Cyclopedia
of
Applied Electricity

A General Reference Work on

DIRECT-CURRENT GENERATORS AND MOTORS, STORAGE BATTERIES, ELECTRIC WIRING, ELECTRICAL MEASUREMENTS, ELECTRIC LIGHTING, ELECTRIC RAILWAYS, POWER STATIONS, POWER TRANSMISSION, ALTERNATING-CURRENT MACHINERY, TELEPHONY, TELEGRAPHY, ETC.

Prepared by a Corps of

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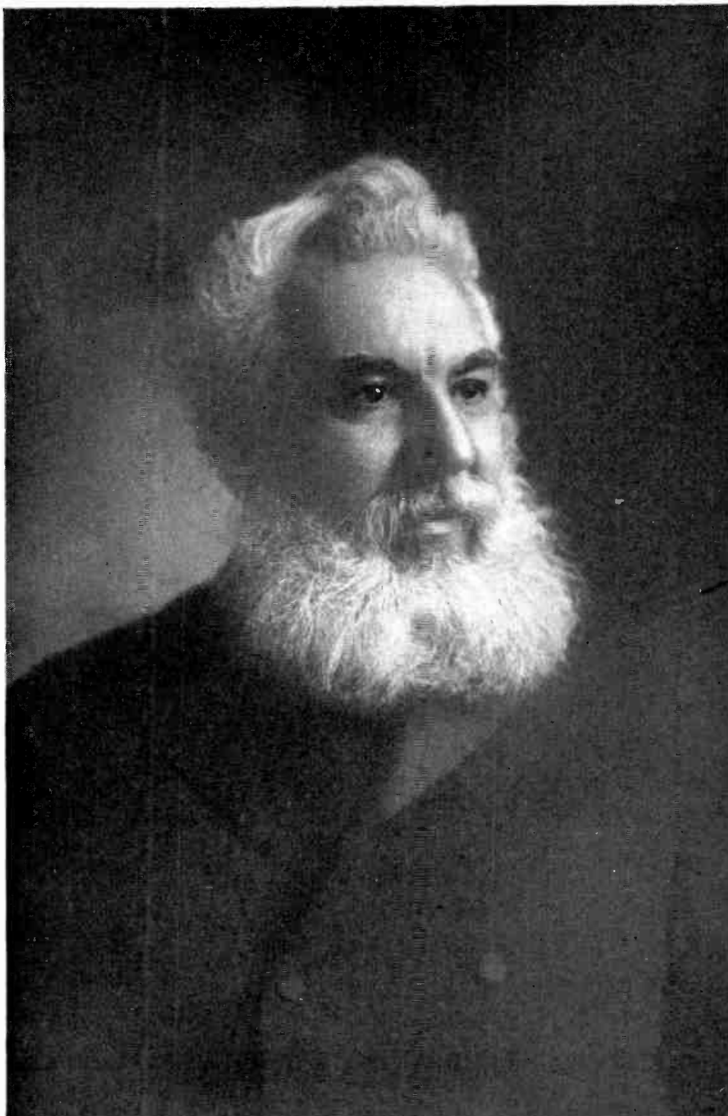

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Grateful acknowledgment is here made also for the invaluable co-operation of the foremost engineering firms and manufacturers in making these volumes thoroughly representative of the very best and latest practice in the design, construction, and operation of electrical machinery and instruments; also for the valuable drawings, data, suggestions, criticisms, and other courtesies.

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OLD SWITCHBOARD OF BELL EXCHANGE SERVING CHINATOWN, SAN FRANCISCO, CALIFORNIA

Foreword

ONE of the simplest acts in modern life is switching on the electric current that gives light or power, or that makes possible communication between distant points. A child can perform that act as effectively as a man, so thoroughly has electricity been broken to the harness of the world's work; but behind that simple act stand a hundred years of struggle and achievement, and the untiring labors of thousands of the century's greatest scientists. To compact the results of these labors into the compass of a practical reference work is the achievement that has been attempted—and it is believed accomplished—in this latest edition of the Cyclopedia of Applied Electricity.

¶ Books on electrical topics are almost as many as the subjects of which they treat and many of them are worthy of a place in the first rank. But many, also, worthy in themselves, are too scientific in their treatment to be available for the mass of electrical workers; and all of them, if gathered into a great common library, would contain so many duplicate pages that their use would entail an appalling waste of time upon the man who is trying to keep up with electrical progress. To overcome these difficulties the publishers of this Cyclopedia went direct to the original sources, and secured as writers of the various sections, men of wide practical experience and thorough technical training, each an acknowledged authority in his work; and these contributions have been correlated by our Board of Editors so as to make the work a unified whole, logical in arrangement and at the same time devoid of duplication.

¶ The Cyclopedia is, therefore, a complete and practical working treatise on the generation and application of electric power. It covers the known principles and laws of Electricity, its generation by dynamos operated by steam, gas, and water power; its transmission and storage; and its commercial application for purposes of power, light, transportation, and communication. It includes the construction as well as the operation of all plants and instruments involved in its use; and it is exhaustive in its treatment of operating "troubles" and their remedies.

¶ It accomplishes these things both by the simplicity of its text and the graphicness of its supplementary diagrams and illustrations. The Cyclopedia is as thoroughly scientific as any work could be; but its treatment is as free as possible from abstruse mathematics and unnecessary technical phrasing, while it gives particular attention to the careful explanation of involved but necessary formulas. Diagrams, curves, and practical examples are used without stint, where they can help to explain the subject under discussion; and they are kept simple, practical, and easy to understand.

¶ The Cyclopedia is a compilation of many of the most valuable Instruction Books of the American School of Correspondence, and the method adopted in its preparation is that which this School has developed and employed so successfully for many years. This method is not an experiment, but has stood the severest of all tests—that of practical use—which has demonstrated it to be the best devised for the education of the busy, practical man.

¶ In conclusion, grateful acknowledgment is due to the staff of authors and collaborators, without whose hearty co-operation this work would have been impossible.

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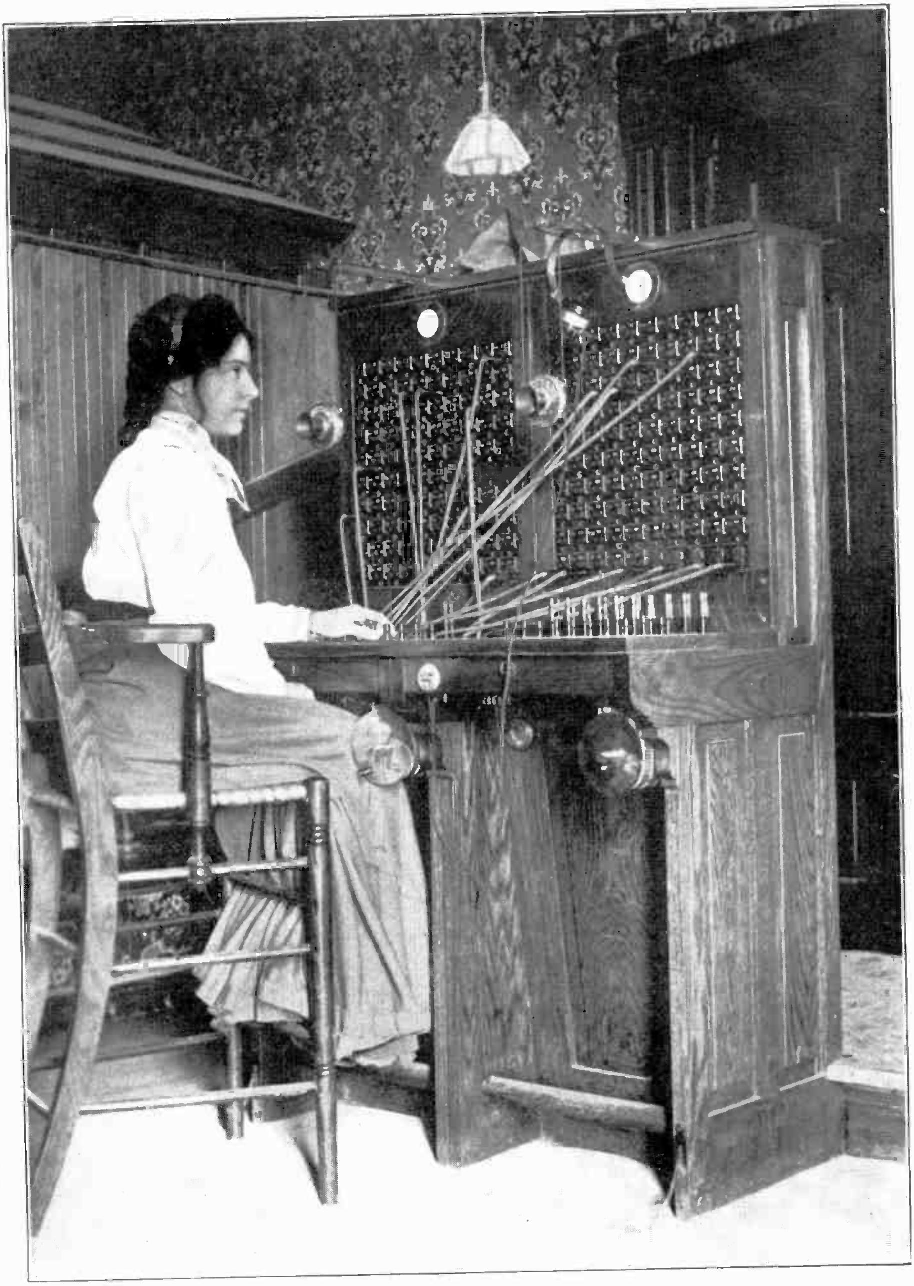

A TYPICAL SMALL MAGNETO SWITCHBOARD INSTALLATION

*TELEPHONY

CHAPTER I

ACOUSTICS

Telephony is the art of reproducing at a distant point, usually by the agency of electricity, sounds produced at a sending point. In this art the elements of two general divisions of physical science are concerned, sound and electricity.

Sound is the effect of vibrations of matter upon the ear. The vibrations may be those of air or other matter. Various forms of matter transmit sound vibrations in varying degrees, at different specific speeds, and with different effects upon the vibrations.

Propagation of Sound. Since human beings communicate with each other by means of speech and hearing through the air, it is with air that the acoustics of telephony principally is concerned. In air. sound vibrations consist of successive condensations and rarefactions tending to proceed outwardly from the source in all directions. The source is the center of a sphere of sound vibrations. Whatever may be the nature of the sounds or of the medium transmitting them, they consist of waves emitted by the source and observed by the ear. A sound wave is one complete condensation and rarefaction of the transmitting medium. It is produced by one complete vibration of the sound-producing thing.

Sound waves in air travel at a rate of about 1,090 feet per second. The rate of propagation of sound waves in other materials varies with the density of the material. For example, the speed of transmission is much greater in water than in air, and is much less in highly rarefied air than in air at ordinary density. The propagation of sound waves in a vacuum may be said not to take place at all.

Characteristics of Sound. Three qualities distinguish sound: loudness, pitch, and timbre.

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*This volume is an abridgment of "Telephony," by Kempster B. Miller and Samuel G. McMeen, published by the American School of Correspondence. Those wishing to specialize in Telephony are referred to the complete work.

Loudness. Loudness depends upon the violence of the effect upon the ear; sounds may be alike in their other qualities and differ in loudness, the louder sounds being produced by the stronger vibrations of the air or other medium at the ear. Other things being equal, the louder sound is produced by the source radiating the greater energy and so producing the greater *degree* of condensation and rarefaction of the medium.

Pitch. Pitch depends upon the frequency at which the sound waves strike the ear. Pitches are referred to as *high* or *low* as the frequency of waves reaching the ear are greater or fewer. Familiar low pitches are the left-hand strings of a piano; the larger ones of stringed instruments generally; bass voices; and large bells. Familiar high pitches are right-hand piano strings; smaller ones of other stringed instruments; soprano voices; small bells; and the voices of most birds and insects.

Doppler's Principle:—As pitch depends upon the frequency at which sound waves strike the ear, an object may emit sound waves at a constant frequency, yet may produce different pitches in ears differently situated. Such a case is not usual, but an example of it will serve a useful purpose in fixing certain facts as to pitch. Conceive two railroad trains to pass each other, running in opposite directions, the engine bells of both trains ringing. Passengers on each train will hear the bell of the other, first as a *rising* pitch, then as a *falling* one. Passengers on each train will hear the bell of their own train at a *constant* pitch.

The difference in the observations in such a case is due to relative positions between the ear and the source of the sound. As to the bell of their own train, the passengers are a fixed distance from it, whether the train moves or stands; as to the bell of the other train, the passengers first rapidly approach it, then pass it, then recede from it. The distances at which it is heard vary as the secants of a circle, the radius in this case being a length which is the closest approach of the ear to the bell.

If the bell have a constant intrinsic fundamental pitch of 200 waves per second (a wave-length of about 5.5 feet), it first will be heard at a pitch of about 200 waves per second. But this pitch rises rapidly, as if the bell were changing its own pitch, which bells do not do. The rising pitch is heard because the ear is rushing down the wave-train, every instant nearer to the source. At a speed of 45 miles an hour, the pitch rises rapidly, about 12 vibrations per second. If the *rate of approach* between the ear and the bell were constant, the pitch of the bell would be heard at 212 waves per second. But suddenly the ear passes the bell, hears the pitch stop rising and begin to fall; and the tone drops 12 waves per second as it had risen. Such a circumflex is an excellent example of the bearing of wave-lengths and frequencies upon pitch.

Vibration of Diaphragms:—Sound waves in air have the power to move other diaphragms than that of the ear. Sound waves constantly vibrate such diaphragms as panes of windows and the walls of houses. The recording diaphragm of a phonograph is a window pane bearing a stylus adapted to engrave a groove in a record blank. In the cylinder form of record, the groove varies in depth with the vibrations of the diaphragm. In the disk type of phonograph, the groove varies sidewise from its normal true spiral.

If the disk record be dusted with talcum powder, wiped, and examined with a magnifying glass, the waving spiral line may be seen. Its variations are the result of the blows struck upon the diaphragm by a train of sound waves.

In reproducing a phonograph record, increasing the speed of the record rotation causes the pitch to rise, because the blows upon the air are increased in frequency and the wave-lengths shortened. A transitory decrease in speed in recording will cause a transitory rise in pitch when that record is reproduced at uniform speed.

Timbre. Character of sound denotes that difference of effect produced upon the ear by sounds otherwise alike in pitch and loudness. This characteristic is called timbre. It is extraordinarily useful in human affairs, human voices being distinguished from each other by it, and a great part of the joy of music lying in it.

A bell, a stretched string, a reed, or other sound-producing body, emits a certain lowest possible tone when vibrated. This is called its *fundamental tone.* The pitch, loudness, and timbre of this tone depend upon various controlling causes. Usually this fundamental tone is accompanied by a number of others of higher pitch, blending with it to form the general tone of that object. These higher tones are called *harmonics.* The Germans call them *overtones.* They are always of a frequency which is some multiple of the fundamental frequency. That is, the rate of vibration of a harmonic is 2, 3, 4, 5, or some other integral number, times as great as the fundamental itself. A tone having no harmonics is rare in nature and is not an attractive one. The tones of the human voice are rich in harmonics.

In any tone having a fundamental and harmonics (multiples), the wave-train consists of a complex series of condensations and rarefactions of the air or other transmitting medium. In the case of mere noises the train of vibrations is irregular and follows no definite order. This is the difference between vowel sounds and other musical tones on the one hand and all unmusical sounds (or noises) on the other.

Human Voice. Human beings communicate with each other in various ways. The chief method is by speech. Voice is sound vibration produced by the vocal cords, these being two ligaments in the larynx. The vocal cords in man are actuated by the air from the lungs. The size and tension of the vocal cords and the volume and the velocity of the air from the lungs control the tones of the voice. The more tightly the vocal cords are drawn, other things being equal, the higher will be the pitch of the sound; that is, the higher the frequency of vibration produced by the voice. The pitches of the human voice lie, in general, between the frequencies of 87 and 768 per second. These are the extremes of pitch, and it is not to be understood that any such range of pitch is utilized in ordinary speech. An average man speaks mostly between the fundamental frequencies of 85 and 160 per second. Many female speaking voices use fundamental frequencies between 150 and 320 vibrations per second. It is obvious from what has been said that in all cases these speaking fundamentals are accompanied by their multiples, giving complexity to the resulting wave-trains and character to the speaking voice.

Speech-sounds result from shocks given to the air by the organs of speech; these organs are principally the mouth cavity, the tongue, and the teeth. The vocal cords are *voice-organs;* that is, man only truly speaks, yet the lower animals have voice. Speech may be whispered, using no voice. Note the distinction between speech and voice, and the organs of both.

The speech of adults has a mean pitch lower than that of children; of adult males, lower than that of females.

There is no close analogue for the voice-organ in artificial mechanism, but the use of the lips in playing a bugle, trumpet, cornet, or trombone is a fairly close one. Here the lips, in contact with each other, are stretched across one end of a tube (the mouthpiece) while the air is blown between the lips by the lungs. A musical tone results; if the instrument be a bugle or a trumpet of fixed tube length, the pitch will be some one of several certain tones, depending on the tension on the lips. The loudness depends on the force of the blast of air; the character depends largely on the bugle.

Human Ear. The human ear, the organ of hearing in man, is a complex mechanism of three general parts, relative to sound waves: a wave-collecting part; a wave-observing part, and a wave-interpreting part.

The outer ear collects and reflects the waves inwardly to beat upon the tympanum, or ear drum, a membrane diaphragm. The uses of the rolls or convolutions of the outer ear are not conclusively known, but it is observed that when they are filled up evenly with a wax or its equivalent, the sense of direction of sound is impaired, and usually of loudness also.

The diaphragm of the ear vibrates when struck by sound waves, as does any other diaphragm. By means of bone and nerve mechanism, the vibration of the diaphragm finally is made known to the brain and is interpretable therein.

The human ear can appreciate and interpret sound waves at frequencies from 32 to about 32,000 vibrations per second. Below the lesser number, the tendency is to appreciate the separate vibrations as separate sounds. Above the higher number, the vibrations are inaudible to the human ear. The most acute perception of sound differences lies at about 3,000 vibrations per second. It may be that the range of hearing of organisms other than man lies far above the range with which human beings are familiar. Some trained musicians are able to discriminate between two sounds as differing one from the other when the difference in frequency is less than one-thousandth of either number. Other ears are unable to detect a difference in two sounds when they differ by as much as one full step of the chromatic scale. Whatever faculty an individual may possess as to tone discrimination, it can be improved by training and practice.

CHAPTER II

ELECTRICAL REPRODUCTION OF SPEECH

The art of telephony in its present form has for its problem so to relate two diaphragms and an electrical system that one diaphragm will respond to all the fundamental and harmonic vibrations beating upon it and cause the other to vibrate in exact consonance, producing just such vibrations, which beat upon an ear.

The art does not do all this today; it falls short of it in every phase. Many of the harmonics are lost in one or another stage of the process; new harmonics are inserted by the operations of the system itself and much of the volume originally available fails to reappear. The art, however, has been able to change commercial and social affairs in a profound degree.

Conversion from Sound Waves to Vibration of Diaphragm. However produced, by the voice or otherwise, sounds to be transmitted by telephone consist of vibrations of the air. These vibrations, upon reaching a diaphragm, cause it to move. The greatest amplitude of motion of a diaphragm is, or is wished to be, at its center, and its edge ordinarily is fixed. The diaphragm thus serves as a translating device, changing the energy carried by the molecules of the air into localized oscillations of the matter of the diaphragm. The waves of sound in the air advance; the vibrations of the molecules are localized. The agency of the air as a medium for sound transmission should be understood to be one in which its general volume has no need to move from place to place. What occurs is that the vibrations of the sound-producer cause alternate condensations and rarefactions of the air. Each molecule of the air concerned merely oscillates through a small amplitude, producing, by joint action, shells of waves, each traveling outward from the sound-producing center like rapidly growing coverings of a ball.

Conversion from Vibration to Voice Currents. Fig. 1 illustrates a simple machine adapted to translate motion of a diaphragm into an alternating electrical current. The device is merely one form of magneto telephone chosen to illustrate the point of immediate conversion. *1* is a diaphragm adapted to vibrate in response to the sounds reaching it. *2* is a permanent magnet and *3* is its armature. The armature is in contact with one pole of the permanent magnet and nearly in contact with the other. The effort of the armature to touch the pole it nearly touches places the diaphragm under tension. The free arm of the magnet is surrounded by a coil *4*, whose ends extend to form the line.

When sound vibrates the diaphragm, it vibrates the armature also, increasing and decreasing the distance from the free pole of the magnet. The lines of force threading the coil *4* are varied as the gap between the magnet and the armature is varied.

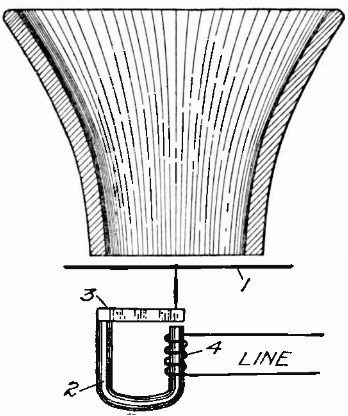


Fig. 1. Type of Magneto Telephone

The result of varying the lines of force through the turns of the coil is to produce an electromotive force in them, and if a closed path is provided by the line, a current will flow. This current is an alternating one having a frequency the same as the sound causing it. As in speech the frequencies vary constantly, many pitches constituting even a single spoken word, so the alternating voice currents are of great varying complexity, and every fundamental frequency has its harmonics superposed.

Conversion from Voice Currents to Vibration. The best knowledge of the action of such a telephone as is shown in Fig. 1 leads to the conclusion that a half-cycle of alternating current is produced by an inward stroke of the diaphragm and a second half-cycle of alternating current by the succeeding outward stroke, these half-cycles flowing in opposite directions. Assume one complete cycle of current to pass through the line and also through another such device as in Fig. 1 and that the first half-cycle is of such direction as to increase the permanent magnetism of the core. The effort of this increase is to narrow the gap between the armature and pole piece. The diaphragm will throb inward during the half-cycle of current. The succeeding half-cycle being of opposite direction will tend to oppose the magnetism of the core. In practice, the flow of opposing current never would be great enough wholly to nullify and reverse the magnetism of the core, so that the opposition results in a mere decrease, causing the armature's gap to increase and the diaphragm to respond by an outward blow.

Complete Cycle of Conversion. The cycle of actions thus is complete; one complete sound-wave in air has produced a cycle of motion in a diaphragm, a cycle of current in a line, a cycle of magnetic change in a core, a cycle of motion in another diaphragm, and a resulting wave of sound. It is to be observed that the chain of operation involves the expenditure of energy only by the speaker, the only function of any of the parts being that of *translating* this energy from one form to another. In every stage of these translations, there are losses; the devising of means of limiting these losses as greatly as possible is a problem of telephone engineering.

Magneto Telephones. The device in Fig. 1 is a practical magneto receiver and transmitter. It is chosen as best picturing the idea to be proposed. Fig. 2 illustrates a pair of magneto telephones of the early Bell type; *1-1* are diaphragms; *2-2* are permanent magnets with

Fig. 2. Magneto Telephones and Line

a free end of each brought as near as possible, without touching, to the diaphragm. Each magnet bears on its end nearest the diaphragm a winding of fine wire, the two ends of each of these windings being joined by means of a two-wire line. All that has been said concerning Fig. 1 is true also of the electrical and magnetic actions of the devices of Fig. 2. In the latter, the flux which threads the fine wire winding is disturbed by motions of the transmitting diaphragm. This disturbance of the flux creates electromotive forces in those windings. Similarly, a variation of the electromotive forces in the windings varies the pull of the permanent magnet of the receiving instrument upon its diaphragm.

