AUTOMATIC ELECTRIC TRAINING SERIES

STROWGER AUTOMATIC TELEPHONE SYSTEMS

No. 800

ELEMENTARY PRINCIPLES OF TELEPHONY

AUTOMATIC ELECTRIC

MAKERS OF TELEPHONE, SIGNALING AND COMMUNICATION APPARATUS
ELECTRICAL ENGINEERS, DESIGNERS AND CONSULTANTS

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This booklet is one of the

AUTOMATIC ELECTRIC TRAINING SERIES

on

STROWGER AUTOMATIC TELEPHONE SYSTEMS

comprising the following:

800 Elementary Principles of Telephony
801 Mechanical Principles *
802 Fundamentals of Apparatus and Trunking **
805 The Plunger Lineswitch and Associated Master-Switch
806 Rotary Lineswitch
807 The Connector
808 The Selector
809 Secondary Lineswitch
810 Impulse Repeater
811 Trunking
812 Power and Supervisory Equipment
813 Special Connectors
814 Reverting Call Switch
815 Testing Equipment
816 The Toll Switch Train
817 Switching Selector Repeater
818 Private Automatic Exchanges with P-A-B-X Appendix
819 Community Automatic Exchanges
821 Line Finder Switches

* To be prepared. This bulletin will supersede existing Bulletin 546.

** To be prepared. This bulletin will supersede existing Bulletin 301.

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ELEMENTARY PRINCIPLES OF TELEPHONY

PART 1
ELEMENTARY ELECTRICITY--DEFINITIONS

It is the object of this bulletin to treat only such fundamental conceptions, which have been found desirable, for providing a practical understanding of subsequent phases of the telephone industry.

Its informative level has been designed for the beginner but it also effectively serves the experienced personnel as a refresher to re-emphasize essential ideas.

1. ELECTRICITY AND ITS EFFECTS

The general term electricity is the name given to an invisible agent known only by its effects. The electrical effects with which we are most familiar are light, heat, power, voice transmission, and many others which we use and depend upon each day.

The exact nature of electricity is unknown, however, it is obvious that it is unnecessary to know exactly what water is, in order to use the energy of falling water or water under pressure to develop power. It is, however, necessary to know how water acts and how it may be used in the development of power. Therefore, in the study of practical electricity, the question of what electricity is, need not be considered; but the description of how it acts and how it can be directed and controlled so as to do useful work is essential.

The laws which govern the flow of electricity in closed circuits are in general similar to those which determine the flow of water in a water circuit. Water flowing in a pipe may be a medium for transmitting energy, in the same way that electricity flowing in a conductor is a means of transmitting energy.

2. TRANSMISSION OF ELECTRICITY

Contrivances such as batteries and generators should be regarded as arrangements whereby electricity may be put into motion or forced to move. An electric generator may be thought of as a pump which forces electricity to flow within a circuit.

3. ELECTRICAL UNITS

The three fundamental electrical units are the ampere, volt, and ohm. These units are explained as follows:

(a) Ampere

Electricity in motion is called an electric current. Therefore, a current of electricity in a wire is electricity in motion in that wire. There can be no current flow without a complete circuit to and from the source. The electrical unit of current flow is the "ampere", generally designated by "I".

(b) Volt

The force which causes electricity to move or to flow is known as electro-motive force (e.m.f.), pressure, potential difference, or voltage. The electrical unit of pressure is the "volt", generally designated by "E". If an e.m.f. is applied to a closed or complete conducting circuit it will force electricity to circulate or flow around in the metal or material of that circuit. The flow of water through a pipe is determined largely by the hydraulic pressure that is forcing the water through the pipe. A similar electric pressure or e.m.f., measured in volts, causes electricity to flow through conductors.

(c) Ohm

Electrical resistance is the opposition which is offered by an electrical conductor to the flow of current. It is obvious that the opposition offered by the friction of the flowing water against the insides of the pipes will tend to decrease the flow of water in a hydraulic circuit. In a similar manner the flow of the current in an electrical conductor will vary in accordance with the resistance offered to the flow. The electrical unit of resistance is the "ohm" generally designated by "R" in a formula or "ω" (omega) as an abbreviation. It is evident that the amount of electricity that will flow through a given circuit will be determined not only by the voltage forcing the current, but also by the resistance offered by the conductors. With a specified voltage, the greater the resistance the smaller the current and vice versa.

4. MEASUREMENTS

Electrical units and measurements are used to measure electricity in a manner similar to those used to measure pressures or quantities of other things. These units were determined by scientists and standards were adopted in order that the units would be the same in all parts of the world. Meters have been built so that when applied to an electrical circuit, they would indicate its relative value to that of the standard. Meters are depended upon for the measurements of all of our electrical units including amperes, volts, and ohms.

5. OHM'S LAW

A simple but important relation exists between the e.m.f. (volts), the current (amperes) and the resistance (ohms) in any electrical circuit. This relation which has been termed "Ohm's Law" may be expressed as follows: The result produced (current flow in amperes) is directly proportional to the effort (electromotive force in volts) and inversely proportional to the opposition (resistance). Formulas expressing the same relation are shown below.

$I = \frac{E}{R}$ or, $\text{Amperes} = \frac{\text{Volts}}{\text{Ohms}}$

$R = \frac{E}{I}$ or, $\text{Ohms} = \frac{\text{Volts}}{\text{Amperes}}$

$E = IR$ or, Volts = Amperes X Ohms

Example in Ohm's Law

Assume that it is desired to ascertain the amount of current that will flow through a coil having a resistance of 24 ohms and an impressed e.m.f. of 48 volts. Using the formula $I = \frac{E}{R}$; $E = 48$, $R = 24$, $I = \frac{48}{24} = 2$ amperes. If the voltage and current are known, to find the resistance, use the formula $R = \frac{E}{I}$. The resistance of a coil through which 3 amperes flows when 48 volts is impressed on it is found as follows: $E = 48$, $I = 3$, $R = \frac{48}{3} = 16$ ohms.

Knowing the current flow and the resistance, the voltage can be determined. A coil with a resistance of 12 ohms has a current flowing through it of 4 amperes. Using the formula $E = IR$: $I = 4$, $R = 12$, $E = 4 \times 12 = 48$ volts.

It should be noted that Ohm's law does not consider polarity, namely the direction of electric current flow.

Therefore when direct current resistance measurements are made which include the junction of certain electrical conductors, two different resistance values may be obtained, depending on the polarity used.

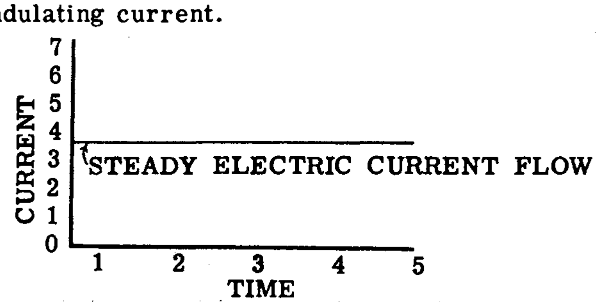
Some examples of such conductor junctions are the copper sulphide, copper oxide and selenium rectifiers.

—▶|—— STANDARD RECTIFIER SYMBOL

Consequently, whenever two different resistance measurements of a junction of electrical conductors are obtained because of reversing the polarity, it is necessary to specify the polarity used for each resistance value obtained.

6. ELECTRIC CURRENTS

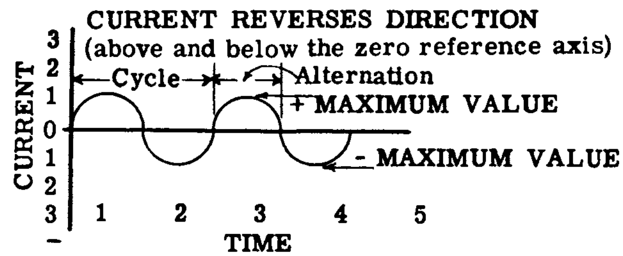
Of the various forms of electric current the four most commonly considered in telephone work are: direct current, alternating current, pulsating current, and undulating current.



This is a graphical representation of direct current

(a) Direct Current

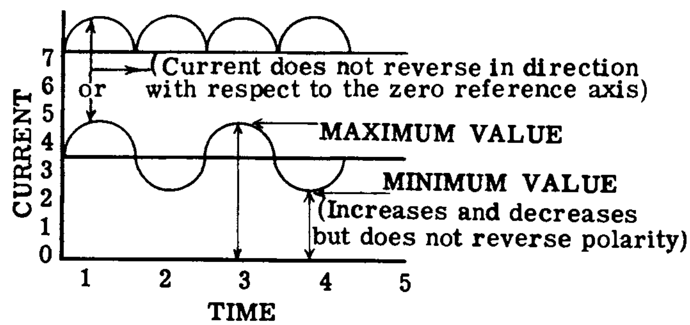
A direct current is one which always flows in one direction and when of constant strength is called a continuous current. The storage battery, the rectifier in various forms, and the direct current generator are the most commonly known sources of direct current used in telephone practice.



This is a graphical representation of alternating current

(b) Alternating Current

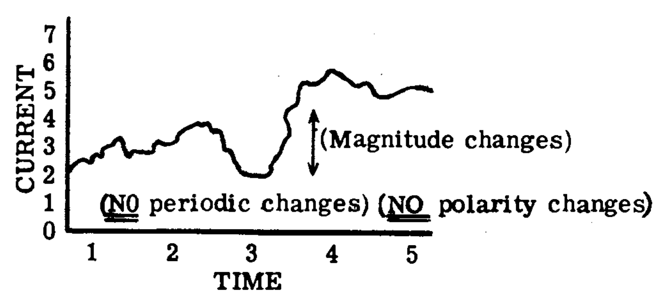
An alternating current is one which is constantly reversing its direction. A cycle is one complete reversal of current flow, that is, a current rising to maximum value and returning to zero, first in one direction, and then rising to a maximum value and returning to zero in the opposite direction. The number of cycles per second is known as the frequency. Alternating currents of frequencies from 16 to 66 cycles per second are used for operating telephone sub-station ringers. These are known as ringing currents. Alternating currents of frequencies up to about 10,000 cycles are audible. Frequencies from 250 to 3,000 cycles play an important part in voice transmission.



This is a graphical representation of pulsating current

(c) Pulsating Current

Pulsating current is a current which always flows in one direction, but periodically varies in magnitude so as to flow with a series of pulsations.



This is a graphical representation of undulating current

(d) Undulating Current

Undulating current flows always in one direction but changes in magnitude in a non-periodic manner.

7. A.C. CIRCUITS

In dealing with alternating current and pulsating current circuits, besides the resistance of the conductors there are two other factors that must be considered; viz., inductance and capacitance.

(a) Inductance

Electricity in motion always produces a magnetic field. This magnetic field is produced at right angles to the wire. When the current in an electric circuit varies, the number of lines of force will also vary, increasing when the current increases and decreasing when the current decreases, thereby inducing an e.m.f. in any conductor within their range of action. When current is changing, increasing or decreasing, a proportional current will be induced in a wire or coil parallel with it. This effect is termed inductance. The unit of inductance is the "henry".

Since a coil consists of a number of parallel turns of wire in close proximity to each other, a varying current flowing through a coil will cause each turn of wire to have an inductive effect on the adjacent turns. Thus, a coil is said to have inductance. The inductance of coils is usually measured in "milli-henrys" (thousandths of a henry).

(b) Capacitance

When two plates of conductive material are parallel and close to each other, they are said to possess electrostatic capacitance. If an e.m.f. is applied to the plates, they will receive an electric charge and a very small quantity of electricity will be stored in them. When constructed specially for this purpose the plates are called condensers, and the quantity of charge they will hold is a measure of their capacitance. The unit of capacitance is the "farad".

Since the "farad" is too large for a commercial unit, a fractional part of it is used in making measurements. Thus, condensers are measured in "micro-farads" (millionths of a farad).

In calculating current flow in alternating current circuits, inductance and capacitance of the circuit must be properly combined with the resistance of the conductor in order to get the total retardation or resistance (called impedance in the case of alternating currents) offered to the flow of electricity; however, it is beyond the scope of this bulletin to go into details on this subject.

8. CONDUCTORS

A substance which offers little resistance to the flow of electricity is a good electrical conductor.

Most metals are good conductors, copper being one of the best. For this reason copper wire is used on relays and magnet windings for automatic telephone equipment. German silver wire is a fair conductor, but offers a much greater resistance than copper. It is used in the windings of resistance coils.

9. INSULATORS

A substance which offers a very high resistance to the flow of electricity is a poor conductor. Extremely poor conductors, such as rubber, cotton, silk, mica, enamel, and many others, are known as insulators, and are used to safeguard a body against the flow of electricity to or from that body.

Most metals increase in resistance as they become heated. Non-metals, such as carbon and glass, decrease in resistance as they become heated.

