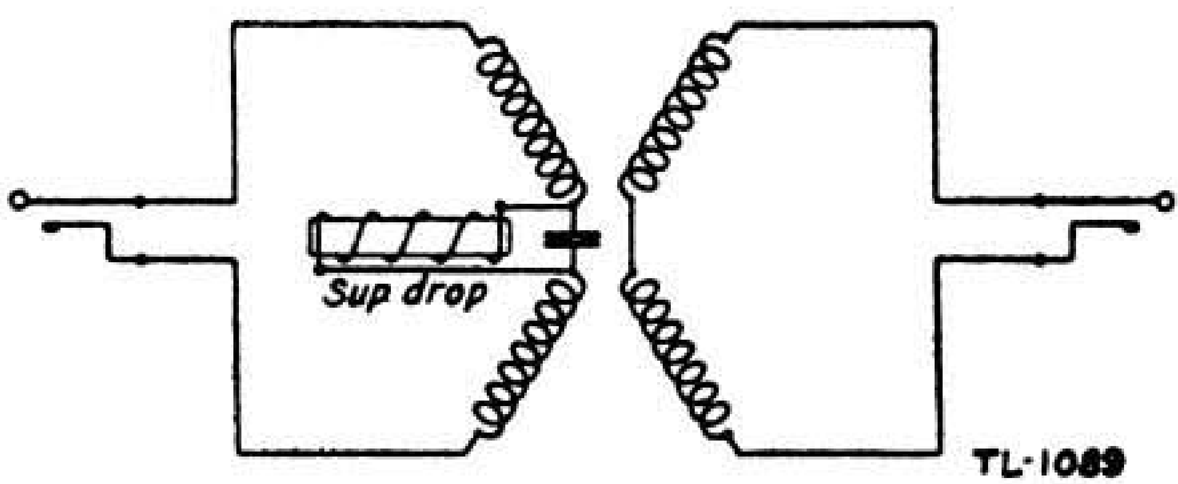

FIGURE 41.—Partial repeating coil cord circuit.

29. Common connections of cord circuits.—In an ordinary local-battery switchboard of from 50 to 100 lines capacity, there are usually from six to fifteen cord circuits. Thus there will be a row of ringing and listening keys, one of ring-back keys, one of calling plugs, one of answering plugs, and one of supervisory drops appearing as the visible parts of the cord circuits. These different parts are interconnected by wiring which pertains to each cord circuit only.

It is this wiring of one cord circuit which has been shown in the preceding figures. There are, however, additional connections which are common. For example, in a switchboard there is but one operator's telephone and one hand generator, and it is necessary to use this one with every cord circuit. This means that certain contacts of one cord circuit must be wired in common to the cor-

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responding contacts of every other cord circuit in the switchboard. These common points of the cord circuit are indicated in figure 38 by means of short oblique lines. This symbol will be used in subsequent drawings, where it is necessary to indicate that parts are wired common.

30. Questions for self-examination.—

1. Draw a diagram of a drop showing the winding, shutter, shutter rod and armature.

2. What means has been adopted commercially to prevent magnetic lines of force from one drop straying to another?

3. Show by a diagram the electrical connection between a drop winding and the associated jack.

4. Draw a diagram of a make-one break-one jack.

5. What is meant by a double cut-off jack?

6. Give two advantages of having the drop and associated jack built as one unit.

7. How is the operation of a shutter made positive?

8. How are drops and jacks mounted on a switchboard?

9. How are the shutters restored on most switchboards?

10. What is the resistance of a drop winding?

11. What is the disadvantage of using two spools in a drop?

12. Draw a diagram of a magneto telephone set, include the line connecting it to the switchboard and the switchboard equipment immediately associated with it.

13. Would direct current operate a drop? Why?

14. What is a cord circuit?

15. How are cord circuits usually terminated?

16. Why are repeating coils sometimes placed in cord circuits?

17. What is the difference between single and double supervision?

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18. Why is it necessary to remove the calling party from the line before ringing the called party?

19. What type of local-battery supervision is usually found on signal corps boards? Why?

20. Are ring-back keys used on all local-battery telephone switchboards?

21. Why is a ring-back key desirable?

22. Are ringing keys ordinarily of the locking type? Why?

23. Draw a diagram of a two-conductor plug.

24. Make a diagram of a listening key. Draw a diagram of an operator's telephone set and properly connect it to the key.

25. Show how you would connect an operator's transmitter and receiver to a twin plug. Why is it connected this way?

26. Draw a diagram of a complete local-battery cord circuit, including a generator circuit and the operator's telephone set, which will have the following features:

a. Ringing on answering cord without ringing on calling cord.

b. Ringing on calling cord without ringing on answering cord.

c. Means for operator listening on cord circuit only when listening key is closed.

d. Means for operator talking on cord circuit and primary circuit completed only when listening key is closed.

e. Supervision by operator.

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SECTION IV

MISCELLANEOUS SWITCHBOARD EQUIPMENT

31. Definition of miscellaneous circuits.—Under the heading of miscellaneous circuits are grouped all circuits of a local-battery switchboard except line, cord, and operator's telephone circuits.

32. Night alarm circuit.—This circuit is found on every switchboard. Its purpose is to give an audible as well as a visual signal every time either a line or supervisory drop is operated. At the bottom of each drop there is a contact spring which normally

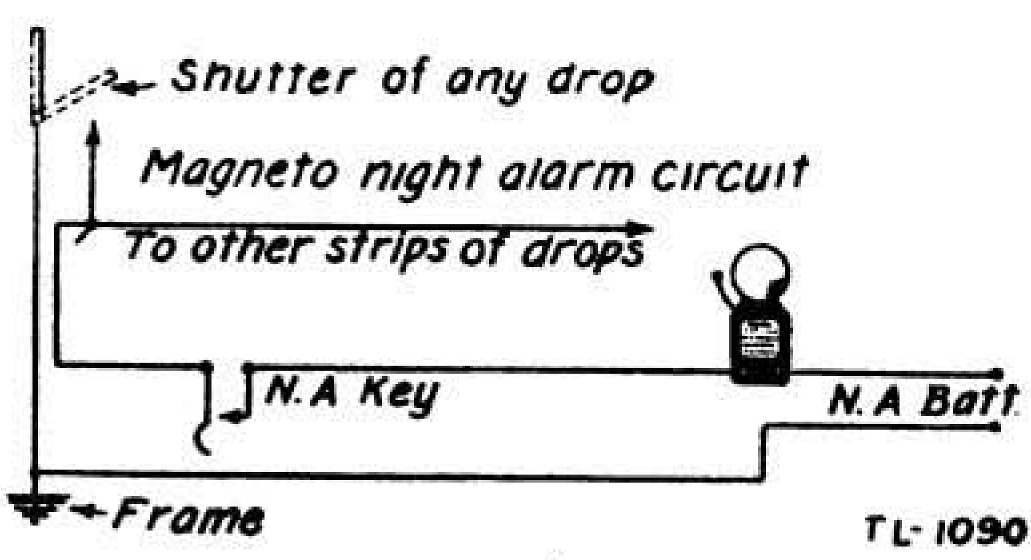

FIGURE 42.—Night alarm circuit.

stands open from the frames, but is closed against the frame by the shutter when it falls. In a switchboard all of these contacts are wired common. The common wire is then connected in series with a locking key, an electric bell, two or three dry cells, and a ground connection. When the key is closed, the night alarm circuit will be

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completed by the falling of any line or supervisory shutter, and the bell will ring until the shutter is restored or the key is opened. For normal use the night alarm circuit is rendered inoperative by opening the key. At night or other times when the operator is away from the board but on duty, the key should be closed. A typical circuit is shown in figure 42.

33. Generator switching circuit.—When the exchange is provided with a source of ringing current other than the hand generator, a generator switching circuit is required. This is controlled by a key which functions as a double-pole double-throw switch and enables the operator to change from one source of ringing current to the other. Figure 43 shows such an arrangement.

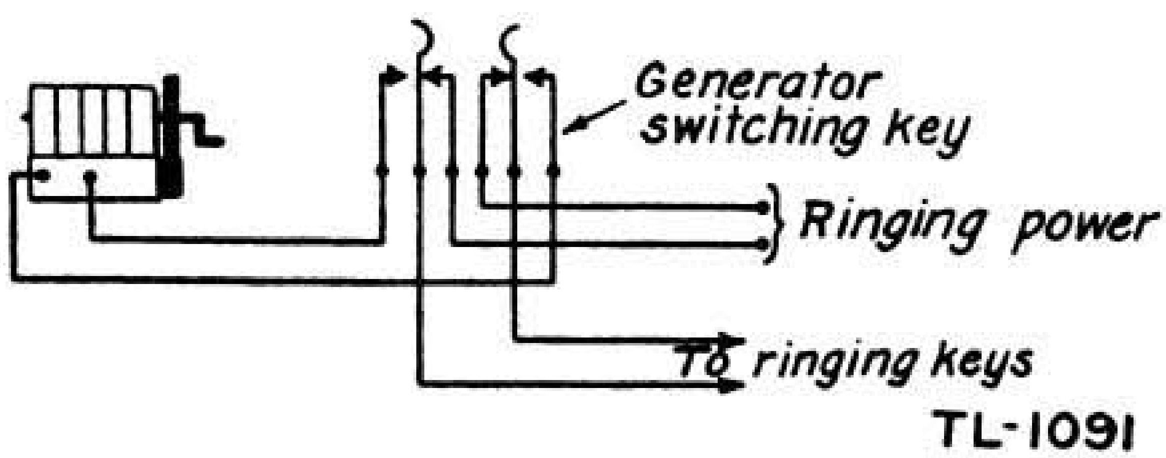

FIGURE 43.—Generator switching circuit.

34. Trunk circuits.—*a. General.*—Trunk circuits are line circuits used to terminate trunk lines or trunks which connect two switchboards together. They are a variation of a normal line circuit. A local-battery trunk circuit, in its simplest form, consists of a drop and jack. This circuit is the same as the normal line circuit, and its operation is the same as for any local-battery line circuit.

b. Common-battery trunk circuit.—When local-battery switchboards are connected by trunks to common-battery switchboards, special circuits must be used at one of the switchboards. If the trunk comes in on an ordinary line circuit at the local-battery end, the special equipment will be at the common-battery switchboard. This equipment will not be discussed in this text. If, however, the trunk terminates on a line circuit at the common-battery exchange, then the special arrangements must be made at the local-battery end. A short circuit placed on a common-battery line circuit by a local-battery drop would permit the flow of direct current from one side of the line through the drop to the other side bringing in the signal on the common-battery board. It would also operate the drop

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at the local switchboard. The solution of the problem then requires that a special circuit be developed to provide proper operation. Provision must be made to give the proper signals to the common-battery switchboard both for calling and supervision. This can be accomplished by the circuit shown in figure 44. This trunk circuit will terminate a common-battery manual trunk and satisfy all of the above conditions. First, consider the operation of the circuit for an incoming call. Twenty-cycle ringing current is applied by the distant operator and the drop associated with the trunk circuit on the local switchboard will fall. The local operator then plugs the

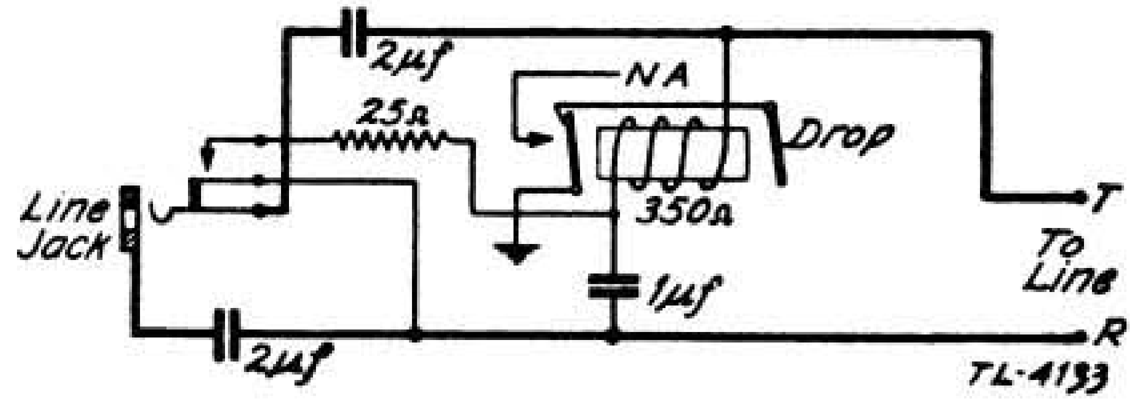

FIGURE 44.—Common-battery trunk circuit.

answering cord into the line jack. This closes the make contact on the line jack which sets up a circuit through the drop winding and the 25-ohm resistor which holds the supervisory relay at the distant switchboard operated. The call is now completed by the local operator. When the conversation is completed the local subscriber rings off, and the supervisory drop on the cord circuit will drop. The local operator then takes down the connection, opening the loop to the distant switchboard and giving the distant operator a disconnect signal. When the call is outgoing the local operator merely plugs into the line jack which closes the direct-current loop described above. This causes the line lamp associated with this line to light and the distant operator handles the call the same as for a local call.

35. Interposition trunks.—In some cases where several local-battery switchboards are grouped together as positions of one large switchboard, each position is equipped with trunks to each other position. This is to enable a line on one position to be connected to a line on some other position. These trunks may be unnecessary between adjacent positions as the cords may be long enough to reach from one position to the next.

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36. Through line circuit.—In cases where the switchboard is at an intermediate point on a through line, a switching arrangement is sometimes used to provide for its being used either way or both ways from the intermediate office. This is accomplished by the equipment shown in figure 45 and consists of two double cut-off jacks and a combined drop and jack. This equipment is wired as

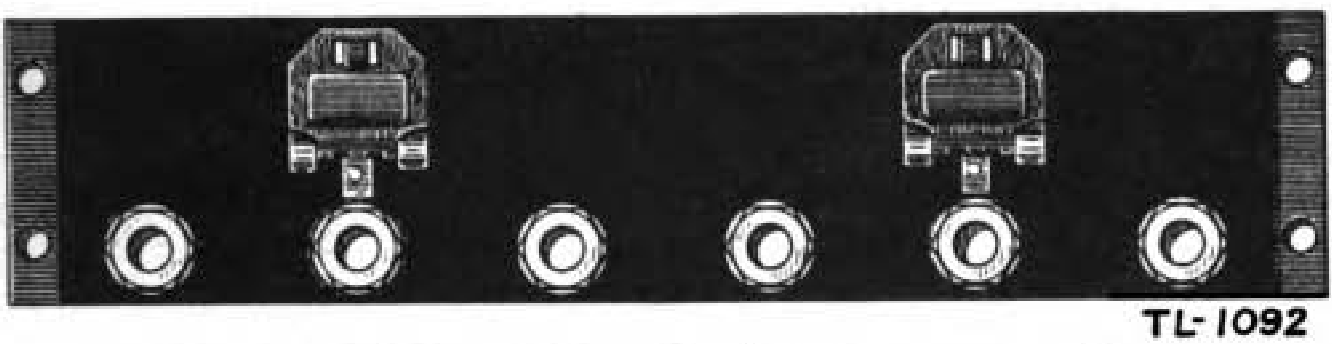

FIGURE 45.—Through line circuit jack arrangement.

shown in figure 46. When this apparatus is used, code ringing must be used on the line. When the operator at the intermediate station sees the shutter fall and hears the shutter-rod rattle with his code,

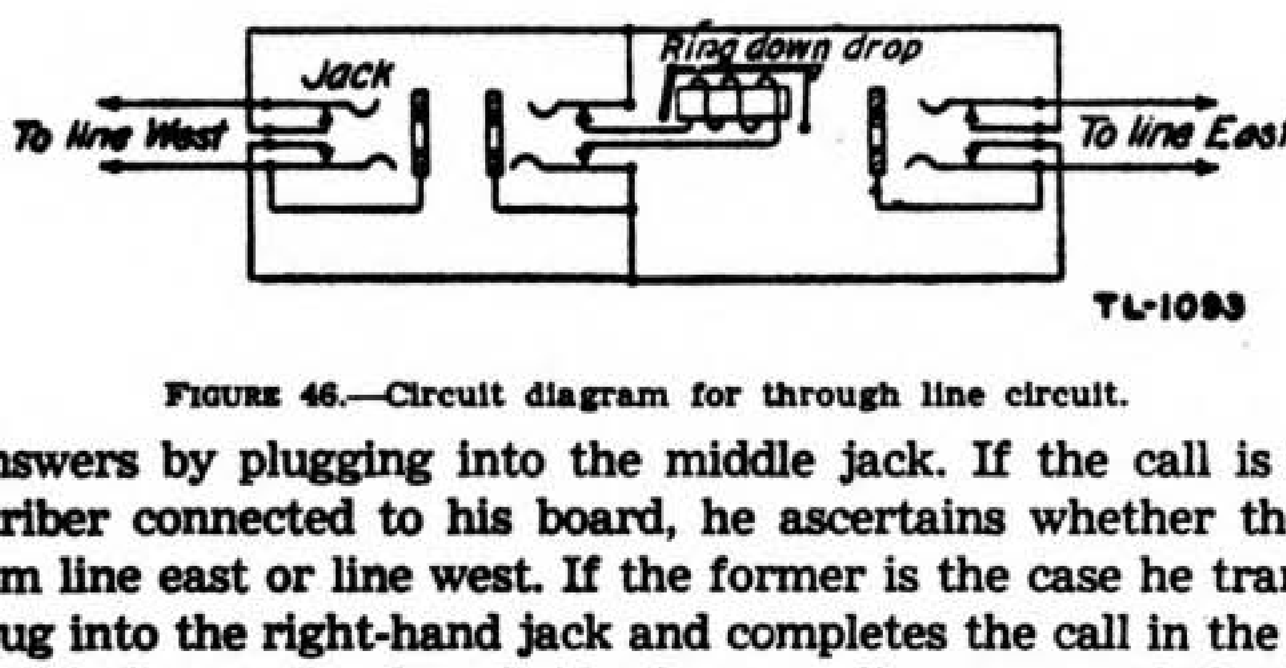

FIGURE 46.—Circuit diagram for through line circuit.

he answers by plugging into the middle jack. If the call is for a subscriber connected to his board, he ascertains whether the call is from line east or line west. If the former is the case he transfers his plug into the right-hand jack and completes the call in the usual way. This leaves the drop bridged across line west and the intermediate operator must answer calls on this line for his station and for the stations east of him, in the latter case notifying the calling operator that the line east is busy. In the case of a call originating at the intermediate office the operator, before calling east or west, should go in on the line through the middle jack and listen to insure that it is not in use. Having determined that the line is idle, the operator can plug into the left-hand jack and ring to call over line west or into the right-hand one for line east. When either line, east or west, is left because of an outgoing call, the operator must an-

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swer all calls from distant stations for his station and for those on that portion of the line being used as previously described.

37. Transfer circuits.—When, on a two-position switchboard, the load is so light that one operator can handle all the calls, as at night, it is customary to use only one operator. As long as he handles all the calls with the cords of his position no complications arise. But there may be some cases where he must use the cords of the other position. In order to do this and save him the trouble of changing receiver and transmitter, his receiver and transmitter must be connected into the telephone set associated with this other set of cord circuits. The circuit used for this purpose is called a transfer circuit.

38. Ringing machines.—*a. 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 Set 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 47 is a schematic diagram of the Model "H" Telering. Fundamentally, it has the same circuit as other models. By referring to figure 47, 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 the resulting current divides, part flowing through the 50-watt lamp and the output load, and part through the 2000 ohm resistor and winding of the motor coil. The current flows through these two circuits and joins at the vibrating reed. From the vibrating

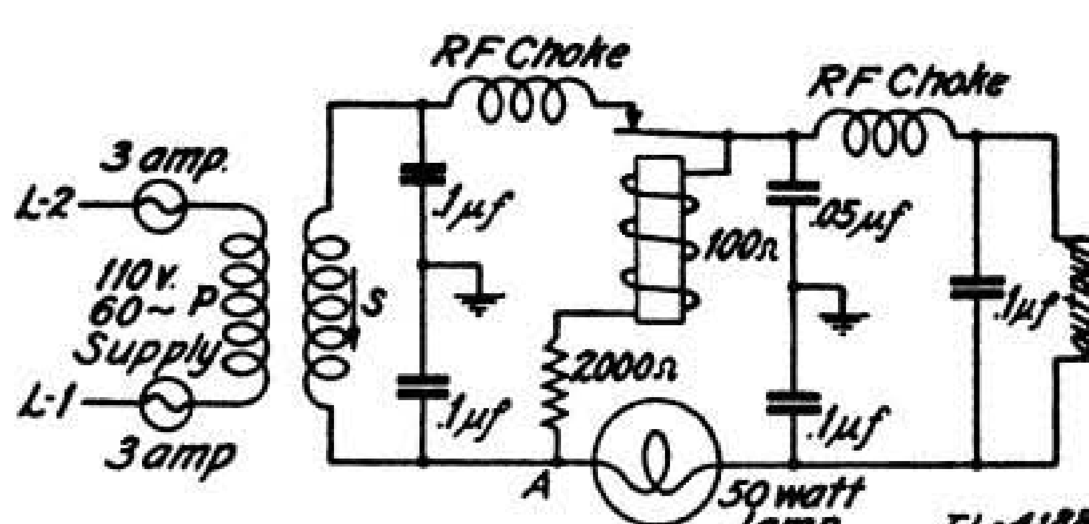

FIGURE 47.—Model H Telering.

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reed it flows through the radio-frequency 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, 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 50-watt lamp to the output each time the contact is closed.

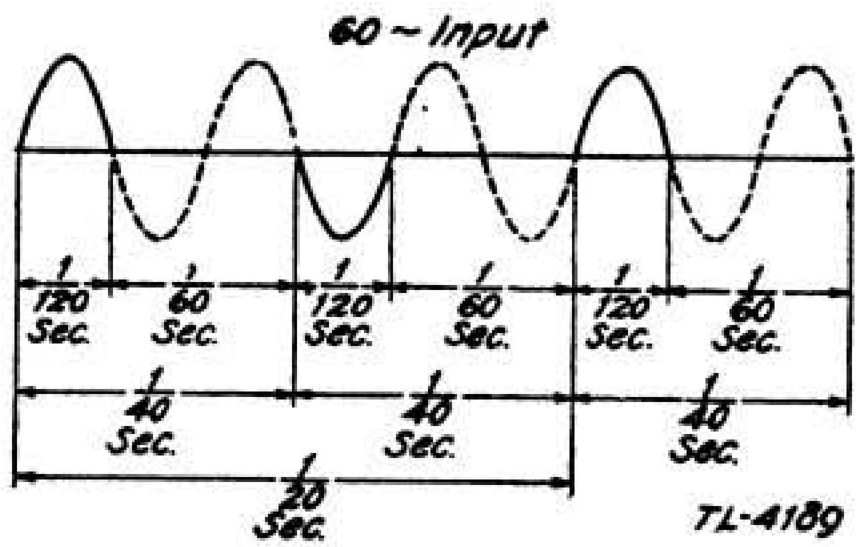

FIGURE 48.—20-cycle output of Telering.

Due to the characteristics of the tuned vibrating reed, the contact is closed for $\frac{1}{120}$ of a second and open for $\frac{1}{60}$ of a second. The input is 60 cycles, or 120 alternations per second; therefore, each alternation takes $\frac{1}{120}$ of a second. When the contact at the reed is closed for $\frac{1}{120}$ of a second, one alternation is permitted to flow through the output. The contact is then opened for $\frac{1}{60}$ 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 48 that 40 alternations or 20 cycles are selected per second, and are allowed to flow into the output.

b. 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,

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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.

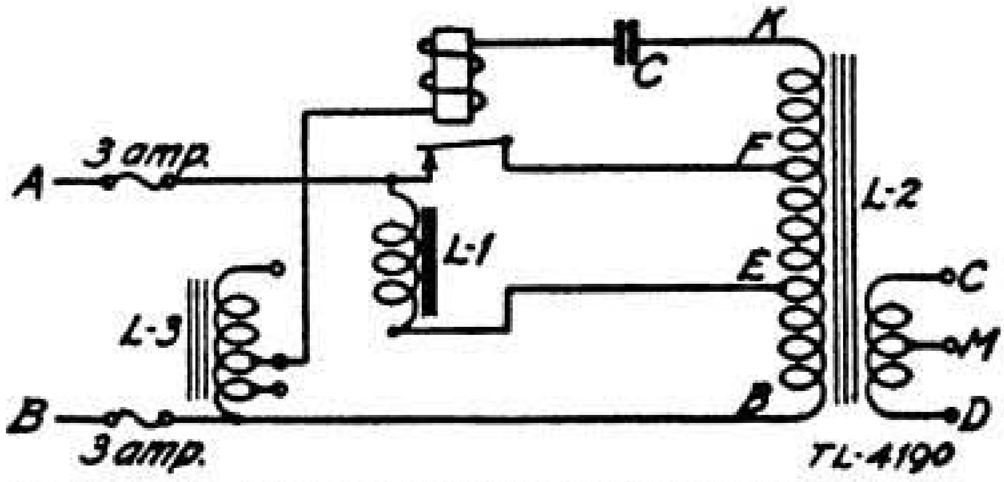

FIGURE 49.—"Sub-cycle" static frequency converter.

(1) *Starting.*—The 115-volt 60-cycle supply is applied to points *A* and *B*, figure 49 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 resistance of L–3 and the relay winding is 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.

(2) *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

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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.

(3) *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.

39. Questions for self-examination.—

1. What is meant by a miscellaneous circuit in a switchboard?
2. Name five miscellaneous circuits.
3. What is a trunk circuit?
4. What is a transfer circuit?
5. Draw a diagram of a night alarm circuit.
6. Draw a diagram of a bell that can be operated from dry cells.
7. Could a ringer be used as a night alarm bell? Why?
8. Assume that you have two sources of ringing current available, hand generator and power ringing. Show by a diagram how you could change from one to the other at will.

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9. Draw a diagram of a through line circuit containing the following features:

a. A means of signaling when either line east or west rings.

b. A means for talking with both line east and line west at the same time.

c. A means for cutting off line west when talking to line east.

d. A means for cutting off line east when talking to line west.

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SECTION V

DISTRIBUTING FRAMES

40. 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 non-multiple board, but in a large exchange with a multiple board it is

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of utmost importance. In fact without the use of such frames the wiring in a large central office would be a hopeless tangle.

41. 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 50.

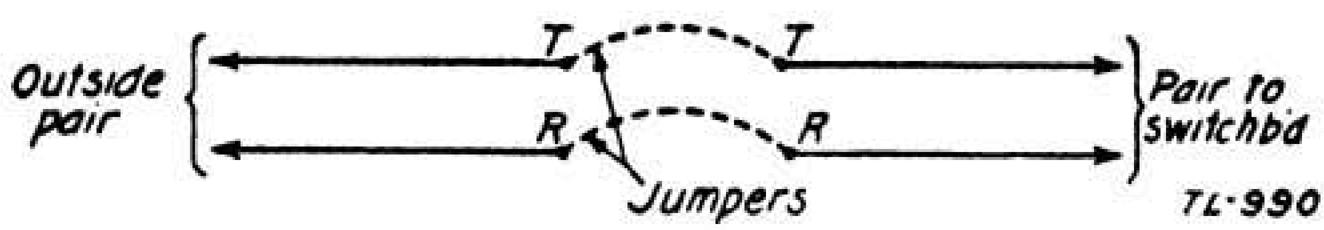

FIGURE 50.—Connections through a distributing frame.