Fig. 3 illustrates a similar arrangement, but it is to be understood that the cores about which the windings are carried in this case are of soft iron and not of hard magnetized steel. The necessary magnetism which constantly enables the cores to exert a pull upon the diaphragm is provided by the battery which is inserted serially in the

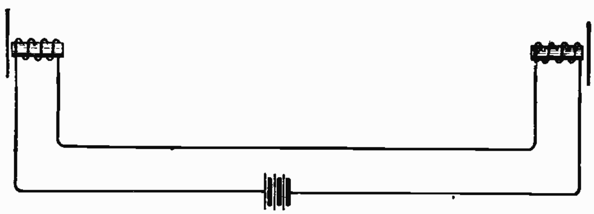


Fig. 3. Magneto Telephones without Permanent Magnets

line. Such an arrangement in action differs in no particular from that of Fig. 2, for the reason that it matters not at all whether the magnetism of the core be produced by electromagnetic or by permanently magnetic conditions. The arrangement of Fig. 3 is a fundamental counterpart of the original telephone of Professor Bell, and it is of particular interest in the present stage of the art for the reason that a tendency lately is shown to revert to the early type, abandoning the use of the permanent magnet.

The modifications which have been made in the original magneto telephone, practically as shown in Fig. 2, have been many. Thirty-five years' experimentation upon and daily use of the instrument has resulted in its refinement to a point where it is a most successful receiver and a most unsuccessful transmitter. Its use for the latter purpose may be said to be nothing. As a receiver, it is not only wholly satisfactory for commercial use in its regular function, but it is, in addition, one of the most sensitive electrical detecting devices known to the art.

Loose Contact Principle. Early experimenters upon Bell's device, all using in their first work the arrangement utilizing current from a battery in series with the line, noticed that sound was given out by disturbing loose contacts in the line circuit. This observation led to the arrangement of circuits in such a way that some imperfect contacts could be shaken by means of the diaphragm, and the resistance of the line circuit varied in this manner. An early and interesting form of such imperfect contact transmitter device consisted merely of metal conductors laid loosely in contact. A simple example is that of three wire nails, the third lying across the other two, the two loose contacts thus formed being arranged in series with a battery, the line, and the receiving instrument. Such a device when slightly jarred, by the voice or other means, causes abrupt variation in the resistance of the line, and will transmit speech.

Early Conceptions. The conception of the possibility and desirability of transmitting speech by electricity may have occurred to many, long prior to its accomplishment. It is certain that one person, at least, had a clear idea of the general problem. In 1854, Charles Bourseul, a Frenchman, wrote: "I have asked myself, for example, if the spoken word itself could not be transmitted by electricity; in a word, if what was spoken in Vienna might not be heard in Paris? The thing is practicable in this way:

"Suppose that a man speaks near a movable disk sufficiently flexible to lose none of the vibrations of the voice; that this disk *alternately makes and breaks* the connection from a battery; you may

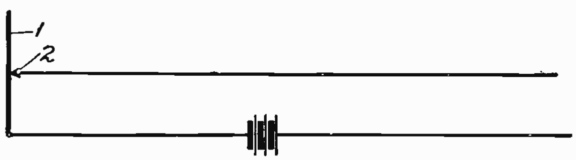


Fig. 4. Reis Transmitter

have at a distance another disk which will simultaneously execute the same vibrations." The idea so expressed is weak in only one particular. This particular is shown by the words italicized by ourselves. It is impossible to transmit a complex series of waves by any simple series of makes and breaks. Philipp Reis, a German, devised the arrangement shown in Fig. 4 for the transmission of sound, letting the make and break of the contact between the diaphragm *1* and the point *2* interrupt the line circuit. His receiver took several forms, all electromagnetic. His success was limited to the transmission of musical sounds, and it is not believed that articulate speech ever was transmitted by such an arrangement.

It must be remembered that the art of telegraphy, particularly in America, was well established long before the invention of the telephone, and that an arrangement of keys, relays, and a battery, as shown in Fig. 5, was well known to a great many persons. Attaching the armatures of the relays of such a line to diaphragms,

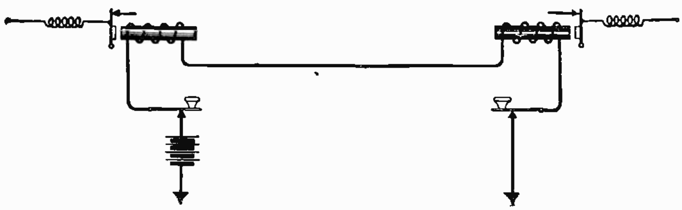


Fig. 5. Typical Telegraph Line

as in Fig. 6, at any time after 1838, would have produced the telephone. "The hardihood of invention" to conceive such a change was the quality required.

Limitations of Magneto Transmitter. For reasons not finally established, the ability of the magneto telephone to produce large currents from large sounds is not equal to its ability to produce large sounds from large currents. As a receiving device, it is unexcelled, and but slight improvement has been made since its first invention. It is inadequate as a transmitter, and as early as 1876, Professor Bell exhibited other means than electromagnetic action for producing the varying currents as a consequence of diaphragm

Fig. 6. Telegraph Equipment Converted into Telephone Equipment

motion. Much other inventive effort was addressed to this problem, the aim of all being to send out more robust voice currents.

Other Methods of Producing Voice Currents. Some of these means are the variation of resistance in the path of direct current, variation in the pressure of the source of that current, and variation in the electrostatic capacity of some part of the circuit.

Electrostatic Telephone. The latter method is principally that of Dolbear and Edison. Dolbear's thought is illustrated in Fig. 7. Two conducting plates are brought close together. One is free to vibrate as a diaphragm, while the other is fixed. The element *1* in Fig. 7 is merely a stud to hold rigid the plate it bears against. Each of two instruments connected by a line contains such a pair of plates, and a battery in the line keeps them charged to its potential. The two diaphragms of each instrument are kept drawn towards each other because their unlike charges attract each other. The vibration of one of the diaphragms changes the potential of the other pair; the degree of attraction thus is varied, so that vibration of the diaphragm and sound waves result.

Examples of this method of telephone transmission are more familiar to later practice in the form of condenser receivers. A condenser, in usual present practice, being a pair of closely adjacent conductors of considerable surface insulated from each other, a rapidly varying current actually may move one or both of the conductors. Ordinarily these are of thin sheet metal (foil) interleaved with an insulating material, such as paper or mica. Voice currents can vibrate the metal sheets in a degree to cause the condenser to speak. These condenser methods of telephony have not become commercial.

Fig. 7. Electrostatic Telephone

Variation of Electrical Pressure. Variation of the pressure of the source is a conceivable way of transmitting speech. To utilize it, would require that the vibrations of the diaphragm cause the electromotive force of a battery or machine to vary in harmony with the sound waves. So far as we are informed this method never has come into practical use.

Variation of Resistance. Variation of resistance proportional to the vibrations of the diaphragm is the method which has produced the present prevailing form of transmission. Professor Bell's Centennial exhibit contained a water-resistance transmitter. Dr. Elisha Gray also devised one. In both, the diaphragm acted to increase and diminish the distance between two conductors immersed in water, lowering and raising the resistance of the line. It later was discovered by Edison that carbon possesses a peculiarly great property of varying its resistance under pressure. Professor David E. Hughes discovered that two conducting bodies, preferably of rather poor conductivity, when laid together so as to form a *loose contact* between them, possessed, in remarkable degree, the ability to vary the resistance of the path through them when subject to such vibrations as would alter the *intimacy of contact.* He thus discovered and formulated the principles of *loose contact* upon which the operation of all modern transmitters rests. Hughes' device was named by him a "microphone," indicating a magnification of sound or an ability to respond to and make audible minute sounds. It is shown in Fig. 8. Firmly attached to a board are two carbon blocks, shown in section in the figure. A rod of carbon with cone-shaped ends is supported loosely between the two blocks, conical depressions in the blocks receiving the ends of the rod. A battery and magneto receiver are connected in series with the device. Under certain conditions of contact, the arrangement is extraordinarily sensitive to small sounds and approaches an ability indicated by its name. Its practical usefulness has been not as a serviceable speech transmitter, but as a stimulus to the devising of transmitters using carbon in other ways. Variation of the resistance of metal conductors and of contact between metals has served to transmit voice currents, but no material approaches carbon in this property.

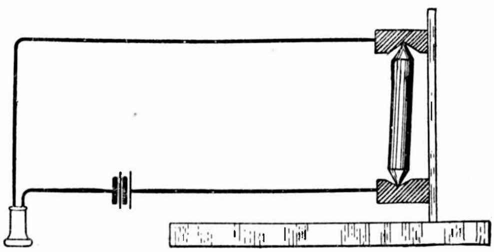


Fig. 8. Hughes' Microphone

Carbon. *Adaptability.* The application of carbon to use in transmitters has taken many forms. They may be classified as those having a single contact and those having a plurality of contacts; in all cases, the *intimacy of contact* is varied by the diaphragm excursions. An example of the single-contact type is the Blake transmitter, long familiar in America. An example of the multiple-contact type is the loose-carbon type universal now. Other types popular at other times and in particular places use solid rods or blocks of carbon having many points of contact, though not in a powdered or granular form. Fig. 9 shows an example of each of the general forms of transmitters.

The use of granular carbon as a transmitter material has extended greatly the radius of speech, and has been a principal contributing cause for the great spread of the telephone industry.

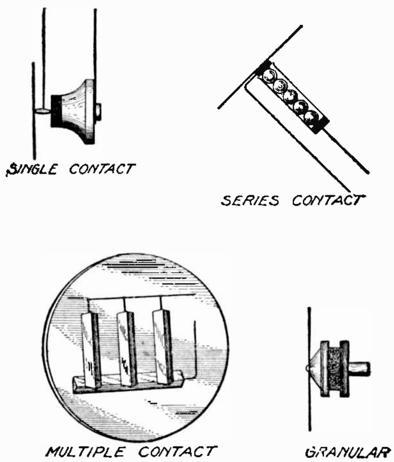


Fig. 9. General Types of Transmitters

Superiority. The superiority of carbon over other resistance-varying materials for transmitters is well recognized, but the reason for it is not well known. Various theories have been proposed to explain why, for example, the resistance of a mass of carbon granules varies with the vibrations or compressions to which they are subjected.

Four principal theories respectively allege:

First, that change in pressure actually changes the specific resistance of carbon.

Second, that upon the surface of carbon bodies exists some gas in some form of attachment or combination, variations of pressure causing variations of resistance merely by reducing the thickness of this intervening gas.

Third, that the change of resistance is caused by variations in the length of electrical arcs between the particles.

Fourth, that change of pressure changes the area of contact, as is true of solids generally.

One may take his choice. A solid carbon block or rod is not found to decrease its resistance by being subjected to pressure. The gas theory lacks experimental proof also. The existence of arcs between the granules never has been seen or otherwise observed under normal working conditions of a transmitter; when arcs surely are experimentally established between the granules the usefulness of the transmitter ceases. The final theory, that change of pressure changes area of surface contact, does not explain why other conductors than carbon are not good materials for transmitters. This, it may be noticed, is just what the theories set out to make clear.

There are many who feel that more experimental data is required before a conclusive and satisfactory theory can be set up. There is need of one, for a proper theory often points the way for effective advance in practice.

Carbon and magneto transmitters differ wholly in their methods of action. The magneto transmitter *produces* current; the carbon transmitter *controls* current. The former is an alternating-current generator; the latter is a rheostat. The magneto transmitter produces alternating current without input of any electricity at all; the carbon transmitter merely controls a direct current, supplied by an external source, and varies its amount without changing its direction.

The carbon transmitter, however, may be associated with other devices in a circuit in such a way as to *transform* direct currents into

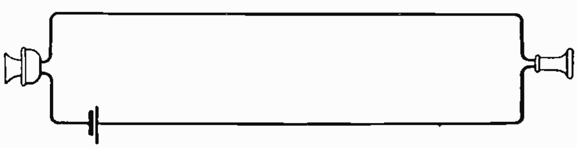


Fig. 10. Battery in Line Circuit

alternating ones, or it may be used merely to change constant direct currents into *undulating* ones, which *never* reverse direction, as alternating currents *always* do. These distinctions are important.

Limitations. A carbon transmitter being merely a resistance-varying device, its usefulness depends on how much its resistance can vary in response to motions of air molecules. A granular-carbon transmitter may vary between resistances of 5 to 50 ohms while transmitting a particular tone, having the lower resistance when its diaphragm is driven inward. Conceive this transmitter to be in a line as shown in Fig. 10, the line, distant receiver, and battery together having a resistance of 1,000 ohms. The minimum resistance then is 1,005 ohms and the maximum 1,050 ohms. The variation is limited to about 4.5 per cent. The greater the resistance of the line and other elements than the transmitter, the less relative change the transmitter can produce, and the less loudly the distant receiver can speak.

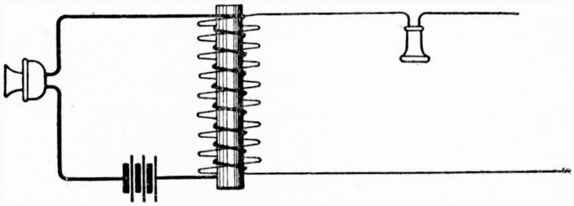
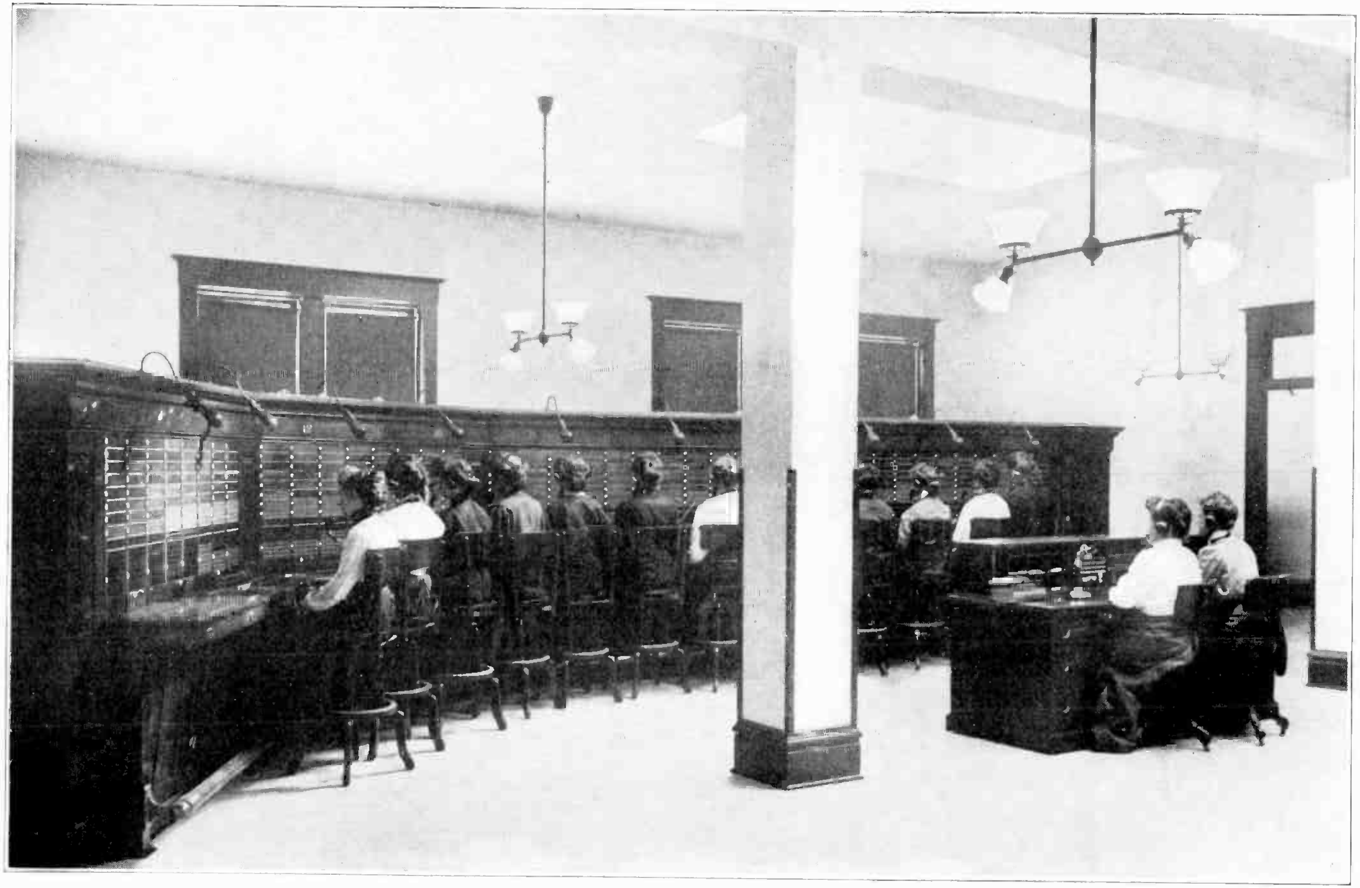


Fig. 11. Battery in Local Circuit

Induction Coil. Mr. Edison realized this limitation to the use of the carbon transmitter direct in the line, and contributed the means of removing it. His method is to introduce an induction coil between the line and the transmitter, its function being to translate the variation of the direct current controlled by the transmitter into true alternating currents.

An induction coil is merely a transformer, and for the use under discussion consists of two insulated wires wound around an iron core. Change in the current carried by one of the windings *produces* a current in the other. If direct current be flowing in one of the windings, and remains constant, no current whatever is produced in the other. It is important to note that it is change, and change only, which produces that alternating current.

Fig. 11 shows an induction coil related to a carbon transmitter, a battery, and a receiver. Fig. 12 shows exactly the same arrangement, using conventional signs. The winding of the induction coil which is in series with the transmitter and the battery is called the primary winding; the other is called the secondary winding. In the arrangement of Figs. 11 and 12 the battery has no metallic connection with the line, so that it is called a *local battery*. The circuit containing the battery, transmitter, and primary winding of the induction coil is called the *local circuit.*



A TYPICAL MEDIUM-SIZED MULTIPLE SWITCHBOARD EQUIPMENT

Let us observe what is the advantage of this arrangement over the case of Fig. 10. Using the same values of resistance in the transmitter and line, assume the local circuit apart from the transmitter to have a fixed resistance of 5 ohms. The limits of variations in the local circuit, therefore, are 10 and 55 ohms, thus making the maximum 5.5 times the minimum, or an increase of 450 per cent as against 4.5 per cent in the case of Fig. 10. The changes, therefore, àre 100 times as great.

The relation between the windings of the induction coil in this practice are such that the secondary winding contains many more turns than the primary winding. Changes in the circuit of the primary winding produce potentials in the secondary winding correspondingly higher than the potentials producing them. These secondary potentials depend upon the *ratio* of turns in the two windings and therefore, within close limits, may be chosen as wished. High potentials in the secondary winding are admirably adapted to transmit currents in a high-resistance line, for exactly the same reason that long-distance power transmission meets with but one-quarter of one kind of loss when the sending potential is doubled, one-hundredth of that loss when it is raised tenfold, and similarly. The induction

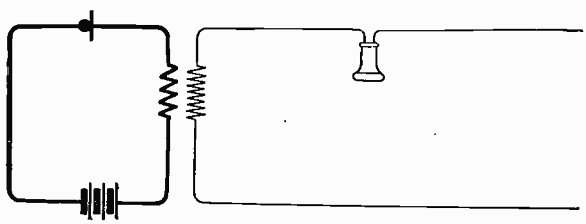


Fig. 12. Conventional Diagram of Talking Circuit

coil, therefore, serves the double purpose of a step-up transformer to limit line losses and a device for vastly increasing the range of change in the transmitter circuit.

Fig. 13 is offered to remind the student of the action of an induction coil or transformer in whose primary circuit a direct current is increased and decreased. An increase of current in the local winding produces an impulse of *opposite* direction in the turns of the secondary winding; a decrease of current in the local winding produces an impulse of *the same* direction in the turns of the secondary winding. The key of Fig. 13 being closed, current flows upward in the primary winding as drawn in the figure, inducing a downward impulse of current in the secondary winding and its circuit as noted at the right of the figure. On the key being opened, current ceases in the primary circuit, inducing an upward impulse of current in the secondary winding and circuit as shown. During other than instants of opening and closing (changing) the local circuit, no current whatever flows in the secondary circuit.

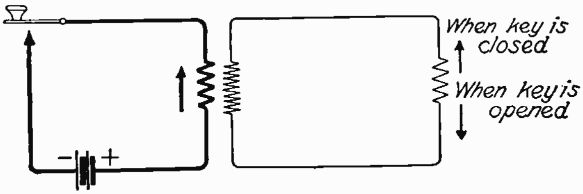


Fig. 13. Induction-Coil Action

It is by these means that telephone transmitters draw direct current from primary batteries and send high-potential alternating currents over lines; the same process produces what in Therapeutics are called "Faradic currents," and enables also a simple vibrating contact-maker to produce alternating currents for operating polarized ringers of telephone sets.

Detrimental Effects of Capacity. Electrostatic capacity plays an important part in the transmission of speech. Its presence between the wires of a line and between them and the earth causes one of the losses from which long-distance telephony suffers. Its presence in condensers assists in the solution of many circuit and apparatus problems.

A condenser is a device composed of two or more conductors insulated from each other by a medium called the *dielectric*. A pair of metal plates separated by glass, a pair of wires separated by air, or a pair of sheets of foil separated by paper or mica may constitute a condenser. The use of condensers as pieces of apparatus and the problems presented by electrostatic capacity in lines are discussed in other chapters.

Measurements of Telephone Currents. It has been recognized in all branches of engineering that a definite advance is possible only when quantitative data exists. The lack of reliable means of measuring telephone currents has been a principal cause of the difficulty in solving many of its problems. It is only in very recent times that accurate and reliable means have been worked out for measuring the small currents which flow in telephone lines. These ways are of two general kinds: by thermal and by electromagnetic means.

Thermal Method. The thermal methods simply measure, in some way, the amount of heat which is produced by a received telephone current. When this current is allowed to pass through a conductor the effect of the heat generated in that conductor is observed in one of three ways: by the expansion of the conductor, by its change in resistance, or by the production of an electromotive force in a thermo-electric couple heated by the conductor. Any one of these three ways can be used to get some idea of the amount of current which is received. None of them gives an accurate knowledge of the forms of the waves which cause the reproduction of speech in the telephone receiver.

Electromagnetic Method. An electromagnetic device adapted to tell something of the magnitude of the telephone current and also something of its form, *i. e.*, something of its various increases and decreases and also of its changes in direction is the oscillograph. An oscillograph is composed of a magnetic field formed by direct currents or by a permanent magnet, a turn of wire under mechanical tension in that field, and a mirror borne by the turn of wire, adapted to reflect a beam of light to a photographic film or to a rotating mirror.

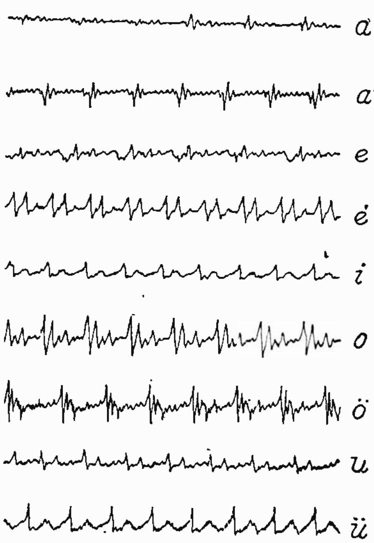


Fig. 14. Oscillogram of Telephone Currents

When a current is to be measured by the oscillograph, it is passed through the turn of wire in the magnetic field. While no current is passing, the wire does not move in the magnetic field and its mirror reflects a stationary beam of light. A photographic film moved in a direction normal to the axis of the turn of wire will have drawn upon it a straight line by the beam of light. If the beam of light, however, is moved by a current, from side to side at right angles to this axis, it will draw a wavy line on the photographic film and this wavy line will picture the alternations of that current and the oscillations of the molecules of air which carried the originating sound. Fig. 14 is a photograph of nine different vowel sounds which have caused the oscillograph to take their pictures. They are copies of records made by Mr. Bela Gati, assisted by Mr. Tolnai. The measuring instrument consisted of an oscillograph of the type described, the transmitter being of the carbon type actuated by a 2-volt battery. The primary current was transformed by an induction coil of the ordinary type and the transformed current was sent through a non-inductive resistance of 3,000 ohms. No condensers were placed in the circuit. It will be seen that the integral values of the curves, starting from zero, are variable. The positive and the negative portions of the curves are not equal, so that the solution of the individual harmonic motion is difficult and laborious.