PART 2

MAGNETISM

10. MAGNETS

Any substance which attracts iron and steel is said to be magnetized or to possess magnetism, and is called a magnet. The following paragraphs define some of the most common terms generally used in connection with magnets and explain the various types of magnets.

(a) Magnetic Poles

The two ends of a magnet where the magnetism is the strongest are called magnetic poles.

(b) Magnetic Field

The space immediately surrounding the magnet through which the magnetism acts is called the magnetic field.

Magnets are classified into two general classes; viz., natural and artificial magnets.

(c) Natural Magnets

Natural magnets are pieces of iron ore known as magetite or lodestone and are found in a number of places. The earth itself is a magnet with poles near the geographic north and south poles, and with a field covering the entire earth. This enables the compass, which will be explained later, to function to guide people about the earth. Natural magnets are not used very often, therefore it is not necessary to spend much time studying them.

(d) Artificial Magnets

Artificial or commercial magnets are divided into two general groups; viz., permanent magnets and temporary magnets.

A permanent magnet is any substance which will maintain indefinitely a magnetic field in the immediate space outside its own volume, without aid from any source. This is true of hardened steel which has been magnetized.

Temporary magnets are by far the most extensively used of any of the magnets. Temporary magnets generally take the form of an electromagnet.

An electromagnet usually consists of a soft iron core around which there is wound a number of turns of insulated copper wire. This wire is connected to a source of electric current such as a battery or direct current generator. While the current is flowing, the device becomes a magnet. As soon as the source of current is discontinued, the magnetism dies away rapidly. The relays used in Strowger Automatic Telephone equipment are electromagnets of this type and will be further explained later.

(e) Residual Magnetism

Residual magnetism is the magnetism retained by the core of an electromagnet after the circuit has been broken.

Magnetism, as previously indicated, may be set up more easily in some metals than in others. Temporary magnets use soft iron, instead of hardened steel as used in permanent magnets. Soft iron differs from steel in that magnetic lines are set up more easily in iron, and the number of lines set in iron are greater than in steel of the same volume. On the other hand, steel may hold its magnetism indefinitely while iron loses it almost instantly as soon as the current flow ceases. Where more complete absence of residual magnetism is desired, the iron is further softened by annealing. For this reason annealed or soft iron cores are used in the construction of relays for Strowger Automatic Telephone apparatus.

11. THEORY OF MAGNETISM

It is very difficult indeed to say just what magnetism really is. It is invisible, it has no weight, yet it manifests itself according to very definite and well known laws. Several theories have been advanced to explain magnetism and one of these, the molecular theory, is generally accepted as correct.

(a) Molecular Theory

The theory assumes that a bar of steel or iron, composed, like all matter, of small molecules, is made up of minute magnets. If the steel or iron is not magnetized, these molecules arrange themselves promiscuously in the body; therefore, there is no resulting external magnetism. Thus the steel is said to be demagnetized. When a bar of iron or steel is placed in a magnetic field, those tiny magnets arrange themselves in a systematic order, with all like poles pointing in the same direction and external magnetism is evident.

(b) Arrangement of Molecules

In order to understand this theory more clearly the case presented by a straight bar of steel should be considered. In its original state the bar is not magnetized, and the molecules are arranged in every conceivable direction, As soon as the bar is magnetized, however, the molecules are caused to rearrange themselves in systematic order with all of their north poles pointing in one direction, the south poles in the opposite direction. That pole of the magnet towards which the molecular north poles are pointed is called the north pole and the opposite is called the south pole.

If this bar is suspended from a string at its center point it will turn around until this north points north. If disturbed, it will always come to rest with the same pole pointing north.

(c) Compass

Such a permanent magnet supported at its center on a jeweled pivot point is commercially known as a compass. One end of the magnet, or needle as it is known in a compass, is distinctively marked, either by color or shape, and that end always points north.

If a magnet is dipped into some iron filings, it will be seen that the filings will cling to the ends of the magnet and not to the middle. This shows clearly the presence of the poles which are the points at which the magnetism is the strongest.

(d) Attraction and Repulsion

If the north pole of any magnet is brought near the north pole of a suspended magnet, the latter will turn away. If the south pole of the first magnet is brought near to the north pole of the suspended magnet, the latter will turn toward it. In other words like poles repel, and unlike poles attract each other. This is an important fact and should be remembered.

(e) Geographic Poles

The north and south poles of a compass and of a magnet have just been defined. Poles of the earth which are divided into two classes may be defined as follows:

Geographic poles are those points which represent the position of the north and south extremities of the earth's axis, the imaginary line around which the earth rotates.

Magnetic poles, located in a position not greatly distant from the geographical poles, are the points where the intensity of the earth's magnetic lines is greatest.

A north pole of a magnet has been defined as the pole which seeks the north pole of the earth. Since unlike poles attract each other, it follows that the magnetic pole near the earth's geographic north pole is the magnetic south pole, and the magnetic pole situated near the earth's geographic south pole is the magnetic north pole. In other words:

Earth's South Pole = Magnetic North Pole.
Earth's North Pole = Magnetic South Pole.

(f) Lines of Force

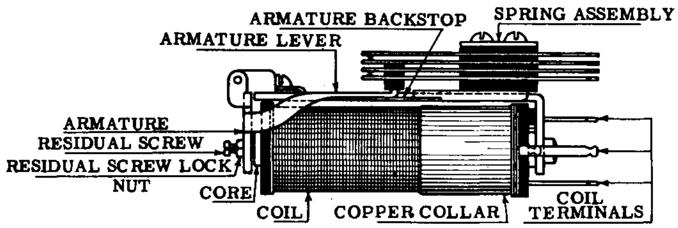
In the course of the explanation of the molecular theory, it was mentioned that when a bar is magnetized the magnetic circuit is completed both internally and externally. This may be proven.

The fact that the lines of force pass through the bar and form a complete loop, and do not start at the north pole and end at the south pole is proven by breaking the bar magnet into several pieces. Each piece becomes a separate magnet with a north pole and a south pole of its own, thus indicating that the lines of force form a complete loop. Lines of force which leave the magnet at the north pole enter the magnet at the south pole, pass through the magnet and return to the north pole, completing the loop. The space outside the magnet occupied by the magnetic lines of force is called the field. If a magnet is placed under a piece of glass on which iron filings have been sprinkled, the filings will arrange themselves along the lines of force, thus indicating the presence and position of the magnetic field.

12. ELECTROMAGNETS

Electromagnets are in common use in every branch of industry. The iron and steel industries use an electromagnet attached to a crane to hoist large quantities of iron or steel. Every motor has an electromagnet in it, that magnet being known as the field of the motor. Scores of other uses for electromagnets in equipment varying in size from the door bell to the largest electric locomotive could be mentioned. Strowger Automatic equipment would be impossible without them.

In 1820, H. C. Oersted, a European scientist, discovered that there is a magnetic field immediately around a wire through which an electric current is passed; that is, the electric current in the wire produces magnetism around it. This magnetic field lasts as long as there is a flow of current in the wire. Just why such a thing happens is not known, but it is definitely known that it does happen. The strength of this magnetic field, that is, the amount of magnetism present, depends upon the number of amperes flowing in the wire, and, when the wire is wound in a coil, the number of turns in the coil. The product of these two factors is known as the ampere-turns, a term about which a great deal will be said and which one should be thoroughly familiar with.



Horizontal Type Relay

13. RELAYS

The relays so extensively used by Automatic Electric Company consist of a coil, or electromagnet, with a mounting upon which a movable piece of metal called an armature is attached; also an assembly of springs operated by the movement of the armature. When the relay is not connected to a battery supply, the relay is said to be de-energized, or at normal. When in its normal position, the armature which is hinged, is away from the core; and there is an air gap between the armature and core. When the relay is connected to a battery supply, a magnetic field is set up in the coil and core which attracts the armature to the core. The movement of the armature from its normal position toward the core causes the relay springs to be forced into an operated position. The operation of the relay springs brings about the necessary circuit conditions, which will be explained in detail later. The removal of the battery supply from the relay causes a great reduction of the magnetism which permits the armature to return to normal.

Relays could be made to work by having a single turn of wire around the core, but the current consumed would be so great that trouble would result. In order to cut down the number of amperes required, the number of turns of wire is increased. Relays are wound with numbers of turns ranging from a few hundred to about ten thousand. The current consumed by such relays varies from about one ampere down to a few thousandths of an ampere.

(a) Slow Acting Relays

Slow-acting relays play an important part in the circuit design of the present day Strowger Automatic Switches. They are used to delay momentarily certain circuit operations.

Slow acting relays may be divided into two classes; viz., the slow operating relay and the slow releasing relay. This slow acting feature is accomplished by the use of a copper collar mounted on the relay, which delays momentarily the operation of the relay armature.

(b) Slow Operating Relay

The slow operating relay is slow to attract its armature after the circuit has been completed. The copper collar being mounted on the armature end of the relay causes a delay in the attraction of the armature. The action that takes place may be more easily understood when the relay winding is considered as the primary of a transformer and the copper sleeve as a short circuited secondary winding consisting of a single turn having a very low resistance. When a voltage is first applied to the terminals of the winding, the current tends to build up and establish the magnetic field in the relay core. The instant the lines of force cut through the copper collar a voltage is induced in the latter causing a current to flow in it in the opposite direction from that in the winding. This current in the copper collar sets up a field in the same magnetic path, which opposes the field which is being built up by the current in the relay winding. Gradually the field in the copper collar dies away, and the magnetism due to the winding builds up until it reaches a maximum value and attracts the relay armature.

(c) Slow Releasing Relay

The slow releasing relay holds its armature, momentarily, after the circuit to the relay has been opened. In this case, the copper collar is mounted on the heel end of the relay. When the circuit to the coil is broken the magnetic field in collapsing sets up a current in the copper collar. This current is in such a direction as to try to maintain the existing magnetism. But since this current itself depends upon the decreasing magnetism, both the field in the copper collar and the relay gradually die away. This action delays the release of the armature.

14. NON-INDUCTIVE COILS

The direction of the magnetic field about a wire depends on the direction of the current flow in that wire. Therefore, the magnetic fields of two currents flowing in opposite directions oppose each other and will neutralize each other if they are of equal strength and if the wires are near enough together. Use is made of this fact by winding two wires into a single coil so that the current in one wire flows in the opposite direction to the current flowing in the other wire, around the coil. Such a coil has no perceptible magnetic field and is said to be non-inductively wound.

15. IMPEDANCE COILS

Alternating current finds it more difficult to pass through an inductively wound coil than it does through a non-inductive coil of equal resistance. A different effect is produced when an inductively wound coil is placed in an alternating current circuit than when placed in a direct current circuit. In an A.C. circuit a counter e.m.f. is set up which acts as a "choke" to the impressed electromotive force. This effect is known as inductive reactance and the combination of reactance and resistance is known as impedance. Impedance coils are often used in telephone practice to prevent the flow of high frequency currents. The action which takes place in an impedance coil may be described as follows: the magnetic field around the coil, rapidly changing in direction at each cycle, causes a counter electromotive force (c.e.m.f.) to be set up, which opposes the impressed e.m.f. The effect of this c.e.m.f. coupled with the resistance of the coil jointly limits the flow of current.

PART 3

SYMBOLS--CIRCUITS--FAULTS

16. SYMBOLS

Electrical circuits are explained by a form of writing which employs symbols arranged in such a way as to tell the reader the electrical conditions and relations which exist. These records are valuable because they enable people to duplicate past work, to study the action of electrical apparatus, and to make easier the detection of troubles. The symbols were derived from rude pictures of the apparatus, which have in course of time been simplified to their present form. Many times the present symbol does not look at all like the object which it represents, but it usually suggests the original form of the apparatus. The apparatus has developed into modern form and the symbol has developed toward simplicity. (Figs. 1 to 23.)

17. COMBINATIONS OF APPARATUS

Some of the most common combinations of apparatus are explained in the following paragraphs.

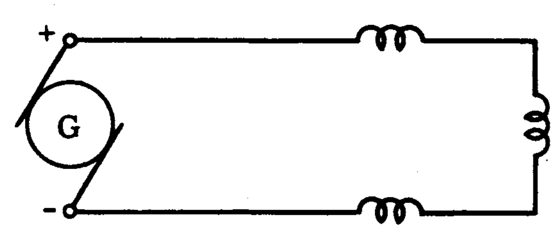


Fig. 24: Series Combination

(a) Series Connection

A series connection is a method of connecting the parts of an electric system so that the same current passes through each device in the circuit, one after the other in direct succession. (Fig. 24.)

