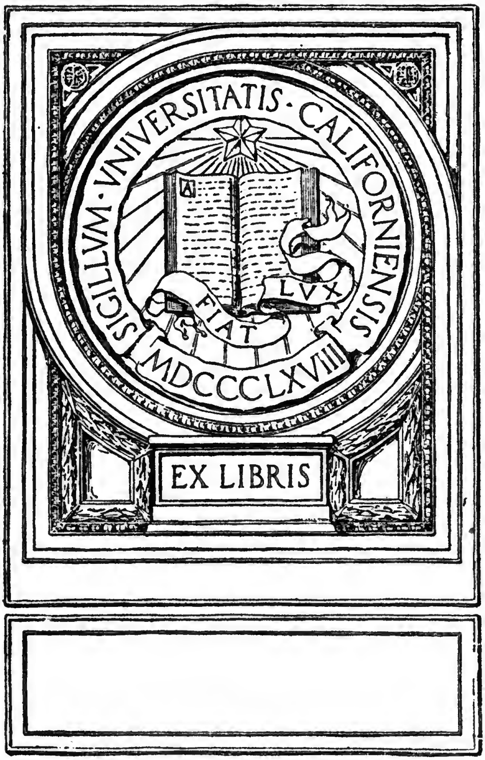
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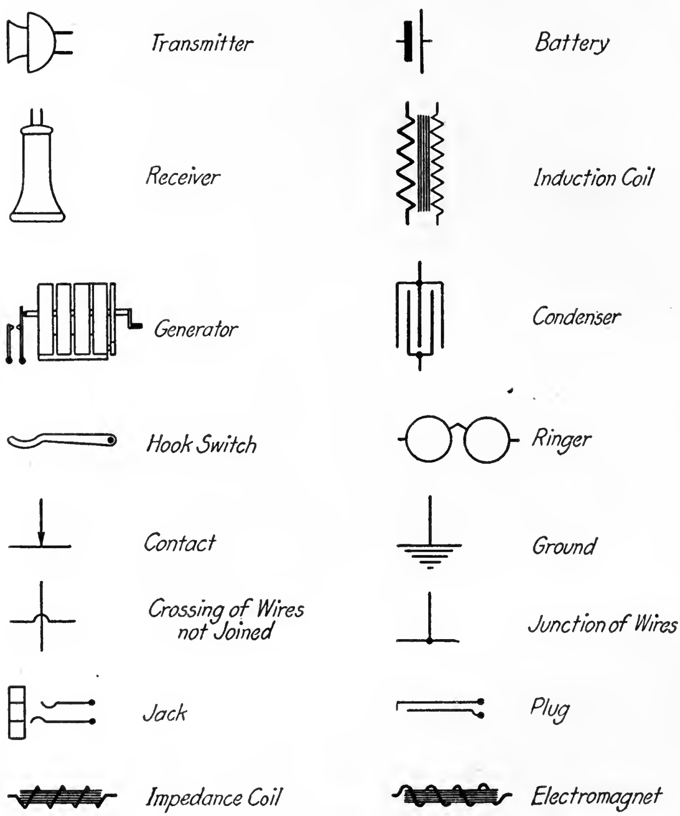
PRINCIPLES OF THE TELEPHONE

PART I

SUBSCRIBER'S APPARATUS



Symbols used in diagrams.

Frontispiece

INDUSTRIAL EDUCATION SERIES

PRINCIPLES OF THE TELEPHONE

PART I

SUBSCRIBER'S APPARATUS

PREPARED IN THE
EXTENSION DIVISION OF
THE UNIVERSITY OF WISCONSIN

BY

CYRIL M. JANSKY, B. S., B. A.
ASSOCIATE PROFESSOR OF ELECTRICAL ENGINEERING
THE UNIVERSITY OF WISCONSIN

AND

DANIEL C. FABER, E. E.
ASSISTANT PROFESSOR OF ELECTRICAL ENGINEERING
THE UNIVERSITY OF WISCONSIN

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PREFACE

In order that this text might appeal to and be of practical use to men who are actively engaged in the installation, care, and operation of telephone apparatus, every advantage of contact with the men engaged in the industry was utilized by the authors, including conferences especially with the engineers of the Wisconsin Telephone Company, from whom many valuable suggestions were received.

Although details of construction are not given to any extent it was the purpose of the authors to clearly set forth the principles that underlie good construction. The main emphasis, however, is placed upon the principles of operation of different types or makes of subscribers' apparatus, together with a discussion of methods of locating faults and their correction.

This is the first part of the course and is mainly confined to subscribers' apparatus. The two other parts to follow, which are in preparation, will treat of central office equipment and outside construction.

The authors wish to acknowledge their indebtedness to manufacturers of telephone apparatus for their unfailing courtesy in furnishing illustrative material and data. They are also under great obligation to Mr. L. Killam, H. L. Miller, and F. J. Mayer of the Wisconsin Telephone Company for advice and suggestions, and especially to the latter for reading the manuscript.

C. M. J.
D. C. F.

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PRINCIPLES OF THE TELEPHONE

CHAPTER I

INTRODUCTORY

1. Historical.—The first mention of the transmission of speech to a considerable distance probably was by Robert Hooke in 1667 who described how he had transmitted sounds through a considerable distance by the aid of a tightly stretched string. Later developments of Hooke's method of transmitting sound show the substitution of a wire for the string in the original experiments. In any case the sounds of speech could be transmitted only a few hundred feet, and it was not until use was made of electricity that the telephone became a commercial possibility.

The electric telephone was patented by Alexander Graham Bell in 1876, and the first public exhibition of it was made that year at the Centennial Exposition in Philadelphia. Since that date the number of telephones has grown rapidly; in fact, it is doubtful if any other invention can show such a rapid commercial development. At present it is not only possible to carry on a conversation between New York and San Francisco by wire, but between New York and Honolulu by wireless telephony.

2. Telephone Operation.—The modern telephone system consists of subscribers' instruments, the central office, and the connecting lines, so arranged that any subscribers' instrument can be connected at will to any other instrument of the system. It is in the central office that connections between subscribers' lines are made, a switchboard in which the lines terminate being located at this place. In the manually operated system, which will be the only one considered at present, switchboard or central operators, who make the desired connections by hand, are provided.

The person making the call first signals the central operator by turning the crank of the telephone generator in the magneto system. Turning this crank causes an electric current to flow through the wires to the central office, where it operates a signal, showing the operator that a connection is desired. As soon as the subscriber has signalled the central office he removes the receiver from the hook and listens until the operator has answered his signal, when he tells the operator the desired number. The

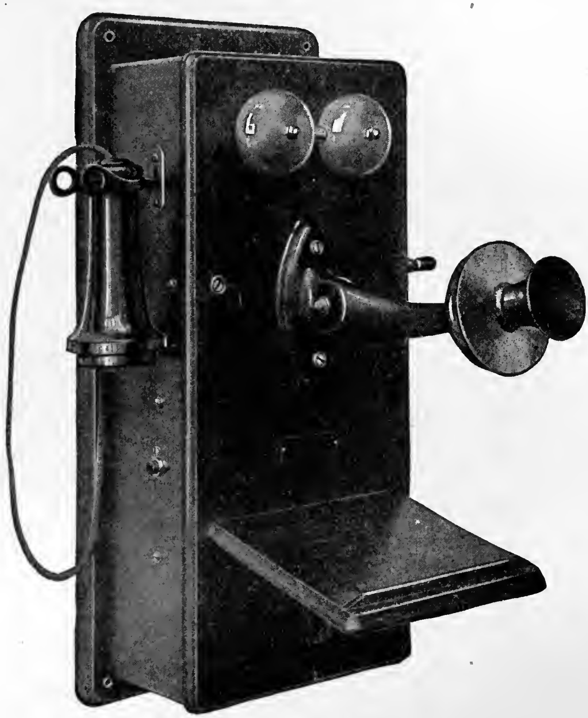

Fig. 1.

operator then connects the line of the calling subscriber to the line having the number for which he called.

The next step is to attract the attention of the called subscriber, which is done by ringing his telephone bell. As soon as the wanted subscriber answers his call by removing the receiver from the hook, the connections between the two instruments are complete, and the two subscribers can talk with each other.

In order to understand the manner in which the sound of speech made at one end of a telephone system is reproduced at the other end, it will be necessary first to get rid of the popular idea that the sounds produced at one end of the wire actually travel to the other end, for such is not the case. Speech is transmitted electrically. The sound waves of the voice, at the transmitting or sending station, set up fluctuating electric currents which pass over the line and cause a diaphragm at the opposite end to vibrate as these currents fluctuate, thus reproducing as nearly as possible, by means of the vibrations of the receiver diaphragm, the original sounds.

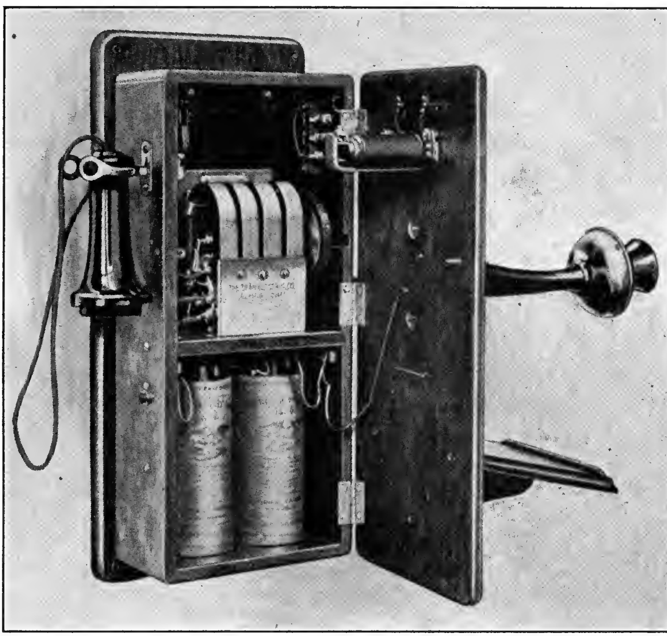

FIG. 2.

3. Telephone Instruments.—In Figs. 1 and 2 are shown the main working parts of a common form of subscribers' instrument.

4. The Transmitter.—The transmitter, as its name indicates, is used for transmitting or sending the message. The working parts of the transmitter consist of a thin iron diaphragm about 2¾ in. in diameter, and two carbon disks about ¾ in. in diameter separated by a small quantity of granulated carbon. One of the carbon disks is attached to the iron diaphragm, which is caused to vibrate by the sound waves of the voice when the transmitter is in use. The variations in the pressure between the disks cause the electric current flowing through the transmitter to vary from time to time, thus sending fluctuating currents over the line. The details of construction and operation of the transmitter are taken up in a later chapter.

5. The Receiver.—The receiver consists of a shell, usually made of hard rubber, containing an electromagnet and a thin iron diaphragm. The fluctuating electric currents from the line flowing through the coil of the electromagnet cause the force with which the magnet attracts the diaphragm to vary from time to time, thus causing the diaphragm to vibrate and give out sounds.

6. The Generator.—The generator is a small dynamo and operates only while the crank is being turned. It is not used during conversation over the telephone, but is used to signal the central office when a connection is desired by the subscriber.

7. The Ringer.—The ringer is an electric bell which is used to attract the subscriber's attention when he is wanted at the telephone.

8. The Hook Switch.—The hook switch is used to connect or disconnect the receiver and transmitter from the line. When the instrument is not in use the receiver hangs on the hook, holding it down, connecting the ringer to the line so that the bell can be rung when the subscriber is wanted. While the ringer is connected to the line the talking system, consisting of the transmitter and receiver, is disconnected from the line. When the subscriber answers his call by removing the receiver, the hook is raised by a spring and the ringing system is disconnected from the line, while the talking circuit is connected to the line.

9. The Induction Coil.—The induction coil is used to increase the distance speech can be transmitted. The induction coil consists of an iron core on which are two separate windings of insulated wire. The principles of operation are explained later.

10. The Battery.—While it is well known that the operation of the telephone depends upon electricity, the exact nature of electricity is not known, although a number of laws governing its action have been determined by observation and experiment. In order to understand the operation of the telephone, it is necessary to know something of these laws of electricity. The electrical supply for telephone work is derived from batteries, or generators.

In Fig. 2 a local battery telephone is shown; that is, each instrument has its individual battery. In large systems the central battery is used, or, in other words, a single battery in the central office supplies current for all the instruments in use.

CHAPTER II

ELEMENTARY ELECTRICAL PRINCIPLES

Electric batteries may be divided into two general classes and are known as primary and secondary batteries. A primary battery is a device used to generate an electrical pressure by means of chemical action; that is, the chemical energy of the battery is changed into electrical energy. The secondary battery, or as it is more often called, the storage battery, also makes use of chemical action in supplying electrical energy. But before such a battery can give off electricity, it must be charged. That is, electricity must be passed through it. Primary batteries are used in local battery telephone systems, and in the central battery system storage batteries are used.

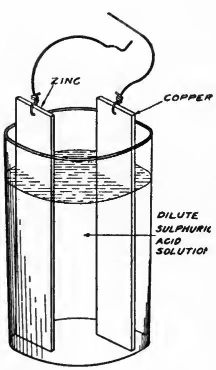

FIG. 3.

11. Primary Batteries.—A simple primary cell or battery may be made by placing a strip of amalgamated zinc[1] and one of copper in a glass partly filled with a mixture of sulphuric acid and water, care being taken that the metals do not touch each other, see Fig. 3. As far as can be seen no chemical action is taking place with the battery as shown. However, if the two plates be connected by a wire, it may be noticed that the zinc plate is being consumed and that bubbles of gas are formed on the surface of the copper plate. If the wire connection be broken, the chemical action ceases. It is evident that there is some action going on when the plates are connected which does not take place when the connection is broken. The fact is that an electrical current is flowing in the wire.

The plates of a battery are known as the elements or electrodes, and the solution in which they are placed is known as the electro-

[1] A piece of zinc may be amalgamated by cleaning it with diluted sulphuric acid and then rubbing the surface with mercury. One part of sulphuric acid poured into twenty parts of water makes a mixture of the proper strength.

lyte. In the above-mentioned battery the zinc and copper plates are the elements or electrodes, and the sulphuric acid is the electrolyte. In order to have an electrical action it is not necessary to have plates of copper and zinc and an electrolyte of sulphuric acid, for many other substances may be used in batteries.

One of the most common types of commercial batteries has elements of carbon and zinc and an electrolyte of sal ammoniac. The arrangement of such a battery is shown in Fig. 4. This type of battery is known as the Le Clanche cell. Dry cells are modified Le Clanche cells.

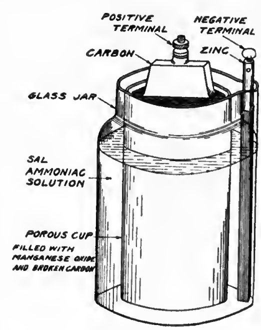

Fig. 4.

12. Electrical Pressure.—The two plates of a battery are said to be charged if an electrical current flows from one to the other when they are connected by a wire. An electrical pressure, which causes the electricity to move from one point to another, exists between the two charged plates. One of the plates of a battery is said to be charged positively (+) and the other is said to be charged negatively (−).

Electricity behaves in many respects like water, and it is just as necessary to have a difference in pressure between the two ends of an electrical conductor if we are to have a current flow as it is to have a difference in pressure between the two ends of a water pipe if we are to have the water run through the pipe. It is easy to see from the above statements that if two points having equal electrical pressures are connected, no electricity will move from one point to the other.

As water flows from a point of high pressure to one of lower pressure, so an electrical current flows from a point of high pressure or potential, as it is usually called, to one of lower potential. It is customary, in speaking of two electrical charges, to speak of the charge having the high pressure as positive (+) and the one of lower pressure as negative (−). Accordingly an electric current flows from a positive to a negative point. In the wire connecting the electrodes of the Le Clanche cell the current flows from the carbon (+) to the zinc (−).

13. Telephone Batteries.—In early telephone practice some form of Le Clanche cell, similar to Fig. 4, was largely used.

This battery costs little to operate, as the materials used in its construction are not expensive, and when the battery is idle there is no waste as the sal ammoniac does not attack the zinc to any extent except when current is flowing. Such a cell requires little attention except to replace the water lost by evaporation, and to replace the zinc element when it has been destroyed.

At present a later development of the Le Clanche battery, known as a dry cell, is used almost to the exclusion of other forms of primary cells in telephone operation.

The dry cell has electrodes of carbon and zinc, the zinc being in the form of a cylindrical cup and, in addition to being one of the battery elements, it also acts as a container for the electrolyte. One form of dry cell is shown in Fig. 5. The carbon element is in the form of a rod, and is held in the center of the zinc cup, without touching it at any point, the electrolyte occupying the intervening space. The electrolyte, instead of being a liquid as in the wet batteries, is in the form of a paste consisting of sal ammoniac, manganese dioxide, carbon, and water, in varying proportions depending upon the make of the cell. Several thicknesses of blotting paper separate the electrolyte from the zinc cup so that only the sal ammoniac which is dissolved in the water can come into contact with it. The outside of the cell is protected by a pasteboard covering which also insulates the cell from other cells of the same battery in case more than one are used. The cell is sealed with pitch or wax. The standard size of dry cell for telephone work is $2\frac{3}{4}$ in. in diameter and 6 in. high.

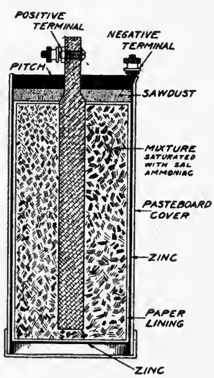

Fig. 5.

Dry cells have replaced wet batteries in telephone work on account of their smaller size, the fact that they are not easily broken, can not be spilled, have a low first cost, and require no attention except renewal when they are worn out.

14. Conductors and Insulators.—When the two plates of the simple battery mentioned above are not connected there is no current flow from one to the other, as shown by the fact that there is no chemical action taking place; neither is there any action when the plates are connected by pieces of wood, rubber, or glass. If, however, a wire of iron, copper, or other metal join the plates, a current flows from one plate to the other. In other words, the air, wood, glass, etc., do not conduct the electricity, while the wires do. All metals or substances which conduct electricity readily are known as conductors. Substances which do not conduct electricity readily, such as rubber, glass, etc., are known as nonconductors or insulators. Any insulator will conduct some little electricity, however slight that quantity may be; and every conductor will offer some resistance to the flow of electricity.

15. Electrical Resistance.—Electrical resistance is the name given to that property of a conductor which resists or opposes the passage of electricity through it. Electrical resistance may be compared with the resistance which a stream of water encounters in flowing through a pipe, the pressure in one case forcing the water to flow, and in the other case an electrical pressure causing the electricity to move from one point to another. The electrical resistance of a conductor depends upon the material of which the conductor is made, and upon the size and length of the conductor.

16. Resistivity.—As some substances conduct heat more readily than others, so in the case of electricity some substances conduct it more readily than others.

TABLE I

Metal	Resistivity in ohms at 0°C.
Silver, annealed	8.781
Silver, hard-drawn	9.538
Copper, annealed	9.61
Copper, hard-drawn	9.86
Aluminum, annealed	15.8
Aluminum, hard-drawn	15.93
Platinum	54.35
Iron	58.31
Tin	79.29
Lead	115.1
Mercury	565.9

In order to compare the conductivities of different substances some unit of conductor must be agreed upon. In scientific calculations the unit conductor is one whose length is 1 cm. and whose cross-sectional area is 1 sq. cm. In practical work, however, the unit conductor is a piece of circular wire 1 ft. long and 1/1000 (0.001) in. in diameter. The resistance of such a conductor is called the resistivity of the material of which the wire is made.

Table I gives the resistivities of a number of metals. The first, silver, has the lowest resistivity, while the last, mercury, has the highest resistivity of the metals given.

If we wish merely to compare the resistivities of wires of the same size and lengths but of different materials we can call the resistivity of silver unity. The relative resistivities are then as follows:

Table II

Metal	Relative resistivity
Silver	1.0
Copper	1.09
Aluminum	1.8
Platinum	6.19
Iron	6.64
Tin	9.03
Lead	13.1
Mercury	64.4

From the table it can be seen readily why so much copper wire is used in electrical apparatus. Silver, which is a better conductor and would be more desirable for some work for that reason, costs several times as much as copper.

The resistance of a conductor depends upon its length. The longer the conductor, the greater its resistance. Thus a No. 16 wire 200 ft. long will have twice as great a resistance as 100 ft. of the same wire.

A small conductor offers a greater resistance to the flow of an electric current than does a large one of the same material, just as a small pipe hinders the flow of water more than a large one. The resistance of conductors varies inversely as the areas of their cross-sections, or in other words, inversely as the quantity of material in a given length.

17. Wire Measurement.—In this country the length of wire is usually given in feet, and the size is specified either by diameter, cross-sectional area, or gage number. The units used for the measurement of the diameter and cross-sectional area are not the inch and square inch, but the mil and circular mil.

The Mil.—The unit of length in measuring the diameter is the $\frac{1}{1000}$ (= 0.001) in. and is called the mil. A 1-in. cable has a diameter of 1,000 mils. The diameter of a wire 0.25 in. is equal to 250 mils, etc.

Circular Mils.—A circle whose diameter is 0.001 in. (= 1 mil) is said to have an area of 1 cir. mil. Since the areas of two circles having different diameters are to each other as the squares of their diameters, to express the cross-section of any wire in circular mils, when its diameter in mils is given, all that is necessary is to square the diameter, that is, multiply the diameter by itself.

EXAMPLES

1. What is the cross-sectional area in circular mils of a wire $\frac{1}{4}$ in. in diameter?

Solution

$$\frac{1}{4} \text{ in.} = 0.25 \text{ in.}$$
$$0.25 \text{ in.} = \frac{250}{1000} = 250 \text{ mils}$$

Area in circular mils equals diameter squared

$$\text{Diameter} = 250 \text{ mils}$$
$$250^2 = 250 \times 250 = 62{,}500 \text{ cir. mils.}$$

2. A No. 0000 wire has a cross-sectional area of 211,600 cir. mils. What is its diameter in mils and in inches?

Solution

Since the cross-sectional area in circular mils is equal to the square of the diameter in mils, the diameter in mils must be equal to the square root of the cross-sectional area. In symbols

$$D^2 = \text{area}$$
$$\text{and } D = \sqrt{\text{area}}$$
$$\text{But area} = 211{,}600 \text{ cir. mils}$$
$$\text{Hence } D = \sqrt{211{,}600}$$
$$= 460 \text{ mils}$$
$$1 \text{ mil} = \frac{1}{1000} \text{ in.}$$
$$\text{Then } 460 \text{ mils} = \frac{460}{1000} = 0.46 \text{ in.}$$

18. Gage Numbers.—In the United States practically the only gage now used for copper wire is the American Wire Gage commonly called the Brown and Sharpe (B. & S.) Gage. This gage was devised in 1857 by J. R. Brown, one of the founders of the Brown & Sharpe Manufacturing Co. In this gage the size of wire is specified by number. The mathematical law on which

TABLE III.—TABULAR COMPARISON OF WIRE GAGES, DIAMETERS IN MILS

Gage No.	American Wire Gage (B. & S.)	Steel Wire Gage	Birmingham Wire Gage (Stubs')	(British) Standard Wire Gage
7–0	.....	490.0	.....	500.0
6–0	.....	461.5	.....	464.0
5–0	.....	430.5	.....	432.0
4–0	460.0	393.8	454.0	400.0
3–0	410.0	362.5	425.0	372.0
2–0	365.0	331.0	380.0	348.0
0	325.0	306.5	340.0	324.0
1	289.0	283.0	300.0	300.0
2	258.0	262.5	284.0	276.0
3	229.0	243.7	259.0	252.0
4	204.0	225.3	238.0	232.0
5	182.0	207.0	220.0	212.0
6	162.0	192.0	203.0	192.0
7	144.0	177.0	180.0	176.0
8	128.0	162.0	165.0	160.0
9	114.0	148.3	148.0	144.0
10	102.0	135.0	134.0	128.0
11	91.0	120.5	120.0	116.0
12	81.0	105.5	109.0	104.0
13	72.0	91.5	95.0	92.0
14	64.0	80.0	83.0	80.0
15	57.0	72.0	72.0	72.0
16	51.0	62.5	65.0	64.0
17	45.0	54.0	58.0	56.0
18	40.0	47.5	49.0	48.0
19	36.0	41.0	42.0	40.0
20	32.0	34.8	35.0	36.0
21	28.5	31.7	32.0	32.0
22	25.3	28.6	28.0	28.0
23	22.6	25.8	25.0	24.0
24	20.1	23.0	22.0	22.0
25	17.9	20.4	20.0	20.0
26	15.9	18.1	18.0	18.0
27	14.2	17.3	16.0	16.4
28	12.6	16.2	14.0	14.8
29	11.3	15.0	13.0	13.6
30	10.0	14.0	12.0	12.4
31	8.9	13.2	10.0	11.6
32	8.0	12.8	9.0	10.8
33	7.1	11.8	8.0	10.0
34	6.3	10.4	7.0	9.2
35	5.6	9.5	5.0	8.4
36	5.0	9.0	4.0	7.6
37	4.5	8.5	.....	6.8
38	4.0	8.0	.....	6.0
39	3.5	7.5	.....	5.2
40	3.1	7.0	.....	4.8

this gage is based is, the ratio of any diameter to the next smaller is a constant number.

For practical purposes tables are prepared giving the gage number, diameter in mils or inches, cross-sectional area in circular mils, and other data that may be useful, depending upon the completeness of the table. The numbers usually range from 0000 to 40. The diameter of No. 0000 is 460 mils and of No. 40, 3.145 mils. The student will thus see that the larger the gage number the smaller the diameter. A wire table for ordinary practical calculations is given on page 14. This table was prepared by the Bureau of Standards and is published in circular No. 31 together with others of greater accuracy and detail.

The telephone companies still use the "Standard Wire Gage," otherwise known as the New British Standard (N.B.S.) Gage, for copper wire and the Birmingham Gage for steel wire. The other steel wire gage used in this country is now known as the Steel Wire Gage (Stl.W.G.). Manufacturers of wire as a rule prefer that the size of wire be specified in decimal fractions of an inch, without the use of gage numbers. A comparative table of the four gages used by telephone companies is given in Table III.

19. Unit of Resistance.—In order that the resistance of different wires may be compared, a unit of resistance has been adopted. This unit of resistance is known as the ohm. The resistance of 1,000 ft. of No. 10 copper wire at a temperature of 20°C. or 68°F. is about 1 ohm.

The standard ohm is defined as the resistance offered to the flow of an unvarying electric current by a column of mercury 106.3 cm. long, 14.4521 grams mass, and of a constant cross-sectional area, at a temperature of melting ice.

20. Unit of Electrical Pressure.—Just as it has been necessary to choose a unit of resistance, so it has been necessary to choose a unit of electrical pressure or electromotive force, as this pressure is usually called. The unit of pressure is known as the volt. Electromotive force or electrical pressure is not electricity; it is merely the force that causes electricity to move, so that the voltage of a battery is no measure of the quantity of electricity that can be obtained from that battery, but is merely a measure of the electrical pressure existing between the two plates. The pressure in a standard dry cell is about 1½ volts. A voltmeter is an instrument for measuring electrical pressure. Since the electrical pressure of a battery exists between its two electrodes, in order to secure a voltmeter reading of this pressure the instrument must be connected to the electrodes.

TABLE IV.—NUMBER, DIMENSIONS, AND RESISTANCE OF STANDARD ANNEALED COPPER WIRE (SOLID)

No.	Diameter	Area	Weight	Resistance in ohms at 68°F.
A.W. Gage	In mils	Circular mils	Lb. per 1,000 ft.	Ohms per 1,000 ft.[1]
6	162.0	26,250.0	79.46	0.3951
7	144.3	20,820.0	63.02	0.4982
8	128.5	16,510.0	49.98	0.6282
9	114.4	13,090.0	39.63	0.7921
10	101.9	10,380.0	31.43	0.9989
11	90.74	8,234.0	24.92	1.260
12	80.81	6,530.0	19.77	1.588
13	71.96	5,178.0	15.68	2.003
14	64.08	4,107.0	12.43	2.525
15	57.07	3,257.0	9.858	3.184
16	50.82	2,583.0	7.818	4.015
17	45.26	2,048.0	6.200	5.064
18	40.30	1,624.0	4.917	6.385
19	35.89	1,288.0	3.899	8.051
20	31.96	1,022.0	3.092	10.15
21	28.46	810.1	2.452	12.80
22	25.35	642.4	1.945	16.14
23	22.57	509.5	1.542	20.36
24	20.10	404.0	1.223	25.67
25	17.90	320.4	0.9699	32.37
26	15.94	254.1	0.7692	40.82
27	14.20	201.5	0.6100	51.46
28	12.64	159.8	0.4837	64.90
29	11.26	126.7	0.3836	81.84
30	10.03	100.5	0.3042	103.2
31	8.928	79.70	0.2413	130.1
32	7.950	63.21	0.1913	164.1
33	7.080	50.13	0.1517	206.9
34	6.305	39.75	0.1203	260.9
35	5.615	31.52	0.09542	329.0
36	5.000	25.00	0.07568	414.8
37	4.453	19.83	0.06001	523.1
38	3.965	15.72	0.04759	659.6
39	3.531	12.47	0.03774	831.8
40	3.145	9.888	0.02993	1049.0

[1] For hard-drawn copper wire increase these values by 2.7 per cent.

21. Electric Current.—In order to have a flow of electricity from one point to another it is necessary that a difference in electrical pressure exist between the two points, and that these points be connected by a conductor.

The rate of flow in any circuit depends upon the pressure or voltage, and the resistance of the path through which the current flows. It is evident that a greater rate of flow will take place under a high pressure than under a low one. Thus a pressure of 2 volts would cause twice as much electricity to flow through a circuit in a given time as a pressure of 1 volt. The resistance which has to be overcome in any conductor determines the current, since the greater the resistance, the more the current will be held back or hindered in flowing through the conductor.

22. The Ampere.—The ampere is the unit of current, and is the current that will flow in a circuit having a resistance of 1 ohm under an electrical pressure of 1 volt. An ammeter is an instrument for measuring the rate of flow of electricity in a circuit.

23. Pressure, Current, and Resistance.—It has been shown above that electric current depends upon the pressure and resistance of a circuit, or that for different pressures and resistances different currents will flow. Thus if a certain current is flowing in a circuit and it is desired to change that current, it is necessary to change either the pressure or resistance of the circuit.

The units of pressure, resistance, and current have been so chosen that if two of these quantities are known, the third can be easily calculated. Since 1 ampere represents the current in a circuit having a resistance of 1 ohm under a pressure of 1 volt, in order to have 2 amperes flow in the same circuit it would be necessary to have a pressure of 2 volts, etc. A simple way of expressing this relationship is: Current equals pressure divided by resistance, or

$$\text{Amperes} = \frac{\text{Volts}}{\text{Ohms}}$$

In telephone operation the pressure remains constant, so that the fluctuating current which is necessary to send a message is obtained by the rapid variations in the resistance of the transmitter when it is being used.

24. Electric Circuits.—An electric circuit is a system of conductors and apparatus connected so that a current, under certain conditions, may flow from one point to another point on the conductors. With reference to the manner in which the conductors are connected, we have two general classes of circuits; namely, series and parallel. With reference to the possibility of current flowing, circuits are classed as closed and open.

25. Series Circuit.—A series circuit is one in which the current must flow through each part of the circuit in succession. The current has the same strength at whatever point in the circuit it is measured. Fig. 6*a* is a series circuit consisting of a magneto generator, two wires and a telephone ringer.

26. Parallel Circuit.—Parallel circuits are shown in Fig. 6*b*. The current from the generator divides and goes through the bell coils in parallel. Thus a parallel circuit is one consisting

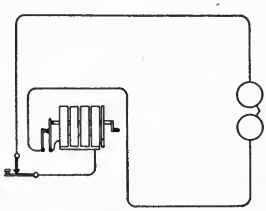

FIG. 6*a*.

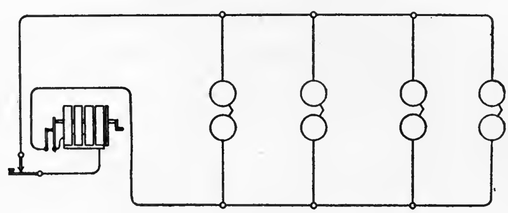

FIG. 6*b*.

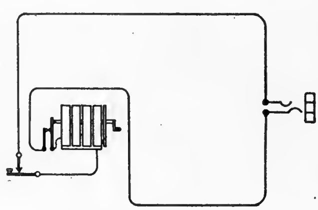

FIG. 6*c*.

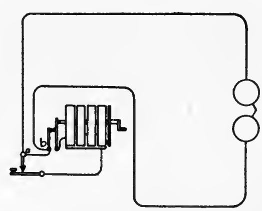

FIG. 6*d*.

of two or more individual circuits connected in parallel, or, in short, a parallel circuit is a divided circuit.

27. Closed Circuit.—When the conductors are connected so that a current can flow, the circuit is said to be closed. Fig. 6*a* is also a closed series circuit.

28. Open Circuit.—An open electrical circuit is one in which some part is disconnected so that a current can not flow. Fig. 6*c* shows an open circuit, opened at the jack, and at the magneto.

29. Short Circuit.—A short circuit is said to exist when a shunt or parallel circuit of comparatively low resistance has been connected to the main circuit. A shunt is one of the branches of a parallel circuit. Fig. 6*d* shows a connection from the point *a* to the point *b* short-circuiting the generator.

30. Grounded Circuit.—A circuit is said to be grounded when any part of it is connected to the ground. Such a circuit is shown in Fig. 6*e*. In many telephone systems the ground is made a part of the circuit, but one wire being used. This is made possible by the fact that wet earth is a good conductor of electricity.

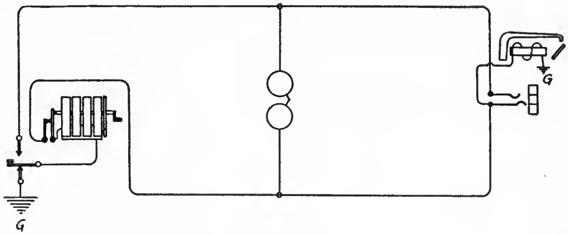

FIG. 6*e*.

31. Resistance of a Series Circuit.—When conductors are connected end to end so that the total current must flow through each conductor in succession, the joint resistance of the conductors or the resistance of the circuit is the sum of the resistances of the individual conductors so connected. Thus in Fig. 7 the resistance of the receiver circuit is $70 + 10 + 87.5 + 175 + 10 + 32 = 384.5$ ohms.

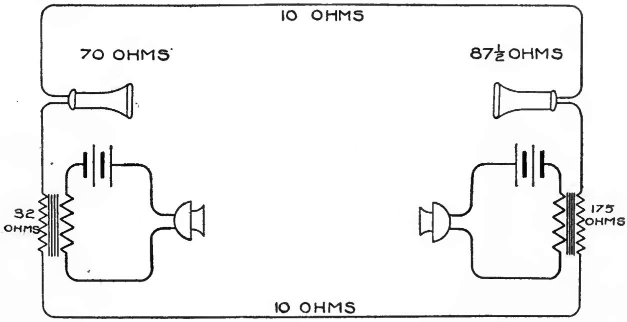

FIG. 7.