42. 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 smaller 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

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frames the two sets of terminal blocks are on opposite side 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 51 shows part of a typical distributing 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 a type A frame. With the horizontal side connected to the board, it is known as a type B frame. The bridle rings are to assist in an orderly running of jumper wires between protectors and terminal blocks.

43. 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

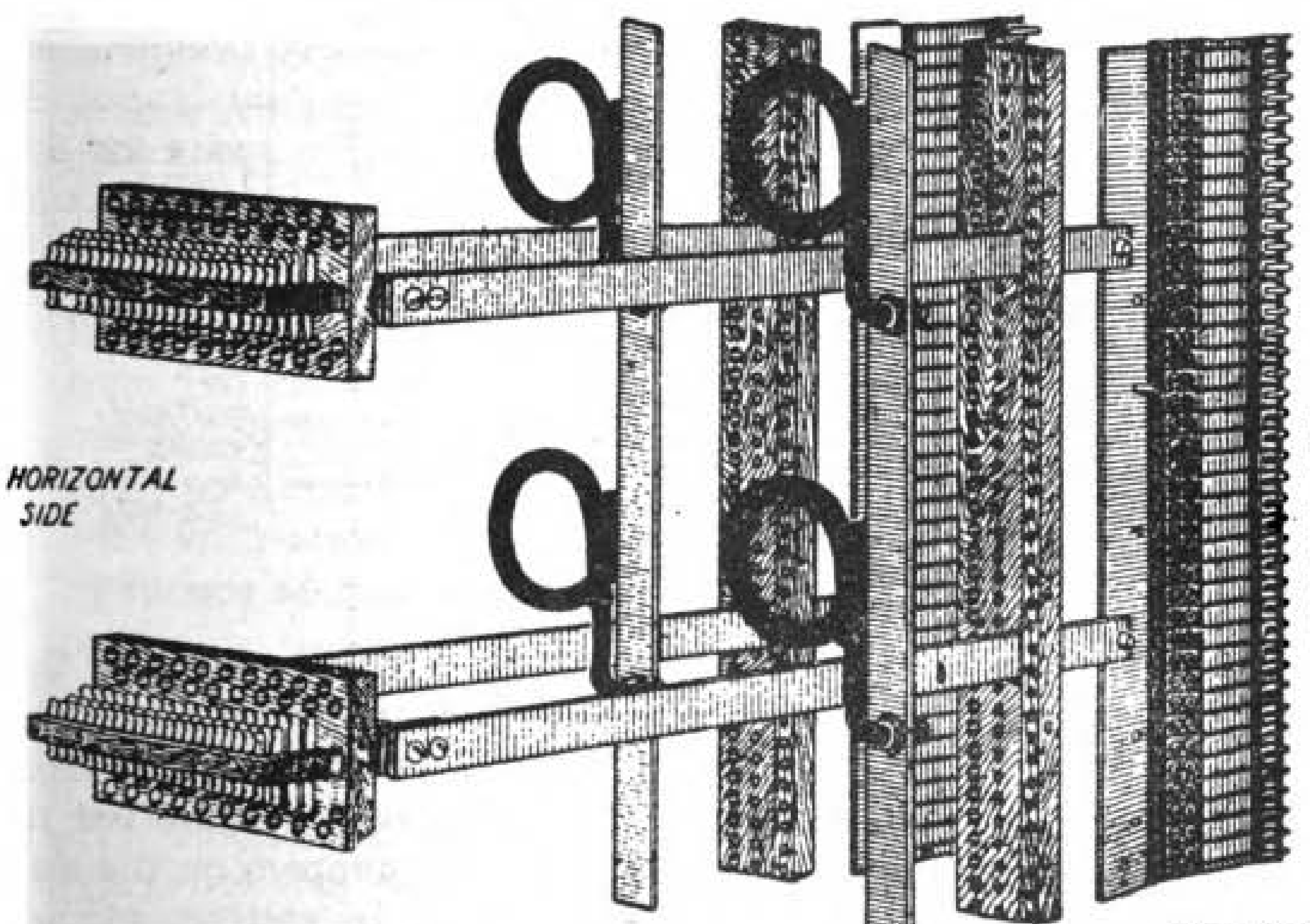

FIGURE 51.—Floor frames.

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

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attached. Figure 52 shows the manner in which connections are made through the two frames. In the diagram, VMDF means ver-

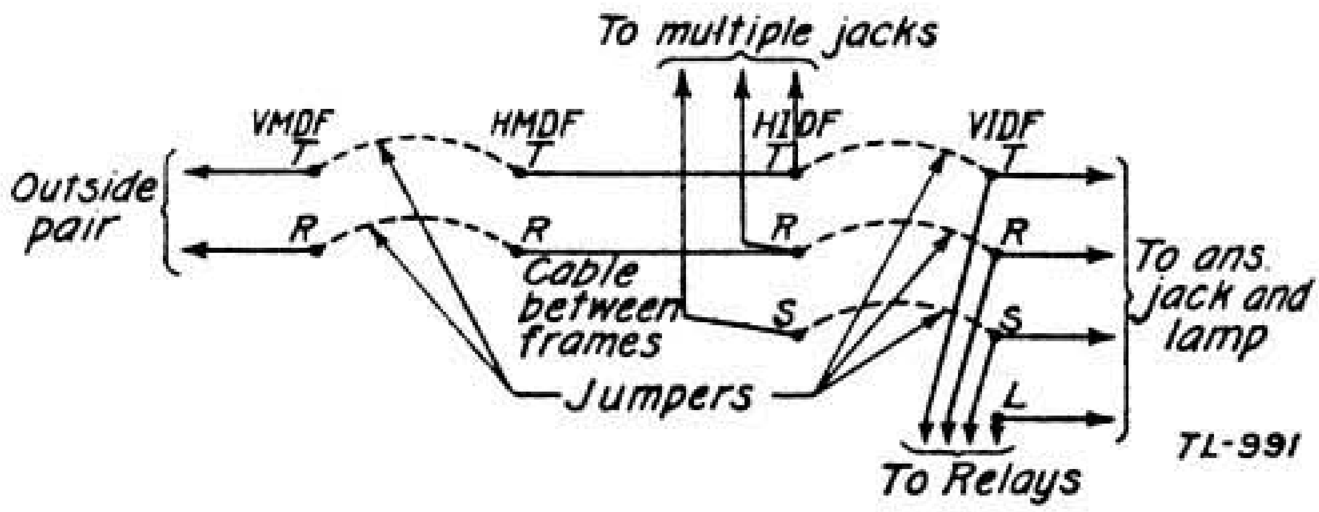

FIGURE 52.—Connections through standard MDF and IDF.

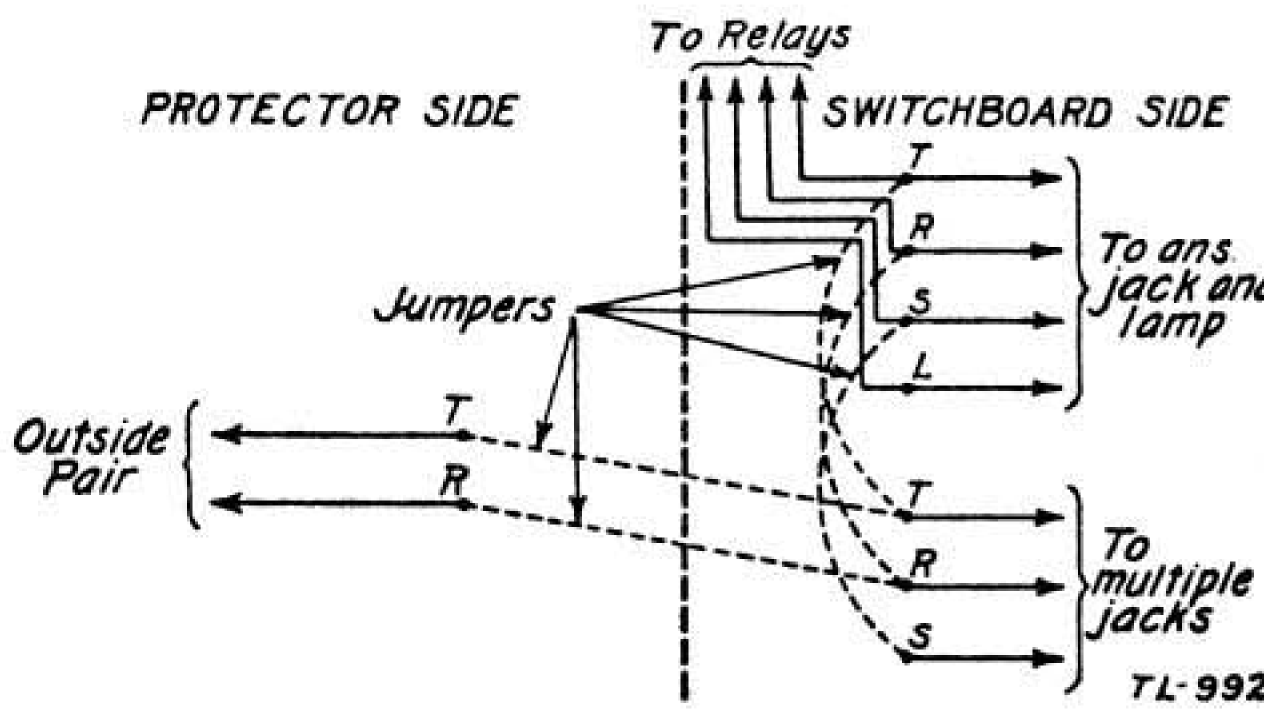

FIGURE 53.—Connections through combination MDF and IDF.

tical 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 telephones 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.

44. 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 des-

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cribed above. One frame known as 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 52. The upper half corresponds to the VIDF. Thus the two sets of jumpers are used on the one frame. Figure 53 shows a schematic diagram of this arrangement.

45. 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.

46. Cables from outside plant.—The cables of the ouside 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.

47. 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?

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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 separate main and intermediate frames?

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.

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SECTION VI

CENTRAL OFFICE PROTECTION

48. 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 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:

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(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.

49. 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 core. 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

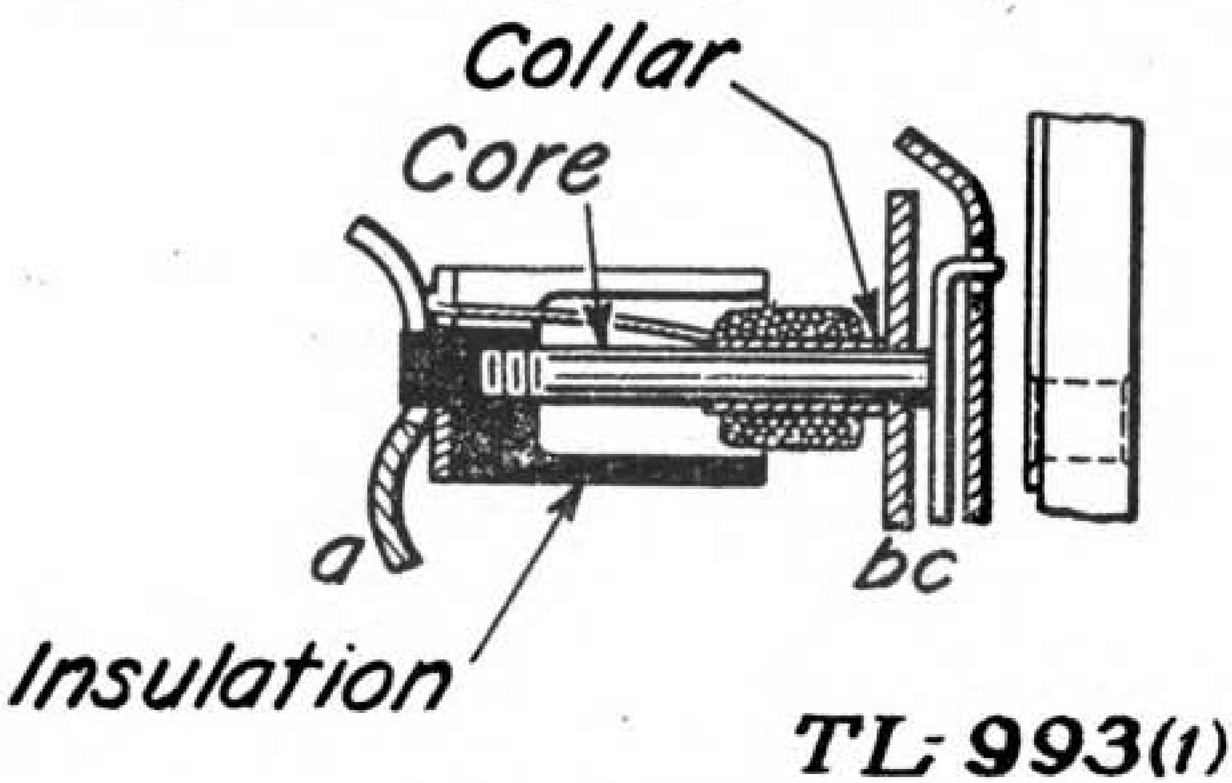

FIGURE 54.—Heat coil.

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grounds the line. The Western Electric heat coil has a resistance of about 3½ ohms and operates on ½ ampere in less than 3½ minutes. Figure 54 shows a diagram of that coil (with the shell cut away) and the springs between which it is mounted. The coil is mounted 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.

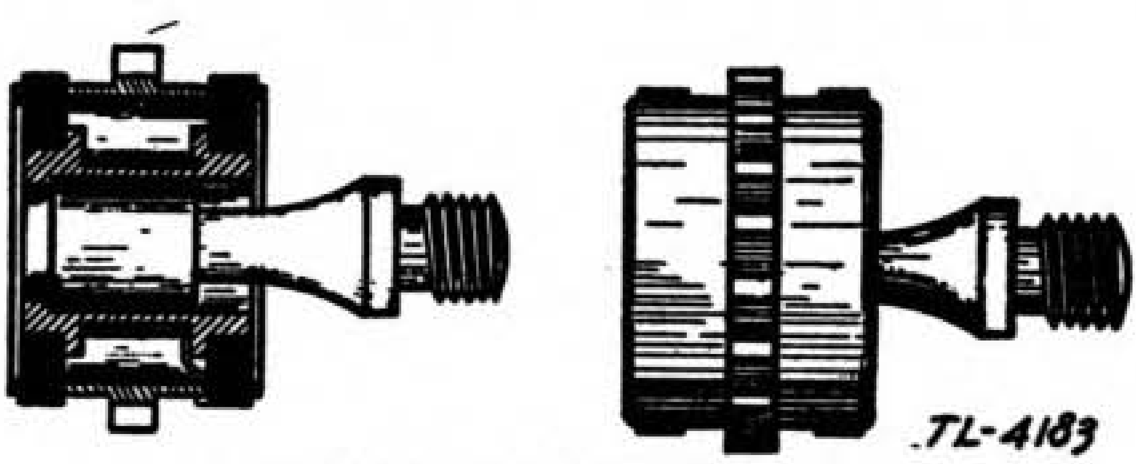

FIGURE 55.—Cook self-soldering heat coil.

The most widely used coil of this type is shown in figure 55. 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

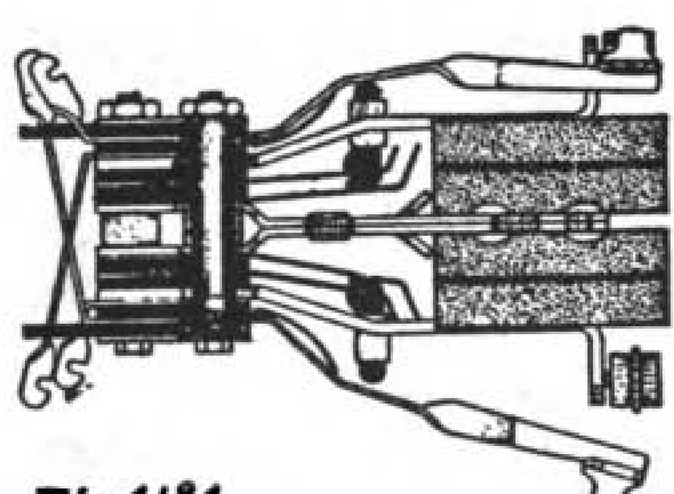

FIGURE 56.—Cook central-office protector.

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releasing the spring. These protectors are reset by merely placing the controlling spring in engagament with another tooth of the coil after the solder has again hardened.

As shown in figure 56 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 56 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 ampere for 3 hours with a room temperature of 68° F. As heat coils are used in conjunction with open space cutouts in the central office, their location and the way in which they fit into the circuits will be shown later.

50. Fuses.—When a telephone conductor is grounded by the operation of a protector, current will continue to flow through the telephone conductor to ground as 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 pótential (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

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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 accomplishes the same result as if fuses were used.

51. Lightning arrestors or open space cut-outs.—Open space cut-outs are designed to protect against lightning or other extra high potential by affording a path for it to arc to ground. Figure 57 shows a standard arrestor 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 57 there is a small air gap between the two carbon blocks. The right hand drawing of figure 57 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

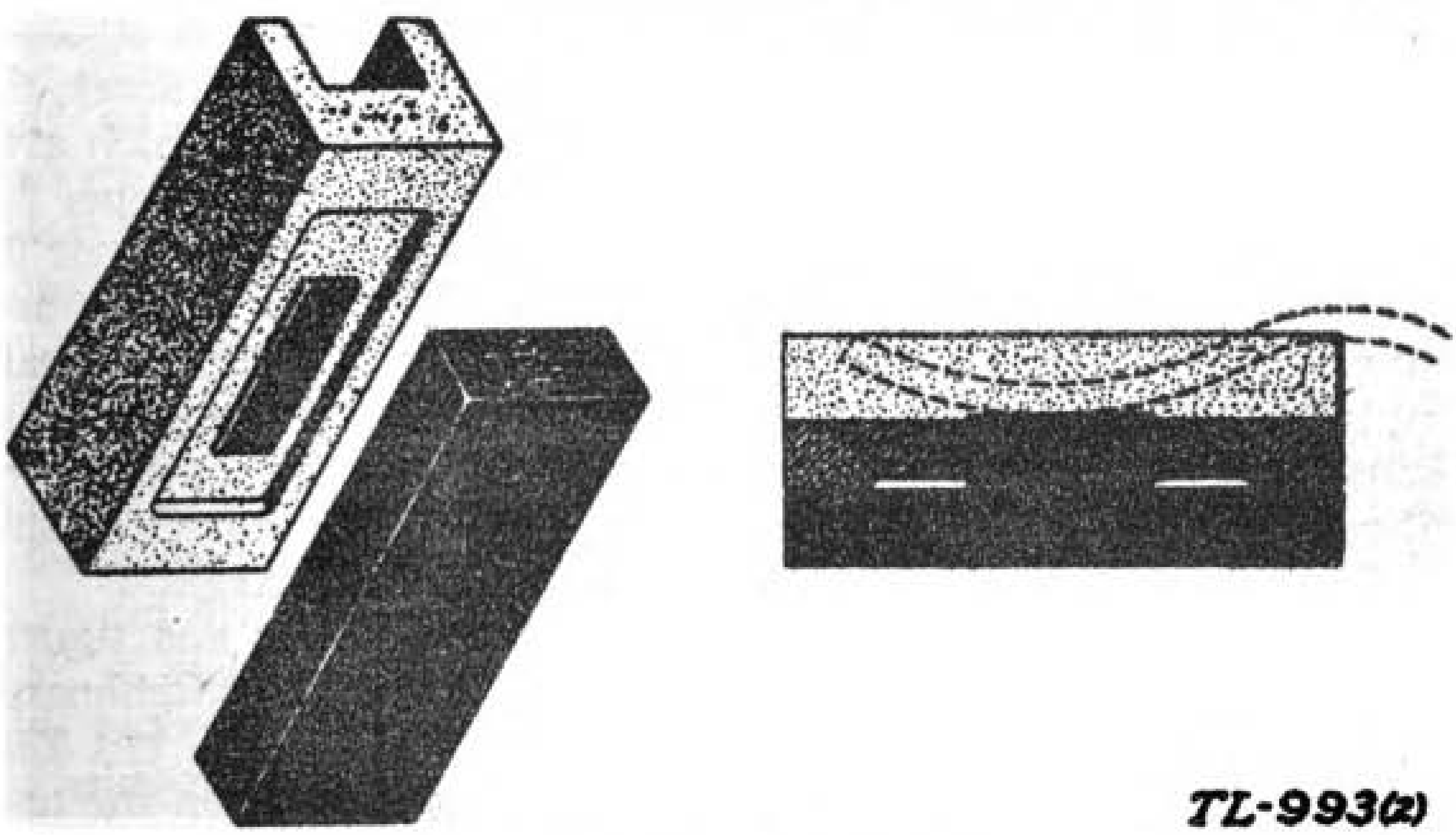

FIGURE 57.—Open space cut-out.

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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 stations and in central offices is about 350 volts.

The older type of lightning 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.

52. Protectors.—Lightning arresters 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 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 58 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 brought 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 58 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.

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53. Switchboard fuses.—*a.* 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 pro-

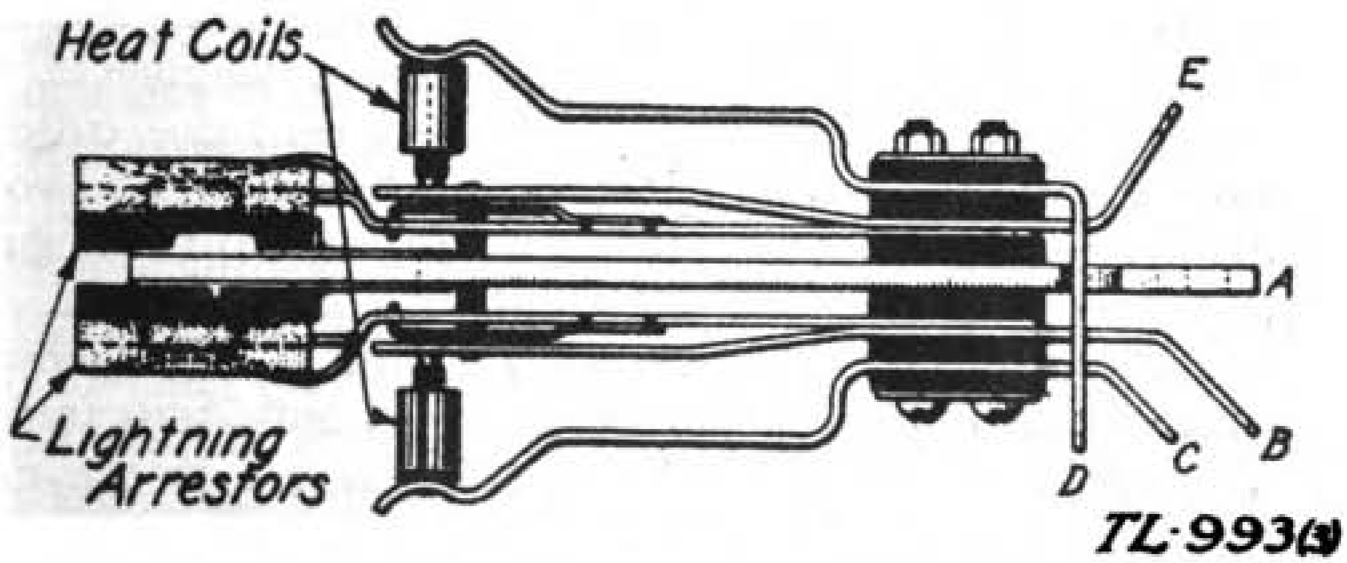

FIGURE 58.—Western Electric Co. central-office protector.

vided 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 necessary 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 59, 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

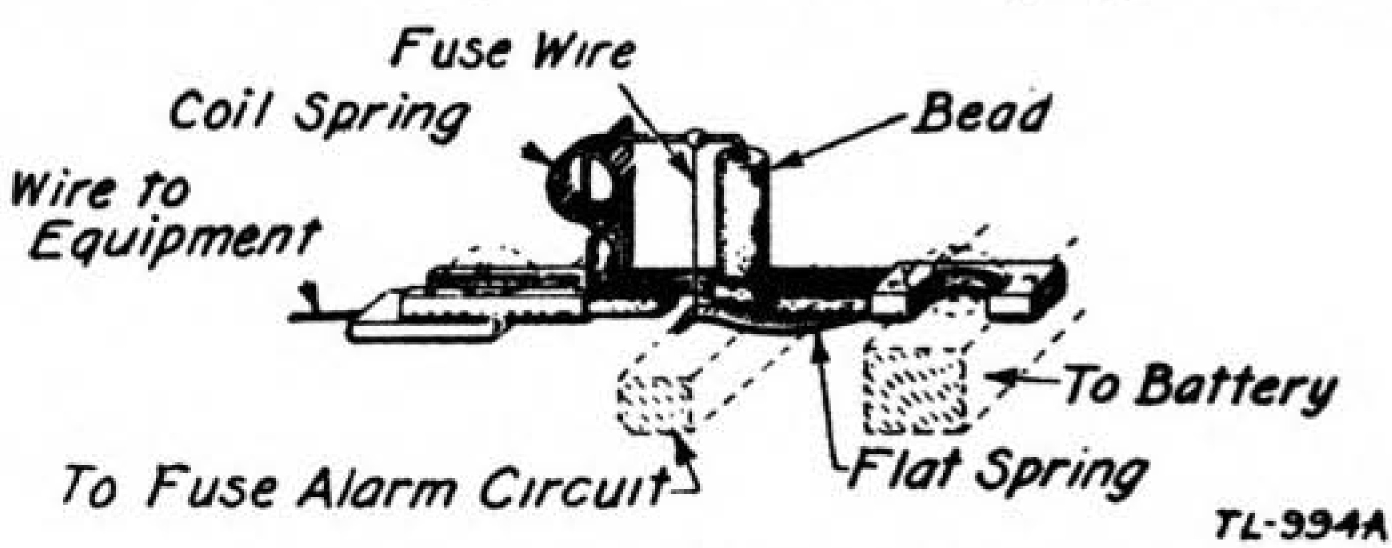

FIGURE 59.—Western Electric Co. 35-type alarm fuse.

with the fuse alarm bus, putting battery on that circuit. The ringing of the bell calls the attention of the attendant and the particular pilot lamp burning shows him on which panel the blown fuse is

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located. By inspection of the panel for a fuse with the bead raised out of line the particular fuse is located. It is usual to replace one fuse without investigating the cause of failure, but if the second fuse blows out the cause of the trouble is searched out and cleared.

b. Fuse sizes.—Switchboard fuses are avilable in various sizes of which ½, 1-⅓, 2, and 3 ampere capacities are most common. The fuse circuit prints will show which size to install in each case, and when replacing fuses the capacity of the fuse removed will show the 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 copper wire in place of a fuse, and never replace a fuse with another of larger capacity.

54. 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 operator's circuit. In use, the varistor is bridged on the receiver branch of the operator's telephone set, usually being wired across the receiver leads at 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.

55. Questions for self-examination.—

1. What is meant by a hazard?

2. Name three types of hazards to which the 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.

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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 generally used in the army exchanges?

14. Describe the older type cut-out containing the two carbon blocks.

15. What two protective devices are combined and called a 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.

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Section VII

NOISE, CROSSTALK AND TRANSPOSITIONS

56. General.—An important factor upon which the intelligibility of a telephone conversation depends is the absence of excessive noise and crosstalk. It is not only necessary to keep the attenuation or loss on the line within certain limits but noise and crosstalk should be reduced to a minimum. This requires what is known as a high degree of line balance, involving the use of transpositions, and other means of preventing a transfer of energy from so-called disturbing circuits (i.e. power circuits, other communication circuits) to disturbed circuits. In general terms, crosstalk is the transfer of energy from another communication circuit, and noise is the transfer of energy from a power circuit or other source. If crosstalk comes from several other communication circuits at the same time the results may be considered to be noise, or what is frequently called babble. Since the fundamental explanation for the causes of crosstalk is the same as for noise, a discussion of the former will be given in more detail in this section.