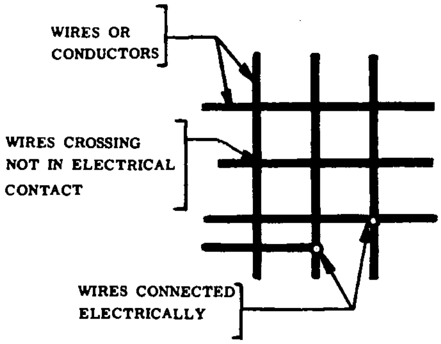


FIG. 1

FIG. 2

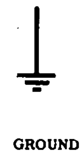


FIG. 3

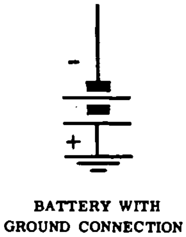


FIG. 4

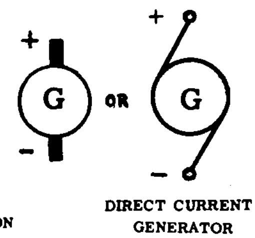


FIG. 5

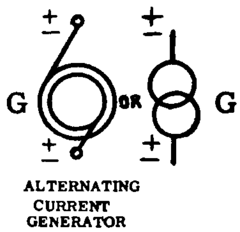


FIG. 6

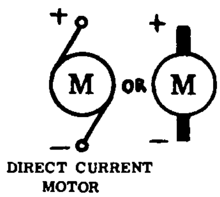


FIG. 7

FIG. 8

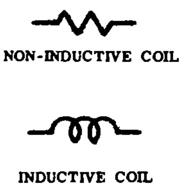


FIG. 9

FIG. 10

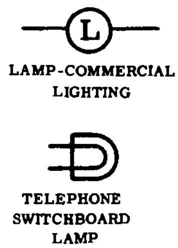


FIG. 11

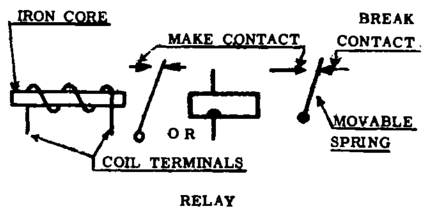


FIG. 12

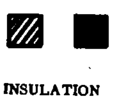


FIG. 13

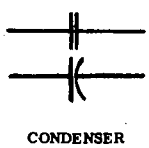


FIG. 14

FIG. 15

FIG. 16

FIG. 17

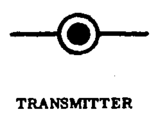


FIG. 18

FIG. 19

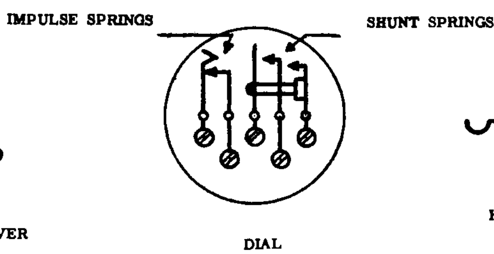


FIG. 20

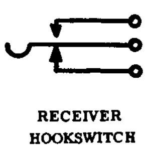


FIG. 21

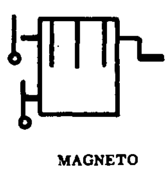


FIG. 22

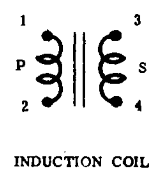


FIG. 23

Figs. 1 to 23: Elementary Symbols

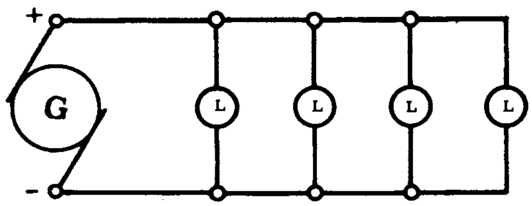


Fig. 25: Parallel Combination

(b) Parallel Connection

A parallel connection is a method of connecting the leads of an electric system in which all the positive terminals are joined to one conductor, and all the negative terminals to the other. When the pieces are thus connected the current is divided between them, and they are said to be in parallel with one another. Multiple or shunt are other names for this combination. (Fig. 25.)

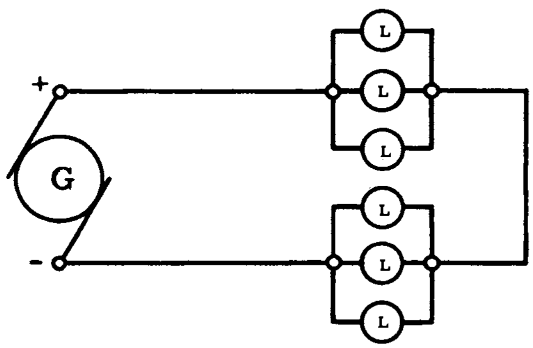


Fig. 26: Parallel Groups Connected In Series

(c) Series Parallel Connection

When devices such as lamps, in an electric circuit, are arranged in groups and connected in parallel in each group, these groups in turn being connected in series, the arrangement is known as a series parallel connection. (Fig. 26.)

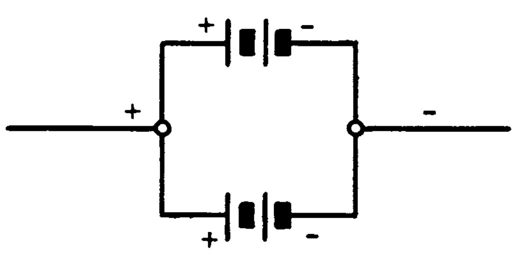


Fig. 27: Series Groups Connected In Parallel

(d) Parallel Series Connection

The parallel series connection is a method of connecting groups of devices such as cells, in an electric system so that these cells are in series in each group and the groups in turn are connected in parallel. (Fig. 27.)

18. METHODS OF CIRCUIT CONTROL

There are many methods of circuit control. A few of the most common are described briefly below.

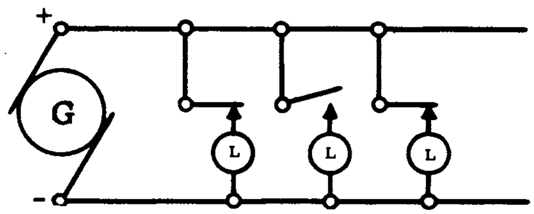


Fig. 28: Break Control

(a) Break Control

As an illustration of break control assume that three lamps are arranged to be lighted by one generator and each lamp is controlled by a switch. Any one lamp could then be cut off by breaking or opening its circuit at the switch without interfering with other lamps of the circuit. (Fig. 28.)

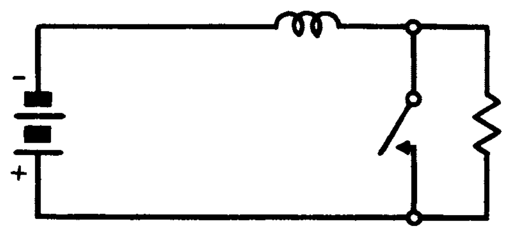


Fig. 29: Shunt Control

(b) Shunt Control

A shunt control arrangement for example, might consist of an inductive coil in series with a non-inductive coil. The latter could be removed from the circuit by shunting or short circuiting it by means of the switch. This would not cut off the inductive coil. (Fig. 29.)

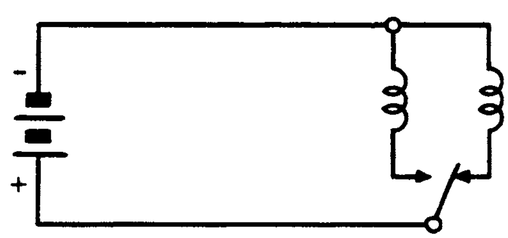


Fig. 30: Substitution Switching By Breaking

(c) Substitution Switching by Breaking

Switching by breaking may be illustrated by having two inductive coils controlled by a switch whose main spring may connect the battery circuit through either coil by breaking the circuit to the first coil. (Fig. 30.)

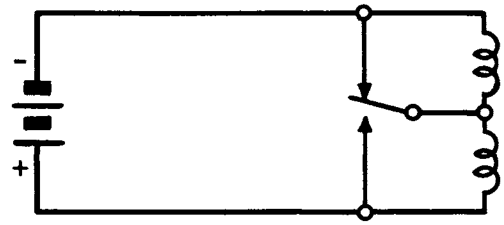


Fig. 31: Switching By Shunting

(d) Switching by Shunting

By having two inductive coils wired in series it can be readily seen what is meant by switching by shunting. Either coil may be shunted or short circuited out by the switch whose main spring may touch either contact. (Fig. 31.)

19. CIRCUITS

In order for electric current to flow there must be a complete path, that is, a closed circuit; and this closed circuit must include the battery or whatever source of current is used. A break in a wire, or other conductor, will prevent the flow of electricity past that part of the circuit in which the break occurs. When tracing a circuit, start at one terminal of the battery and follow the circuit through wires, connections, and apparatus until you reach the opposite terminal of the same battery.

(a) Wiring and Schematic Diagrams

Electric circuits are shown in two general classes, wiring diagrams and schematic diagrams. A wiring diagram shows the apparatus approximately in its relative location. It is used mostly for reference when wiring the apparatus and tracing connections. A schematic diagram is electrically the same as above, but the parts are rearranged in such a way as to show more clearly the paths of current flow, the relation of the apparatus, and the principles underlying the design of the circuit. A schematic diagram may contain all the circuits of a layout, or it may contain only one circuit path, rearranged to show itself more clearly.

(b) Circuits and Circuit Faults

In studying the descriptions of the following circuits and circuit faults, the illustrations should be referred to.

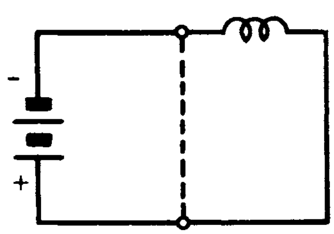


Fig. 32: Leak And Short Circuit

(c) Leak and Short Circuit

If there is an additional path in the circuit, Fig. 32, through which electricity can flow, as shown by the dotted line, some of the current will go through it. If the resistance of this path is high enough not to interfere to any extent with the operation of the coil, the path is called a "leak".

If the resistance is low enough to exclude practically all of the current from the coil, the fault is called a "short circuit".

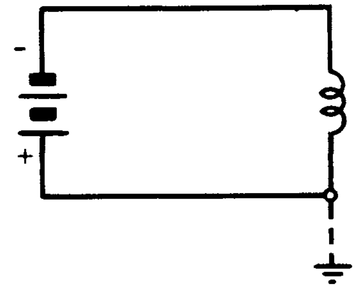


Fig. 33: Grounded Circuit

(d) Grounded Circuits

Fig. 33 shows a complete circuit with an accidental ground indicated by the dotted line. This ground would not affect the circuit and will not interfere with the current flow or the operation of the coil, because no other part of the circuit is grounded.

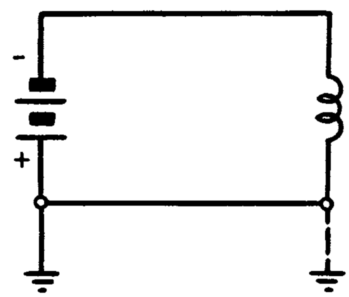


Fig. 34: Grounded Circuit

Fig. 34 shows a complete circuit with the positive side of the battery grounded. Should an accidental ground occur on the positive side of this circuit, as shown by the dotted line, it will not affect the current flow to the coil, or its operation.

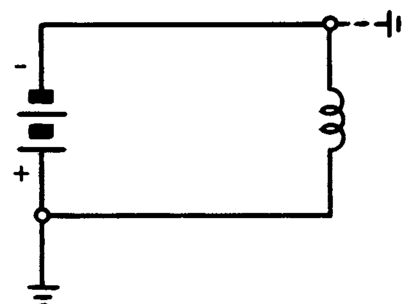


Fig. 35: Grounded Circuit

Fig. 35 shows a complete circuit with the positive side of the battery grounded. Should an accidental ground occur on the negative side of this circuit, as shown by the dotted line, the coil will be shunted out by having a ground on both sides of its winding. The battery will also be short circuited as the ground is on the negative side of the line.

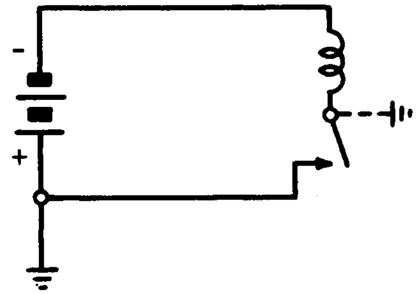


Fig. 36: Grounded Circuit

Fig. 36 shows an accidental ground on one side of the inductive coil. This would cause the coil to be operated at all times, regardless of the position of the switch, since there is a complete circuit from the accidental ground through the coil to negative battery.

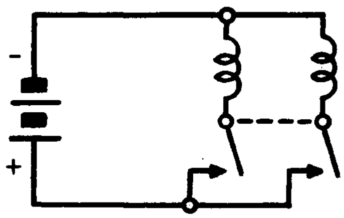


Fig. 37: Cross Circuit

(e) <u>Crossed Circuit</u>

The crossed circuit, Fig. 37, as indicated by the dotted line, would cause both coils to operate when either switch makes contact because a circuit is completed to both coils by the closing of either switch.