32. Resistance of a Parallel Circuit.—When several conductors are connected in parallel, as the ringers in Fig. 6*b*, the joint conductivity is the sum of the conductivities of the several branches. This will be more evident if we consider a hydraulic analogy. Suppose two large water mains are connected by several small pipes. It is very evident that the current of water flowing from one main to the other main is equal to the sum of the currents in the small pipes. That is, the joint conductivity is equal to the sum of the conductivities of the small pipes. In exactly an analogous manner, when the circuit consists of several conductors in parallel, the total current is the sum of the currents in the several parallel conductors. This fact, together with Ohm's law, enables us to calculate the joint resistance in the following manner:

Suppose the resistances of the ringers in Fig. 6*b* are R_1, R_2, and R_3 respectively, and that a difference of electrical pressure of E volts exists between their terminals; then by Ohm's law the current in ringer 1 is

$$i_1 = \frac{E}{R_1}$$

$$\text{current in 2 is } i_2 = \frac{E}{R_2}$$

and

$$\text{current in 3 is } i_3 = \frac{E}{R_3}$$

If R is the joint resistance, the total current is

$$I = \frac{E}{R}$$

But $i_1 + i_2 + i_3 = I$

Therefore

$$\frac{E}{R} = \frac{E}{R_1} + \frac{E}{R_2} + \frac{E}{R_3}$$

or

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Solving this for R, we get

$$R = \frac{R_1 \times R_2 \times R_3}{R_1 \times R_2 + R_1 \times R_3 + R_2 \times R_3}$$

If the resistances of the bells are equal then

$$R_1 = R_2 = R_3, \text{ and}$$

$$R = \frac{R_1^3}{3R_1^2} = \frac{1}{3}R_1$$

That is, the joint resistance is equal to one-third the resistance of one bell.

EXAMPLE

Three ringers whose resistances are 1,000 ohms, 1,600 ohms, and 2,000 ohms are bridged across a line to which is connected a storage battery of 24 volts.

(*a*) What is the current in each bell?
(*b*) What is the total current given out by the battery?
(*c*) What is the joint resistance of the ringers?

Solution

(*a*) By Ohm's law the several currents are

$$i_1 = \frac{24}{1{,}000} = 0.024 \text{ amp.}$$

$$i_2 = \frac{24}{1{,}600} = 0.015 \text{ amp.}$$

and

$$i_3 = \frac{24}{2{,}000} = 0.012 \text{ amp.}$$

(*b*) The total current is equal to the sum of $i_1 + i_2 + i_3$ or

$$I = 0.024 + 0.015 + 0.012 = 0.051 \text{ amp.}$$

(*c*) The joint resistance may be calculated in two ways. First by Ohm's law

$$R = \frac{E}{I}$$

$$= \frac{24}{0.051} = 470.6 \text{ ohms;}$$

or by the formula

$$R = \frac{R_1 \times R_2 \times R_3}{R_1 \times R_2 + R_1 \times R_3 + R_3 \times R_2}$$

$$\begin{aligned} R_1 \times R_2 \times R_3 &= 1{,}000 \times 1{,}600 \times 2{,}000 \\ &= 3{,}200{,}000{,}000 \\ R_1 \times R_2 &= 1{,}600{,}000 \\ R_1 \times R_3 &= 2{,}000{,}000 \\ R_2 \times R_3 &= 3{,}200{,}000 \\ \hline R_1 \times R_2 + R_1 \times R_3 + R_2 \times R_3 &= 6{,}800{,}000 \end{aligned}$$

and

$$R = \frac{32{,}000}{68}$$

$$= \frac{32{,}000}{68} = \frac{8{,}000}{17}$$

$$= 470.6 \text{ ohms, nearly.}$$

To calculate the joint resistance of any number of conductors connected in parallel, we proceed in exactly the same way. It is not necessary to show how any more formulas are calculated. A general rule will suffice.

Rule.—To find the joint resistance of any number of parallel conductors, *divide the product of the resistances of all of the conductors by the sum of the products obtained by multiplying together all of the resistances less one. The same resistance must not appear in any partial product more than once.*

33. Cells in Series.—In the application of Ohm's law the electromotive force E must be the total electrical pressure in the circuit. It is, therefore, necessary to be able to calculate the pressure when cells are connected in series or in parallel. Cells are said to be connected in series when the carbon electrode of one is connected to the zinc electrode of the next and so on as shown in Fig. 8.

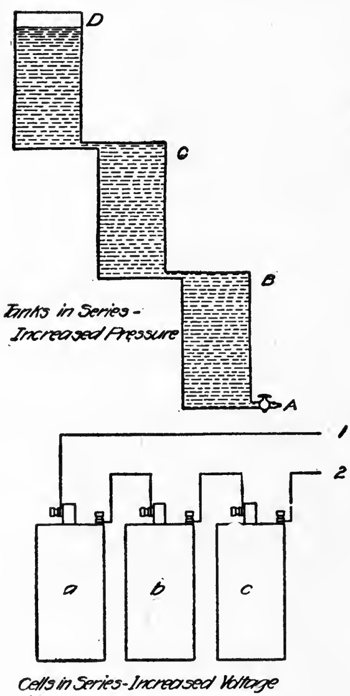

FIG. 8.

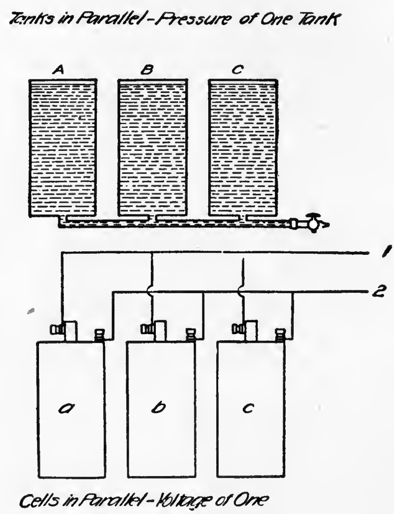

FIG. 9.

The analogous diagram of tanks in series may help to show how the total pressure is calculated. The hydrostatic pressure at A is evidently the sum of the pressures due to the elevations of the water $AB + BC + CD$; that is, the sum of the pressures in the individual tanks. Similarly, the electrical pressure between the terminals 1 and 2 is the sum of the pressures across the cells a, b, and c. In general, if E is the pressure of one cell and n cells are connected in series, the total pressure is nE.

34. Cells in Parallel.—Fig. 9 is a diagram of tanks and cells connected in parallel. It is evident that the hydrostatic pressure exerted by the water in tank *A* is the same as that in *B* and *C*, since the height of the water is the same in each. The total pressure is equal to that of one tank. The three tanks could be replaced by one large tank, and as long as the water was maintained at the same height, the pressure at the orifice would be exactly the same in the two cases.

When cells are connected in parallel the total pressure is equal to the pressure of one cell, and the three cells *a*, *b*, and *c*, can be replaced by one large cell having the same cross-section of zinc and carbon as the three cells taken together.

When tanks are connected in parallel it is evident that each supplies only a part of the current. The same principle holds with reference to cells connected in parallel—each cell supplies only a part of the total current. The student can readily verify the law of pressures by connecting three cells in parallel and then connecting a voltmeter to terminals 1 and 2, Fig. 9, and comparing the voltmeter reading with the reading given when the voltmeter is connected to each cell separately.

35. Battery Resistance for Parallel Connections.—The effect of connecting cells in parallel is to increase the current capacity and decrease the internal resistance. In so far as the internal resistance of one cell is concerned, it may be considered as a conductor whose resistance is r. Three cells in parallel will thus be the equivalent of three resistances in parallel. It has been shown that when three equal resistances are in parallel, the joint resistance is equal to one-third of the resistance of one wire. Accordingly, the joint internal resistance of a battery of m parallel cells is $\frac{r}{m}$.

EXAMPLE

Five cells each having an internal resistance of 1 ohm are connected in parallel. What is the joint resistance?

Solution

Since the resistances of the cells are the same, the joint resistance is ⅕ of 1 ohm = 0.2 ohm.

QUESTIONS

1. Explain the steps necessary in order to send a telephone message from one point to another.

2. Name the main parts of a telephone instrument and give briefly the uses of each.

3. Of what use is a battery in telephone work?

4. Explain how a simple battery is made.

5. What is a conductor? An insulator? Name the five best conductors of which you know. The five best insulators.

6. What are the elements of a battery? What is the electrolyte?

7. What is meant when an object is said to be "charged?"

8. What do you understand by electrical pressure? Compare it with water pressure.

9. What are the elements and electrolyte of the Le Clanche cell? Explain briefly how a dry cell is made.

10. What is electrical resistance? Upon what does the resistance of a conductor depend?

11. Which has the greater resistance, copper or silver? Iron or copper? Iron or lead?

12. Why is a unit of resistance necessary? What is this unit?

13. What is the unit of electrical pressure? By what other name is electrical pressure usually known? What is the voltage of a dry cell?

14. What causes an electrical current to flow? What conditions are necessary in order to have a current of electricity?

15. What is the unit of current? Define it in terms of volts and ohms.

16. What is the relation between volts, amperes, and ohms?

17. What is the rate of current flow through a coil of telephone wire having a resistance of 1 ohm, if the ends are connected to the terminals of a dry cell? If another coil of half the length is used, what will be the current in amperes?

18. Define the following: Circuit, open circuit, closed circuit, short circuit, series circuit, parallel circuit, shunt.

19. Four resistances of 80, 95, 40, and 50 ohms are connected in series. What is the joint resistance?

20. Four series ringers of 80 ohms resistance each were connected in parallel. What was the joint resistance?

21. Four dry cells, each having an electromotive force of 1.4 volts and an internal resistance of 1 ohm, were connected in series to a circuit whose resistance was 10 ohms. What was the current in the circuit?

22. Suppose the cells mentioned in question 21 were connected in parallel to the same circuit, what current would flow?

CHAPTER III

MAGNETIC PRINCIPLES

36. Receiver Action.—An examination of a telephone receiver shows the working parts to consist of a permanent magnet on which coils of fine insulated wire are wound, and a thin iron disk mounted close to, but not touching, the poles of the magnet. This arrangement is shown in Fig. 10 for a single-pole receiver, which was the earliest type in use.

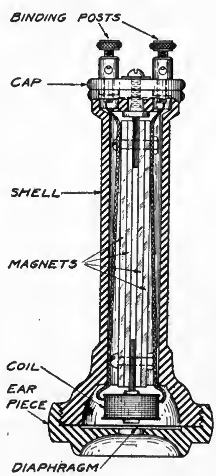

FIG. 10.

This examination also shows the iron disk or diaphragm to be attracted by the permanent magnet. Since the outer edge of the disk can not move, the disk will become slightly "dished," as the center is drawn in toward the magnet. When the receiver is not in use this pull will be steady, and there will be no movement of the disk. If the strength of the magnet be increased, however, it will exert greater attraction for the disk, and the latter will be pulled closer to the magnet pole. On the other hand, if the force of the magnet's attraction be decreased the diaphragm will spring away from the pole, and return more nearly to its original shape.

When the receiver is in use, the strength of the magnet is changed from time to time by the fluctuating line current which flows through the coil of the receiver. If these changes in the force of the magnet take place rapidly enough, the disk will vibrate at such a rate that sounds will be produced by it. In order to understand how an electric current flowing in the coil can change the strength of the magnet, it will be necessary to investigate a few of the relations existing between electricity and magnetism.

37. Magnetism.—The magnet, as first known, existed in the form of a certain iron ore known as magnetite (so named in honor of the city of Magnesia, where the ore having this peculiarity was discovered) which has the property of attracting pieces of iron. The strange force by which the particles of iron were attracted was likewise known as magnetism. These first magnets were natural magnets.

It was found, somewhat later, that artificial magnets could be formed by subjecting pieces of iron to the influence of a magnetizing force. One of the early methods of producing such artificial magnets, was by stroking or rubbing a piece of iron with a piece of magnetic ore or natural magnet. There are at present other methods of producing artificial magnets. The first artificial magnets were in the form of a bar as shown in Fig. 11*a*.

Fig. 11*a*.

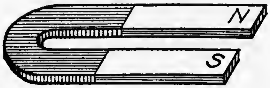

Fig. 11*b*.

38. Magnetic Substances.—Iron in its various commercial forms, such as wrought iron, cast iron, steel, etc., is strongly magnetic and is known as a magnetic substance. Substances such as wood, glass, copper, etc., which can not be made to act as magnets, are known as nonmagnetic substances.

39. Magnetic Induction.—When a magnetic substance is magnetized by coming into contact with a magnet, the substance is said to have been magnetized by induction, or the magnetism is said to be induced in the substance.

40. Experiment 1.—*Apparatus:*

Bar Magnet.
Iron Filings.
Wire Nails.

(*a*) Dip the ends of the bar magnet into the iron filings, and note that the filings cling to the ends of the magnet. The parts to which filings cling are called the poles of the magnet. Those points to which no filings cling are known as neutral points.

(*b*) Rub a knife blade or other piece of steel with one end of the magnet; always move the magnet in the same direction along the knife. Dip the end of the blade in the filings. Has the blade become magnetized?

(*c*) Hold one end of the bar magnet against the head of a nail and dip the point of the nail into the iron filings. Note that a magnet pole has been developed on the point of the nail.

(*d*) Try the last experiment with a piece of wood or short piece of copper wire in place of a nail, and note that there is no evidence of these substances becoming magnetized.

41. Magnetic Action.—If a bar magnet be suspended by a fine thread attached to its center, the magnet will turn so that one end will point in a northerly direction and the other in a southerly direction, no matter what the original position of the magnet may be. The end of the magnet that will point toward the north is called the North pole (marked N.), and the other end is called the South pole (marked S.). A compass needle is merely a very light bar magnet.

42. Experiment 2.—*Apparatus:*

Horseshoe Magnet.
Two Bar Magnets.

(*a*) Suspend a bar magnet by a fine thread attached to its center. When the magnet has come to rest, it will point north and south. Mark the end that points north, to indicate the N. pole. Suspend the second bar magnet in the same way and mark its N. pole. Bring the N. pole of the first bar magnet near the N. pole of the suspended one. Observe that the two poles repel each other. Now bring a N. and S. pole near each other and observe the strong attraction exerted between the two.

(*b*) Using the suspended bar magnet as in the first part of the experiment, test the poles of the horseshoe magnet, and mark the N. pole.

43. Laws of Magnetic Attraction and Repulsion.—If the N. pole of one bar magnet is brought near the S. pole of the other, a strong attraction is exerted between the two; but if the two N. or two S. poles are brought together, they repel each other; hence we can write two laws governing the action of one magnetic pole on another, as follows: (1) Like magnetic poles repel each other, and (2) unlike magnetic poles attract each other.

The action of the compass in taking a north and south position can be understood, since investigation has proved that the earth is a gigantic magnet, having one magnetic pole near the earth's north pole, and the other magnetic pole near the earth's south pole.

A horseshoe magnet is another common form of artificial magnet, one of the ends being a N. and the other a S. pole, as shown in Fig. 11*b*.

44. Experiment 3.—*Apparatus:*

Bar Magnet.
Nail.
Piece of Watch or Clock Spring about 3 in. long.

(*a*) Repeat the third part of Experiment 1, and note that as long as the magnet and nail are in contact the point of the nail will hold a considerable quantity of the filings, but as soon as this contact is broken the nail loses the greater part of its magnetism and most of the filings drop. The nail, being of soft iron, is only a temporary magnet.

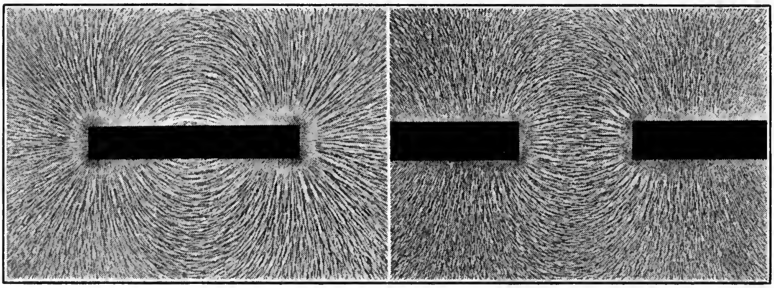

FIG. 12*a*. FIG. 12*b*.

(*b*) Repeat the experiment using the piece of watch spring in place of the nails. Even after the contact between the spring and the magnet has been broken, the spring retains the greater part of its power to pick up the filings. The spring, being of hard steel, has become a permanent magnet. Try the bar magnet used in this experiment with a file to see whether or not it is of hard steel.

45. Permanent and Temporary Magnets.—Artificial magnets which retain their magnetism a long time are known as permanent magnets. Wrought iron may be strongly magnetized, but as soon as the magnetizing force is removed it loses the greater part of its magnetism. Hard steel, when once magnetized, will retain its magnetic properties indefinitely. Both these forms of iron are made use of in telephone work; in some cases we use hard steel because we want the part to retain its magnetism, as in the magnets of a ringer, and in other cases we want to magnetize the part temporarily and then want the same part to lose its magnetism a moment later, as in the receiver diaphragm. The action of these parts will be explained later.

46. Experiment 4.—*Apparatus:*

Bar Magnet.
Piece of Watch Spring.

Be sure that the spring used in Experiment 3 is magnetized. After testing the spring by dipping in the filings, cut it into several short pieces; and test each piece for magnetic properties. A magnetic pole will exist at each end of each of the small pieces, and each will have the same power of attraction as the original magnet.

47. Magnetic Lines.—The property by which a magnet will

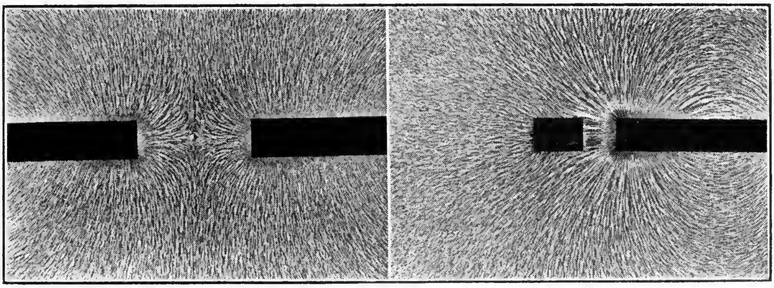

FIG. 13. FIG. 14.

attract pieces of iron or other magnetic material has given rise to the conception of magnetic lines. Magnetic lines are the imaginary lines along which the forces of attraction and repulsion are exerted. The space surrounding a magnet in which these forces are exerted is known as the magnetic field. Each individual line forms a complete loop or circuit passing through the poles of a magnet, and the number of these lines which pass through the poles determine the strength of the magnetic field.

A bar magnet is surrounded by these lines which enter at one pole and leave through the other, as shown in Fig. 12*a*. Magnetic lines are considered as passing out of the magnet at the N. and into the magnet at the S. pole.

The distribution of magnetic lines under different conditions is shown in Figs. 12*a* and 12*b*, 13, and 14.

A magnet can not be produced with but one pole. If a bar magnet is broken into a number of small pieces, each piece will have a N. and a S. pole.

48. Experiment 5.—*Apparatus:*

Horseshoe Magnet.
Bar Magnet.
Iron Filings.
Sheet of Smooth, Stiff Paper.

(*a*) Lay the bar magnet on the table, and over it place a sheet of paper. Sprinkle iron filings over the paper. Tap the paper gently while sprinkling the filings and note that the arrangement of the filings is similar to the diagram of the magnetic field shown in Fig. 12*a*.

(*b*) Repeat the above experiment using the horseshoe magnet instead of the bar magnet.

49. The Magnetic Circuit.—The path of the magnetic lines is known as the magnetic circuit. Thus in Fig. 12*a* the magnetic circuit is made up of two parts, the steel of the magnet and the air through which the lines pass. A magnetic circuit is said to be closed when the circuit is composed entirely of magnetic substances, such as iron or steel. Whenever pieces of iron or steel are brought into a magnetic field, the lines pass through them very readily and they become magnetized. If the material is soft iron, when taken out of the field it will lose most of its magnetism, while if it is hard steel it will retain its magnetism, both substances behaving the same as if they had been in actual contact with a magnet.

Magnetic lines tend to pass along the path offering the least resistance, the same as electric currents. Iron and steel offer the least resistance to the passage of magnetic lines, so are used for magnetic circuits whenever possible. Air offers from 1 to 10,000 times as much resistance to magnetic lines as iron, depending upon the degree of magnetization. Copper, glass, paper, and other nonmagnetic substances offer the same resistance to magnetic lines as air. Magnetic circuits through substances other than iron are usually made short, so that the number of lines in the magnetic field will be as great as possible. The horseshoe magnet is stronger than the bar magnet of the same size because the magnetic circuit through air is shorter. That air does offer considerable resistance to magnetic lines can be seen from the fact that it is necessary to bring a magnet quite near a piece of iron before any attraction is noticed. The resistance which any substance offers to the passage of magnetic lines is known as reluctance.

50. Electromagnetism.—Any conductor carrying an electric current is surrounded by a magnetic field, as shown in Fig. 15. The dark spot in the center of the figure represents a cross-section of the wire.

51. Experiment 6.—*Apparatus:*

Two Feet of Bare Copper Wire.
Dry Cells.
Iron Filings.
Compass.

(*a*) Dip the wire in the iron filings and note that the filings do not stick to the wire. Now connect the ends of the wire to the terminals of the dry cells; place the wire in the filings and

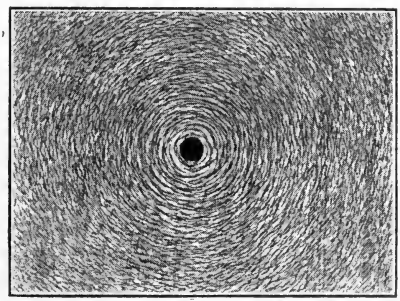

Fig. 15.

observe that the filings stick to the wire, although it is not a magnetic substance. Disconnect one end of the wire and repeat the experiment. It is evident that the magnetic field exists only as long as the current is flowing.

(*b*) Place the wire over the compass so that it is parallel to the needle and close the circuit. Observe that the needle is deflected, showing the magnetic action of the current. Reverse the current through the wire by reversing the connections to the battery, and note that the needle is deflected in the opposite direction, showing the magnetic field has been reversed.

52. Solenoids.—If a wire carrying a current be wound into a coil, as shown in Fig. 16, the magnetic lines surrounding each turn of the coil will be in the same direction as those of the other turns, and the result will be a magnetic field similar to that of a cylindrical bar magnet. A coil so arranged and carrying a current is called a solenoid. A solenoid behaves exactly like a bar magnet. At one end of the solenoid a N. pole exists, while at the other end a S. pole exists, depending upon the direction of the current flowing in the wire. A reversal of the current will cause a reversal of the magnetic field.

The strength of the magnetic field of any coil depends upon the number of turns in the coil and upon the current flowing in the coil, since the magnetic field of a solenoid is due to the added effect of all the turns in the coil.

53. Experiment 7.—*Apparatus:*

Solenoid.
Dry Cells.
Compass.

(*a*) Connect the solenoid to the dry cell and by placing one end near the N. pole of the compass observe whether it attracts or repels the compass.

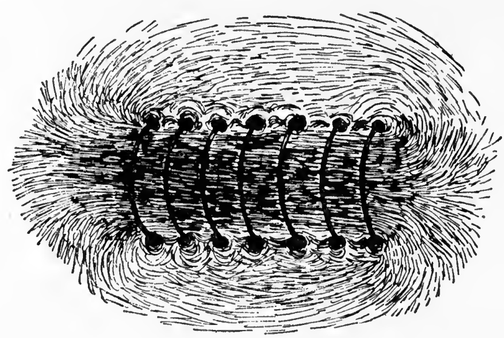

FIG. 16.

If it attracts the N. pole of the compass, what kind of a pole is it? If it repels? Mark the end with an N. or S.

Now test the other end the same way and observe that it is of opposite polarity. Mark this end according to its polarity.

(*b*) By reversing the connections at the battery, cause the current to flow in the opposite direction through the coils.

Test as before with the compass and note that the pole which was marked N. in the first case has now become a S. pole, and the one which was marked S. has become a N. pole.

54. Electromagnets.—If an iron core be placed in a solenoid, it becomes what is known as an electromagnet. Since magnetic lines pass through iron much more readily than through air, the same magnetizing force can produce a stronger field through iron than through air or some other nonmagnetic substance.

Hence the purpose of the iron core is to increase the strength of the magnetic field of the coil without increasing the current or the number of turns in the coil.

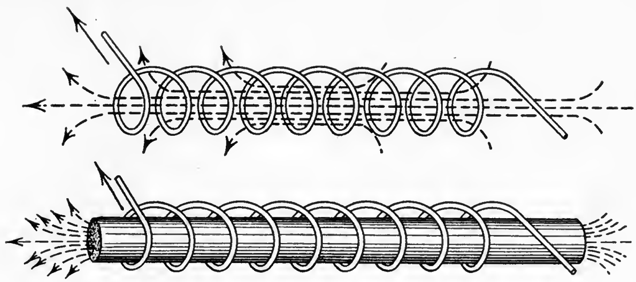

Fig. 17.

The electromagnets used in telephone work are of three general forms, classified according to the form of the iron core.

One form, the bar electromagnet, consists of a solenoid wound on a straight iron core, as shown in Fig. 17. An examination

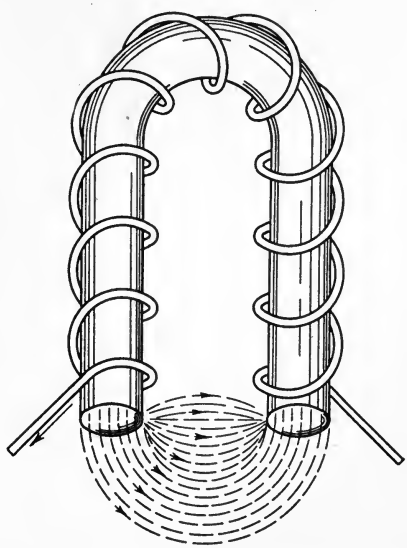

Fig. 18.

shows that the magnetic circuit contains a long air gap. If this air gap be shortened, the number of lines and therefore the strength of the magnetic field will be increased without changing the current or coil in any way.

55. Horseshoe Electromagnet.—One of the easiest ways of shortening the air gap is to bend a bar electromagnet in the form of a horseshoe, as shown in Fig. 18. To facilitate manufacture, however, the core of the horseshoe electromagnet is usually made in three parts instead of being bent as shown. Fig. 19 shows the general form of commercial horseshoe magnets, consisting of two spools and the yoke joining their cores. Since such a magnet usually is arranged to attract an armature, the latter further decreases the air gap, as shown, to the short spaces between the armature and poles.

56. The Ironclad Electromagnet.—The ironclad or tubular electromagnet is shown in Fig. 20. In this type, the coil is wound

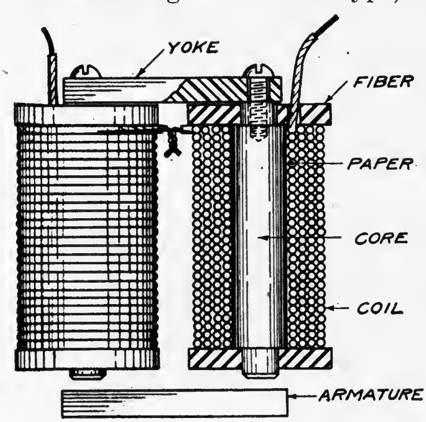

Fig. 19.

on an iron core and is surrounded by a tubular shell. Such a magnet has the advantages of occupying small space, and of having its magnetic field confined strictly within the shell so that there are no stray lines to affect other apparatus which may be near.

57. Construction of Electromagnets.—The coils for electromagnets are usually wound in the form of spools. Such a spool may be entirely of fiber so that it can be removed from the core if desirable, or the fiber ends may be forced on the iron core as shown in Fig. 18. In the latter form several layers of paper are wrapped around the core to insulate it thoroughly from the coil. On this spool the insulated wire of the coil is wound in layers. Sometimes the layers are further insulated from each other by a thickness of paper.

58. Magnet Wire.—The insulated copper wire used in winding coils for electromagnets is known as magnet wire.

Most magnet wire is covered with either silk or cotton. Of the two, silk has the higher insulating properties and is used largely on very fine wire, as a covering of silk is thinner than one of cotton. Cotton is used almost exclusively on the larger sizes. Silk or cotton insulated wire has either one or two layers of the insulating materials, and is known as single silk (or cotton) covered, and double silk (or cotton) covered. When two layers are used they are wound in opposite directions. As both silk and cotton absorb moisture readily, wire insulated with these materials is sometimes saturated with melted paraffine, shellac, varnish, or some other insulating compound to make it waterproof. More often the coil is so treated after being wound.

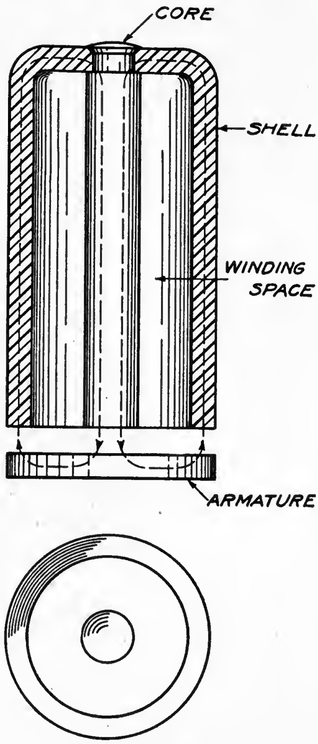

Fig. 20.

Enameled wire is a later development in the insulation of magnet wire. Enameled wire is made by coating the wire with liquid enamel which is then baked on. The advantages of this wire are that it is waterproof, will stand high temperatures, and the covering of insulating material is very thin.

59. Magnetic Action of Receiver.—If an electric current be sent through the coil of the receiver in such a direction that the magnetic lines set up by it are in the same direction as those of the permanent magnet, the strength of the magnet will be increased and the disk will be drawn closer to the pole. If a current be sent through the coil in the opposite direction, however, so that the magnetic lines due to the current oppose those of the magnet, the strength of the magnet will be decreased and the diaphragm will spring away from the pole.

When a fluctuating current flows through the coil, the magnetic field of the coil will increase with increasing current and decrease as the current decreases, and these changes will cause changes in the strength of the field of the permanent magnet. Thus, whether or not the lines induced by the coil are in the same direction as those of the permanent magnet, there will be changes in the strength of the magnetic field whenever there are variations of the current flowing in the coil. Hence the diaphragm will vibrate in harmony with the changes of current.

QUESTIONS

1. What is a magnet? What is magnetism?

2. What is an artificial magnet? How made?

3. What is the pole of a magnet? How many poles do magnets have?

4. What is a compass needle? Which is the N. pole of a magnet?

5. What is a magnetic substance? Name the most common magnetic substance.

6. What is meant by magnetic induction? Give an illustration of magnetic induction. Can magnetism be induced in a bar of iron without having the bar come into contact with a magnet?

7. Give the law of attraction and repulsion between magnet poles.

8. What is a permanent magnet? What kind of material is usually used in permanent magnets?

9. What is a magnetic line? What is a magnetic circuit?

10. What is a magnetic field? Upon what does the strength of a magnet depend?

11. Which offers the greater resistance to magnetic lines: Air or steel? Steel or copper? Wrought iron or air?

12. Why is a horseshoe magnet stronger than a bar magnet of the same size?

13. If a telephone receiver is examined it will be noticed that there is a steady pull between the disk and the magnet. How can this be explained?

14. What would be the effect if the disk and magnet poles should be moved closer together?

15. What relation exists between an electric current and magnetism?

16. What is a solenoid? Explain how a solenoid is similar to a bar magnet.

17. What happens when the current stops flowing in a solenoid? When the current is reversed what happens? Upon what does the strength of a solenoid depend?

18. What is an electromagnet? Why is an iron core used? What are the common forms of electromagnets? Name the advantages of each.

19. How is magnet wire insulated? Name advantages of each kind of insulation.

20. Explain how a fluctuating electric current flowing in the receiver coil will affect the diaphragm. Explain fully.

CHAPTER IV

SOUND

60. Sound.—Sound is produced by the vibration of some body, and is transmitted through space in the form of waves in the air; hence sound may be defined as wave motion in the air, capable of affecting the sense of hearing.

If a stone be dropped into a pond of water, a disturbance is set up which spreads in the form of waves in ever-widening circles.

If a tuning fork be started vibrating, sound is produced. The sound travels from the source of disturbance in the form of air waves. Investigation and experiment have shown that the air moves forward and backward in the direction in which the sound travels. At one instant the air in front of the fork is condensed, while that behind it is rarefied, and the next instant the air in front of the fork is rarefied while that behind it is compressed. The waves thus travel as a series of compressions and expansions. The sounds which issue from a telephone receiver are caused by the rapid vibration of the iron diaphragm.

Air is not the only substance that will transmit sound waves, water, wood, iron, etc., being useful in this respect. The early telephone experiments mentioned in the first chapter depended upon the transmission of sound waves through a tightly stretched wire. That some material medium is necessary for the transmission of sound waves can be shown by placing an electric bell under the receiver of an air pump and exhausting the air. As the air is exhausted from the receiver, the sounds from the bell grow weaker and weaker until they cease entirely when the air has been all exhausted, although the bell may be seen in full operation all the time.

Since vibrating bodies produce sound waves, it is to be expected that sound waves are capable of causing certain bodies to vibrate when the waves come into contact with such bodies. This is shown by the fact that a person talking in a room where there is a piano will cause certain wires of the instrument to vibrate and thus give out sounds. Another proof is that a heavy clap of thunder will often cause the windows of a house to shake violently. In the telephone the sound waves of the voice are directed against the diaphragm of the transmitter, causing it to vibrate.

61. Velocity of Sound.—It is well known that sound waves take a considerable amount of time to travel from one point to another. Experiments have shown that sound travels at the rate of about 1,090 ft. per second. In connection with this statement it is interesting to compare the speeds of electricity and light with that of sound. Electric waves and light travel with the same speed, which is in round numbers 186,000 miles a second, or about 930,000 times as fast as sound, since sound travels about 1 mile in 5 sec. That light travels at a much higher speed than sound can be verified easily by watching a locomotive at a distance and observing how long a time is required for the sound to reach the ear after one sees the steam issuing from the whistle.

62. Properties of Sound.—The properties of sound depend upon three different quantities: pitch, loudness, and timbre or quality.

63. Pitch.—Pitch is determined by the rate of vibration of the sounding body; that is, the number of vibrations per second determine whether the sounds given off will be "high" or "low," a high rate of vibration giving a higher pitched sound than a low rate of vibration. The short wires of a piano give off high-pitched sounds because their rate of vibration is rapid, and the longer bass strings which vibrate at a slower rate give off lower tones.

64. Loudness.—Loudness of sound depends upon the distance through which the sounding body vibrates. The distance through which the vibrating body moves is called the amplitude. Thus when a piano key is struck a sharp blow, the amplitude of the string will be greater than when a light blow is given the key. In the former case, the sound is louder or stronger than in the second case, though the pitch is the same. Loudness depends upon the energy of the vibration.

65. Timbre or Quality.—Quality is that property of sound not due to pitch or loudness, that enables us to tell one sound from another. For an example, a violin and piano may be sounding the same note, yet a difference in quality can be detected. This difference is not due to pitch or loudness. The characteristics of the waves given out by the two strings are different. This perhaps can be made clearer by considering a water wave. When such a wave is examined it is seen that many small waves surmount it. Similarly a string or other sounding body can start waves which consist of a fundamental wave and also small waves. These small waves are called overtones, and so change the wave form, and thus the quality of the sound, that we are able to tell one person's voice from another's, or to distinguish between the sounds of different musical instruments.

66. Transmission of Speech.—If the sounds of speech were simply in the form of waves of a given pitch, they could be transmitted over the telephone lines by merely opening and closing the circuit at the transmitter the required number of times per second. For every time the circuit was opened or closed there would be change of current through the receiver and a corresponding magnetic action which would cause the diaphragm to move. The loudness of the sound, which depends upon the amount of movement of the receiver diaphragm, could be controlled by variations in the strength of the current.

However, the vibrations due to the sound of the human voice are very complex, due to overtones and the variations of both pitch and loudness which take place hundreds of times a second. Hence to transmit such sounds is much more difficult than we might at first imagine, since the current flowing in the telephone circuit must vary with the slightest variation in the sounds to be transmitted, whether these variations be in timbre, pitch, or loudness.

67. Experiment 8.—*Apparatus:*

Telephone Receiver.
Two Dry Cells.
Copper Wire.
Coarse File.