These photographs point out several facts very clearly. One is that the alternations of currents in the telephone line, like the motions of the molecules of air of the original sound, are highly complex and are not, as musical tones are, regular recurrences of equal vibrations. They show also that any vowel sound may be considered to be a regular recurrence of certain groups of vibrations of different amplitudes and of different frequencies.

CHAPTER III

ELECTRICAL SIGNALS

Electric calls or signals are of two kinds: audible and visible.

Audible Signals. *Telegraph Sounder.* The earliest electric signal was an audible one, being the telegraph sounder, or the Morse register considered apart from its registering function. Each tele-

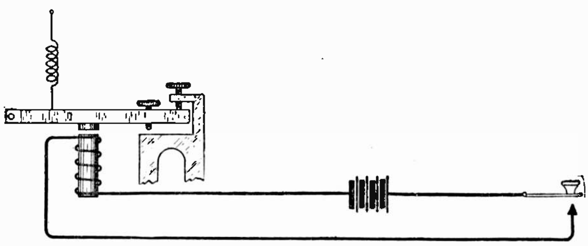


Fig. 15. Telegraph Sounder and Key

graph sounder serves as an audible electric signal and is capable of signifying more than that the call is being made. Such a signal is operated by the making and breaking of current from a battery. An

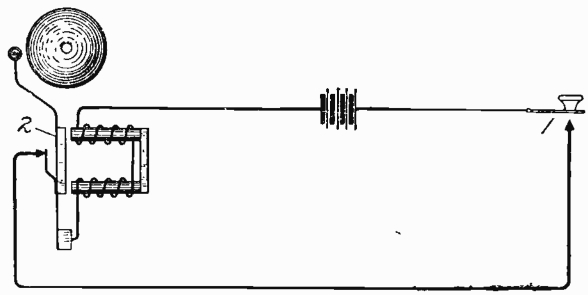


Fig. 16. Vibrating Bell

arrangement of this kind is shown in Fig. 15, in which pressure upon the key causes the current from the battery to energize the sounder and give one sharp audible rap of the lever upon the striking post.

Vibrating Bell. The vibrating bell, so widely used as a door bell, is a device consequent to the telegraph. Its action is to give a series of blows on its gong when its key or push button closes the battery circuit. At the risk of describing a trite though not trivial thing, it may be said that when the contact *1* of Fig. 16 is closed, current from the battery energizes the armature *2*, causing the latter to strike a blow on the gong and to break the line circuit as well, by opening the contact back of the armature. So de-energized, the armature falls back and the cycle is repeated until the button contact is released. A comparison of this action with that of the polarized ringer (to be described later) will be found of interest.

Magneto-Bell. The magneto-bell came into wide use with the spread of telephone service. Its two fundamental parts are an alternating-current generator and a polarized bell-ringing device.

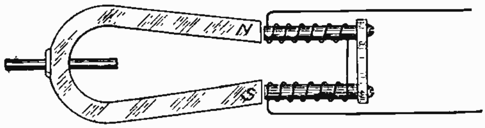


Fig. 17. Elemental Magneto-Generator

Each had its counterpart long before the invention of the telephone, though made familiar by the latter. The alternating-current generator of the magneto-bell consists of a rotatable armature composed of a coil of insulated wire and usually a core of soft iron, its rotation taking place in a magnetic field. This field is usually provided by a permanent magnet, hence the name "magneto-generator." The purist in terms may well say, however, that every form whatever of the dynamo-electric generator is a magneto-generator, as magnetism is one link in every such conversion of mechanical power into electricity. The terms magneto-electric, magneto-generator, etc., involving the term "magneto," have come to imply the presence of *permanently* magnetized steel as an element of the construction.

In its early form, the magneto-generator consisted of the arrangement shown in Fig. 17, wherein a permanent magnet can rotate on an axis before an electromagnet having soft iron cores and a winding. Reversals of magnetism produce current in alternately reversing half-cycles; one complete rotation of the magnet producing one such cycle. Obviously the result would be the same if the magnet were stationary and the coils should rotate, which is the construction of more modern devices. The turning of the crank of a magneto-bell rotates the armature in the magnetic field by some form of gearing at a rate usually of the order of twenty turns per second, producing an alternating current of that frequency. This current is caused by an effective electromotive force which may be as great as 100 volts, produced immediately by the energy of the user. In an equipment using a magneto-telephone as both receiver and transmitter and a magneto-bell as its signal-sending machine, as was usual in 1877, it is interesting to note that the entire motive power for signals and speech transmission was supplied by the muscular tissues of the user—a case of working one's passage.

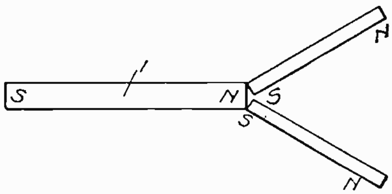


Fig. 18. Extension of a Permanent Magnet

The alternating current from the generator is received and converted into sound by means of the *polarized ringer*, a device which is interesting as depending upon several of the electrical, mechanical, and magnetic actions which are the foundations of telephone engineering.

"Why the ringer rings" may be gathered from a study of Figs. 18 to 21. A permanent magnet will impart temporary magnetism to pieces of iron near it. In Fig. 18 two pieces of iron are so energized. The ends of these pieces which are nearest to the permanent magnet *1* are of the opposite polarity to the end they approach, the free ends being of opposite polarity. In the figure, these free ends are marked *N*, meaning they are of a polarity to point north if free to point at all. English-speaking persons call this *north polarity*. Similarly, as in Fig. 19, any arrangement of iron near a permanent magnet always will have free poles of the same polarity as the end of the permanent magnet nearest them.

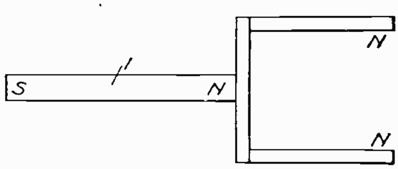


Fig. 19. Extension of a Permanent Magnet

A permanent magnet so related to iron forms part of a polarized ringer. So does an electromagnet composed of windings and iron cores. Fig. 20 reminds us of the law of electromagnets. If current flows from the plus towards the minus side, with the windings as drawn, polarities will be induced as marked.

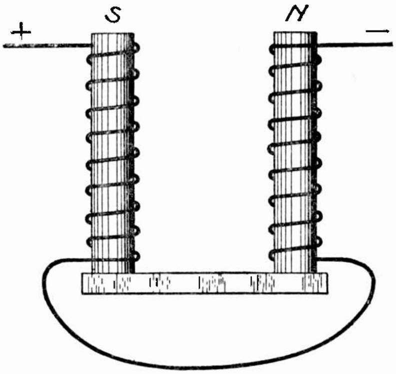


Fig. 20. Electromagnet

If, now, such an electromagnet, a permanent magnet, and a pivoted armature be related to a pair of gongs, as shown in Fig. 21, a polarized ringer results. It should be noted that a permanent magnet has both its poles presented (though one of the poles is not actually attached) to two parts of the iron of the *electro-magnet*. The result is that the ends of the armature are of south polarity and those of the core are of north polarity. All the markings of Fig. 21 relate to the polarity produced by the permanent magnet. If, now, a current flow in the ringer winding from plus to minus, obviously the right-hand pole will be additively magnetized, the current tending to produce north magnetism there; also the left-hand pole will be subtractively magnetized, the current tending to produce south magnetism there. If the current be of a certain strength, relative to the certain ringer under study, magnetism in the left pole will be neutralized and that in the right pole doubled. Hence the armature will be attracted more by the right pole than by the left and will strike the right-hand gong. A reversal of current produces an opposite action, the left-hand gong being struck. The current ceasing, the armature remains where last thrown.

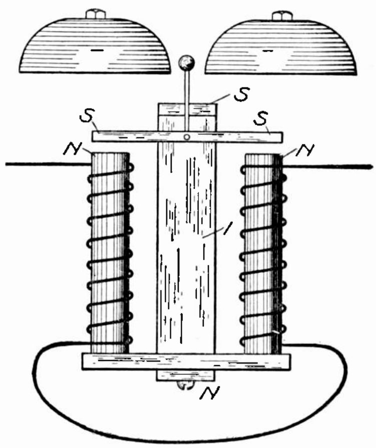


Fig. 21. Polarized Ringer

It is important to note that the strength of action depends upon the strength of the current up to a certain point only. That depends upon the strength of the permanent magnet. Whenever the current is great enough just to neutralize the normal magnetism of one pole and to double that of the other, no increase in current will cause the device to ring any louder. This makes obvious the importance of a proper permanent magnetism and displays the fallacy of some effort to increase the output of various devices depending upon these principles. This discussion of magneto-electric signaling is introduced here because of a belief in its being fundamental. Chapter VII treats of such a signaling in further detail.

Telephone Receiver. The telephone receiver itself serves a useful purpose as an audible signal. An interrupted or alternating current of proper frequency and amount will produce in it a musical tone which can be heard throughout a large room. This fact enables a telephone central office to signal a subscriber who has left his receiver off the switch hook, so that normal conditions may be restored.

Visible Signals. *Electromagnetic Signal.* Practical visual signals are of two general kinds: electromagnetic devices for moving a target or pointer, and incandescent lamps. The earliest and most widely used visible signal in telephone practice was the annunciator, having a shutter adapted to fall when the magnet is energized. Fig. 22 is such a signal. Shutter *1* is held by the catch *2* from dropping to the right by its own gravity. The name "gravity-drop" is thus obvious. Current energizing the core attracts the armature *3*, lifts the catch *2*, and the shutter falls. A simple modification of the gravity-drop produces the visible signal shown in Fig. 23. Energizing the core lifts a target so as to render it visible through an opening in the plate *1*. A contrast of color between the plate and the target heightens the effect.

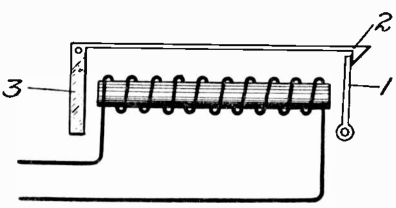


Fig. 22. Gravity-Drop

The gravity-drop is principally adapted to the magneto-bell system of signaling, where an alternating current is sent over the line to a central office by the operation of a bell crank at the subscriber's station, this current, lasting only as long as the crank is turned, energizes the drop, which may be restored by hand or otherwise and will remain latched. The visible signal is better adapted to lines in which the signaling is done by means of direct current, as, for example, in systems where the removal of the receiver from the hook at the subscriber's station closes the line circuit, causing current to flow through the winding of the visible signal and so displaying it until the receiver has been hung upon the hook or the circuit opened by some operation at the central office. Visible signals of the magnetic type of Fig. 23 have been widely used in connection with common-battery systems, both for line signals and for supervisory purposes, indicating the state and the progress of the connection and conversation.

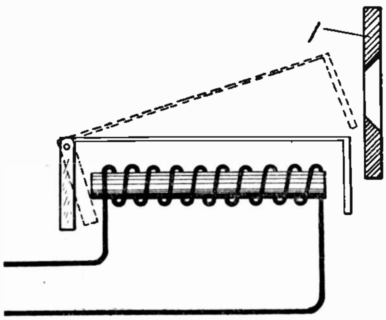


Fig. 23. Electromagnetic Visible Signal

Electric-Lamp Signal. Incandescent electric lamps appeared in telephony as a considerable element about 1890. They are better than either form of mechanical visible signals because of three principal qualities: simplicity and ease of restoring them to normal as compared with drops; their compactness; and their greater prominence when displayed. Of the latter quality, one may say that they are more *insistent,* as they give out light instead of reflecting it, as do all other visible signals. In its best form, the lamp signal is mounted behind a hemispherical lens, either slightly clouded or cut in facets. This lens serves to distribute the rays of light from the lamp, with the result that the signal may be seen from a wide angle with the axis of the lens, as shown in Fig. 24. This is of particular advantage in connection with manual-switchboard connecting cords, as it enables the signals to be mounted close to and even among the cords, their great visible prominence when shining saving them from being hidden.

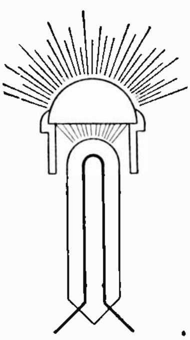


Fig. 24. Lamp Signal and Lens

The influence of the lamp signal was one of the potent ones in the development of the type of multiple switchboard which is now universal as the mechanism of large manual exchanges. The first large trial of such an equipment was in 1896 in Worcester, Mass. No large and successful multiple switchboard with any other type of signal has been built since that time.

Any electric signal has upper and lower limits of current between which it is to be actuated. It must receive current enough to operate but not enough to become damaged by overheating. The magnetic types of visible signals have a wider range between these limits than have lamp signals. If current in a lamp is too little, its filament either will not glow at all or merely at a dull red, insufficient for a proper signal. If the current is too great, the filament is heated beyond its strength and parts at the weakest place.

This range between current limits in magnetic visible signals is great enough to enable them to be used direct in telephone lines, the operating current through the line and signal in series with a fixed voltage at the central office being not harmfully great when the entire line resistance is shunted out at or near the central office. The increase of current may be as great as ten times without damage to the winding of such a signal. In lamps, the safe margin is much less. The current which just gives a sufficient lighting of the signal may be about doubled with safety to the filament of the lamp. Consequently it is not feasible to place the lamp directly in series with long exposed lines. A short circuit of such a line near the central office will burn it out.

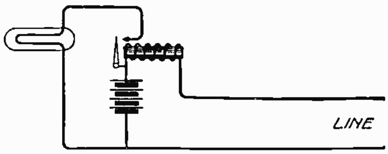


Fig. 25. Lamp Signal Controlled by Relay

The qualities of electromagnets and lamps in these respects are used to advantage by the lamp signal arrangement shown in Fig. 25. A relay is in series with the line and provides a large range of sensibility. It is able to carry any current the central-office current source can pass through it. The local circuit of the relay includes the lamp. Energizing the relay lights the lamp, and the reverse; the lamp is thus isolated from danger and receives the current best adapted to its needs.

All lines are not long and when enclosed in cable or in well-insulated interior wire, may be only remotely in danger of being short-circuited. Such conditions exist in private-branch exchanges, which are groups of telephones, usually local to limited premises, connected to a switchboard on those premises. Such a situation permits the omission of the line relay, the lamp being directly in the line. Fig. 26 shows the extreme simplicity of the arrangement, containing no moving parts or costly elements. Lamps for such service have improved greatly since the demand began to grow. The small bulk permitted by the need of compactness, the high filament resistance required for simplicity of the general power scheme of the system, and the need of considerable sturdiness in the completed thing have made the task a hard one. The practical result, however, is a signal lamp which is highly satisfactory.

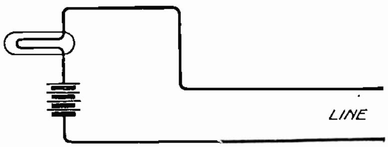


Fig. 26. Lamp Signal Directly in Line

The nature of carbon and certain earths being that their conductivity *rises* with the temperature and that of metals being that their conductivity *falls* with the temperature, has enabled the Nernst lamp to be successful. The same relation of properties has enabled incandescent-lamp signals to be connected direct to lines without relays, but compensated against too great a current by causing the resistance in series with the lamp to be increased inversely as the resistance of the filament. In Fig. 27 is shown its relation to a signal lamp directly in the line. *1* is the carbon-filament lamp; *2* is the ballast. The latter's conductor is fine iron wire in a vacuum. The resistance of the lamp falls as that of the ballast rises. Within certain limits, these changes balance each other, widening the range of allowable change in the total resistance of the line.

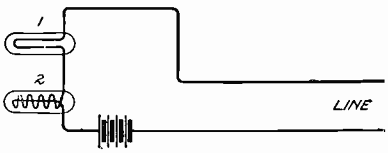


Fig. 27. Lamp Signal and Ballast

CHAPTER IV

TELEPHONE LINES

The line is a path over which the telephone current passes from telephone to telephone. The term "telephone line circuit" is equivalent. "Line" and "line circuit" mean slightly different things to some persons, "line" meaning the out-of-doors portion of the line and "line circuit" meaning the indoor portion, composed of apparatus and associated wiring. Such shades of meaning are inevitable and serve useful purposes. The opening definition hereof is accurate.

A telephone line consists of two conductors. One of these conductors may be the earth; the other always is some conducting material other than the earth—almost universally it is of metal and in the form of a wire. A line using one wire and the earth as its pair of conductors has several defects, to be discussed later herein. Both conductors of a line may be wires, the earth serving as no part of the circuit, and this is the best practice. A line composed of one wire and the earth is called a *grounded line;* a line composed of two wires not needing the earth as a conductor is called a *metallic circuit.*

In the earliest telephone practice, all lines were grounded ones. The wires were of iron, supported by poles and insulated from them by glass, earthenware, or rubber insulators. For certain uses, such lines still represent good practice. For telegraph service, they represent the present standard practice.

Copper is a better conductor than iron, does not rust, and when drawn into wire in such a way as to have a sufficient tensile strength to support itself is the best available conductor for telephone lines. Only one metal surpasses it in any quality for the purpose: silver is a better conductor by 1 or 2 per cent. Copper is better than silver in strength and price.

In the open country, telephone lines consist of bare wires of copper, of iron, of steel, or of copper-covered steel supported on insulators borne by poles. If the wires on the poles be many, cross-arms carry four to ten wires each and the insulators are mounted on pins in the cross-arms. If the wires on the poles be few, the insulators are mounted on brackets nailed to the poles. Wires so carried are called *open wires.*

In towns and cities where many wires are to be carried along the same route, the wires are reduced in size, insulated by a covering over each, and assembled into a group. Such a bundle of insulated wires is called a *cable.* It may be drawn into a duct in the earth and be called an *underground cable;* it may be laid on the bottom of the sea or other water and be called a *submarine cable;* or it may be suspended on poles and be called an *aërial cable.* In the most general practice each wire is insulated from all others by a wrapping of paper ribbon, which covering is only adequate when very dry. Cables formed of paper-insulated wires, therefore, are covered by a seamless, continuous lead sheath, no part of the paper insulation of the wires being exposed to the atmosphere during the cable's entire life in service. Telephone cables for certain uses are formed of wires insulated with such materials as soft rubber, gutta-percha, and cotton or jute saturated with mineral compounds. When insulated with rubber or gutta-percha, no continuous lead sheath is essential for insulation, as those materials, if continuous upon the wire, insulate even when the cable is immersed in water. Sheaths and other armors can assist in protecting these insulating materials from mechanical injury, and often are used for that purpose. The uses to which such cables are suitable in telephony are not many, as will be shown.

A wire supported on poles requires that it be large enough to support its own weight. The smaller the wire, the weaker it is, and with poles a given distance apart, the strength of the wire must be above a certain minimum. In regions where freezing occurs, wires in the open air can collect ice in winter and everywhere open wires are subject to wind pressure; for these reasons additional strength is required. Speaking generally, the practical and economical spacing of poles requires that wires, to be strong enough to meet the above conditions, shall have a diameter not less than .08 inch, if of hard-drawn copper, and .064 inch, if of iron or steel. The honor of developing ways of drawing copper wire with sufficient tensile strength for open-air uses belongs to Mr. Thomas B. Doolittle of Massachusetts.

Lines whose lengths are limited to a few miles do not require a conductivity as great as that of copper wire of .08-inch diameter. A wire of that size weighs approximately 100 pounds per mile. Less than 100 pounds of copper per mile of wire will not give strength enough for use on poles; but as little as 10 pounds per mile of wire gives the necessary conductivity for the lines of the thousands of telephone stations in towns and cities.

Open wires, being exposed to the elements, suffer damage from storms; their insulation is injured by contact with trees; they may make contact with electric power circuits, perhaps injuring apparatus, themselves, and persons; they endanger life and property by the possibility of falling; they and their cross-arm supports are less sightly than a more compact arrangement.

Grouping small wires of telephone lines into cables has, therefore, the advantage of allowing less copper to be used, of reducing the space required, of improving appearance, and of increasing safety. On the other hand, this same grouping introduces negative advantages as well as the foregoing positive ones. It is not possible to talk as far or as well over a line in an ordinary cable as over a line of two open wires. Long-distance telephone circuits, therefore, have not yet been placed in cables for lengths greater than 200 or 300 miles, and special treatment of cable circuits is required to talk through them for even 100 miles. One may talk 2,000 miles over open wires. The reasons for the superiority of the open wires have to do with position rather than material. Obviously it is possible to insulate and bury any wire which can be carried in the air. The differences in the properties of lines whose wires are differently situated with reference to each other and surrounding things are interesting and important.

A telephone line composed of two conductors always possesses four principal properties in some amount: (1) conductivity of the conductors; (2) electrostatic capacity between the conductors; (3) inductance of the circuit; (4) insulation of each conductor from other things.

Conductivity of Conductors. The conductivity of a wire depends upon its material, its cross-section, its length, and its temperature. Conductivity of a copper wire, for example, increases in direct ratio to its weight, in inverse ratio to its length, and its conductivity falls as the temperature rises. Resistance is the reciprocal of conductivity and the properties, conductivity and resistance, are more often expressed in terms of resistance. The unit of the latter is the *ohm;* of the former the *mho.* A conductor having a resistance of 100 ohms has a conductivity of .01 mho. The exact correlative terms are *resistance* and *conductance, resistivity* and *conductivity.* The use of the terms as in the foregoing is in accordance with colloquial practice.

Current in a circuit having resistance only, varies inversely as the resistance. Electromotive force being a cause, and resistance a state, current is the result. The formula of this relation, Ohm's law, is

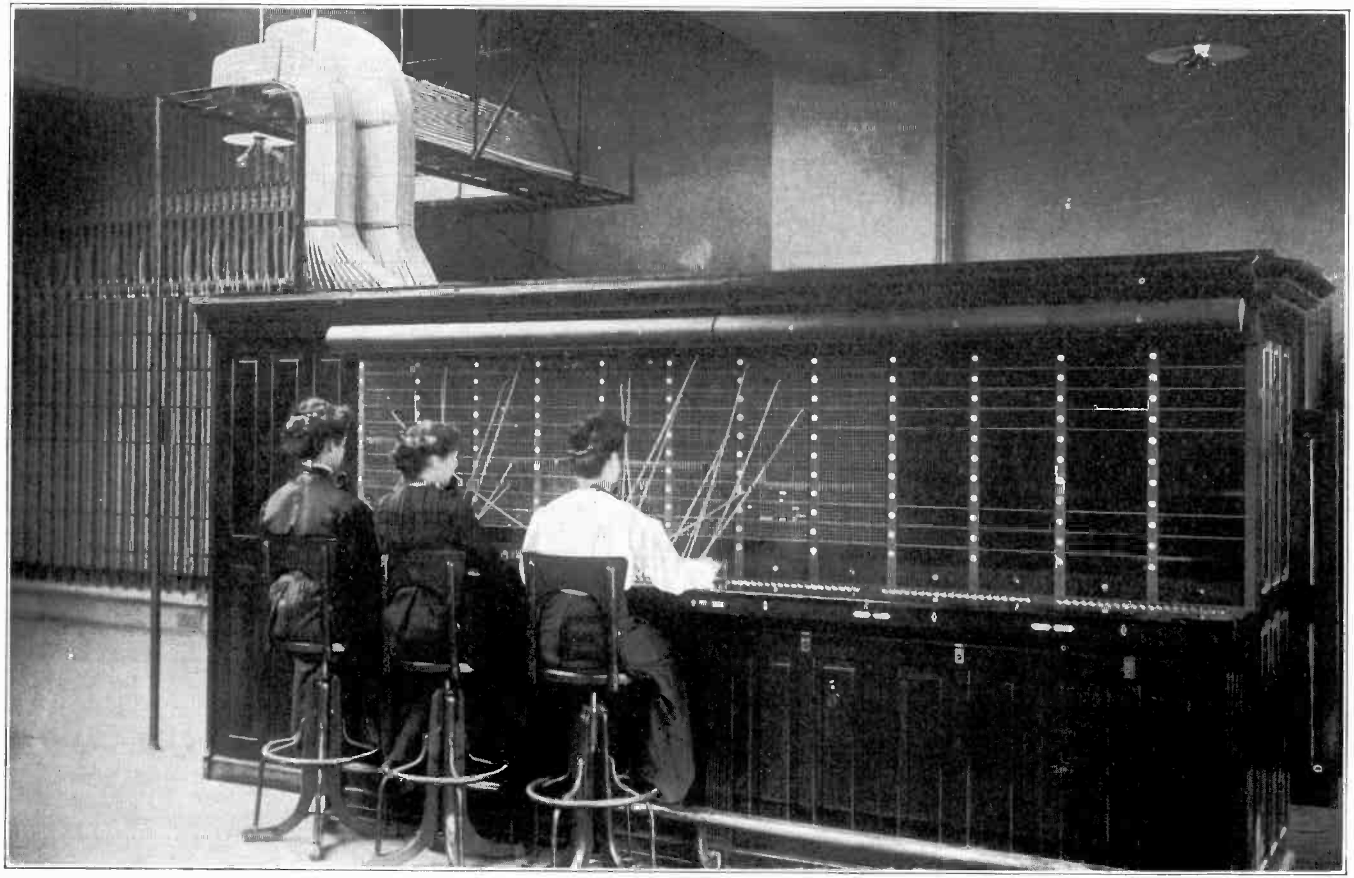
$$C = \frac{E}{R}$$

C being the current which results from E, the electromotive force, acting upon R, the resistance. The units are: of current, the ampere; of electromotive force, the volt; of resistance, the ohm.