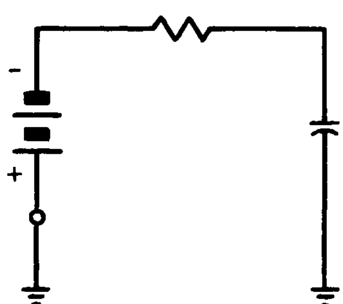


Fig. 38: Incomplete Direct Current Circuit

(f) <u>Incomplete D.C. Circuit</u>

A condenser in series with a coil in a direct current circuit, as shown in Fig. 38, will prevent the flow of current in the coil. The condenser in a D.C. circuit acts the same as an open conductor. A.C. but not D.C. will flow through a condenser.

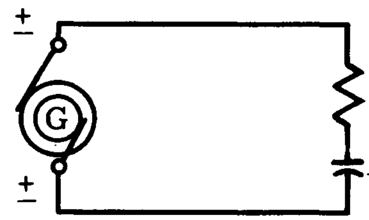


Fig. 39: Alternating Current Circuit

(g) <u>Alternating Current Circuit</u>

Since a condenser does not prevent the flow of current in an A.C. circuit, we can trace a complete circuit, Fig. 39, from one side of the generator, through the non-inductive coil, through the condenser, to the other side of the generator.

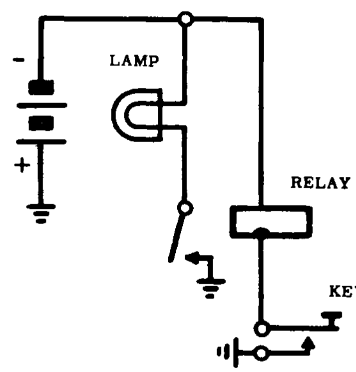


Fig. 40: Complete Relay and Lamp Circuit

20. DESCRIBING A CIRCUIT

In the description of a circuit, care should be used to state exactly what is meant. Always state which polarity of battery is referred to, and when speaking of any point in a circuit, define that point so that there will be no doubt as to what is meant. For example, Fig. 40 may be described as follows: By closing the key there is a complete circuit from negative battery through the relay, and through the closed key to ground (positive battery). This will cause the relay to operate, which completes the circuit from negative battery through the lamp, and through the closed relay contacts to ground, causing the lamp to light. The relay will remain operated and the lamp will remain lighted, as long as the key is closed.

PART 4
TELEPHONE PARTS

21. GENERAL

In order to bring out the principles underlying the transmission of sound waves in telephony, the following definitions are given:

A telephone transmitter is that portion of a telephone by means of which sound waves from the voice are converted into electrical energy which can be transmitted to another point on the line for reception by means of a receiver.

A telephone receiver is that portion of a telephone by means of which the electrical energy from the transmitter is converted back into audible sound waves.

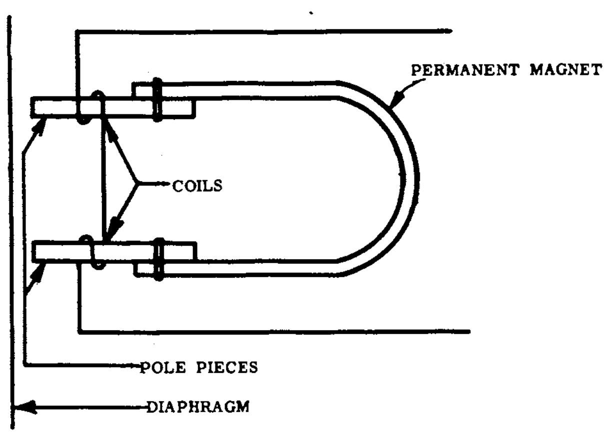


Fig. 41: Bi - Polar Receiver

22. PERMANENT MAGNET RECEIVER

The receiver, as shown in Fig. 41, includes a permanent magnet, magnet coils, and a diaphragm.

The permanent magnet attracts the diaphragm and places a certain tension upon it. One-half cycle of alternating current flowing through the magnet coils adds to the pull on the diaphragm that is exerted by the permanent magnets, and the other half cycle subtracts from their pull; therefore, the diaphragm makes one complete vibration or cycle during the period that one complete cycle of alternating current flows through the magnet coils.

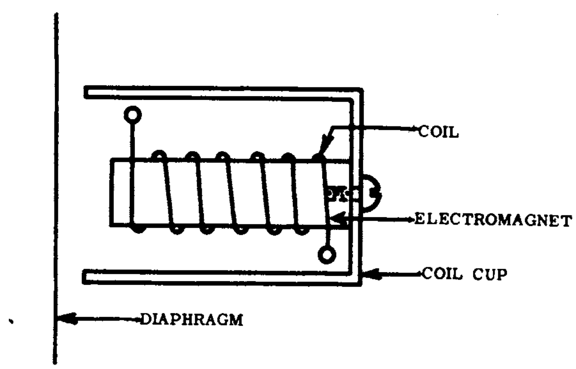


Fig. 42: Direct Current Receiver

23. DIRECT CURRENT RECEIVER

Fig. 42 shows a schematic drawing of a direct current receiver. In common battery systems where the direct current is fed from the central office to local stations, it has been found that the current which must flow through the line to furnish talking battery may be used for the additional purpose of energizing the receiver magnets so as to give them the necessary initial polarity. When the strength of the current flowing through the receiver magnet coils is varied, the tension on the diaphragm varies directly with the current and results in a vibration of the receiver diaphragm. When a voice through a telephone transmitter causes the variation of current, the receiver diaphragm responds and reproduces the sound of the voice.

This type of receiver was used to a considerable extent, however, present day practice favors the permanent magnet type of receiver. The newer designs are greatly improved and have a much smaller magnet than the earlier receiver had.

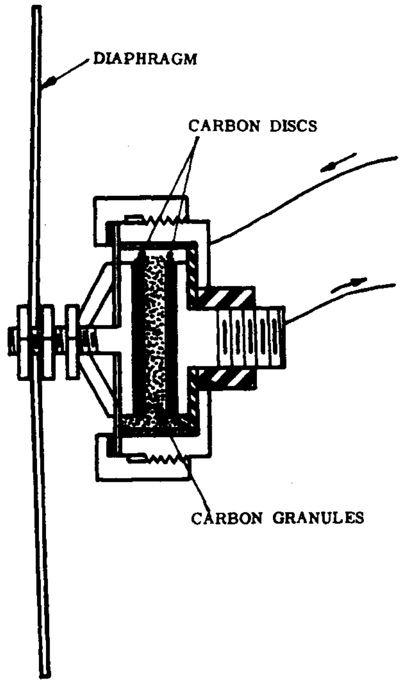


Fig. 43 Transmitter

24. TRANSMITTER

The transmitter, as shown in Fig. 43, is made up of a diaphragm so mounted that its vibratory motion, caused by sound waves directed against it, will be transmitted to a mass of carbon granules in a cup, the granules being arranged in series with the transmitter circuit. This is known as the variable-resistance method of producing current undulations.

electrodes. In this way the resistance of the path from one electrode to the other through the carbon granules, is varied. The current is thereby varied in strength as the air pressure varies on the diaphragm. This varying current is sent out over the line to the connected receivers.

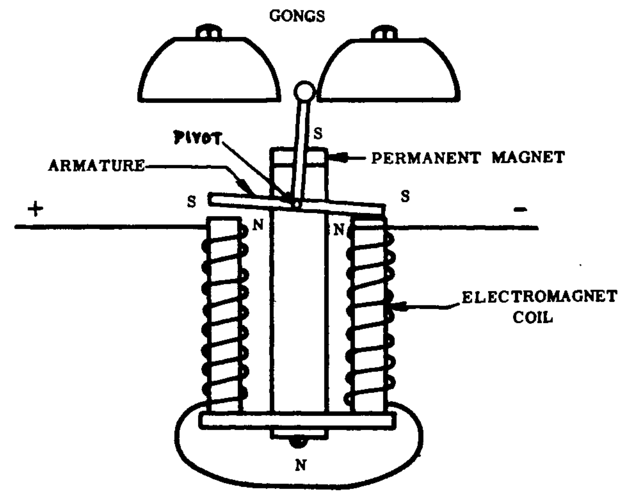


Fig. 44: Polarized Bell

25. POLARIZED RINGER

The working parts of the polarized bell or ringer, as shown in Fig. 44, include an electromagnet, a permanent magnet, a pivoted armature carrying a bell clapper, and two gongs.

The armature is so pivoted that it vibrates in front of the poles of the electromagnet. The permanent magnet, usually in the shape of a broad "U", has one of its poles

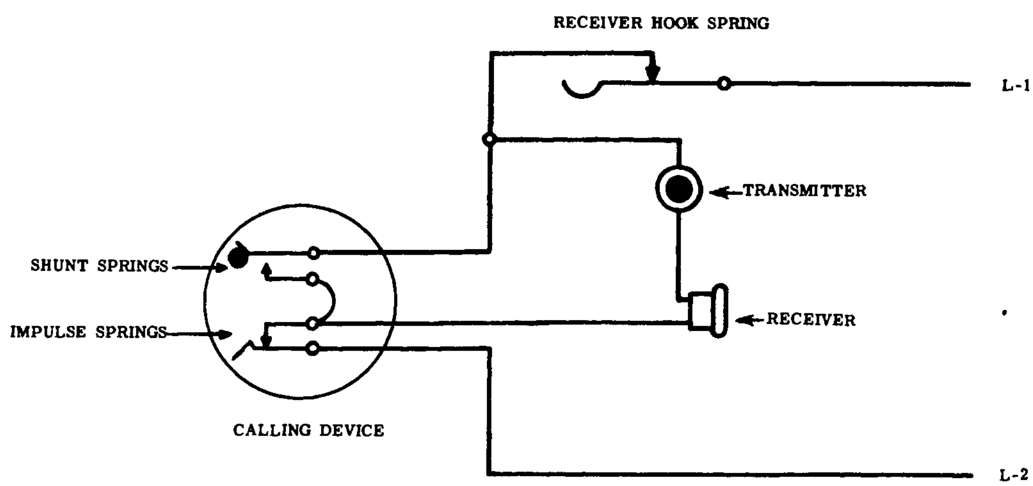


Fig. 45: Automatic Telephone Circuit Showing Calling Device Connections

The carbon granules are contained in an insulated metal cup known as the electrode chamber in which are two carbon discs. These carbon discs, namely the front and rear electrodes, support the carbon granules. The movement of the diaphragm compresses and decompresses the mass of granular carbon between the two

secured to the middle of the yoke of the electromagnet; while the other extends to a point just beyond the middle of the pivoted armature but out of contact with it.

When there is no current flowing in the ringer coils, the ends of the armature are of south polarity and those of the electromagnet cores are of north polarity. With a current flowing in the electromagnet winding from positive to negative, the right pole will be additionally magnetized, due to the fact that the current is producing north magnetism and the left-hand pole subtractively magnetized, since the current is now producing south magnetism. Therefore, the magnetism of the right pole will be increased while that of the left pole will be decreased, causing the armature to be attracted more by the right pole than by the left, and the clapper will strike the right-hand gong. A reversal of current produces opposite action, the left-hand gong being struck. When the current ceases, the armature remains where last thrown.

26. DIAL

For the purpose of automatic operation, each telephone is equipped with a calling device or dial as shown in Fig. 45. The dial is essentially a circuit interrupter. When a finger plate of a dial is released after being turned from its normal position, it interrupts the line circuit in quick succession a number of times corresponding to the digit dialed. Each time the line is interrupted, what is known as a current pulse is transmitted to the automatic switchboard equipment. It is the current pulses that are sent over the line at the will of the subscriber, which start the automatic switches in motion and cause them to establish connections between subscribers.

PART 5

TELEPHONES--TELEPHONE SYSTEMS

27. GENERAL

Telephone systems are divided into two classes with respect to the source of talking current. One class, in which the talking current for each subscriber is supplied from a battery placed at the subscriber's station, is called the local-battery system. The other class, in which the talking current for all subscribers is supplied from a battery placed at the central office, is called the common-battery system.

28. LOCAL BATTERY TELEPHONE

The complete local-battery telephone has within itself all the apparatus needed for talking and signaling, both sending and receiving.

The transmission of the voice by local-battery is much older commercially than by common battery. The term "local-battery" implies the use of a battery at each telephone. At the present time dry cells are used, in most cases two, but occasionally three in series.