57. Crosstalk.—In explaining the reason for crosstalk, let us assume typical open wire, long distance lines, and see how conversation over one pair of wires may be heard in another if the lines are not properly balanced.

a. Magnetic induction.—Referring to figure 60, we will assume that an alternating current with its source at the left end is flowing in the circuit made up of wires *1* and *2*. Assume further that the current is flowing for the instant in the direction indicated by the arrows in figure 61, which represents the same circuit as figure 60. We know that a current flowing through a wire sets up a magnetic

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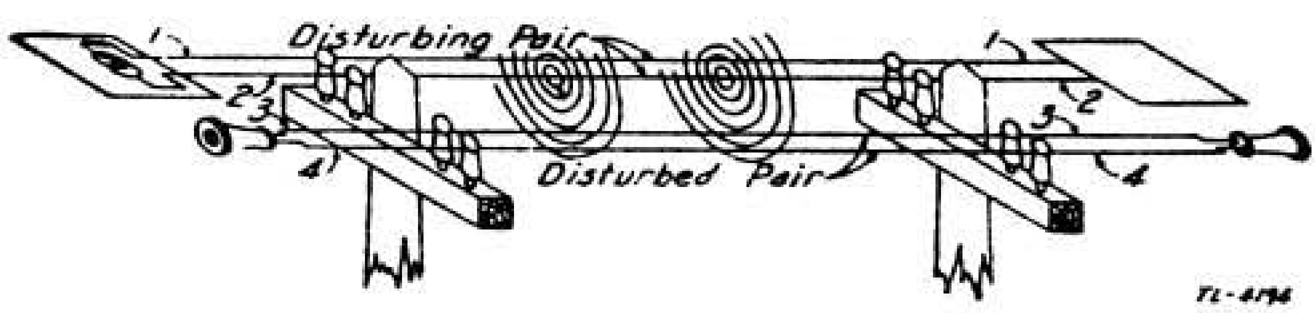

FIGURE 60.—Crosstalk-magnetic induction.

field or lines of force about itself in circular form and perpendicular to the wire. This field set up about wire *2*, expanding and contracting with the rise and fall of the current in the wire, cuts wires *3* and *4*. More lines of the field cut conductor *3* than cut conductor *4*, because the former is nearer the disturbing wire. Due to magnetic induction, wires *3* and *4* will have voltages induced in them. This effect may be likened to an infinite number of tiny alternating current generators, each in series with the line, those in wire *3* producing a slightly higher voltage than the ones in wire *4*. This is illustrated in figure 61. In figure 61 let us designate the sum of

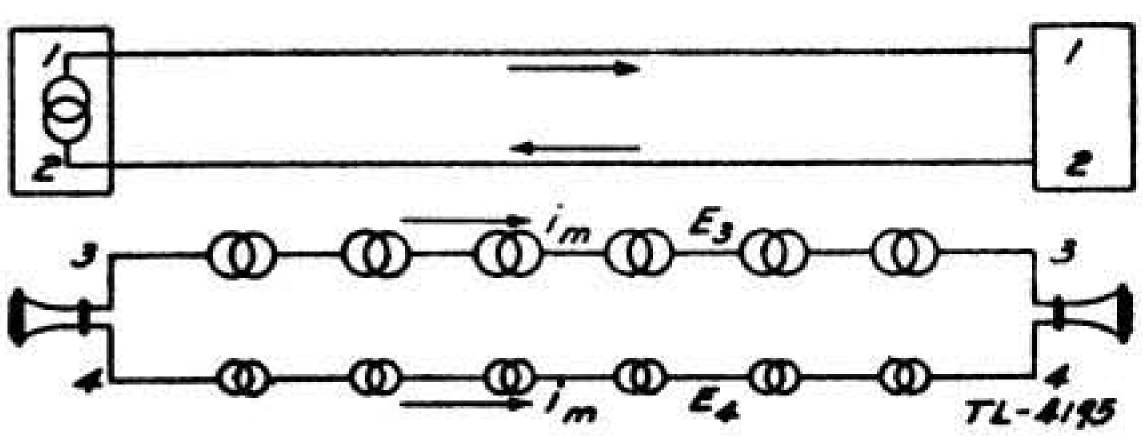

FIGURE 61.—Crosstalk-equivalent magnetic circuit.

all the voltages induced in wire *3* as E_3 and in wire *4* as E_4. Assuming the same number of tiny generators in both wires *3* and *4*, it is evident that E_3 is somewhat greater than E_4. Since these voltages are induced from the same magnetic fields, they are all in the same direction and consequently oppose each other when considered around the loop circuit composed of wires *3* and *4*. Thus we have a resultant voltage operating in the loop equal to E_3–E_4. This voltage will cause an alternating current to flow through the receivers at both ends and it will follow the alternations of the current in wire *2*. If the parallel exposure with the disturbing circuit is long enough we can hear distinctly in the receivers on wires *3* and *4* any conversation being carried on over wires *1* and *2*.

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Wire *1* of figure 61 also sets up a resultant voltage in wires *3* and *4* just like wire *2* did, but the voltage will be in the opposite direction because the current in wire *1* is opposite to that in wire *2*. Also, since wire *1* is further away from the disturbed pair the resultant induced voltage is less so it is overcome by that set up by wire *2*.

b. Electro-static induction.—Alternating voltages as well as currents may be the source of crosstalk. In the case of the magnetic induction we say that the lines of force cutting the disturbed conductors produced the voltage causing crosstalk. Due to the electrostatic field around wire *2* there will be a voltage impressed upon wire *3* equal to E_{23} and upon wire *4* equal to E_{24}. The voltage on wire *3* will be greater than that on wire *4* because wire *3* is closer to wire *2*. Thus there will be a difference in potential between wires *3* and *4* equal to E_{34}. This can better be seen by reference to figure 62. Likewise, there will be a difference in potential between

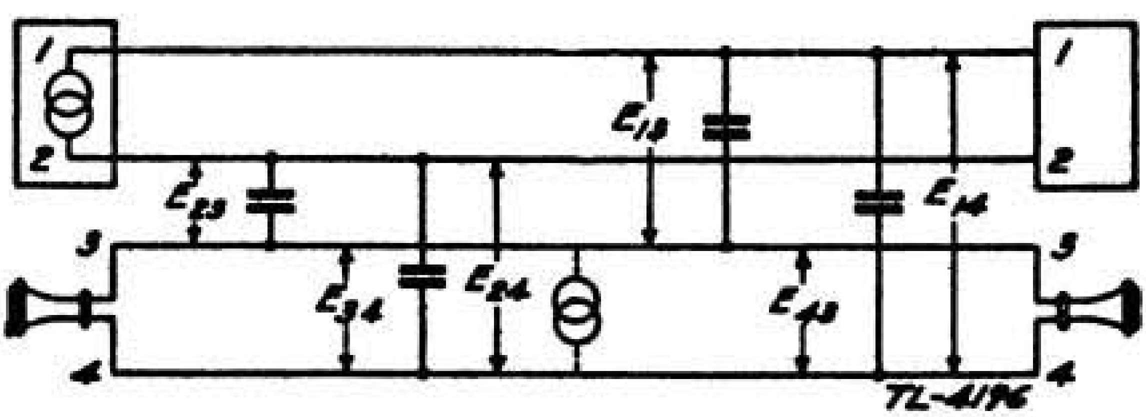

FIGURE 62.—Crosstalk-electro-static induction.

wires *3* and *4*, due to the electro-static field around wire *1*, equal to E_{43}. This latter voltage will be of exact opposite phase as that of E_{34} and will be smaller since wire *1* is further away from the disturbed pair than wire *2*. As far as the disturbed pair is concerned, it may be considered that a small a-c generator with a voltage equal to E_{34} minus E_{43} is connected across wires *3* and *4* as represented in figure 62. Here again if the exposure is long enough, understandable crosstalk will result in the disturbed pair.

c. Combined effect of magnetic and electro-static induction.—To summarize the effects of both magnetic and electro-static induction as causes of crosstalk, let us refer to figure 63. Hence the combined crosstalk effect may be thought of as tiny a-c generators in series and one small generator across the circuit of wires *3* and *4*. Under these conditons it can be seen that the currents from the two sources of crosstalk are additive in the left portion of the line

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and subtractive in the right hand portion. In other words, the combined crosstalk effect of electro-static and magnetic induction is

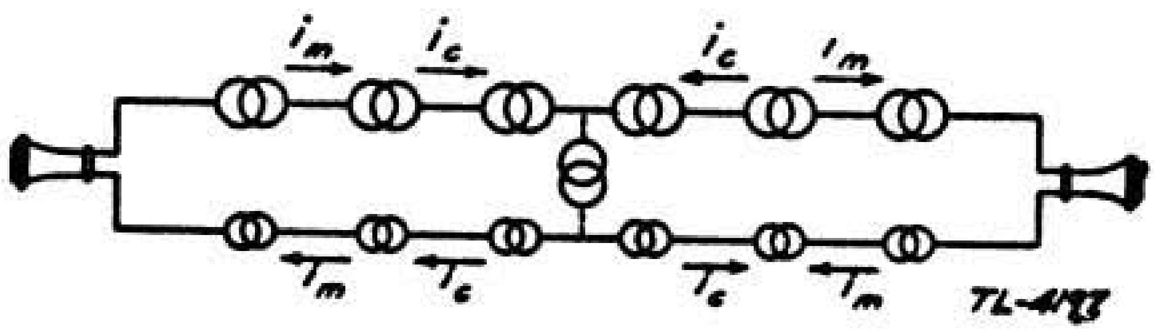

FIGURE 63.—Crosstalk-combined magnetic and electro-static induction.

additive in the case of near-end crosstalk and subtractive in the case of far-end crosstalk.

d. Resistance unbalance and crosstalk.—In addition to the two causes of crosstalk discussed in paragraphs *a* and *b* there is another fundamental consideration. It has been assumed up to this point in our discussion that the two pairs in figures 61 and 62 were electrically identical throughout their entire length; that is they have the same series resistance and size per unit length. This is generally true, particularly of cable, but for open wire there is always the possibility of bad joints, bad insulation, etc. When a circuit, say the disturbed pair in figure 61, is not electrically the same for each unit of length, the assumptions to be made later in this section in discussing transposition will not hold, and transposition loses part of its effect.

(1) *Phantom circuits.*—Phantom circuits are particularly susceptible to resistance unbalances, so they will be discussed here. Even with proper side circuit and phantom transpositions, objectional crosstalk may still exist due to resistance unbalance. Referring to figure 64, assume that there is more resistance in wire *1* than wire *2* of side circuit *1*. Wires *3* and *4* of side circuit *2* have the same resistance as wire *2*. Now assume further that an alternating current is introduced into the phantom circuit at the left end. The current in the phantom through side circuit *1* will divide in wires *1* and *2* inversely proportional to the impedance of these two wires. Since there is more resistance in wire *1* more current will flow in wire *2* than in wire *1*. Thus there is an unbalance in current through both repeating coils of side circuit *1* and crosstalk will result in this side circuit from the phantom. A similar analysis will show that side circuit *1* will crosstalk into the phantom.

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58. Noise.—Assume that wires *1* and *2* of figure 60 are replaced by a commercial power circuit of high voltage and carrying alternating current of large magnitude as compared to that in the telephone circuit. Naturally this condition would induce voltages into

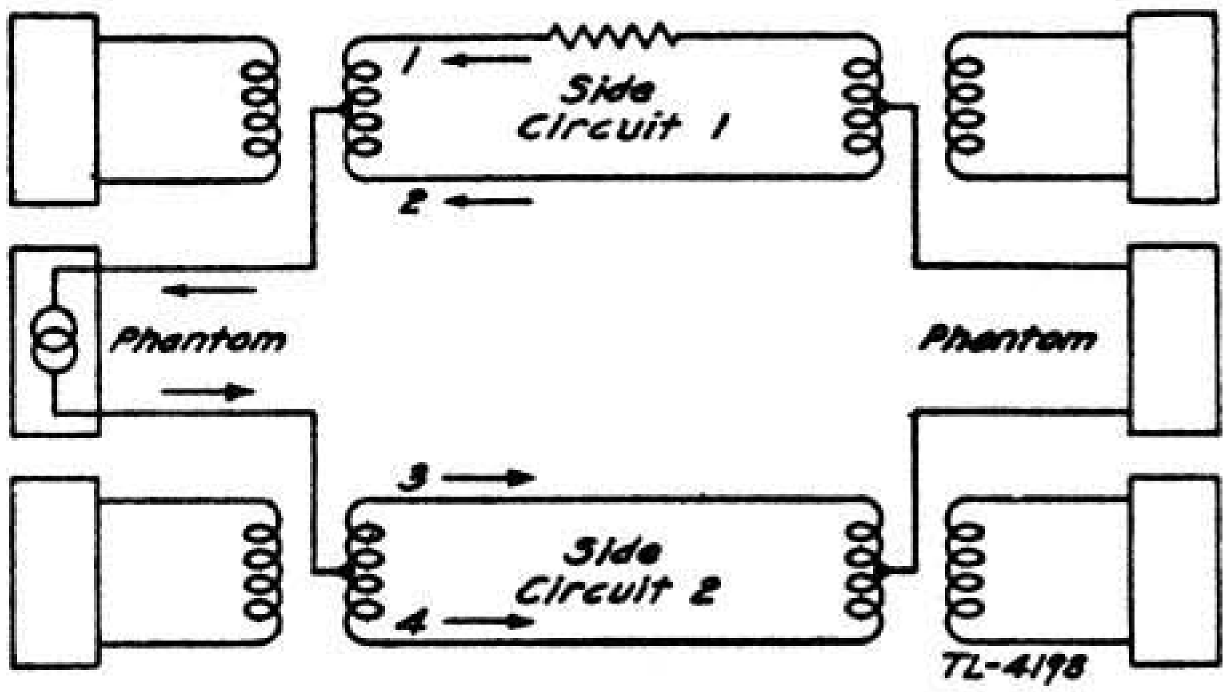

FIGURE 64.—Phantom crosstalk due to resistance unbalance.

lines *3* and *4* in the same manner that the telephone currents did. These induced voltages, however, would be much larger than those from the telephone currents. You can see the necessity of keeping the telephone circuit as far away as possible from all power circuits in order to avoid these so-called "noise effects."

59. Transposition, general.—*a.* Although there are several ways to reduce crosstalk, including symmetrical configuration of the disturbing and disturbed circuits, transposition is the most practical. Refer to figure 61. Transpose wires 3 and 4 at the center and consider the effect of magnetic induction. Figure 65 shows this change.

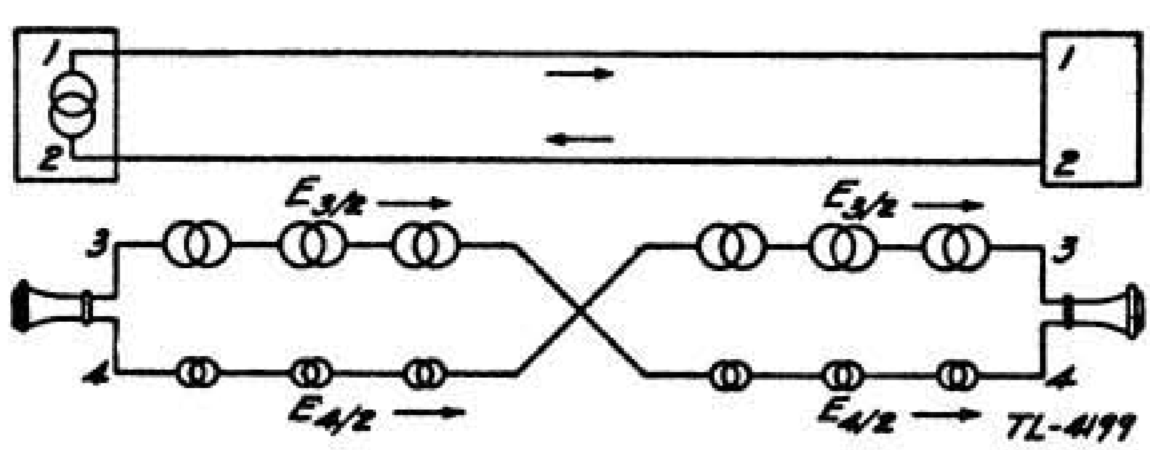

FIGURE 65.—Reduction of noise by transposition.

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It is obvious that the resultant voltage effective around the loop circuit of the disturbed pair is

$$\frac{E_3}{2}+\frac{E_4}{2}-\frac{E_3}{2}-\frac{E_4}{2}$$

or zero. Thus there will be no crosstalk. Inspection will show that wires *1* and *2*, transposed in the same manner, would be just as effective. However, transposing both pairs in the center would be, in effect, the same as no transposition at all as far as balancing out crosstalk is concerned. A similar analogy holds for electro-static induction since the capacitance between the various wires and between wires and ground is balanced on either side of the transposition point. Thus it is seen that transposition reduces crosstalk from both electro-static and magnetic induction.

b. While a single transposition as discussed above is effective in reducing crosstalk in a short section, it will not suffice for too long a section. There are two principal reasons for this. First, because of attenuation, the current and voltage near the energized or so-called near end of a disturbing communication line is many times that at the far end. It would not be expected, therefore, that the induced crosstalk on the near-end side of the transposition would be neutralized by the weaker crosstalk on the far-end side of the same transposition point. As a mattery of fact, even in a short section, the transposition will not completely eliminate near-end crosstalk. The second reason why a single transposition is not effective in reducing crosstalk on too long a section is the change or shift of both current and voltage along the line at a given instant. Although the voice current in a line is considered as flowing in series throughout the line and thus for any particular instant bearing the same phase relationship with the transmitted current, this assumption can not be made for an electrically long line. Actually the magnitude of the current in the line at some instant might look like that shown in the curve of figure 66. Here it can be seen that

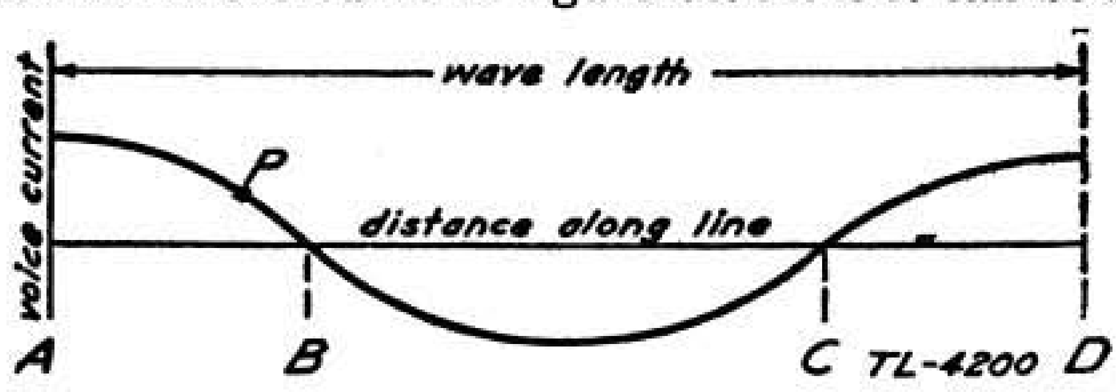

FIGURE 66.—Current cycle in disturbing circuit.

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at points *B* and *C* the current is actually zero. This phenomenon must not be confused with the frequency of the voice currents being transmitted. It represents the instantaneous picture of current on the line between point *A* and *D*. The distance between *A* and *D* will be in the order of 175 miles for open wire and 8 to 50 miles for cable. Thus it can not be expected that crosstalk on both sides of a transposition, say at point *P*, will balance. It is necessary, accordingly, that transposition be installed at rather frequent intervals with respect to the so-called wave length or distance *A–D* in figure 66.

60. Transposition practices.—So far the discussion has considered only the simple condition with two parallel open wire circuits. It is obvious that a greater number of circuits in a group generally will be involved.

a. Open wire.—Physically there are two standard methods of effecting a transposition between wires of a pair on a pole line. These, known as "point-type" and "drop-bracket" transpositions, are shown respectively in figures 67 and 68. The "point type" is used extensively on carrier circuits because it does not change the configuration of the wires in adjacent spans. The "drop-bracket" type is generally used on voice frequency lines. As far as laying out the location and number of transpositions is concerned, there is

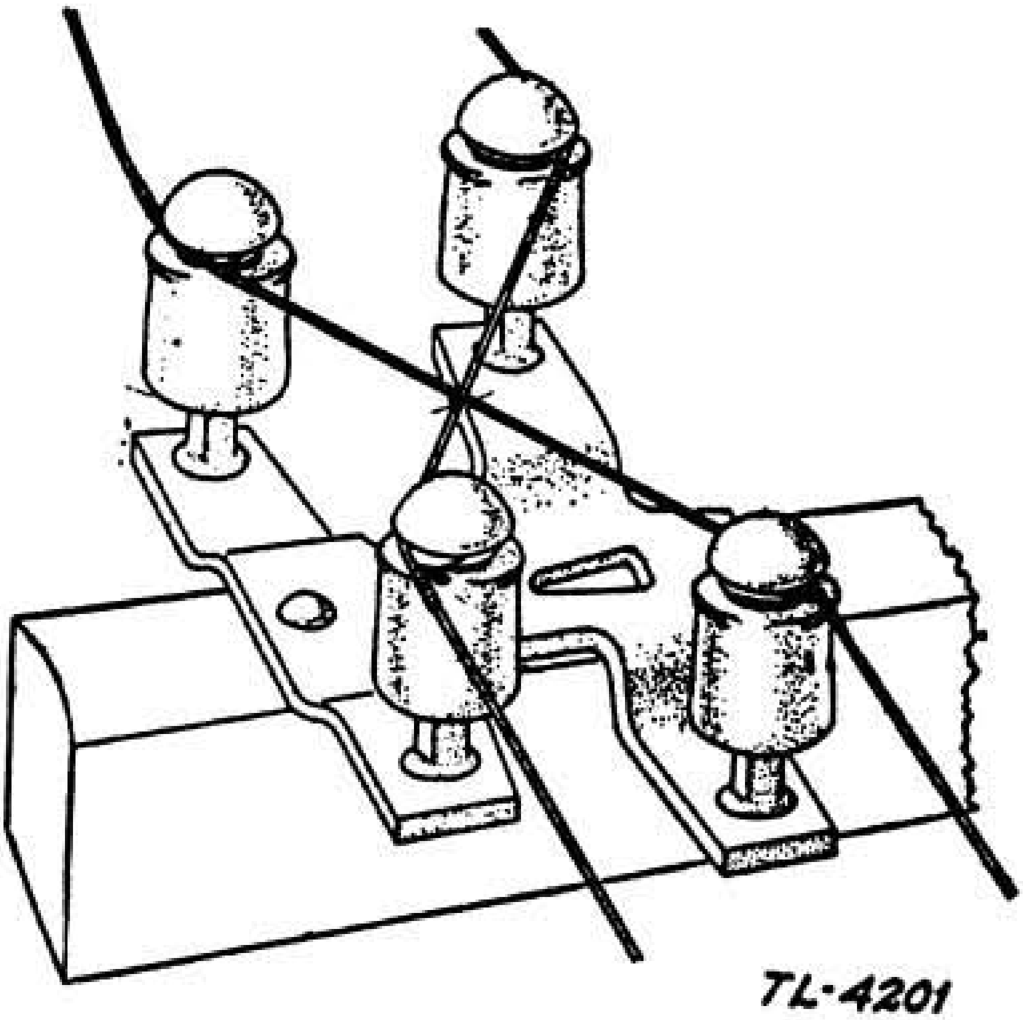

FIGURE 67.—Point-type transposition.

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no hard and fast rule. The line is usually divided into sections in each of which complete crosstalk balance is approached as closely as possible. Thus any number of sections may be connected in tandem. Nonuniformity in length of individual sections may be re-

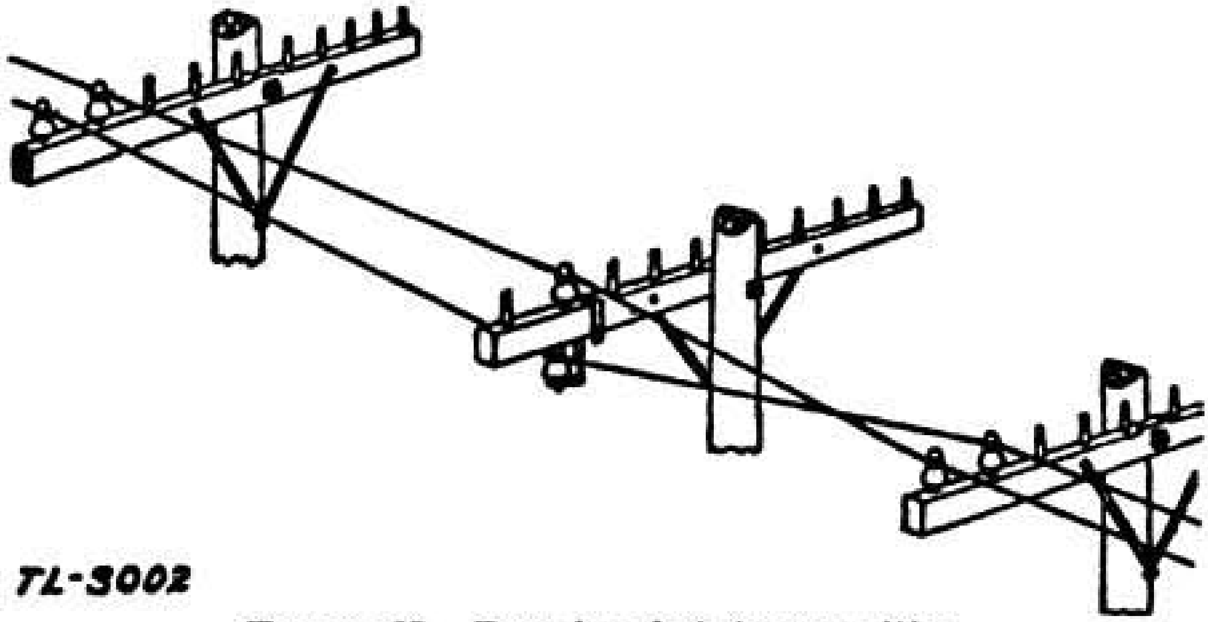

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FIGURE 68.—Drop-bracket transposition.

quired because of discontinuities in the line, such as junctions with other telephone lines, circuits added or dropped off and power line exposures. It is natural that such points of discontinuity should be made to coincide with the junction between transposition sections. Each section may have a number of transposition points, and their location is a matter of calculation for the individual section. For example, a section having a very bad power line exposure would have transpositions spaced much closer together than another section without the exposure. Sections may run from a few hundred feet to 6 or 8 miles.

b. Cable.—Long distance cable circuits, because of the close spacing of the pairs, must be transposed very often. This is done in the course of manufacture by twisting the two wires of a pair together, by twisting the two pairs of each group of four wires together to form so-called quads, and by spiralling the quads in opposite directions about the axis of the cable.

61. Questions for self-examination.—

1. What is noise in a telephone circuit?

2. What is crosstalk in a telephone circuit?

3. What are the two causes of noise and crosstalk, excluding resistance unbalance?

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4. Would it be desirable if an open wire telephone line were properly transposed, to keep it away from power line exposures?