As the conductivity or resistance of a line is the property of controlling importance in telegraphy, a similar relation was expected in early telephony. As the current in the telephone line varies rapidly, certain other properties of the line assume an importance they do not have in telegraphy in any such degree.

The importance that these properties assume is, that if they did not act and the resistance of the conductors alone limited speech, transmission would be possible direct from Europe to America over a pair of wires weighing 200 pounds per mile of wire, which is less than half the weight of the wire of the best long-distance land lines now in service. The distance from Europe to America is about twice as great as the present commercial radius by land lines of 435-pound wire. In other words, good speech is possible through a mere resistance twenty times greater than the resistance of the longest actual open-wire line it is possible to talk through. The talking ratio between a mere resistance and the resistance of a regular telephone cable is still greater.

Electrostatic Capacity. It is the possession of electrostatic capacity which enables the condenser, of which the Leyden jar is a good example, to be useful in a telephone line. The simplest form of a condenser is illustrated in Fig. 28, in which two conducting surfaces



A MULTIPLE MANUAL SWITCHING BOARD FOR TOLL CONNECTIONS IN AN AUTOMATIC SYSTEM
Multiple Jacks are Provided for Each Line through Which Toll Connections are Handled Directly.

are separated by an insulating material. The larger the surfaces, the closer they are together; and the higher the specific inductive capacity of the insulator, the greater the capacity of the device. An insulator used in this relation to two conducting surfaces is called the *dielectric*.

Two conventional signs are used to illustrate condensers, the upper one of Fig. 29 growing out of the original condenser of two

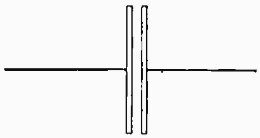


Fig. 28. Simple Condenser

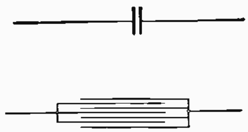


Fig. 29. Condenser Symbols

metal plates, the lower one suggesting the thought of interleaved conductors of tin foil, as for many years was the practice in condenser construction.

With relation to this property, a telephone line is just as truly a condenser as is any other arrangement of conductors and insulators. Assume such a line to be open at the distant end and its wires to be well insulated from each other and the earth. Telegraphy through such a line by ordinary means would be impossible. All that the battery or other source could do would be to cause current to flow into the line for an infinitesimal time, raising the wires to its potential, after which no current would flow. But, by virtue of electrostatic capacity, the condition is much as shown in Fig. 30. The

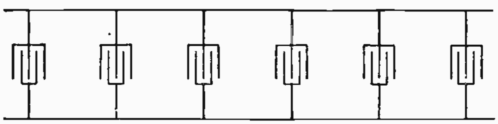


Fig. 30. Line with Shunt Capacity

condensers which that figure shows bridged across the line from wire to wire are intended merely to fix in the mind that there is a path for the transfer of electrical energy from wire to wire.

A simple test will enable two of the results of a short-circuiting capacity to be appreciated. Conceive a very short line of two wires to connect two local battery telephones. Such a line possesses negligible resistance, inductance, and shunt capacity. Its insulation is practically infinite. Let condensers be bridged across the line, one by one, while conversation goes on. The listening observer will notice that the sounds reaching his ear steadily grow less loud as the capacity across the line increases. The speaking observer will notice that the sounds he hears through the receiver in series with the line steadily grow louder as the capacity across the line increases. Fig. 31 illustrates the test.

The speaker's observation in this test shows that increasing the capacity across the line increased the amount of current entering it. The hearer's observation in this test shows that increasing the capacity across the line decreased the amount of energy turned into sound at his receiver.

The unit of electrostatic capacity is the *farad.* As this unit is inconveniently large, for practical applications the unit *microfarad*—a millionth of a farad—is employed. If quantities are known in

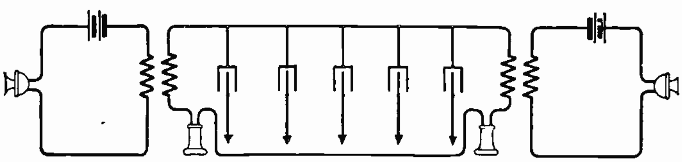


Fig. 31. Test of Line with Varying Shunt Capacity

microfarads and are to be used in calculations in which the values of the capacity require to be farads, care should be taken to introduce the proper corrective factor.

The electrostatic capacity between the conductors of a telephone line depends upon their surface area, their length, their position, and the nature of the materials separating them from each other and from other things. For instance, in an open wire line of two wires, the electrostatic capacity depends upon the diameter of the wires, upon the length of the line, upon their distance apart, upon their distance above the earth, and upon the specific inductive capacity of the air. Air being so common an insulating medium, it is taken as a convenient material whose specific inductive capacity may be used as a basis of reference. Therefore, the specific inductive capacity of air is taken as unity. All solid matter has higher specific inductive capacity than air.

The electrostatic capacity of two open wires .165 inch diameter, 1 ft. apart, and 30 ft. above the earth, is of the order of .009 microfarads per mile. This quantity would be higher if the wires were closer together; or nearer the earth; or if they were surrounded by a gas other than the air or hydrogen; or if the wires were insulated not by a gas but by any solid covering. As another example, a line composed of two wires of a diameter of .036 inch, if wrapped with paper and twisted into a pair as a part of a telephone-cable, has a mutual electrostatic capacity of approximately .08 microfarads per mile, this quantity being greater if the cable be more tightly compressed.

The use of paper as an insulator for wires in telephone cables is due to its low specific inductive capacity. This is because the insulation of the wires is so largely dry air. Rubber and similar insulating materials give capacities as great as twice that of dry paper.

The condenser or other capacity acts as an effective barrier to the steady flow of direct currents. Applying a fixed potential causes a mere rush of current to charge its surface to a definite degree, dependent upon the particular conditions. The condenser does not act as such a barrier to alternating currents, for it is possible to talk through a condenser by means of the alternating voice currents of telephony, or to pass through it alternating currents of much lower frequency. A condenser is used in series with a polarized ringer for the purpose of letting through alternating current for ringing the bell, and of preventing the flow of direct current.

The degree to which the condenser allows alternating currents to pass while stopping direct currents, depends on the capacity of the condenser and on the frequencies of alternating current. The larger the condenser capacity or the higher the frequency of the alternations, the greater will be the current passing through the circuit. The degree to which the current is opposed by the capacity is the reactance of that capacity for that frequency. The formula is

$$\text{Capacity reactance} = \frac{1}{C\omega}$$

wherein C is the capacity in farads and ω is $2\pi n$, or twice 3.1416 times the frequency.

All the foregoing leads to the generalization that the higher the frequency, the less the opposition of a capacity to an alternating current. If the frequency be zero, the reactance is infinite, *i. e.*, the circuit is open to direct current. If the frequency be infinite, the reactance is zero, *i. e.*, the circuit is as if the condenser were replaced by a solid conductor of no resistance. Compare this statement with the correlative generalization which follows the next thought upon inductance.

Inductance of the Circuit. Inductance is the property of a circuit by which change of current in it tends to produce in itself and other conductors an electromotive force other than that which causes

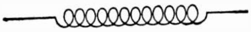


Fig. 32. Spiral of Wire

Fig. 33. Spiral of Wire Around Iron Core

the current. Its unit is the *henry*. The inductance of a circuit is one henry when a change of one ampere per second produces an electromotive force of one volt. Induction *between* circuits occurs because the circuits possess inductance; it is called *mutual induction*. Induction *within* a circuit occurs because the circuit possesses inductance; it is called *self-induction*. Lenz' law says: *In all cases of electromagnetic induction, the induced currents have such a direction that their reaction tends to stop the motion which produced them.*

All conductors possess inductance, but straight wires used in lines have negligible inductance in most actual cases. All wires which are wound into coils, such as electromagnets, possess inductance in a greatly increased degree. A wire wound into a spiral, as indicated in Fig. 32, possesses much greater inductance than when drawn out straight. If iron be inserted into the spiral, as shown in Fig. 33, the inductance is still further increased. It is for the purpose of eliminating inductance that resistance coils are wound with double wires, so that current passing through such coils turns in one direction half the way and in the other direction the other half.

A simple test will enable the results of a series inductance in a line to be appreciated. Conceive a very short line of two wires to connect two local battery telephones. Such a line possesses negligible resistance, inductance, and shunt capacity. Its insulation is practically infinite. Let inductive coils such as electromagnets be inserted serially in the wires of the line one by one, while conversation goes on.

The listening observer will notice that the sounds reaching his ear steadily grow faint as the inductance in the line increases and the speaking observer will notice the same thing through the receiver in series with the line.

Both observations in this test show that the amount of current entering and emerging from the line decreased as the inductance increased. Compare this with the test with bridged capacity and the loading of lines described later herein, observing the curious beneficial result when both hurtful properties are present in a line. The test is illustrated in Fig. 34.

The degree in which any current is opposed by inductance is termed the reactance of that inductance. Its formula is

$$\text{Inductive reactance} = L\omega$$

wherein L is the inductance in henrys and ω is $2\pi n$, or twice 3.1416 times the frequency. To distinguish the two kinds of reactance, that due to the capacity is called *capacity reactance* and that due to inductance is called *inductive reactance.*

All the foregoing leads to the generalization that the higher the frequency, the greater the opposition of an inductance to an alternating current. If the frequency be zero, the reactance is zero, *i. e.*, the circuit conducts direct current as mere resistance. If the frequency be infinite, the reactance is infinite, *i. e.*, the circuit is "open" to the alternating current and that current cannot pass through it. Compare this with the correlative generalization following the preceding thought upon capacity.

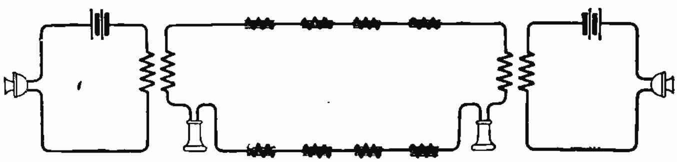


Fig. 34. Test of Line with Varying Serial Inductance

Capacity and inductance depend only on states of matter. Their reactances depend on states of matter and actions of energy.

In circuits having both resistance and capacity or resistance and inductance, both properties affect the passage of current. The joint reaction is expressed in ohms and is called *impedance.* Its value is the square root of the sum of the squares of the resistance and reactance, or, Z being impedance,

$$Z = \sqrt{R^2 + \frac{1}{C^2\omega^2}}$$

and

$$Z = \sqrt{R^2 + L^2\omega^2}$$

the symbols meaning as before.

In words, these formulas mean that, knowing the frequency of the current and the capacity of a condenser, or the frequency of the current and the inductance of a circuit (a line or piece of apparatus), and in either case the resistance of the circuit, one may learn the impedance by calculation.

Insulation of Conductors. The fourth property of telephone lines, insulation of the conductors, usually is expressed in ohms as an insulation resistance. In practice, this property needs to be intrinsically high, and usually is measured by millions of ohms resistance from the wire of a line to its mate or to the earth. It is a convenience to employ a large unit. A million ohms, therefore, is called a *megohm.* In telephone cables, an insulation resistance of 500 megohms per mile at 60° Fahrenheit is the usual specification. So high an insulation resistance in a paper-insulated conductor is only attained by applying the lead sheath to the cable when its core is made practically anhydrous and kept so during the splicing and terminating of the cable.

Insulation resistance varies inversely as the length of the conductor. If a piece of cable 528 feet long has an insulation resistance of 6,750 megohms, a mile (ten times as much) of such cable, will have an insulation resistance of 675 megohms, or one-tenth as great.

Inductance vs. Capacity. The mutual capacity of a telephone line is greater as its wires are closer together. The self-induction of a telephone line is smaller as its wires are closer together. The electromotive force induced by the capacity of a line leads the impressed electromotive force by 90 degrees. The inductive electromotive force lags 90 degrees behind the impressed electromotive force. And so, in general, the natures of these two properties are opposite. In a cable, the wires are so close together that their induction is negligible, while their capacity is so great as to limit commercial transmission through a cable having .06 microfarads per mile capacity and 94 ohms loop resistance per mile, to a distance of about 30 miles. In the case of open wires spaced 12 inches apart, the limit of commercial transmission is greater, not only because the wires are larger, but because the capacity is lower and the inductance higher.

Table I shows the practical limiting conversation distance over uniform lines with present standard telephone apparatus.

TABLE I

Limiting Transmission Distances

Size and Gauge of Wire	Limiting Distance
No. 8 B. W. G. copper	900 miles
10 B. W. G. copper	700 miles
10 B. & S. copper	400 miles
12 N. B. S. copper	400 miles
12 B. & S. copper	240 miles
14 N. B. S. copper	240 miles
8 B. W. G. iron	135 miles
10 B. W. G. iron	120 miles
12 B. W. G. iron	90 miles
16 B. & S. cable, copper	40 miles
19 B. & S. cable, copper	30 miles
22 B. & S. cable, copper	20 miles

In 1893, Oliver Heaviside proposed that the inductance of telephone lines be increased above the amount natural for the interaxial spacing, with a view to counteracting the hurtful effects of the capacity. His meaning was that the increased inductance—a harmful quality in a circuit not having also a harmfully great capacity—would act oppositely to the capacity, and if properly chosen and applied, should decrease or eliminate distortion by making the line's effect on fundamentals and harmonics more nearly uniform, and as well should reduce the attenuation by neutralizing the action of the capacity in dissipating energy.

There are two ways in which inductance might be introduced into a telephone line. As the capacity whose effects are to be neutralized is distributed uniformly throughout the line, the counteracting inductance must also be distributed throughout the line. Mere increase of distance between two wires of the line very happily acts both to increase the inductance and to lower the capacity; unhappily for practical results, the increase of separation to bring the qualities into useful neutralizing relation is beyond practical limits. The wires would need to be so far above the earth and so far apart as to make the arrangement commercially impossible.

Practical results have been secured in increasing the distributed inductance by wrapping fine iron wire over each conductor of the line. Such a treatment increases the inductance and improves transmission.

The most marked success has come as a result of the studies of Professor Michael Idvorsky Pupin. He inserts inductances in series with the wires of the line, so adapting them to the constants of the circuit that attenuation and distortion are diminished in a gratifying degree. This method of counteracting the effects of a distributed capacity by the insertion of localized inductance requires not only that the requisite total amount of inductance be known, but that the proper subdivision and spacing of the local portions of that inductance be known. Professor Pupin's method is described in a paper entitled "Wave Transmission Over Non-uniform Cables and Long-Distance Air Lines," read by him at a meeting of the American Institute of Electrical Engineers in Philadelphia, May 19, 1900.

NOTE. United States Letters Patent were issued to Professor Pupin on June 19, 1900, upon his practical method of reducing attenuation of electrical waves. A paper upon "Propagation of Long Electric Waves" was read by Professor Pupin before the American Institute of Electrical Engineers on March 22, 1899, and appears in Vol. 15 of the Transactions of that society. The student will find these documents useful in his studies on the subject. He is referred also to "Electrical Papers" and "Electromagnetic Theory" of Oliver Heaviside.

Professor Pupin likens the transmission of electric waves over long-distance circuits to the transmission of mechanical waves over a string. Conceive an ordinary light string to be fixed at one end and shaken by the hand at the other; waves will pass over the string from the shaken to the fixed end. Certain reflections will occur from the fixed end. The amount of energy which can be sent in this case from the shaken to the fixed point is small, but if the string be loaded by attaching bullets to it, uniformly throughout its length, it now may transmit much more energy to the fixed end.

The addition of inductance to a telephone line is analogous to the addition of bullets to the string, so that a telephone line is said to be *loaded* when inductances are inserted in it, and the inductances themselves are known as *loading coils.*

Fig. 35 shows the general relation of Pupin loading coils to the capacity of the line. The condensers of the figure are merely conventionals to represent the condenser which the line itself forms. The inductances of the figure are the actual loading coils.

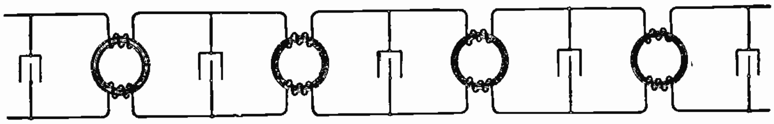


Fig. 35. Loaded Line

The loading of open wires is not as successful in practice as is that of cables. The fundamental reason lies in the fact that two of the properties of open wires—insulation and capacity—vary with atmospheric change. The inserted inductance remaining constant, its benefits may become detriments when the other two "constants" change.

The loading of cable circuits is not subject to these defects. Such loading improves transmission; saves copper; permits the use of longer underground cables than are usable when not loaded; lowers maintenance costs by placing interurban cables underground; and permits submarine telephone cables to join places not otherwise able to speak with each other.

Underground long-distance lines now join or are joining Boston and New York, Philadelphia and New York, Milwaukee and Chicago. England and France are connected by a loaded submarine cable. There is no theoretical reason why Europe and America should not speak to each other.

The student wishing to determine for himself what are the effects of the properties of lines upon open or cable circuits will find most of the subject in the following equation. It tells the value of a in terms of the four properties, a being the attenuation constant of the line.

That is, the larger a is, the more the voice current is reduced in passing over the line. The equation is

$$a=\sqrt{\tfrac{1}{2}\sqrt{(R^2+L^2\omega^2)(S^2+C^2\omega^2)}+\tfrac{1}{2}(RS-LC\omega^2)}$$

The quantities are

R = Resistance in ohms

L = Inductance in henrys

C = Mutual (shunt) capacity in farads

ω = $2\pi n$ = 6.2832 times the frequency

S = Shunt leakage in mhos

The quantity S is a measure of the combined direct-current conductance (reciprocal of insulation resistance) and the apparent conductance due to dielectric hysteresis.

NOTE. An excellent paper, assisting such study, and of immediate practical value as helping the understanding of cables and their reasons, is that of Mr. Frank B. Jewett, presented at the Thousand Islands Convention of the American Institute of Electrical Engineers, July 1, 1909.

Today, cables represent a most important factor in telephone wire-plant development, and the applications of this form of construction are becoming wider and more valuable.

Possible Ways of Improving Transmission. Practical ways of improving telephone transmission are of two kinds: to improve the lines and to improve the apparatus. The foregoing shows what are the qualities of lines and the ways they require to be treated. Apparatus treatment, in the present state of the art, is addressed largely to the reduction of losses. Theoretical considerations seem to show, however, that great advance in apparatus effectiveness still is possible. More powerful transmitters—and more *faithful* ones—more sensitive and accurate receivers, and more efficient translating devices surely are possible. Discovery may need to intervene, to enable invention to restimulate.

In both telegraphy and telephony, the longer the line the weaker the current which is received at the distant end. In both telegraphy and telephony, there is a length of line with a given kind and size of wire and method of construction over which it is just possible to send intelligible speech or intelligible signals. A repeater, in telegraphy, is a device in the form of a relay which is adapted to receive these highly attenuated signal impulses and to re-transmit them with fresh power over a new length of line. An arrangement of two such relays makes it possible to telegraph both ways over a pair of lines united by such a repeater. It is practically possible to join up several such links of lines to repeating devices and, if need be, even submarine cables can be joined to land lines within practical limits. If it were necessary, it probably would be possible to telegraph around the world in this way.

If it were possible to imitate the telegraph repeater in telephony, attenuated voice currents might be caused to actuate it so as to send on those voice currents with renewed power over a length of line, section by section. Such a device has been sought for many years, and it once was quoted in the public press that a reward of one million dollars had been offered by Charles J. Glidden for a successful device of that kind. The records of the patent offices of the world show what effort has been made in that direction and many more devices have been invented than have been patented in all the countries together.

Like some other problems in telephony, this one seems simpler at first sight than it proves to be after more exhaustive study. It is possible for any amateur to produce at once a repeating device which will relay telephone circuits in one direction. It is required, however, that in practice the voice currents be relayed in both directions, and further, that the relay actually augment the energy which passes through it; that is, that it will send on a more powerful current than it receives. Most of the devices so far invented fail in one or the other of these particulars. Several ways have been shown of assembling repeating devices which will talk both ways, but not many assembling repeating devices have been shown that will talk both ways and augment in both directions.

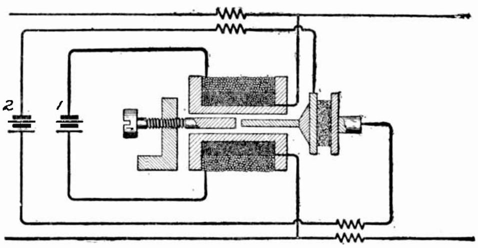


Fig. 36. Shreeve Repeater and Circuit

Practical repeaters have been produced, however, and at least one type is in daily successful use. It is not conclusively shown even of it that it augments in the same degree all of the voice waves which reach it, or even that it augments some of them at all. Its action, however, is distinctly an improvement in commercial practice. It is the invention of Mr. Herbert E. Shreeve and is shown in Fig. 39.

Primarily it consists of a telephone receiver, of a particular type devised by Gundlach, associated with a granular carbon transmitter button. It is further associated with an arrangement of induction coils or repeating coils, the object of these being to accomplish the two-way action, that is, of speaking in both directions and of preventing reactive interference between the receiving and transmitting elements. The battery *1* energizes the field of the receiving element; the received line current varies that field; the resulting motion varies the resistance of the carbon button and transforms current from battery *2* into a new alternating line current.

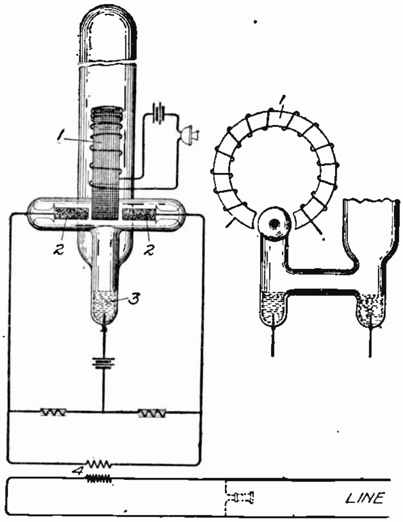


Fig. 37. Mercury-Arc Telephone Relay

By reactive interference is meant action whereby the transmitter element, in emitting a wave, affects its own controlling receiver element, thus setting up an action similar to that which occurs when the receiver of a telephone is held close to its transmitter and humming or singing ensues. No repeater is successful unless it is free from this reactive interference.

Enough has been accomplished by practical tests of the Shreeve device and others like it to show that the search for a method of relaying telephone voice currents is not looking for a pot of gold at the end of the rainbow. The most remarkable truth established by the success of repeaters of the Shreeve type is that a device embodying so large inertia of moving parts can succeed at all. If this means anything, it is that a device in which inertia is absolutely eliminated might do very much better. Many of the methods already proposed by inventors attack the problem in this way and one of the most recent and most promising ways is that of Mr. J. B. Taylor, the circuit of whose telephone-relay patent is shown in Fig. 37. In it, *1* is an electromagnet energized by voice currents; its varying field varies an arc between the electrodes *2-2* and *3* in a vacuum tube. These fluctuations are transformed into line currents by the coil *4*.