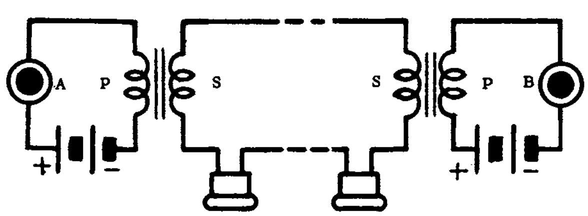


Fig. 46: Local Battery Telephones

Fig. 46 shows the system in its simplest form without signals or switches of any kind. "A" represents a telephone, connected by two wires to another telephone "B". When the transmitters are quiet, a steady direct current flows in each primary circuit and no current at all in the secondary or line circuit. When a person speaks into the transmitter, the transmitter resistance changes rapidly and causes the battery current to become stronger and weaker. This rapidly varying primary current induces an alternating current in the secondary winding, which flows through both receivers. Since both ends of the circuit are alike, B can talk to A as well as A to B.

29. INDUCTION COIL

An induction coil is merely a transformer which consists of two insulated wires wound around an iron core. One of the windings called the primary (P) winding, in series with the transmitter and battery, forms a closed local circuit; while the other winding called the secondary (S) winding, in series with the receiver and the line, forms a separate circuit.

If direct current is flowing in one of the windings and remains constant, no current whatever is produced in the other. However, if there is a change in the current in one of the windings, there will be produced a current in the other. A continued variation of the current flow in one winding will result in the flow of an alternating current in the other winding.

The separation of the transmitter circuit from the line gives a vastly wider range in talking currents.

The secondary winding has more turns than the primary winding, and the voltage in the secondary is correspondingly higher than in the primary. High voltages in the secondary winding are admirably adapted to transmit current in a high resistance line, for exactly the same reason that long distance power transmission meets with but one quarter of the (I^2R) losses when the sending voltage is doubled. Thus the induction coil serves two purposes, increasing the range of change in the transmitter circuit and lessening the loss in the line circuit.

The induction coil may also be regarded as a transformer which has such a ratio as to match the impedance of the transmitter to the impedance of the line.

30. REPEATING COIL

The repeating coil used in a telephone may be considered as an induction coil. It is used when it is necessary to have the inductive association of two circuits that are conductively or physically separated.

In using repeating coils to connect two telephones, it is sometimes necessary to ring through them as well as talk through them. Therefore, it is necessary that the repeating coil shall be designed so as to be capable of transforming ringing as well as the smaller voice currents. Ringing currents ordinarily have a frequency ranging from about 16 to 75 cycles per second, while voice currents have frequencies ranging from a few hundred up to about three thousand per second. Therefore, the best form of repeating coil for transforming voice currents is not the best for transforming ringing currents. Consequently, when a coil is required to carry both ringing and talking currents, it must be designed so that it will be capable of transforming both currents effectively, and a compromise must be effected.

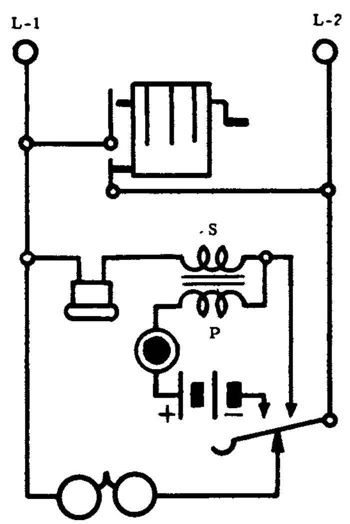


Fig. 47: Bridging Telephone

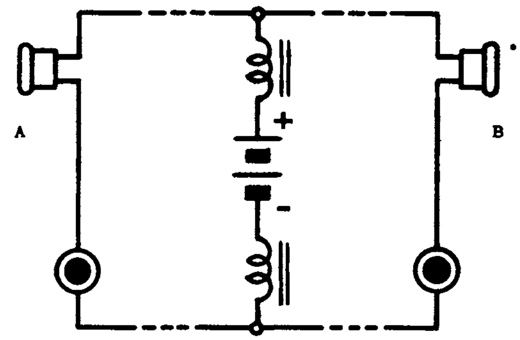


Fig. 49: Stone Common Battery System

31. BRIDGING TELEPHONE

Fig. 47 shows in schematic form a bridging telephone. When the hook is down, only the bell is across the line. The ringer has relatively high resistance, 1000 ohms, 1600 ohms, or 2500 ohms. No blocking condenser (stops direct current flow) is needed as there is no central battery connected to the line. The current for ringing the bells is furnished by a magneto (hand generator), which produces alternating current. When the crank is at rest, the magneto is disconnected from the line but when the crank is turned, a portion of the first revolution operates a switch which connects the magneto across the line.

The secondary circuit is kept open by one of the upper contacts of the hookswitch. When the receiver is taken off the hook, the line (L-2) is switched from the ringer to the talking circuit (receiver and secondary of the induction coil) at the same time the primary circuit is closed by the upper contacts, and there is a complete local-battery arrangement. The primary circuit is kept open when the instrument is not in use, so as to prevent any current flow.

Telephones of this type using high resistance bells are attached to the line in parallel as shown in Fig. 48. It makes no difference which line binding post (L-1 or L-2) is attached to L-1 of the wires which run from station to station. When the receiver is on the hook the ringer is bridged across the line and everything else is cut off.

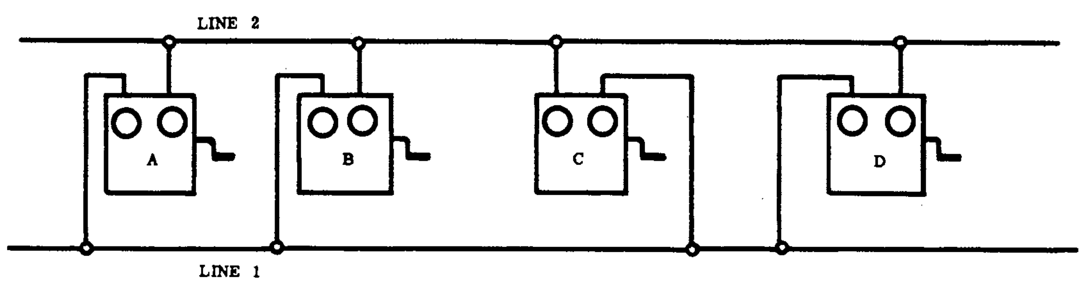


Fig. 48: Bridging Or Magneto Telephones

When any subscriber turns the crank of his magneto it places his magneto across the line and the current generated by it passes through all the bells in parallel. Whenever a receiver is taken from the hook the bell of that telephone is cut off and the secondary circuit (receiver and secondary of induction coil) put in its place. Several subscribers may talk to each other at the same time, all of their talking sets being bridged across or connected in parallel on the line.

32. COMMON-BATTERY TELEPHONES

The common-battery telephone must have talking apparatus, signaling apparatus, and a means of controlling the circuits. The automatic telephone requires in addition a calling device or "dial". The ringing apparatus is used to attract the attention of the subscriber when someone desires to speak to him. The dial enables the subscriber to control automatic switches at the central office, to cause them to establish connection between two telephones. The talking battery and ringing current are received from the central office. Various types of common-battery telephone systems are described in the following paragraphs.

(a) Stone Common Battery System or Impedance Coil System

Fig. 49 shows the schematic wiring diagram of the Stone common-battery system. Current is furnished by a battery through two inductive coils called impedance coils, which are usually wound on the same iron core. The electric current divides, part going to one telephone (A) and the rest to the other (B) over a metallic circuit. Telephones A and B are of similar construction. When no one is talking the current flow is steady. If a person speaks into the transmitter it acts like a variable resistance and makes the current stronger and weaker. It is like a valve in a water pipe, but it is never wide open or tight shut. The undulating current (voice current) caused by the transmitter travels throughout the circuit composed of the two transmitters and the two receivers. Very little will pass through the impedance coils because they are inductive. The sound of the speaker's voice can be heard in both receivers. The impedance coil method is used almost exclusively in private branch systems where the telephone loops are all of about equal length and resistance. When the loop resistance of two connected circuits is unequal, as in the case when one is longer than the other, the line having the higher resistance receives less than the proper amount of current fed to both through the windings of the impedance coils.

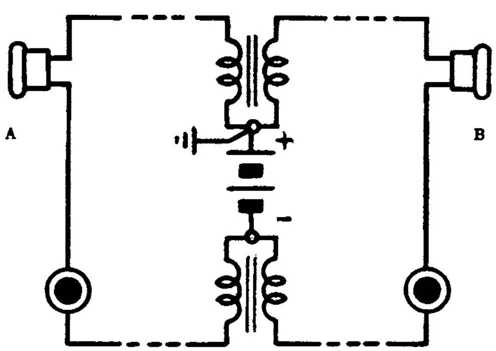


Fig. 50: Repeating Coil Common Battery System

(b) Repeating Coil Common-Battery System

In the Hayes or repeating coil common-battery system, Fig. 50, the battery supplies current through a repeating coil which has four windings. All four windings are on the same iron core. Current is supplied through two windings to telephone (A) and through the other two windings to telephone (B). The battery is customarily grounded. When speaking into the transmitter, electric waves or undulating currents are created which induce an alternating current in the repeating coil windings of that telephone. This alternating current is induced in the two repeating coil windings of the other telephone. Any repeating coil possesses this property of repeating an alternating current from one circuit to another.

The repeating coil method has an advantage over the impedance coil method, because through its use the two lines are practically divided except for the inductive link formed by the windings of the repeating coil. This method is used very largely in systems with longer loops. It has the disadvantage of having the A.C. voice current pass through the battery, with the resultant possibility of picking up battery noise.

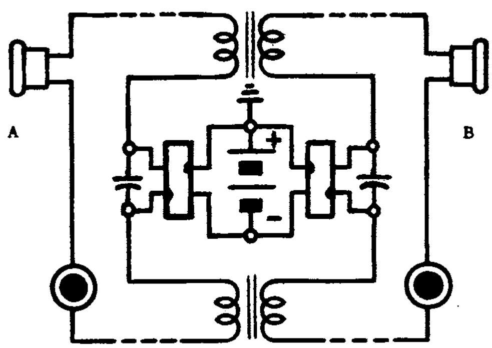


Fig. 50-A: Repeating Coil -- Impedance System

(c) Repeating Coil--Impedance System

Fig. 50-A shows the repeating coil--impedance common battery system. This system is similar to that shown in Fig. 50 with the addition of battery feed impedance coils, which are by-passed by condensers. The A.C. voice current passes through the repeating coils and the condensers, but does not pass through the battery. The battery feed impedance coils serve the double purpose of keeping the A.C. voice current from passing through the battery, and of keeping battery noises from reaching the lines.

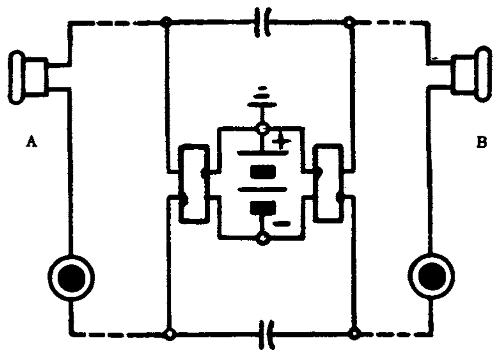


Fig. 51: Condenser Common Battery System

(d) Condenser-Impedance Common-Battery System

In the condenser-impedance common-battery system, shown in Fig. 51, each telephone has associated with it an impedance coil (called battery feed coils). The lines between the two telephones are connected together by condensers; the battery in most cases is grounded. When a person speaks into either transmitter the A.C. voice current caused by its varying resistance travels throughout the circuit composed of the two telephones, the lines and two condensers. Very little of this A.C. current gets through the battery feed coils because they are inductive.

The condensers keep the battery current (direct current) in one telephone line from passing to the other line. They are "open" as far as the battery current is concerned, but alternating current passes through very readily. The condenser common-battery method is also used in systems with long loops.

The condenser-impedance common-battery system has the advantage of less battery noise trouble. The talking current does not pass through the battery. The impedance coils tend to keep any battery noises from getting to the lines.

PART 6
TYPES OF AUTOMATIC TELEPHONES

33. GENERAL

The automatic telephone, generally speaking, differs from the common battery manual telephone only in the addition of a dial. Automatic telephones are made up in what is known as the series and the booster types.

34. SERIES AUTOMATIC TELEPHONE

The series type telephone is generally used with systems having short subscriber loops, that is, where the lines from the exchange to the telephone are not long or of great resistance.

The series type telephone may be easily divided into four separate circuits for convenience in study.

Fig. 52 shows the schematic wiring diagram of the series telephone complete.