(*a*) Connect one dry cell in series with the receiver as shown in Fig. 21. Attach one of the wires to the tang of the file. Draw the end of the other wire along the file so as to open and close the circuit repeatedly, in the meantime observing that the sound given off by the receiver is merely a series of clicks, which occur whenever the circuit is opened or closed. The pitch of the sound depends upon the rapidity with which the wire is drawn along the file.

(*b*) Repeat the above with two cells in series, and note that the only change is that the sound produced by the receiver is louder than when one cell is used. This shows that the loudness of sounds depends upon the energy of the vibrations of the diaphragm.

68. Variable Resistance.—With the telephone parts connected as shown in Fig. 22, a change in resistance in any of the parts causes a change in the current flowing in the circuit. Hence, instead of opening and closing the circuit to send variable cur-

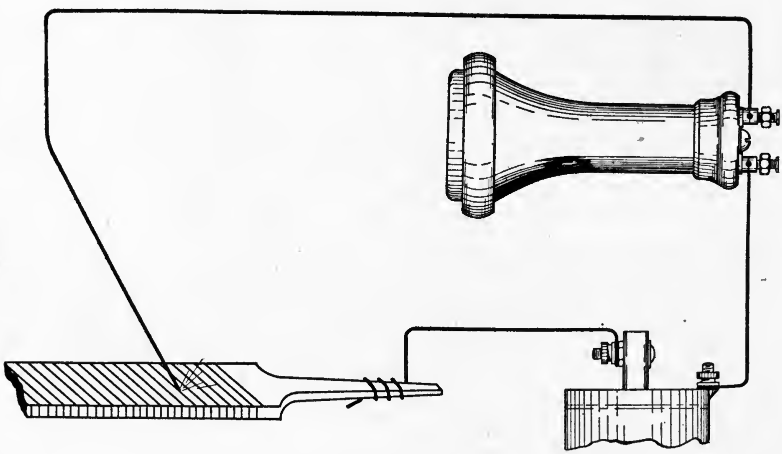

FIG. 21.

rents over the line, the resistance of the transmitter is changed from time to time by the sound waves of the voice. This variable resistance is obtained by the use of carbon.

Carbon is found in a number of well-known forms, such as charcoal, graphite, lampblack, etc. Hard carbon, similar to arc-lamp carbon, is used in telephone transmitters. The property of carbon which makes it suitable for this work is that the electrical resistance of a contact made of this substance can be regulated by the pressure applied. This resistance, which depends in a large measure upon the closeness of contact of the carbon parts, is decreased when the pressure is increased, and increased when the pressure is reduced. Such a contact is very sensitive, the slightest variation in pressure causing a change in its resistance. In the transmitter the changes in pressure necessary to cause variations in the electrical resistance of the carbon parts are produced by the vibrations of the diaphragm, and since the diaphragm is very sensitive and responds to the slightest

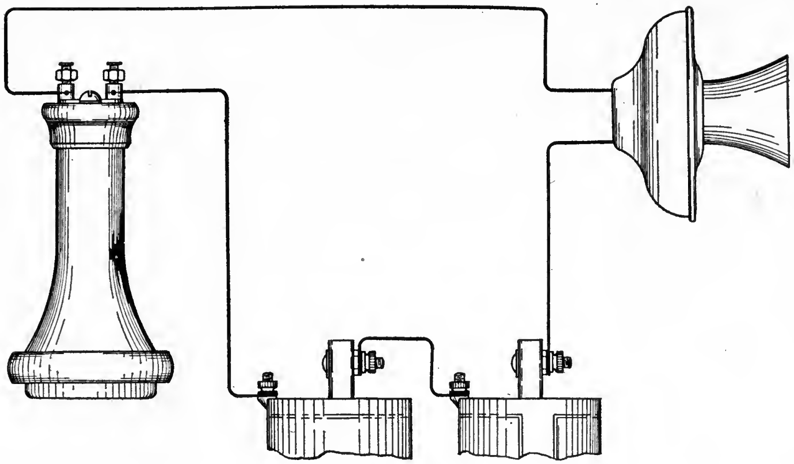

FIG. 22.

variations of pitch, loudness, and quality of the sound waves of the voice, the pressure on the carbon parts varies according to the characteristics of these sound waves.

CHAPTER V

TRANSMITTERS

69. The Carbon Transmitter.—In the earlier forms of transmitters such as the Edison and Blake, the variations in resistance were obtained through the action of the diaphragm on a single disk of carbon. The use of such instruments was limited by the fact that currents heavy enough to give the required transmission burned the surfaces of the carbon electrodes at the points of contact, soon destroying them. In order to provide a large number of points of contact, between which the current is divided, the granulated carbon type of transmitter was developed. This type is used at present to the exclusion of all others, and consists of two carbon disks, one stationary, the other movable and arranged to vibrate with the diaphragm, separated by a small quantity of granulated carbon. The greatest drawback to the early adoption of this type was the tendency of the granulated carbon to "pack" into a compact mass, which rendered the transmitter useless. In order to overcome this tendency the solid-back type was developed.

70. White Solid-back Transmitter.—The White solid-back transmitter which has been the standard of the Bell companies for many years, is shown in section in Fig. 23. The case, *A*, is made of brass, having a heavy cover, *B*, to which is attached the hard-rubber mouthpiece *M*. The mouthpiece serves to collect the sound waves and concentrate them upon the diaphragm, *D*, which is a thin iron or aluminum disk having its edge covered with rubber, *R*. As shown in Fig. 24, two springs, *S*, and *S'*, bear on the diaphragm. The short one holds the edge of the diaphragm firmly against the cover, *B*, and the long one rests on the diaphragm to dampen its vibrations and render it less sensitive to outside noises.

The electrodes, which are two polished carbon disks, *E* and *E'*, are contained in a brass chamber consisting of two parts. The rear electrode, *E*, which is the larger of the two, is firmly secured within the brass cup, *F*. The cup, *F*, is attached to the

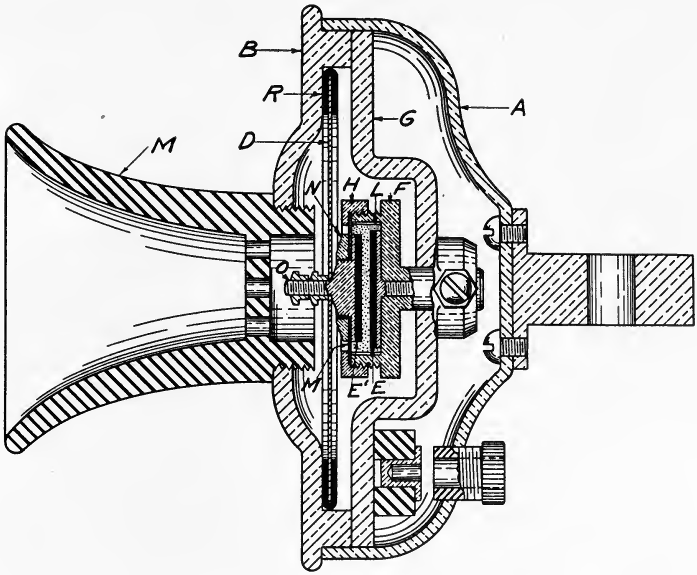

FIG. 23.

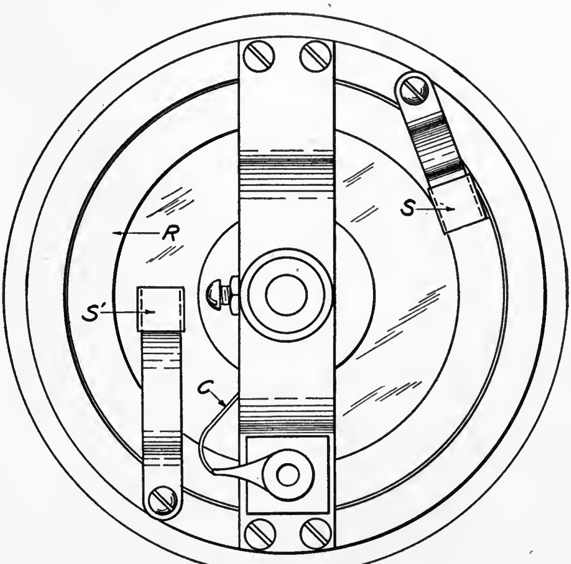

FIG. 24.

bridge, *G*, by means of the pin and set-screw. The front carbon is fastened to the stud, *O*, the shank of which passes through the diaphragm and is held in place by two check nuts. A thin mica washer, *M*, is clamped between the head of the stud and the threaded ring, *N*, the outer edge of this washer being held between the cap, *H*, and the cup, *F*. The center of the mica washer is therefore rigidly attached to the front electrode and partakes of its movements, while the outer edge is fastened to the rear electrode which is fixed. Any changes in relative position of the electrodes can take place only through the bending of the mica washer. In addition to holding the front electrode in its normal position, the mica washer closes the chamber containing the electrodes and keeps the granulated carbon with which this space is filled from falling out. The front electrode is insulated from the frame by the mica washer, and by the fiber lining, *L*, which keeps the granulated carbon away from the sides of the cup. Since one terminal is connected to the front electrode by the flexible connection, *C* (see Fig. 24) and the other to the frame of the transmitter, any current which passes through the instrument must flow through the granulated carbon.

The operation of the solid-back transmitter is as follows: The sound waves of the voice of the person speaking cause vibration of the diaphragm, which, being rigidly connected to the front electrode, causes that to vibrate also, as the mica washer which holds it in place is very flexible. Since the back electrode is held stationary, the granulated carbon is subjected to variations in pressure. As a result the current flowing through the transmitter is varied.

71. New Western Electric Transmitter.—The new Western Electric transmitter, shown in Fig. 25, is a modified form of the White instrument. As in the White transmitter, the front electrode is carried on a mica washer and is connected by a stud to the center of the diaphragm, and the rear electrode is fixed in the bottom of the electrode chamber. This chamber is attached to the back of a metal cup, *S* (which takes the place of the bridge in the White transmitter) by the threaded part, *C*. This not only holds the chamber in place, but also holds the outer edge of the mica washer firmly between the two parts.

The metal cup and diaphragm are insulated from the shell of the transmitter at *R*, so that neither of the electrodes is

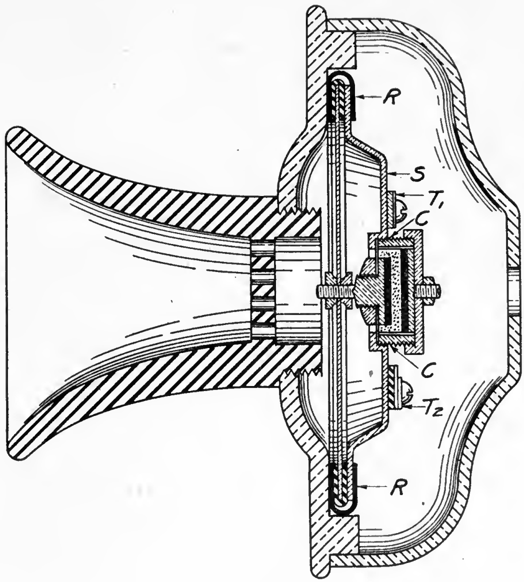

Fig. 25.

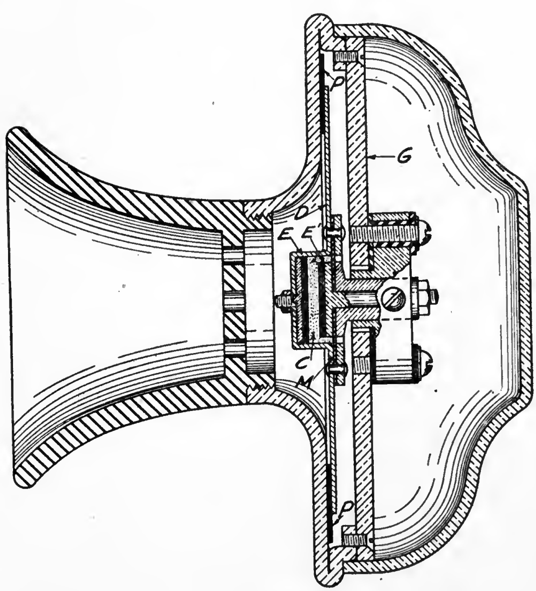

Fig. 26.

connected to the exposed metal parts. Of the terminals, shown in the figure, T_1 is connected to the cup, and the other, T_2, which is insulated from the cup, is connected to the front electrode by a flexible connection.

72. Kellogg Transmitter.—The Kellogg Switchboard and Supply Co.'s transmitter is shown in section in Fig. 26. It will be immediately noticed that the chief difference between this instrument and those previously discussed is that the electrode cup is made a part of the diaphragm, *D*, and therefore partakes

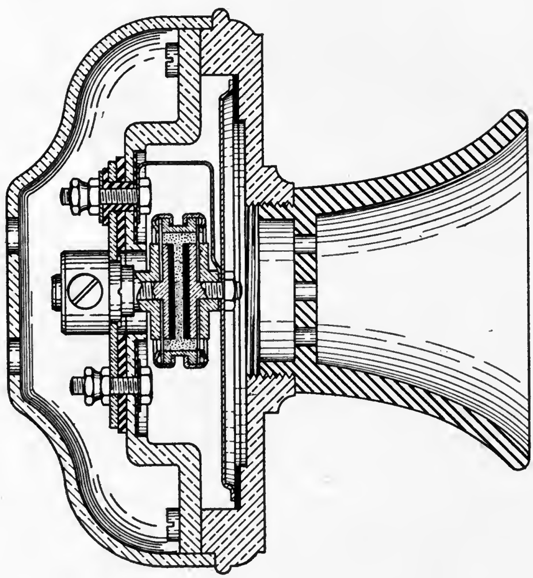

FIG. 27.

of its movements. In order that the moving parts may not be too heavy to respond readily to the sound waves of the voice, the diaphragm is made of hard-drawn aluminum with the electrode chamber stamped in its center. The diaphragm, *D*, the front carbon disk, *E*, which is attached to the bottom of the chamber, the granulated carbon, *C*, and the mica washer, *M*, are the movable parts. The disk *E′* is stationary, as it is rigidly attached to the bridge, *G*. This bridge is a straight piece of hard-drawn brass.

To prevent the transmitter's taking up outside noises and being affected by mechanical vibration which might interfere with talking, the diaphragm rests on a soft pad, *P*. Two damping springs having cushioned tips have been provided as in the White instrument. The working parts of this transmitter are all insulated from the case.

73. Monarch Transmitter.—The Monarch transmitter shown in Fig. 27 differs from those already studied in having both its electrodes mounted on flexible mica washers which support the carbon chamber. The rear electrode, which is attached to the bridge, is the only fixed part. The diaphragm is of aluminum and is separated from the case by an insulating ring. The flexible connection between one terminal and the front electrode is shown in the figure. The stud of the rear electrode, which is insulated from the bridge, is connected to the other terminal.

FIG. 28.

74. Operator's Transmitter.—In Fig. 28 is shown a special form of transmitter for switchboard operators' use. As this instrument is provided with a plate which rests on the operator's breast, the long curved mouthpiece is always in the proper position for use. The breast transmitter and watch-case receiver described in the next chapter make up the operator's set.

In cases where the operator is compelled to leave the switchboard frequently to attend to other duties, as in small exchanges, many of the advantages of the breast transmitter are lost. In such cases a transmitter of the same form as the subscribers' instrument is suspended by adjustable cords in front of the operator.

75. Carbon Electrodes.—The disks for use in transmitters are made of specially prepared hard carbon. The faces in contact with the granulated carbon are made as nearly true as possible, and are highly polished. The reverse sides are copper plated and then soldered to the backing plates of brass. When assembled, the electrodes must be parallel to each other if good results in operation are to be obtained.

The granular carbon is very hard, uniform in size, and free from dust. As mentioned above, a great deal of trouble was caused by the packing of the granulated carbon in the earlier transmitters, due to moisture, unevenness in size of carbon grains, and by wedging apart of the carbon disks. These difficulties were overcome by making the chamber containing the carbon grains waterproof; by making the grains of uniform size and hard enough not to crush in service; and by improvements in manufacture, so that the electrodes are always parallel to each other.

Any transmitter can be packed by pulling the diaphragm forward so as to widely separate the electrodes. This allows the carbon granules to settle and wedge the electrodes apart. In the earlier types this could be done by placing the lips against the mouthpiece and drawing in the breath. In order to prevent this, modern mouthpieces are slotted at the base.

According to a recent report of the American Telephone and Telegraph Co. there were designed, constructed, and installed, during the 37 years from 1877 to 1914, 53 improved types and styles of telephone receivers and 73 types and styles of transmitters. These figures do not include hundreds of minor improvements made in both transmitters and receivers.

QUESTIONS

1. How are sounds transmitted by the telephone? Does sound actually travel from one instrument to the other?

2. What are the parts of the telephone used in transmitting the sounds of speech?

3. Will a telephone work if the battery be removed? Why not?

4. What do you understand sound to be? How is sound produced? How transmitted from place to place?

5. How fast does sound travel through air? Compare the speed of sound with that of light. With electricity.

6. Upon what three things does the quality of sound depend?

7. What is pitch? Loudness? Timbre?

8. Explain how a telephone receiver produces sound.

9. Explain how sound waves can cause the transmitter diaphragm to move.

10. What are the characteristics of the waves set up by the sounds of speech?

11. Why can not the sounds of speech be transmitted by repeatedly opening and closing the telephone circuit as in the experiment?

12. Examine carefully as many different makes of transmitters as possible. What differences do you find?

13. Explain how changes in transmitter resistance can cause the receiver to operate. How are these changes in resistance caused?

14. Why is carbon used in transmitters?

15. Explain briefly the construction and action of the solid-back transmitter.

16. What is meant by packing of a transmitter? How is packing caused?

17. Does the carbon transmitter ever open the battery circuit? Answer this question by studying the transmitters shown in Figs. 23 to 27.

CHAPTER VI

RECEIVERS AND INDUCTION COILS

76. The Receiver.—The telephone receiver makes use of the fluctuating electric currents to reproduce the sound waves which caused these current variations at the transmitting end of the line. Receivers are electromagnetic in their action, as has been briefly explained in an earlier chapter.

77. Early Receivers.—Early receivers were of the single-pole type; that is, the diaphragm was influenced by only one pole of the magnet. An early form of receiver is shown in Fig. 10, the parts being named. The operation of such a receiver is due to the magnetic action of the current flowing through the coil, which either weakens or strengthens the magnetic field of the permanent magnet, and thus causes the diaphragm to vibrate in unison with the changes of current strength.

The magnetic circuit of this type of receiver contains a very long air path; hence a considerable current is required to produce the required changes in magnetic force. Another serious objection to this type of receiver is the ease with which the adjustment is disturbed, owing to the magnet being attached to the shell at the end farthest from the diaphragm.

78. Induced Electric Pressure.—A further investigation of the relations existing between magnetism and electricity shows that when a wire is moved in a magnetic field so as to cut the magnetic lines, an electrical pressure is set up in the wire. The value of this pressure depends upon the rate of cutting the magnetic lines, or, in other words, the number of lines cut per second.

A pressure generated by the relative movement of a conductor and a magnetic field, is called an induced pressure.

The direction of the induced pressure depends upon the direction of the cutting of magnetic lines. Hence a movement of a conductor in one direction through a magnetic field will cause a pressure in one direction, and a movement in the opposite direction will generate a pressure in the opposite direction. A pressure can be induced in a coil by changing the strength of the magnetic field inside the coil. Since a magnetic line makes a complete loop or path, it is evident that if the number of lines inside a coil are changed, some lines must be cut by the coil during the change. Increasing the strength of the field inside a coil sets up a pressure in one direction, while decreasing the number of lines sets up an opposite pressure, because the lines are cut in opposite directions during these changes.

The induced pressure will be maintained only so long as the relative motion of conductor and field is kept up, or while magnetic lines are being cut.

In general we may say that whenever the magnetic field surrounding a conductor varies in intensity an electrical pressure will be set up in the conductor, and if the circuit be closed a current will flow.

Induced pressure may be either direct or alternating, depending upon whether the magnetic lines are cut continuously in one direction or the direction of cutting is reversed from time to time.

79. Direct Current.—A direct current flows continuously in one direction, although its strength may vary from time to time. The flow of a current of electricity caused by the pressure of a battery is in one direction.

Direct currents may be divided into two classes, continuous and pulsating. A continuous current is one the strength of which does not change materially from instant to instant. A pulsating current, however, is a direct current the strength of which may vary from time to time without change in the direction of flow. Continuous currents are used for lighting and power purposes. Pulsating currents are made use of in telephone practice.

80. Alternating Currents.—An alternating current is one which varies continuously in strength and changes direction periodically.

81. Experiment 9.—*Apparatus:*

Two Telephone Receivers.

About 50 ft. of Annunciator Wire.

Connect two telephone receivers by about 25 ft. of copper wire. Have a person in another room to assist you and see if sounds can be transmitted without using any batteries in the circuit.

It will be seen from the above, since no battery or other source of power is used, that the only energy used in operating this telephone is that of the sound waves themselves. This energy is very small; hence the resultant current sent from one station to another is likewise small, and sounds can be transmitted only a short distance. It was early realized by those interested in the development of the telephone that if the telephone was to become of any commercial value, one capable of transmitting speech to a greater distance was necessary.

82. The Receiver as a Transmitter.—Two receivers connected as shown in Fig. 29 formed the first practical telephone for the transmission of speech, and constituted Bell's invention. The operation of such a telephone is as follows:

Suppose that *A* is the sending or transmitting station, and *B* the receiving station. The sound waves due to the sounds of speech strike the diaphragm at *A* and cause it to vibrate in unison

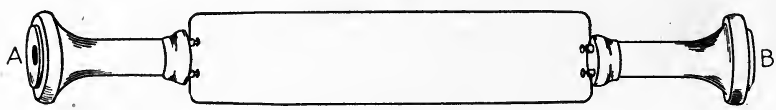

Fig. 29.

with the waves of sound. That is, every variation in the pitch, loudness, or timbre of the sounds affects the diaphragm. The vibrations of the diaphragm cause variations in the strength of the magnetic field, since every vibration causes a change in the length of the air gap between the disk and the pole of the magnet, and thus increases or decreases the number of magnetic lines which pass through the coil.

Every time the magnetic field is disturbed, induced currents are set up in the coil. These electrical currents flowing through the coil at *B* cause the diaphragm at *B* to vibrate in unison with that at *A*, and thus produce sound waves like those which cause the diaphragm at *A* to vibrate.

The receiver seemed to be quite satisfactory, for it would work when large enough currents could be made to flow through it. Hence efforts were made to improve the transmitter, which resulted in the development of the carbon transmitter. We have observed that the carbon transmitter does not generate its own current, but merely controls the current from some outside source, such as batteries.

83. Bipolar Receiver.—In the bipolar type of receiver the air gap is very much shorter than in the single-pole receiver, since both poles are near the diaphragm. The working parts of the receiver are attached to the case near the diaphragm, or are arranged in an inner metallic case so that the adjustment is independent of the outer case.

84. Western Electric Receiver.—Fig. 30 shows the construction of the Western Electric bipolar receiver. The shell is of hard rubber and is made in three parts. Two permanent bar magnets are employed, being fastened together so as to form a single horseshoe magnet. Two soft-iron pole pieces P and P' are attached to the ends of the magnet near the diaphragm. Each one of the soft-iron poles is surrounded by a coil of very fine insulated copper wire, marked M and M' in the figure. Immediately in front of the poles is placed the sheet-iron diaphragm D which must not touch the pole pieces even when vibrating through its widest range. One of the magnet poles is N. and the other is S. The diaphragm forms a part of the magnetic circuit, and where the lines enter the diaphragm a S. pole is formed, and where the lines leave the diaphragm a N. pole is formed. Thus the diaphragm acts as an armature and by the attraction of the magnet is constantly bent or dished toward the pole pieces.

The coils on the pole pieces are connected so that the magnetic lines set up by a current passing through them will make one a N. pole and the other a S. pole. The currents flowing through the coils in one direction tend to strengthen the field of the permanent magnet, and currents flowing in the opposite direction tend to weaken the field of the permanent magnet. The diaphragm will spring away from the pole pieces when they are weakened, and when the current ceases the diaphragm will be drawn back toward the pole pieces. When the magnetic field set up by the coils assists the field of the magnet, the diaphragm will be drawn nearer to the pole pieces, and when the current stops the diaphragm will again spring back to its normal position.

From this it will be seen that if a current flows first in one direction and then in another, or an alternating current flows in the receiver coil, the diaphragm will answer every impulse of current, no matter from which direction it comes. Alternating currents flow in circuits where an induction coil is used.

If the receiver were not equipped with a permanent magnet, its magnetic field would be strengthened by a current flowing

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through the coil in either direction, and the diaphragm would be attracted or drawn in toward the pole whenever a current flowed. However, an alternating current flowing in the receiver

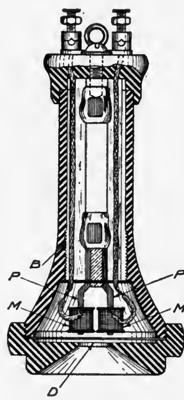

Fig. 30.

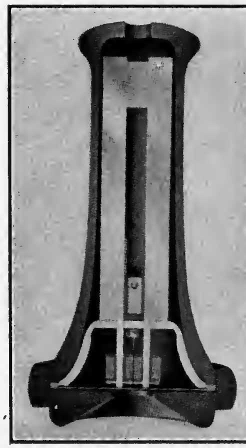

Fig. 30*a*.

coil will alternately strengthen and weaken the field of a permanent magnet, in the first case drawing the diaphragm out of its

Fig. 30*b*.

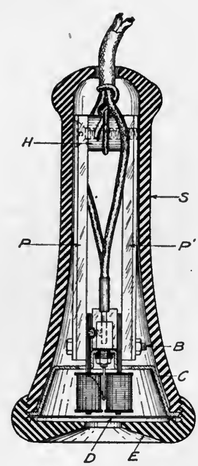

Fig. 31.

normal position, closer to the pole, and when the field is weakened, allowing it to spring farther away. Hence, when a permanent magnet is used, an alternating current is capable of producing a greater vibration of the diaphragm than would be the case if a soft-iron core were used. The pitch is also an octave lower.

The resistance of the coils M and M' is usually about 60 ohms for the pair, or 30 ohms for each coil.

The magnet is attached to the case by means of a threaded block which screws into the internal thread B. This arrangement allows of close adjustment of the distance between the pole faces and the disk, and as a result of the close coupling, changes in temperature do not readily affect this adjustment. The latest type of this receiver no longer has exposed binding posts. This is shown in Fig. 30*a* and *b*. This receiver is the standard in use by the Bell Co.

85. The Kellogg Receiver.—The Kellogg receiver with internal binding posts for the wires, or cords, as they are commonly called, is shown in section in Fig. 31. The shell, S, and

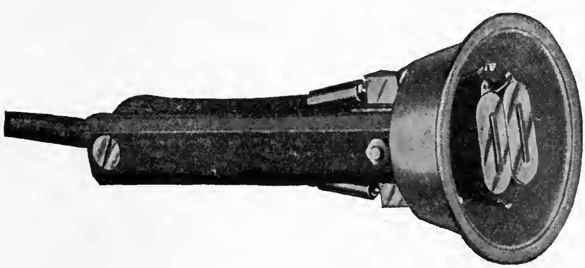

Fig. 32.

the cap, E, are of composition rubber, the shell consisting of a single piece. In order to make the cap stronger and less liable to split under hard usage, a perforated copper disk is molded into it. The diaphragm, D, is firmly clamped between the cap and the brass cup, C, to which the permanent magnets are attached. Therefore, the adjustment which is made between the diaphragm and the poles of the magnet at the time of manufacture is permanent.

The receiver can be completely taken apart, without breaking any connections, by removing the cap. Fig. 32 shows the receiver with shell removed. The permanent magnets, P and P', Fig. 31, are placed side by side with corresponding poles at opposite ends and bolted together at the rear end, holding the block of iron, H, firmly between them, in effect forming a U magnet. At the diaphragm end the soft-iron pole pieces are attached. The two pole pieces are separated by a part of the brass cup, and are firmly clamped between the permanent magnets by the brass bolt, B. Brass being a nonmagnetic substance, as has been shown above, has no effect on the magnetic field of the magnet. In order that no strain may be placed upon the binding posts when the receiver is in use, the cord is firmly tied to the block, H.

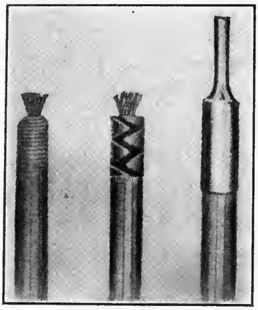

Fig. 33.

As receiver cords are a considerable source of annoyance, it is interesting in connection with this receiver to note the method of fastening the metal tips to the flexible strands of the cords. Fig. 33 shows the details of making this connection. The cord tip is first wrapped tightly with wire, and the strands are brought back over this and firmly held in place by a metal clamp, as

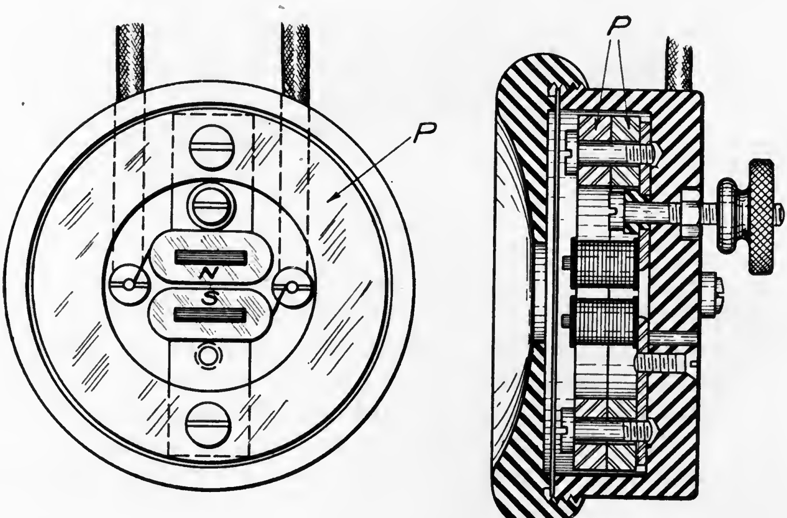

Fig. 34.

shown. The tip, which is turned and bored from a solid brass rod, is then soldered over this special clamp.

The particular advantages of a receiver with internal binding posts are that the binding posts, being inside the case, are not subject to injury; the cord at point of contact is not subject to damage; the user of the receiver cannot receive shocks from the same, since he can not touch the posts; and the receiver has a very neat appearance.

86. Operator's Receiver.—The operator's receiver (or watch-case receiver, as it is often called on account of its shape) is shown in Figs. 34 and 35.

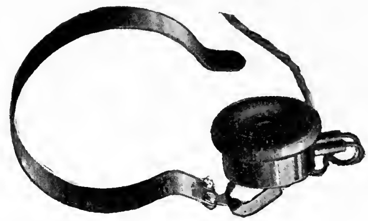

Fig. 35.

This instrument is a double-pole receiver; hence the operation is the same as that of the hand receivers described above. The permanent magnet consists of steel rings, *P*, which are cross-magnetized so that a N. pole exists on one side and a S. pole on the other. The soft-iron pole pieces are clamped between the bottom ring and the case, as shown in the sectioned view.

87. Sensitiveness of Receivers.—The sensitiveness of a receiver depends upon the strength of the permanent magnet and upon the diameter and thickness of the diaphragm, and its distance from the magnet poles. A thin diaphragm responds very readily to currents of high frequency (or rapid vibration) and gives clear and sharp tones, while a thicker one is more rigid and responds readily only to those currents having low frequency. About $\frac{1}{100}$ in. is the average thickness of sheet iron used in receiver diaphragms, the diameter being about $2\frac{1}{4}$ in. For successful operation a thick diaphragm must be larger than a thin one. The chief objection to a very sensitive receiver is that it reproduces any disturbances which the line may have taken up as faithfully as it does the sound from the transmitting end. A very sensitive receiver, therefore, would be unsuitable for use on a grounded line or on a metallic circuit of poor construction. On a long metallic circuit of good construction, the simple weakening of the transmitter current may be compensated to some extent by using a sensitive and delicate receiver.

To secure loudness, the receiver must be arranged so that the alternating currents from the line produce the largest possible movement of the diaphragm in both directions from its normal position. The strength of the permanent magnet must be designed with reference to the properties of the diaphragm and the strength of the line currents. If the permanent magnet be too strong, the diaphragm will be dished excessively, and no considerable movement is possible when the magnet is made still stronger, although a large movement takes place in the opposite direction when the magnet is weakened. If the permanent magnet be too weak, the movement of the diaphragm will be large when the magnet is strengthened, and small when it is weakened. Hence, if the permanent magnet be either too strong or too weak, the receiving will be imperfect.

88. Direct-current Receiver.—A later development in receiver construction is the direct-current receiver.

In common battery telephone practice when the line is in use there is a steady current flowing from the central office to the subscriber's instrument to energize the transmitter of the latter. In the direct-current receiver this current is made to flow through the windings of the receiver, thus producing a magnetic field which takes the place of that due to the permanent magnets in the common receiver. Hence no permanent magnets are required. This action will be more fully understood when the common battery system is studied in a later chapter.

89. The Automatic Electric Co.'s Direct-current Receiver.—The Automatic Electric Co.'s direct-current receiver is shown in

Fig. 36.

Fig. 36. The working parts of the receiver are contained within the brass cup, *S*. The winding consists of a single coil mounted on the core, *C*, which in turn is attached to the center of a U-shaped iron stamping having its ends, *P* and *P′*, bent up and partially surrounding the coil.

The direct current flowing in the line magnetizes the core and steel stamping. From the shape of the magnetic circuit, it is evident that at any given time the end of the core near the diaphragm will be a N. pole, and the ends, P and P', will be S. poles, or *vice versa*. This receiver, then, has all the advantages of the bipolar receiver in having both its poles near the diaphragm. When the talking circuit is open there is no current flowing in the coil, and the diaphragm will be perfectly flat at a short distance from the poles. However, as soon as the talking circuit is closed, direct current flows through the coil and draws the diaphragm toward the poles of the magnet, exactly as is done in the case of the polarized receivers. When the fluctuating voice currents flow through the coil they will either strengthen or weaken the direct current flowing in the coil, and will cause the magnetic field to fluctuate, thus causing a movement of the diaphragm. This receiver is designed to operate when current values range from 0.45 to 0.80 amp.

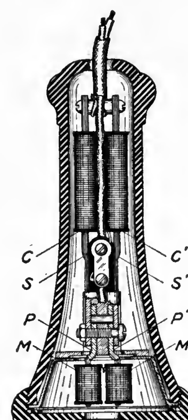

FIG. 37.

90. The Monarch Direct-current Receiver.—The Monarch direct-current receiver shown in Fig. 37 operates on quite a different plan than the one just discussed. This receiver has, instead of permanent magnets, two soft-iron cores, S and S', on which are mounted two long coils, C and C'. Soft-iron pole pieces are attached to the ends of these cores, as shown, and carry the two coils, M and M'. The two sets of coils are connected in parallel to the cords of the receiver. The coils C and C' have a somewhat lower resistance than the coils M and M'; and, owing to the fact that they have a larger number of turns and have iron cores of larger size, they have a greater impedance and are known as impedance coils. The direct current of the line, therefore, will flow very readily through the two long coils and will magnetize the cores, giving the effect of a permanent magnet, but on account of the high impedance of these coils, the high-frequency voice currents will flow more readily through the coils M and M', and will affect the magnetic strength of the cores exactly as do the coils of the polarized receiver.