5. What are the two common types of physical transposition on pole lines?

6. Explain crosstalk as caused by:
  a. Magnetic induction.
  b. Electro-static induction.

7. Explain crosstalk as caused by resistance unbalance in a phantom side circuit.

8. How is cable transposed?

9. Give two reasons why a single transposition in a long telephone line would not be effective in reducing crosstalk.

10. Explain why properly spaced transpositions on a telephone circuit are effective in reducing crosstalk.

11. How are open wire lines usually broken up for the purpose of balancing out crosstalk and noise?

12. Will proper transposition reduce noise as well as crosstalk?

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SECTION VIII

ATTENUATION AND LOADING

62. Attenuation.—*a. Definition.*—(1) It was brought out in section II that the energy of the sound waves produced by the voice moves the transmitter diaphragm of the telephone, thereby translating the mechanical energy into electrical energy. The telephone system is designed to transmit as much of this energy as possible from one telephone to another, regardless of whether the instruments connected are located in the same city or at opposite ends of the country. When the sound received at the receiving station is much lower in volume than the original spoken words, it is evident that some of the energy must have been lost in transmitting it from one point to the other. This loss of energy is commonly called transmission loss, and is made up of all the losses in the individual parts of the circuit. With a few exceptions, such as amplifiers, each piece of apparatus introduced into the talking circuit causes some transmission loss. In addition there is the loss in the line itself, which increases with the length of the line. The loss in the line is known as the attenuation loss or attenuation of the line.

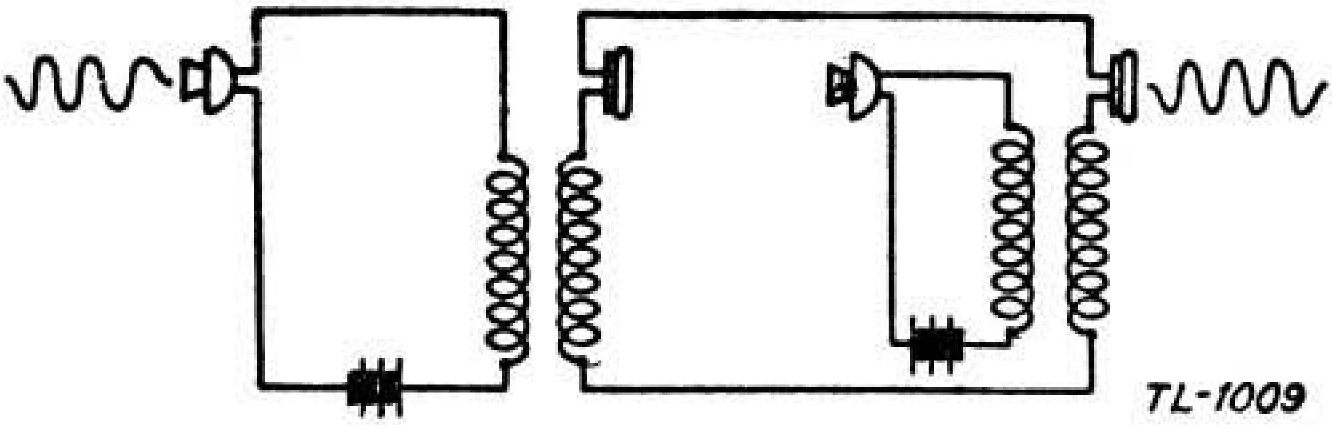

FIGURE 69.—Circuit with no line loss.

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(2) If one telephone set is connected directly to another as shown in figure 69, the sound received will be slightly louder than the original words spoken into the transmitter since the transmitter itself is an amplifying device. The alternating current produced by the transmitting set flows directly to the receiving set, with nothing to impede it or shunt out any part of it. If, however, a length of cable, say 20 miles of 19-gage, is placed between the two instruments, the sound reproduced by the receiver will be much lower than that picked up by the transmitter at the originating end. This is illustrated in figure 70, where the difference in height of the sound waves indicates that a considerable portion of the energy has been lost in traveling from the transmitter to the receiver. As

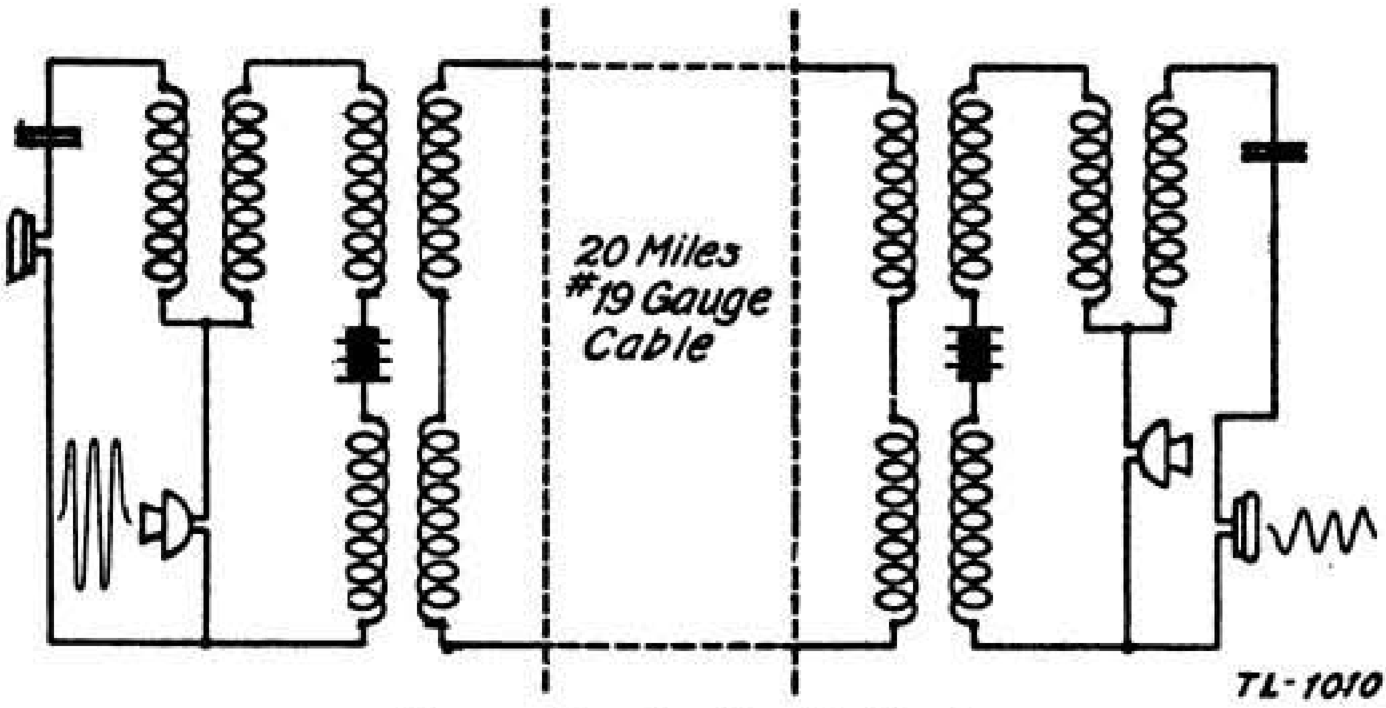

FIGURE 70.—Circuit with line loss.

shown, there is no apparatus in the circuit between the two repeating coils and this loss must, therefore, be due primarily to the attenuation of the line itself.

b. Characteristics of the telephone line.—(1) The energy is transferred from one end of the line to the other by means of alternating current and every line has certain properties or characteristics which affect this current. There is, of course, the resistance *R* of the conductors and also a small amount of inductance *L* causing some inductive reactance. Also, there is a distributed shunt capacitance *C* between the wires of a pair, and between the wires and other circuits and ground. In addition, all circuits have a certain escape of current or leakage, these leaks become larger as the insulation becomes poorer. This loss or leakage is ordinarily very low on cable circuits, but on open wire circuits, especially in rainy weather, it may be quite high.

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(2) The various properties of a telephone line just referred to may be illustrated as in the diagram of figure 71. The diagram shows the distributed series resistance and inductance and the distributed capacitance and insulation resistance in parallel across the line. Attenuation in a telephone line may be defined as the progressive loss along a telephone line due to the combined effect of resistance, inductance, capacitance and leakage.

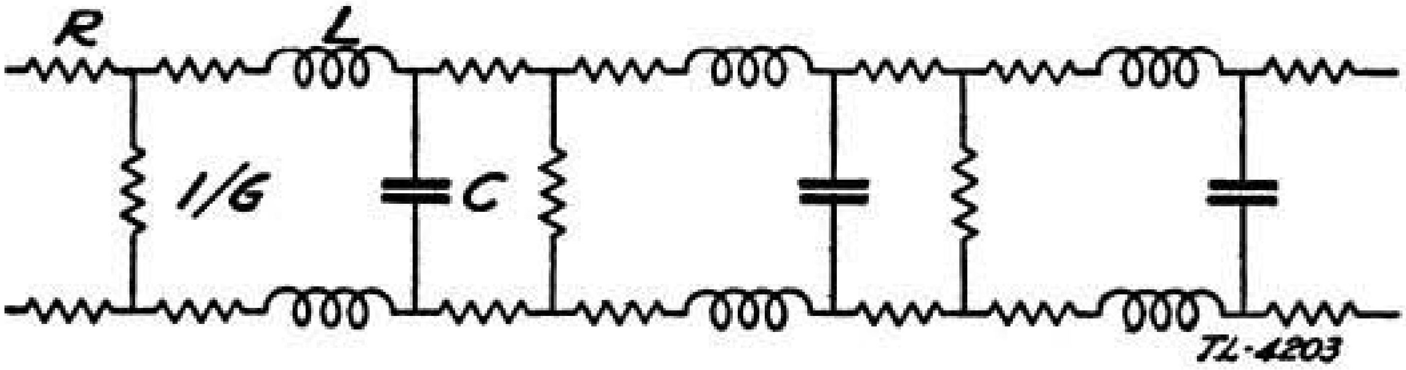

FIGURE 71.—Distributed line constants.

c. Effect of line characteristics on attenuation.—(1) The loss of the transmitted voice current between two telephone stations is due primarily to the attenuation in the line itself. If a circuit of any given type is long enough, it is naturally expected that the loss will tend to become so great that the energy reaching the distant end will be insufficient to operate the telephone receiver. It is to be expected in long transmission circuits that the resistance of the cable or line will consume a large percent of the power delivered by the transmitter, and the current through the leakage resistance will be lost. In cable circuits and long open wire lines the line capacitance is considerable, and accounts for a large portion of the loss incurred on the line. However, while transmission of the required volume is essential, it is not the only consideration. The loss due to this distributed capacitance is not equal for all frequencies, and this fact can readily be seen if you consider that the reactance of a capacitor varies inversely with the frequency: that is

$$X_C = \frac{1}{2\pi fC} \qquad (1)$$

Where X_C=capacitive reactance in ohms, f=frequency in cycles per second, C=circuit capacitance. Since the distributed capacitance has a shunting effect upon alternating current, it is evident from this equation that there will be a greater loss to currents of higher frequencies than the lower frequencies. An increase in f decreases X_C. Figure 72 illustrates the manner in which the attenuaation varies with frequency in cable circuits.

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(2) The wave shape of voice currents is of a very complex nature and it can be proven that regardless of its complexity, the wave can be broken down into a number of sine waves. As these various frequencies are attenuated unequally, the shape of the received wave at the distant station will be materially changed so that

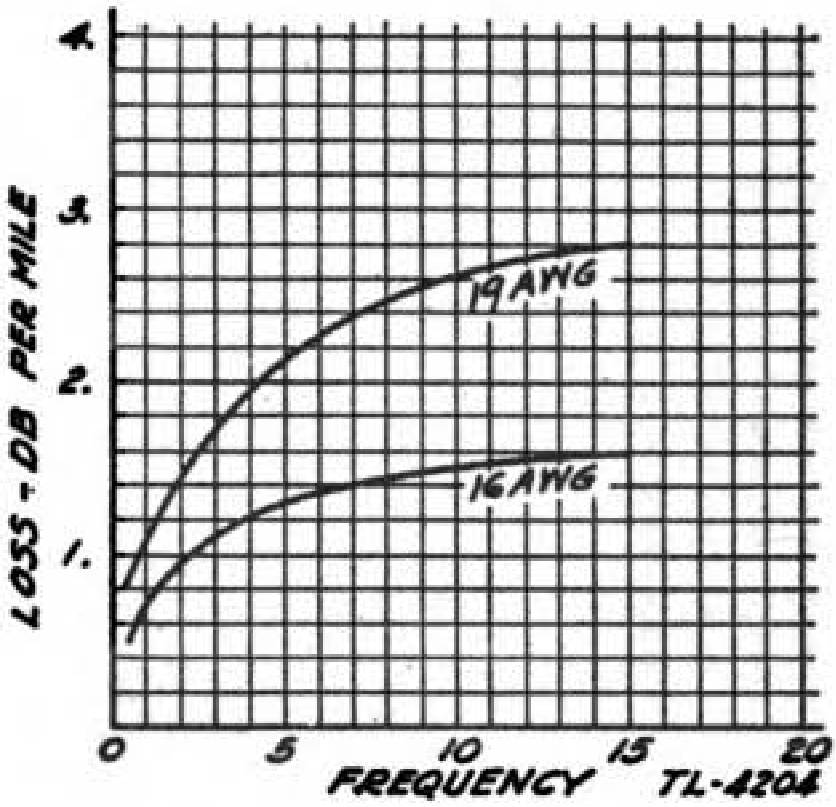

FIGURE 72.—Attenuation of cable circuits.

it will not produce the same sound in the receiver as that which was spoken into the transmitter. The effect of this unequal attenuation of the various frequencies making up the voice current is distortion, and can become serious enough to make the received signal unintelligible.

(3) There is also some inductance inherent in parallel conductors which decreases as the distance between conductors decreases. In cable the distributed inductance is negligible and that of open wire lines is very small. The effect of inductance is opposite to that of the capacitance and tends to neutralize to a degree the effect of the capacitance. This is explained under **Loading**, in paragraph 63.

d. Manner in which energy in line is attenuated.—The manner in which the energy in a line is attenuated can best be shown by a diagram. Consider the 20 miles of 19-gage cable shown in figure 70. The values of *R, L, C,* and *G* for a mile of this could be found from a table, or measured. From these values the attenuation constant could be calculated for some definite frequency. The amount of energy at any point in the circuit could then be found, assuming the energy delivered to the line as 100 percent. The results could

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then be plotted as shown in figure 73. The diagram shows that the attenuation does not increase in a straight line relation with the length, but that the curve is logarithmic.

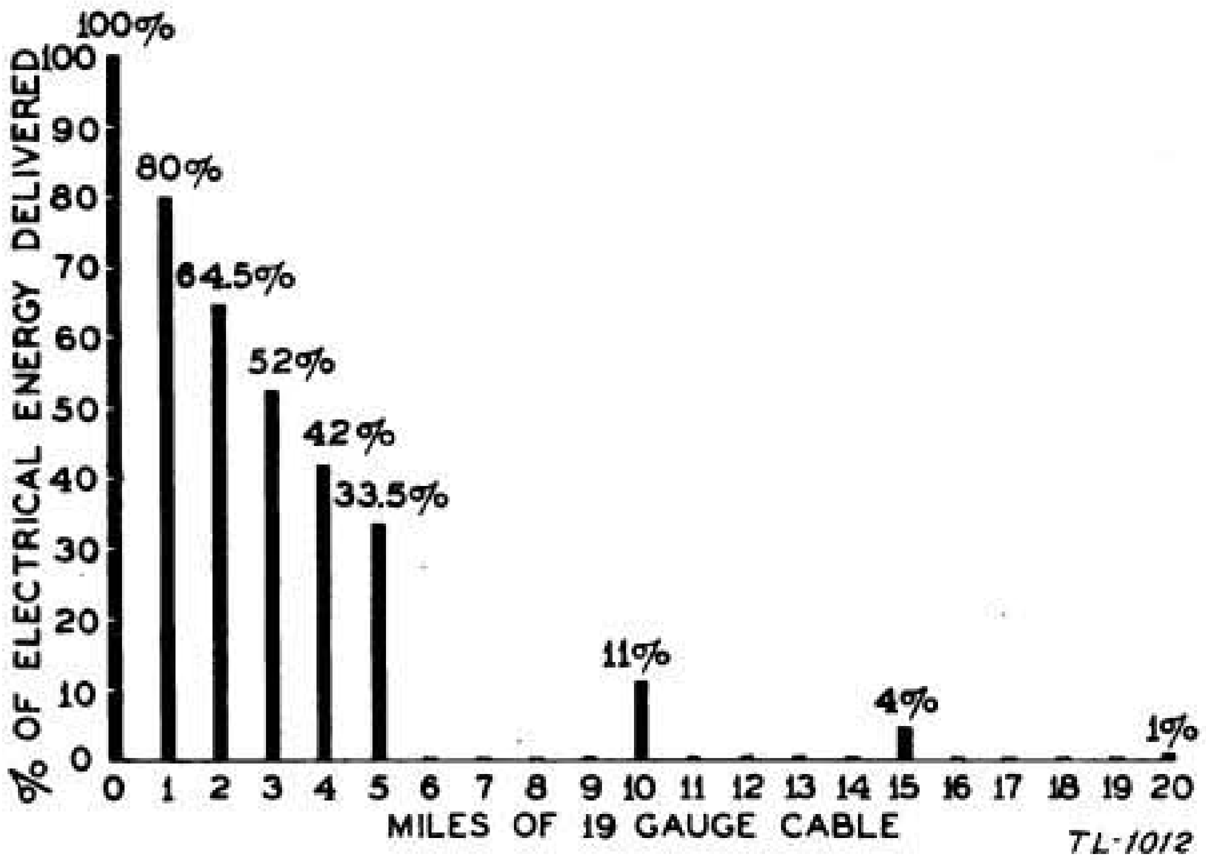

FIGURE 73.—Attenuation chart, 19-gage cable.

This curve drops off sharply in the first few miles (in fact 20 percent is lost in the first mile), and continues the same percentage drop for each mile of cable. That is, the energy leaving any one mile section of cable is always a definite percentage of the energy entering the other end of the same mile section. Thus, at the end of the first mile there remains 80 percent of the total energy. At the end of the second mile there is 64.5 percent of the total or approximately 80 percent of the energy that entered the second mile. The percentage factor varies, of course, with different types and sizes of conductor and with the insulation between conductors.

e. Means of reducing attenuation.—When the wire facilities are extended beyond the satisfactory transmission range there are several ways the attenuation may be reduced. Attenuation can be reduced by increasing the size of the conductor so that the series resistance is decreased, or by further separation of the conductors to reduce capacitance, or by reducing the line leakage with improved insulation, but beyond a certain point there are economic and physical limitations that make this impractical. The two most commonly used methods to increase the transmission range are loading and use of amplifiers.

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63. Loading.—*a. Definition.*—By loading is meant the insertion of series inductance in a circuit to neutralize partially the effect of the distributed capacitance of the line or cable.

b. Purpose.—Loading has a two-fold purpose. It reduces line attenuation and reduces distortion caused by unequal attenuation of the harmonics of the voice current. The latter is of primary importance since the development of voice repeaters. Also, a more constant characteristic impedance for the frequencies within the band to be transmitted is obtained by loading.

c. Theory of loading.—(1) The theory of loading is by no means simple, and it is not in the scope of this text to make a mathematical analysis of loading. However, the subject can be covered by giving the general principles of loading so that it can be understood by anyone having a knowledge of alternating currents.

(2) It may be stated that loading corrects the phase angle, enabling us to obtain the advantage of a lower current transmission system, resulting in less line loss. In power systems, the effect of distributed line capacitance and inductance is not serious at 60-cycles, and usually the length of the line is a small fraction of a wave length. Therefore, the input impedance of the line is largely determined by the terminating impedance. In the power system the problem is relatively simple, as the reactance causing the voltage and current to be out of phase is at the termination, and can be corrected for by introducing a lumped reactance that will cause the current to be out of phase by the same angle as that caused by the load, but of the opposite sign. In a communication line the frequencies are higher, and the distributed capacitance of the line is large as compared with the distributed inductance. The length (in wave lengths) is also much greater. Under these conditions the input impedance is largely determined by the constants of the line, rather than its termination. The capacitive reactance of the line causes the current to lead the voltage, resulting in less power delivered to the receiving end.

(3) By inserting series inductance in the circuit, the phase angle is reduced, since inductive reactance will cause the current to lag the voltage. This tends to neutralize the effect of the capacitive reactance. Unfortunately, it is not possible to increase the inductance without increasing the resistance, due to the wire used in winding the coils, so that a balance between the inductive and capacitive reactance is approached only at the expense of adding

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more resistance to the circuit. When loading, a point will be reached where adding more loading coils will not continue to produce an economic gain in transmission.

(4) Since the capacitance of the circuit is distributed over the entire length of the line, the problem of loading a telephone circuit is made more difficult than where the constants are lumped, as in power systems. It is possible to increase the inductance uniformily along a line by wrapping it with a tape of some ferrous material, such as permalloy. This treatment, called continuous loading, is expensive, and the amount of inductance which can be economically provided is small. Such loading is, at present, used only on submarine cable, where the difficulty of adding lumped loading is great.

(5) In practice a solution is effected by supplying the loading inductance in the form of coils inserted in the circuit at regularly spaced intervals. The addition of inductance in "lumps" will produce the effect of increasing the distributed inductance provided that the "lumps" are sufficiently close together. Thus it is that a loaded circuit usually has loading coils, which are nothing more or less than "lumps" of inductance, inserted at periodic intervals along the circuit, the interval depending upon a number of factors but always small enough to obtain the effect of distributed inductance with its accompanying reduction in attenuation. A circuit with "lumped" loading has the disadvantage of rapidly increasing attenuation when the frequency exceeds a certain value due to the fact that a series of "lumped" inductance and capacitance constitutes a low-pass filter.

d. Problems of loading.—There is a great deal to be said about the proper use, installation and maintenance of loading coils which cannot be covered here but will be found in the standard instructions. A few considerations are important however. On circuits using telephone repeaters the loading coils should be properly spaced and coils of the proper size used if the best results are to be obtained. The loading coil, C-114, used in the army is built into a case having terminals so arranged that there can be no error made in the connections to the line, but where the coils are to be connected into a cable circuit and are of the type where the four leads for each coil are brought out together. care must be taken to prevent a connection causing a reversal of one winding thereby neutralizing the coil's inductance. It is possible to place loading in

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the two side circuits without loading the phantom circuit, and it is also possible by proper connection of the windings and by having the four windings of each wire of the phantom group wound on the same core, to load the phantom circuit without loading the side circuits. The connections are so made that the inductance cancels out as far as each side circuit is concerned, but is additive for the phantom circuit. One side circuit should not be loaded when the other side circuit is not loaded. The value of loading may be seen from the fact that a 19-gage side circuit if not loaded has an attenuation of slightly more than one db per mile and the line impedance has reactance to the extent that its angle is almost minus 43°. The same circuit loaded every 6,000 feet with load coils having 245 millihenries of inductance now has only a fourth as much attenuation and the impedance angle is reduced to slightly more than 2°. Loading the phantom with 155 millihenries every 6,000 feet improves the phantom circuit in the same manner.

64. The transmission measuring unit.—*a. The mile of standard cable as a unit of measure.*—It was realized early that some method of determining the transmission loss of a telephone circuit would be necessary if satisfactory service was to be given. In order to measure anything it is first necessary to have a standard unit of measurement. With this idea in mind the telephone people years ago selected one mile of the type of 19-gage cable first manufactured as the standard unit of measurement. This cable had a capacity of .054 microfarad and a resistance of 88 ohms per circuit mile. One mile of a cable of this type was known as a mile of standard cable. In order to determine the transmission loss of any circuit, two observers would talk over the circuit and then over a variable length of standard cable. When the standard cable was varied until the same volume of sound was obtained over it as over the circuit to be measured, the number of miles of standard cable was taken as the loss or transmission equivalent of the circuit. For example, if 18 miles of standard cable gave the same transmission as the tested circuit, the circuit was said to have a transmission equivalent of 18 miles.

b. The transmission unit or decibel.—(1) You have seen that the energy leaving any one mile section of a long circuit is a definite proportion of the energy entering that same mile section. This is true of sections of standard cable but this unit of measurement has the big disadvantage that the ratio of energy leaving a mile section

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to the energy entering a mile section is not the same at all frequencies. This situation led to the dropping of the mile of standard cable as a unit of measurement and the substitution of an arbitrarily selected unit not differing greatly in magnitude from the standard cable mile through the voice range, but having exactly the same significance at any frequency. That is to say, this new unit represents always a fixed percentage reduction in power no matter what frequency is involved.

(2) For several years this new unit went without a name and was called the transmission unit or *TU*. Now the transmission unit or *TU* has been given a name, the "decibel," abbreviated to *db*. The number of *db* is 10 times the common logarithm of the power ratio, or

$$N_{db}=10\ log_{10}\ \frac{P_1}{P_2} \qquad (2)$$

where P_1 is the input power or energy entering the circuit and P_2 is the output. Thus, where a circuit has a transmission loss of 1 *db* at a certain frequency, the ratio of input power to output power is 1.25. The *db* is also the unit of amplification or transmission gain as well as loss and in such case P_1 in equation (2) would be the output power and P_2, the input.

(3) When referred to some arbitrary level, the decibel is often used as a unit of absolute value of power, e.g., in telephone testing the zero level is 1 milliwatt of power across a 600-ohm load and other powers are referred to it. When not otherwise specified, the reference level is 1 milliwatt into a 600-ohm impedance at a frequency of 1000 cycles, the average of voice frequencies.

(4) While the decibel is primarily a unit of power ratio, it is apparent that if the receiving end impedance is constant and equal to the output impedance, equation (2) may also be written

$$N_{db}=10\ log_{10}\frac{I_1^2\ Z}{I_2^2\ Z}=20\ log_{10}\frac{I_1}{I_2} \qquad (3)$$

where I_1 and I_2 are input and output currents respectively, or

$$N_{db}=20\ log_{10}\ \frac{E_1}{E_2} \qquad (4)$$

where E_1 and E_2 are input and output voltages respectively.

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65. Questions for self-examination.—

1. What is attenuation?

2. What are the distributed characteristics of a telephone line?

3. How do these characteristics affect attenuation?

4. What effect other than attenuation do these line characteristics have upon voice currents?

5. Explain how the voice currents are distorted in long transmission lines.

6. In what manner is energy in the line attenuated?

7. What are the practical methods of increasing the transmission range of a circuit?

8. What are loading coils?

9. How are they connected in a line?

10. Explain how loading coils reduce the line attenuation.

11. In a phantom group, is it possible to load the phantom without loading the side circuits?

12. Is it possible to load the side circuits without loading the phantom?

13. Should one side circuit be loaded without loading the other?

14. What is meant by continuous loading?

15. What is the decibel?

16. When the current ratio rather than the power ratio is known, what must be true of the input and output impedances to satisfy equation (3)?