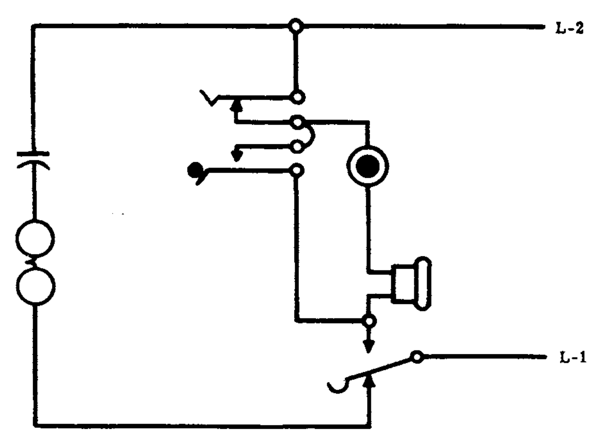
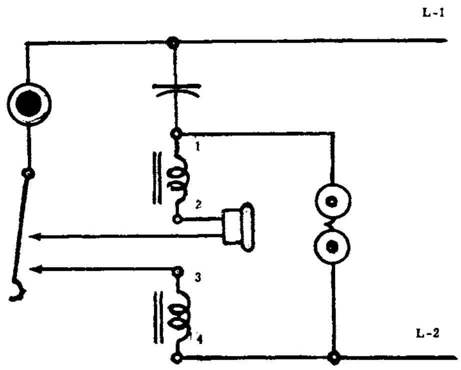


Fig. 52: Series Automatic Telephone



Schematic

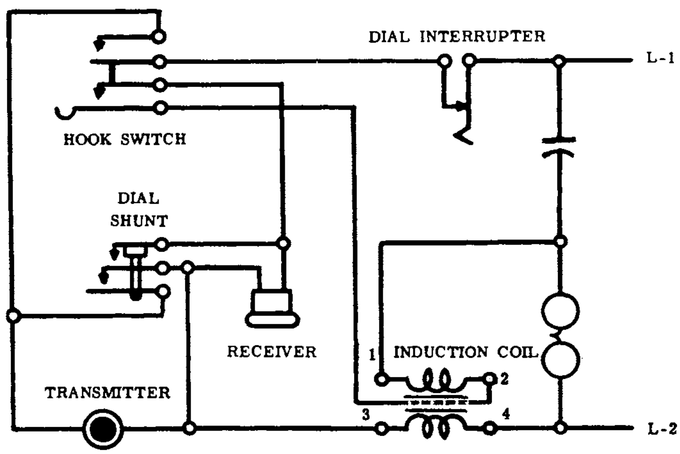


Fig. 53: Booster Automatic Telephone

35. BOOSTER AUTOMATIC TELEPHONE

The booster telephone circuit, shown in Fig. 53, is especially effective on long lines. It has an induction coil of the two winding type so connected in the circuit that it will assist the transmitter in sending. Fig. 53 also differs from Fig. 52 in that the ringing apparatus is bridged permanently across the line, and the receiver is of the permanent magnet type which requires no direct current to make it operative. Also, three dial shunt springs are necessary to short circuit the transmitter and receiver.

In order to understand the operation of the booster circuit during speech transmission, two distinct circuits must be kept in mind: (a) the main talking circuit which includes the two limbs of the line, L-1 and L-2, the transmitter, and the secondary winding (3-4) of the induction coil; and (b) the local talking circuit, purely local to the substation, which includes the transmitter, receiver, primary winding (1-2), and the condenser. It will be readily seen that when talking into the transmitter, two distinct sets of current undulations will be set up: (a) those directly produced in the line due to the variations in resistance of the transmitter; and (b) those produced in the local talking circuit by the charging and discharging of the condenser, due to the varying potential drop across the transmitter. The local talking circuit current undulations will be better understood if it be kept in mind that the condenser is connected across the terminals of the transmitter, directly on one side and through the receiver and primary winding (1-2) on the other side. The effect of the small direct current through the ringer is negligible, and it is evident from the above connections that the potential difference across the condenser will be varied by variations in potential across the transmitter. Alternating currents will then flow in the local circuit as the condenser adjusts its charge to the varying difference of potential across the transmitter and across its own terminals.

The alternating currents flowing in the primary winding (1-2) will induce currents in the secondary winding (3-4). Thus, if the two windings (1-2) and (3-4) of the induction coil are connected in proper relation to each other, the induced currents will reinforce or "boost" the currents which are directly produced in the line by the transmitter-- hence the name "booster circuit".

During the reception of speech the action of the induction coil is that of an ordinary transformer. The line winding (3-4) becomes the primary, and what was the primary winding (1-2), during the transmission of speech, becomes the secondary. The incoming voice current flows from the positive line through the primary winding (3-4) of the induction coil, and the transmitter to the negative line and vice versa. There is a tendency for a very small portion of the incoming voice current to reach the negative line over the path composed of the receiver, the secondary winding of the induction coil, and the condenser, as well as through the transmitter; but it is prevented from flowing over this path, because the voice current, in passing through the primary winding (3-4), induces a stronger current in opposition to it, into the secondary winding (1-2). The induced current flows through the receiver over the local circuit embracing the transmitter, condenser, and secondary winding (1-2) of the induction coil.

36. ANTI-SIDE TONE CIRCUIT

The anti-side tone circuit has been designed to either eliminate or suppress sidetone. Sidetone is the sound reproduced in the speaker's receiver by his voice current acting through his own transmitter.

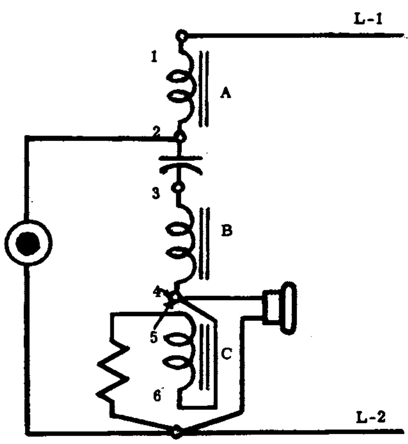


Fig. 54: Anti-Sidetone

Referring to Fig. 54, the windings "A" and "B" act like an auto-transformer. If the average of all the voice frequencies is taken as 1000 cycles per second, it will permit the matching of impedances at this frequency. The matching of impedances is the circuit condition necessary to get the maximum electrical power transfer from a generator to a connected load.

The condenser (blocks direct current) is employed to keep the talking current out of the receiver. The voltage generated in the winding "C" leads the current past the receiver instead of through it.

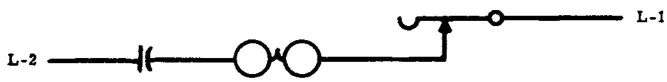


Fig. 55: Ringer Circuit

Fig. 55 shows the ringer circuit with the condenser and the bells in series. These permit the apparent flow of alternating current only.

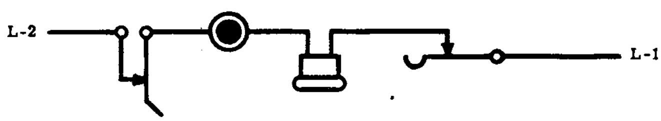


Fig. 56: Talking Circuit

Fig. 56 shows the talking circuit with the receiver, transmitter and impulse springs in series. The circuit shown is completed when the receiver has been removed from the hook and the dial is at normal.

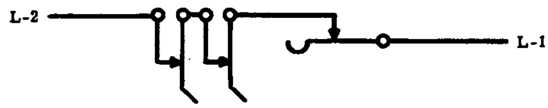


Fig. 57: Impulse Circuit

Fig. 57 shows the impulse circuit with impulse springs and shunt springs in series. The circuit completed to the impulse springs is interrupted a number of times corresponding to the number dialed. The opening of the circuit, or the impulses, which are sent out, cause the switches at the central office to operate to complete the connection to the called number.

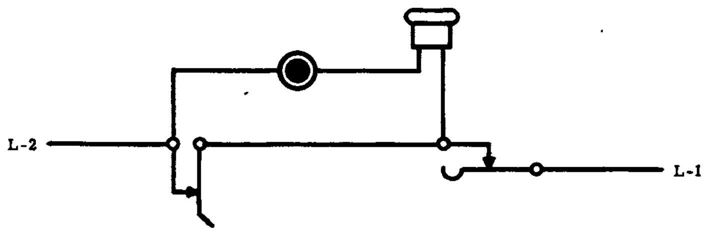


Fig. 58: Shunt Circuit

Fig. 58 shows the shunt circuit, completed whenever the dial is in an operated position. The shunt springs upon making their contacts shunt out the receiver and transmitter to prevent the impulses from being heard in the receiver of that telephone. This shunt circuit is completed only while the dial is other than in its normal position.

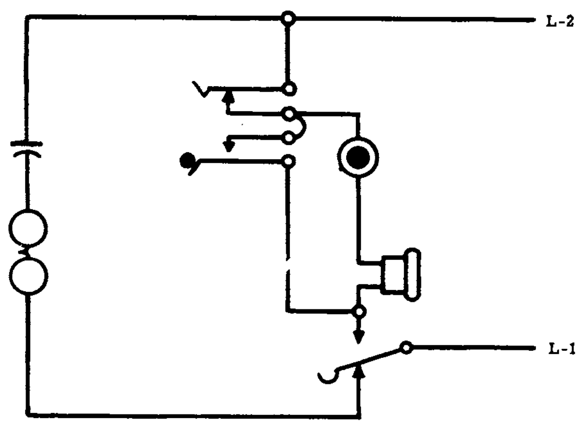


Fig. 52: (Repeated) Series Automatic Telephone

37. HOOKSWITCH

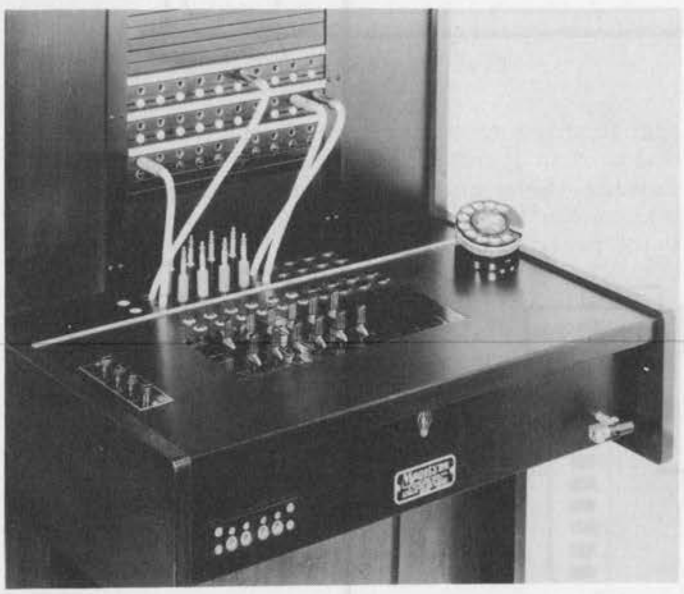
The hookswitch, as shown in Fig. 52, has a lever spring which touches the bottom contact when the receiver is hanging on the hook. When the receiver is removed from the hook, the lever spring leaves the bottom contact and touches the upper contact. The two line wires from the central office enter the telephone at L-1 and L-2. The receiver is non-polarized and requires direct current flowing through it to make it capable of operating.

When the receiver is on the hook, no battery current from the central office can get through the telephone. There is, however, a path through the condenser and bell through which alternating current may flow. To signal the subscriber, the central office apparatus sends out alternating current, which passes through the condenser and the bell and rings the latter. If a subscriber wishes to make a call, he first takes the receiver off the hook. This cuts the bell out and cuts the talking apparatus into the circuit. Battery now flows from L-2, through the calling device, transmitter, receiver, upper contact of hook lever spring to L-1. To operate the switches, the subscriber operates the calling device, which causes the circuit to be interrupted at the impulse springs at the rate of approximately ten per second. To prevent these interruptions from making a disagreeable noise in the receiver and to provide a uniform resistance in the impulsing circuit, the shunt springs come together and short circuit both transmitter and receiver.

The plunger switch on the Monophone type of telephone instrument corresponds to the hookswitch.

PART 7

TELEPHONE SWITCHBOARDS



Manual Switchboard

38. MANUAL

The telephone lines in a simple manual system terminate in individual answering jacks on the manual switchboard. When the subscriber removes the receiver, a signal appears opposite his answering jack. The operator inserts the plug of the answering cord into the answering jack and requests the desired number. She then inserts the plug of the calling cord into the multiple jack of the desired number and signals the called telephone. When the conversation is completed and the subscribers replace their receivers on the hook, the operator receives a disconnect signal. She then breaks the connection between the two telephones by removing the cords, which are then free to handle another call.

Each position of a manual board is usually equipped with from 10 to 15 cords. The number of positions is dependent upon the number of lines in the system and the amount of traffic handled.

39. AUTOMATIC

The automatic switchboard differs from the manual in that connections are set up automatically through a series of switches located in the central office, and controlled from the dial at the subscriber's telephone.

The central office equipment or switchboard, in a simple automatic system, consists of lineswitches (or linefinder switches), selectors, and connectors. All co-operate in establishing a connection between two lines.