91. Self-induction.—A most important property of electric circuits is their action and reaction upon each other. Fig. 15 shows that every current carrying wire is surrounded by a magnetic field. The current in the wire builds up this field. It has also been shown that whenever the intensity of a magnetic field around a conductor changes either by being built up, by decay, or by relative motion in such a way that the magnetic lines cut across the conductor, an electromotive force is developed in the conductor. This electromotive force is in such a direction as to oppose any change in the current flowing or in the magnetic field surrounding the conductor. This principle of electro-magnetic induction evidently does not depend upon the source of the magnetic field. Hence an e.m.f. is induced in a conductor when the current in the conductor changes, for every change in current is accompanied by a change in the density of the magnetic field which is due to the current. This principle of inducing an e.m.f. by variations in the current flowing is known as self-induction.

When an e.m.f. is impressed upon a circuit, the current can not rise to a maximum value at once on account of the counter-pressure of self-induction.

It is very evident that the value of the counter e.m.f. of self-induction depends upon the rate at which the flux surrounding the conductor changes; hence it will depend upon the shape of the circuit. If the conductor is wound into a coil of such shape that all of the magnetic lines thread through it, the counter-pressure of self-induction for a corresponding change in the current will be greater than when the conductor is straight.

92. Self-inductance.—If a conductor is wound into a coil so that if the current varies at the rate of 1 amp. per second the pressure of self-induction is 1 volt, the coil is said to have unit self-inductance. Self-inductance is thus the numerical value of the property which causes a counter-pressure of self-induction to be developed. It may also be defined as the ratio of the flux threading through a coil to the current producing it. For any given coil with an air core the self-inductance is a constant quantity. If the coil has an iron core the self-inductance is not constant for the reason that the flux does not vary uniformly with the current. In other words, the permeability of iron is not constant, but varies with the current.

93. Mutual Induction.—If the magnetic flux produced by a current in one coil threads through a neighboring coil, an electromotive force is also induced in the second coil. This e.m.f. is said to be due to mutual induction. In so far as the physical principles are concerned, self and mutual induction are alike.

The only difference is that in one case the e.m.f. is induced in the circuit in which the current is flowing, and in the other case the e.m.f. is induced in a neighboring but separate circuit.

94. Impedance.—In any circuit that has self-induction any change in the current will be opposed. When the current is increasing the induced e.m.f. opposes the increase and when the current is decreasing the e.m.f. induced is in such a direction as to oppose the decrease. The value of this opposing e.m.f. depends not only upon the self-inductance of the circuit or coil, but also the rate at which the current is changing.

If an alternating e.m.f. of a given value is impressed upon a coil which has some self-inductance, the resulting current will be smaller than if a constant direct e.m.f. were impressed upon the same coil. The ratio of the e.m.f. to the current flowing is called the impedance. In other words, the alternating e.m.f. divided by the impedance gives the current in the circuit. The higher the impedance, the smaller the current. As the impedance increases with the frequency, the higher the frequency the smaller the current in an inductive circuit. The currents in a telephone line which are produced by the voice are of high frequency, hence only a small current will pass through a coil which has considerable inductance.

95. The Induction Coil.—In order to transmit telephone messages to any considerable distance it is necessary to use

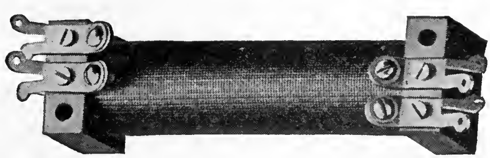

FIG. 38*a*.

induction coils in the circuit to increase the voltage, so that the resistance of the line may be overcome.

The induction coil is designed to raise the voltage of the line current, which is controlled by the transmitter. The current through the transmitter and battery is a direct current but is pulsating, due to the variable resistance of the transmitter. Another function of the induction coil is to change this pulsating direct current to an alternating one. An induction coils are shown in Figs. 38*a* and 38*b*.

The induction coil consists of an iron core and two windings of insulated wire, known as the primary and secondary, as shown in the diagram of Fig. 39. The core is made of a bundle of iron wires which have been softened by annealing. The primary winding consists of from 250 to 600 turns of insulated copper wire, and the secondary of from 1,500 to 3,500 turns. The primary is made of larger wire than the secondary, and the two windings are not connected inside the coil. The primary is connected in the circuit with the transmitter and batteries, as

FIG. 38b.

shown in Fig. 40, and the secondaries are connected to the line. Hence the only currents which flow in the line are the alternating currents induced in the secondaries of the coils.

The operation of the induction coil is as follows: The pulsating current flowing through the primary induces a pulsating magnetic field in the iron core, increasing as the current increases and decreasing as the current decreases. The secondary, being wound on the same core as the primary, must cut the magnetic

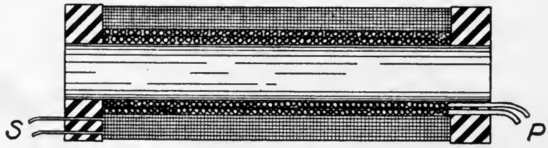

FIG. 39.

lines every time the field changes. Thus a voltage will be induced in the secondary winding every time there is a change in the value of the core magnetism. When this field increases there will be a voltage induced in one direction, and when it decreases a voltage will be induced in the opposite direction. An alternating current thus flows in the line. Since the magnetic field is of the same value through each of the turns of both the primary and secondary, at any instant the voltage of one turn of the primary which causes the change of field must equal the voltage caused by that field in one turn of the secondary. Since the turns are all in series, the primary and secondary voltages will be in the same ratio as the number of turns in the primary and secondary windings. Thus for a coil having 500 primary turns and 2,000 secondary turns, the voltage ratio would be 1 to 4; and if the primary pressure were 3 volts, the secondary would be 12 volts.

The induction coil helps transmission by permitting the use of a low-resistance battery circuit; by producing alternating currents; and by producing currents of higher voltage than could be successfully handled by a transmitter.

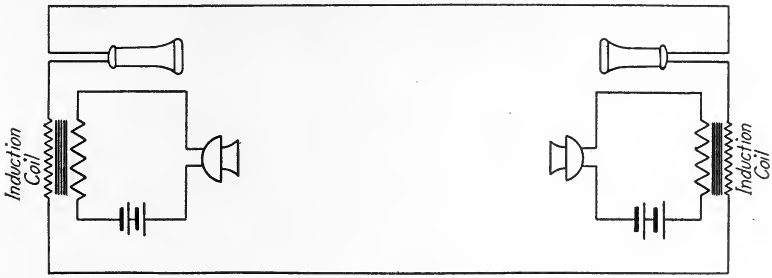

FIG. 40.

QUESTIONS

1. Explain the action of a telephone receiver.

2. Why is a permanent magnet used instead of a soft-iron core? Give two reasons.

3. Explain how a pressure can be generated by induction.

4. What is a direct current? How is it produced?

5. What is an alternating current? How is it produced?

6. Are most induced currents direct or alternating? Why?

7. Can a receiver be used as a transmitter? If so, explain its action as such.

8. What are the objections to the use of a single-pole receiver?

9. Explain the construction of a double-pole receiver.

10. Upon what does the sensitiveness of a receiver depend?

11. Why are receivers not made as sensitive as possible?

12. What are the advantages of inside binding posts?

13. Why should the magnet be attached to the case near the diaphragm?

14. For what purpose is an induction coil placed in a telephone circuit?

15. What are the principal parts of an induction coil?

16. Explain how an induction coil increases the voltage in a telephone system.

17. What determines the ratio of the primary voltage to secondary voltage?

18. In what ways does an induction-coil help transmission?

19. Why is an alternating current better than a pulsating direct current in the operation of a receiver?

20. Explain the operation of the Monarch direct-current receiver.

21. Explain self-induction; mutual induction. Cross talk is usually due to mutual induction.

22. What is the self-inductance of a circuit if a pressure of 2 volts is induced when the current in the circuit varies at the rate of 50 amp. per second? The unit of self-inductance is called a henry.

23. What quantities determine the current strength when an alternating pressure is connected to a circuit?

CHAPTER VII

SIGNALLING APPARATUS AND CIRCUITS

96. Signalling Circuits.—So far, only the transmitting and receiving circuits (or, as they are generally called, the talking and listening circuits) have been considered. In addition to these circuits, some means must be provided for signalling the subscriber when he is wanted, and likewise for him to signal the central operator when he wants some other party.

In the local battery system, that is, the system where each telephone instrument has its own batteries, a hand generator or small dynamo and a bell or ringer form the signalling circuit.

97. Generators.—In the study of magnetism it was said that if a conductor be moved in a magnetic field, so as to cut the magnetic flux, an electric pressure is generated, and if the circuit be closed a current will flow. The operation of the electric generator is dependent upon this principle.

Faraday, a noted scientist, discovered this principle of magneto-electric induction in 1831. Following out his experiments along this line, he made the first dynamo known. This model consisted of a disk of copper 12 in. in diameter, which was mounted on a shaft so that it was free to rotate with the shaft. A permanent magnet was so placed that its poles embraced the disk and the magnetic lines of the permanent magnet passed through the disk. When this disk was caused to rotate between the poles of the magnet, the magnetic lines were cut and an electrical pressure was induced.

Since Faraday's time the dynamo has been developed through numerous types and with many modifications of designs, but all have been developed on the principle which he laid down and which has been stated as follows:

When a conductor is moved in a magnetic field so as to cut the magnetic lines, there is an electromotive force induced in the conductor, in a direction at right angles to the direction of motion and also at right angles to the direction of the magnetic lines.

While the Faraday disk dynamo did not generate any considerable pressure, it led the way to the development of other forms of the dynamo, in which the arrangement of the conductors with respect to the field was better suited to the development of large pressures and currents.

The necessary elements of a dynamo for the generation of current are a magnetic field and a conductor or conductors which can be caused to move across the field. The simplest form of such a machine is shown in Fig. 41. A loop of wire is mounted on a shaft so that it can be rotated on its axis and cut through the magnetic lines passing from N. to S. At the instant at which the loop is in the vertical position, as shown by the full lines, the conductors are moving parallel to the magnetic lines, and since there are no lines being cut, no pressure is induced.

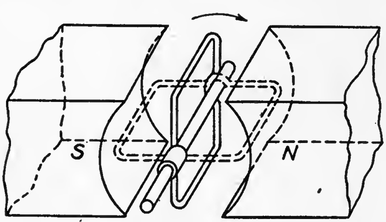

Fig. 41.

When the loop is in the horizontal position, as shown by the dotted lines, it is moving at right angles to the magnetic lines; and as the rate of cutting magnetic lines is a maximum in this position, the pressure induced will be a maximum.

The direction of the pressure induced, when the conductor is passing through the field in this direction of rotation, is from front to back on the right side of the loop, and from back to front on the left side of the loop. The pressures in the two sides of the loop will tend to cause current to flow in the same direction around the loop and the pressure in the loop will be the sum of the pressures induced in the two conductors.

When the loop is moved 90 degrees further it will again be in a vertical position, but the conductor which was at the top in the first case will now be at the bottom, and the other will be at the top. Advancing the loop past this point, a pressure will again be induced in the conductor, but the position of each conductor with respect to the N. and S. poles will be reversed. Since the positions of the conductors have been interchanged and the current has the same direction with respect to the magnetic field and the direction of motion, it will flow through the loop in a direction opposite to that of the first half revolution. That is, the direction of the flow of current through the loop will reverse every 180 degrees.

If two rings be attached to the loop, one being connected to each end, and mounted so they will rotate with the shaft and loop, the pressure at these rings will reverse each time the loop has passed through 180 degrees. Current can be taken from these rings by placing a brush on each of the rings, as shown in Fig. 42 and connecting them to a conducting circuit.

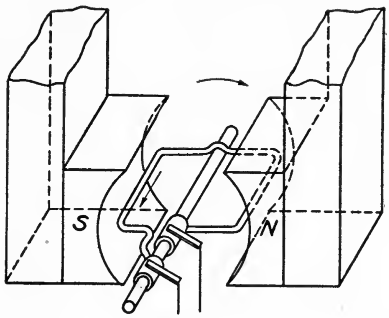

FIG. 42.

Since the direction of the induced pressure changes each 180 degrees, the flow of current in the circuit will reverse correspondingly. That is, an alternating current will flow in the circuit. This changing of current from zero to a maximum value, then decreasing to zero, reversing, building up to a maximum value in the opposite direction, and then decreasing to

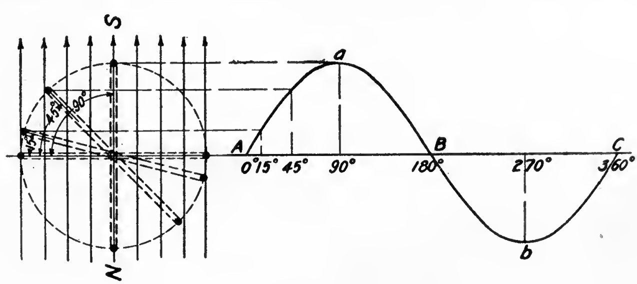

FIG. 43.

zero again, is shown by Fig. 43 and is known as a cycle. The number of cycles per second is called the frequency. When the loop is in the vertical position as shown by full lines in Fig. 41, the pressure is zero corresponding to point *A*, or zero degrees, Fig. 43. The curve above the line *ABC* shows positive voltages, and that below shows negative voltages.

If this generator be supplied with a commutator as shown in Fig. 44, the output will be a pulsating direct current. It has been shown above that the current in the armature coil reverses every time the conductors pass from one pole to the next, and that an alternating current flows in the coil. However, the coil is so connected to the commutator that every time a conductor passes through a neutral point, the brush contact is changed from one segment to the next; thus the current through the brushes is always in the same direction.

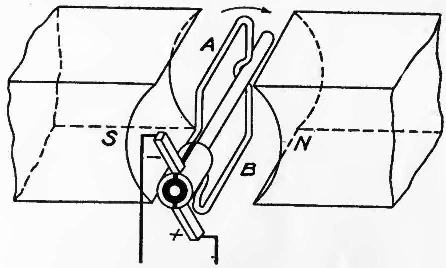

FIG. 44.

The curve in Fig. 45 shows the effect the commutator has on the alternating voltage represented in Fig. 43.

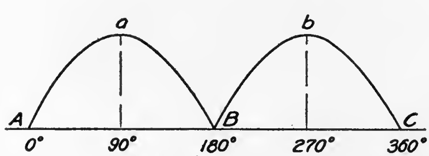

FIG. 45.

98. The Telephone Generator.—The telephone generator or magneto is usually an alternating-current generator, one form of which is shown in Fig. 46.

The magnetic field of such a generator is produced by U-shaped permanent magnets. In the figure, five permanent magnets are shown, but the number used varies from two to six in different classes of service, depending upon the ringing power required. Several small magnets instead of one large one are used, because it is easier to properly shape the smaller ones, and also because small pieces of steel can be magnetized more readily than large ones. It is necessary that the permanent magnets retain their strength indefinitely, if the generator is to remain in service. Cast-iron pole pieces are usually attached to the permanent magnets in order to have the pole face conform to the shape of the armature, and thus have a small air gap for the magnetic lines to cross. The pole pieces are also made of use in holding the magnets together, and are usually connected with each other by brass rods which hold them the proper distance apart. It is very necessary that this adjustment be maintained, as there is little clearance between the pole faces and the armature. If it ever becomes necessary to take a magneto-generator apart, care should be taken in assembling the magnets so as to place all like poles together. In case of the reversal of

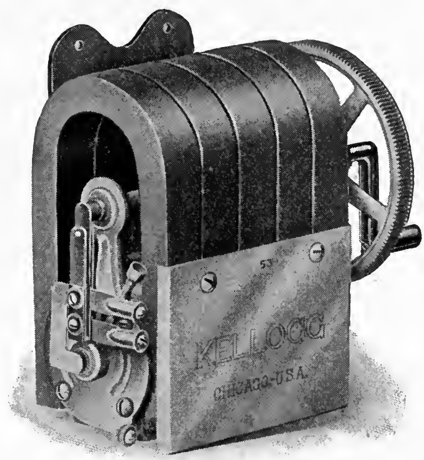

FIG. 46.

one magnet in a five-bar generator, only three bars will be effective.

The armature consists of a large number of turns of fine insulated copper wire wound on an iron core. A common form of core shown in Fig. 47 is of cast iron or is built up of thin, soft-iron sheets having the shape shown in the end view of the armature. If built up, enough sheets to form a core of the desired length are riveted together. Inside the hollow shaft, *S*, is a brass rod, *P*, which is insulated from the shaft by a fiber sleeve, *F*. One end of the coil is connected to the insulated brass rod and the other end is connected to the armature core, and thus through the armature shaft and bearings is connected to the frame of the machine. The bearings for the armature shaft are of brass and are attached to the pole pieces. On one end of the armature shaft is a pinion driven by a larger gear when the crank is turned.

Another form of armature known as the H-type is shown in Fig. 48. The core is held between two end plates, *B* and *B′*, having projecting studs, *S* and *S′*, which take the place of

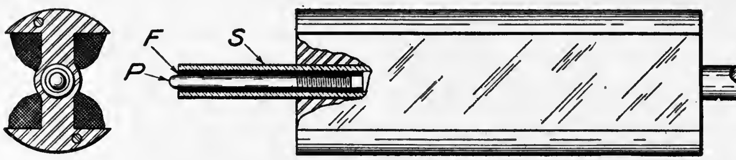

Fig. 47.

the shaft. The main advantage of this type of armature is that the winding space is large, as it is not obstructed by the shaft, and will accommodate a large number of turns. One end of the coil is connected to the core, and the other to the insulated pin, *P*, which passes through the stud, *S*. This form of armature is used in the Kellogg generator shown in Fig. 46.

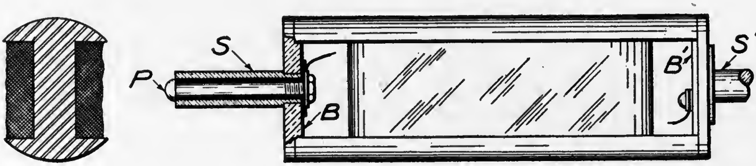

Fig. 48.

99. Automatic Switch.—Every telephone generator is provided with an automatic switch which disconnects the generator from the line when it is not in use. Such a switch is operated by a lengthwise movement of the main generator shaft. In early types of telephones the required lengthwise movement of the shaft was produced by the subscriber's pushing in on the crank while ringing. In modern telephones the switch is operated automatically when the subscriber first turns the crank by the use of some device similar to that shown in Fig. 49. In the device shown the shaft can be moved within the hub of the large gear. The spring, *S*, between the hub of the gear and the collar, *C*, on the shaft holds the crank to the right when it is not in use.

However, as soon as the crank is turned, the notch, *V*, in the collar, *B*, forces the shaft to the left before the large gear commences to turn, and operates the switch; since the lengthwise movement of the shaft takes place under less force than is required to cause the armature to turn. The distance which the shaft moves to the left is determined by the distance between the hub of the gear and the collar, *C*.

Local battery telephones may be divided into two general classes; series and bridging. The automatic generator switch used must be different in the two cases. These differences are taken up in a later chapter devoted to these two classes of instruments.

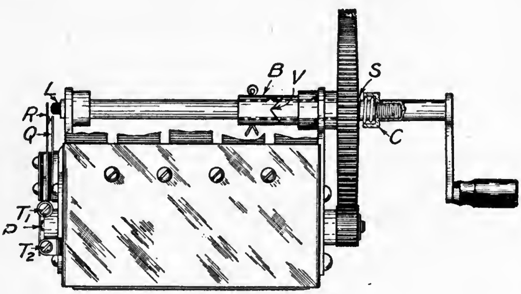

FIG. 49.

100. The Ringer.—The bell used in telephone signalling is ordinarily known as a polarized bell or ringer because the moving part or armature is permanently magnetized or polarized.

In Fig. 50 is shown a common form of telephone ringer. *M* and *M'* are the coils composed of a large number of turns of small wire wound upon soft-iron cores, both cores being attached to the iron yoke, *Y*. The iron armature, *A*, is pivoted at *F*, and has the clapper rod, *C*, attached to its center; hence any movement of the armature results in a movement of the clapper. The armature is supported by the brass bar, *B*, which can be adjusted to vary the distance between the poles of the electromagnet and the armature. The permanent magnet is not in contact with the armature; hence the armature is influenced by the permanent magnet by induction, and since the N. pole of the permanent magnet is opposite the center of the armature, a S. pole will be induced at that point and the two ends of the armature will become N. poles, exactly as if the armature were a part of the permanent magnet.

When no current is flowing in the coils, either end of the armature will attract either magnet core, as the armature is polarized by the permanent magnet.

When current flows through the winding of an electromagnet, one core becomes a S. pole, and the other becomes a N. pole. Hence in the ringer shown in the figure current flowing in one direction through the coils will cause the core *M* to be a N. pole and the core *M′* to be a S. pole. Since the armature has a N. pole at each end, one end of the armature will be attracted by the S. pole of the electromagnet, and the other will be repelled by the

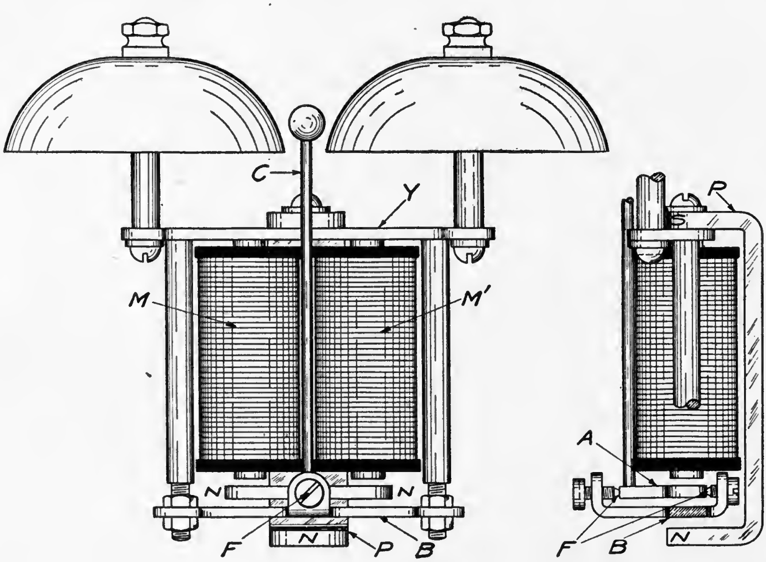

FIG. 50.

N. pole of the electromagnet, and the armature will be tilted, causing the clapper to move to one side. If the current in the coils be reversed, the polarity of the magnet cores will be reversed, causing the armature to be tilted in the opposite direction.

When alternating current is used in ringing, the polarity of the magnet cores reverses just as often as the current in the coils reverses in direction. Hence every time the current reverses the armature is tilted from one side to the other, causing the ball of the clapper to strike one of the gongs. The rapidity of ringing depends upon the frequency or rate of reversal of the alternating current. As the quality of the ring depends largely upon the position of the gongs, they are made adjustable with reference to the ball of the clapper.

The Kellogg ringer has no provision for adjustment of the distance between the armature and magnet poles after leaving the factory. As this adjustment is very close, a strip of German silver is placed between the armature and magnet poles to keep them from coming into direct contact and thus freezing or sticking together. The gongs are adjustable as in the ringer described above.

CHAPTER VIII

THE SUBSCRIBER'S TELEPHONE SET

101. The Complete Telephone.—The following separate pieces of telephone apparatus have been discussed: The battery, transmitter, induction coil, receiver, generator, and ringer. These parts make up the talking and signalling circuits, and in order to have successful commercial operation must be connected in a certain manner.

It is necessary to save battery current when the transmitter is not in use; hence some means must be provided for opening the battery circuit when the instrument is idle, since the transmitter itself never opens this circuit, but merely changes or controls the resistance of the same.

The receiver must also be disconnected from the line when not in use, so as to leave the line free for signalling currents.

The signalling circuit must be disconnected when the talking circuit is being used.

102. The Hook Switch.—The above connections are established and broken by the hook switch. In order to make the action of the hook switch as nearly automatic as possible, the hook is made the most convenient point on which to hang the receiver when it is not in use, as it is not rigidly attached to the telephone. When the receiver is on the hook, its weight pulls the hook down and holds the battery or transmitting circuit open, thus saving battery current, and also holds the receiver circuit open, leaving the line free for signalling purposes. When the receiver is off the hook, however, a spring raises the latter, and closes the circuits through the receiver and transmitter so that the line can be used for communication.

The Western Electric hook switch for wall telephones, shown in Fig. 51, is commonly known as the short-lever type. The hook is pivoted to the bracket, and when the receiver is removed the lever is raised by the hook spring which at the same time closes the switch contacts. When the receiver is hung on the hook, its weight pulls the lever down and compresses the hook spring, allowing the switch springs to fall back against the two short springs which act only as supports. These springs are so spaced that when the lever is clear down, all the contacts shown will be open. The spring arrangement shown is varied to suit the conditions under which the hook is used.

The Stromberg-Carlson hook switch, shown in Fig. 52, operates on a somewhat different principle. The bracket, *F*, on

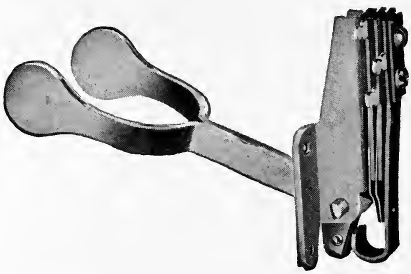

Fig. 51.

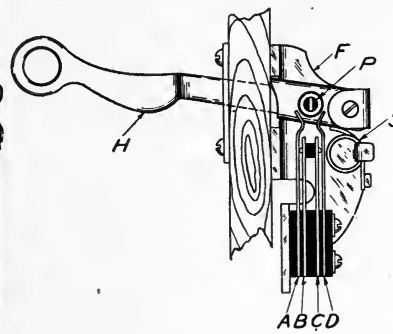

Fig. 52.

which the hook and switches are mounted, is a one-piece steel punching. The spring, *S*, raises the hook when the receiver is in use. When the receiver is placed on the hook its weight pulls it down, and the rubber roller, *P*, forces apart the springs *A* and *D*, thus opening the contacts. The hook can be removed from the telephone cabinet for shipping or transportation

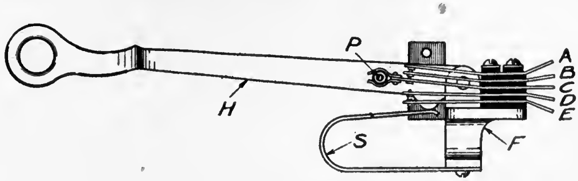

Fig. 53.

purposes if desired without disturbing the adjustment of the switch springs.

The Kellogg hook switch, shown in Fig. 53, is of the long-lever type, having all parts mounted on the casting, *F*, which is firmly secured to the backboard of the telephone. The switch springs are operated by means of the fiber roller, *P*. In the switch shown, when the hook is up the two upper contacts between *A*, *B*, and *C* are open. When the hook is down this condition is reversed and the lower contacts are closed. These switch springs are of German silver, having platinum contact points. Platinum points are used in hook switches because this metal does not corrode readily and the contacts are therefore easy to maintain.

Hook switches for use in desk stands are of somewhat different design. The Western Electric switch is contained in the barrel of the stand, and is operated by the lever very much as in the wall telephone of the same make.

The Kellogg desk stand hook switch is arranged somewhat differently, as is shown in Fig. 54, the switch springs being placed

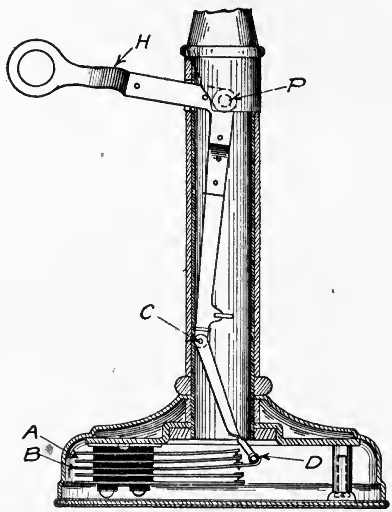

FIG. 54.

in the base of the instrument. The hook lever is in two parts. One part is pivoted at P, and the other at D to the spring B; and the two points are pinned together at C. When the hook is raised the spring contact is closed. When the lever is depressed the point C is moved to the right and D is forced downward, opening the contact between A and B. Other spring arrangements are used for different classes of service, as mentioned above.

QUESTIONS

1. Of what does the signalling circuit of a telephone consist? Show by diagram.

2. For what is the generator used? The ringer?

3. Upon what principles does the operation of a dynamo depend?

4. In the simple dynamo shown in Fig. 41 why do not the voltages generated in each side of the loop oppose each other?

5. What kind of a current will be generated by the simple dynamo mentioned above? Explain.

6. Of what use is a commutator? Are magneto generators ever provided with a commutator?

7. How is the magnetic field of a telephone generator constructed?

8. Describe two types of magneto armatures.

9. For what is the automatic switch used? How does it operate?

10. Why is the ordinary telephone ringer said to be polarized?

11. Explain the action of the ringer, including the effect of the permanent magnet on the armature.

12. For what is the hook switch used? Explain in a general way how the hook switch works.

13. Name the parts of the talking circuit.

14. Show how the Kellogg desk stand hook switch operates.

CHAPTER IX

LOCAL BATTERY SYSTEMS

103. Classification of Local Battery Systems.—It has been mentioned previously that local battery telephones are of two classes: series and bridging. The series instruments are so named because the generator and ringer are placed in series with each other. The bridging instruments are so called because the bell and generator are separately bridged or connected in parallel across the line.

104. Series Telephone System.—Fig. 55 is a diagram showing the connections of the various parts of the series telephone.

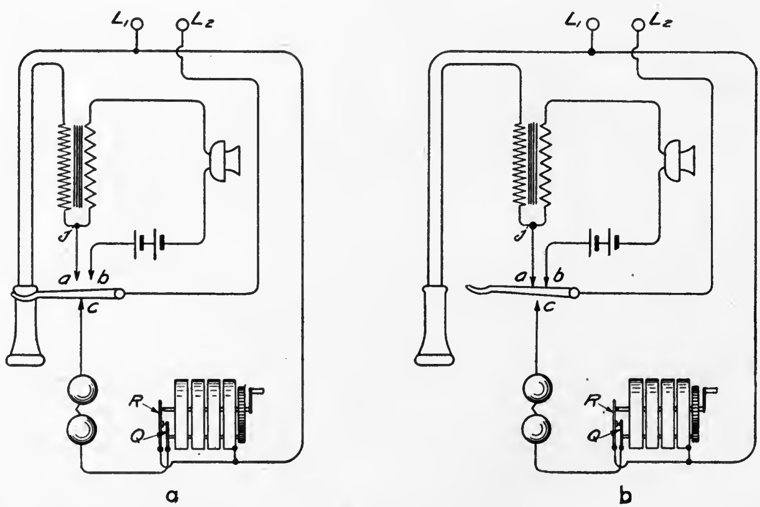

Fig. 55.

When the receiver is on the hook the signalling circuit is closed at the point *C*. If the central operator wishes to call the left station of Fig. 55, ringing current is sent over the line, let us say, entering at terminal L_1, and leaving at L_2 as follows: Following the line from L_1, we reach the spring, *R*, of the generator. For the operation of the series telephone ringer, a generator with an automatic switch, as shown in Fig. 49, is required. This switch contains two springs, R and Q, insulated from each other except when the switch is closed. The spring R is in contact with the insulated pin, P, to which one end of the armature coil is connected; and the spring Q is attached to the frame of the generator, to which the other end of the armature coil is connected. Hence these two springs form the terminals of the armature coil. One of the terminals, either T_1 or T_2, is connected to the line, and the other terminal is connected to one end of the bell or ringer coil. When the generator is not in use the circuit is closed, through the two springs, R and Q, as shown in Fig. 55, thus forming a low-resistance shunt for the generator and allowing the ringing currents to flow readily through the bell. If these currents had to flow through the high resistance of the armature coil, in addition to the bell coil, they would be much weakened.

As soon as the subscriber has heard his bell ring, he removes the receiver from the hook which is raised by a spring, opening the signalling circuit, at the same time closing the talking and listening circuits through the contact points, a and b. The diagram at the right in Fig. 55 shows the connections after the receiver has been removed from the hook, the contacts a and b being closed and contact c opened.

Referring to the diagram at the right of Fig. 55, the talking current can be traced through the receiver, reproducing the sounds of the operator's voice, and through the secondary of the induction coil to the point j. From j the current flows through the wire to contact a, through the receiver hook and to L_2. From j to the hook there are two paths for the current, one through the wire connecting j and a, and the other through the primary of the induction coil, the transmitter, and battery; but the resistance of this latter circuit is so much higher than that of the first that practically all of the current flows through the wire directly from j to a.

From the diagram of connections it is evident that battery current is flowing in the transmitter circuit when the receiver hook is up, whether the transmitter is in use or not, since the latter never opens the circuit. It is the variation of current in the primary of the induction coil, however, which causes current to flow in the secondary, and a continuous direct current (no matter what its value may be) can not produce current in the secondary. Hence there is no interference with the talking current from the central operator's instrument.

105. Local Battery Circuit.—The circuit made up of the battery, transmitter, primary of the induction coil, and the connecting wires form what is known as the local battery circuit.

When the subscriber talks, a variable current is set up in the transmitter circuit on account of the variations in resistance of the transmitter. This current flows from the battery, through the transmitter, through the primary of the induction coil, and through the contact *a*, through a part of the hook, and through contact *b*, back to the battery. The variations in the current flowing in the primary of the induction coil cause an alternating current to be induced in the secondary of the coil. This current flows through the circuit as outlined above, out over the line, and is finally converted by means of the receiver at the receiving station into mechanical energy of sound.

As soon as the subscriber is through talking he hangs the receiver on the hook. The hook, being pulled down, opens the talking circuit and closes the signalling circuit, thus leaving the instrument ready to receive future signals.

If the subscriber wishes to signal the central operator, he turns the generator crank while the receiver is on the hook. Whenever the generator crank is turned, the shaft is moved horizontally and the pressure of the hard-rubber tip, *L*, Fig. 49, opens the circuit by pressure on the spring *R*, allowing the current to flow through the line. If the contact between *R* and *Q* were not broken, the current from the generator would flow through the shunt instead of the line.

106. The Bridging Telephone.—Fig. 56 is a diagram of the connections of the bridging telephone. It will be seen that the ringer and generator are connected in parallel across the line. The generator is provided with an automatic switch which opens the circuit when the generator is not in use, so that no current can be shunted from the ringer or talking circuit. The switch has three springs: *R*, *Q*, and *J*. The ends of the armature coil are connected to spring *R* and to the frame of the generator. When the subscriber is called, the ringing current passes from L_1 to spring *Q*, then to spring *J*, through the bell coils and to the other side of the line.

When the subscriber wishes to call central or some other subscriber, the motion of the ringer shaft to the left opens the bell circuit between *Q* and *J* and closes the generator circuit between *R* and *J*. The ringing current leaves through *R* to *Q*, then to line at L_1 and returns by L_2 and the connecting wires to the generator frame to which the other generator terminal is connected. The pin, *P*, is insulated from the generator frame. Bridging bell coils are wound to a resistance of 1,000 to 2,500 ohms, varying with different manufacturers.

The number of turns on the bell coils is much greater than with the series bells; therefore the current necessary for ringing is much less than with the other type. Again, the impedance of the bell coils is so high, compared with that of the circuit through the telephone receivers, that the amount of high-fre-

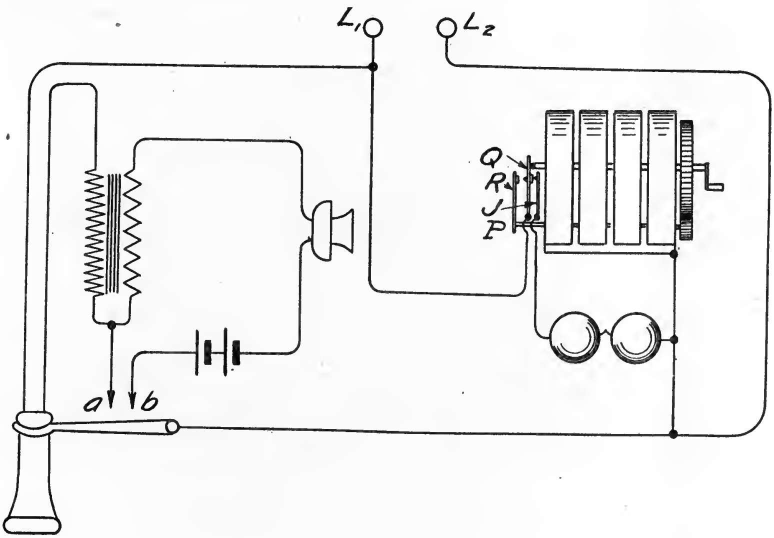

Fig. 56.

quency talking current shunted is of no consequence in the operation of the system.