CHAPTER V

TRANSMITTERS

Variable Resistance. As already pointed out in Chapter II, the variable-resistance method of producing current waves, corresponding to sound waves for telephonic transmission, is the one that lends itself most readily to practical purposes. Practically all telephone transmitters of today employ this variable-resistance principle. The reason for the adoption of this method instead of the other possible ones is that the devices acting on this principle are capable, with great simplicity of construction, of producing much more powerful results than the others. Their simplicity is such as to make them capable of being manufactured at low cost and of being used successfully by unskilled persons.

Materials. Of all the materials available for the variable-resistance element in telephone transmitters, carbon is by far the most suitable, and its use is well nigh universal. Sometimes one of the rarer metals, such as platinum or gold, is to be found in commercial transmitters as part of the resistance-varying device, but, even when this is so, it is always used in combination with carbon in some form or other. Most of the transmitters in use, however, depend solely upon carbon as the conductive material of the variable-resistance element.

Arrangement of Electrodes. Following the principles pointed out by Hughes, the transmitters of today always employ as their variable-resistance elements one or more loose contacts between one or more pairs of electrodes, which electrodes, as just stated, are usually of carbon. Always the arrangement is such that the sound waves will vary the intimacy of contact between the electrodes and, therefore, the resistance of the path through the electrodes.

A multitude of arrangements have been proposed and tried. Sometimes a single pair of electrodes has been employed having a single point of loose contact between them. These may be termed single-contact transmitters. Sometimes the variable-resistance element has included a greater number of electrodes arranged in multiple, or in series, or in series-multiple, and these have been termed multiple-electrode transmitters, signifying a plurality of electrodes. A later development, an outgrowth of the multiple-electrode transmitter, makes use of a pair of principal electrodes, between which is included a mass of finely divided carbon in the form of granules or small spheres or pellets. These, regardless of the exact form of the carbon particles, are called granular-carbon transmitters.

Single Electrode. *Blake.* The most notable example of the single-contact transmitter is the once familiar Blake instrument. At

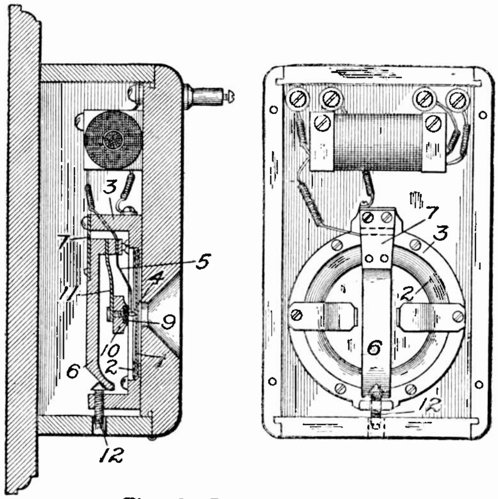


Fig. 38. Blake Transmitter

one time this formed a part of the standard equipment of almost every telephone in the United States, and it was also largely used abroad. Probably no transmitter has ever exceeded it in clearness of articulation, but it was decidedly deficient in power in comparison with the modern transmitters. In this instrument, which is shown in Fig. 38, the variable-resistance contact was that between a carbon and a platinum electrode. The diaphragm *1* was of sheet iron mounted, as usual in later transmitters, in a soft rubber gasket *2*. The whole diaphragm was mounted in a cast-iron ring *3*, supported on the inside of the box containing the entire instrument. The front electrode *4* was mounted on a light spring *5*, the upper end of which was supported by a movable bar or lever *6*, flexibly supported on a spring *7* secured to the casting which supported the diaphragm. The tension of this spring *5* was such as to cause the platinum point to press lightly away from the center of the diaphragm. The rear electrode was of carbon in the form of a small block *9*, secured in a heavy brass button *10*. The entire rear electrode structure was supported on a heavier spring *11* carried on the same lever as the spring *5*. The tension of this latter spring was such as to press against the front electrode and, by its greater strength, press this against the center of the diaphragm. The adjustment of the instrument was secured by means of the screw *12*, carried in a lug extending rearwardly from the diaphragm supporting casting, this screw, by its position, determining the strength with which the rear electrode pressed against the front electrode and that against the diaphragm. This instrument was ordinarily mounted in a wooden box together with the induction coil, which is shown in the upper portion of the figure.

The Blake transmitter has passed almost entirely out of use in this country, being superseded by the various forms of granular instruments, which, while much more powerful, are not perhaps capable of producing quite such clear and distinct articulation.

The great trouble with the single-contact transmitters, such as the Blake, was that it was impossible to pass enough current through the single point of contact to secure the desired power of transmission without overheating the contact. If too much current is sent through such transmitters, an undue amount of heat is generated at the point of contact and a vibration is set up which causes a peculiar humming or squealing sound which interferes with the transmission of other sounds.

Multiple Electrode. To remedy this difficulty the so-called multiple-electrode transmitter was brought out. This took a very great number of forms, of which the one shown in Fig. 39 is typical. The diaphragm shown at *1*, in this particular form, was made of thin pine wood. On the rear side of this, suspended from a rod *3* carried in a bracket *4*, were a number of carbon rods or pendants *5*, loosely resting against a rod *2*, carried on a bracket *6* also mounted on the rear of the diaphragm. The pivotal rod *3* and the rod *2*, against which the pendants rested, were sometimes, like the pendant rods, made of carbon and sometimes of metal, such as brass. When the diaphragm vibrated, the intimacy of contact between the pendant rod *5* and the rod *2* was altered, and thus the resistance of the path through all of the pendant rods in multiple was changed.

A multitude of forms of such transmitters came into use in the early eighties, and while they in some measure remedied the difficulty encountered with the Blake transmitter, *i. e.*, of not being able to carry a sufficiently large current, they were all subject to the effects of extreme sensitiveness, and would rattle or break when called upon to transmit sounds of more than ordinary loudness. Furthermore, the presence of such large masses of material, which it was necessary to throw into vibration by the sound waves, was distinctly against this form of transmitter. The inertia of the moving parts was so great that clearness of articulation was interfered with.

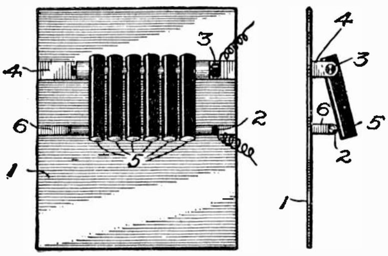


Fig. 39. Multiple-Electrode Transmitter

Granular Carbon. The idea of employing a mass of granular carbon, supported between two electrodes, one of which vibrated with the sound waves and the other was stationary, was proposed by Henry Hunnings in the early eighties. While this idea forms the basis of all modern telephone transmitters, yet it did not prevent the almost universal adoption of the single-contact form of instrument during the next decade.

Western Electric Solid-Back Transmitter. In the early nineties, however, the granular-carbon transmitter came into its own with the advent and wide adoption of the transmitter designed by Anthony C. White, known as the *White*, or *solid-back*, transmitter. This has for many years been the standard instrument of the Bell companies operating throughout the United States, and has found large use abroad. A horizontal cross-section of this instrument is shown in Fig. 40, and a rear view of the working parts in Fig. 41. The working parts are all mounted on the front casting *1*. This is supported in a cup *2*, in turn supported on the lug *3*, which is pivoted on the transmitter arm or other support. The front and rear electrodes of this instrument are formed of thin carbon disks shown in solid black.

THE OPERATING ROOM OF THE EXCHANGE AT WEBB CITY, MISSOURI

The rear electrode, the larger one of these disks, is securely attached by solder to the face of a brass disk having a rearwardly projecting screw-threaded shank, which serves to hold it and the rear electrode in place in the bottom of a heavy brass cup *4*. The front electrode is mounted on the rear face of a stud. Clamped against the head of this stud, by a screw-threaded clamping ring *7*, is a mica washer, or disk *6*. The center portion of this mica washer is therefore rigid with respect to the front electrode and partakes of its movements. The outer edge of this mica washer is similarly clamped against the

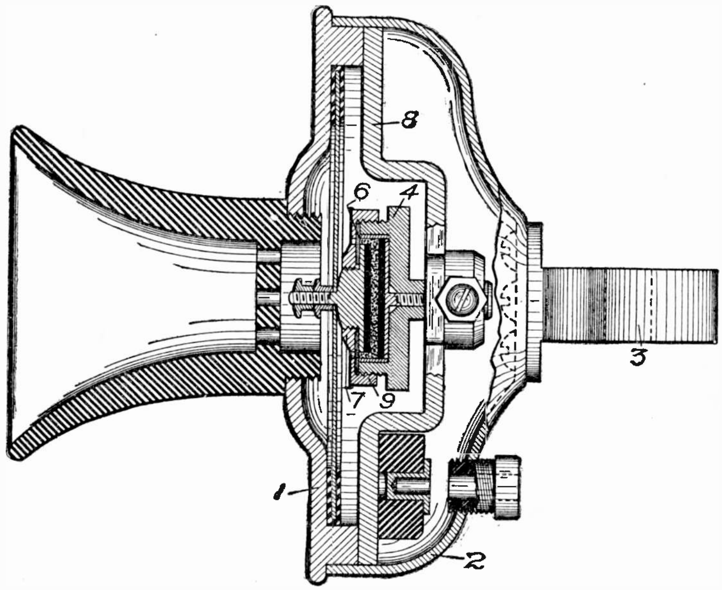


Fig. 40. White Solid-Back Transmitter

front edge of the cup *4*, a screw-threaded ring *9* serving to hold the edge of the mica rigidly against the front of the cup. The outer edge of this washer is, therefore, rigid with respect to the rear electrode, which is fixed. Whatever relative movement there is between the two electrodes must, therefore, be permitted by the flexing of the mica washer. This mica washer not only serves to maintain the electrodes in their normal relative positions, but also serves to close the chamber which contains the electrodes, and, therefore, to prevent the granular carbon, with which the space between the electrodes is filled, from falling out.

The cup *4*, containing the electrode chamber, is rigidly fastened with respect to the body of the transmitter by a rearwardly projecting shank held in a bridge piece *8* which is secured at its ends to the front block. The needed rigidity of the rear electrode is thus obtained and this is probably the reason for calling the instrument the *solid-back.* The front electrode, on the other hand, is fastened to the center of the diaphragm by means of a shank on the stud, which passes through a hole in the diaphragm and is clamped thereto by two small nuts. Against the rear face of the diaphragm of this transmitter there rest two damping springs. These are not shown in Fig. 40 but are in Fig. 41. They are secured at one end to the rear flange of the front casting *1*, and bear with their other or free ends against the rear face of the diaphragm. The damping springs are prevented from coming into actual contact with the diaphragm by small insulating pads. The purpose of the damping springs is to reduce the sensitiveness of the diaphragm to extraneous sounds. As a result, the White transmitter does not pick up all of the sounds in its vicinity as readily as do the more sensitive transmitters, and thus the transmission is not interfered with by extraneous noises. On the other hand, the provision of these heavy damping springs makes it necessary that this transmitter shall be spoken into directly by the user.

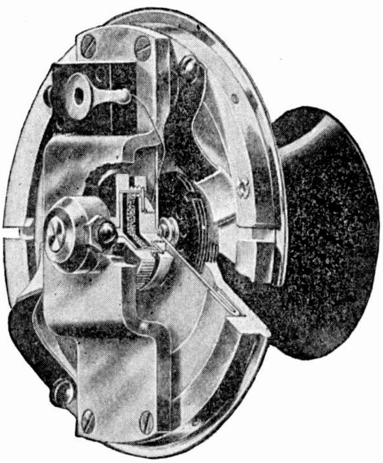


Fig. 41. White Solid-Back Transmitter

The action of this transmitter is as follows: Sound waves are concentrated against the center of the diaphragm by the mouth-piece, which is of the familiar form. These waves impinge against the diaphragm, causing it to vibrate, and this, in turn, produces similar vibrations in the front electrode. The vibrations of the front electrode are permitted by the elasticity of the mica washer *6*. The rear electrode is, however, held stationary within the heavy chambered block *4* and which in turn is held immovable by its rigid mounting. As a result, the front electrode approaches and recedes from the rear electrode, thus compressing and decompressing the mass of granular carbon between them. As a result, the intimacy of contact between the electrode plates and the granules and also between the granules themselves is altered, and the resistance of the path from one electrode to the other through the mass of granules is varied.

New Western Electric Transmitter. The White transmitter was the prototype of a large number of others embodying the same features of having the rear electrode mounted in a stationary cup or chamber and the front electrode movable with the diaphragm, a washer of mica or other flexible insulating material serving to close the front of the electrode chamber and at the same time to permit the necessary vibration of the front electrode with the diaphragm.

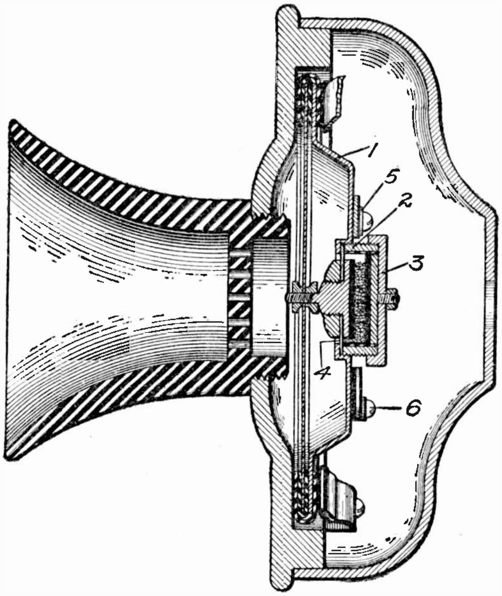


Fig. 42. New Western Electric Transmitter

One of these transmitters, embodying these same features but with modified details, is shown in Fig. 42, this being the new transmitter manufactured by the Western Electric Company. In this the bridge of the original White transmitter is dispensed with, the electrode chamber being supported by a pressed metal cup *1*, which supports the chamber as a whole. The electrode cup, instead of being made of a solid block as in the White instrument, is composed of two portions, a cylindrical or tubular portion *2* and a back *3*. The cylindrical portion is externally screw-threaded so as to engage an internal screw thread in a flanged opening in the center of the cup *1*. By this means the electrode chamber is held in place in the cup *1*, and by the same means the mica washer *4* is clamped between the flange in this opening and the tubular portion *2* of the electrode chamber. The front electrode is carried, as in the White transmitter, on the mica washer and is rigidly attached to the center of the diaphragm so as to partake of the movement thereof. It will be seen, therefore, that this is essentially a White transmitter, but with a modified mounting for the electrode chamber.

A feature in this transmitter that is not found in the White transmitter is that both the front and the rear electrodes, in fact, the entire working portions of the transmitter, are insulated from the exposed metal parts of the instrument. This is accomplished by insulating the diaphragm and the supporting cup *1* from the transmitter front. The terminal *5* on the cup *1* forms the electrical connection for the rear electrode, while the terminal *6*, which is mounted *on* but insulated *from* the cup *1* and is connected with the front electrode by a thin flexible connecting strip, forms the electrical connection for the front electrode.

Kellogg Transmitter. The transmitter of the Kellogg Switchboard and Supply Company, originally developed by Mr. W. W. Dean and modified by his successors in the Kellogg Company, is shown in Fig. 43. In this, the electrode chamber, instead of being mounted in a stationary and rigid position, as in the case of the White instrument, is mounted on, and, in fact, forms a part of the diaphragm. The electrode which is associated with the mica washer instead of moving with the diaphragm, as in the White instrument, is rigidly connected to a bridge so as to be as free as possible from all vibrations.

Referring to Fig. 43, which is a horizontal cross-section of the instrument, *1* indicates the diaphragm. This is of aluminum and it has in its center a forwardly deflected portion forming a chamber for the electrodes. The front electrode *2* of carbon is backed by a disk of brass and rigidly secured in the front of this chamber, as clearly indicated. The rear electrode *3*, also of carbon, is backed by a disk of brass, and is clamped against the central portion of a mica disk by means of the enlarged head of stud *6*. A nut *7*, engaging the end of a screw-threaded shank from the back of the rear electrode, serves to bind these two parts together securely, clamping the mica washer between them. The outer edge of the mica washer is clamped to the main diaphragm *1* by an aluminum ring and rivets, as clearly indicated. It is seen, therefore, that the diaphragm itself contains the electrode chamber as an integral part thereof. The entire structure of the diaphragm, the front and back electrodes, and the granular carbon within are permanently assembled in the factory and cannot be dissociated without destroying some of the parts. The rear electrode is held rigidly in place by the bridge *5* and the stud *6*, this stud passing through a block *9* mounted on the

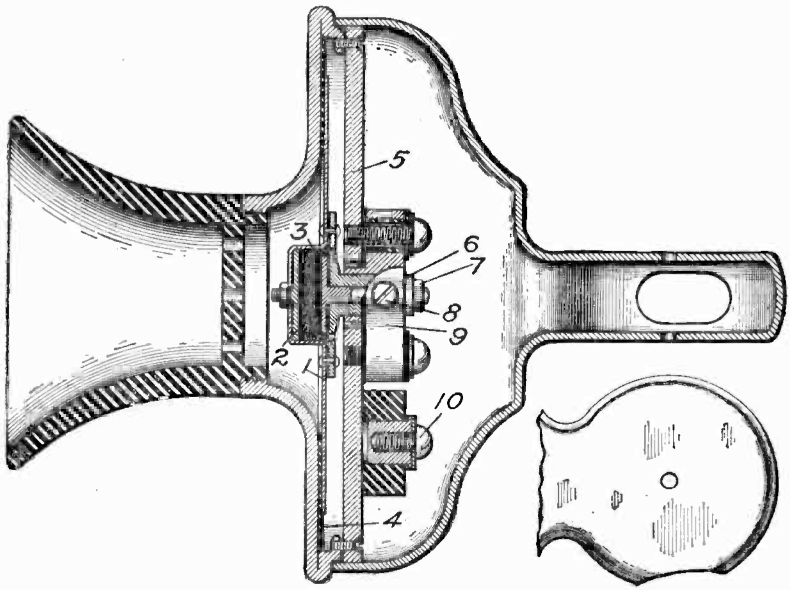


Fig. 43. Kellogg Transmitter

bridge but insulated from it. The stud *6* is clamped in the block *9* by means of the set screw *8*, so as to hold the rear electrode in proper position after this position has been determined.

In this transmitter, as in the transmitter shown in Fig. 42, all of the working parts are insulated from the exposed metal casing. The diaphragm is insulated from the front of the instrument by means of a washer *4* of impregnated cloth, as indicated. The rear electrode is insulated from the other portions of the instrument by means of the mica washer and by means of the insulation between the block *9* and the bridge *5*. The terminal for the rear electrode is mounted on the block *9*, while the terminal for the front electrode, shown at *10*, is mounted on, but insulated from, the bridge. This terminal *10* is connected with the diaphragm and therefore with the front electrode by means of a thin, flexible metallic connection. This transmitter is provided with damping springs similar to those of the White instrument.

It is claimed by advocates of this type of instrument that, in addition to the ordinary action due to the compression and decompression of the granular carbon between the electrodes, there exists another action due to the agitation of the granules as the chamber is caused to vibrate by the sound waves. In other words, in addition to the ordinary action, which may be termed *the piston action between the electrodes*, it is claimed that the general shaking-up effect of the granules when the chamber vibrates produces an added effect. Certain it is, however, that transmitters of this general type are very efficient and have proven their capability of giving satisfactory service through long periods of time.

Another interesting feature of this instrument as it is now manufactured is the use of a transmitter front that is struck up from sheet metal rather than the employment of a casting as has ordinarily been the practice. The formation of the supporting lug for the transmitter from the sheet metal which forms the rear casing or shell of the instrument is also an interesting feature.

Automatic Electric Company Transmitter. The transmitter of the Automatic Electric Company, of Chicago, shown in Fig. 44, is of the same general type as the one just discussed, in that the electrode chamber is mounted on and vibrates with the diaphragm instead of being rigidly supported on the bridge as in the case of the White or solid-back type of instrument. In this instrument the transmitter front *1* is struck up from sheet metal and contains a rearwardly projecting flange, carrying an internal screw thread. A heavy inner cup *2*, together with the diaphragm *3*, form an enclosure containing the electrode chamber. The diaphragm is, in this case, permanently secured at its edge to the periphery of the inner cup *2* by a band of metal *4* so formed as to embrace the edges of both the cup and the diaphragm and permanently lock them together. This inner chamber is held in place in the transmitter front *1* by means of a lock ring *5* externally screw-threaded to engage the internal screw-thread on the flange on the front. The electrode chamber proper is made in the form of a cup, rigidly secured to the diaphragm so as to move therewith, as clearly indicated. The rear electrode is mounted on a screw-threaded stud carried in a block which is fitted to a close central opening in the cup *2*.

This transmitter does not make use of a mica washer or diaphragm, but employs a felt washer which surrounds the shank of the rear electrode and serves to close and seal the carbon containing cup. By this means the granular carbon is retained in the cham-

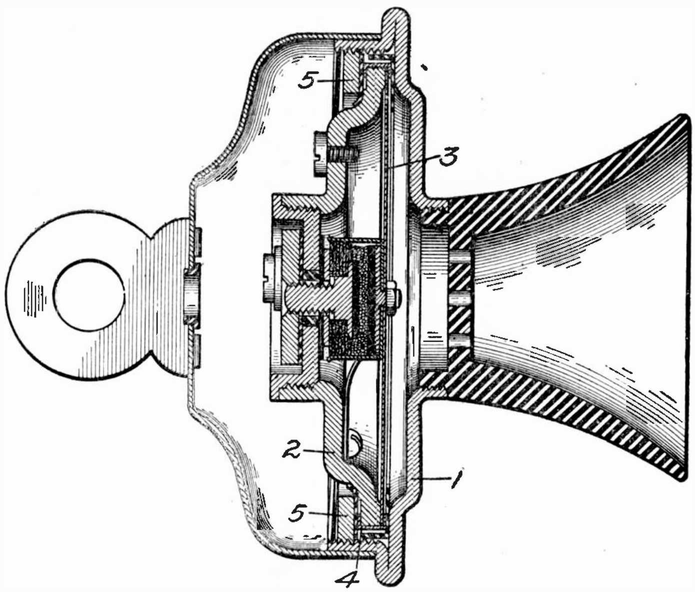


Fig. 44. Automatic Electric Company Transmitter

ber and the necessary flexibility or freedom of motion is permitted between the front and the rear electrodes. As in the Kellogg and the later Bell instruments, the entire working parts of this transmitter are insulated from the metal containing case, the inner chamber, formed by the cup *2* and the diaphragm *3*, being insulated from the transmitter front and its locking ring by means of insulating washers, as shown.

Monarch Transmitter. The transmitter of the Monarch Telephone Manufacturing Company, shown in Fig. 45, differs from both the stationary-cup and the vibrating-cup types, although it has the characteristics of both. It might be said that it differs from each of these two types of transmitters in that it has the characteristics of both.

This transmitter, it will be seen, has two flexible mica washers between the electrodes and the walls of the electrode cup. The front and the back electrodes are attached to the diaphragm and the bridge, respectively, by a method similar to that employed in the solid-back transmitters, while the carbon chamber itself is free to vibrate with the diaphragm as is characteristic of the Kellogg transmitter.