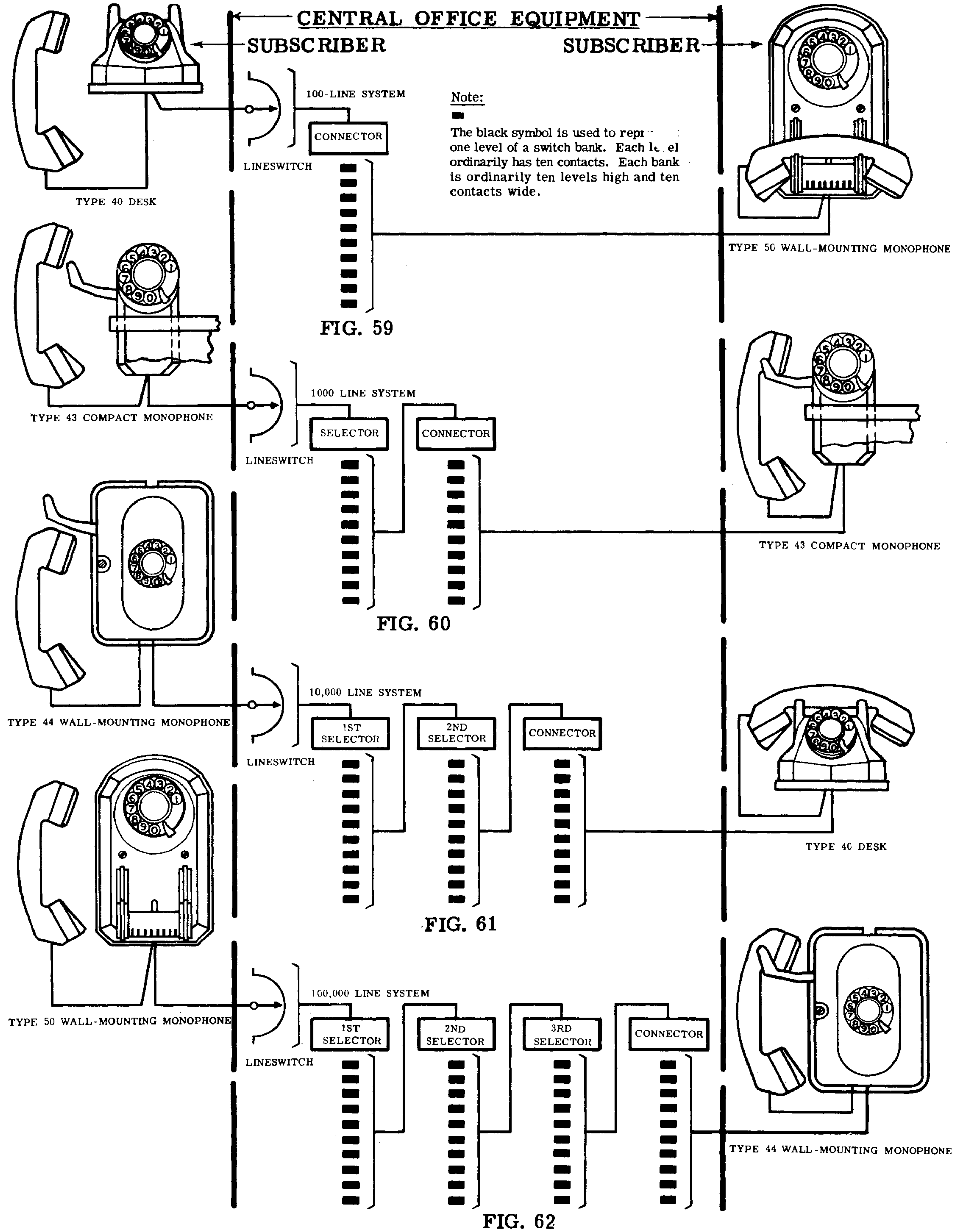
40. THE LINESWITCH

The lineswitch is a switch attached to each subscriber's line which automatically serves to connect the line to a trunk leading to an idle connector in a one hundred line system or an idle first selector in a larger system, as soon as the receiver is removed from the hook.

41. THE LINEFINDER SWITCH

The linefinder switch is another means of connecting a subscriber's line to a trunk leading to an idle connector, or selector depending upon the size of the system. The principle of operation of a linefinder switch is simple, and as the name implies, this switch "finds" the calling line.

Instead of an individual lineswitch for each subscriber's line, the linefinder switch is common to a group of lines. When the receiver is removed from the hook of a telephone in the group of lines, the linefinder switch



Figs. 59 to 62: Strowger Automatic Telephone Systems automatically "finds" the calling line. The calling subscriber's line is now extended directly through to the succeeding switch (connector or selector), which is connected directly to the linefinder switch.

42. THE SELECTOR

The selector is also a selecting mechanism of entirely different construction, which makes the intermediate connections. A group of selectors is provided for each of the figures of the call number except the last two. A three-digit number like 345 requires a group of selectors for the first figure. A four digit number like 2345 requires a group of selectors for the first figure and another group of selectors for the second figure. The first movement of the selector, the vertical, is under the control of the subscriber's dial. When the shaft has been elevated in response to the digit dialed, it automatically rotates and connects to an idle trunk in the group selected by the digit dialed. In other words, the rotary steps of a selector are not under the control of the subscriber's dial, but are automatic until an idle trunk is reached.

43. THE CONNECTOR

The connector is the "Operator" of the Strowger Automatic System. It is similar in general mechanical appearance and construction to the selector. The action of the connector is controlled by the dialing of the last two digits of the call number. The connector switch makes the final connection to the desired line. It can connect with any one of the one hundred subscriber lines. When 100 lines or less are included in a system, connector switches only are required.

44. FUNCTIONS OF THE CONNECTOR

Each telephone is connected to the switchboard by two wires. By means of a calling device on the telephone, the subscriber controls the selector and connector switches, and causes them to connect this telephone line to the line of any other subscriber. This is the act of switching. The connector tests the called line for busy. If that line is busy, a busy tone is connected to the calling subscriber's line as an indication that the desired line is in use. If the called line is not busy, the connector switch completes the ringing circuit to signal the called subscriber. When the called party answers, the direct current circuit for transmission purposes is completed by the connector. When both subscribers hang up their receivers, all the automatic switches return to their normal position, releasing the connection. It takes from three (3) to six (6) seconds to dial a connection and less than one (1) second to release it.

45. HUNDRED LINE SYSTEM

The hundred line system, shown in Fig. 59, consists of lineswitches (one for each telephone line) and connectors. The process of setting up a call is briefly as follows:

(a) The calling subscriber either removes his Monophone handset from the switch-hook, or from the Monophone cradle, preparatory to dialing.

(b) The lineswitch associated with his line operates to select an idle connector switch. "Dial tone" is sent back to the calling subscriber as a signal to commence dialing.

(c) The subscriber dials the first figure of the call number, thus causing the connector to select the desired "tens" group.

(d) The subscriber dials the second or last figure of the call number, thus causing the connector to select the desired "unit".

(e) The connector tests the called line. If the line is already engaged, it sends a "busy tone" back to the dialing party. If the line is not engaged, it sends ringing current to signal the called party.

(f) The called subscriber answers and conversation takes place.

(g) Both subscribers hang up their receivers upon which all switches in the connection release and are immediately ready to be used for another call.

46. THOUSAND LINE SYSTEM

The thousand line system shown in Fig. 60 is similar to the one hundred line system except for the addition of selector switches between the lineswitches and connectors. The purpose of the selector is to provide a means of selecting the particular hundred group being called. For example, if 345 is the number to be called, the selector extends the calling line to an idle connector in the three hundred group. The call then proceeds in the same manner as in a one hundred line system.

All selectors and connectors may be used by any subscriber. The lineswitch alone is individual to the subscriber.

47. TEN THOUSAND LINE SYSTEM

The ten thousand line system shown in Fig. 61, is made up of tens groups, each having one thousand lines. It requires "first selectors" to select any one of the thousand line groups. It requires in each thousand line group "second selectors" to select the desired hundred line group in that thousand. It differs from the thousand line system only in the addition of a second group or train of selectors to choose the desired thousand group.

48. MULTI-OFFICE SYSTEM

A telephone system larger than ten thousand lines is generally divided into more than one office, primarily to save cable. A system of this type, called a multi-office exchange, is one whose apparatus is grouped at several centers instead of being located at one place. Each center is termed an "office", it is not an exchange but is part of an exchange. The apparatus is sub-divided so that the length of the subscriber's line may be as short as possible. It often occurs that an exchange smaller than this can, to advantage, be operated in several centers.

A complete diagram showing the interlinking of a large multi-office exchange is too complicated for our present study. Fig. 62 shows the connections in a one hundred thousand line system. It will be noticed that it is similar to the ten thousand line system except for the addition of another group of selectors. The "first selectors" in this case choose the desired 10,000 group or office.

PART 8
GLOSSARY OF TELEPHONE TERMS

(Conforming in part with American Standards Association's "Electrical Definitions")

- A -

An "A" OPERATOR is an operator assigned to an "A" switchboard.

A-C—D-C RINGING is ringing in which a combination of alternating and direct currents is utilized, the direct current being provided to facilitate the functioning of the relay which stops the ringing.

An ALARM SIGNAL is a device for attracting attention to some abnormal condition.

An ANTI-SIDETONE TELEPHONE INSTRUMENT is a telephone instrument which includes a balancing network for the purpose of reducing sidetone.

An "A" SWITCHBOARD is a switchboard in a local central office arranged primarily for receiving from subscribers orders for telephone connections, for the completion of these connections, either at the same switchboard or by way of trunks to other switching equipment, and for their supervision.

An AUDIBLE BUSY SIGNAL is a signal audible to the calling party, indicating that the called party's line is in use.

An AUDIBLE RINGING SIGNAL is a signal audible to the calling party to indicate that the called station is being rung.

An AUTOMATIC CENTRAL OFFICE is a central office of an Automatic telephone system.

An AUTOMATIC TELEPHONE INSTRUMENT is a telephone equipped with a dial for the purpose of selecting a called party.

An AUTOMATIC TELEPHONE SYSTEM is a telephone system in which telephone connections between customers are ordinarily established by electric and mechanical apparatus controlled by manipulations of dials operated by the calling parties ("doing by a machine that which was formerly done by hand").

- B -

A BANK is an assemblage of fixed contacts formed into a single rigid unit to which permanent electric connections may be made and over which, or assigned sections of which, may move the wipers or brushes of a selector or switch capable of making electric connections with the contacts.

A "B" OPERATOR is an operator assigned to a "B" switchboard.

A "B" SWITCHBOARD is a switchboard in a local central office arranged primarily for receiving and completing to subscriber lines telephone connections which have been routed over trunks from other switchboards or Automatic switching equipment.

A BUSY TEST is a test made to find out whether or not certain facilities which may be desired, such as a subscriber line or trunk, are available for use.

- C -

A CALLING DEVICE is an apparatus which generates the pulses required for establishing connections in an Automatic system.

A CENTRAL OFFICE is an office in a telephone system providing service to the general public where orders for or signals controlling telephone connections are received and connections established.

Note: The term "central office", as applied to either manual or Automatic equipment used in switching subscriber lines, includes any unit of equipment having a separate office name or code and in addition having independent incoming trunks and switching equipment for switching subscriber lines. A central office may serve some subscribers on a theoretical office basis with additional names or codes. In this case for special reasons some separate incoming trunk groups may be provided for the traffic to the theoretical offices. There may be one or more central offices in a central office building.

CLEAR (see release)

CODE RINGING is party-line ringing wherein the number of rings, or their duration, or both, indicate which subscriber is being called.

Note: The term code ringing is not used to cover semi-selective ringing, although the latter employs a form of code ringing.

A COMMON BATTERY CENTRAL OFFICE is a central office which supplies transmitter and signaling currents for its associated stations and current for the central office equipment from batteries located in the central office.

A COMMON BATTERY TELEPHONE INSTRUMENT is a telephone instrument for which both the telephone transmitter and the signaling currents are supplied from a central office, private branch exchange or other centralized power source.

A CONNECTOR is a switching mechanism designed to connect a trunk to a desired subscriber line or PBX extension and often having facilities to hunt for an idle terminal when the terminals are grouped.

A CORD CIRCUIT is a connecting circuit terminating in a plug at one or both ends and used at switchboard positions in establishing telephone connections.

- D -

A DIAL is a type of calling device, which, when wound up and released, generates pulses required for establishing connections in an Automatic system.

DIAL TONE is a tone employed in Automatic telephone systems to indicate that the equipment is ready for the dialing operation.

DISCONNECT (see release)

A DISTRIBUTING FRAME is a structure for terminating permanent wires of a central office, private branch exchange or private exchange and for permitting the easy change of connections between them by means of cross-connecting wires.

- E -

An EXTENSION STATION is a telephone station associated with a main station through connection to the same subscriber line and having the same call number designation as the associated main station.

An EXCHANGE (telephone) is a telephone system for providing telephone communication within a particular local area, usually within or embracing a city, town or village, and environs.