107. Connections of Bridging Telephone.—The connections of the bridging telephone, Fig. 56, show that there is no bottom contact for the hook switch. When the receiver is on the hook the only path for current from the line is from L_1 through the ringer to L_2. When the receiver is removed from the hook, the contacts *a* and *b* are closed, establishing the listening and talking circuits, which are the same as in the series instrument.

When the subscriber wishes to signal the central operator he turns the generator crank, which closes the contact between *R* and *Q* and connects the generator to the line, and at the same time opens the contact between Q and J and thus disconnects the ringer so that none of the calling current is shunted from the line.

108. Telephone Instruments.—Telephone instruments commonly used are of the types known as wall and desk sets; the former so called because they are usually attached to the wall, and the latter because they are intended for use on a desk or table.

109. Standard Wall Set.—A common form of magneto wall set is shown in Figs. 1 and 2; and a view of another instrument

Fig. 57*a*.

Fig. 57*b*.

of the same type but of different make is shown in Figs. 57*a* and 57*b*.

It is seen that the essential parts are all mounted within the cabinet or on the outside where they are most convenient for the user. The transmitter is carried on a hollow adjustable arm, through which the wires pass to the interior of the cabinet. The ringer is mounted on the inside of the door, and as the gongs are on the outside it is necessary for the clapper rod to pass through a hole in the door. The induction coil is mounted on the inside of the door, as is the condenser, the use of which in magneto telephones will be explained in a later section on party lines. In some other makes of telephones the induction coil is not mounted on the door, but is placed in the cabinet. The hook switch is of the short-lever type, the switch being inside the cabinet. The magneto is mounted on a shelf, and has its shaft

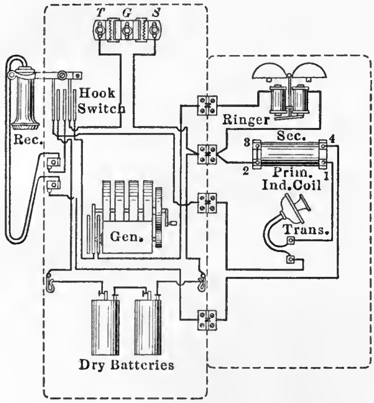

Fig. 58.

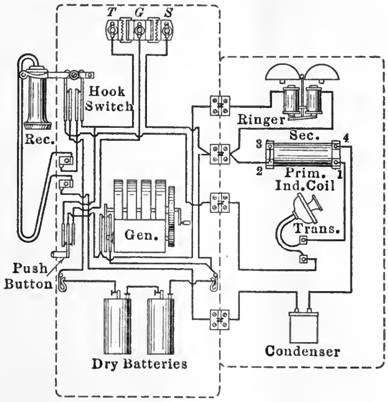

Fig. 59.

extending through the right side of the box. The receiver, as in all telephones of this type, is connected with the instrument by means of a flexible cord.

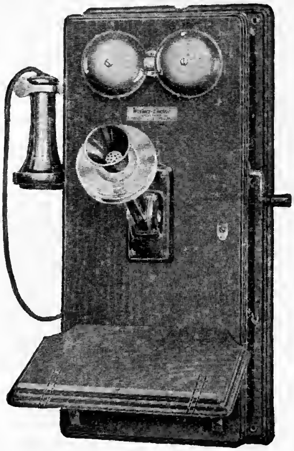

Fig. 60*a*.

Fig. 60*b*.

In order that connections between the parts mounted on the door and those within the box will not be broken when the door is opened for inspection or other purposes, the hinges are made a part of the conducting circuit. A special form of spring joins the two leaves of the hinges in order that the circuits may not be opened through corrosion and wearing of the parts.

A wiring diagram of the series instrument of this type is shown in Fig. 58, and a diagram of the bridging set is shown in Fig. 59. A comparison of these diagrams with the simplified ones preceding will show the connection of the parts to be practically the same.

Another wall set of standard make is shown in Figs. 60*a* and 60*b*. The set shown in the figure does not contain a condenser, but a place is provided for one immediately under the induction coil.

Fig. 61.

The wiring of this set differs in one respect from that shown in Fig. 57. The wires are carried in a conduit from the apparatus inside of the box to that on the door and accordingly the hinges do not form a part of the electrical circuit. The variation of the resistance in the hinge contacts is thus obviated.

110. Hotel Set.—Figs. 61 and 62 show a local battery telephone of small size, commonly known as the residence or hotel type. It is, in fact, a simple magneto box cabinet containing all the talking and signalling apparatus except the batteries, which are placed in any convenient location away from the instrument, This telephone has all the operating advantages of other types, and is installed where a larger cabinet would be objectionable, and where the writing shelf is not necessary. All of the working

Fig. 62.

parts are of standard size, and the wiring is practically the same as that of the standard instrument previously shown.

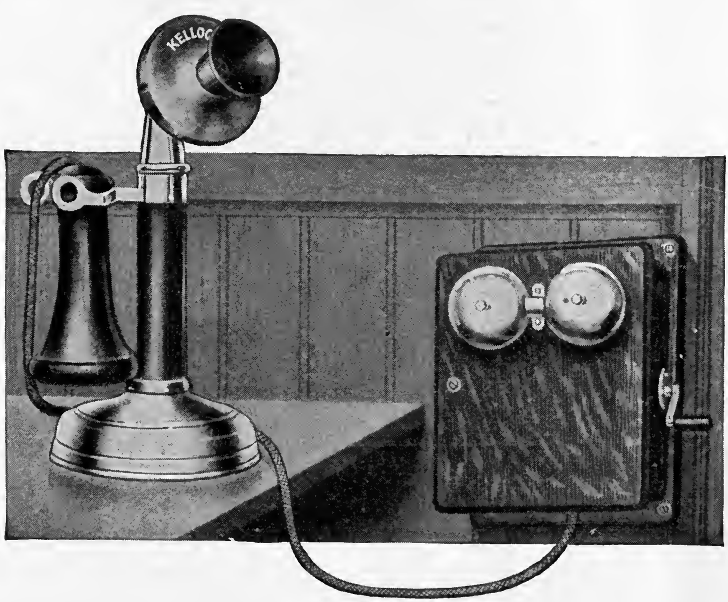

Fig. 63.

111. Desk Set.—A desk set consists of the desk stand, comprising the transmitter, receiver, hook switch, and induction coil; the desk box, containing the magneto and ringer; and the battery box, although the latter is often omitted, as the batteries may be set in an out-of-the-way place where a box is not required. A desk stand and desk box are shown in Figs. 63 and 64. The wiring diagram of a desk set does not differ materially from a wall set except that as the apparatus is not all mounted

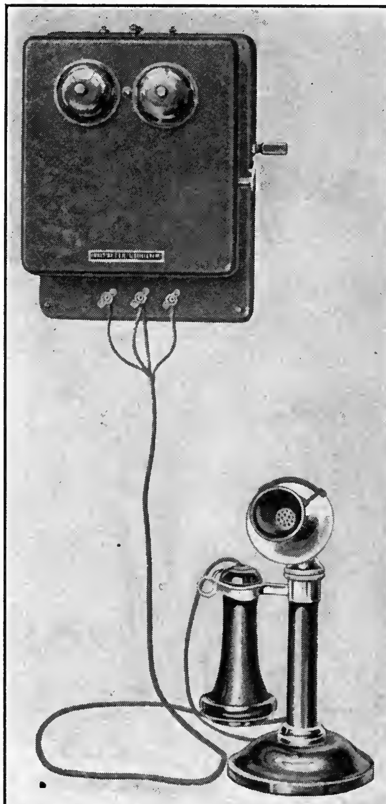

Fig. 64.

in one cabinet, flexible conductors are used to connect the various parts. A wiring diagram for the Stromberg and Carlson desk set is shown in Figs. 65 and 66.

An apparatus consisting of a combination of receiver and transmitter, and known as a hand telephone is shown in Fig. 67. Although these are not in common use, they are made in two styles. The one shown in the figure opens and closes the circuits in the usual way, that is, through the medium of the hook

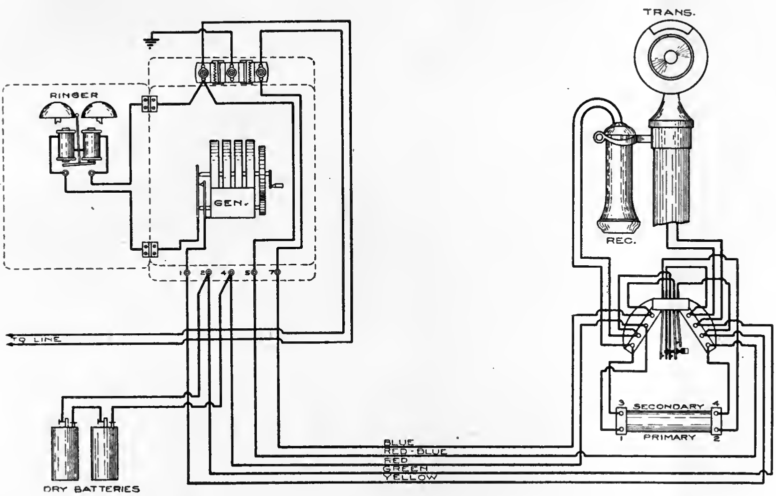

FIG. 65.—Desk telephone wired for series operation.

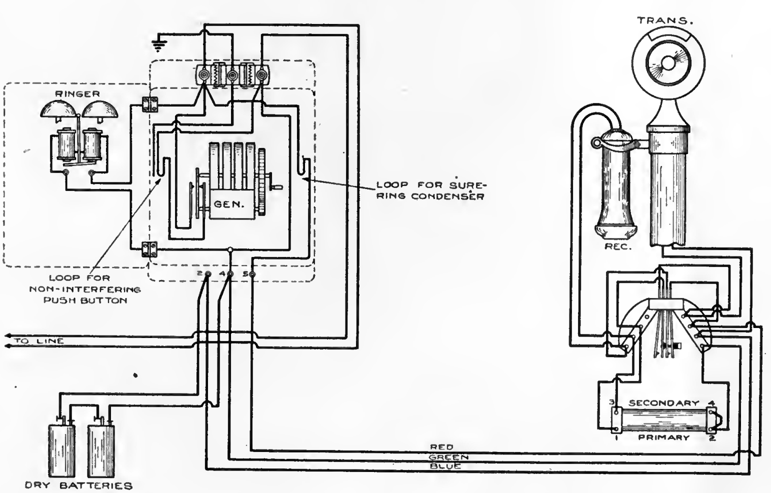

FIG. 66.—Desk telephone wired for bridging operation.

switch. Another make has no hook switch, the ringing circuit being open and the talking circuit closed by the pressure of a lever in the barrel of the instrument.

QUESTIONS

1. What is meant by a local battery telephone?

2. Explain the difference between the two types of local battery telephones.

3. Trace the path of current in series telephone: when the operator is signalling the subscriber; when the subscriber is answering his call; and when the subscriber is signalling the central office. Use diagrams.

4. What objections are there to the use of series instruments on party lines?

5. What is the difference between a series and bridging ringer?

Fig. 67.

6. Trace the circuits of the bridging telephone as you did for the series instrument in question 3.

7. Why does not the current from the line flow through the battery when the hook is up, since the circuit is closed?

8. Explain why the talking current does not flow through the ringer, instead of the receiver, in the bridging telephone.

9. Explain the difference between the generator switches used in series and bridging instruments, and give the reasons for the difference.

10. Why does not the battery current flowing through the primary of the induction coil interfere with the talking current from the line which passes through the secondary?

CHAPTER X

COMMON BATTERY TELEPHONES

112. General.—The common battery or central energy telephone system is so named on account of the fact that the current for the operation of the system is supplied from a central or common source instead of from batteries at each subscriber's station. The common source is invariably a storage battery[1] located at the central office.

The electrical characteristics of common battery substation apparatus are the same as those of the local battery equipment, but on account of the central source of energy some of the apparatus found in local battery installation is not used, and some other equipment is added. The design and connections are also modified and changed. The operation of the induction coil in connection with the condenser in the common battery system is somewhat the more complicated.

A common battery transmitter has a higher resistance than the local battery transmitter. This is due to the fact that the voltage employed is much higher in the former than in the latter systems. In general exchange practice the higher voltage is not needed for transmission, but for signalling. The resistance of the line is the same in the two cases. Therefore, to reduce the current in the talking circuit, the resistance of the various parts is increased. The resistance of standard common battery transmitters of various makes is in the neighborhood of 100 ohms.

The common battery induction coil differs also somewhat from the induction coil of the local battery system. In the latter system the electrical pressure employed is comparatively low, approximately 4 volts. This is too low for efficient transmission, so an induction coil is used which transforms the low primary pressure to a secondary pressure which is sufficiently high to force the current to the other instrument.

[1] The storage battery will be explained in connection with central office equipment.

In common battery systems the primary voltage is high enough so that, instead of using a step-up coil, the coil may be entirely omitted, or one that slightly lowers the pressure may be employed. Induction coils, however, vary in this respect considerably, being designed for the particular instrument circuit in which they are used. As a general rule it is advisable never to replace any part of an instrument equipment with that of another manufacture unless investigation shows that the apparatus which it is proposed to substitute is designed for that type of circuit.

The added feature of the common battery system is the condenser, the construction and use of which will be explained in the succeeding paragraphs. Instead of each instrument having a hand generator for signalling the central office, the current for calling the operator, or central, is supplied by the common battery. The ringing generator is thus omitted from the common battery system.

113. The Condenser.—When an insulated electrical conductor is connected to a battery or some other source of electrical

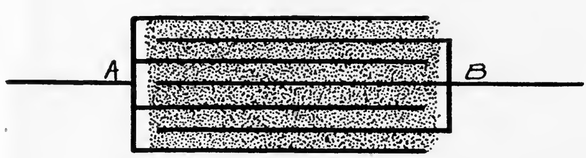

Fig. 68.

pressure, the conductor becomes charged; that is, a sufficient quantity of electricity flows into the conductor to raise its potential or pressure to that of the battery. If a conductor be connected to the positive terminal of a battery, it becomes positively charged, and if it be connected to the negative terminal it becomes negatively charged. A condenser is an arrangement of conducting plates which are insulated from each other, and therefore can be charged by connecting them to a source of electrical pressure.

The most simple form of a condenser consists of two or more conducting plates close together, but separated by some insulating material called the dielectric. Fig. 68 is a cross-section of a simple condenser of this type. The heavy horizontal lines represent a cross-section of the conducting material, and the fine dots represent the insulating material.

Capacity of a Condenser.—The capacity of a condenser is measured by the quantity of electricity required to charge it to a difference of pressure of 1 volt. The unit of capacity is called the farad, a word derived from the name Faraday. A condenser is said to have a capacity of 1 farad when a charge of 1 coulomb raises its potential by 1 volt. The farad is entirely too large for practical purposes, and so the microfarad, which is one-millionth of a farad, is used. Condensers are thus rated in microfarads.

The capacity of a condenser depends upon several factors; the number and dimensions of the sheets of conducting material, the material and thickness of the dielectric. The greater the area of the sheets of conducting material and the thinner the layers of insulation, the higher the capacity.

Furthermore, if the dielectric is paraffined paper, the capacity is 1.9 to 2.4 times as large as it would be if air of the same thickness were used. This property of the insulating material upon which the capacity of the condenser depends is called the *dielectric constant* or *specific inductive capacity.*

The principal materials used in the manufacture of telephone condensers are tin-foil, paper, and paraffine.

The tin-foil is made from an alloy of about 90 per cent. lead and 10 per cent. tin. This is rolled out until it is very thin. In the preparation of the foil, great care is taken to insure purity of the product and freedom from grit, which would puncture the condenser when assembled and pressed.

The paper employed is a special grade of what is commercially known as rice paper. It is white in color, very flexible, of high tensile strength, and quite tough. Condenser paper is purchased in several thicknesses varying from 0.0005 to 0.001 in. It is put up in rolls of different widths, depending upon the finished dimensions of the condenser for which it is intended.

There are two main reasons for the use of paraffine: first, its insulating properties are quite high, and thus it reinforces the dielectric strength of the paper; and second, its dielectric constant is somewhat higher than that of paper alone. When a dielectric with a large constant is used, the dimensions of a condenser of a given capacity are less than when the dielectric constant is small. This constant for paraffine ranges from 1.9 to 2.4, depending somewhat upon the temperature. The capacity of a condenser may be calculated by the following formula:

$$C = 884 \times 10^{-10} \times \frac{kS}{t} \text{ microfarads}$$

where

k = dielectric constant
S = area of dielectric between conducting plates in square centimeters
t = thickness of dielectric in centimeters

$$10^{-10} = \frac{1}{10{,}000{,}000{,}000}$$

EXAMPLE

A condenser is made of 501 sheets of tin-foil separated by sheets of paraffined paper 0.007 in. thick. The overlapping portions of the sheets of

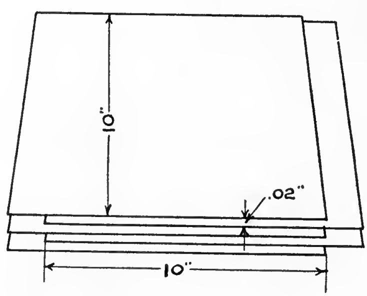

FIG. 69.

tin-foil are 10 in. by 10 in. as shown in Fig. 69. Calculate the capacity of the condenser.

Solution

If there are 501 sheets of tin-foil, there are 500 sheets of paraffined paper between the sheets of tin-foil. The total area of these sheets of paper will be

$$500 \times 10 \times 10 \times 6.45 = 322{,}500 \text{ sq. cm.}$$

Therefore

$$S = 322{,}500 \text{ sq. cm.}$$
$$t = 0.001 \times 2.54 = 0.00254 \text{ cm.}$$
$$K = 2.3 \text{ about}$$

Then

$$C = 884 \times 10^{-10} \times \frac{2.3 \times 322{,}500}{.0.00254} \text{ microfarads}$$
$$= 26 \text{ microfarads nearly.}$$

The capacity of paper condensers varies greatly with the rate of charge and discharge.

114. Manufacture of Telephone Condensers.—The process of manufacturing telephone condensers is well shown in Fig. 70.

The machine used for the winding of the condensers is usually provided with six spindles arranged to carry the rolls of the paper and foil in the manner indicated. A collapsible mandrel upon

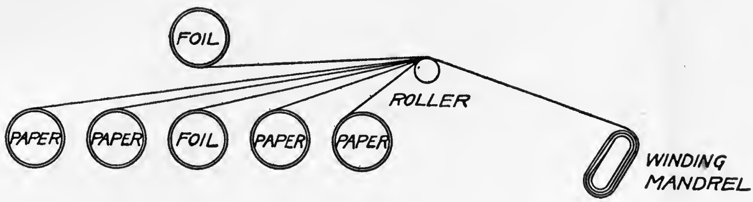

Fig. 70.

which the tin-foil and paper are wound is shown to the right. The first step in the assembly of the condenser is the winding of a few turns of paper, only, on the mandrel to form a core. This is done to avoid sharp bends in the inner layers of the foil. Very thin strips of brass about ¼ in. wide and about an inch longer than the width of the foil are attached to each strip of foil. These brass strips are used to connect the tin-foil to the terminals on the condenser case. In some makes of condensers the connecting strips are placed midway in the foil strip to reduce the plate resistance and thus decrease the loss of energy, and heating of the condenser. The required number of turns of paper and foil are then wound on the mandrel, the foil is cut off and a few extra layers of paper wound on for protection.

Fig. 71.

The condensers, after being assembled in pressing "jigs," are next placed in perforated baskets and immersed in a large tank of molten paraffine, a cover is placed on the tank and the air exhausted until a desired degree of vacuum is obtained.

After the condensers have remained in the tank for about an hour the air is again admitted. This forces the paraffine into the remote recesses of the condensers. By hydraulic presses the condensers are next subjected to heavy pressure which removes all excess paraffine and forces the plates together as closely as possible. This process increases the capacity of the condenser as is evident from the formula given, which shows that the capacity increases as the thickness, t, of the dielectric decreases.

The partially completed condensers are now tested for capacity and insulation resistance at a voltage of at least double the working value. Those passing this test are next placed in moisture-proof containers. The containers are lined with pasteboard, the condenser placed in position and the case is filled with paraffine. The terminals are next placed in position and the cover is soldered on, after which a further test is made to check the capacity and insulation. A finished condenser is shown in Fig. 71.

115. Analogy for a Condenser.—A better understanding of the action of a condenser may be had by considering an analogy. Suppose we have an air tank that under 1 atmospheric pressure holds a certain definite quantity of air, say 5 lb. We can define the capacity of the vessel in terms of the number of pounds of air it holds, and call it a 5-lb. tank.

If the pressure is doubled, the tank will hold 10 lb. of air. Since we have defined the capacity of the tank in terms of unit (1 atmosphere) pressure, we can not call it a 10-lb. tank. A 10-lb. tank under the same conditions will hold 20 lb. of air.

Furthermore, if the tank be exhausted, evidently no back pressure will be exerted when air is first admitted to the tank. As soon as some air is admitted to the tank, back pressure begins to manifest itself, and when the back pressure equals the maximum applied pressure, no more air enters the tank. We thus see that the amount of air entering per unit of time depends upon the back pressure, and this back pressure will depend upon the capacity of the tank. For instance, if we put 5 lb. of air in a 10-lb. tank, the back pressure will be one-half as great as when 5 lb. of air are put into a 5-lb. tank. We can then say that unit capacity of a tank is such that when 1 lb. of air is forced into it the pressure will be equal to 1 atmosphere. Evidently a certain amount of work will be done in forcing the air into the tank, and we could define unit capacity in terms of the work expended.

The capacity of electrical conductors is analogous to the capacity of the air tank discussed above. The capacity of a condenser or system of conductors is usually defined in terms of the quantity of electricity required to raise the difference of pressure between the terminals by 1 volt. In accordance with this definition the quantity of electricity that a condenser will contain is equal to the product of the capacity and pressure.

116. Action of a Condenser.—If a condenser has one of its plates connected to each side of a battery circuit, it will become charged; that is, a quantity of electricity will flow into the condenser due to the battery pressure, and one plate will become positively and the other negatively charged. After a condenser has been connected to a direct-current circuit for a short time, there will be no flow of current to or from the condenser, since the condenser becomes fully charged almost instantaneously; and when charged, the difference in pressure between its plates is the same as that of the battery or other source of charging current. If the pressure in the circuit be decreased or reversed, the charge will flow out of the condenser and back through the circuit.

When an alternating pressure is impressed upon a condenser the action is somewhat different. As the pressure increases from zero to a maximum a current flows into the condenser, one side becoming charged positively and the other side negatively. The current flows as long as the pressure is changing, and the back pressure of the condenser is always just equal to the applied pressure. When the applied pressure begins to decrease, the current begins to flow out of the condenser. When the applied pressure is reversed the current flows into the condenser in the opposite direction. This continues until the applied pressure again attains a maximum value, when the current again is reversed. These fluctuations of current continue so long as the applied pressure fluctuates or changes. An alternating current may thus flow in a circuit containing a condenser. The exact value of such a current will depend upon the applied e.m.f., the frequency, the capacity, and the resistance of the circuit. The algebraic expression for a current in a circuit having capacity and resistance is

$$I = \frac{E}{\sqrt{R^2 + \frac{1}{(2\pi fC)^2}}}$$

where

E = applied e.m.f.
R = resistance in ohms
f = frequency of the applied e.m.f.
π = 3.1416
and C = capacity in farads.

EXAMPLES

1. A pressure of 110 volts at 60 cycles is impressed upon a circuit whose resistance is 5 ohms and capacity ⅓ microfarad, what is the current?

Solution

Given

E = 110 volts
R = 5 ohms
f = 60
$C = \frac{1}{3} \times 10^{-6}$ farads

To find I

$$I = \frac{110}{\sqrt{5^2 + \frac{1}{(2\pi \times 60 \times \frac{1}{3} \times 10^{-6})^2}}}$$

$$= \frac{110}{\sqrt{25 + \left(\frac{10^6}{2\pi \times 20}\right)^2}}$$

$$= \frac{110}{\sqrt{25 + (7{,}955)^2}}$$

$$= \frac{110}{\sqrt{(7{,}955)^2}} = \frac{110}{7{,}955}$$

as 25 is negligible in comparison with $(7{,}955)^2$ = 0.013 amp.

2. Suppose that in problem 1 the frequency were increased to 600, what would the current be then?

Solution

The solution is exactly the same as the foregoing, except for f we substitute 600. The equation for current becomes

$$I = \frac{110}{\sqrt{25 + \left(\frac{3 \times 10^6}{2\pi \times 600}\right)^2}}$$

$$= \frac{110}{\sqrt{25 + (795.5)^2}}$$

$$= \frac{110}{796} = 0.13 \text{ amp., nearly.}$$

This shows that when the resistance is small, the current increases or varies directly as the frequency so long as the pressure remains constant. Both the voice currents and ringing currents are of high enough frequency to give an appreciable current through a condenser. The frequencies of voice currents range between 100 and 2,500 cycles per second in ordinary telephonic communication.

117. Function of Condenser in Telephone Circuit.—The functions of a condenser in a telephone circuit are determined somewhat by the system of connections employed. The physical basis for its use is the action of a condenser with reference to direct and alternating currents.

The subscriber's apparatus in the common battery system comprises a transmitter, receiver, and ringer. Direct current is used to operate the transmitter, while alternating current is preferable for the operation of the receiver and ringer. As a condenser will not permit the passage of direct current, but will permit the flow of an alternating current, a condenser is connected into that part of the circuit through which only alternating current is to flow. The points of connection will depend upon the system of connections used. There are several different connections used in practice of which the following are the most common:

118. Receiver and Transmitter in Series; Condenser and Ringer in Series.—What is perhaps the simplest connection is

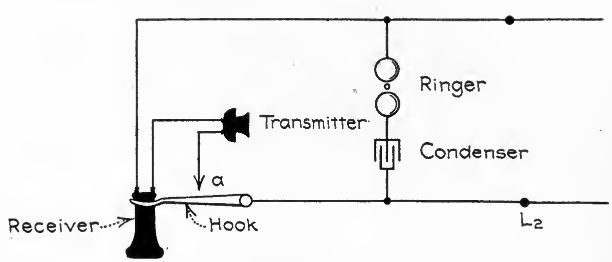

FIG. 72.

indicated in Fig. 72, the bell being bridged across the line in series with the condenser. Since the condenser will allow the ringing current to flow in the circuit, the instrument is ready to receive signals from central at any time when the receiver is on the hook. As direct current from the central battery can not flow through the condenser, there is no battery current flowing as long as the talking circuit is open.

When the subscriber desires to signal central, he merely removes the receiver from the hook, which closes contact *a*, thus completing the talking circuit and allowing battery current to flow in his circuit. As soon as the talking circuit is closed, the battery current flowing lights a small electric lamp in the central office, thus attracting the attention of the operator.

When a circuit like that shown in Fig. 72 is used, the talking current flows directly through the receiver. If the receiver should happen to be connected in the line the wrong way, the effect of its permanent magnet would be largely destroyed, for usually there is enough battery current employed on a line to overcome entirely the permanent magnets of a receiver, if it flows through the receiver in such a way as to oppose them. A receiver with line battery flowing through it in this manner will have only about half the efficiency that it should have.

119. Induction Coil, No Condenser in Receiver Circuit.—Fig. 73 shows a more common arrangement of the circuits of a C.B. telephone. The receiver as shown is connected to the

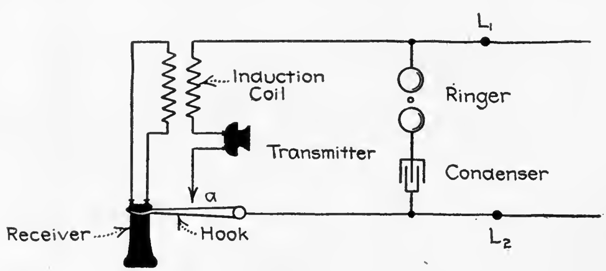

FIG. 73.

talking circuit, through the induction coil only. In this case the circuits are so arranged that only the currents induced in the secondary winding, due to the variations in battery current, flow through the receiver.

120. Induction Coil and Condenser in Ringer and Receiver Circuits.—Another system of connections very extensively used is that shown in Fig. 74. This diagram shows that when the hook switch is open no direct current can flow. Alternating current can, however, be sent over the line to operate the ringer.

When the receiver is removed from the hook the receiver circuit is connected in series with the condenser. In such a connection the condenser minimizes the inductive effect of the secondary winding of the induction coil and the receiver windings, increasing the efficiency of transmission. A brief consideration of the principles involved will make clear how the condenser increases the sensitiveness of the receiver. Let us consider the receiving circuit closed and the subscriber listening. Under this condition the direct line current flows through the primary of the induction coil and transmitter. The transmitter offers a fixed resistance to the flow of current. The line current fluctuates in volume according to the sound waves causing the distant transmitter to vibrate. With the substation circuit closed and the transmitter at rest the condenser is charged to a difference of

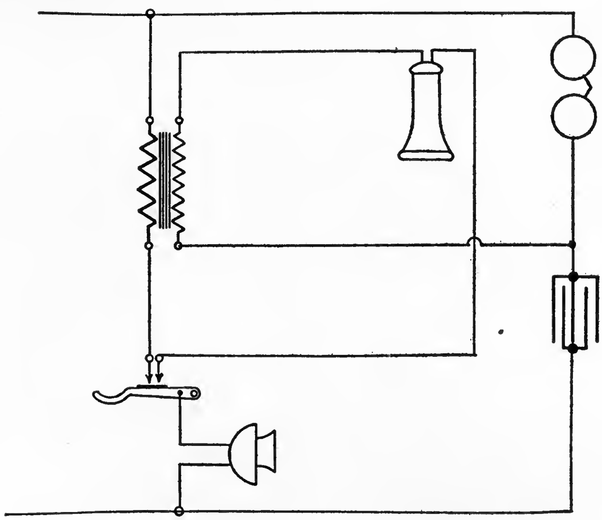

FIG. 74.

potential equal to that across the transmitter. Now when a pulsating current flows in the primary, an alternating current is induced in the secondary. At one instant it flows through the receiver into the transmitter circuit, and as a reversal occurs it flows into the condenser but does not pass through; it is retained there only during the interval required for the current to reverse in the coil when the condenser discharges into the circuit through the receiver. This oscillating action of the condenser increases the sensitiveness of the receiver in reproducing the vibrations of the distant transmitter. This is the main reason for the use of a condenser in a receiver circuit. In this connection it performs two functions; to prevent direct current from flowing through the ringer, and to reinforce the action of the induction coil and thus increase the sensitiveness of the receiver. This system of connections is standard with the American Telephone and Telegraph Co. and is widely used both in this country and in England.

A modification of the American Telephone and Telegraph Company's system of connections is shown in Fig. 75. An examination of this diagram will show that the transmitter, the receiver, and the primary of the induction coil are in the line circuit, while the secondary, the transmitter, and the condenser form a local circuit. When the transmitter is stationary—that is, when the subscriber is listening—the pulsating

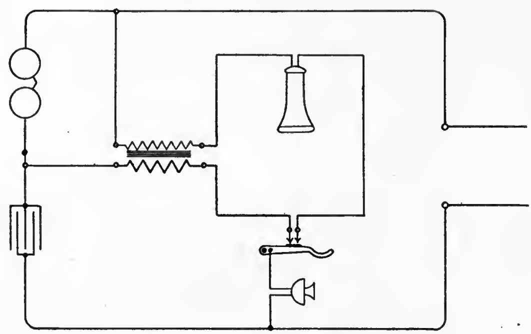

FIG. 75.

current causes a variation in the potential at the terminals of the condenser. These variations in pressure cause the condenser to be charged and discharged, thus reinforcing the fluctuations in the receiver. A similar action takes place when the transmitter is used.

121. Retardation Coil in Place of Induction Coil.—The self-inductance of a coil prevents the current in the coil from reaching a maximum value at the instant of maximum pressure. The growth, or increase or decrease, of current through such a coil is retarded in time, and hence a coil with large self-inductance is called a retardation coil. A retardation coil differs from an induction coil in that it contains only one winding. The use of such a coil in the subscriber's circuit is shown in Fig. 76. The function of the retardation coil will be readily understood from the following:

Assuming the receiver on the hook, the ringing circuit may be traced from line conductor 1 to branch 3, ringer 4, conductor 5, switch-hook points 6 and 7, around the receiver by way of the shunt 16, thence through condenser 15 to the other side of the line 2. With the receiver off the hook, as shown in the diagram, it will be observed that two parallel paths are provided, one containing the condenser and receiver and the other the retardation coil 13 and the transmitter. When the subscriber is listening, the passage of the high-frequency voice currents is opposed by the retardation coil, but they have practically free passage through the condenser and receiver. The direct current for the transmitter on the other hand can not pass through the condenser but passes quite freely through the retardation coil. Such a combination of retardation or impedance coil and condenser provides an automatic means of separating the high-frequency voice currents from the direct current. No direct current ever flows through the receiver. The system of connections shown in Fig. 76 is that employed by the Kellogg Switchboard and Supply Co.

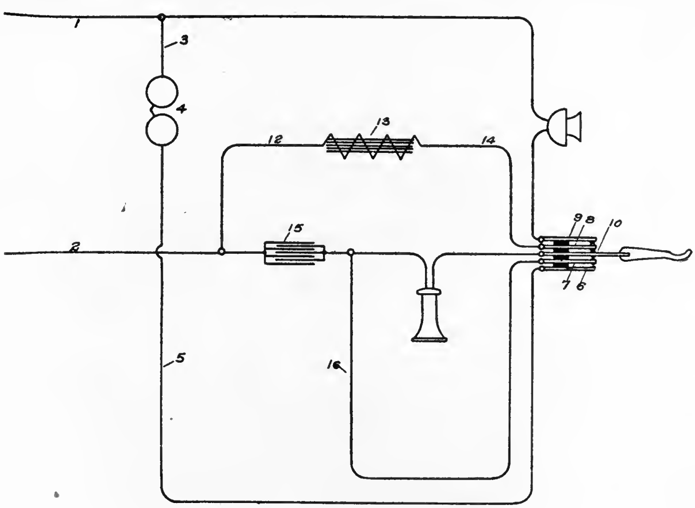

FIG. 76.