An aluminum diaphragm is employed, the circumferential edge of which is forwardly deflected to form a seat. The edge of the

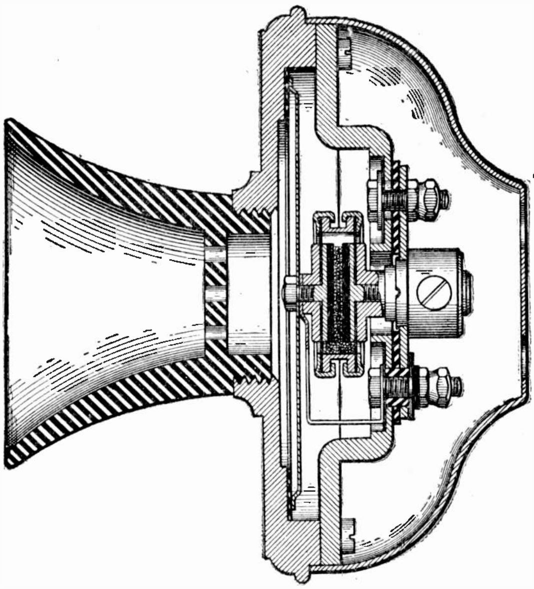


Fig. 45. Monarch Transmitter

diaphragm rests *against* and is separated *from* the brass front by means of a one-piece gasket of specially treated linen. This forms an insulator which is not affected by heat or moisture. As in the transmitters previously described, the electrodes are firmly soldered to brass disks which have solid studs extending from their centers. In the case of both the front and the rear electrodes, a mica disk is placed over the supporting stud and held in place by a brass hub which has a base of the same size as the electrode. The carbon-chamber wall consists of a brass ring to which are fastened the mica disks of the front and the back electrodes by means of brass collars clamped over the edge of the mica and around the rim of the brass ring forming the chamber.

Electrodes. The electrode plates of nearly all modern transmitters are of specially treated carbon. These are first copper-plated and soldered to their brass supporting disks. After this they are turned and ground so as to be truly circular in form and to present absolutely flat faces toward each other. These faces are then highly polished and the utmost effort is made to keep them absolutely clean. Great pains are taken to remove from the pores of the carbon, as well as from the surface, all of the acids or other chemicals that may have entered them during the process of electroplating or of soldering them to the brass supporting disk. That the two electrodes, when mounted in a transmitter, should be parallel with each other, is an item of great importance as will be pointed out later.

In a few cases, as previously stated, gold or platinum has been substituted for the carbon electrodes in transmitters. These are capable of giving good results when used in connection with the proper form of granular carbon, but, on the whole, the tendency has been to abandon all forms of electrode material except carbon, and its use is now well nigh universal.

Preparation of Carbon. The granular carbon is prepared from carefully selected anthracite coal, which is specially treated by roasting or "re-carbonizing" and is then crushed to approximately the proper fineness. The crushed carbon is then screened with extreme care to eliminate all dust and to retain only granules of uniform size.

Packing. In the earlier forms of granular-carbon transmitters a great deal of trouble was experienced due to the so-called packing of the instrument. This, as the term indicates, was a trouble due to the tendency of the carbon granules to settle into a compact mass and thus not respond to the variable pressure. This was sometimes due to the presence of moisture in the electrode chamber; sometimes to the employment of granules of varying sizes, so that they would finally arrange themselves under the vibration of the diaphragm into a fairly compact mass; or sometimes, and more frequently, to the granules in some way wedging the two electrodes apart and holding them at a greater distance from each other than their normal distance. The trouble due to moisture has been entirely eliminated by so sealing the granule chambers as to prevent the entrance of moisture. The trouble due to the lack of uniformity in size of the granules has been entirely eliminated by making them all of one size and by making them of sufficient hardness so that they would not break up into granules of smaller size. The trouble due to the settling of the granules and wedging the electrodes apart has been practically eliminated in well-designed instruments, by great mechanical nicety in manufacture.

Almost any transmitter may be packed by drawing the diaphragm forward so as to widely separate the electrodes. This allows the granules to settle to a lower level than they normally occupy and when the diaphragm is released and attempts to resume its normal position it is prevented from doing so by the mass of granules between. Transmitters of the early types could be packed by placing the lips against the mouthpiece and drawing in the breath. The slots now provided at the base of standard mouthpieces effectually prevent this.

In general it may be said that the packing difficulty has been almost entirely eliminated, not by the employment of remedial devices, such as those often proposed for stirring up the carbon, but by preventing the trouble by the design and manufacture of the instruments in such forms that they will not be subject to the evil.

Carrying Capacity. Obviously, the power of a transmitter is dependent on the amount of current that it may carry, as well as on the amount of variation that it may make in the resistance of the path through it. Granular carbon transmitters are capable of carrying much heavier current than the old Blake or other single or multiple electrode types. If forced to carry too much current, however, the same frying or sizzling sound is noticeable as in the earlier types. This is due to the heating of the electrodes and to small arcs that occur between the electrodes and the granules.

One way to increase the current-carrying capacity of a transmitter is to increase the area of its electrodes, but a limit is soon reached in this direction owing to the increased inertia of the moving electrode, which necessarily comes with its larger size.

The carrying capacity of transmitters may also be increased by providing special means for carrying away the heat generated in the variable-resistance medium. Several schemes have been proposed for this. One is to employ unusually heavy metal for the electrode chamber, and this practice is best exemplified in the White solid-back instrument. It has also been proposed by others to water-jacket the electrode chamber, and also to keep it cool by placing it in close proximity to the relatively cool joints of a thermopile. Neither of these two latter schemes seems to be warranted in ordinary commercial practice.

Sensitiveness. In all the transmitters so far discussed damping springs of one form or another have been employed to reduce the sensitiveness of the instrument. For ordinary commercial use too great a degree of sensitiveness is a fault, as has already been pointed out. There are, however, certain adaptations of the telephone transmitter which make a maximum degree of sensitiveness desirable. One of these adaptations is found in the telephone equipments for assisting partially deaf people to hear. In these the transmitter is carried on some portion of the body of the deaf person, the receiver is strapped or otherwise held at his ear, and a battery for furnishing the current is carried in his pocket. It is not feasible, for this sort of use, that the sound which this transmitter is to reproduce shall always occur immediately in front of the transmitter. It more often occurs at a distance of several feet. For this reason the transmitter is made as sensitive as possible, and yet is so constructed that it will not be caused to produce too loud or unduly harsh sounds in response to a loud sound taking place immediately in front of it. Another adaptation of such highly sensitive transmitters is found in the special intercommunicating telephone systems for use between the various departments or desks in business offices. In these it is desirable that the transmitter shall be able to respond adequately to sounds occurring anywhere in a small-sized room, for instance.

Acousticon Transmitter. In Fig. 46 is shown a transmitter adapted for such use. This has been termed by its makers the *acousticon transmitter.* Like all the transmitters previously discussed, this is of the variable-resistance type, but it differs from them all in that it has no damping springs; in that carbon balls are substituted for carbon granules; and in that the diaphragm itself serves as the front electrode.

This transmitter consists of a cup *1*, into which is set a cylindrical block *2*, in one face of which are a number of hemispherical recesses. The diaphragm *3* is made of thin carbon and is so placed in the transmitter as to cover the openings of the recesses in the carbon block, and lie close enough to the carbon block, without engaging it, to prevent the carbon particles from falling out. The diaphragm thus serves as the front electrode and the carbon block as the rear electrode. The recesses in the carbon block are about two-thirds filled with small carbon balls, which are about the size of fine sand. The front piece *4* of the transmitter is of sheet metal and serves to hold the diaphragm in place. To admit the sound waves it is provided with a circular opening opposite to and about the size of the rear electrode block. On this front piece are mounted the two terminals of the transmitter, connected respectively to the two electrodes, terminal *5* being insulated from the front piece and connected by a thin metal strip with the diaphragm, while terminal *6* is mounted directly on the front piece and connected through the cup *1* with the carbon block *2*, or back electrode of the transmitter.

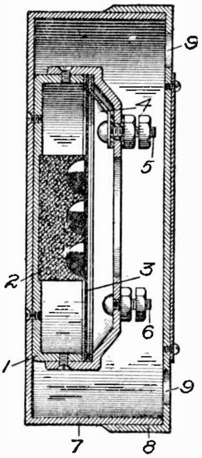


Fig 46. Acousticon Transmitter

When this transmitter is used in connection with outfits for the deaf, it is placed in a hard rubber containing case, consisting of a hollow cylindrical piece *7*, which has fastened to it a cover *8*. This cover has a circular row of openings or holes near its outer edge, as shown at *9*, through which the sound waves may pass to the chamber within, and thence find their way through the round hole in the center of the front plate *4* to the diaphragm *3*. It is probable also that the front face of the cover *8* of the outer case vibrates, and in this way also causes sound waves to impinge against the diaphragm. This arrangement provides a large receiving surface for the sound waves, but, owing to the fact that the openings in the containing case are not opposite the opening in the transmitter proper, the sound waves do not impinge directly against the diaphragm. This peculiar arrangement is probably the result of an endeavor to prevent the transmitter from being too strongly actuated by violent sounds close to it. Instruments of this kind are very sensitive and under proper conditions are readily responsive to words spoken in an ordinary tone ten feet away.

Switchboard Transmitter. Another special adaptation of the telephone transmitter is that for use of telephone operators at central-office switchboards. The requirements in this case are such that the operator must always be able to speak into the transmitter while seated before the switchboard, and yet allow both of her hands to be free for use. This was formerly accomplished by suspending an ordinary granular-carbon transmitter in front of the operator, but a later development has resulted in the adoption of the so-called breast transmitter, shown in Fig. 47. This is merely an ordinary granular-carbon transmitter mounted on a plate which is strapped on the breast of the operator, the transmitter being provided with a long curved mouthpiece which projects in such a manner as to lie just in front of the operator's lips. This device has the advantage of automatically following the operator in her movements. The breast transmitter shown in Fig. 47, is that of the Dean Electric Company.

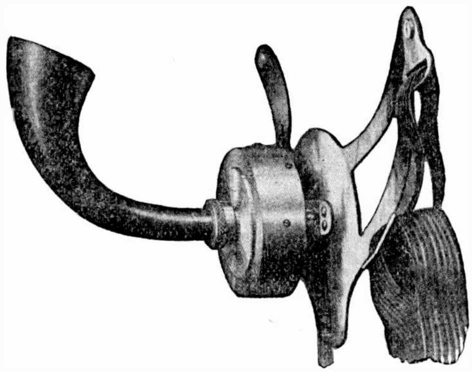


Fig. 47. Switchboard Transmitter

Conventional Diagram. There are several common ways of illustrating transmitters in diagrams of circuits in which they are employed. The three most common ways are shown in Fig. 48. The one at the left is supposed to be a side view of an ordinary instrument, the one in the center a front view, and the one at the right to be merely a suggestive arrangement of the diaphragm and the rear electrode. The one at the right is best and perhaps most common; the center one is the poorest and least used.

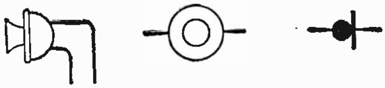


Fig. 48. Transmitter Symbols

CHAPTER VI

RECEIVERS

The telephone receiver is the device which translates the energy of the voice currents into the energy of corresponding sound waves. All telephone receivers today are of the electromagnetic type, the voice currents causing a varying magnetic pull on an armature or diaphragm, which in turn produces the sound waves corresponding to the undulations of the voice currents.

Early Receivers. The early forms of telephone receivers were of the *single-pole* type; that is, the type wherein but one pole of the electromagnet was presented to the diaphragm. The single-pole receiver that formed the companion piece to the old Blake transmitter and that was the standard of the Bell companies for many years, is shown in Fig. 49. While this has almost completely passed out of use, it may be profitably studied in order that a comparison may be made between certain features of its construction and those of the later forms of receivers.

The coil of this receiver was wound on a round iron core *2*, flattened at one end to afford means for attaching the permanent magnet. The permanent magnet was of laminated construction, consisting of four hard steel bars *1*, extending nearly the entire length of the receiver shell. These steel bars were all magnetized separately and placed with like poles together so as to form a single bar magnet. They were laid together in pairs so as to include between the pairs the flattened end of the pole piece *2* at one end and the flattened portion of the tail piece *3* at the other end. This whole magnet structure, including the core, the tail piece, and the permanently magnetized steel bars, was clamped together by screws as shown. The containing shell was of hard rubber consisting of three pieces, the barrel *4*, the ear-piece *5*, and the tail cap *6*. The barrel and the ear piece engaged each other by means of a screw thread and served to clamp the diaphragm between them. The compound bar magnet was held in place within the shell by means of a screw *7* passing through the hard rubber tail cap *6* and into the tail block *3* of the magnet. External binding posts mounted on the tail cap, as shown, were connected by heavy leading-in wires to the terminals of the electromagnet.

A casual consideration of the magnetic circuit of this instrument will show that it was inefficient, since the return path for the lines of force set up by the bar magnet was necessarily through a very long air path. Notwithstanding this, these receivers were capable of giving excellent articulation and were of marvelous delicacy of action. A very grave fault was that the magnet was supported in the shell at the end farthest removed from the diaphragm. As a result it was difficult to maintain a permanent adjustment between the pole piece and the diaphragm. One reason for this was that hard rubber and steel contract and expand under changes of temperature at very different rates, and therefore the distance between the pole piece and the diaphragm changed with changes of temperature. Another grave defect, brought about by this tying together of the permanent magnet and the shell which supported the diaphragm at the end farthest from the diaphragm, was that any mechanical shocks were thus given a good chance to alter the adjustment.

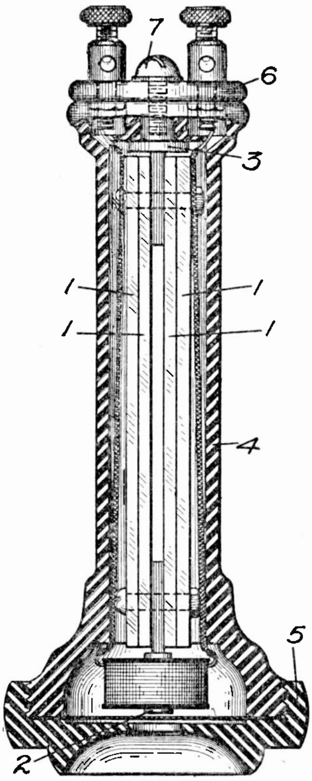


Fig. 49. Single-Pole Receiver

Modern Receivers. Receivers of today differ from this old single-pole receiver in two radical respects. In the first place, the modern receiver is of the bi-polar type, consisting essentially of a horseshoe magnet presenting both of its poles to the diaphragm. In the second place, the modern practice is to either support all of the working parts of the receiver, *i. e.*, the magnet, the coils, and the diaphragm, by an inner metallic frame entirely independent of the shell; or, if the shell is used as a part of the structure, to rigidly fasten the several parts close to the diaphragm rather than at the end farthest removed from the diaphragm.

Western Electric Receiver. The standard bi-polar receiver of the Western Electric Company, in use by practically all of the Bell operating companies throughout this country and in large use abroad, is shown in Fig. 50. In this the shell is of three pieces, consisting of the barrel *1*, the ear cap *2*, and the tail cap *3*. The tail cap and the barrel are permanently fastened together to form substantially a single piece. Two permanently magnetized bar magnets *4-4* are employed, these being clamped together at their upper ends, as shown, so as to include the soft iron block *5* between them. The north pole of one of these magnets is clamped to the south pole of the other, so that in reality a horseshoe magnet is formed. At their lower ends, these two permanent magnets are clamped against the soft iron pole pieces *6-6*, a threaded block *7* also being clamped rigidly between these pole pieces at this point. On the ends of the pole pieces the bobbins are wound. The whole magnet structure is secured within the shell *1* by means of a screw thread on the block *7* which engages a corresponding internal screw thread in the shell *1*. As a result of this construction the whole magnet structure is bound rigidly to the shell structure at a point close to the diaphragm, comparatively speaking, and as a result of this close coupling, the relation between the diaphragm and the pole piece is very much more rigid and substantial than in the case where the magnet structure and the shell were secured together at the end farthest removed from the diaphragm.

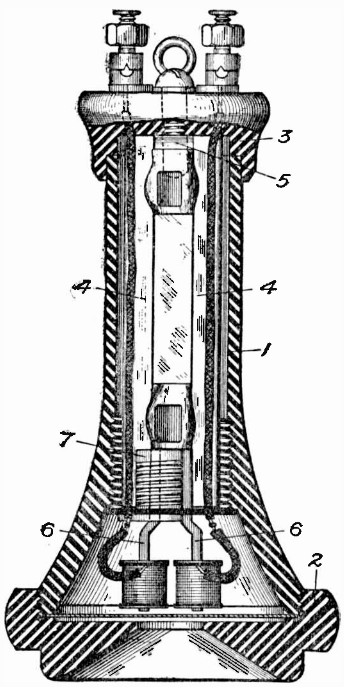


Fig. 50. Western Electric Receiver

Although this receiver shown in Fig. 50 is the standard in use

ONE WING OF OPERATING ROOM, BERLIN, GERMANY
Ultimate Capacity 24,000 Subscribers' Lines and 2,100 Trunk Lines. Siemens-Halske Equipment. Note Horizontal Disposal of Multiple Jack Field.

by the Bell companies throughout this country, its numbers running well into the millions, it cannot be said to be a strictly modern receiver, because of at least one rather antiquated feature. The binding posts, by which the circuit conductors are led to the coils of this instrument, are mounted on the outside of the receiver shell, as indicated, and are thus subject to danger of mechanical injury and they are also exposed to the touch of the user, so that he may, in case of the wires being charged to an abnormal potential, receive a shock. Probably a more serious feature than either one of these is that the terminals of the flexible cords which attach to these binding posts are attached outside of the receiver shell, and are therefore exposed to the wear and tear of use, rather than being protected as they should be within the shell. Notwithstanding this undesirable feature, this receiver is a very efficient one and is excellently constructed.

Kellogg Receiver. In Fig. 51 is shown a bi-polar receiver with internal or concealed binding posts. This particular receiver is typical of a large number of similar kinds and is manufactured by the Kellogg Switchboard and Supply Company. Two straight permanently magnetized bar magnets *1-1* are clamped together at their opposite ends so as to form a horseshoe magnet. At the end opposite the diaphragm these bars clamp between them a cylindrical piece of iron *2*, so as to complete the magnetic circuit at the end. At the end nearest the diaphragm they clamp between them the ends of the soft iron pole pieces *3-3*, and also a block of composite metal *4* having a large circular flange *4′* which serves as a means for supporting the magnet structure within the shell. The screws by means of which the disk *4′* is clamped to the shouldered seat in the shell do not enter the shell directly, but rather enter screw-threaded brass blocks which are moulded into the structure of the shell. It is seen from this construction that the diaphragm and the pole pieces and the magnet

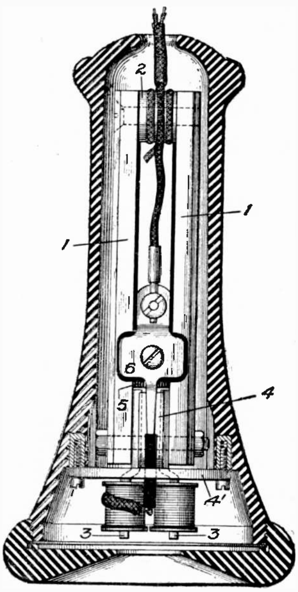


Fig. 51. Kellogg Receiver

structure itself are all rigidly secured together through the medium of the shell at a point as close as possible to the diaphragm.

Between the magnets *1-1* there is clamped an insulating block *5*, to which are fastened the terminal plates *6*, one on each side of the receiver. These terminal plates are thoroughly insulated from the magnets themselves and from all other metallic parts by means of sheets of fiber, as indicated by the heavy black lines. On these plates *6* are carried the binding posts for the receiver cord terminals. A long tongue extends from each of the plates *6* through a hole in the disk *4'*, into the coil chamber of the receiver, at which point the terminal of the magnet winding is secured to it. This tongue is insulated from the disk *4'*, where it passes through it, by means of insulating bushing, as shown. The other terminal of the magnet coils is brought out to the other plate *6* by means of a similar tongue on the other side.

In order that the receiver terminals proper may not be subjected to any strain in case the receiver is dropped and its weight caught on the receiver cord, a strain loop is formed as a continuation of the braided covering of the receiver cord, and this is tied to the permanent magnet structure, as shown. By making this strain loop short, it is obvious that whatever pull the cord receives will not be taken by the cord conductors leading to the binding posts or by the binding posts or the cord terminals themselves.

A number of other manufacturers have gone even a step further than this in securing permanency of adjustment between the receiver diaphragm and pole pieces. They have done this by not depending at all on the hard rubber shell as a part of the structure, but by enclosing the magnet coil in a cup of metal upon which the diaphragm is mounted, so that the permanency of relation between the diaphragm and the pole pieces is dependent only upon the metallic structure and not at all upon the less durable shell.

Direct-Current Receiver. Until about the middle of the year 1909, it was the universal practice to employ permanent magnets for giving the initial polarization to the magnet cores of telephone receivers. This is still done, and necessarily so, in receivers employed in connection with magneto telephones. In common-battery systems, however, where the direct transmitter current is fed from the central office to the local stations, it has been found that this current which must flow at any rate through the line may be made to serve the additional purpose of energizing the receiver magnets so as to give them the necessary initial polarity. A type of receiver has come into wide use as a result, which is commonly called the *direct-current receiver*, deriving its name from the fact that it employs the direct current that is flowing in the common-battery line to magnetize the receiver cores. The Automatic Electric Company, of Chicago, was probably the first company to adopt this form of receiver as its standard type. Their receiver is shown in cross-section in Fig. 52, and a photograph of the same instrument partially disassembled is given in Fig. 53. The most noticeable thing about the construction of this receiver is the absence of permanent magnets. The entire working parts are contained within the brass cup *1*, which serves not only as a container for the magnet, but also as a seat for the diaphragm. This receiver is therefore illustrative of the type mentioned above, wherein the relation between the diaphragm and the pole pieces is not dependent upon any connection through the shell.

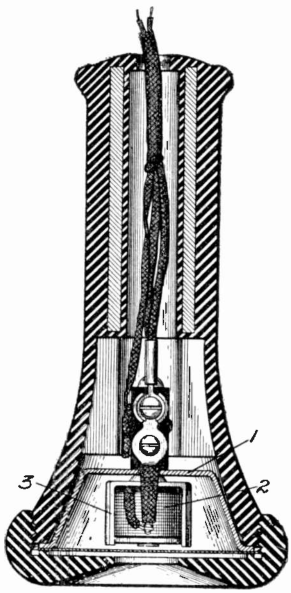


Fig. 52. Automatic Electric Company Direct-Current Receiver

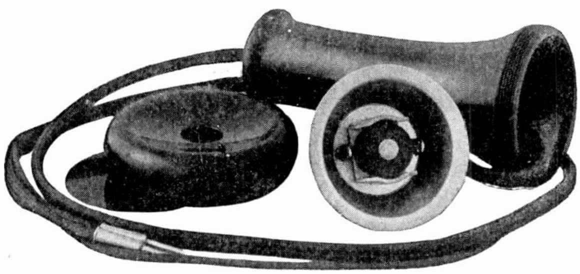


Fig. 53. Automatic Electric Company Direct-Current Receiver

The coil of this instrument consists of a single cylindrical spool *2*, mounted on a cylindrical core. This bobbin lies within a soft iron-punching *3*, the form of which is most clearly shown in Fig. 53, and this punching affords a return path to the diaphragm for the lines of force set up in the magnet core. Obviously a magnetizing current passing through the winding of the coil will cause the end of the core toward the diaphragm to be polarized, say positively, while the end of the enclosing shell will be polarized in the other polarity, negatively. Both poles of the magnet are therefore presented to the diaphragm and the only air gap in the magnetic circuit is that between the diaphragm and these poles. The magnetic circuit is therefore one of great efficiency, since it consists almost entirely of iron, the only air gap being that across which the attraction of the diaphragm is to take place.

The action of this receiver will be understood when it is stated that in common-battery practice, as will be shown in later chapters, a steady current flows over the line for energizing the transmitter. On this current is superposed the incoming voice currents from a distant station. The steady current flowing in the line will, in the case of this receiver, pass through the magnet winding and establish a normal magnetic field in the same way as if a permanent magnet were employed. The superposed incoming voice currents will then be able to vary this magnetic field in exactly the same way as in the ordinary receiver.

An astonishing feature of this recent development of the so-called direct-current receiver is that it did not come into use until after about twenty years of common-battery practice. There is nothing new in the principles involved, as all of them were already understood and some of them were employed by Bell in his original telephone; in fact, the idea had been advanced time and again, and thrown aside as not being worth consideration. This is an illustration of a frequent occurrence in the development of almost any rapidly growing art. Ideas that are discarded as worthless in the early stages of the art are finally picked up and made use of. The reason for this is that in some cases the ideas come in advance of the art, or they are proposed before the art is ready to use them. In other cases the idea as originally proposed lacked some small but essential detail, or, as is more often the case, the experimenter in the early days did not have sufficient skill or knowledge to make it fit the requirements as he saw them.