17. If the input power is .001 watts and the output power is .00001 watts, what is the loss expressed in db?

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SECTION IX

TELEPHONE REPEATERS

66. General.—*a. Need for repeaters.*—Even with the most efficient circuits and the standardized practices of loading there are limitations to the distance over which satisfactory telephone communication can be obtained. Where the circuit net losses are greater than 30 db, the attenuation is so great that conversation is barely possible. The loss over a 104-mil copper circuit 1000 miles long is approximately 70 db. In terms of power this means that if the input to such a circuit were 1 milliwatt, the power received at the distant end would be 10^{-10} watts or 1/10,000,000 of a milliwatt. It is evident from these figures that some amplifying device to boost the transmitted power along must be used in very long circuits.

b. Definition.—Such a device to maintain the energy of the signal is the voice repeater. The voice repeater is simply an amplifying device. It performs the same function in telephone circuits that telegraph repeaters perform in telegraph circuits. In fact the first telephone repeaters were mechanical, following more or less the idea involved in the design of the telegraph repeater. With the development of the vacuum tube, and the subsequent development of the vacuum tube repeater, the use of the mechanical repeater was discontinued.

c. Spacing of repeaters.—An important consideration in all communication systems is the signal-to-noise ratio. As there are always small amounts of energy picked up by any circuit, it is necessary to keep the strength of the signal much greater than that of the

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noise. When the strength of the signal falls so low that the signal-to-noise ratio is small and then is amplified, the strength of the noise current as well as the strength of the signal current is increased. If this signal is again attenuated to an energy level comparable to the noise level, then the signal-to-noise ratio drops further and the intelligibility of the signal suffers. The signal-to-noise ratio is kept high by using several repeaters with small gain rather than one repeater with a large gain.

In practice it has been found that in most cases the repeater spacing, on open wire 104-mil copper, should not exceed 150 miles, and the average spacing of repeaters on cable circuits is approximately 50 miles.

d. Levels.—In telephone circuits employing voice repeaters the energy level at various points along the circuit is often referred to, and a knowledge of the actual values of these levels is of utmost importance in spacing and adjusting repeaters. Since gains and losses are expressed in decibels, it is convenient to express energy levels in the same unit. However, since energy levels are a definite value and not a ratio, the decibel, when used to express energy levels must express a definite unit of power. In order to make the decibel express an absolute unit of power, an arbitrary value is taken as a reference level to which all other powers are compared. In telephone testing, the zero level or reference point is 1 milliwatt, which is the approximate average output power of a telephone transmitter. All other energy levels are expressed as plus or minus a certain number of decibels depending upon whether the power level is above or below 1 milliwatt. This is illustrated graphically in figure 74. The input at point *A* is 1 milliwatt. The curve repre-

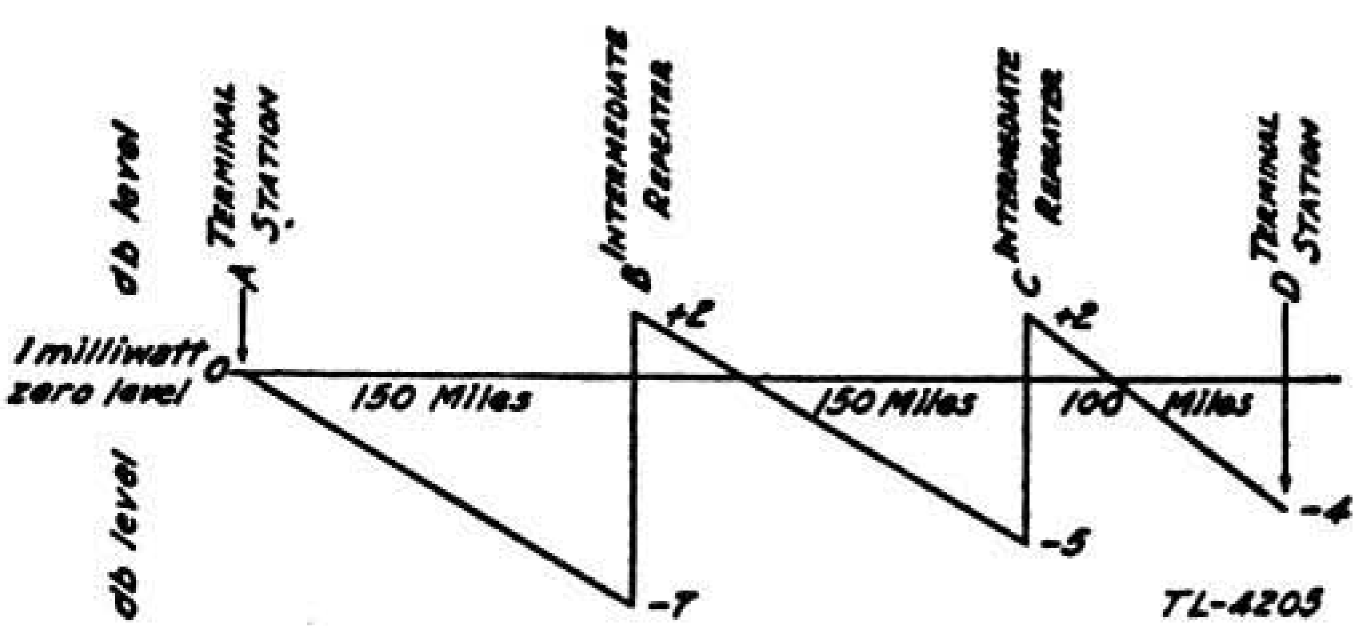

FIGURE 74.—Energy level diagram.

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sents the energy level at all points along the circuit referred to the output power at *A*. Between points *A* and *B* the attenuation of the line reduces the energy, and the input at *B* is referred to as being 7 db below zero level, or simply as a minus 7 db. The repeater at *B*, having a gain of 9 db, amplifies the signal and raises the output power at that point above the level of the input power by 2 db, and is referred to as plus 2 db level. Between *B* and *C* the line again attenuates the signal. At the input to point *C* the signal level is minus 5 db. The gain of the repeater at *C* is 7 db, which brings the level from a minus 5 db back to a plus 2 db. The signal arrives at the distant terminal at a level of minus 4 db. By having a common unit for expressing levels, gains, and losses, these units may be added and subtracted algebraically, simplifying considerably the testing of such circuits.

e. Amplification of alternating currents—vacuum tubes.—Since the vacuum tube amplifier is an essential part of a repeater an understanding of the amplification process is desirable.

(1) *Two-element tube.*—The simplest form of vacuum tube is the two element tube consisting of a cathode and an anode (plate) enclosed in a glass or metal shell from which the air is exhausted. Figure 75 shows a two element tube. The cathode is the source from which electrons or negatively charged particles are emitted when the cathode is heated. This emission of electrons forms an electron

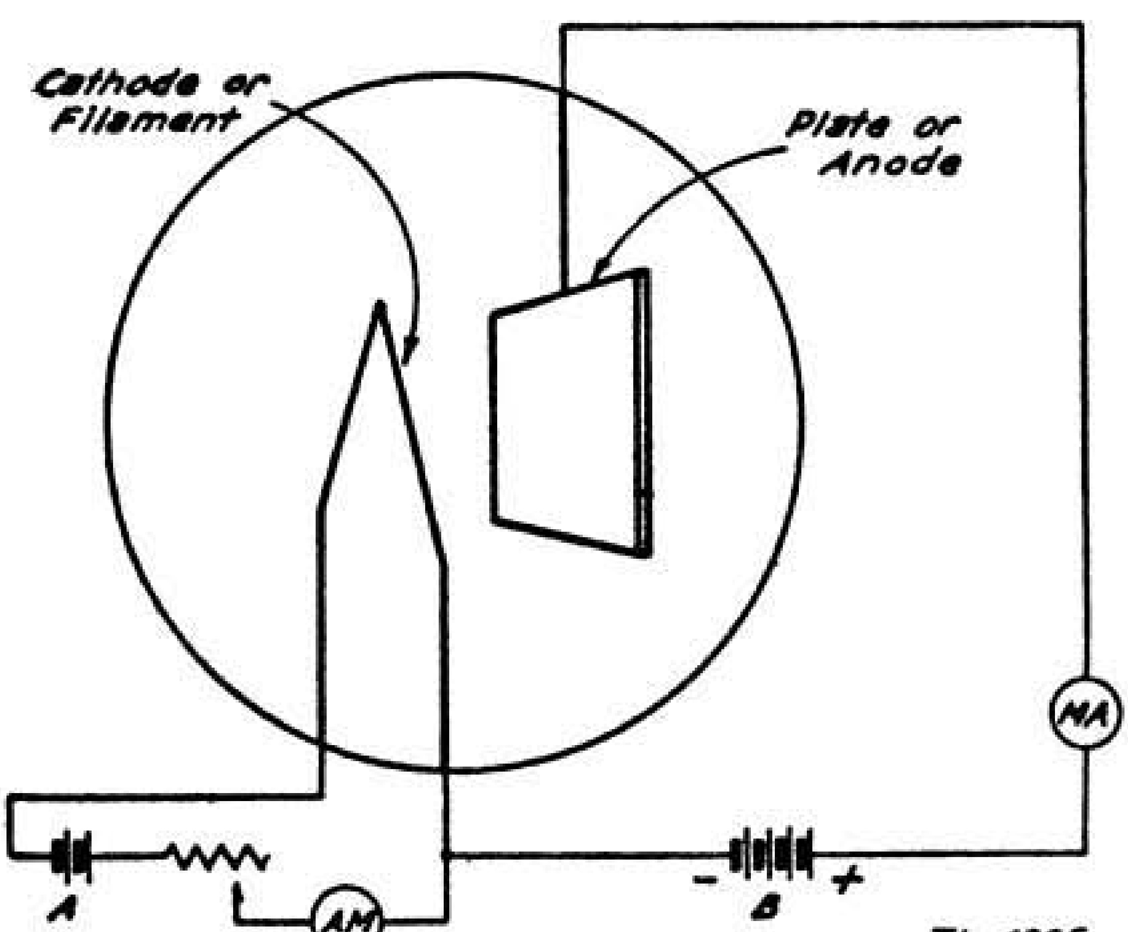

FIGURE 75.—Two-element vacuum tube.

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cloud around the cathode called the "space charge." The function of the plate is to collect these charged particles. In order to make the plate collect these freed negative particles the plate is given a positive charge. A battery is connected between the cathode and the plate and is poled so as to give the plate a positive charge. This charge will exert a force of attraction on the electrons emitted from the cathode. Electrons escaping from the cathode will be drawn to the plate by the force set up by its positive charge and a continuous flow of electrons from cathode to plate will result. The electron flow through the ammeter is called the "plate current." The speed with which the electrons cross from the cathode to the plate is determined by the potential of the plate with respect to the cathode. However, a point of saturation will be reached where further increase in plate voltage will not increase the flow of electrons. This is illustrated in figure 76 where plate voltage is plotted against plate current.

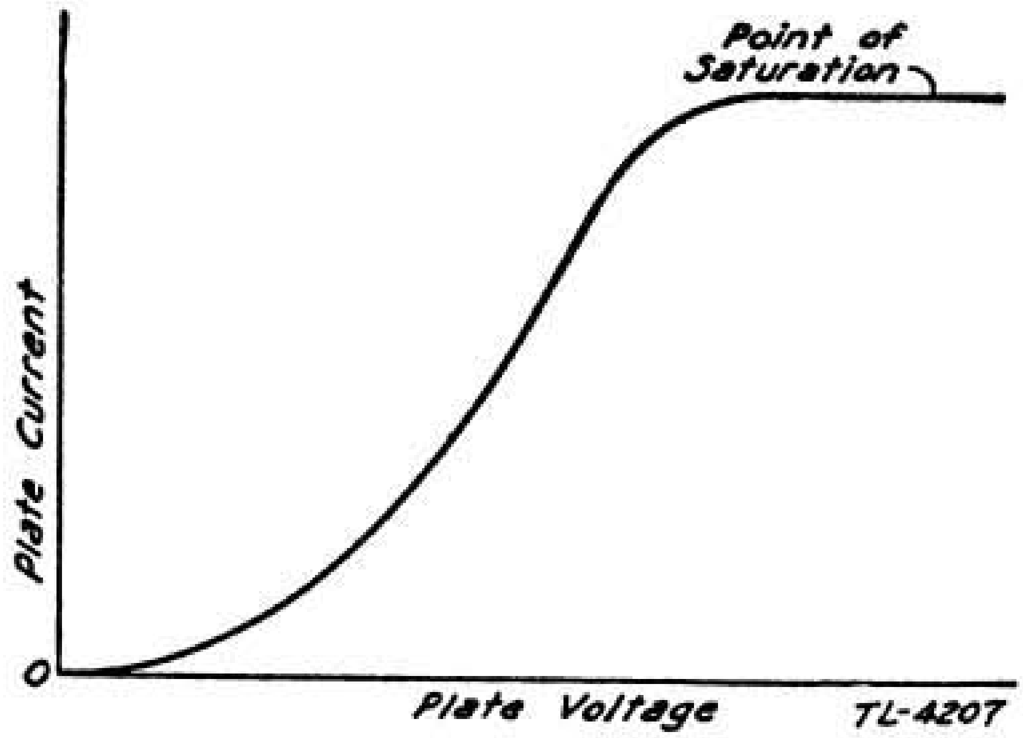

FIGURE 76.—Plate voltage vs. plate current characteristic.

The flow of electrons between the cathode and plate is simply an electric current, and the *B* battery will sustain this current in the same way that a battery sustains a current when it is connected to any closed electrical circuit.

If the *B* battery is replaced by an alternator, current will flow only when the plate is positive, consequently the circuit acts as a valve passing current in one direction only. Such a circuit is called a rectifying circuit.

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(2) *Three-element tube.*—By introducing a third element, the grid, in the tube the flow of electrons from the cathode to the plate may be controlled by varying the potential applied to the grid. Figure 77 shows the same tube as figure 75 with a grid added.

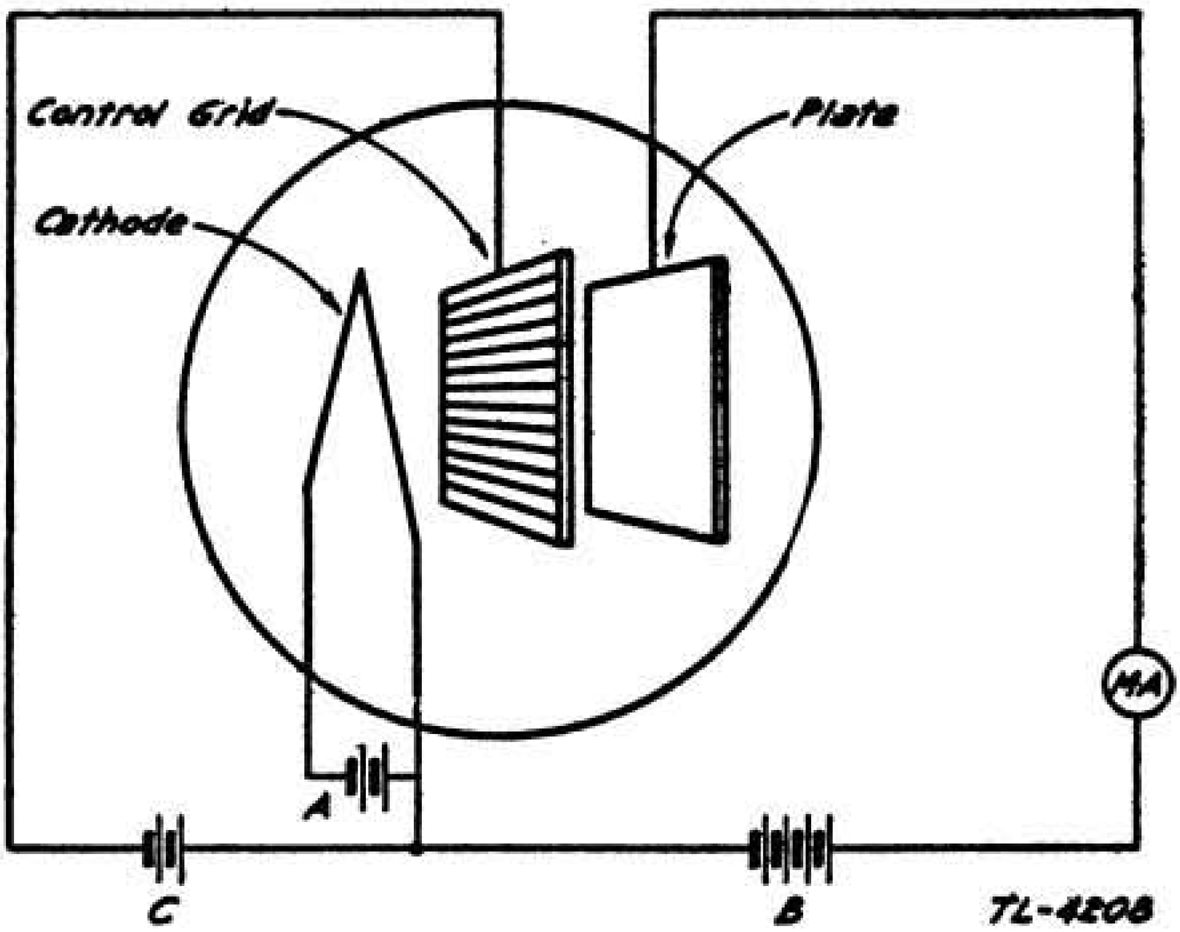

FIGURE 77.—Three-element vacuum tube.

The grid is usually in the form of an open spiral or mesh of fine wires and is inserted between the cathode and the plate. In this device the electrons which leave the cathode must pass through the meshes of the grid to reach the plate. Their passage is influenced by any force that may be set up by a charge on this grid. Since the force exerted by charged bodies varies as the square of the distance between these bodies, a small voltage applied to the grid would make a large change in the number of electrons leaving the cathode. This fact gives the three element tube its amplifying characteristic.

If the charge on the grid is negative with respect to the cathode, the electrons will be repelled by this negative charge and fewer electrons will reach the plate. If the voltage applied to the grid is large enough no electrons will pass to the plate. However, if the grid is made positive with respect to the cathode, more electrons will be drawn from the cathode. When they reach the grid, a few electrons collect there and cause current to flow in the grid circuit, but due to the velocity of the electrons most of them pass through the

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wire mesh and are drawn to the higher charged plate. Thus, a negative grid decreases the plate current and a positive grid increases the plate current.

(3) *Simple amplifier.*—If an input transformer is added in the grid circuit and a load such as a telephone receiver in the output circuit, figure 77 becomes a simple amplifier. These additions are shown in figure 78. If an a-c signal is applied across the input coil, the grid will be made alternately more and less negative and cause

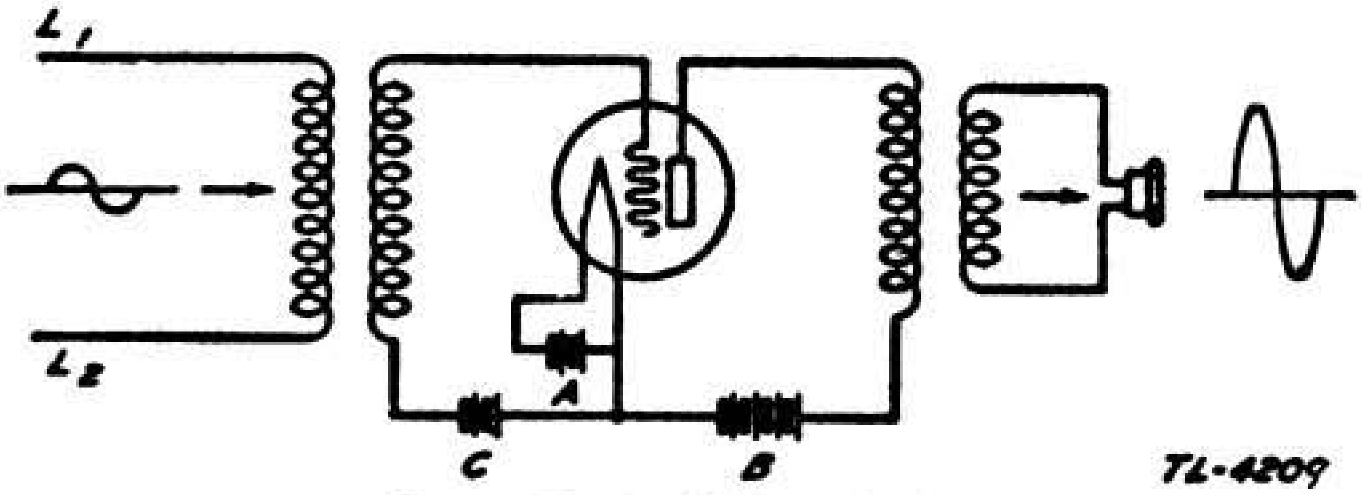

FIGURE 78.—Amplifying circuit.

the plate current to vary in accordance with the applied signal. This pulsating current in the plate will appear as alternating current in the secondary of the output transformer, causing the receiver to respond to the input signal. The output signal will be of a much greater magnitude than the input signal, due to the amplification of the tube.

(4) *Bias.*—In such a circuit where a minimum of distortion is desired it is very important that no current flow in the grid circuit. A positive grid collects some electrons and will cause distortion. This source of distortion is overcome by applying a negative grid bias (a fixed d-c voltage) to the grid so that the applied signal voltage will make the grid more or less negative about a mean point (operating point), but will never swing the grid positive. The grid voltage being made more or less negative will vary the plate current accordingly, but will not collect any electrons since it is always at a negative potential. This is shown in figure 79.

By using the proper grid bias, an operating point may be selected on the straight section or linear portion of the characteristic curve. At this point it is evident that the plate current wave shapes are identical reproductions of the grid voltage wave shapes and will remain so as long as the grid voltage amplitude does not reach values sufficient to run into the lower- or upper-bend regions of the curve. If this occurs the output waves will be flattened or distorted.

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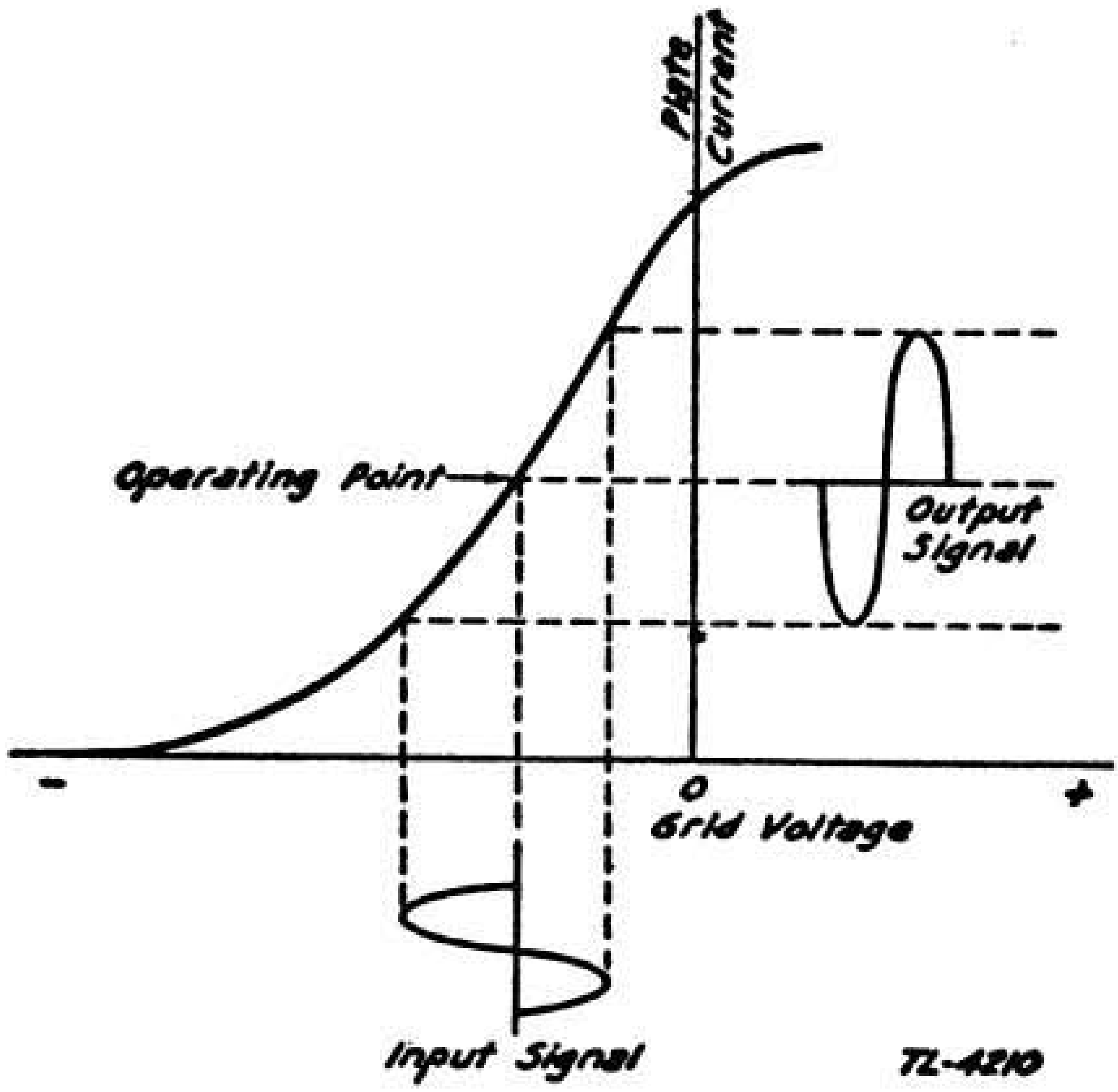

FIGURE 79.—Vacuum tube as amplifier.

If the grid is always at a negative potential, the circuit between the cathode and grid is substantially open to incoming signals. Therefore, since no power is dissipated in this circuit, the received signal need only be strong enough to supply the excitation losses in the input transformer. Thus, a very small amount of power can be used to control a relatively large flow of current in the plate circuit.

In this discussion of the amplifier only three-element tubes have been considered. Other types of tubes having four or five elements perform in a similar manner. The additional elements are refinements which give the tube better and more stable operating characteristics.

67. Requirements of a repeater.—*a.* There are various types of repeaters to meet the many different situations where amplifying devices are needed. The simplest form of a repeater is the one-way repeater. The requirement of this repeater is that it amplify the voice currents in one direction only. Such an arrangement is shown in figure 80. The only place where such a repeater is used ordinarily is on a circuit used for the transmission of programs between radio stations.