122. Wheatstone's Bridge Connection.—A very interesting substation circuit is that shown in Fig. 77. The principle of the retardation coil is again employed to keep the direct current out of the receiver. As shown, the circuit consists of four coils, two retardation coils, and two noninductive resistance coils. These four coils are connected so as to form the four arms of the Wheatstone bridge. The two parallel paths from *A* to *B* have the same resistance, hence the steady direct current entering at *A* divides, one half passing by way of *ACB* and the other by way of *ADB*. The potentials of the points *C* and *D* are equal, and hence no direct current flows through the receiver. When, however, high-frequency voice currents enter at *A*, their passage is opposed much more by the retardation coil between *A* and *D* than by the noninductive coil between *A* and *C*; hence they pass

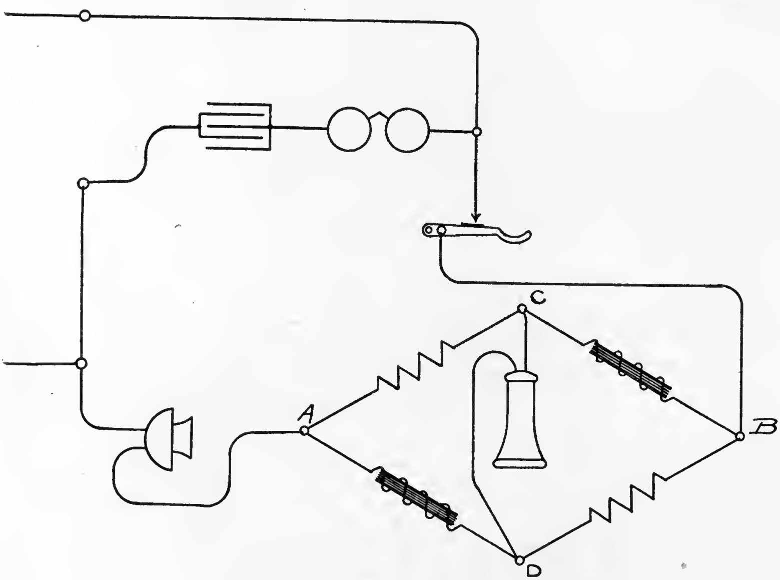

FIG. 77.

to *C* through the receiver to *D* and then to *B*. Such a combination of noninductive and inductive coils, when properly balanced, successfully keeps the steady direct current out of the receiver. The condenser is placed in the ringing circuit only. This system of connections has been largely used by the Dean Electric Co. in connection with their common battery telephones.

123. C.B. Wall Sets.—A common form of wall set is shown in Fig. 78, this particular one being of Kellogg manufacture. The wiring diagram for this instrument is shown in Fig. 76.

124. Hotel Sets.—The common battery hotel or residence set is designed to be used in places where it is desirable to economize space, as are the local battery sets of the same type. These cabinets are made either of wood or pressed steel; the latter have been in growing favor of recent years. A Stromberg-Carlson steel hotel set is shown in Fig. 79. An open view of this set, with a part of the cover cut away to show the connections of the

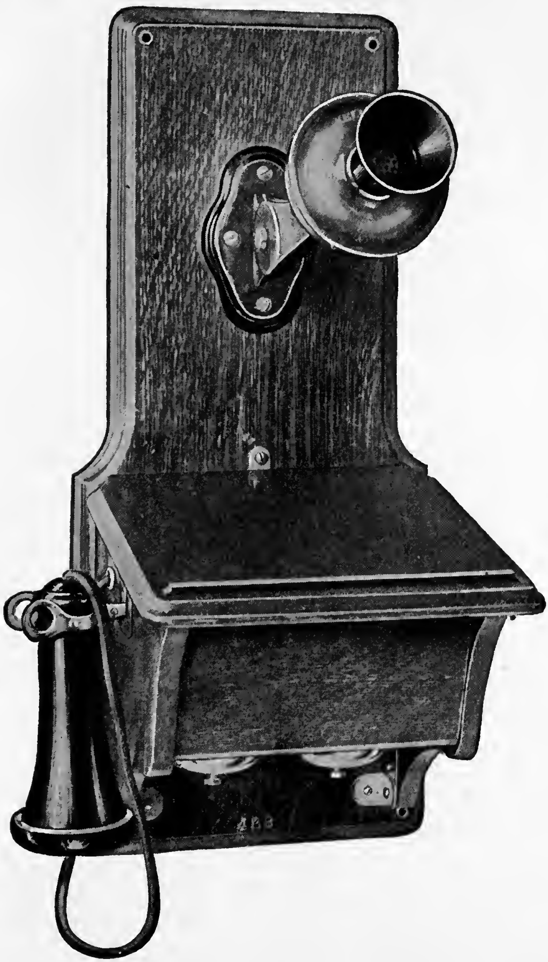

Fig. 78.

transmitter, is given in Fig. 80, while Fig. 81 shows a Western Electric hotel "phone."

125. Desk Sets.—The common battery desk set consists of the desk stand, and the desk box containing the ringer; the latter

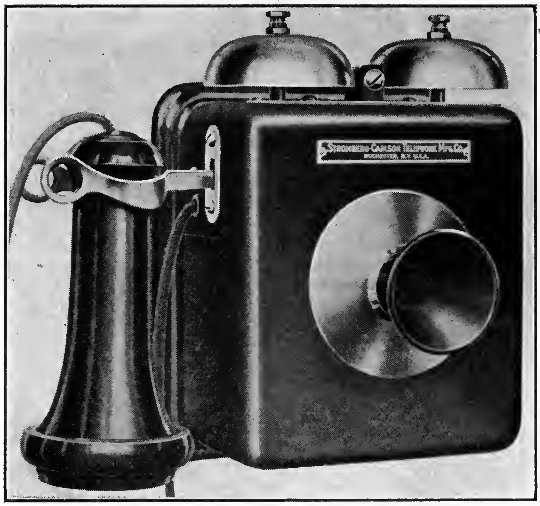

FIG. 79.

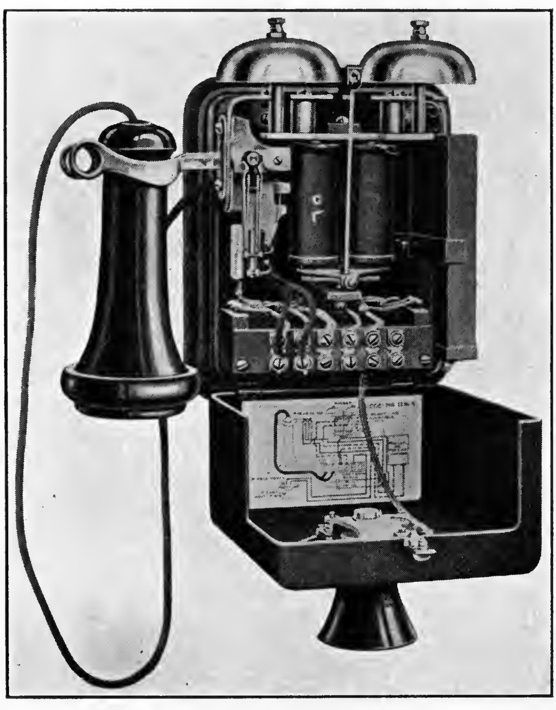

FIG. 80.

may be of either wood or steel. In Fig. 82 are shown the parts of the Kellogg desk set. The desk stand itself contains all the working parts of this telephone, except the ringer and its con-

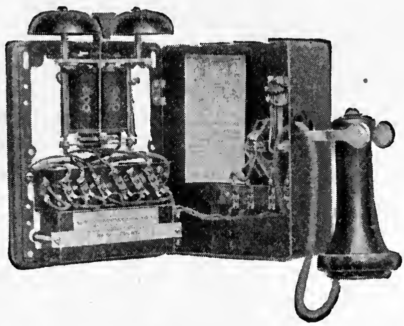

Fig. 81.

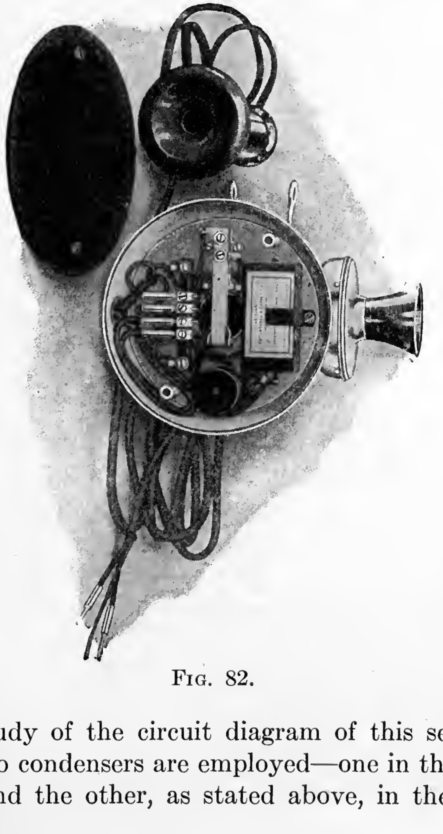

Fig. 82.

denser. A study of the circuit diagram of this set in Fig. 83 shows that two condensers are employed—one in the base of the desk stand, and the other, as stated above, in the ringer box.

The reason for the employment of two condensers is that with such an arrangement only two conductors are needed between the desk box and desk stand. With the addition of extra conductors between the desk box and desk stand, a single condenser can be made to serve in this place as readily as it does in the wall type previously discussed, as in all other respects the wiring and arrangement of parts are practically the same.

The general practice of some other companies is to mount only the transmitter, hook switch, and receiver in the desk stand, all other parts being mounted in the desk box. There are many other forms of common battery telephones, including special

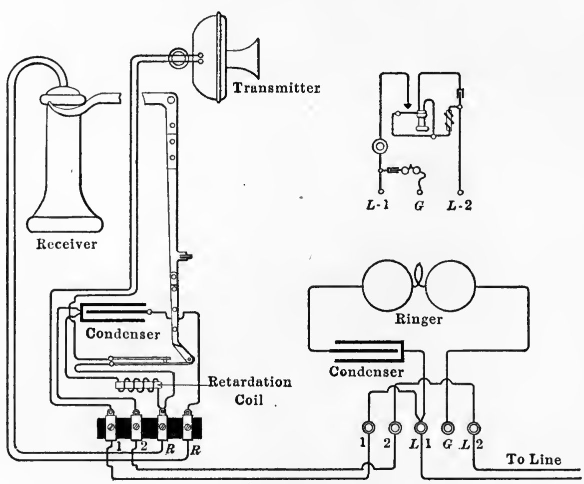

FIG. 83.

forms of wall telephones, adjustable desk stands, hand telephones, etc., which we will not discuss in this course, although they have a considerable field of usefulness.

QUESTIONS

1. In what ways does a central battery telephone system differ from a local battery system?

2. Do you see any advantage in a C.B. system? In an L.B. system? Explain.

3. What is a condenser? How does it work?

4. Why is a condenser necessary in a C.B. telephone system? Explain its action.

5. How are telephone condensers made?

6. What is the method of signalling the central operator in a C.B. system?

7. What is the objection to having the receiver directly in the talking circuit?

8. Show by diagrams how the circuits of a C.B. telephone are arranged so that the receiver is not directly connected to the line.

9. Diagram and explain the Wheatstone bridge method of connections.

10. A pressure of 100 volts alternating at a frequency of 60 cycles is connected to a circuit having a resistance of 1 ohm and a capacity of 3 microfarads. What is the current?

11. If the resistance of a circuit is small in comparison with the capacity reactance of a circuit, how does the current in the circuit vary with the frequency?

12. What is a farad? What is a microfarad?

13. What is meant by dielectric constant? If we use a dielectric whose constant is high, how will the capacity of a condenser compare with the capacity of one of same size but with air as the dielectric?

14. Explain fully the action of the condenser when connected as shown in Fig. 74.

15. Explain the retardation coil. If an alternating e.m.f. be connected to a retardation coil, will the current reach its maximum value at the same time as the applied e.m.f.?

CHAPTER XI

FAULTS IN SUBSTATION TELEPHONE APPARATUS

126. General.—In order that a telephone may give efficient service any trouble or difficulty in operation must be promptly located and removed. Troubles are called faults, and the process of locating the trouble is called "trouble shooting" or fault finding.

As the telephone is an apparatus which makes use of mechanical, electrical, and magnetic principles, trouble may develop in any one of these classes.

Mechanical troubles are usually disclosed by the faulty operation, or nonoperation of the electrical devices, hence in their localization, electrical principles are used.

The most common fault in an electrical apparatus is due either to short circuits or open circuits. In one way or another these cause most of the telephone troubles. Where batteries and a magneto ringer are used, these may fail by exhaustion, that is, the batteries may be used up; and the magnets on the generator may be too weak or reversed.

If a telephone is in good operating condition, the different parts will behave under test in a certain positive manner. The first step in localizing trouble is to perform what are known as O. K. or correct tests. These are five in number, and are as follows:

127. O. K. or Correct Tests, Local Battery Telephones, Line Disconnected.—

1. When the magneto is turned, the bells should ring.
2. No generator current should flow through the coils of the receiver when the hook is down.
3. A spark should be seen at the hook-switch contact when it is moved up and down.
4. Under normal conditions no battery current should flow through the receiver.

To test for battery current in the receiver hold the receiver to the ear and short-circuit the line terminals. If you hear clicks, the battery current is flowing through the receiver.

5. If in Fig. 84 points L_1 and L_2 are bridged or short-circuited, a very strong side tone should be heard in the receiver when one blows or speaks into the transmitter.

128. Side Tone.—An examination of Fig. 84 will make clear what is meant by side tone. If L_1 and L_2 are short-circuited and the receiver raised from the hook, it is evident that the currents induced in the secondary of the induction coil must pass through the receiver; that is, any sound causing a vibration in the transmitter can be heard at the receiver. This is called side tone. When this circuit has low resistance, as when the line terminals are short-circuited, the sound given out by the receiver will be comparatively loud, or a strong side tone will be heard.

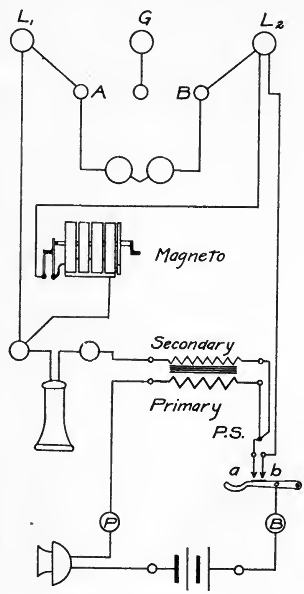

Fig. 84.

129. Classification of Faults.—If the above-mentioned conditions are not fulfilled, there is a fault in the apparatus which must be found. Trouble manifests itself by the inactivity or faulty operation of some part of the telephone set. This inactivity is the symptom of trouble, and it is more convenient to classify the faults with reference to the symptoms disclosed; hence the following classification.

Bell Does Not Ring.—In the series type of instrument the subscriber's bell should ring whenever the generator crank is turned. If the bell does not ring under such conditions, it may be due to an open line. To test for open line, connect the two line terminals of the telephone; if the bell rings when the generator is operated, the line is open. If the bell does not ring when the line terminals are short-circuited, the fault may be in the generator, ringer, switch contacts, or inside wiring. Examine inside wiring and be sure that all connections are firm and that there are no broken wires. Examine the generator switch and see that the switch contact is open when the crank is turned; otherwise the generator is short-circuited through this switch. Examine the hook-switch contacts and see that the contacts are all clean, and that the upper ones are closed when the hook is up. If no faulty contacts or connections are found, the trouble is probably an open circuit in the generator or ringer coil. Place one finger on the frame of the generator and another on the spring at the end of the armature, turn the crank, and see if a shock can be felt. If no shock can be felt, an open circuit in the armature coil exists. If the generator proves to be all right, the ringer coils must be defective.

If a bridging instrument is being tested, failure to ring might be due to a short-circuited line. To test for this, disconnect the line wires, and if the bell rings the trouble is on the line. Some bridging sets are so arranged that when the generator is cut in, the ringer is automatically cut out, in order that no ringing current may be shunted from the line by the local bell. Be sure that the instrument is not of such a type before making further tests. If such be the operation of the set, of course the bell will not ring when the crank is turned, and in order to continue the test the ringer must be connected across the line. If disconnecting the line wire does not locate the trouble, proceed with the test as for the series instrument, examining the switches, wiring, etc., remembering that in the case of a bridging set the generator switch must be closed instead of opened when the crank is turned.

If the bell does not give a strong, clear ring, the trouble is perhaps mechanical rather than electrical, and the ringer should be adjusted as directed under ringer adjustments below.

Can Not Call the Central Operator.—This condition may be due to weak or defective generator. To test, disconnect the line wires, place the fingers across the line terminals of the telephone, and feel for current when the crank is turned. If no current be felt, test the generator directly with the fingers by placing one on the frame and another on the spring at the end of the armature, as above. If no current be felt, the armature winding is open. If current be felt, the circuit is open in the switch or wiring. If the generator turns hard, there is a short-circuit in the generator or some other part of the telephone.

Can Not Hear nor be Heard.—This condition is probably due to an open listening circuit. Examine hook contacts and see that the contacts are closed when the hook is up. With the hook up, turn the generator crank. If the generator can not be heard in the receiver, the circuit is open. Short-circuit the secondary of the induction coil and ring as before. If the generator is now heard, it proves that the secondary or the induction coil is open. To test the receiver and cord, place the fingers across the receiver terminals. If the receiver be open, current can be felt when the crank is turned.

Can Hear but Can Not be Heard.—This condition is evidently due to some fault in the transmitter circuit. The defect may be due to weak or worn-out cells, poor contact at the hook switch, an open or short circuit in some other part of the primary circuit or in the secondary of the induction coil.

First examine and if possible test the cells with an ammeter. If they are found to be in good condition, examine all connections and hook-switch contacts. To test the transmitter, short-circuit the line at L_1 and L_2, Fig. 84, and move the hook up and down. If a spark appears at the hook-switch contact *a* when contact is broken, test for side tone. If the side tone is found to be medium, the trouble is a weak transmitter. If there is no side tone, or if it is very weak, either the transmitter is short-circuited or the primary of the induction coil is short-circuited.

If, when the hook is moved up or down, no spark appears at the hook-switch contacts, then short-circuit the transmitter. If this gives a strong click in the receiver, the transmitter is open; if no click is heard in the receiver, then short-circuit the primary of the induction coil and move the hook switch up and down. If a spark appears, the primary of the induction coil is open; if no spark appears, the wiring is open.

Can be Heard but Can Not Hear.—In such cases the trouble is usually in the receiver circuit, and is probably due to a defective receiver or to a short-circuit in the receiver cords.

Intermittent Faults.—Whenever there is a complete break or short circuit, the fault is complete and lasting unless repaired. There is another class of faults which are more difficult to localize, namely, occasional faults, or those that last for only a short time, while in the interval the apparatus works satisfactorily. Such faults are due, as a rule, to loose contacts or open circuits which may become closed under vibration, change in temperature, movement of some part, etc.

In locating faults of this nature careful inquiries must be made concerning the circumstances and conditions under which the fault appears or is manifest, and how it affects the operation of the telephone. One of the most common sources of intermittent trouble is the local cord circuit. The conductors may become broken, and in a certain position maintain close enough contact to make transmission possible, while in other positions the conductors may be separated so as to form a complete break. Then, again, some of the strands in one conductor may become broken, pierce the covering, and form a short circuit with the other conductor while externally the cord may show no defect whatever.

Test for Faulty Cord.—Whether or not the cord is at fault may usually be determined by putting the receiver to the ear and then continuously blowing in the transmitter, while the cord is pulled, twisted, and wound in different ways. If the fault is in the cord, this movement will cause interruptions in the noise due to blowing into the transmitter. Another method is to connect the cord and receiver to a dry cell directly, and then to listen while the cord is pulled, bent, and twisted. If there are any faults in the cord, they will be disclosed by clicks or sputtering sounds in the receiver.

To facilitate the work in localizing faults the following tabular arrangement has been prepared.

130. Fault Finding, Local Battery Telephones, Substation Apparatus.—Disconnect the line wires before beginning the tests. Begin with the five O.K. tests mentioned at the beginning of this chapter. If possible test the cells with an ammeter.

I. Bells ring weakly.

- A. Adjust ringer and turn magneto.
  1. If bells ring O.K. the bells were out of adjustment.
  2. If bells still ring weakly.
     a. Hold hook down and turn magneto.
        (*a*) If there is magneto current in receiver, hook is crossed with spring.
        (*b*) If there is no current in the receiver, the magnets of the magneto are weak. This may be due to a reversal of one or more magnets.

II. Bells do not ring.

- A. Bridge fingers across line and turn magneto.
  1. If current is felt, the ringer coils are open, or the connecting wires are open.
  2. If no current is felt.
     a. Short-circuit magneto terminals and turn the magneto.

(*a*) If it turns hard, magneto coils are short-circuited.

(*b*) If it turns easy, magneto coils are open-circuited.

III. Can hear but can not be heard.

A. Short-circuit line at L_1 and L_2.

1. If there is a spark at hook switch and

a. Medium side tone, then

(*a*) Poor transmitter, or

(*b*) Weak dry cells.

b. Weak or no side tone

(*a*) Transmitter short-circuited or

(*b*) Primary of induction coil is short-circuited.

2. If there is no spark at hook-switch contacts, short-circuit transmitter and

a. If, when hook switch is closed, a strong click is heard in receiver, then transmitter is open.

3. If no click results, then short-circuit primary coil, and

a. If a spark appears at hook, primary coil is open.

b. If no spark results, wiring is open.

IV. Can not hear nor be heard.

A. Lift hook switch and turn magneto.

1. If no current flows in receiver, bridge fingers across receiver terminals and turn magneto again.

a. If you feel current effect, receiver or cord is open.

2. If you feel no current, short-circuit secondary of induction coil and turn magneto.

a. If there is current in the receiver, secondary of induction coil is open.

b. If no current flows in receiver, wiring is open.

131. Faults in Central Energy Substation Instruments.—The foregoing remarks apply mainly to faults commonly found in connection with local battery apparatus and circuits. In many respects they also apply to common battery substation instruments. As the batteries in a common battery system are not located at the substation, any faults in connection with them are quickly located and remedied. This fact also makes the localization of faults in a common battery telephone somewhat easier, as a steady source of current is always assured. A common source of trouble with common battery circuits is in connection with the leading-in wires where they are fastened to damp walls. The dampness will in time cause deterioration of the insulation and grounds will result. Good practice requires that where the leading-in wires pass through a window or door frame they should be protected by a porcelain tube. The wires should enter through a hole sloping downward from within. Where the walls are damp, the leading-in wires should be run on porcelain knobs so as to avoid all contact with the walls.

132. Circuits of C.B. Subscribers' Telephones.—As indicated in Figs. 72 and 85, there are two common methods of connecting the receiver and transmitter in a C.B. subscriber's set. In Fig.

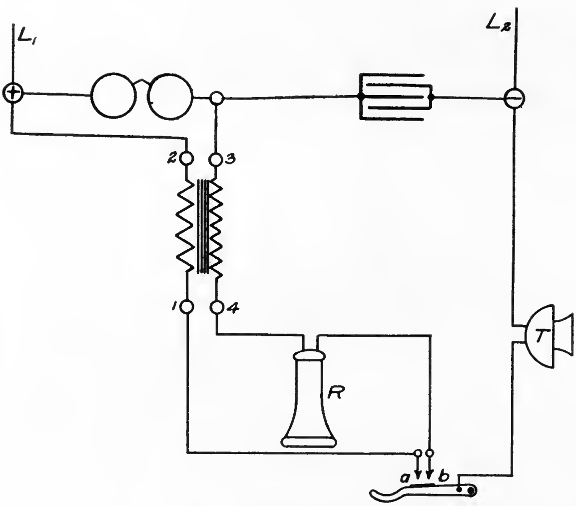

FIG. 85.

72 the receiver and transmitter are in series; that is, they are connected in such a manner that the transmitter current also passes through the receiver. In this diagram no induction coil is used. A similar arrangement may be employed with an induction coil, as indicated in Fig. 85. This arrangement in practice is known as side-tone wiring.

The other method is that shown in Fig. 86. This shows the transmitter removed from the receiver circuit, and placed between the hook and primary of the induction coil. This arrangement is known as side-tone reduction wiring. The reason for these two designations will presently appear. When the arrangement shown in Fig. 85 is employed, the variations of current in the primary of the induction coil induce currents in the secondary. These secondary currents have a high frequency, hence can flow quite readily in the receiver circuit. Then, again, as the current in the transmitter varies, a variation in potential or pressure will result across the terminals of the receiver circuit. As the potential increases, the condenser will be charged, and as the potential decreases, the condenser will discharge. There are thus two sets of currents flowing in the receiver circuit. When the arrangement of Fig. 86 is employed, only the induced currents flow in the receiver circuit. There will thus be side tone

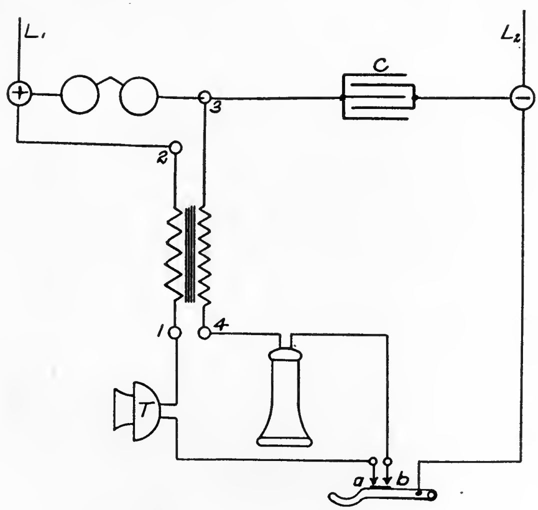

FIG. 86.

in either case, but it will be weaker when the side-tone reduction connection is used. Referring to Fig. 85 we see that there are three circuits in the common battery telephone set:

1. The talking or battery circuit is from L_1 through the primary of the induction coil to the hook switch at *a*, and then through transmitter and to L_2.

2. The listening circuit is from *b* to the receiver, to the secondary of the induction coil and condenser back to *b*.

3. The ringing circuit is from L_1 through ringer and condenser to L_2.

133. Locating Faults in C.B. Telephones.—In testing a subscriber's set for faults some difficulties may be experienced which are not evident from the simplicity of the connections. An examination of Figs. 85 and 86 will show that current may flow through the receiver from three directions: namely, from the line through the primary of the induction coil, from the line through the ringer, and through the condenser. The transmitter may receive current from the line through the ringer, or through the secondary of the induction coil. These different possible sources of current may cause difficulty in locating trouble. The first step in locating trouble is to examine the hook switch to see if it makes good contact, if there is current on the line, and also if the trouble is in the listening or talking circuits.

The most common faults in C.B. subscriber's apparatus with bridged ringer may be located in the following manner:

Can Not Call Central Operator.—This is due generally to line trouble or, on party lines, to another receiver off the hook. If neither of the above is the cause, examine hook contacts. *Hold the hook down and short-circuit the receiver momentarily. Clicks in the receiver mean receiver spring b, Fig.* 85, *is crossed with hook.* Next move hook up and down and look carefully for sparks. If no spark appears, the other spring *a* is crossed with the hook. Next short-circuit the condenser. If no spark be seen when the short-circuiting wire is removed, it is a sign that an internal short circuit exists in the condenser. On desk sets a damp cord will also prevent the subscriber's signalling the operator.

Bell Does Not Ring.—This may be due to the bell being out of adjustment, switch-hook contacts crossed, or an open circuit in the ringer.

To adjust the ringer proceed as follows:

First, loosen lock nut and adjust front bearing screw, so that the armature will move freely but not be loose. After the adjustment has been made, hold the screw and tighten the lock nut.

Second, adjust the stroke of clapper ball, if ringer be adjustable in this respect. Move bell gongs outward as far as possible, and adjust the armature so that the clapper ball has a stroke of about $\frac{1}{8}$ in.

Third, adjust the gongs. Move left gong toward the clapper ball so that when the left end of the armature is lifted and quickly released, the ball will strike the gong once only and will not remain in contact with it. Make the same adjustment for the right gong.

If the bell be a biased one, the biasing springs should next be adjusted. The biasing spring should give sufficient tension to produce a clear and even ring on each gong, and should be tightened or loosened to give the desired effect.

If the bell does not ring after adjustment, ask the operator for a ring, hold the hook down, and see if the generator is heard in the receiver. If such be the case, the hook contacts are crossed. If no sound be heard in the receiver, raise the hook and see if clicks are heard in the receiver when the binding posts are short-circuited. If such be the case, the primary and secondary of the induction coil are crossed. If none of these tests locate the trouble, it is probably due to an open-circuited ringer coil.

Can Call Central but Can Not be Heard.—This means that when the receiver is raised from the hook the circuit through the primary of the induction coil and transmitter is complete and that current is on the line. If under these conditions the subscriber can not be heard, the trouble must be in the transmitter, and as the circuit is closed the transmitter must be short-circuited or packed.

Can be Heard but Can Not Hear.—This condition indicates a fault in the receiver circuit. It may be in the secondary of the induction coil, the receiver, or the wiring. Short-circuit the secondary of the induction coil and listen for a click in the receiver. If no click is heard in the receiver, either the receiver or connections are open; if a click is heard, the secondary of the induction coil is open.

These simple methods apply mainly to a C.B. telephone set whose connections are shown in Figs. 85 and 86. If the connections differ radically, the general principles may still apply, although the procedure for localizing the fault may differ somewhat.

QUESTIONS

Explain how you would locate the causes of the following local battery faults:

1. Series bell does not ring.
2. Bridging bell does not ring.
3. Can not call operator.
4. Can not hear or talk.
5. Can hear but can not be heard.
6. Can talk but can not hear.

Explain how you would locate the causes of the following central battery faults:

7. Can not call operator.
8. Bell does not ring.
9. Can get central but can not talk.
10. Can talk but can not hear.

Give complete adjustments for:

11. Ordinary polarized bell.
12. Biased bell.

CHAPTER XII

PROTECTION OF TELEPHONE LINES AND APPARATUS

134. Need for Protection.—Whenever a telephone circuit receives a voltage higher than that for which it is designed, excessive currents may flow, overheating and possibly destroying the apparatus connected to the circuit. The excessive currents also increase the fire hazard and may cause injuries to persons coming into contact with the circuit even at some distance from the point of application of the excessive voltage.

135. Sources of Excessive Voltage.—The sources of excessive voltage against which telephone apparatus must be protected may be classified under the following heads:

1. Lightning.
2. High-voltage power circuits.
3. Low-voltage power circuits.

The low-voltage currents may cause damage in two ways:

1. By heating.
2. By electrolytic action.

To prevent, or at least reduce to a minimum, the danger from these sources, protection devices of various kinds are used.

136. Heating Effect of Current.—The heating effect of an electric current is proportional to the square of the current flowing and to the resistance of the circuit within which it flows. If we wish to calculate the heat developed by a given current within a given resistance in a given time, we use the formula

$$\text{Heat} = 0.24 I^2 R t \text{ calories}$$

I is the current in amperes.
R is the resistance of the circuit in ohms.
t is the time in seconds during which the current has been flowing.
A calorie is the amount of heat required to raise the temperature of 1 gram of water 1°C.

EXAMPLES

1. A current of 30 amp. flows through a resistance of 5 ohms for ½ hr. How many calories of heat are developed?

Solution

Formula $H = 0.24I^2Rt$ calories
$I = 30$ amp., $R = 5$ ohms, $t = 1{,}800$ sec.
Then

$$H = 0.24 \times 30^2 \times 5 \times 1{,}800$$
$$= 0.24 \times 900 \times 5 \times 1{,}800$$
$$= 1{,}944{,}000 \text{ calories.}$$

2. Assuming that all of the heat developed is utilized in heating water, to what temperature would the heat developed in the circuit mentioned in example 1 raise 10 gal. of water?

Solution

1 gal. of water weighs 8.33 lb.
10 gal. of water weigh 83.3 lb.
1 lb. = 453.6 grams
83.3 lb. = 83.3 × 453.6 = about 37,785 grams.
As 1 calorie will raise the temperature of 1 gram of water 1°C., the temperature to which 1,944,000 calories will raise 37,785 grams is 1,944,000 ÷ 37,785 or 51.4°C. This is the equivalent of 92.5°F.

These problems seem to indicate that the current alone is responsible for the heating. This view is correct, but it must not be forgotten that in a given resistance the current is directly proportional to the pressure and, hence, it is just as correct to consider the heating effect to be proportional to the square of the pressure; for by Ohms' law

$$I = \frac{E}{R}$$

Then

$$I^2 = \frac{E^2}{R^2}$$

which, when substituted in the formula for heat, gives:

$$\text{Heat} = 0.24 \frac{E^2}{R^2} \times Rt = 0.24 \frac{E^2}{R} t.$$

The danger from excessive voltage or pressure is thus of two kinds: It may cause excessive currents, and it may puncture the insulation, causing short circuits. Two kinds of protective devices are thus necessary, one to prevent excessive currents and the other to prevent the entrance of high pressures.

137. Lightning Phenomena.—Although lightning is the oldest manifestation of the dissipation of large quantities of electrical energy, it is the least understood today. We shall not go into the theories of lightning, but it may be of interest to point out certain characteristics of lightning and their modern explanation. The old idea, one still commonly held, is that lightning is a simple discharge of electricity between clouds, or between clouds and the earth. This conception is in some respects inadequate, although it does seem to state what one actually sees. Perhaps the more correct explanation of lightning phenomena is that due to Dr. Steinmetz. His explanation is that instead of being a rupture of the air under an excessive high voltage, lightning is in reality an equalization of stresses within the ether. Lightning may be compared to the breaking of a piece of glass which has been rapidly chilled and thereby filled with internal tension and compression strains. If such a piece of glass is scratched it will suddenly break all over. So, with our present knowledge, we must consider as the most probable explanation—although not certain by any means—that lightning discharge is the phenomena of the equalization of internal electric stresses in the cloud, and is analogous to the splintering or breaking of an unevenly stressed brittle material like glass.

If such a discharge, or even a small portion of it, happens to pass through a telephone instrument, those parts connected with the line at that time will probably be destroyed either by having their windings fused by the heavy current, or by having the insulation of the windings punctured by the high voltage. Of course, the person using the telephone when such a stroke occurs would be very fortunate to escape without serious injury. There are two somewhat different lightning effects encountered in telephone work. The first of these is the direct stroke, which has been discussed above; the second is that due to induction. Whenever a discharge takes place, electromagnetic waves move out in the ether somewhat like water waves in a lake when a disturbance takes place at some point. These electromagnetic waves when they cross telephone lines induce currents in the wires. The effect of electromagnetic induction due to a lightning discharge is usually neglected. There is, however, another kind of induction which must be considered, namely, electrostatic induction. To understand this, suppose a heavily charged cloud moves up to the region over the line. If the cloud is negatively charged, a positive charge will be induced on the telephone line, and an equal negative charge will have a tendency to pass to earth. If the approach of the cloud is slow enough, this free negative charge will pass to earth by gradual leakage over the insulators. If the approach of the cloud is rapid, and if the potential difference between its charge and the earth is great, the free charge on the line may puncture the insulation and pass to earth. When the telephone line is metallic and well insulated upon poles or other fixtures and not connected with the earth by conducting material, the inductive effect of the lightning discharge will not be so great as upon a line whose ends are grounded.

The telephone line, as a rule, does not offer an easy and direct path for the lightning discharge between the cloud and the earth, owing to its horizontal position, and usually receives only a portion of the discharge which finds its way to or from the earth over several poles nearest the main path of the discharge. The total quantity of electricity in a lightning discharge is not great, but as the voltage is high the energy is comparatively great, and as the duration of the discharge is short, the power is very high.

138. Lightning Conductors.—Before the laws governing the dissipation of electrical energy were well understood, it was supposed that lightning would obey Ohm's law, and that whenever a discharge took place it would follow the easiest path to earth, and that if an easy path were provided it would protect all others. It is not merely a charge of electricity that must be conducted to earth, but a large quantity of energy must be dissipated as quickly as possible and in such a way as not to be destructive.

Lightning is an oscillatory discharge; that is, in effect it can be compared to the action of a compressed or extended spring which is suddenly released. The spring does not dissipate its energy in one swing from the extended position to its position of rest, but it overshoots the neutral position and oscillates back and forth for some time. If, however, the spring is immersed in some viscous material, it will not overshoot its position of equilibrium, but will dissipate its energy in moving slowly from the extended position to its position of rest. The material will not be violently disturbed and no harm will be done.