Monarch Receiver. The receiver of the Automatic Electric

Company just discussed employs but a single electromagnet by which the initial magnetization of the cores and also the variable magnetization necessary for speech reproduction is secured. The problem of the direct-current receiver has been attacked in another way by Ernest E. Yaxley, of the Monarch Telephone Manufacturing Company, with the result shown in Fig. 54. The construction in this case is not unlike that of an ordinary permanent-magnet receiver, except that in the place of the permanent magnets two soft iron cores *1-1* are employed. On these are wound two long bobbins of insulated wire so that the direct current flowing over the telephone line will pass through these and magnetize the cores to the same degree and for the same purpose as in the case of permanent magnets. These soft iron magnet cores *1-1* continue to a point near the coil chamber, where they join the two soft iron pole pieces *2-2*, upon which the ordinary voice-current coils are wound. The two long coils *4-4*, which may be termed the direct-current coils, are of somewhat lower resistance than the two voice-current coils *3-3*. They are, however, by virtue of their greater number of turns and the greater amount of iron that is included in their cores, of much higher impedance than the voice-current coils *3-3*.

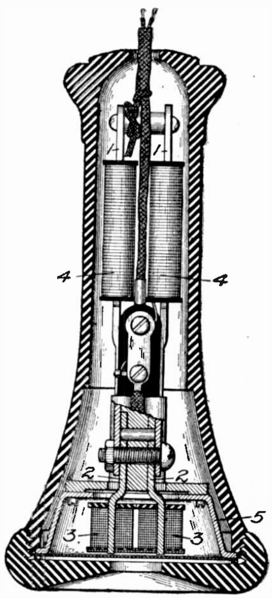


Fig. 54. Monarch Direct-Current Receiver

These two sets of coils *4-4* and *3-3* are connected in multiple. As a result of their lower ohmic resistance the coils *4-4* will take a greater amount of the steady current which comes over the line, and therefore the greater proportion of the steady current will be employed in magnetizing the bar magnets. On account of their higher impedance to alternating currents, however, nearly all of the voice currents which are superposed on the steady currents, flowing in the line will pass through the voice-current coils *3-3*, and, being near the diaphragm, these currents will so vary the steady magnetism in the cores *2-2* as to produce the necessary vibration of the diaphragm.

This receiver, like the one of the Automatic Electric Company, does not rely on the shell in any respect to maintain the permanency of relation between the pole pieces and the diaphragm. The cup *5*, which is of pressed brass, contains the voice-current coils and also acts as a seat for the diaphragm. The entire working parts of this receiver may be removed by merely unscrewing the ear piece from the hard rubber shell, thus permitting the whole works to be withdrawn in an obvious manner.

Dean Receiver. Of such decided novelty as to be almost revolutionary in character is the receiver recently put on the market by the Dean Electric Company and shown in Fig. 55. This receiver is of the direct-current type and employs but a single cylindrical bobbin of wire. The core of this bobbin and the return path for the magnetic lines of force set up in it are composed of soft iron punchings of substantially **E** shape. These punchings are laid together so as to form a laminated soft-iron field, the limbs of which are about square in cross-section. The coil is wound on the center portion of this *E* as a core, the core being, as stated, approximately square in cross-section. The general form of magnetic circuit in this instrument is therefore similar to that of the Automatic Electric Company's receiver, shown in Figs. 52 and 53, but the core is laminated instead of being solid as in that instrument.

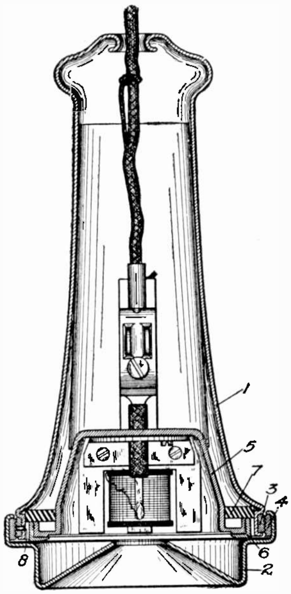


Fig. 55. Dean Steel Shell Receiver

The most unusual feature of this Dean receiver is that the use of hard rubber or composition does not enter into the formation of the shell, but instead a shell composed entirely of steel stampings has been substituted therefor. The main portion of this shell is the barrel *1*. Great skill has evidently been exercised in the forming of this by the cold-drawn process, it presenting neither seams nor welds. The ear piece *2* is also formed of steel of about the same gauge as the barrel *1*. Instead of screw-threading the steel parts, so that they would directly engage each other, the ingenious device has been employed of swaging a brass ring *3* in the barrel portion and a similar brass ring *4* in the ear cap portion, these two being slotted and keyed, as shown at *8*, so as to prevent their turning in their respective seats. The ring *3* is provided with an external screw thread and the ring *4* with an internal screw thread, so that the receiver cap is screwed on to the barrel in the same way as in the ordinary rubber shell. By the employment of these brass screw-threaded rings, the rusting together of the parts so that they could not be separated when required—a difficulty heretofore encountered in steel construction of similar parts—has been remedied.

The entire working parts of this receiver are contained within the cup *5*, the edge of which is flanged outwardly to afford a seat for

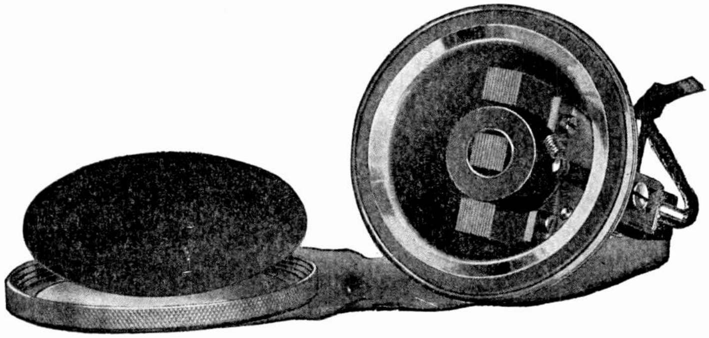


Fig. 56. Working Parts of Dean Receiver

the diaphragm. The diaphragm is locked in place on the shell by a screw-threaded ring *6*, as is clearly indicated. A ring *7* of insulating material is seated within the enlarged portion of the barrel *1*, and against this the flange of the cup *5* rests and is held in place by the cap *2* when it is screwed home. The working parts of this receiver partially disassembled are shown in Fig. 56, which gives a clear idea of some of the features not clearly illustrated in Fig. 55.

It cannot be denied that one of the principal items of maintenance of subscribers' station equipment has been due to the breakage of receiver shells. The users frequently allow their receiver to fall and strike heavily against the wall or floor, thus not only subjecting the cords to great strain, but sometimes cracking or entirely breaking the receiver shell. The innovation thus proposed by the Dean Company of making the entire receiver shell of steel is of great interest. The shell, as will be seen, is entirely insulated from the circuit of the receiver so that no contact exists by which a user could receive a shock. The shell is enameled inside and out with a heavy black insulating enamel baked on, and said to be of great durability. How this enamel will wear remains to be seen. The insulation of the interior portions of the receiver is further guarded by providing a lining of fiber within the shell at all points where it seems possible that a cross could occur between some of the working parts and the metal of the shell. This type of receiver has not been on the market long enough to draw definite conclusions, based on experience in use, as to what its permanent performance will be.

Thus far in this chapter only those receivers which are commonly called *hand receivers* have been discussed. These are the receivers that are ordinarily employed by the general public.

Operator's Receiver. At the central office in telephone exchanges the operators are provided with receivers in order that they

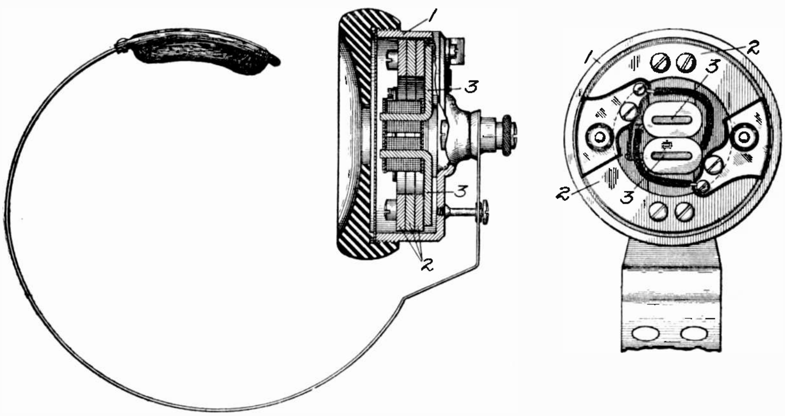


Fig. 57. Operator's Receiver

may communicate with the subscribers or with other operators. In order that they may have both of their hands free to set up and take down the connections and to perform all of the switching operations required, a special form of receiver is employed for this purpose, which is worn as a part of a head-gear and is commonly termed a *head receiver*. These are necessarily of very light construction, in order not to be burdensome to the operators, and obviously they must be efficient. They are ordinarily held in place at the ear by a metallic head band fitting over the head of the operator.

Such a receiver is shown in cross-section in Fig. 57, and completely assembled with its head band in Fig. 58. Referring to Fig. 57 the shell *1* of the receiver is of aluminum and the magnets are formed of steel rings *2*, cross-magnetized so as to present a north pole on one side of the ring and a south pole on the other. The two L-shaped pole pieces *3* are secured by screws to the poles of these ring magnets, and these pole pieces carry the magnet coils, as is clearly indicated.

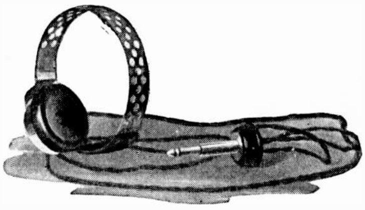


Fig. 58. Operator's Receiver and Cord

These poles are presented to a soft iron diaphragm in exactly the same way as in the larger hand receivers, the diaphragm being clamped in place by a hard rubber ear piece, as shown. The head bands are frequently of steel covered with leather. They have assumed numerous forms, but the general form shown in Fig. 58 is the one commonly adopted.

Conventional Symbols. The usual diagrammatic symbols for hand and head receivers are shown in Fig. 59. They are self-explanatory. The symbol at the left in this figure, showing the general

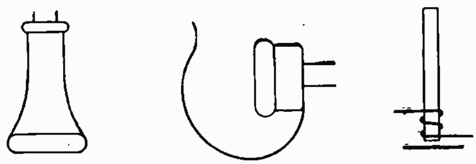


Fig. 59. Receiver Symbols

outline of the receiver, is the one most commonly used where any sort of a receiver is to be indicated in a circuit diagram, but where it becomes desirable to indicate in the diagram the actual connections with the coil or coils of the receiver, the symbol shown at the right is to be preferred, and obviously it may be modified as to number of windings and form of core as desired.

MAIN OFFICE, KANSAS CITY HOME TELEPHONE CO., KANSAS CITY, MO.

CHAPTER VII

MAGNETO SIGNALING APPARATUS

Method of Signaling. The ordinary apparatus, by which speech is received telephonically, is not capable of making sufficiently loud sounds to attract the attention of people at a distance from the instrument. For this reason it is necessary to employ auxiliary apparatus for the purpose of signaling between stations. In central offices where an attendant is always on hand, the sense of sight is usually appealed to by the use of signals which give a visual indication, but in the case of telephone instruments for use by the public, the sense of hearing is appealed to by employing an audible rather than a visual signal.

Battery Bell. The ordinary vibrating or battery bell, such as is employed for door bells, is sometimes, though not often, employed in telephony. It derives its current from primary batteries or from any direct-current source. The reason why they are not employed to a greater extent in telephony is that telephone signals usually have to be sent over lines of considerable length and the voltage that would be required to furnish current to operate such bells over such lengths of line is higher than would ordinarily be found in the batteries commonly employed in telephone work. Besides this the make-and-break contacts on which the ordinary battery bell depends for its operation are an objectionable feature from the standpoint of maintenance.

Magneto Bell. Fortunately, however, there has been developed a simpler type of electric bell, which operates on smaller currents, and which requires no make-and-break contacts whatever. This simpler form of bell is commonly known as the *polarized,* or *magneto,* bell or *ringer.* It requires for its operation, in its ordinary form, an alternating current, though in its modified forms it may be used with pulsating currents, that is, with periodically recurring impulses of current always in the same direction.

Magneto Generator. In the early days of telephony there was nearly always associated with each polarized bell a magneto generator for furnishing the proper kind of current to ring such bells. Each telephone was therefore equipped, in addition to the transmitter and receiver, with a signal-receiving device in the form of a polarized bell, and with a current generator by which the user was enabled to develop his own currents of suitable kind and voltage for ringing the bells of other stations.

Considering the signaling apparatus of the telephones alone, therefore, each telephone was equipped with a power plant for generating currents used by that station in signaling other stations, the prime mover being the muscles of the user applied to the turning of a crank on the side of the instrument; and also with a current-consuming device in the form of a polarized electromagnetic bell adapted to receive the currents generated at other stations and to convert a portion of their energy into audible signals.

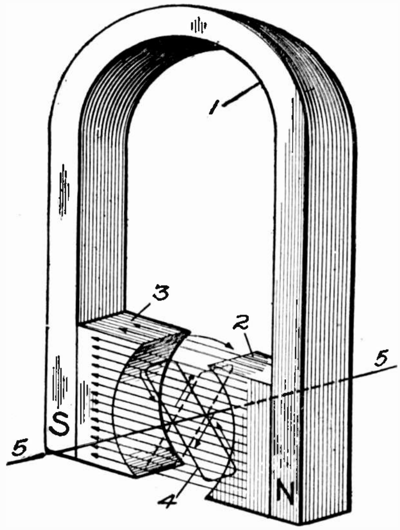


Fig. 60. Principles of Magneto Generator

The magneto generator is about the simplest type of dynamo-electric machine, and it depends upon the same principles of operation as the much larger generators, employed in electric-lighting and street-railway power plants, for instance. Instead of developing the necessary magnetic field by means of electromagnets, as in the case of the ordinary dynamo, the field of the magneto generator is developed by permanent magnets, usually of the horseshoe form. Hence the name *magneto*.

In order to concentrate the magnetic field within the space in which the armature revolves, pole pieces of iron are so arranged in connection with the poles of the permanent magnet as to afford a substantially cylindrical space in which the armature conductors may revolve and through which practically all the magnetic lines of force set up by the permanent magnets will pass. In Fig. 60 there is shown, diagrammatically, a horseshoe magnet with such a pair of pole pieces, between which a loop of wire is adapted to rotate. The magnet *1* is of hardened steel and permanently magnetized. The pole pieces are shown at *2* and *3*, each being of soft iron adapted to make good magnetic contact on its flat side with the inner flat surface of the bar magnet, and being bored out so as to form a cylindrical recess between them as indicated. The direction of the magnetic lines of force set up by the bar magnet through the interpolar space is indicated by the long horizontal arrows, this flow being from the north pole (N) to the south pole (S) of the magnet. At *4* there is shown a loop of wire supposed to revolve in the magnetic field of force on the axis *5-5*.

Theory. In order to understand how currents will be generated in this loop of wire *4*, it is only necessary to remember that if a conductor is so moved as to cut across magnetic lines of force, an electromotive force will be set up in the conductor which will tend to make the current flow through it. The magnitude of the electromotive force will depend on the rate at which the conductor cuts through the lines of force, or, in other words, on the number of lines of force that are cut through by the conductor in a given unit of time. Again, the direction of the electromotive force depends on the direction of the cutting, so that if the conductor be moved in one direction across the lines of force, the electromotive force and the current will be in one direction; while if it moves in the opposite direction across the lines of force, the electromotive force and the current will be in the reverse direction.

It is evident that as the loop of wire *4* revolves in the field of force about the axis *5-5*, the portions of the conductor parallel to the axis will cut through the lines of force, first in one direction and then in the other, thus producing electromotive forces therein, first in one direction and then in the other.

Referring now to Fig. 60 and supposing that the loop *4* is revolving in the direction of the curved arrow shown between the upper edges of the pole pieces, it will be evident that just as the loop stands in the vertical position, its horizontal members will be moving in a horizontal direction, parallel with the lines of force and, therefore, not cutting them at all. The electromotive force and the current will, therefore, be zero at this time.

As the loop advances toward the position shown in dotted lines, the upper portion of the loop that is parallel with the axis will begin to cut downwardly through the lines of force, and likewise the lower portion of the loop that is parallel with the axis will begin to cut upwardly through the lines of force. This will cause electromotive forces in opposite directions to be generated in these portions of the loop, and these will tend to aid each other in causing a current to circulate in the loop in the direction shown by the arrows associated with the dotted representation of the loop. It is evident that as the motion of the loop progresses, the rate of cutting the lines of force will increase and will be a maximum when the loop reaches a horizontal position, or at that time the two portions of the loop that are parallel with the axis will be traveling at right angles to the lines of force. At this point, therefore, the electromotive force and the current will be a maximum.

From this point until the loop again assumes a vertical position, the cutting of the lines of force will still be in the same direction, but at a constantly decreasing rate, until, finally, when the loop is vertical the movement of the parts of the loop that are parallel with the axis will be in the direction of the lines of force and, therefore, no cutting will take place. At this point, therefore, the electromotive force and the current in the loop again will be zero. We have seen, therefore, that in this half revolution of the loop from the time when it was in a vertical position to a time when it was again in a vertical position but upside down, the electromotive force varied from zero to a maximum and back to zero, and the current did the same.

It is easy to see that, as the loop moves through the next half revolution, an exactly similar rise and fall of electromotive force and current will take place; but this will be in the opposite direction, since that portion of the loop which was going down through the lines of force is now going up, and the portion which was previously going up is now going down.

The law concerning the generation of electromotive force and current in a conductor that is cutting through lines of magnetic force, may be stated in another way, when the conductor is bent into the form of a loop, as in the case under consideration: Thus, *if the number of lines of force which pass through a conducting loop be varied, electromotive forces will be generated in the loop.* This will be true whether the number of lines passing through the loop be varied by moving the loop within the field of force or by varying the field of force itself. In any case, *if the number of lines of force be increased, the current will flow in one way, and if it be diminished the current will flow in the other way.* The amount of the current will depend, other things being equal, on the rate at which the lines of force through the loop are being varied, regardless of the method by which the variation is made to take place. One revolution of the loop, therefore, results in a complete cycle of alternating current consisting of one positive followed by one negative impulse.

The diagram of Fig. 60 is merely intended to illustrate the principle involved. In the practical construction of magneto generators more than one bar magnet is used, and, in addition, the conductors in the armature are so arranged as to include a great many loops of wire. Furthermore, the conductors in the armature are wound around an iron core so that the path through the armature loops or turns may present such low reluctance to the passage of lines of force as to greatly increase the number of such lines and also to cause practically all of them to go through the loops in the armature conductor.

Armature. The iron upon which the armature conductors are wound is called the *core*. The core of an ordinary armature is shown in Fig. 61. This is usually made of soft gray cast iron, turned so as to form bearing surfaces at *1* and *2*, upon which the entire armature may rotate, and also turned so that the surfaces *3* will be truly cylindrical with respect to the axis through the center of the shaft. The armature conductors are put on by winding the space between the two parallel faces *4* as full of insulated wire as space will admit. One end of the armature winding is soldered to the pin *5* and, therefore, makes contact with the frame of the generator, while the other end of the winding is soldered to the pin *6*, which engages the stud *7*, carried in an insulating bushing in a longitudinal hole in the end of the armature shaft. It is thus seen that the frame of the machine will form one terminal of the armature winding, while the insulated stud *7* will form the other terminal.

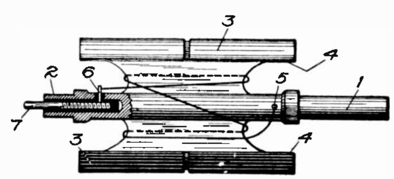


Fig. 61. Generator Armature

Another form of armature largely employed in recent magneto generators is illustrated in Fig. 62. In this the shaft on which the armature revolves does not form an integral part of the armature core

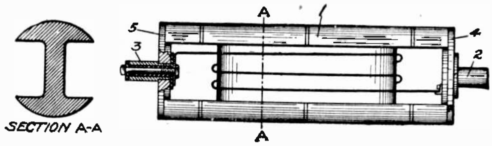


Fig. 62. Generator Armature

but consists of two cylindrical studs *2* and *3* projecting from the centers of disks *4* and *5*, which are screwed to the ends of the core *1*. This **H** type of armature core, as it is called, while containing somewhat more parts than the simpler type shown in Fig. 61, possesses distinct advantages in the matter of winding. By virtue of its simpler form of winding space, it is easier to insulate and easier to wind, and furthermore, since the shaft does not run through the winding space, it is capable of holding a considerably greater number of turns of wire. The ends of the armature winding are connected, one directly to the frame and the other to an insulated pin, as is shown in the illustration.

The method commonly employed of associating the pole pieces with each other and with the permanent magnets is shown in Fig.

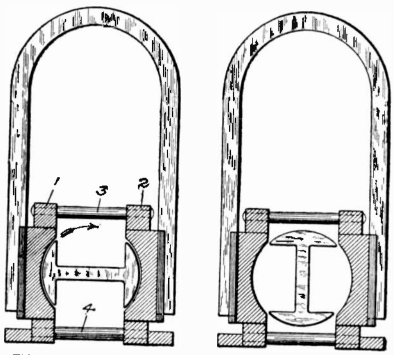
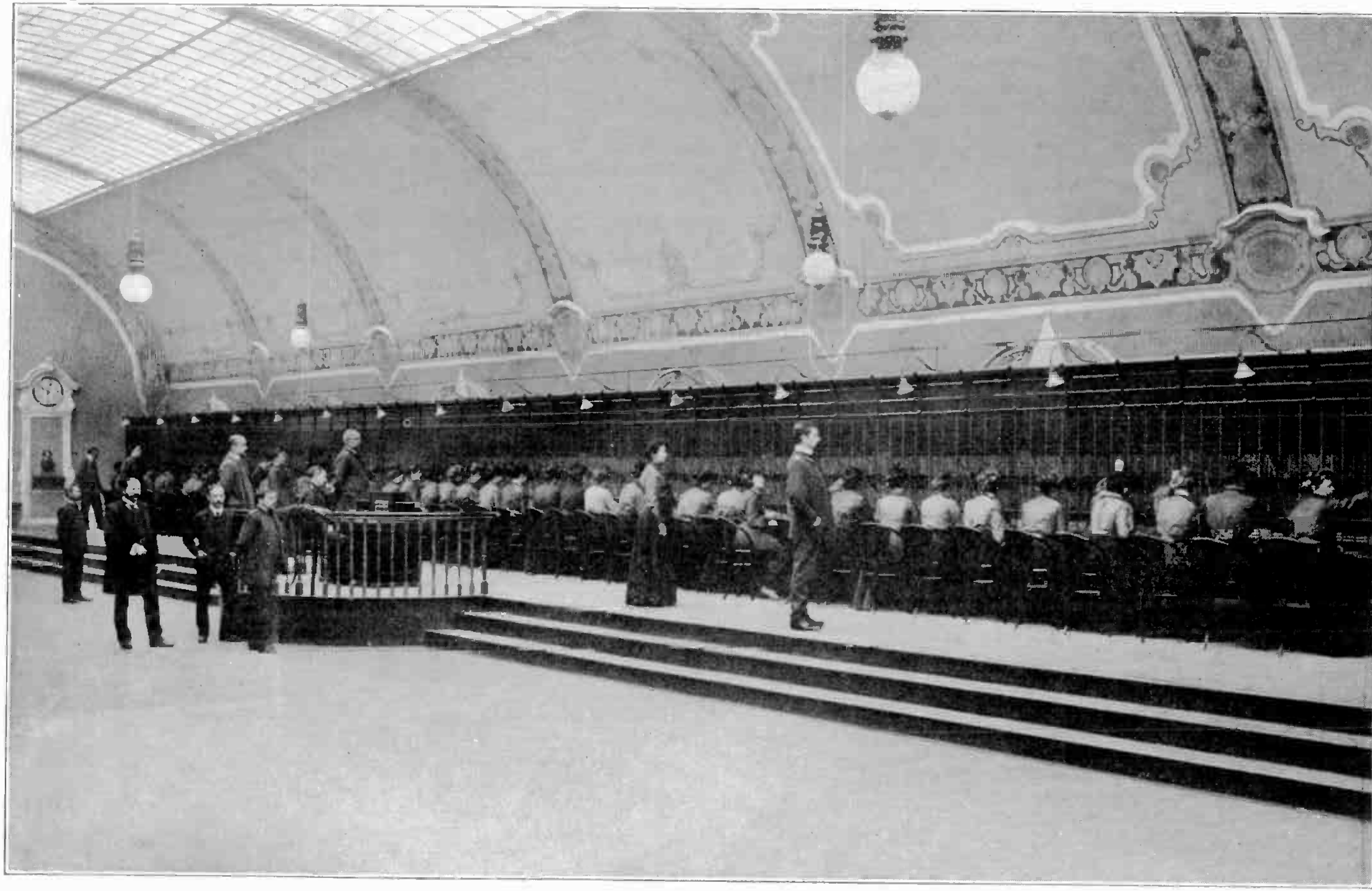


Fig. 63. Generator Field and Armature

63. It is very important that the space in which the armature revolves shall be truly cylindrical, and that the bearings for the armature shall be so aligned as to make the axis of rotation of the armature coincide with the axis of the cylindrical surface of the



VIEW OF A LARGE FOREIGN MULTIPLE SWITCHBOARD

pole pieces. A rigid structure is, therefore, required and this is frequently secured, as shown in Fig. 63, by joining the two pole pieces *1* and *2* together by means of heavy brass rods *3* and *4*, the rods being shouldered and their reduced ends passed through holes in flanges extending from the pole pieces, and riveted. The bearing plates in which the armature is journaled are then secured to the ends of these pole pieces, as will be shown in subsequent illustrations. This assures proper rigidity between the pole pieces and also between the pole pieces and the armature bearings.