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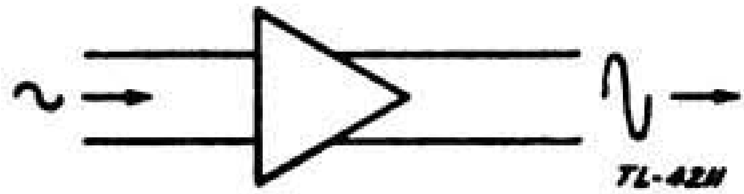

FIGURE 80.—One-way amplifier.

b. In communication systems where transmission is in both directions, a repeater necessarily has to be a two-way amplifying device. The first idea which occurs to the experimenter is to connect two amplifiers side-by-side as shown in figure 81, one to operate in one direction and the second to operate in the opposite direction. This arrangement will not work, however, because any energy amplified in one circuit is connected to the input of the other, to be again amplified and returned to the first. This returning energy

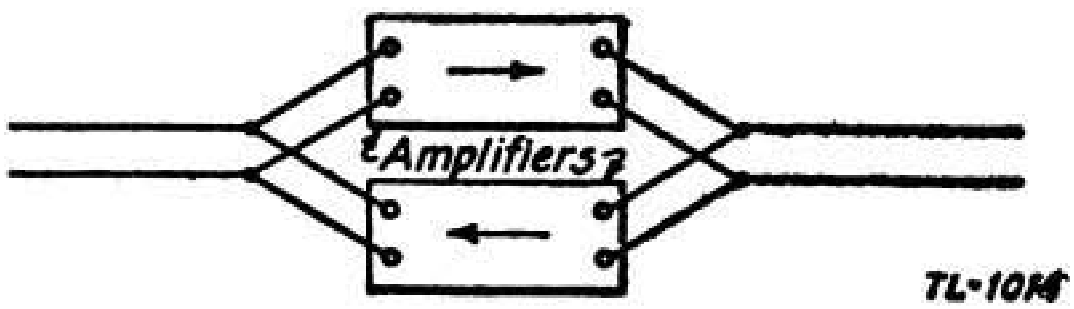

FIGURE 81.—Two-way amplifier (will cause singing).

again reaches the input of the first amplifier, and the cycle is repeated with energy, thus circulating through the two amplifiers and increasing in value until the condition of saturation is reached. The repeater then continues to "howl" or "sing" indefinitely, rendering the telephone circuit useless. In telephone repeater operation, as in duplex telegraph, we must receive incoming energy and direct it into a receiving circuit which is separate and distinct from the sending circuit. The use of amplifiers without some device for securing transmission in both directions would be restricted to such a layout as in figure 82, which would require not only twice the circuit facilities for each long distance connection, but also special telephones at each terminal. It may be recalled that duplex

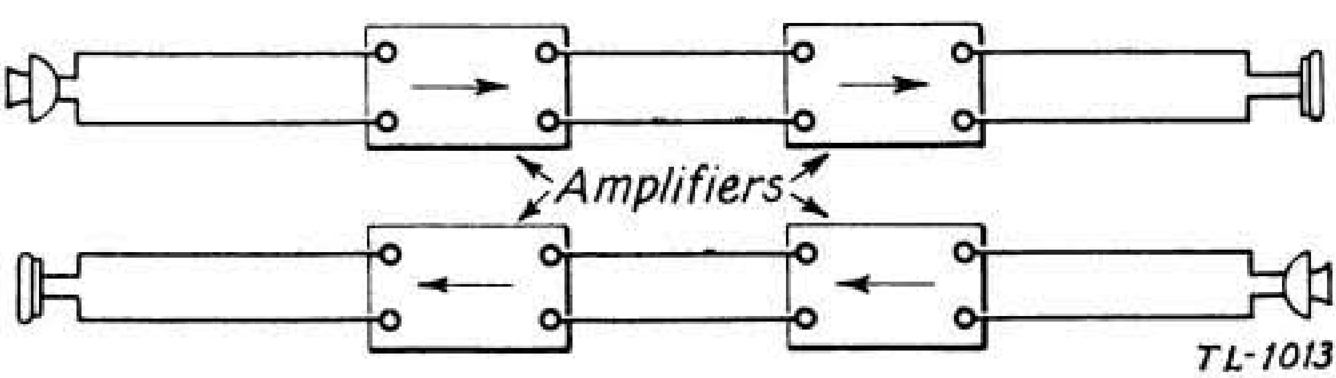

FIGURE 82.—Telephone circuit with one-way amplifiers.

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telegraphy was accomplished over a single wire by application of the Wheatstone bridge principle and the use of an artificial line. The problem in telephony is somewhat more difficult, but its solution was effected by using the principle of bridge balance, using an artificial line called a "balancing network."

68. Hybrid coil.—*a.* Since an amplifier will pass current in one direction only, the amplifiers of a two-way repeater necessarily have to be placed side by side, but some device must be introduced at the point where the output of one amplifying circuit is connected to the input of the other, which will isolate the two circuits. In order to isolate these circuits and to eliminate the possibility of "repeater singing," the ordinary telephone circuit must be converted into a "receiving" and a "sending" circuit which are independent of each other, so that the energy will not be transferred around in a circle as previously described. This can be accomplished by the use of a Wheatstone bridge arrangement. A Wheatstone bridge with proper modifications can be operated as well on alternating current as on direct current. To illustrate, in figure 83 a repeating coil is connected as a Wheatstone bridge with a few simple modifications. Here the source of voltage is an alternating

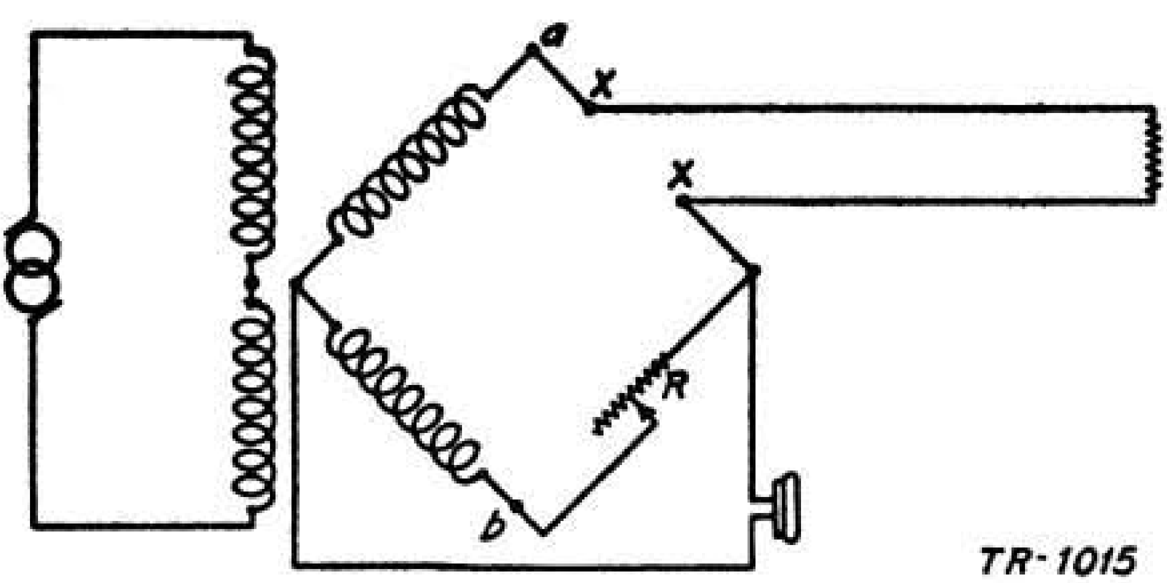

FIGURE 83.—A-c bridge.

current generator instead of a battery, and instead of connecting the voltage to the points *a* and *b* as is usually done, the same results are accomplished by connecting it across the other winding of the repeating coil. The electromotive force is then impressed across *a* and *b* by mutual inductance instead of by direct connection, but the result is the same. Since a galvanometer cannot be used with the alternating current, a telephone receiver (which for alternating current of voice frequency range is very sensitive) has

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been substituted. This circuit can now be used to measure the value of any resistance that may be connected to the *X* terminals; further, this same circuit can be used to measure any impedance that might be connected to the *X* terminals, provided the variable arm *R* has in series with it a variable reactance for balancing the reactive component of the unknown impedance.

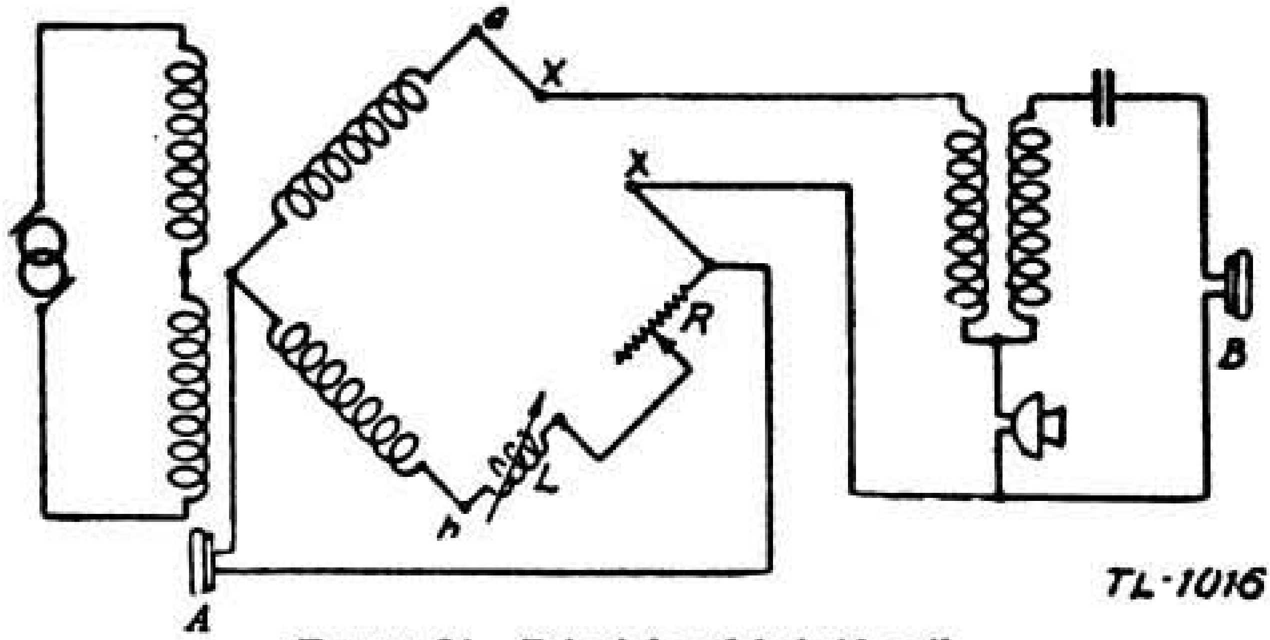

FIGURE 84.—Principle of hybrid coil.

b. With the above hook-up perfectly balanced, no sound from the generator would be heard in the telephone receiver. Suppose now that a telephone line terminating in a subset is substituted for the unknown impedance. This is shown in figure 84. You can again vary the arm of the bridge until it exactly balances the line and subset. When this is done, there will be no note in the receiver at *A* due to the audio generator, but the note can be heard in the receiver at *B*. Also any audio frequency produced at subset *B* will be heard in the receiver at *A*.

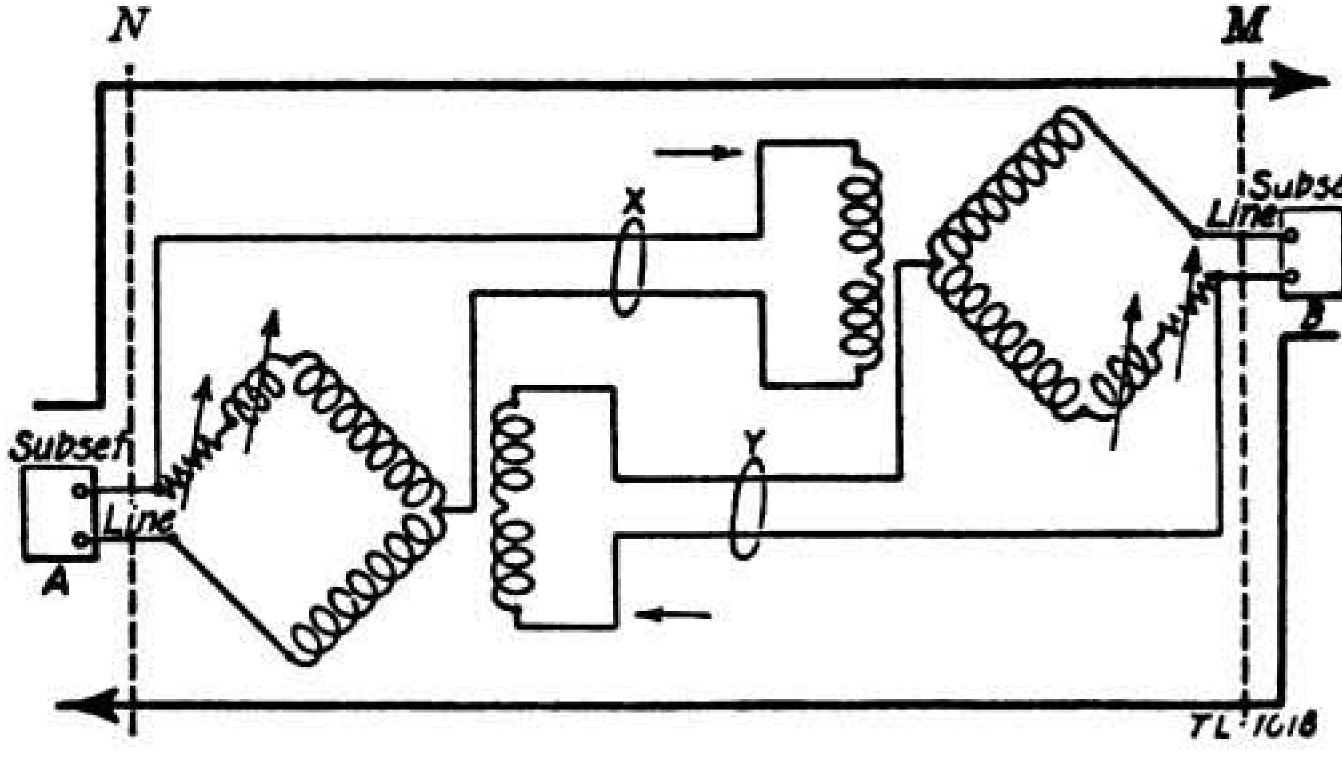

FIGURE 85.—Telephone repeater, without amplifiers.

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c. If you now take two circuits, and introduce two amplifiers, at points *x* and *y* in figure 85, you have a device that may be used as a telephone repeater. It can be seen that energy in an *N* to *M* direction will pass through the repeaters as indicated by the upper arrow and energy in the *M* to *N* direction will pass through the repeater as indicated by the lower arrow. Since both the bridges are balanced, energy coming from one amplifier cannot find its way into the input of the other and cause "singing."

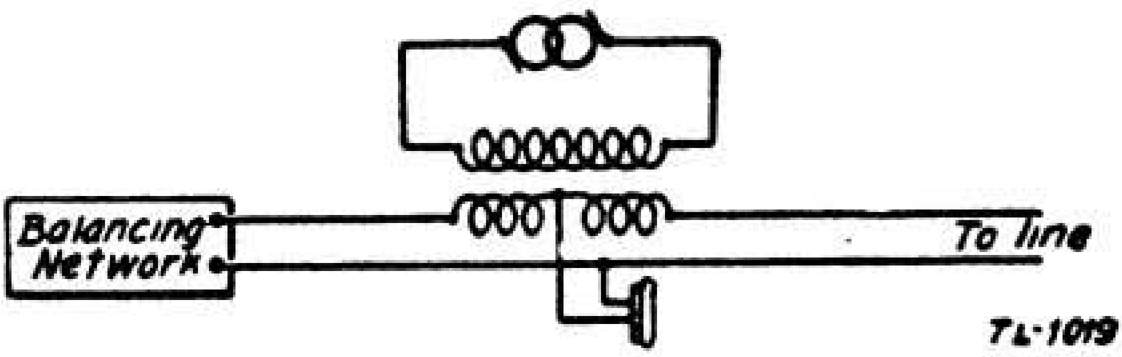

FIGURE 86.—Conventional hybrid coil symbol.

d. The coil that takes the place of the bridge mechanism in the preceding figures is known as a "hybrid coil," sometimes called a bridge transformer or "three-winding transformer." In the actual coil, however, there are a few additional details of design which do not permit the identity of the bridge circuit to be so easily recognized. The hybrid coil is conventionally shown in figure 86. It will be observed that figure 86 is really the same as figure 83, but does not resemble the Wheatstone bridge so closely. In the actual hybrid

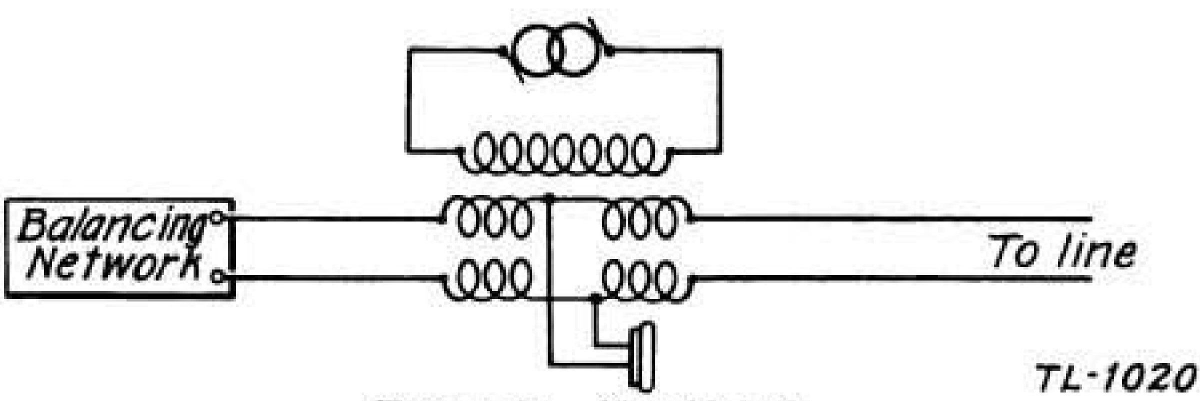

FIGURE 87.—Hybrid coil.

coil, the coils are divided and connected on both sides of the line as shown in figure 87, in order to insure symmetry of wiring, thereby reducing noise. Both sets of windings are inductively connected to the external winding.

69. The 22-type repeater.—*a. General.*—Figure 88 shows the schematic diagram of the amplifier connections to two hybrid coils in a two-wire, two-element (type 22) telephone repeater circuit. The 22-type repeater is perhaps the most commonly used. In addition to

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the hybrid coils and amplifiers there are generally equalizers and low-pass filters completing the component parts of the 22-type repeater.

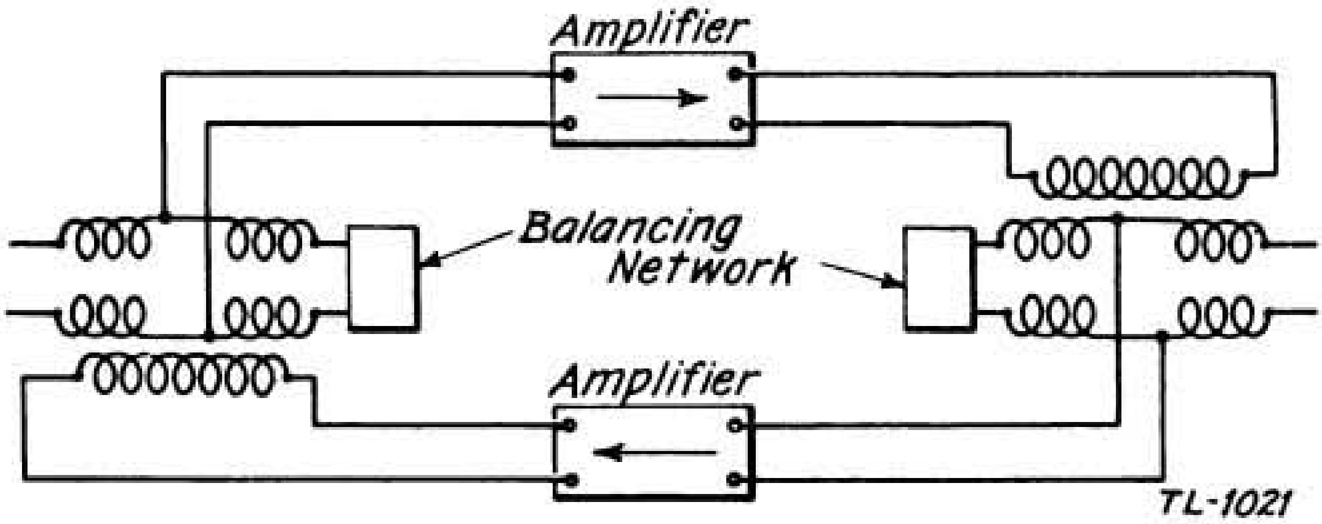

FIGURE 88.—22-type repeater.

(1) *Equalizers.*—It was explained in section VIII that high-frequency voice currents on an electrically long line are attenuated more than the low-frequency voice currents and distortion results if nothing is done to compensate for this unequal attenuation. You learned that one method of minimizing this type of distortion was to use loading coils. It is not practical to load a line sufficiently to eliminate this distortion completely. The purpose of the equalizer is to reduce this distortion further. The attenuator-type equalizer is an a-c network designed to attenuate lower frequencies more than the higher frequencies; thus the overall loss in the line and equalizer will be the same for all frequencies.

(2) *Filters.*—The low-pass filters found in voice repeaters introduce loss at high frequencies, particularly above 2500 cycles, thus reducing the tendency of the repeater to sing in the range where the balance between the balancing network and line is poor. Most of these frequencies are out of the audible range, but will overload the amplifiers, resulting in distortion and reduced gain.

(3) *Repeater gains.*—A repeater forms a closed transmission path containing gains and losses. When the sum of all the gains through this path just exceeds the sum of all the losses, singing will take place. Under ideal conditions where the line and balancing network are perfectly balanced, there is an infinite loss from the output of one amplifier circuit into the input of the other, therefore, an infinite gain could be obtained in each amplifier without any tendency to sing. Therefore, the gain of a repeater is limited by the degree of balance obtained between the balancing net-

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work and the line. Unfortunately, the impedance of a line is usually rather a variable quantity because at various times it may be connected to different types of local trunks. Changing weather conditions causes the line impedance to be unstable also. Any great precision of balance is, of course, impossible under these conditons, and it is necessary in practice to resort to a compromise balancing network designed to give an approximate overall balance. In commercial practice where good balance could be obtained, the sum of the usable net gains in the transmitting and receiving circuit has been found to be approximately 30 db. The gain. of course, depends upon the degree of balance obtained.

The level of the signal at the output of a repeater is another factor which must be considered in repeater gains. As the energy level of the signal increases, the tendency to crosstalk is increased. In telephone practice the signal level is never in excess of 6 db above zero level at any point in the circuit.

70. The 44-type repeater.—Another very common form of repeater is the four-wire, four-element (44-type) telephone repeater. This repeater is used primarily on four-wire cable circuits where different cable pairs are used for transmitting and receiving. The 44-type repeater can be thought of as simply a 22-type repeater where the hybrid coils, instead of being located in each piece of equipment, are located at each end of the line with the two cable pairs connecting them. A circuit employing 44-type repeaters is shown in figure 89.

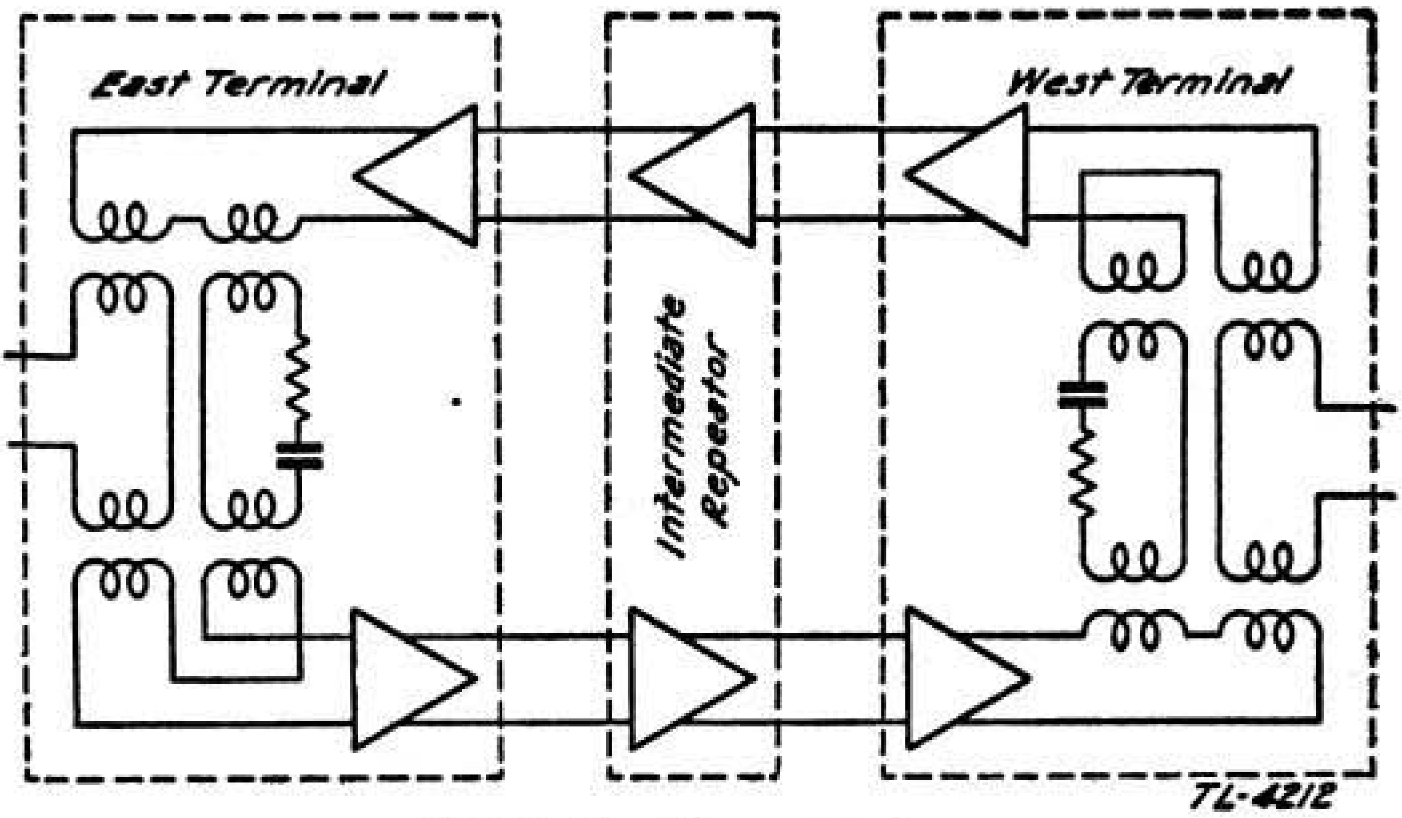

FIGURE 89.—44-type repeater.