In a lightning discharge there is a certain amount of energy to be dissipated, and it may be that a single rush of electricity in one direction does not suffice to dissipate all of the energy. If the path has a moderately high resistance, a single rush may be sufficient, but if the resistance of the path is low a single rush is not sufficient, and the discharge will oscillate until all the energy is turned into heat. The rush in either case, however, is likely to be violent and the discharge will not always take the easiest path but will make its own paths, which are sometimes quite unexpected.

The relatively high resistance of iron as compared with that of copper makes the use of iron wire for lightning rods on telephone poles beneficial in damping the oscillations of the flash, and thus permitting the discharge to leak away slowly and without side flashes. Its high melting point and cheapness are also advantages. The wire must not be too small, however, or there will be risk of its fusing.

An electric current, like matter, seems to possess inertia. That is, it takes some time to start a current, and likewise when its flow has once been established some time is required to reduce it to zero. Thus, when a source of e.m.f. is connected to a circuit, the resulting current will not at once, or immediately, reach a maximum value. This is due to the fact that the establishment of a current in a circuit is accompanied by the storage of energy in the space surrounding the circuit. To store energy in the magnetic field requires time. When the circuit is broken the energy is returned to the circuit and thus does not permit the current to drop instantly to zero. This property of a circuit is called inductance. Whenever a wire is bent, its inductance is increased, and a greater opposition is presented to the establishment of a current. It is thus evident that wire used for lightning rods should have no sharp bends, and in fact, should be as free from bends as possible. As already stated, a lightning discharge is of an oscillatory character with an exceedingly high frequency. This high frequency increases the reactance of a bend or kink to such an extent that the discharge is liable to jump across to some other conductor and not pass around the bend.

139. Lightning Arresters.—There are two ways, then, in which lightning can affect a telephone circuit: by electrostatic induction and by direct stroke. The object of lightning arresters is to protect the subscribers' station apparatus, cables, and central office equipment against damage from both these causes. The operation of lightning arresters depends upon the fact that current due to a lightning discharge will jump across a short air gap more readily than it will pass through a coil or other piece of apparatus having considerable impedance. It has been stated above that when high-frequency current flows in a coil having impedance, a high counter-pressure is set up, which tends to hold back the current. As lightning has a frequency many times higher than that of currents used in telephone practice, lightning will not pass through the coils and windings of telephone instruments readily if some other convenient path to ground be provided. In Fig. 87 is shown a diagram of a lightning arrester and connections. The two short plates are connected to the line; and the long plate is connected to ground. The gaps between the plates are made very small so that any current due to lightning finds an easier path to ground through the air gap than through the coils of the instrument. Arresters were formerly made with metal blocks of the general form shown, but proved to be quite unsatisfactory on account of the fact that heavy discharges were likely to fuse the plates and fill the gaps with molten metal, thus destroying the arrester as well as putting the line out of commission.

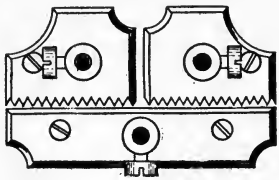

Fig. 87.

140. Carbon Block Arresters.—The carbon block arrester is in common use on account of the fact that discharges between the carbon blocks do not melt or fuse the blocks readily; hence the arrester is not difficult to maintain. One form of carbon arrester is shown in Fig. 88. This arrester consists of carbon blocks, having the two inside ones connected to the ground, and the outside blocks connected one to each side of the line. Between the outside and inside blocks are placed separators of mica, which are perforated with a number of circular holes through which the discharge takes place when the arrester operates. Forms of micas are shown in Fig. 89.

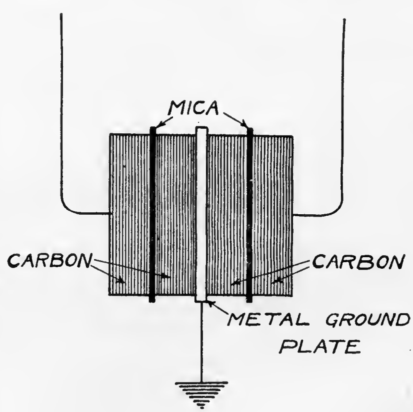

Fig. 88.

The American Telephone and Telegraph Co. uses two types of open space "cut-outs," as the carbon block arresters are sometimes called.

The cut-out employed at substations and at the central office consists of small carbon blocks, one of which is connected to the telephone circuit and the other to earth, separated by thin sheets of mica 0.0055 in. thick. A small cavity in one of the opposite faces of the carbon is filled with a button of fusible metal which melts at about 160°F. A carbon with the fusible button is shown in Fig. 90.

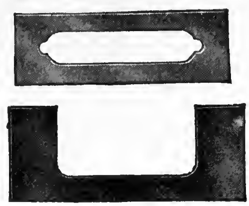

FIG. 89.

"The distance between these carbons is such that electricity at over 350 volts will pass from the carbon connected with the telephone circuit across the space to the opposite carbon and thence to earth. When this escape of current to earth takes place a tiny arc in the space between the carbons may be sufficient to warm the carbons and cause the fusible metal to flow from its recess and fill the space between the carbons and thus establish a permanent connection to ground. If the escape of current to earth does not sufficiently heat the carbon to cause the fusible metal globule to flow, a permanent connection to ground may not be established. In

FIG. 90.

many instances, however, even if the fusible metal globule does not fuse, small particles of carbon from the carbon blocks are broken loose by the sudden current discharge and these may partially ground the line.

"For the protection of aerial and underground cable conductors extended by open wires over ½ mile in length, the open space cut-out is not as sensitive as the one above described. In this case the discharge surfaces consist of two metal blocks and these are separated by means of a mica 0.011 in. in thickness."

The Kellogg Co. equips its magneto telephones with carbon arresters of the type shown in Figs. 91*a* and 91*b*. The metal back plates are semicircular, and are connected to the line. The front disk of carbon is connected to ground and is separated from the line plates by a thin sheet of perforated mica.

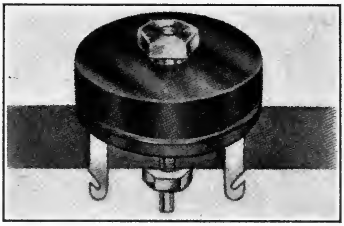

FIG. 91*a*.

141. Self-cleaning Arresters.—Continual electrical discharges between blocks are likely to cause deposits of fine carbon dust which interfere with the operation of the arrester. This can be removed readily, however, by taking the arrester apart and cleaning the parts. To obviate the necessity for frequent cleaning a cut-out has been devised in which the discharge gap is wedge-shaped, being narrower at the top than at the bottom. It is claimed that the carbon particles will not lodge between the carbons when such a gap is used. The construction of the Roberts "self-cleaning arrester" is shown in Fig. 92.

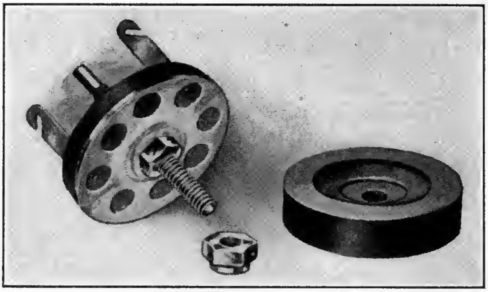

FIG. 91*b*.

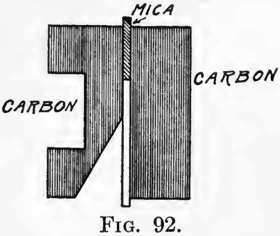

FIG. 92.

A self-cleaning arrester for outdoor installation is shown in Fig. 93. This arrester has three carbon blocks, one of which is connected to ground and one to each side of the line.

There are numerous arresters on the market, but they are practically all of the carbon type, and work on the same principles as those outlined above. Another make is shown in Fig. 94.

142. Location of Lightning Arresters.—Arresters may be made a part of the instrument, or connected to the line at the point of entrance to the building. Good practice requires that an arrester be placed in the latter position if the line inside the building is of any considerable length.

143. Protection against Power Circuits.—The voltage of lightning and power circuits is always higher than that of the telephone line; hence it is necessary to protect the latter against possible contact, either partial or complete, with the former. To accomplish this several types of protective devices are used. These devices must protect against an almost infinite number of possible conditions of voltage and current strength.

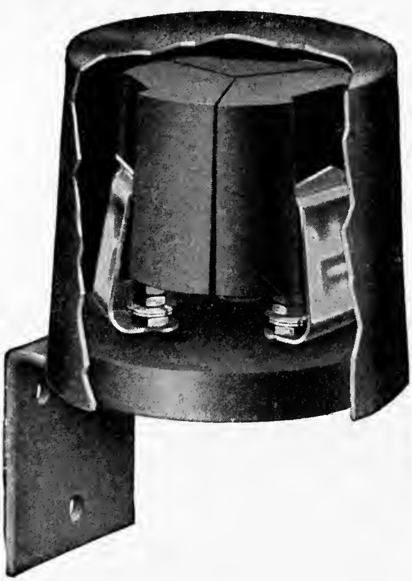

Fig. 93.

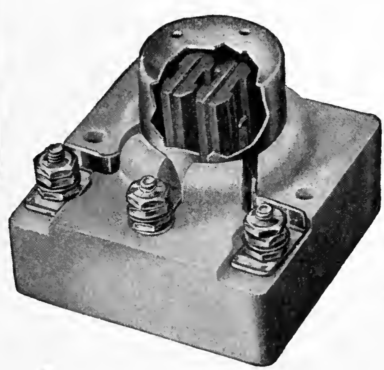

Fig. 94.

The protection against damage from crosses with high-pressure power circuits is accomplished by means of the same devices as used for guarding against damage by lightning or static discharges, namely, the open space cut-out. The open space cut-out operates, as previously explained, by grounding the line. If the disturbing voltage is of short duration such as a lightning discharge no other protection is necessary. When, however, the disorder is due to a cross with a high-tension or other power line, the resulting current will probably continue to flow even if the telephone circuit is grounded. In fact, the grounding may even increase the current by reducing the resistance. In order to guard against such accidents fuses are used.

144. Fuses.—A fuse is a piece of conductor made of an alloy having a low melting point and forming part of the circuit. The action of fuses depends upon the heating effect of the electric current flowing through them. They are, therefore,

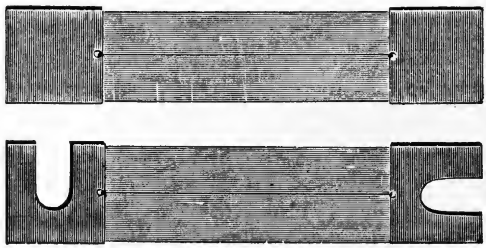

FIG. 95.

used not to protect against high voltages, but to guard against the flow of currents which might damage an instrument by overheating the windings of its various parts. Fuse wires are designed to melt when a current above a predetermined strength flows, thus opening the circuit and breaking the current before the parts of the instrument are overheated.

A fuse does not offer much protection against lightning, as a lightning discharge may destroy an instrument before the tem-

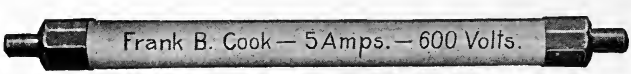

FIG. 96.

perature of the fuse is high enough to melt it, or it may even jump across the gap made by a blown fuse. Fuses used in telephone circuits are invariably of the enclosed type. The mica fuse having a small copper wire between two sheets of mica, as shown in Fig. 95, is quite commonly used. The fuse wire is attached to metal terminals at each end, by means of which the fuse is held in the block.

Another type of enclosed fuse consists of a fusible wire contained within a tube of fiber or porcelain. Usually the wire is surrounded by some nonconducting powder to assist in destroying the arc when the fuse wire is vaporized. An enclosed fuse is

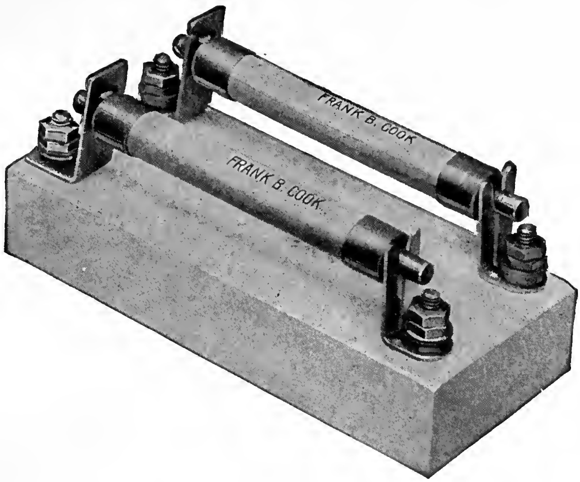

Fig. 97.

shown in Fig. 96, and a porcelain fuse block, with fuses, is shown in Fig. 97.

145. Protectors.—Arresters and fuses are used singly or in combination, and are known as protectors.

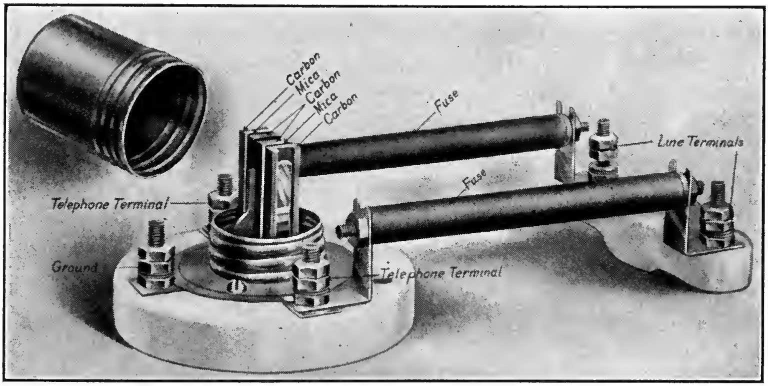

Fig. 98.

The Western Electric 58A protector, shown in Fig. 98, affords protection against lightning, high voltage, and heavy power currents. It consists of a carbon block arrester, designed to operate at 400 volts, and two enclosed fuses designed to carry 5 amp. continuously and to operate at 7 amp. As protection against a continued arc after a lightning or high-voltage discharge, a plug of lead is placed in the outside arrester blocks. The operation of this arrester is as follows: Assume that one side of the line has come into contact with a 600-volt trolley wire. The potential of this line is immediately raised to that of the trolley wire, and the arrester operates. At the time of the operation of the arrester, an electric arc is set up between the two plates. This arc has a very much lower resistance than that of the original air gap; hence the current flow through the arrester tends to increase. If this rises to a value of above 7 amp., the fuse will blow in a short time, disconnecting the arrester and telephone instrument from the line. However, should this current only reach a value of 5 or 6 amp., the fuse might not blow for some

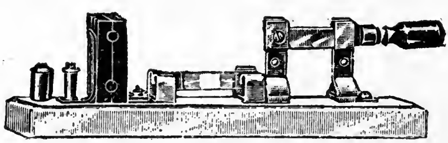

Fig. 99.

time, in which case the fusible plug of the arrester would be melted by the heat of the arc, and the metal would run down between the two arrester plates, short-circuiting them and allowing a large current to flow. This large current would at once cause the fuse to operate and disconnect the arrester from the line. After the fusible plug has been melted the arrester must be taken apart and the metal removed before the arrester can be put into service again.

Fig. 99 shows another type of protector which, in addition to the arrester and fuse, consists of a switch by which the telephone can be entirely disconnected from the line during the time of a storm. The protector as shown is supposed to take care of one side of the line only, and is sufficient for grounded lines. On full metallic lines, however, a double-pole arrester of the same type is used.

146. Protection against Weak Currents.—Very weak currents, usually called "sneak" currents, may flow if the telephone line is crossed with low-voltage power or lighting lines, or with comparatively high-voltage lines through a high resistance.

In central-energy systems these sneak currents may be caused by a ground on one of the line wires, or the crossing of two wires without being subjected to a foreign potential. The danger from such currents lies in the fact that the heat generated by them accumulates and thus raises the temperature of the coil through which they flow to an excessively high value. The accumulated heat causes deterioration of the insulation and may cause open circuits.

In order to protect against currents that are too small to operate the fuse, and which are harmful only when permitted to flow for a considerable time, a circuit grounding device called a heat coil is used. The heat coil consists of a coil of fine German silver wire which forms a part of the telephone circuit, Fig. 100.

The general principles of the operation of heat coils will be readily understood by reference to Fig. 101, which shows a

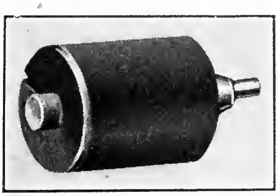

FIG. 100.

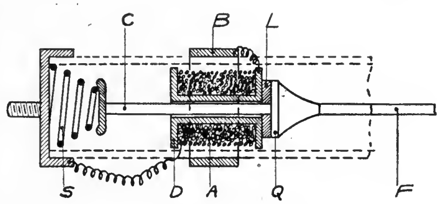

FIG. 101.

section of one type of this protective device. The coil *A* is wound on a metal bobbin *D* which is soldered to a metal stud *Q*. The sneak current, on passing through the coil, heats the bobbin, and if it flows for a sufficient length of time the accumulated heat will melt the solder when the stud *Q* is pushed away by the glass rod *C* breaking the circuit. The glass rod is actuated by the spring *S*. To ground the current the lug *Q* is pushed against a grounding contact.

In some makes of heat coils the soldered connection is under tension. When the solder melts, a spring breaks the circuit through the apparatus and grounds the line by making contact with a grounded lug. This type of heat coil will be more fully explained when the protection of central office equipment is taken up.

The action of the heat coil is to protect the apparatus against prolonged currents of just sufficient strength to overheat its windings, such currents being below 1 amp. and consequently below the range of practical fuse operation. For local battery systems the heat coils are made very sensitive, since they have to protect apparatus which, on account of its high resistance and low heat conductivity, may be injured by comparatively weak currents. In this system the telephone and ringing currents, which under ordinary conditions flow over the line between a substation and the central office, will not operate the heat coil. The telephone current is of minute strength and the ringing current, though greater, is of comparatively short duration. The quantity of heat developed by these currents in the heat coil is so small that there is no danger of its operation.

In the common battery systems the line from the central office to the substation carries, in addition to the ringing and telephone currents, the direct current for the transmitter. If the line is of very low resistance, this current may attain a considerable strength. For this reason it has been necessary to provide a heat coil of sufficiently low resistance to carry this current without operating, but in addition all the pieces of the telephone apparatus in the line circuit have been designed so as to withstand the heating effect of this current for an indefinite time.

The resistance of the sneak current arrester for local battery systems is about 46 ohms. The effect on telephone transmission of the resistance of these arresters in the line has been made the subject of carefully conducted experiments, and it has been found that their effect is quite imperceptible on local service transmission. On the other hand, in order to secure high-efficiency telephone transmission in common battery systems, it is necessary that the resistance be kept as low as possible. The sneak current arrester for this system is designed with a resistance of about 3.6 ohms. This is found sufficiently high to develop the necessary amount of heat to cause the arrester to operate promptly on dangerous currents.

147. When Substations Need Protection.—As regards the necessity for protection, subscribers' stations are of two types; exposed and unexposed. An exposed station is one which is liable to be affected by lightning discharges, or by the line coming into contact with high-voltage transmission and other electric light and power wires. Ordinarily, therefore, the line of any subscriber's station which is connected with the central office through aerial wiring or cable is considered exposed. A station is likewise considered exposed where a building is fed by a tap from an aerial cable, even though this tap may be carried underground. Wherever a station is so located that electric light wires or other circuits carrying a pressure of over 250 volts are liable in case of failure to come into contact with the wall wiring of the telephone, the station should be considered as exposed, and the substation should be protected.

Subscribers' stations connected directly to the central office through an underground cable are considered unexposed, and therefore need no protection.

CHAPTER XIII

INSTALLATION

148. Entrance Holes.—Before making any holes for the entrance of the leading-in wires, the location of the protector must be decided upon. Having decided upon the location of the protector, one entrance hole sloping downward from within should be made, care being taken that the distance between the protector and the entrance hole is as short as possible. In locating entrance holes and protectors, it is desirable to locate

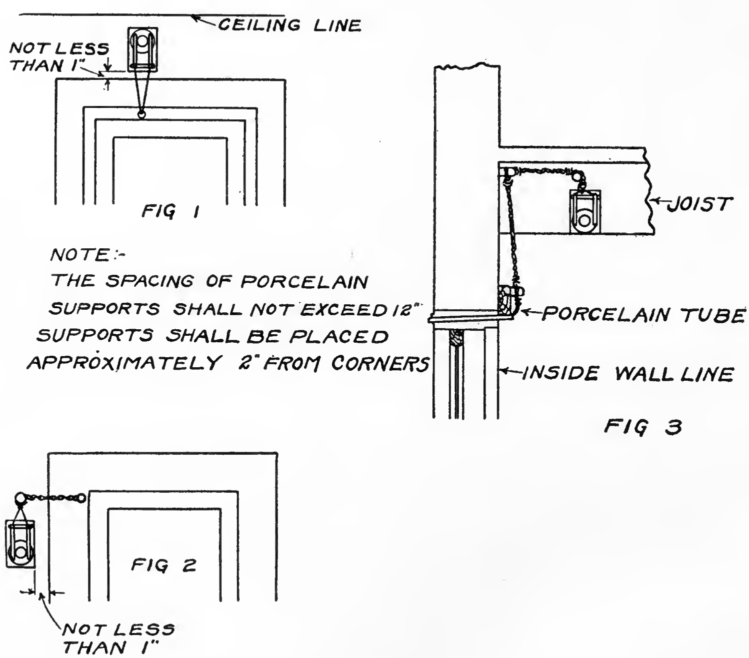

Fig. 102.

both so as to give the shortest and most direct connection for the ground wire.

149. Leading-in Wires.—The wires extending from the pole or fixture to the building should be attached to a support on the outside of the latter. The distance from the last outside support to the entrance hole should not be over 1 ft., Fig. 102. From the last support a twisted pair of wires should be used to enter the building. To prevent water following the wire into the building, a drip-loop should be made at the leading-in wires at a point immediately below the entrance hole, Fig. 103. All entrance holes should have porcelain tubes for the protection of the leading-in wires, and these tubes should project a short distance from the hole. The leading-in wires should not come into contact with any part of the building; and if these wires must be extended through walls, floors, or partitions, they should be enclosed in porcelain tubes in the same manner as in passing through the outside wall. Porcelain tubes should always be firmly secured so that they will not slip out of place. If it is necessary to carry the leading-in wires any distance inside the

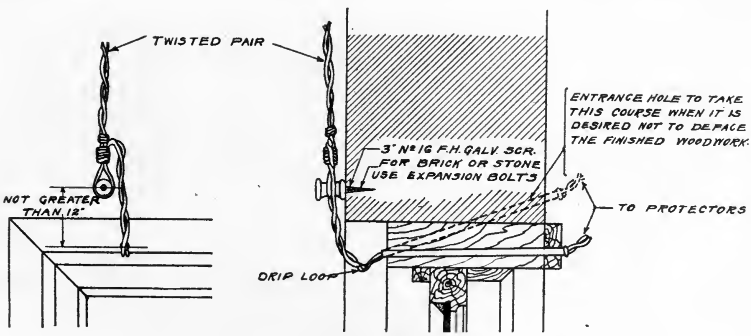

Fig. 103.

building before they reach the protector, they should be supported by porcelain knobs or cleats.

150. Location of Protector.—The protector should be mounted upon the wall in such a manner that the fuses are vertical, and should be placed as near as possible to the point where the leading-in wires enter. It is essential that the protector be not exposed to water or dampness; if such is the case, a protector designed for outside service should be used. The protector should be mounted away from all combustible materials.

151. The Inside Wiring.—The wires used on the inside of the building after the protector has been passed should be what is known as inside wire, and may be either single, double, or triple conductor wire, depending upon the requirements. As neatness is a desirable characteristic of all inside wiring, it is essential that wires should be run only horizontally and vertically, and in as workmanlike manner as possible. As far as possible, such wires should be concealed. Wherever picture molding is provided, wires may be conveniently carried along this molding; or if the latter is not available, they may be carried along the mopboard, in corners, etc., but should never cross open walls or ceilings.

All wire must be fastened in such a manner as not to injure its insulation. For this purpose insulated staples, cleats, or insulated tacks may be used.

Telephone wires should never be run through hollow partitions, under floors, or other places where there is any liability of coming into contact with electric light wiring. When it is necessary to cross any open electric light or power wire, pipes, or other conducting material, the telephone wires should not come within 2 in. of these wires or pipes, and should be protected by porcelain tubes, or several wrappings of friction tape. Whenever practicable, wires should be run above pipes and conducting materials which it is necessary for them to cross. There should be no coils or knots made in any of the wires at the protector or telephone set terminals, or any other part of the inside wiring. Where necessary to splice wires of the system within the building, all joints should be soldered and carefully wrapped with rubber and friction tape. If tracer wires or wires of different colors are used, corresponding wires should always be spliced together.

152. Ground Wiring.—In order to secure the best service from protectors, it is necessary that the ground wire be properly installed. The ground wire should run as directly as possible from the protector to ground, and should have no kinks, coils, knots, or sharp bends. Where necessary to carry a ground wire through an outside wall, a separate hole should be provided at least 3 in. distant from the entrance hole. If necessary to protect this wire from injury, it should be protected by a wooden molding or enclosed in a nonmetallic conduit, and never run in an iron pipe.

The ground connection may be made through a water or gas pipe, or to a ground rod driven in permanently damp earth. Whenever connections are made to pipes, preference should be given to water pipes; and when made to gas pipes, should be at a point between the meter and the street so that the removal of the meter will not break the ground connection. When ground connections are made to pipes, some form of clamps is used. Fig. 104 shows a good form. Steam or hot-water pipes or other parts of heating systems are not desirable as ground connections. If it be necessary to use a ground rod, the latter should be located within the building if possible. In connecting the ground wire to the ground pipe or rod, the pipe or rod should be thoroughly clean, the ground wire wrapped around it a number of times, and the connection soldered.

153. Location of Telephone Set.—A wall set should be so located that the mouthpiece of the transmitter will be at the most convenient height for the average person using the same. The height from the floor to the center of the transmitter should be about 4 ft. 10 in. A telephone set should not be located where it will be injured by doors or movable furniture, or where it will interfere with persons passing through the room. The set should not be mounted on a damp wall, if the same can be avoided, nor near a window that is liable to be opened during a storm. However, if such be the only space available, a waterproof board should be mounted on the wall, and the telephone in turn mounted on this. Vibrating partitions and noisy locations should be avoided.

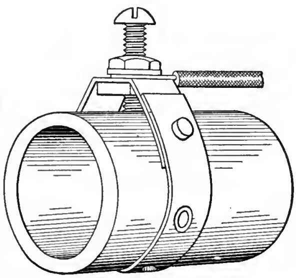

Fig. 104.

The wall sets should be fastened firmly and securely to the wall. In attaching a set to a wooden or plastered wall, round-head wood screws should be used. To fasten a set to brick, cement, or stone walls, holes should be drilled in the wall in proper position for the screws. The holes should then be plugged, and the set fastened with round-head wood screws. Care should be taken that thoroughly dry wood is used, and that the plugs are large enough to hold securely. Expansion bolts may be used in place of the above. If a set is to be attached to a hollow tile wall, holes should be drilled at the proper places and toggle bolts used to attach the same.

A desk stand should be placed where it is most accessible and convenient for the subscriber. If possible, the bell box should be so located that the cord can be connected directly to the terminals in the box, so as to prevent the cord from lying on the floor or where it might be exposed to dampness or damage.

QUESTIONS

1. Why is it necessary to protect telephone instruments from lightning and high-voltage light wires?

2. What is the principle of operation of lightning arresters? Why will lightning jump across a small air gap rather than pass through a telephone instrument?

3. Explain the construction of the carbon block arrester. What are its advantages?

4. Explain the construction of fuses and give their uses.

5. Describe and explain the operation of the Western Electric 58A protector.

6. What is meant by exposed and unexposed subscribers' stations?

7. When a telephone is being installed, where should the protector be located?

8. How are the leading-in wires carried through outside walls, partitions, etc.?

9. How should inside wiring be done?

10. How should the ground wire be run, and the ground connections made?

11. What precautions should be observed in locating the telephone set?

12. Why are the leading-in wires not allowed to touch any part of the building, while the inside wiring may be run along molding, etc?

13. Explain the function and action of sneak-current arresters.

14. What is the difference between sneak arresters for common battery systems and for local battery systems?

CHAPTER XIV

PARTY LINES

154. Definition.—The simplest form of a telephone installation is a line to each end of which is connected a subscriber's telephone set, Fig. 105. It is evident that other telephones may be bridged

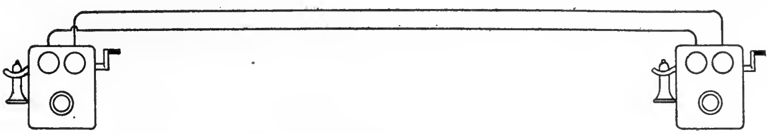

FIG. 105.

across the line anywhere between the two ends, or that a branch line may be run from some point on the main line and one or more telephones connected to the branch line, as shown in Fig. 106.

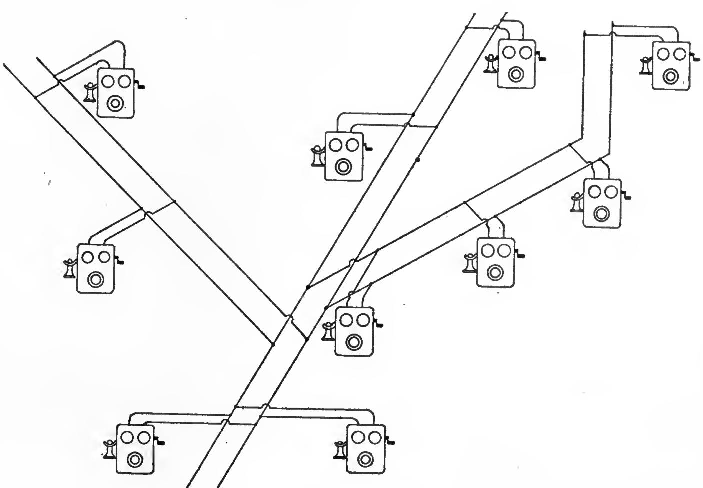

FIG. 106.

Telephone lines connected so that more than one subscriber can be called on the same line are known as party lines.

155. Classification of Party Lines.—When telephone service is supplied to a few subscribers scattered over a comparatively large area, as in country districts, party lines are invariably used. Within cities, where all lines run to a central office, few party lines are used, and where they are used seldom more than four subscribers are connected to the same line. Party lines can then be classified in accordance with the number of subscribers connected to the same line, but it is undoubtedly preferable to classify them in accordance with the calling system used. We thus have two classes of party lines: namely, code ringing and selective ringing.

156. Code Ringing.—The most simple party line system, and the one which was first used, employs the code system. In this system all ringers are bridged or connected across the line in parallel, and all must be of the same resistance in order that the ringing current may be equally divided between them. Any number of telephones, up to about 20, may be connected to the line, and as all the bells ring when ringing current is sent over the line, a code system of ringing is used. A code system with which everyone is more or less familiar consists of a system of short and long rings. Below is a code system for 14 stations, with their corresponding numbers.

Station No.	1 –	11 — –	21 — — –	31 — — — –
	2 – –	12 — – –	22 — — – –	32 — — — – –
	3 – – –	13 — – – –	23 — — – – –	
	4 – – – –	14 — – – – –		
	5 – – – – –			

The central office is always given ring one. It will be noticed that the dashes which symbolize long rings represent tens, and that the short dashes represent units. Of course in the telephone directory only the number is given. This scheme of ringing is not often used in towns or cities, but is usually used on country party lines.

On local battery party lines it frequently happens that subscribers fail to restore their receiver to the hooks or several parties may be listening at the same time. In either case, the receivers and induction coils connected across the line being of low resistance, the ringing current passes through them and not through the ringer coils, thus preventing the central operator's calling the desired party. To remedy this condition and to permit the receiving of a call if receivers are left off the hooks, a condenser is often connected in the receiver circuit, Fig. 107. This condenser prevents the passage of the low-frequency ringing currents and causes them to pass through the ringer coils, but it does not offer any considerable opposition to the high-frequency voice currents. Hence, this condenser has the same use as in the central-battery system. It is the practice on code party lines for one subscriber to call another by giving the code ring without the call going through the central office. Some com-

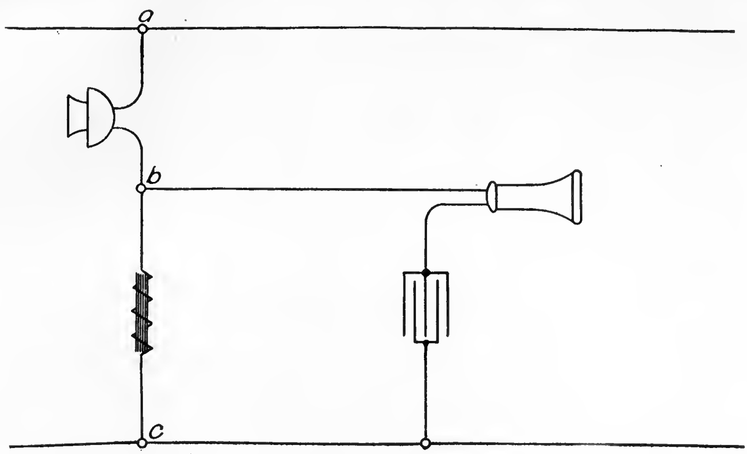

FIG. 107.

panies, however, desire to have all calls originating on magneto party lines come into the central office in order to have a record of all calls made on the line, and at the same time relieve the subscribers of the necessity of ringing parties by code. When

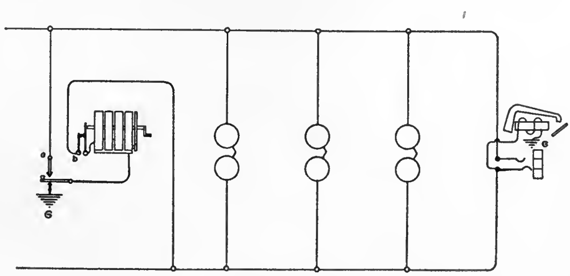

FIG. 108.

this is the case, the instrument is provided with a push button which may be used to connect the generator to ground, and thus use only one side of the line for signalling purposes. The operation of such a device will be readily understood from Fig. 108. When the switch is closed to ground the ringing-current circuit is through the sleeve side of the line to the drop at central, then to ground and back to ringer. The other bells on the line are not affected.

Another plan is to have a direct- or pulsating-current generator in each subscriber's instrument. This current has no effect on the ringers of the instruments, but operates the signals at the central office. The pulsating-current generator is merely the ordinary magneto generator equipped with a commutator and a push-button switch for making connection with the commutator. When the line is connected to the commutator and the generator is turned, the current in the line flows continuously in one direction. It fluctuates in value, as shown in Fig. 45, but does not reverse in direction. Such a current will operate the drop at central, but will not operate the ringers of the other subscribers.

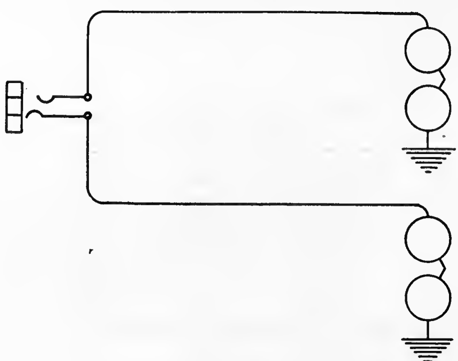

Fig. 109.

157. Selective Ringing.—In selective ringing the ringers are so arranged that only the bell of the person wanted at the telephone is rung. Selective ringing is accomplished by two principal methods. One is by the use of a biased bell with pulsating ringing currents; and the other is by making use of bells which will respond only to a given frequency of an alternating current, this latter method being known as harmonic ringing.