- F -

A FINDER SWITCH is a switching mechanism, (a machine doing the work formerly done by hand) associated with a circuit, designed to move over a number of terminals to which are connected circuits, over any one of which a signal to start the switch may be transmitted, in order to find the specific circuit from which the starting signal has come and connect it to the circuit associated with this finder switch.

- H -

A HANDSET (Monophone-Automatic Electric Co. Trade Name) is a combination of a telephone transmitter and a telephone receiver mounted on a handle.

A HANDSET TELEPHONE INSTRUMENT (Monophone - Automatic Electric Co. Trade Name) is one having a handset and a mounting which serves to support the handset when the latter is not in use.

Note: The prefix "desk", "wall", "compact", etc., may be applied to the term handset telephone instrument to indicate the type of mounting.

HARMONIC SELECTIVE RINGING is selective ringing which employs currents of several frequencies and ringers, each tuned mechanically or electrically to the frequency of one of the ringing currents, so that only the desired ringer may be actuated.

- I -

An INDIVIDUAL LINE is a subscriber line arranged to serve only one main station although additional stations may be connected to the line as extensions.

Note: An individual line is not arranged for discriminatory ringing with respect to the stations on that line.

An INTERMEDIATE DISTRIBUTING FRAME in a switchboard, is a terminating device, for cross-connecting lines and trunks to equalize traffic.

An INTEROFFICE TRUNK is a direct trunk between local central offices in the same exchange.

- J -

A JACK is a connecting device to which the wires of a circuit may be attached and which is arranged for the insertion of a plug. The jacks most generally used have three separate contacting parts: the tip spring, the ring spring and the sleeve, which make contact with the corresponding parts of the plug.

- K -

A **KEY** is a hand operated switching device ordinarily formed of concealed spring contacts with an exposed handle or push button, capable of switching one or more parts of a circuit.

KEYLESS RINGING is a form of machine ringing used in manual central offices which does not require that an operator press a key in order to select the desired station but the ringing is automatically started by the insertion of the plug of the completing cord into the jack of the called party's line.

- L -

LINE (Open Wire) consists of one wire and ground return or two wires strung on poles and customarily spaced approximately from 8 to 10 inches apart.

A **LOCAL BATTERY TELEPHONE INSTRUMENT** is a telephone for which the transmitter current is supplied from a battery, or other current supply circuit, individual to the telephone set. The signaling current may be supplied from a local hand generator or from a centralized power source.

A **LOCAL CENTRAL OFFICE** is a central office arranged for terminating subscriber lines and provided with trunks for establishing connections to and from other central offices.

- M -

MACHINE RINGING is ringing which is started either mechanically or by an operator, after which it continues automatically until a response to the signal has been obtained or until stopped by disconnection upon abandoning the call.

A **MAGNETO CENTRAL OFFICE** is a central office serving stations each of which is provided with a local battery for talking and a magneto (generator) for signaling.

A **MAGNETO TELEPHONE INSTRUMENT** is a local battery telephone instrument provided with a hand magneto generator, for supplying signaling current.

A **MAIN DISTRIBUTING FRAME** (abbreviated MDF) is a distributing frame, on one part of which terminate the permanent outside lines entering the central office building and on another part of which terminate the subscriber line multiple cabling, trunk multiple cabling, etc., used for associating any outside line with any desired terminal in such a multiple or with any other outside line. It usually carries the central office protective devices and functions as a test point between line and office. In a private exchange the main distributing frame is for similar purposes.

A **MAIN STATION** is a telephone station with a distinct call number designation, directly connected to a central office.

A **MANUAL CENTRAL OFFICE** is a central office housing a manual switchboard.

MANUAL RINGING is ringing which is effected by the manual operation of a key, and continues only during the time the key is held operated.

A **MANUAL SWITCHBOARD** is one in which the connections are made by hand by operators', customarily in accordance with the subscriber's verbal request.

A **MANUAL TELEPHONE** is a telephone instrument not equipped with a dial.

A **MANUAL TELEPHONE SYSTEM** is one which employs manual switchboard.

A **MONITORING KEY** is a key which when operated makes it possible for an attendant or operator to "monitor" or to listen on a telephone circuit without appreciably impairing transmission on the circuit.

A **MULTI-OFFICE EXCHANGE** is an exchange served by more than one local central office.

(a) (Noun) A **MULTIPLE** is a group of terminals arranged to make a circuit or group of circuits accessible at a number of points at any one of which connection can be made.

(b) (Verb) To **MULTIPLE** is to render a circuit accessible at a number of points at any one of which connection can be made.

- O -

An **OPERATING ROOM** is a room in which operators handle calls by means of a switchboard.

An **OPERATOR'S TELEPHONE EQUIPMENT** consists of all the apparatus necessary for talking and listening.

- P -

A **PARTY LINE** is a telephone line arranged to serve more than one main station.

A **PLUG** is a device to which may be attached the conductors of a cord and which by insertion in a jack, establishes contact between the conductors of the attached cord and the conductors connected permanently to the jack. The plug most generally used has three separate contacting parts: the tip, the ring and the sleeve.

A **PRIVATE BRANCH EXCHANGE** (abbreviated PBX) is a telephone system, usually installed on the premises of a subscriber, having centralized switching equipment for interconnecting the stations of the subscriber and for connecting these stations to lines to a central office.

A PRIVATE EXCHANGE is a telephone system which serves one business organization or individual, and is not connected to a public central office.

PRIVATE TELEPHONE LINE is a telephone line which is not connected to any public telephone system.

A PUBLIC TELEPHONE STATION (often referred to as a "pay station") is a telephone available for use by the public generally on the payment of a fee which is deposited in a coin collector or is paid to an attendant.

A PULSE (for relay operation) is a sudden change of brief duration, produced in the current or voltage of a circuit in order to actuate or control a switch or relay.

(Impulse)*

* Deprecated.

A PULSE REPEATER is an arrangement of apparatus used in Automatic telephone systems for receiving pulses from one circuit and retransmitting corresponding pulses into another circuit. It may also correct the wave form of the pulses and perform other functions such as supplying transmitter current to stations, repeating a supervisory condition, etc.

- R -

To RELEASE, to disconnect or to clear is to disengage the apparatus used in a telephone connection and to restore it to its condition when not in use.

The RING of a plug is the ring-shaped contacting part of the plug immediately back of the tip.

RINGING is the production of an audible or visual signal at a station or switchboard by means of an alternating, pulsating, or sometimes direct current.

- S -

A SELECTOR SWITCH is a switching mechanism, associated with a circuit, designed to move over a number of terminals to which are connected groups of circuits in order to select a particular group of circuits in accordance with signals received over the circuit associated with this selector, and then to choose from the group an idle circuit and connect to it the circuit associated with this selector.

SELECTIVE RINGING is party-line ringing wherein only the ringer of the called subscriber's station (or stations) is rung.

SEMI-SELECTIVE RINGING is party-line ringing wherein the ringers of two subscribers' stations are rung, differentiation between subscribers being by a one-ring, two-ring code.

A SIDETONE TELEPHONE INSTRUMENT is a telephone instrument which does not include a balancing network for the purpose of reducing sidetone.

A SINGLE-OFFICE EXCHANGE is an exchange served by a single central office.

The SLEEVE of a plug is the cylindrical contacting part of the plug immediately back of the ring.

A STATION RINGER is an alternating-current electric bell or similar device associated with a telephone station for indicating a telephone call to the station.

A STROWGER AUTOMATIC TELEPHONE SYSTEM is a type of Automatic (the doing of work by a machine which was formerly done by hand) telephone system in which the switching apparatus is generally characterized by the following features:

(1) The wipers of the selecting mechanisms are moved both vertically and in horizontal circular arcs.

(2) The selecting mechanisms are individually driven by a combination of electromagnet and ratchet mechanisms.

(3) The dial pulses may either actuate the successive selecting mechanisms directly or may be received and stored by controlling mechanisms, which, in turn, actuate the selecting mechanisms by pulses similar to dial pulses.

SUPERPOSED RINGING is party-line ringing in which a combination of alternating and direct currents is utilized, the direct currents, of both polarities, being provided for selective ringing.

A SUBSCRIBER LINE (sometimes called a "subscriber loop" or "central office line") is a telephone line between a central office and a station, private branch exchange or other subscriber switching equipment.

A SUPERVISORY RELAY is a relay which, during a call, is generally controlled by the transmitter current supplied to a subscriber line in order to receive from the associated station directing signals which control the actions of operators or switching mechanisms with regard to the connection.

A SUPERVISORY SIGNAL is a device for attracting attention of an attendant to a duty in connection with the switching apparatus or its accessories.

A SWITCHBOARD CORD is a cord which is used in conjunction with switchboard apparatus to complete or build up a telephone connection.

A SWITCHBOARD LAMP is a small electric lamp associated with the wiring of a switchboard in such a way as to give a visual indication of the status of a call, or to give information concerning the condition of trunks, subscriber lines, apparatus, etc.

A SWITCHBOARD POSITION is that part of a switchboard designed for the use of one operator.

A SWITCHBOARD SECTION is a structural unit, providing for one or more operator positions. A complete switchboard may consist of one or more sections.

A SWITCHBOARD (telephone) is a switchboard for interconnecting telephone lines and associated circuits.

A SWITCH ROOM is that part of a central office building which contains an assemblage of Automatic switches and the associated apparatus of the Automatic central office, group of Automatic central offices, Automatic private branch exchange or private Automatic exchange.

A SYSTEM (telephone) is an assemblage of telephones, lines, channels and switching arrangements for their interconnection, together with all the accessories for providing telephone communication.

- T -

A TALKING KEY is a key which when operated makes it possible for the person operating the key to converse on the circuit with which the contacts of the key are associated.

A TANDEM OFFICE is a central office used exclusively for interconnection of other central offices within the same exchange and nearby exchanges.

A TELEPHONE CONNECTION is a two-way telephone channel completed between two points by means of suitable switching apparatus and arranged for the transmission of telephone currents, together with the associated arrangements for its functioning with the other parts of a telephone system in switching and signaling operations.

Note: The term is also sometimes used to mean a two-way telephone channel permanently established between two telephone stations.

A TELEPHONE CURRENT is an electric current produced or controlled by the operation of a telephone transmitter.

A TELEPHONE INSTRUMENT (often abbreviated "telephone") is an assemblage of apparatus including a telephone transmitter, a telephone receiver, and usually a switch, and the immediately associated apparatus, wiring and signaling arrangements for the use of these instruments in telephony.

A TELEPHONE INSTRUMENT (Automatic) equipped with a dial for the purpose of selecting the called party.

TELEPHONE LINE is a general term used in communication practice in several different senses, the more important of which are:

(a) The conductor or conductors and supporting or containing structures extending between subscriber stations and central offices or between central offices whether they be in the same or different communities.

(b) The conductors and circuit apparatus associated with a particular communication channel.

A TELEPHONE STATION is an installed telephone instrument and associated wiring and apparatus, in service for telephone communication.

Note: As generally applied, this term does not include the telephone equipment employed by central office operators and by certain other personnel in the operation and maintenance of a telephone system.

A TELEPHONE SWITCHBOARD is a switchboard for interconnecting telephone lines and associated circuits.

A TELEPHONE OPERATOR is a person who handles switching and signaling operations needed to establish telephone connections between stations or who performs various auxiliary functions associated therewith.

Note: An operator at a private branch exchange is called an "attendant".

A TERMINAL ROOM is a room, associated with a central office, private branch exchange or private exchange, which contains distributing frames, relays and similar apparatus except that mounted in the switchboard sections.

A TELEPHONE SUBSCRIBER is a customer of a telephone system who is served by the system under a specific agreement or contract.

A TEST BOARD is a switchboard equipped with testing apparatus, so arranged that connections can be made from it to telephone lines or central office equipment for testing purposes.

A TIE TRUNK is a telephone line or channel directly connecting two private branch exchanges.

A TRUNK is a telephone line or channel between two central offices or switching devices, which is used in providing telephone connections between subscribers generally.

TRUNK HUNTING is the operation of a selector, or other similar device, in moving its wipers or brushes to a terminal or contact associated with an idle circuit of a chosen group. This is usually accomplished by successively testing terminals associated with this group until a terminal is found which has an electrical condition indicating it to be idle.

The **TIP** of a plug is the contacting part at the end of the plug.

A **TOLL BOARD** is a switchboard used primarily for establishing connections over toll lines.

A **TOLL LINE** is a telephone line or channel between two central offices in different exchanges.

A **TOLL OFFICE** is a central office primarily arranged for terminating toll lines, toll switching trunks, recording trunks and recording-completing trunks and for their interconnection with each other as necessary for the purpose of establishing connections over toll lines.

A **TOLL SWITCHING TRUNK** is a trunk extending from a toll office to a local central office for connecting toll lines to subscriber lines.

- W -

A **WALL TELEPHONE INSTRUMENT** is a telephone instrument arranged for wall mounting.

A **WIPER OR BRUSH** is that portion of the moving member of a selector, or other similar device, which makes contact with the terminals of a bank.

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