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a. Gain available.—The closed transmission path formed by the circuit now includes the losses due to the attenuation of the line. As in the 22-type repeater the total gain in the closed path cannot exceed the total losses. However, the circuit length may be increased indefinitely and as the line loss increases, the gain of the circuit can be increased proportionately without any tendency for the system to sing. The advantage of this system is that much higher gains in the repeater amplifier are possible. Two stages of amplification are used in the 44-type repeater, giving a combined gain of about 50 db without appreciable distortion. However, it is not practical to utilize all the gain available since the energy level from a noise and crosstalk consideration is the determining factor. In the 44-type repeater the input level should not be lower than 25 db below zero level and the output level should not exceed 10 db above zero level; thus the possible usable gain is 35 db.

b. Hybrid coil arrangement.—It will be noted in figure 89 that instead of the hybrid coil two repeating coils are arranged to reduce the four-wire system to a two-wire system. The principle involved here is the same as that for the hybrid coil. An analysis of figure 85 will show that the transmission loss from *x* into *y* or from *y* into *x* will be infinitely high. In figure 90 the

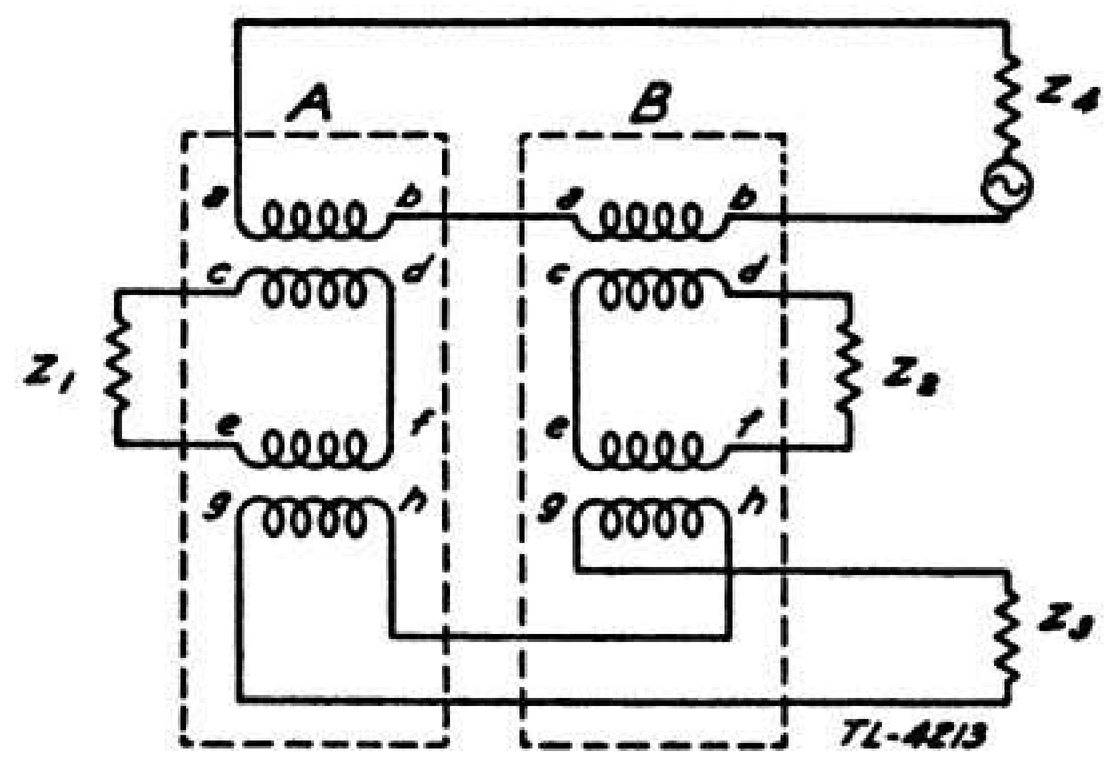

FIGURE 90.—Four-wire terminating set.

impedance of Z_2 is made equal to Z_1 and the repeating coils *A* and *B* are identical. Current flowing in the Z_4 circuit will induce equal voltage in the Z_1 and Z_2 circuits and also across the *g-h* windings of both coils, but the *g-h* winding of coil *B* is connected so that its

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voltage is 180° out of phase with that of the *g-h* winding of coil *A*. Since the two voltages are equal, there will be no current flow in Z_3. One half the energy is lost in Z_2 and one half will be delivered to Z_1.

71. V1 repeater.—A recently developed repeater is the general purpose repeater, coded the V1 telephone repeater, which can be used as a four-wire repeater, a two-wire repeater, or as a four-wire repeater on one side and a two-wire repeater on the other. The advantage of this repeater is that it is very flexible. Also the amplifier circuit makes use of negative feedback, resulting in a better frequency response and lower tube noise than was obtained in the 22- and 44-type repeater amplifiers.

The V1 repeater is shown schematically in figure 91 for a two-wire arrangement. The component parts are the same as that of the 22-type. The three-winding transformer-type hybrid coil is replaced by a two-coil combination called the "hybrid repeating-coil." The two repeating coils are interconnected in such a manner as to serve the combined function of a repeating coil of proper impedance ratio and of a hybrid coil. The phantom is derived from the mid-point of two series condensers bridged across the line circuit on the repeater side of the hybrid repeating-coil. An analysis of this coil arrangement will show that again there is an infinite loss from the output of one circuit to the input of the other.

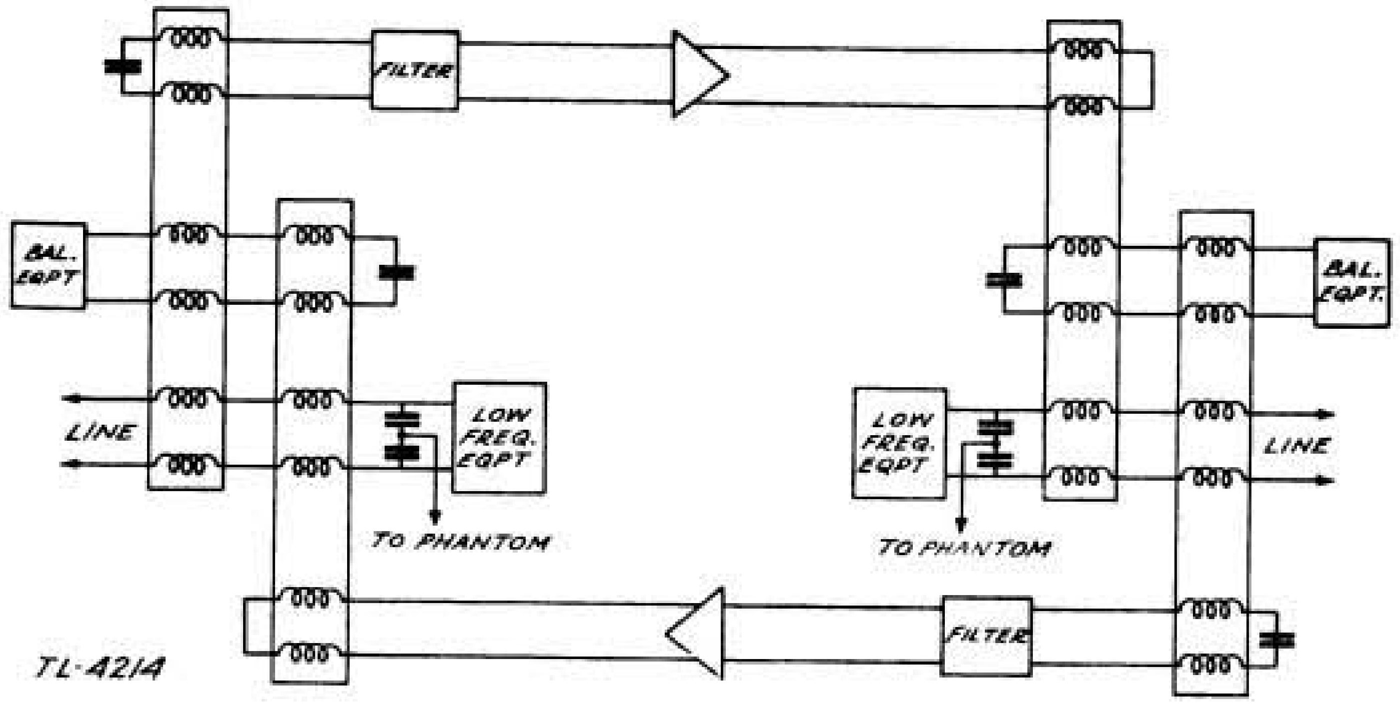

FIGURE 91.—Schematic diagram of V1 repeater.

72. The 21-type repeater.—Another form of telephone repeater less common than the types already mentioned is the 21-type repeater. It is a two-way, one-element device and is connected at

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some intermediate point of a two-way circuit as shown in figure 92. Here the line west, which must be identical in all respects with the line east, maintains the bridge transformer balance and prevents energy from the output of the single amplifier from reaching its input. Of course, the amplified energy is divided at the midpoint of the bridge transformer and is fed to both transmitting and receiving station. This is objectionable, and since the circuit has other limitations, at the present time it is not in very general use.

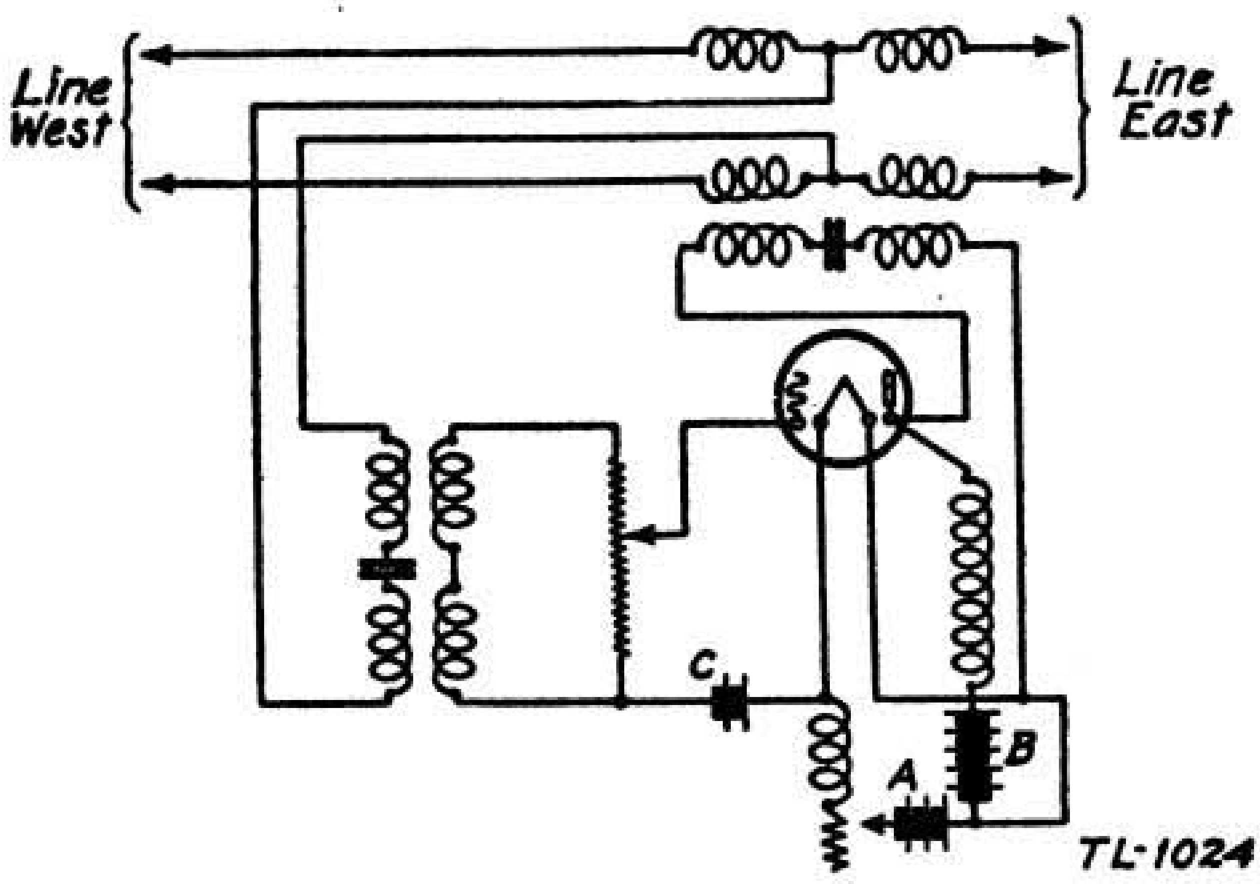

FIGURE 92.—21-type repeater.

73. Ringing over repeater circuits.—Due to the great difference in the voice signal frequency and the 20-cycle ringing frequency it is not practical to build a voice repeater that would repeat both voice and 20-cycle ringing frequencies.

a. Bypass filter.—Where the circuit is within the operating range of the 20-cycle signaling system, a low-pass filter is used to bypass the voice repeater. However, on very long lines sufficient ringing current to operate the signaling device at the distant end would be impossible to obtain without the use of repeaters.

b. Relayed signaling.—The 20-cycle ringing current may be repeated by means of relays at the repeater stations which will operate on the incoming 20 cycles. The action of this relay causes a 20-cycle supply to be connected to the line on the opposite side of

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the repeater, thus relaying the 20 cycles around the repeater. This method is called relayed signaling.

c. 1000-cycle signaling.—Another method of signaling on repeater circuits is accomplished by the use of 1000-cycle ringing current. This method requires no signaling equipment at the intermediate points since the repeaters will amplify the 1000-cycle ringing current. At the terminal station, however, it is necessary to have special equipment that will convert the 20-cycle ringing current received from the switchboard to 1000 cycles, interrupted 20 times per second, to be transmitted over the line. At the distant end the same equipment converts this interrupted 1000-cycle ringing current to 20-cycle.

74. Questions for self-examination.—

1. What is a telephone repeater?
2. What is gained by the use of repeaters?
3. What determines the spacing of repeaters?
4. What is meant by "signal level"?
5. How can levels be expressed in terms of decibels?
6. What is the reference level in telephone testing?
7. What is meant by a repeater "singing"?
8. What device is used in a repeater to prevent the energy from being transferred around in a circle, thus causing the repeater to sing?
9. Draw a diagram of a hybrid coil and explain its operation.
10. What is the principle upon which the operation of this transformer is based?
11. By what means is the real line balanced?
12. What is the purpose of an equalizer?
13. What is the function of the filters used in telephone repeaters?
14. What limits the gain that can be obtained from a repeater?
15. Draw a schematic diagram of a 22-type repeater.
16. Draw a schematic diagram of a 44-type repeater.

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17. What is significant of the two numerals (22, 44, 21) designating a type of repeater?

18. What is the primary difference in the type 22 and 44 repeaters?

19. What is the advantage of the V1 repeater?

20. Draw a schematic diagram of the V1 type repeater.

21. What is the disadvantage of the 21-type repeater?

22. How is ringing accomplished over circuits employing voice repeaters?

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SECTION X

CARRIER SYSTEMS

75. Definition and object of carrier system.—*a. Definition.*—The term "carrier current system" is ordinarily used to cover the assembly of apparatus and equipment whereby additional telephone channels over and above the usual telephone circuits are obtained by means of carrier currents. The term "carrier" is derived from the fact that alternating currents of certain selected frequencies are employed to carry messages. More specifically, the voice frequency currents that normally flow in telephone circuits are impressed on a high-frequency carrier current, thus translating the message from the voice frequency to a higher frequency range. By means of suitable selective equipment, these message-bearing, high-frequency currents are then transmitted over existing telephone lines without interference to the ordinary voice telephone message.

b. Object.—The object of carrier telephony is the simultaneous, independent transmission of several telephone conversations over a single wire-circuit. In general, the number of communication channels is dependent only upon the number of different carrier frequencies available. In order that separation of channels may be accomplished at the receiving end, the carrier frequencies must be sufficiently far apart so that there is no interference between the transmitted bands.

76. Elements of carrier system.—The steps required to accomplish

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the desired object as mentioned above may be summarized as follows:

a. Carrier source.—There must be provided a source of high-frequency currents to be used as carriers. Vacuum-tube oscillators are used for this purpose, a separate oscillator generally being used for each different carrier frequency employed.

b. Modulation.—The message current from the terminal telephone station must be impressed upon the carrier-current wave. This process which translates the message currents from the voice-frequency range to the high-frequency range is known as modulation.

c. Transmission.—The desired products of each modulation process are then amplified and applied on the same physical circuit for transmission to the distant station.

d. Channel selection.—In order that the transmitted messages reach the proper terminal telephone, the incoming high-frequency currents must be separated and directed into the proper receiving circuits. This separation is accomplished by means of selecting circuits known as electrical filters.

e. Demodulation.—After proper channel selection is made the original message current must be restored from the transmitted side-band. This restoring process is called demodulation. After demodulation the voice signal is amplified and transmitted to the terminal telephone.

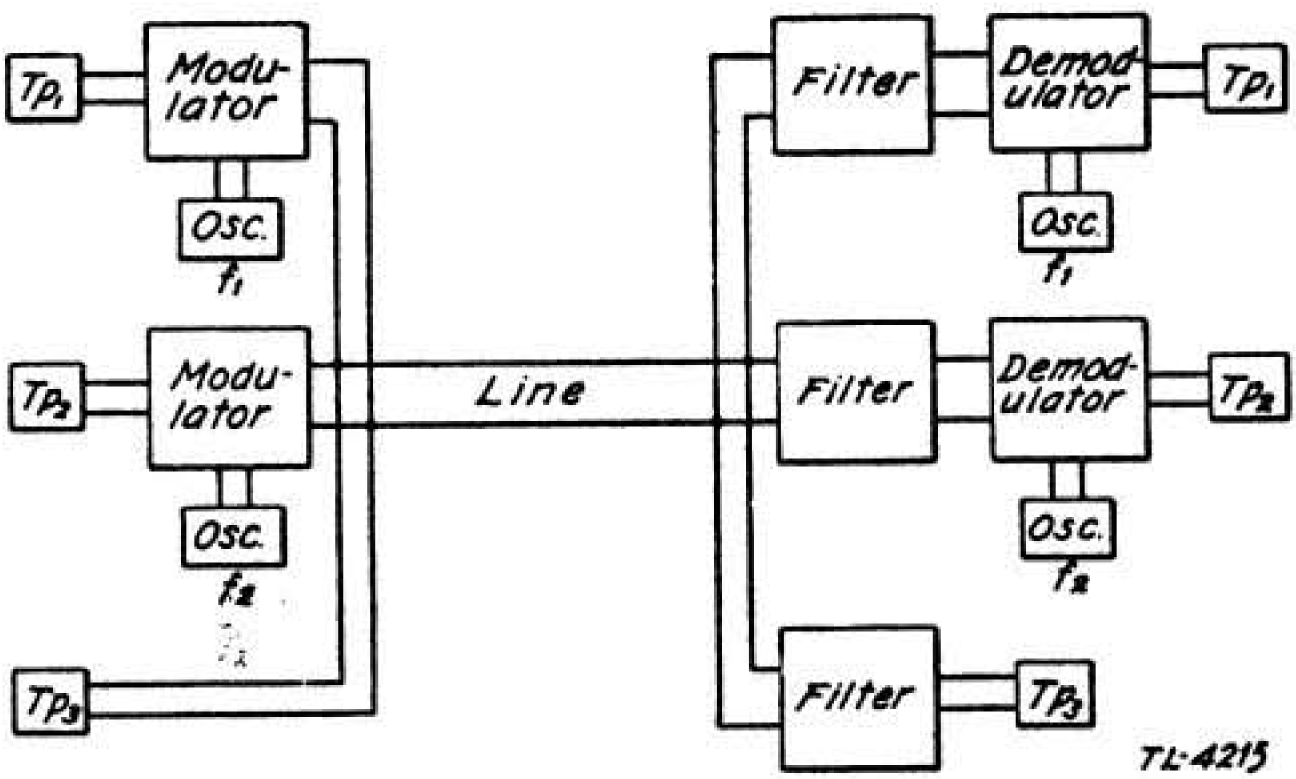

FIGURE 93.—Principle of carrier operation.

Figure 93 illustrates graphically the required steps outlined

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above. While this figure provides transmission in one direction only, it will be seen that with proper arrangement of filters or selector circuits and other terminal equipment, two-way communication can be provided.

77. Modulation and demodulation.—*a. Definition.*—The process of modulation may be defined as varying the amplitude of a high frequency "carrier" current in accordance with a low frequency "signal," the voice. It is the translation of the voice-frequency signals from the original frequency range to a higher frequency range for transmission purposes. This translation of frequency is accomplished by the use of vacuum tubes, or other nonlinear impedances, as modulators. The demodulation process is identical with modulation, the frequency translation being in the reverse order.

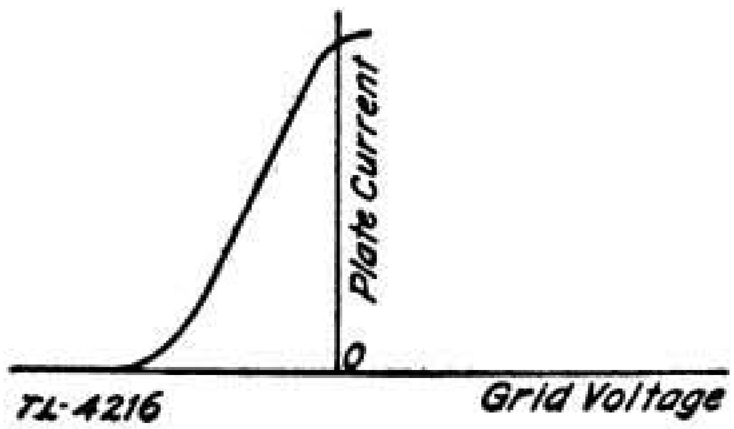

FIGURE 94.—Vacuum tube characteristic curve.

b. Modulation theory.—Referring to figure 94, it will be seen that the relation between the plate current and grid voltage is a curved line for values of grid voltage near the point of cut-off, or zero plate current. This curved or nonlinear portion of the characteristic is used for modulation as practiced in carrier systems.

If you impress two currents, one a carrier current which we will call C and the other a voice current which we will call V, on the grid of a vacuum tube, and if we adjust the grid battery voltage so that we are operating on the curved portion of the tube characteristic, the current in the plate circuit will be a function of the square of the sum of the input voltages. This output current is a complex wave composed of a number of currents of various frequencies, of which two are the useful results of modulation. These two new frequencies are the sum of the carrier and voice frequencies $(C+V)$ and the difference between the carrier and voice frequencies $(C-V)$. For example, if the carrier frequency had been 10,000 cycles and the modulating frequency (voice) 1000 cycles, you would have in the output wave, an 11,000 cycle frequency and a

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9000-cycle frequency. These two new frequencies are called the upper and lower "side bands" respectively. Both of these side bands carry the characteristic of the original signal or message frequency, and either side band, combining with the carrier frequency in a suitable device, is capable of producing the original signal frequency. Either of the side bands can be transmitted to the distant end of the line and there demodulated.

c. Demodulation.—The process of demodulation requires the presence of a carrier current of exactly the same frequency as the original carrier. This may be supplied by a separate source at the receiving end, or transmitted over the line together with the transmitted side band. Modern practice is to supply the carrier at the receiving station.

Assume that you have transmitted the upper side band $(C+V)$ and are adding it, at the receiving end, with another carrier current of the same frequency as used before. In this case, you use a vacuum tube circuit similar to that used in modulation. The two voltages applied to the grid of the vacuum tube are the upper side band, $(C+V)$, and the carrier C. When the grid of the tube is properly biased, the current flowing in the plate circuit includes frequencies equal to the sum and the difference of the input voltage frequencies, namely, $(C+V)+C$, and $(C+V)-C$. This latter term is the original voice frequency message and is transmitted from the demodulator to the receiving terminal telephone, all other products of demodulation being suppressed by filters.

78. Copper-oxide varistors.—*a. Used as modulators and demodulators.*—As mentioned in the foregoing paragraph, the nonlinear characteristic of a vacuum tube creates new frequencies in the output circuit when two or more different frequencies are applied to the input. This same result is accomplished by use of other devices having nonlinear input-output characteristics. More recent design practices have replaced the vacuum tube with copper-oxide *varistors* as modulators and demodulators. This device is capable of accomplishing the same results as the vacuum tube and with a considerable reduction in equipment cost, maintenance, and space.

b. Properties of copper-oxide unit.—The copper-oxide disc unit, in addition to passing current in one direction only, possess an additional characteristic in that the resistance across the unit varies with the magnitude and polarity of the applied voltage. These facts make varistors particularly adaptable for use as modulators.

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The units are very stable in operation and apparently after initial aging they deteriorate no further.

79. Filters.—*a. Definition.*—Electrical filters are circuits designed to present a very low impedance to currents of one frequency range and very high impedance to currents of a different frequency range. Thus, currents of the first frequency range will pass through such a circuit with very little or no loss, while currents of the other frequency ranges will suffer high attenuation or be suppressed entirely. Filters are made up of combinations of inductances and capacitors. The impedance of an inductive circuit increases directly with the frequency while the impedance of a capacitor decreases as the frequency increases. The circuit arrangement determines the type of filter.

b. Classification.—Filters may be generally classified as "low-pass", "high-pass", and "band-pass". They differ mainly in the arrangement and magnitude of the inductances and capacities.

(1) *Low-pass filters.*—If you make up a combination of inductances and capacitors as shown in figure 95, the inductance being in series with the line and the capacitors across the line, you have a form of low-pass filter which provides high attenuation to higher frequencies and very little loss to low frequencies. The series, or inductive, branches are low impedance at low frequencies, hence low frequency currents will pass through the filter. The inductances offer high impedance and the parallel capacitive branches low impedance to high frequency currents. Consequently, high frequency currents do not reach the output side of the filter.

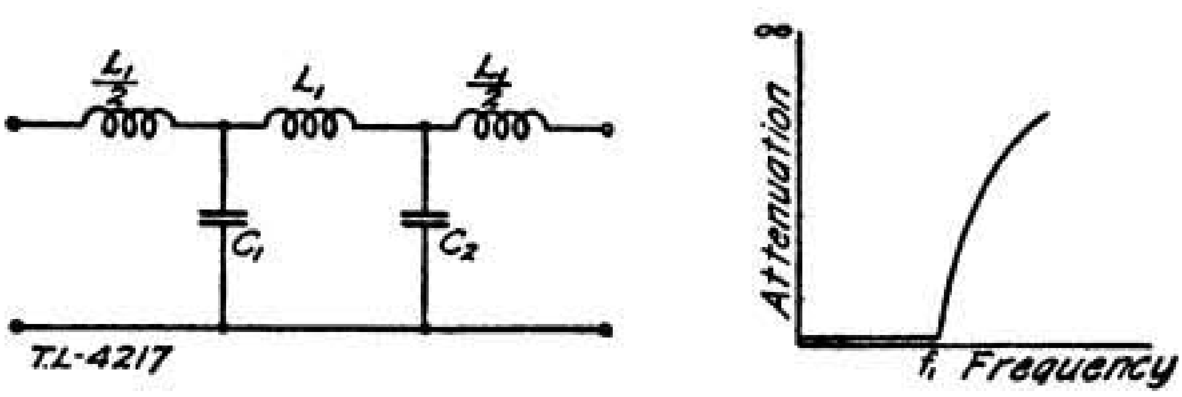

FIGURE 95.—Low-pass filter circuit and attenuation characteristic.

(2) *High-pass filters.*—If you reverse the position of the inductances and capacitors and connect them as shown in figure 96, the transmitted frequencies are above and the suppressed ones are below a certain critical frequency.

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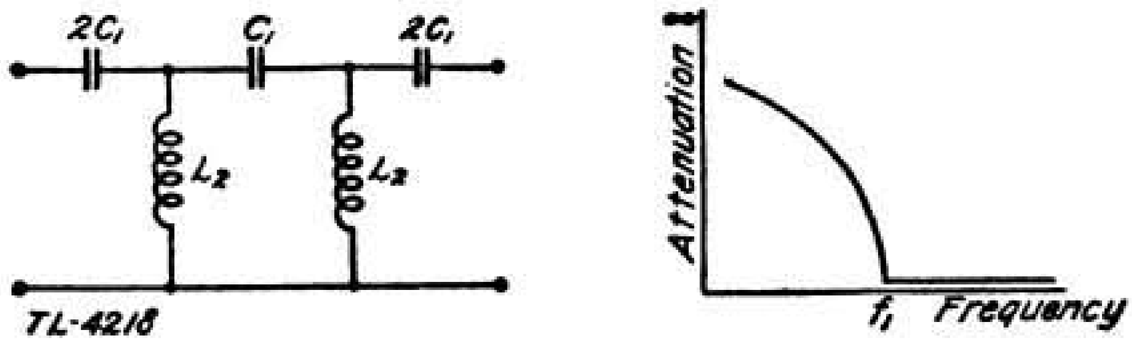

FIGURE 96.—High-pass filter circuit and attenuation characteristic.