A common method of selective ringing, for use where only two parties are connected to a single line, is to connect one subscriber's ringer between one side of the line and ground, and the other subscriber's ringer between the opposite side of the line and ground, Fig. 109. In order to ring either party, then, it is only necessary for the central operator to send ringing current over that side of the line to which the desired subscriber is connected, which will ring his bell but will not call the other subscriber. The talking circuit is connected across the two sides of the line, as usual. In the four-party selective system, biased bells are used.

A biased bell is a polarized ringer designed to operate with pulsating current; that is, current which flows in one direction but is interrupted from time to time. The biased bell shown in Fig. 110 is essentially a polarized ringer with a spring attached to the armature in such a manner as to hold the clapper in the ex-

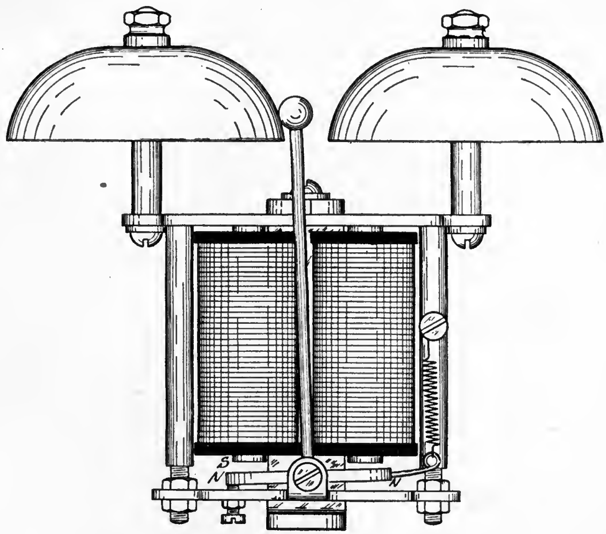

Fig. 110.

treme left or right position when no current is flowing. When the clapper is in the extreme left position, the right end of the armature is near the right core of the magnet. It is evident when the armature is in this position that it can be affected only by current flowing through the coils in such a direction as to cause the left core of the magnet to become a S. pole, when it will attract the left end of the armature and overcome the strength of the spring, causing the clapper to move to the right and strike the right gong. As soon as the current ceases to flow, the armature will be returned to its original position by the spring, and the clapper caused to strike the left gong. The rapidity with which this operation is repeated will depend upon the frequency of the pulsations, or, in other words, the number of times the current is interrupted per second. In order to ring properly, the bell must be in selective adjustment; that is, the spring must be strong enough to pull the armature back to its original position during the time that no current is flowing; yet the spring must not be so strong that the force of the magnet can not overcome it.

Ringers not in selective adjustment can be operated only by alternating currents. In ringing biased bells, selection between four stations on a party line may be had by connecting two biased bells, one of each polarity, between each wire and the ground, four bells in all, as shown in Fig. 111. When the pulsating

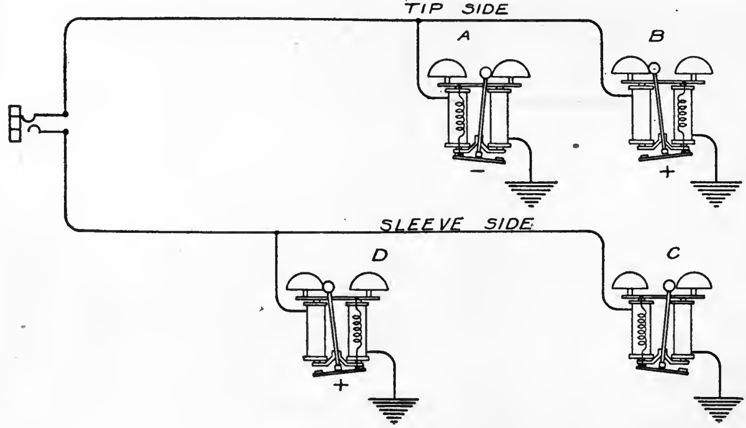

FIG. 111.

generator is connected so that current flows out along the tip side of the line, the ringer at *A* is operated. When the connections are reversed so that the current flows out through ground, it will operate the ringer at station *B*. In the same way the ringers at stations *C* and *D* may be operated by connecting alternately the positive or negative terminal of the generator to the line and the other terminal to ground.

158. Harmonic Ringing.—In a harmonic system alternating current of four different frequencies is used for ringing purposes, the bells being so arranged that each one will ring only when supplied with current at one of the four frequencies. In order that a bell may ring for a given frequency of current, its clapper must swing from one extreme position to the other during the period that the current reverses. Bells used in harmonic ringing have a spring which holds the clapper in its middle position when no current is flowing. In order that the ringers may operate at different frequencies, the strength of these springs and the weights

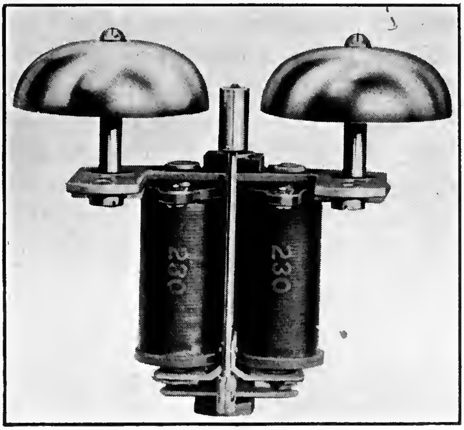

Fig. 112.

of the clappers are different. If the ringer is properly adjusted for the given frequency, a small ringing current will cause the clapper to vibrate violently enough to strike the gongs, in the

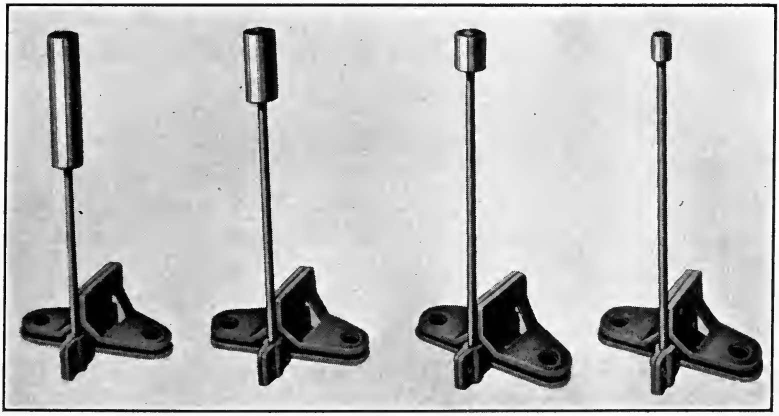

Fig. 113.

same manner that a very small force at the right time causes the pendulum of a clock to swing. Just as a considerable force is required to cause the pendulum of a clock to swing at any but its natural period, so it is necessary that a heavy ringing current be required to cause the tuned ringer to ring at any other than its natural frequency.

The frequencies usually used for harmonic ringing are $16\frac{2}{3}$, $33\frac{1}{3}$, 50, and $66\frac{2}{3}$ cycles per second. Since two alternations are required to complete one cycle, the number of alternations per minute, corresponding to the above, are 2,000, 4,000, 6,000, and 8,000. (For example, $16\frac{2}{3} \times 2 = 33\frac{1}{3}$ alternations per second; and $33\frac{1}{3} \times 60 = 2,000$ alternations per minute.) In Fig. 112 is shown a Western Electric ringer for harmonic party-line service; and the clapper rods for ringers operating at four different frequencies mentioned above are shown in Fig. 113.

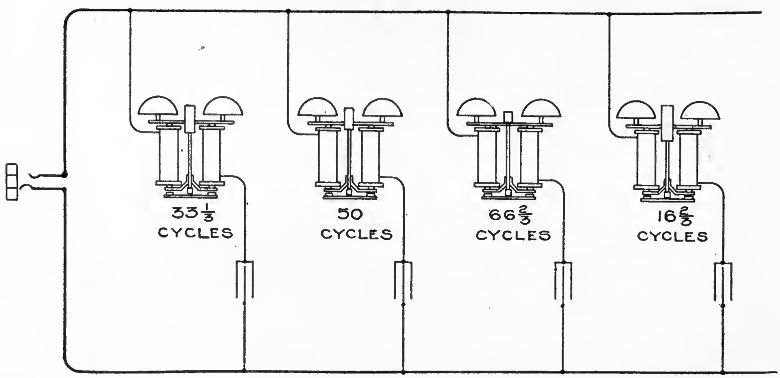

FIG. 114.

Eight-party service may be given by connecting four harmonic ringers of different frequencies between each side of the line and ground, if such service be desired. The ordinary method, however, is to bridge the ringers directly across the line, as shown in Fig. 114, making only four stations on the line.

159. Extension Bells.—Many times a telephone ringer can not be heard as far from the instrument as the subscriber desires, in which case an extension bell can be used. As the extension bell is always connected to the same line as the ringer of the telephone, the extension bell must be of the same resistance and have the same adjustment as the other ringers of the line.

QUESTIONS

1. Into what classes are party lines divided?
2. What is meant by code ringing?

3. What are the advantages and disadvantages of code ringing?

4. Of what use is a condenser in a receiver circuit, in party-line service?

5. What is meant by selective ringing?

6. In what way is a biased bell different from an ordinary polarized ringer? Explain its operation.

7. What kind of ringing current is used with biased bells?

8. Explain the connections and operation of a four-party line using biased bells. Show how each bell can be rung without ringing the others. Show connections by diagram.

9. What is meant by harmonic ringing? What kind of current is used for harmonic ringing?

10. How are harmonic ringers different from other ringers which have been discussed? What is the difference between ringers designed for different frequencies of ringing current?

11. Explain the operation and connections of four- and eight-party harmonic lines.

CHAPTER XV

INTERCOMMUNICATING TELEPHONE SYSTEMS

160. Definition.—An intercommunicating telephone system is the arrangement of several sets of telephones such that any station can call any other station without the assistance of a central operator. Such systems are extensively used in factories, offices, apartment buildings, stores, and large private dwellings as they afford a ready means of communication between different departments.

Telephone systems for intercommunication may be operated either by a local battery for the talking circuit and a magneto for signalling, or they may be operated entirely from a common battery. When the common battery type is used, two sets of batteries are invariably employed.

The most simple system of the local battery type is one in which two telephone sets are connected by a single line. Such a system needs no further discussion. However, when more than two stations make up the system, the arrangement is more complex. Of course, all the instruments could be connected to a single party line, but this would necessitate code ringing. The usual arrangement of intercommunicating systems is to have a separate line run from each instrument to every other one of the system. For magneto ringing the circuits are quite simple and easily designed. Each station is provided with a panel upon which are mounted as many jacks as there are stations, and lines running from any one station connect the jacks into as many parallel groups as there are stations. At each station the ringer is bridged across one line. This line is designated at all other stations as belonging to the station at which the bells are bridged. The talking and ringing circuit at each station is provided with a terminal plug which is used to make connection with the jack of any other station. Fig. 115 is a simplified diagram of such a system. When a person at station *A* wishes to call some one at station *D*, he inserts the plug into the jack connected to the *D* line and turns the magneto. As the only ringer that is bridged across this line is at station *D* it is the only station that will hear the call. As soon as the person at station *D* inserts his plug in jack *D*, the talking circuit with station *A* is complete.

Although such a system is extremely simple, owing to the convenience of automatic signalling provided by the common battery system, the latter is displacing it.

161. Common Battery Interphone Systems.—Most of the manufacturers of standard telephone apparatus also manufacture

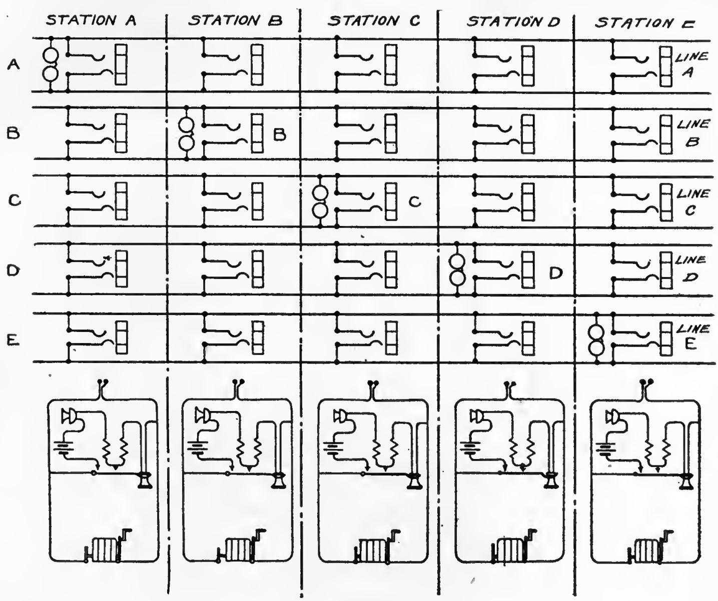

Fig. 115.

intercommunicating telephone apparatus. In general the principles of operation of the different makes are the same, but each has some distinctive method of connection for ringing.

At each station is a telephone set, either a wall set containing the keys and talking set, or a desk stand with a separate key box. Each wall set, or desk set key box has a series of buttons, each one numbered or lettered to indicate the line it controls. Typical C.B. intercommunicating sets are shown in Figs. 116, 117, and 118. A person at one station wishing to talk to one of the other stations presses the corresponding button down to the ringing position, and the desired station is signalled. When this button is pushed down, any other button in the set which might happen to be depressed is automatically restored, thus clearing the station of any previous connection. When the pressure is removed, the button comes back to a halfway or talking position, so that as soon as the called station receiver is removed the talking connections are complete.

The wiring of an intercommunicating system appears complicated, but this is due to the multiplicity of wires at each telephone. As a matter of fact the circuits are quite simple.

FIG. 116.

Diagrams of the circuits of two stations involved when one calls the other of a Western Electric interphone system is shown in Fig. 119. The diagram shows that two sets of batteries are used, one for ringing and one for talking.

162. Western Electric Intercommunicating System.—In the diagram shown the station at the left is supposed to be ringing the station at the right. In doing this the push button *d* is depressed as far as it will go. This closes both the ringing

FIG. 117.

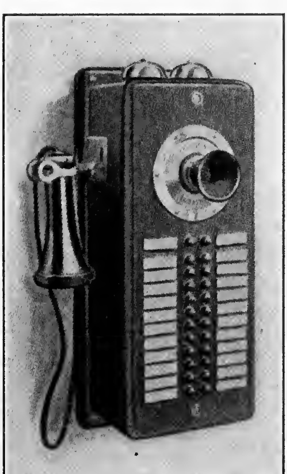

FIG. 118*a*.

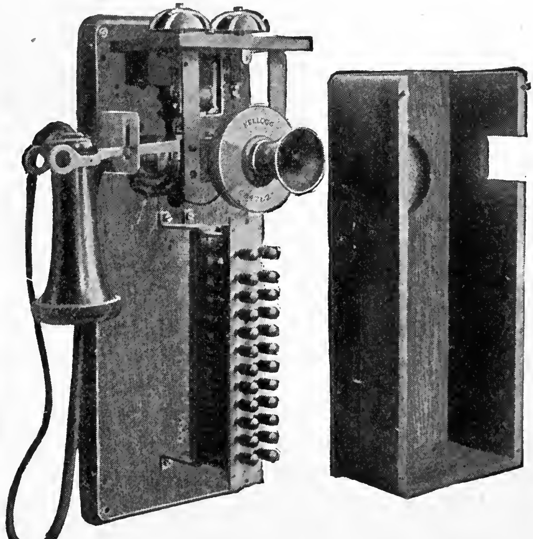

FIG. 118*b*.

circuit at *d*, and the talking circuit at the lower contact. The ringing current then passes from the ringing battery to the bell *c*, which it rings, at the station called, through the back contacts

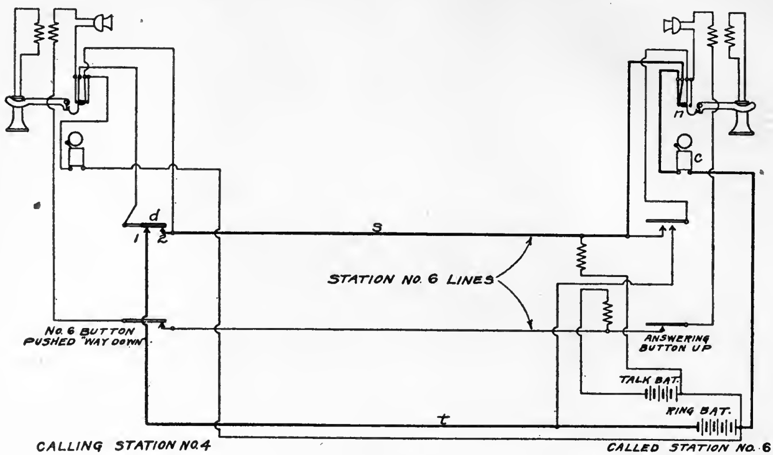

FIG. 119.

n of the switch hook at that station, over the wire *s* of the line and through the lower contact of the button *d* at the calling station, whence over the other wire *t* back to the ringing battery.

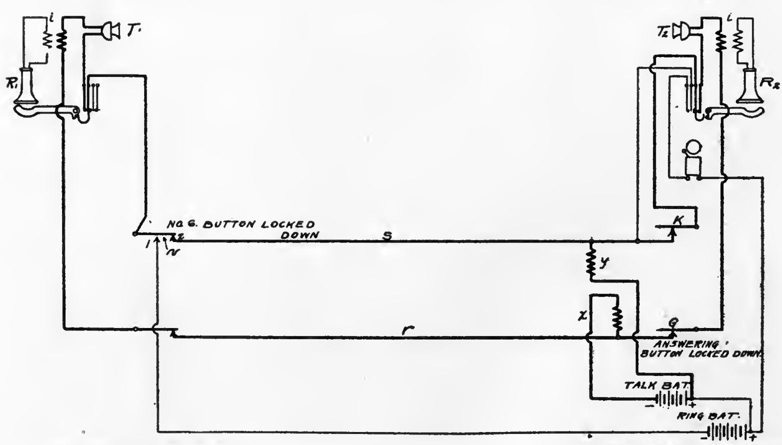

FIG. 120.

When button *d* is released, it springs part way back opening the circuit at 1 but leaving it closed at 2 and at the lower contact. This condition is shown in Fig. 120. As soon as the subscriber

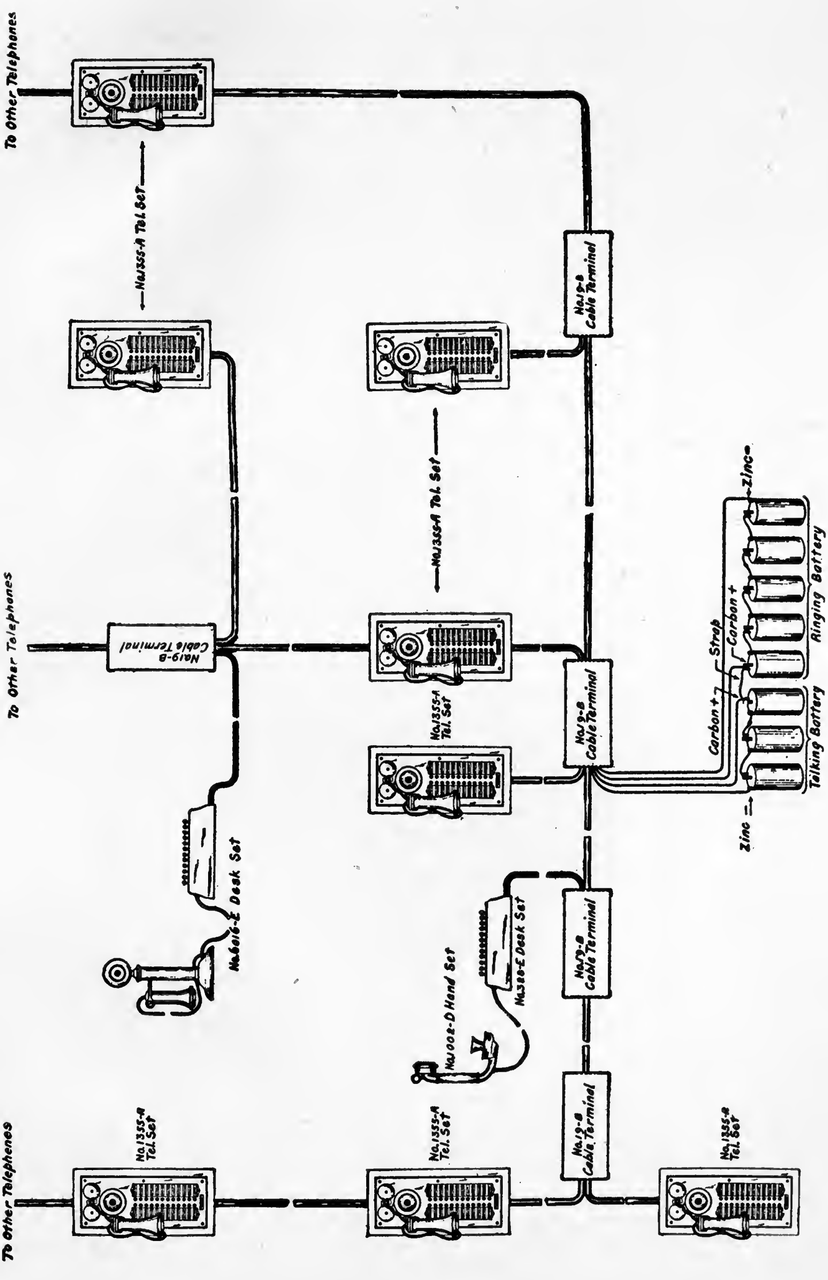
To Other Telephones
No.1355-A Tel. Set
No.19-B Cable Terminal
No.1355-A Tel. Set
To Other Telephones
No.19-B Cable Terminal
No.1355-A Tel. Set
No.19-B Cable Terminal
No.1355-A Tel. Set
Zinc
Strap
Carbon +
Carbon +
Zinc
Ringing Battery
Talking Battery
No.19-B Cable Terminal
No.1002-D Hand Set
No.19-B Cable Terminal
To Other Telephones
No.1355-A Tel. Set
No.1355-A Tel. Set
No.1355-A Tel. Set

FIG. 121a.

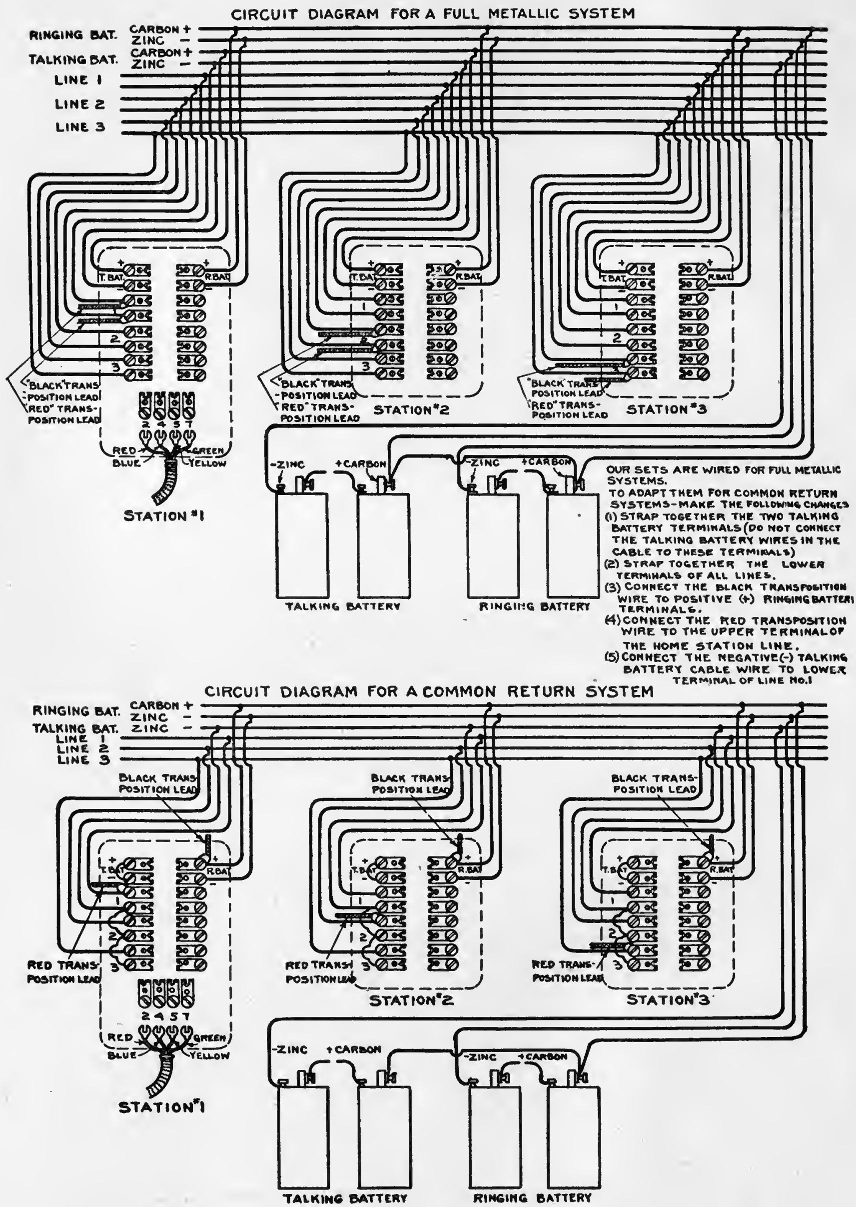
CIRCUIT DIAGRAM FOR A FULL METALLIC SYSTEM
RINGING BAT.
CARBON +
ZINC −
TALKING BAT.
CARBON +
ZINC −
LINE 1
LINE 2
LINE 3
T. BAT.
R. BAT.
"BLACK" TRANS-POSITION LEAD
"RED" TRANS-POSITION LEAD
RED
BLUE
GREEN
YELLOW
STATION #1
STATION #2
STATION #3
−ZINC
+CARBON
TALKING BATTERY
RINGING BATTERY
OUR SETS ARE WIRED FOR FULL METALLIC SYSTEMS.
TO ADAPT THEM FOR COMMON RETURN SYSTEMS-MAKE THE FOLLOWING CHANGES
(1) STRAP TOGETHER THE TWO TALKING BATTERY TERMINALS (DO NOT CONNECT THE TALKING BATTERY WIRES IN THE CABLE TO THESE TERMINALS)
(2) STRAP TOGETHER THE LOWER TERMINALS OF ALL LINES.
(3) CONNECT THE BLACK TRANSPOSITION WIRE TO POSITIVE (+) RINGING BATTERY TERMINALS.
(4) CONNECT THE RED TRANSPOSITION WIRE TO THE UPPER TERMINAL OF THE HOME STATION LINE.
(5) CONNECT THE NEGATIVE (−) TALKING BATTERY CABLE WIRE TO LOWER TERMINAL OF LINE No. 1
CIRCUIT DIAGRAM FOR A COMMON RETURN SYSTEM
RINGING BAT.
CARBON +
ZINC −
TALKING BAT. ZINC −
LINE 1
LINE 2
LINE 3
BLACK TRANS-POSITION LEAD
RED TRANS-POSITION LEAD
STATION #1
STATION #2
STATION #3
TALKING BATTERY
RINGING BATTERY

FIG. 121b.

at the station called takes the receiver off the hook he depresses the answering button K which operation connects the two transmitters T_1 and T_2 directly across the line which is composed of the two conductors s and r. The talking battery is also bridged across the line through the two windings x and y of a retardation coil. The function of this coil is to prevent interference or cross-talk from other stations which might be connected together for conversation at the same time, as the same talking battery is used for all the telephones in the system. The receivers R_1 and R_2 are each connected in a local circuit which includes the secondary of an induction coil at each station. The connection between the talking battery and the ringing battery is necessary to prevent cross-ringing, that is, the ringing

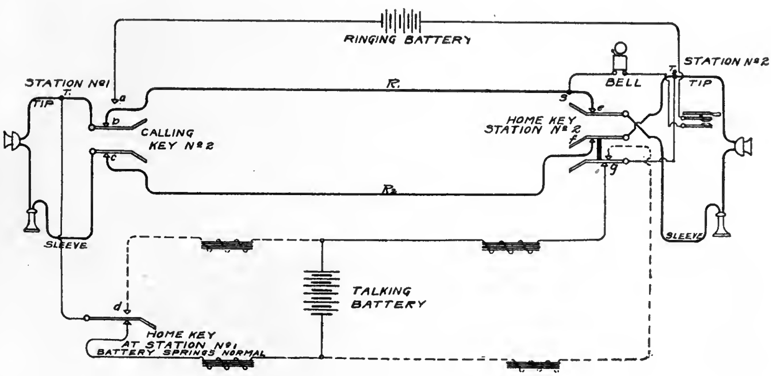

FIG. 122.

of a bell at a station other than the one called. Figs. 121*a* and 121*b* show the arrangement of a typical Western Electric system.

163. The Kellogg Intercommunicating System.—The Kellogg intercommunicating telephone which is shown in Fig. 118 operates on the same principle, but the connections differ somewhat. Instead of employing the same button for connecting the circuit and ringing, separate buttons are provided. Thus to call a station the button corresponding to the station desired is depressed. This closes the ringing circuit but not the talking circuit for the closing of which a separate green button is provided. In answering a call at any station all that is necessary is to press the red or home button and remove the receiver from the hook in the regular manner.

164. The Monarch Intercommunicating System.—The Monarch intercommunicating system is also of the push button type, but a modification is made in the manner of connecting the battery to the talking and ringing circuits. The operation

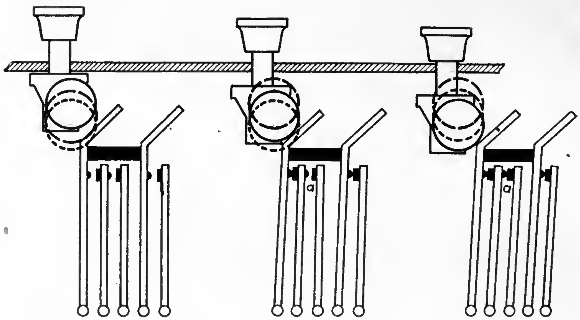

Fig. 123.

of the system will be readily understood from an examination of Figs. 122, 123, 124, and 125. Fig. 122 shows the method of wiring for two stations. Two batteries are employed, one for ringing and one for talking, as in the Western Electric system. The ringing circuit is permanently connected to the talking circuit at the sleeve side of the line at *S;* from there it leads through the buzzer or bell, the lower contacts of the hook switch to the ringing battery, and to the calling key, *a,* for station 2 at station 1. When this key is depressed the circuit is closed through conductor R_1 to *S.* To call station 2, the person calling depresses the calling key 2 which closes the calling circuit as shown at *a,* Fig. 123, completing the circuit and ringing the bell at station No. 2. When the calling key is released it springs back part way opening the ringing circuit at *a,* and when the person called at station No. 2 takes his receiver off the hook the ringing circuit is also opened at the hook switch. The talking circuit is controlled partly by the calling key at station No. 1 and also by the home key at station No. 2. The switch controlled by the home button is shown in Fig. 124. In the

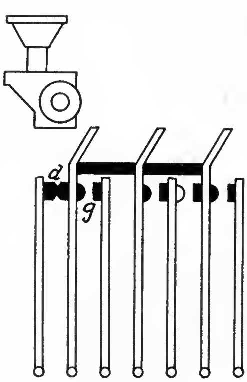

Fig. 124.

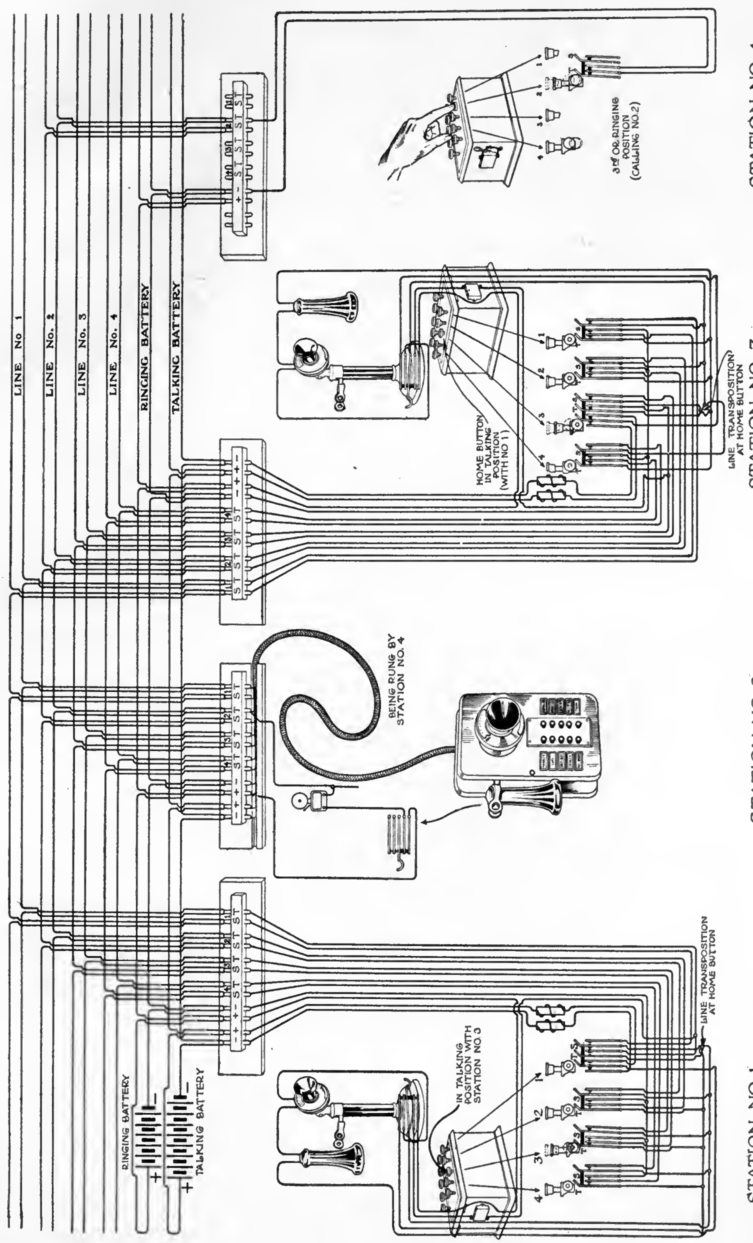
LINE No 1
LINE No. 2
LINE No. 3
LINE No. 4
RINGING BATTERY
TALKING BATTERY
STATION NO. 4
3rd OR RINGING POSITION (CALLING NO.2)
HOME BUTTON IN TALKING POSITION (WITH NO 1)
LINE TRANSPOSITION AT HOME BUTTON
STATION NO. 3
BEING RUNG BY STATION NO. 4
STATION NO. 2
IN TALKING POSITION WITH STATION NO.3
LINE TRANSPOSITION AT HOME BUTTON
RINGING BATTERY
TALKING BATTERY
STATION NO. 1

Fig. 125.

normal position of the home button, the switch points at *d* are closed. This corresponds to the lower contact at *d*, Fig. 122. When the home button is depressed at the station called, the switch points at *d*, Fig. 124, are opened and those at *g* are closed. This corresponds to the point *g* at station 2, Fig. 122. Normally only one side of the battery is connected to the talking circuits. When one station wishes to communicate with another station, the station calling leaves his home button in the normal position, but the station called depresses his button, thus transferring the battery connection at his station to the other side, bridging the battery across the talking circuit through two retardation coils. The circuit is not complete, however, until the receiver is removed from the hook. A complete diagram of connections for ringing and talking between two stations is shown in Fig. 125. An examination of this diagram will make clear the operation of the system.

QUESTIONS

1. (*a*) What is meant by an intercommunicating telephone system?

(*b*) What is the difference between an intercommunicating system and a party line?

2. Show by diagram the connections between two stations for the Western Electric intercommunicating telephone system.

3. Explain the operation of the Western Electric system from your diagram.

4. Diagram the connections between two stations for the Monarch system.

5. Explain the operation of the Monarch system from your diagram.

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