(3) *Band-pass filters.*—The essential elements of the low-pass and the high-pass filters having different critical frequencies can be combined in one filter of the form shown in figure 97. This filter is representative of the band-pass type, transmitting frequencies within the range f_1 to f_2.

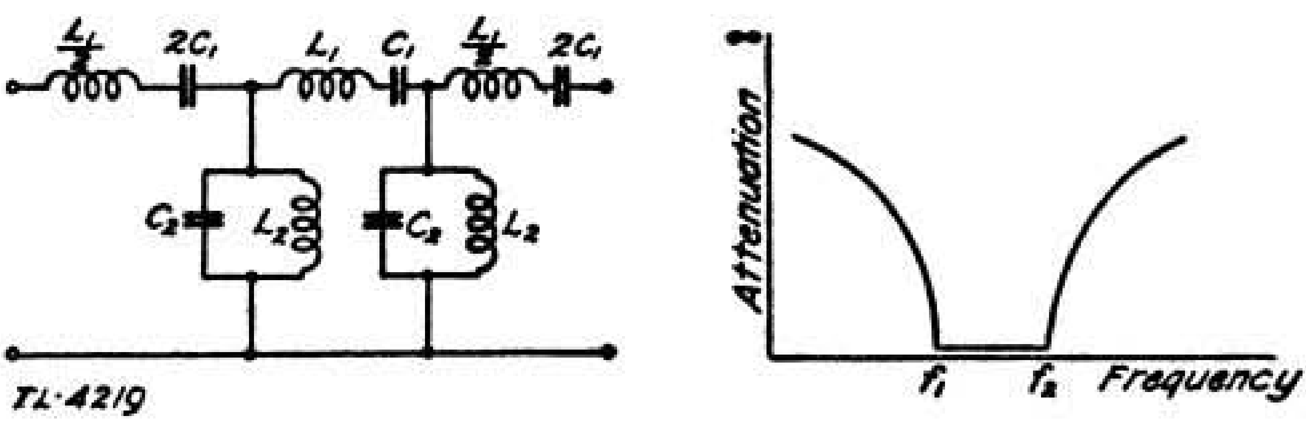

FIGURE 97.—Band-pass filter circuit and attenuation characteristic.

(4) *Tuned circuit.*—The simple resonant circuit, figure 98, is, in effect, a simplified form of band-pass filter which transmits only a narrow frequency band. It is used in certain carrier circuits.

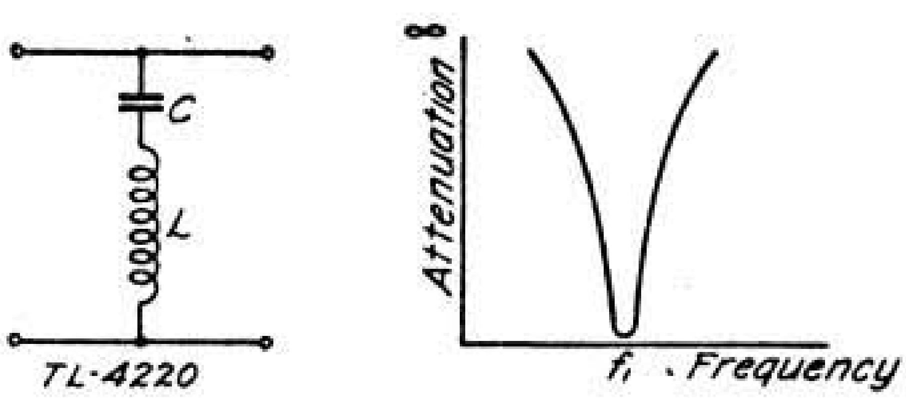

FIGURE 98.—Resonant circuit and attenuation characteristic.

c. Uses.—The high-pass and low-pass filters are generally used for separating the voice frequency channels from the carrier channels. Another use is for providing directional selectivity, that is, separating east-bound channels from west-bound channels. The band filters are more generally used for separating the individual

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channels from each other and for suppressing the undesired products of modulation and demodulation.

d. Crystal filters.—Multi-channel, high-frequency carrier systems employ filters made of quartz crystal. These crystals are very high grade filters having a sharp cut-off at the frequencies used, giving better quality and allowing a wider range of frequencies to be transmitted.

80. Types of carrier systems.—Carrier systems are designated by an alphabetical code in the order of development. They may be divided into two general classes, "low frequency" and "broad band" sytems.

a. Low frequency systems.—Under this category are those systems designed for use over open wire lines and frequencies up to 30,000 cycles. These include the types *A*, *B*, *C*, *D*, *G*, and *H* of which types *A*, *B*, and *D* are no longer manufactured. The systems most commonly in use today are the type *C*, a three channel system, and the type *H*, a single channel system.

b. Broad band systems.—Types *J* and *K* systems, each providing twelve communication channels, employ a frequency range from 12 to 200 kc. Type *J*, designed for use on open wire lines, is a two-wire system employing filters for directional selectivity. Since type *K* is a four-wire system, designed for use on cable circuits, the same frequencies are used in both directions of transmission.

c. Coaxial system, type L.—The most recently developed carrier system, type *L*, is designed for use on coaxial conductors. Such a system affords as many as 500 telephone circuits from a pair of coaxial conductors.

81. Transmission range.—The low frequency carrier systems are comparatively short range systems. Without the use of repeaters, the transmission range extends from 50 to 200 miles depending upon the type of system. This distance can be extended by the use of repeaters. However, the use of too many repeaters may introduce distortion and maintenance problems. The broad band type of carrier systems are toll, or long distance, systems although they require the use of repeaters at very frequent intervals. Type *J* requires a repeater approximately every 50 miles; type *K*, 16 miles; type *L*, 5 miles. This is economically feasible since the repeater amplifier handles the entire frequency range, thus amplifying all channels of the system with one repeater.

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82. Frequency allocation.—The chart of figure 99 shows the channel frequency allocation of carrier telephone systems most commonly found in use today. From this chart, it will be seen that a type *C* and type *J* system can be superimposed on the same wire

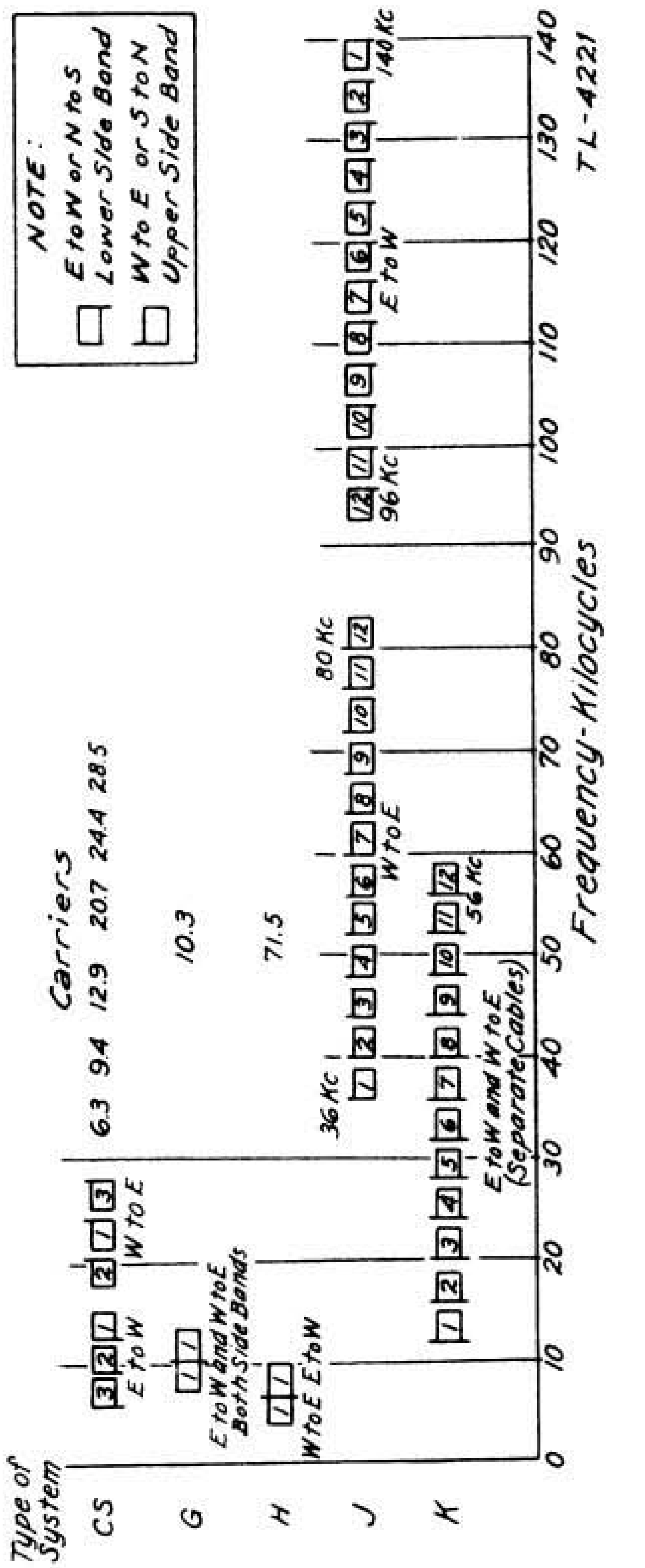

FIGURE 99.—Frequency allocation chart, carrier telephone.

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line already carrying a voice channel, thus providing sixteen telephone channels on one pair of wires.

83. Signaling.—Ringing over a carrier system is accomplished by utilizing a signal frequency which falls within the voice range yet carries a 20-cycle characteristic necessary to operate ringers or drops. A frequency of 1000 cycles interrupted at a 20-cycle rate is provided for this purpose. Each channel carrier is modulated with this 1000-20-cycle signal from a separate source. The process of modulation, transmission, and demodulation, are the same as for a voice signal. After demodulation, the 20-cycle characteristic of the 1000-20-cycle frequency is picked up by a detector circuit and 20-cycle current applied to the signaling circuit to operate the switchboard drop.

84. Questions for self-examination.—

1. Define the term, "carrier current."
2. From what source are carrier currents obtained?
3. What are the four major steps necessary to accomplish transmission by carrier?
4. Explain briefly how the voice frequency current and carrier frequency current are combined in a modulator to produce the desired side-band.
5. What is meant by the term "side-band"?
6. What properties of a copper-oxide disc unit make it useful as a modulator?
7. Name several advantages of using varistors as modulators.
8. Why does an electrical filter pass currents of one frequency range and suppress all others?
9. What is the principal difference between a low-pass filter and a high-pass filter?
10. What requirement must be met in order to operate more than one carrier system over a single pair of wires?
11. How many communication channels are available when using a type *H* and type *J* carrier over an existing voice circuit?
12. What signaling current frequency is used in carrier systems?
13. Why is it necessary to have a frequency of this nature?

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SECTION XI

LOCATING AND CLEARING TROUBLE

85. General.—Trouble may be defined as any undesirable condition which impairs the efficiency of a communication system. From the electrical or mechanical standpoint, there are two fundamental sources of trouble. They are:

a. A connection where one should not be.—This will include shorts, crosses and grounds.

b. No connection where one should be.—This will include broken wire, loose connections and high resistance joints. These same troubles may be classified as to their manner of appearance, either permanent or intermittent. The permanent troubles are those which exist in a steady state long enough for them to be analyzed and cleared. The intermittent troubles come and go at irregular and unpredictable periods, and exist for short periods of time only. This type of trouble is the hardest to analyze and clear, as the maintenance man can never be certain whether he cleared the trouble or it cleared itself and still remains as a potential source of future trouble.

86. Recognition and analysis of trouble.—A great deal of difficulty is usually encountered in getting personnel trained to the point where they will quickly detect trouble, analyze it and determine the proper procedure to be followed in locating and clearing it. As soon as a case of trouble manifests itself, the maintenance man should ask himself the following questions: What happens that should not occur, or what doesn't happen that should occur? What

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could cause this particular type of trouble? Is it in the equipment or the line? How should testing proceed so as to definitely determine the trouble? To avoid undue delay, it is important that the maintence man proceed with deliberation and forethought.

87. Test equipment.—*a. Voltmeter.*—To determine definitely the nature and location of trouble, certain tests must be made. Several types of equipment are available for making these tests, but usually they consist of a battery, voltmeter, and certain key arrangements. When the above equipment is embodied in a test set, the key arrangement is set up so as to give the following circuits:

(1) The battery, voltmeter, and line all in series (fig. 100).

(2) Either side of the line in series with the battery, voltmeter, and ground (fig. 102).

(3) The voltmeter in series with the line (fig. 104).

(4) Either side of the line in series with the voltmeter to ground (fig. 105).

(5) Any of the above circuits may be reversed either at the line or voltmeter.

b. Field telephone.—The field telephone can also be used to advantage if other test equipment is not available. After the primary tests have been made, the repairman should not attempt to take the heavy test set out on the line because the field telephone can tell him everything that he needs to know after the testboard man has analyzed and measured the trouble.

c. Wheatstone bridge.—The Wheatstone bridge is an instrument used when accurate resistance measurements must be made. It allows the use of a method of measurement by which the resistance of a fault will not prevent accurate measurement of line resistance to the fault. The instructions for use of the instruments are contained in the lids and will not be covered in this text. Considerable practice in the use of a bridge is necessary in order that personnel using it can obtain dependable results. An example of a bridge is the standard Signal Corps test set I-49. Other bridge-type test sets are listed in the Signal Corps General Catalogue.

d. Receiver and battery.—A telephone receiver connected in series with a battery and suitable test leads may be used for testing continuity of a circuit. When a circuit is completed through a resistance a click will be heard and another click will be heard when the circuit is broken. If the receiver and battery are connected

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in series with a condenser, a click will be heard when the circuit is made, but none when it is broken. With experience the maintenance man can obtain a rough indication as to the degree of the condition found, by the loudness of the clicks.

e. Receiver only.—When used at common-battery installations the use of an extra battery may be eliminated since a source of battery is available at many parts of the equipment to be tested. A receiver may also be used to advantage at times to give an idea of the approximate location of an open on one side of a comparatively long pair. Noise between each wire and ground is observed separately and the two compared.

f. Test lamp.—A test lamp may be used in the same manner as a receiver to give a visual rather than an audible indication. The lamp should have a voltage rating equal to the battery with which it is to be used. The brilliancy of the lamp will be an indication of the resistance of the short. A lamp will not, however, give an indication of capacitance when used with a battery, nor will it operate on the wide range of currents which will give clicks in a receiver.

88. Methods of testing.—*a. Test for short.*—First have the equipment at the distant end removed from the line. This should be the first thing done whenever tests are to be made. Otherwise, a false indication may be obtained. After this has been done, certain keys are operated so that the line to be tested is placed in series with the voltmeter and battery, and the deflection of the voltmeter needle will indicate the degree or resistance of the short. In this case, as indicated by figure 100, the needle will remain steady at a definite reading, and by use of the formula $X=\frac{R(V-V')}{V'}$, the resistance to and including the short can be determined. In the above formula X, is the unknown resistance, R is the resistance of voltmeter used, V is the battery voltage and V' is the reading of the voltmeter when the above test was made. After X has been calculated, it is quite simple to determine the approximate distance to the short when the resistance per unit length of the wire is known. It is to be remembered that the resistance as determined from the formula includes the resistance of the fault as well as the line to the fault. Calculations therefore show the maximum distance to the fault; the actual location may be somewhat closer to the testing end than calculated.

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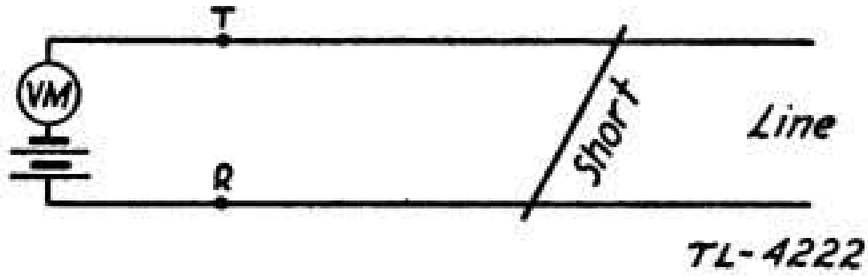
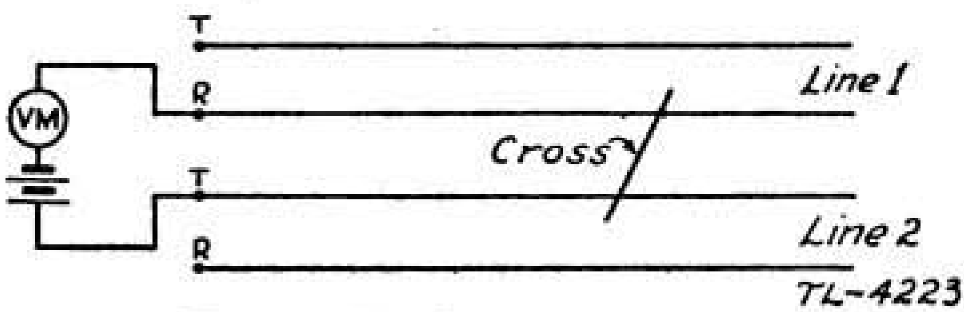


FIGURE 100.—Circuit used to test for short.

b. Test for a cross with another line.—In testing for a cross, the same procedure is used as when testing for a short, except that the wires of two separate pairs are used as shown in figure 101. This trouble is usually indicated by crosstalk between two independent metallic circuits.



FIRURE 101.—Testing for a cross.

c. Test for ground.—When testing for a ground on a circuit, one side of the line is placed in series with voltmeter, battery and ground as shown in figure 102. If a steady reading is obtained, the equipment at the distant end should be removed, and then it will be possible to determine which side of the line is grounded.

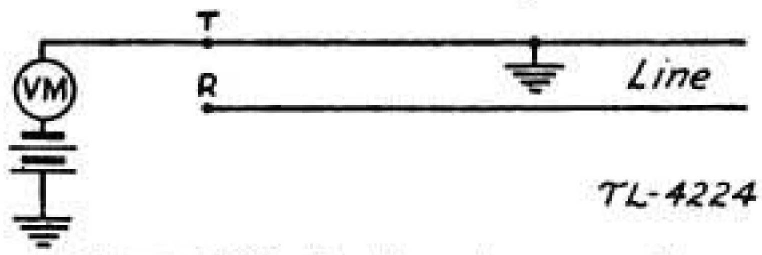


FIGURE 102.—Testing for ground.

d. Test for an open.—Under the best conditions, it is only possible to make a rough approximation as to the distance to the open. The best way to get an estimate is to set up the equipment as shown in figure 103. Due to the proximity of the wire to the ground, there is an appreciable capacitance between each wire and ground so that when battery is applied to one wire and ground, the capacitance will take a charge. Now by reversing the battery connection quickly, the capacitance will be discharged and charged in the opposite direction. This flow of current will give a momentary reading or kick on the voltmeter. If this value is compared to one obtained

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on a wire of known length going over the same route. it is possible to estimate the distance to the open.

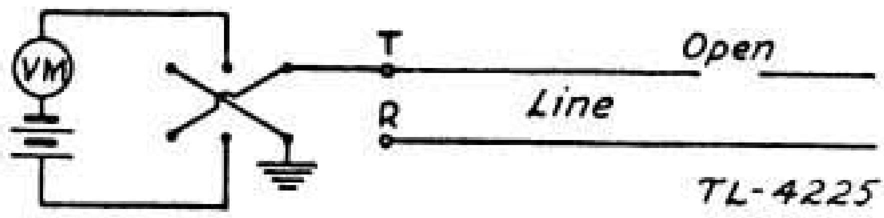

FIGURE 103.—Testing for an open.

e. Test for foreign battery.—(1) To test for foreign battery between the two conductors, first connect the voltmeter directly across the line as shown in figure 104. If the line has foreign voltage applied between the two conductors from any source, the voltmeter will indicate this fact. After the voltage condition has been determined between the two conductors, each conductor should be

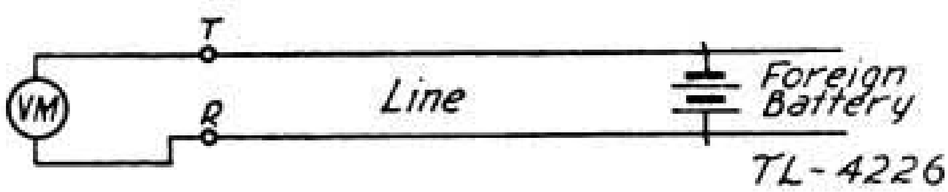

FIGURE 104.—Testing for foreign voltage between wires.

tested separately with respect to ground as shown in figure 105. The fact that foreign voltage is on the line will usually be indicated by erratic results obtained while testing for shorts or opens. If the foreign battery aids the test battery, the voltmeter will indicate the sum of the two voltages, and if the foreign battery opposes the test battery, the voltmeter will indicate the difference between the two voltages.

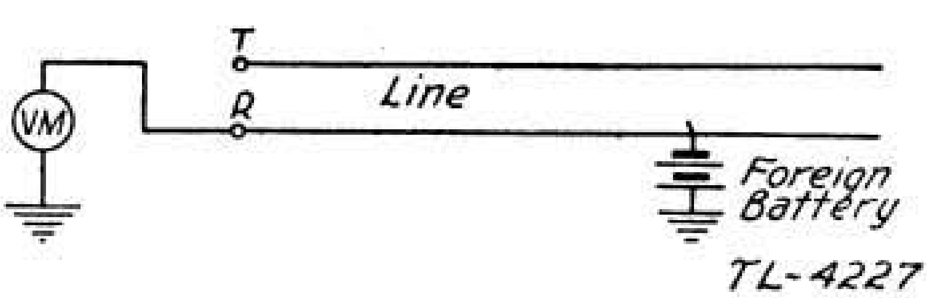

FIGURE 105.—Testing for foreign voltage to ground.

(2) After the testboard man has made all of the above tests he can analyze the trouble and usually tell the approximate distance to the trouble. It is then the duty of the lineman to go out on the line, find the trouble with the aid of the information given him and clear the trouble from the circuit.

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f. Testing for a short with the field telephone.—Under normal conditions the lineman should not take the heavy test equipment out on the line but should take a field telephone instead. In case he is looking for a short he should go to the approximate location as indicated by the test man, open the line and test as shown in figure 106. If the lineman has passed the short he will ring the subset, but

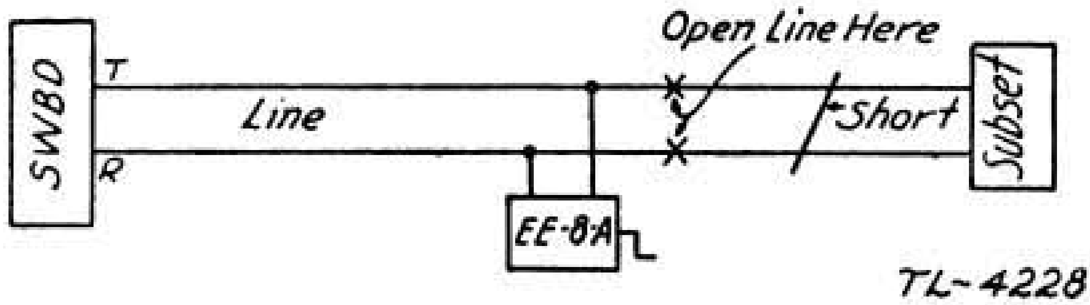

FIGURE 106.—Test for short with field telephone.

if he hasn't passed the short he will get the switchboard. After determining on which side of the short he is located, the lineman will again move towards the short. He will keep this up until the trouble has been bracketed, and then by inspection, and further tests if necessary, the trouble is finally located and cleared.

g. Testing for an open with the field telephone.—It is very simple to test for an open with a field telephone. It is unnecessary for the lineman to cut the line to test in, as shown in figure 106. All he

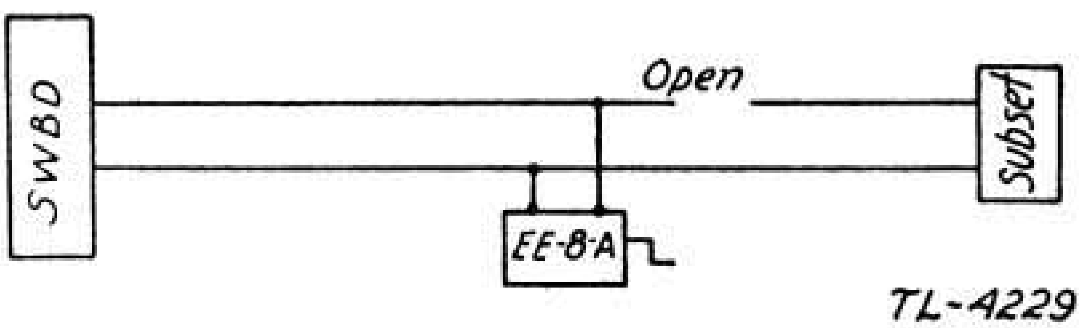

FIGURE 107.—Testing for open with field telephone.

need do is clip his test leads to the line and see whom he can call (fig. 107) and then proceed to bracket and repair the trouble.

When testing a circuit it is important that the person making the test ask himself what the particular test is for and what the results of the test indicate. The man responsible for locating and clearing trouble should be a man who does not get excited under pressure.

89. Inside trouble.—Inside troubles refer to troubles found in equipment inside the telephone office or in the switchboard equipment at the command post. These troubles are of the same genera

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nature as outside troubles, with a few additions. Crosses, shorts, grounds and opens are in general tested in the same manner as the outside troubles. Open circuits are usually the result of blown fuses, burned out lamps, or dirty contacts on the keys, relays or jacks. Adjustments on the relays, other than burnishing the contacts, should not be attempted by any one except a specially trained switchboard man with the special instruments and tools for this particular work.

90. Preventive maintenance.—By making routine tests many cases of potential trouble can be detected and cleared before they cause interruptions of service. By use of gages and known constants a test man can determine when the equipment has become worn to the point where it needs replacement or repair. He can also tell when certain parts are getting out of adjustment. The repairman can then take these reports and make the necessary repairs and adjustments. Without routine tests these potential sources of trouble would not appear until they were serious enough to prevent efficient operation.

91. Questions for self-examination.—

1. What is meant by trouble with respect to communication systems?

2. What are the two fundamental sources of trouble?

3. How are troubles classified as to their manner of appearance?

4. When trouble appears, what is the first thing to be done?

5. What questions should the maintenance man ask himself as soon as trouble appears?

6. What pieces of apparatus are usually incorporated in test sets?

7. Should the test set be taken out on the line by the lineman?

8. What circuit is set up for testing for a short circuit?

9. How is a test for a cross made?

10. What circuit is set up to test for a ground?

11. When testing for an open what causes the voltmeter kick?

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12. What circuit is set up to test for foreign battery?

13. How is the presence of foreign battery detected?

14. What is a short? A ground? A cross? An open?

15. When using a field telephone to test for a short on a line, what procedure should be followed?

16. When using a field telephone, how would you test an open line?

17. What are inside troubles?

18. What are some of the more frequent inside troubles encountered?

19. What is preventive maintenance?

20. Why is preventive maintenance important?

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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
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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 sidetone.* (See Sidetone.)

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

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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 distinguishing 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).

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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 reoccurring 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

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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 de-

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signed 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.

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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 a farad.

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

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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.

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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 parts are placed end-to-end and form a single continuous conductor; opposite 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.

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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.—That part of a telephone which converts the sound

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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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[A. G. 062.11 (7-15-42).]

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:

J. A. ULIO,
Major General,
The Adjutant General.

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(For explanation of symbols see FM 21-6.)

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