The reason why this degree of rigidity is required is that it is necessary to work with very small air gaps between the armature core and its pole pieces and unless these generators are mechanically well made they are likely to alter their adjustment and thus allow the armature faces to scrape or rub against the pole pieces. In Fig. 63 one of the permanent horseshoe magnets is shown, its ends resting in grooves on the outer faces of the pole pieces and usually clamped thereto by means of heavy iron machine screws.

With this structure in mind, the theory of the magneto generator developed in connection with Fig. 60 may be carried a little further. When the armature lies in the position shown at the left of Fig. 63, so that the center position of the core is horizontal, a good path is afforded for the lines of force passing from one pole to the other. Practically all of these lines will pass through the iron of the core rather than through the air, and, therefore, practically all of them will pass through the convolutions of the armature winding.

When the armature has advanced, say 45 degrees, in its rotation in the direction of the curved arrow, the lower right-hand portion of the armature flange will still lie opposite the lower face of the right-hand pole piece and the upper left-hand portion of the armature flange will still lie opposite the upper face of the left-hand pole piece. As a result there will still be a good path for the lines of force through the iron of the core and comparatively little change in the number of lines passing through the armature winding. As the corners of the armature flange pass away from the corners of the pole pieces, however, there is a sudden change in condition which may be best understood by reference to the right-hand portion of Fig. 63. The lines of force now no longer find path through the center portion of the armature core—that lying at right angles to their direction of flow.

Two other paths are at this time provided through the now horizontal armature flanges which serve almost to connect the two pole pieces. The lines of force are thus shunted out of the path through the armature coils and there is a sudden decrease from a large number of lines through the turns of the winding to almost none. As the armature continues in its rotation the two paths through the flanges are broken, and the path through the center of the armature core and, therefore, through the coils themselves, is reëstablished.

As a result of this consideration it will be seen that in actual practice the change in the number of lines passing through the armature winding is not of the gradual nature that would be indicated by a consideration of Fig. 60 alone, but rather, is abrupt, as the corners

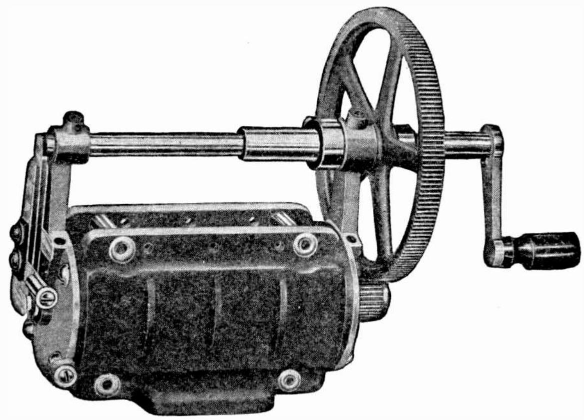


Fig. 64. Generator with Magnets Removed

of the armature flanges leave the corners of the pole pieces. This abrupt change produces a sudden rise in electromotive force just at these points in the rotation, and, therefore, the electromotive force and the current curves of these magneto generators are not usually of the smooth sine-wave type but rather of a form resembling the sine wave with distinct humps added to each half cycle.

As is to be expected from any two-pole alternating generator, there is one cycle of current for each revolution of the armature. Under ordinary conditions a person is able to turn the generator handle at the rate of about two hundred revolutions a minute, and as the ratio of gearing is about five to one, this results in about one thousand revolutions per minute of the generator, and, therefore, in a current of about one thousand cycles per minute, this varying widely according to the person who is doing the turning.

The end plates which support the bearings for the armature are usually extended upwardly, as shown in Fig. 64, so as to afford bearings for the crank shaft. The crank shaft carries a large spur gear which meshes with a pinion in the end of the armature shaft, so that the user may cause the armature to revolve rapidly. The construction shown in Fig. 64 is typical of that of a modern magneto generator, it being understood that the permanent magnets are removed for clearness of illustration.

Fig. 65 is a view of a completely assembled generator such as is used for service requiring a comparatively heavy output. Other

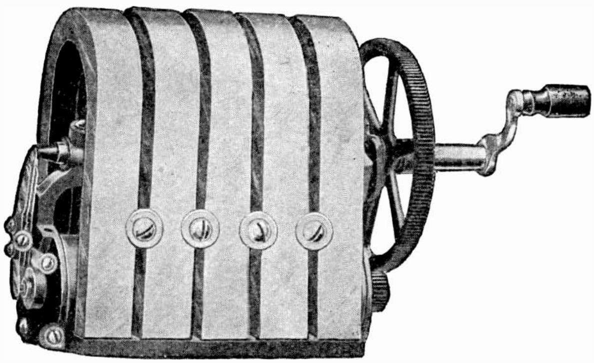


Fig. 65. Five-Bar Generator

types of generators having two, three, or four permanent magnets instead of five, as shown in this figure, are also standard.

Referring again to Fig. 61 it will be remembered that one end of the armature winding shown diagrammatically in that figure, is terminated in the pin *5*, while the other terminates in the pin *7*. When the armature is assembled in the frame of the generator it is evident that the frame itself is in metallic connection with one end of the armature winding, since the pin *5* is in metallic contact with the armature casting and this is in contact with the frame of the generator through the bearings. The frame of the machine is, therefore, one terminal of the generator. When the generator is assembled a spring of one form or another always rests against the terminal pin *7* of the armature so as to form a terminal for the armature winding of such a nature as to permit the armature to rotate freely. Such spring, therefore, forms the other terminal of the generator.

Automatic Shunt. Under nearly all conditions of practice it is desirable to have the generator automatically perform some switching function when it is operated. As an example, when the generator is connected so that its armature is in series in a telephone line, it is quite obvious that the presence of the resistance and the impedance of the armature winding would be objectionable if left in the circuit through which the voice currents had to pass. For this reason, what is termed an *automatic shunt* is employed on generators designed for series work; this shunt is so arranged that it will automatically shunt or short-circuit the armature winding when it is at rest and also break this shunt when the generator is operated, so as to allow the current to pass to line.

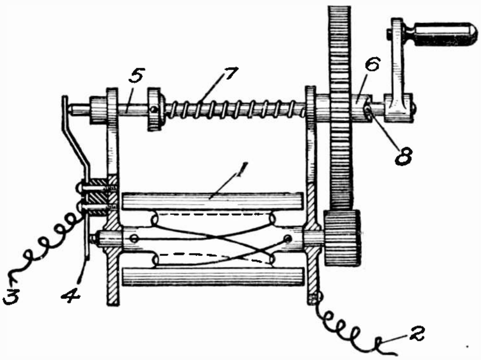


Fig 66. Generator Shunt Switch

A simple and much-used arrangement for this purpose is shown in Fig. 66, where *1* is the armature; *2* is a wire leading from the frame of the generator and forming one terminal of the generator circuit; and *3* is a wire forming the other terminal of the generator circuit, this wire being attached to the spring *4*, which rests against the center pin of the armature so as to make contact with the opposite end of the armature winding to that which is connected with the frame. The circuit through the armature may be traced from the terminal wire *2* through the frame; thence through the bearings to the armature *1* and through the pin to the right-hand side of the armature winding. Continuing the circuit through the winding itself, it passes to the center pin projecting from the left-hand end of the armature shaft; thence to the spring *4* which rests against this pin; and thence to the terminal wire *3*.

Normally, this path is shunted by what is practically a short circuit, which may be traced from the terminal *2* through the frame of the generator to the crank shaft *5;* thence to the upper end of the spring *4* and out by the terminal wire *3*. This is the condition which ordinarily exists and which results in the removal of the resistance and the impedance on the armature winding from any circuit in which the generator is placed, as long as the generator is not operated.

An arrangement is provided, however, whereby the crank shaft *5* will be withdrawn automatically from engaging with the upper end of the spring *4*, thus breaking the shunt around the armature circuit, whenever the generator crank is turned. In order to accomplish this the crank shaft *5* is capable of partial rotation and of slight longitudinal movement within the hub of the large gear wheel. A spring *7* usually presses the crank shaft toward the left and into engagement with the spring *4*. A pin *8* carried by the crank shaft, rests in a **V**-shaped notch in the end of the hub *6* and as a result, when the crank is turned the pin rides on the surface of this notch before the large gear wheel starts to turn, and thus moves the crank shaft *5* to the right and breaks the contact between it and the spring *4*. Thus, as long as the generator is being operated, its armature is connected in the circuit of the line, but as soon as it becomes idle the armature is automatically short-circuited. Such devices as this are termed *automatic shunts.*

In still other cases it is desirable to have the generator circuit normally open so that it will not affect in any way the electrical characteristics of the line while the line is being used for talking. In this case the arrangement is made so that the generator will automatically be placed in proper circuit relation with the line when it is operated.

A common arrangement for doing this is shown in Fig. 67, wherein the spring *1* normally rests against the contact pin of the armature and forms one terminal of the armature circuit. The spring *2* is adapted to form the other terminal of the armature circuit but it is normally insulated from everything. The circuit of the generator is, therefore, open between the spring *2* and the shaft *3*,

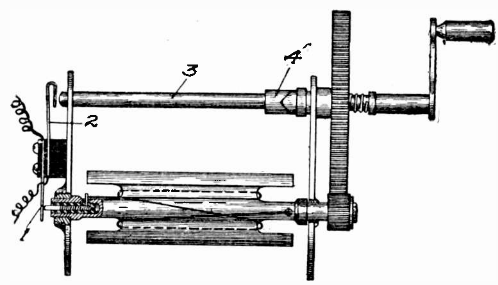


Fig. 67. Generator Cut-In Switch

but as soon as the generator is operated the crank shaft is bodily moved to the left by means of the **V**-shaped notch in the driving collar *4* and is thus made to engage the spring *2*. The circuit of the generator is then completed from the spring *1* through the armature pin to the armature winding; thence to the frame of the machine and through shaft *3* to the spring *2*. Such devices as this are largely used in connection with so-called "bridging" telephones in which the generators and bells are adapted to be connected in multiple across the line.

A better arrangement for accomplishing the automatic switching on the part of the generator is to make no use of the crank shaft as a part of the conducting path as is the case in both Figs. 66 and 67, but to make the crank shaft, by its longitudinal movement, impart the necessary motion to a switch spring which, in turn, is made to engage or disengage a corresponding contact spring. An arrangement of this kind that is in common use is shown in Fig. 68. This needs no further explanation than to say that the crank shaft is provided on its end with an insulating stud *1*, against which a switching spring *2* bears. This spring normally rests against another switch spring *3*, but when the generator crank shaft moves to the right upon the turning of the crank, the spring *2* disengages spring *3* and engages spring *4*, thus completing the circuit of the generator armature. It is seen that this operation accomplishes the breaking of one circuit and the making of another, a function that will be referred to later on in this work.

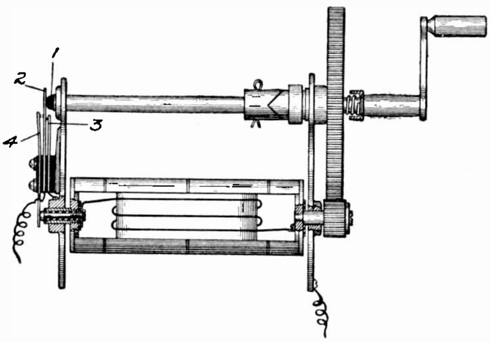


Fig. 68. Generator Cut-In Switch

Pulsating Current. Sometimes it is desirable to have a generator capable of developing a pulsating current instead of an alternating current; that is, a current which will consist of impulses all in one direction rather than of impulses alternating in direction. It is obvious that this may be accomplished if the circuit of the generator be broken during each half revolution so that its circuit is completed only when current is being generated in one direction.

Such an arrangement is indicated diagrammatically in Fig. 69. Instead of having one terminal of the armature winding brought out through the frame of the generator as is ordinarily done, both terminals are brought out to a commuting device carried on the end of the armature shaft. Thus, one end of the loop representing the armature winding is shown connected directly to the armature pin *1*, against which bears a spring *2*, in the usual manner. The other end of the armature winding is carried directly to a disk *3*, mounted *on* but insulated *from* the shaft and revolving therewith. One-half of the circumferential surface of this disk is of insulating material *4* and a spring *5* rests against this disk and bears alternately upon the conducting portion *3* or the insulating portion *4*, according to the position of the armature in its revolution. It is obvious that when the generator armature is in the position shown the circuit through it is from the spring *2* to the pin *1*; thence to one terminal of the armature loop; thence through the loop and back to the disk *3* and out by the spring *5*. If, however, the armature were turned slightly, the spring *5* would rest on the insulating portion *4* and the circuit would be broken.

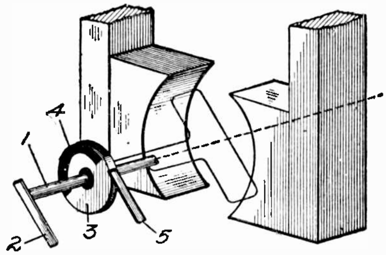


Fig. 69. Pulsating-Current Commutator

It is obvious that if the brush *5* is so disposed as to make contact with the disk *3* only during that portion of the revolution while positive current is being generated, the generator will produce positive pulsations of current, all the negative ones being cut out. If, on the other hand, the spring *5* may be made to bear on the opposite side of the disk, then it is evident that the positive impulses would all be cut out and the generator would develop only negative impulses. Such a generator is termed a "direct-current" generator or a "pulsating-current" generator.

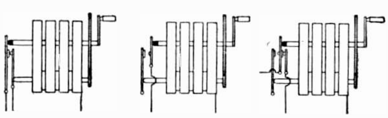


Fig. 70. Generator Symbols

The symbols for magneto or hand generators usually embody a simplified side view, showing the crank and the gears on one side and the shunting or other switching device on the other. Thus in Fig. 70 are shown three such symbols, differing from each other only in the details of the switching device. The one at the left shows the simple shunt, adapted to short-circuit the generator at all times save when it is in operation. The one in the center shows the cut-in, of which another form is described in connection with Fig. 67; while the symbol at the right of Fig. 70 is of the make-and-break device, discussed in connection with Fig. 68. In such diagrammatic representations of generators it is usual to somewhat exaggerate the size of the switching springs, in order to make clear their action in respect to the circuit connections in which the generator is used.

Polarized Ringer. The polarized bell or ringer is, as has been stated, the device which is adapted to respond to the currents sent out by the magneto generator. In order that the alternately opposite currents may cause the armature to move alternately in opposite directions, these bells are polarized, *i. e.*, given a definite magnetic set, so to speak; so the effect of the currents in the coils is not to create magnetism in normally neutral iron, but rather to alter the magnetism in iron already magnetized.

Western Electric Ringer. A typical form of polarized bell is shown in Fig. 71, this being the standard bell or ringer of the Western Electric Company. The two electromagnets are mounted side by side, as shown, by attaching their cores to a yoke piece *1* of soft iron. This yoke piece also carries the standards *2* upon which the gongs are mounted. The method of mounting is such that the standards may be adjusted slightly so as to bring the gongs closer *to* or farther *from* the tapper.

The soft iron yoke piece *1* also carries two brass posts *3* which, in turn, carry another yoke *4* of brass. In this yoke *4* is pivoted, by means of trunnion screws, the armature *5*, this extending on each side of the pivot so that its ends lie opposite the free poles of the electromagnets. From the center of the armature projects the tapper rod carrying the ball or striker which plays between the two gongs.

In order that the armature and cores may be normally polarized, a permanent magnet *6* is secured to the center of the yoke piece *1*. This bends around back of the electromagnets and comes into close proximity to the armature *5*. By this means one end of each of the electromagnet cores is given one polarity—say north—while the armature is given the other polarity—say south. The two coils of the electromagnet are connected together in series in such a way that current in a given direction will act to produce a north pole in one of the free poles and a south pole in the other. If it be assumed that the permanent magnet maintains the armature normally of south polarity and that the current through the coils is of such direction as to make the left-hand core north and the right-hand core south, then it is evident that the left-hand end of the armature will be attracted and the right-hand end repelled. This will throw the tapper rod to the right and sound the right-hand bell. A reversal in current will obviously produce the opposite effect and cause the tapper to strike the left-hand bell.

An important feature in polarized bells is the adjustment between the armature and the pole pieces. This is secured in the

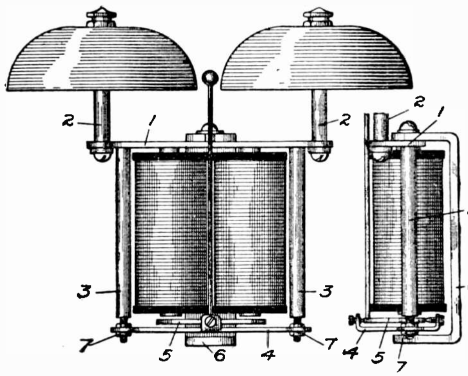


Fig. 71. Polarized Bell

Western Electric bell by means of the nuts *7*, by which the yoke *4* is secured to the standards *3*. By moving these nuts up or down on the standards the armature may be brought closer *to* or farther *from* the poles, and the device affords ready means for clamping the parts into any position to which they may have been adjusted.

Kellogg Ringer. Another typical ringer is that of the Kellogg Switchboard and Supply Company, shown in Fig. 72. This differs from that of the Western Electric Company mainly in the details by which the armature adjustment is obtained. The armature supporting yoke *1* is attached directly to the cores of the magnets, no supporting side rods being employed. Instead of providing means whereby the armature may be adjusted toward or from the poles, the reverse practice is employed, that is, of making the poles themselves extensible. This is done by means of the iron screws *2* which form extensions of the cores and which may be made to approach or recede from the armature by turning them in such direction as to screw them in or out of the core ends.

Biased Bell. The pulsating-current generator has already been discussed and its principle of operation pointed out in connection with Fig. 69. The companion piece to this generator is the so-called biased ringer. This is really nothing but a common alternating-current polarized ringer with a light spring so arranged as to hold the armature normally in one of its extreme positions so that the tapper will rest against one of the gongs. Such a ringer is shown in Fig. 73 and needs no further explanation. It is obvious that if a current flows in the coils of such a ringer in a direction tending to move the tapper toward the left, then no sound will result because the

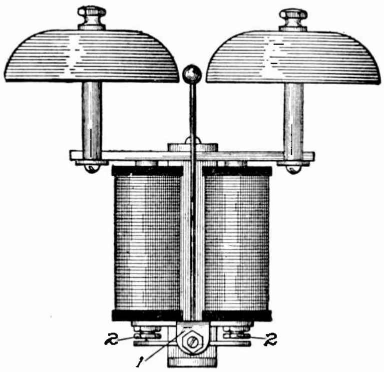


Fig. 72. Polarized Bell

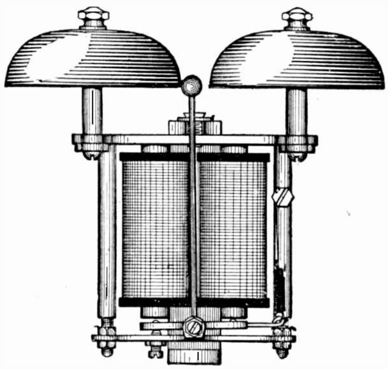


Fig. 73. Biased Bell

tapper is already moved as far as it can be in that direction. If, however, currents in the opposite direction are caused to flow through the windings, then the electromagnetic attraction on the armature will overcome the pull of the spring and the tapper will move over and strike the right-hand gong. A cessation of the current will allow the spring to exert itself and throw the tapper back into engagement with the left-hand gong. A series of such pulsations in the proper direction will, therefore, cause the tapper to play between the two gongs and ring the bell as usual. A series of currents in a wrong direction will, however, produce no effect.

Conventional Symbols. In Fig. 74 are shown six conventional symbols of polarized bells. The three at the top, consisting merely of two circles representing the magnets in plan view, are perhaps to be preferred as they are well standardized, easy to draw, and rather suggestive. The three at the bottom, showing the ringer as a whole in side elevation, are somewhat more specific, but are objectionable in that they take more space and are not so easily drawn.

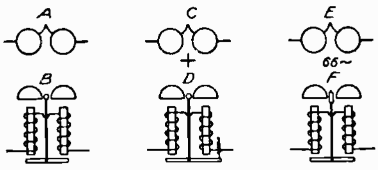


Fig. 74. Ringer Symbols

Symbols *A* or *B* may be used for designating any ordinary polarized ringer. Symbols *C* and *D* are interchangeably used to indicate a biased ringer. If the bell is designed to operate only on positive impulses, then the plus sign is placed opposite the symbol, while a minus sign so placed indicates that the bell is to be operated only by negative impulses.

Some specific types of ringers are designed to operate only on a given frequency of current. That is, they are so designed as to be responsive to currents having a frequency of sixty cycles per second, for instance, and to be unresponsive to currents of any other frequency. Either symbols *E* or *F* may be used to designate such ringers, and if it is desired to indicate the particular frequency of the ringer this is done by adding the proper numeral followed by a short reversed curve sign indicating frequency. Thus 50 ~ would indicate a frequency of fifty cycles per second.

CHAPTER VIII

THE HOOK SWITCH

Purpose. In complete telephone instruments, comprising both talking and signaling apparatus, it is obviously desirable that the two sets of apparatus, for talking and signaling respectively, shall not be connected with the line at the same time. A certain switching device is, therefore, necessary in order that the signaling apparatus alone may be left operatively connected with the line while the instrument is not being used in the transmission of speech, and in order that the signaling apparatus may be cut out when the talking apparatus is brought into play.

In instruments employing batteries for the supply of transmitter current, another switching function is the closing of the battery circuit through the transmitter and the induction coil when the instrument is in use for talking, since to leave the battery circuit closed all the time would be an obvious waste of battery energy.

In the early forms of telephones these switching operations were performed by a manually operated switch, the position of which the user was obliged to change before and after each use of the telephone. The objection to this was not so much in the manual labor imposed on the user as in the tax on his memory. It was found to be practically a necessity to make this switching function automatic, principally because of the liability of the user to forget to move the switch to the proper position after using the telephone, resulting not only in the rapid waste of the battery elements but also in the inoperative condition of the signal-receiving bell. The solution of this problem, a vexing one at first, was found in the so-called automatic hook switch or switch hook, by which the circuits of the instrument were made automatically to assume their proper conditions by the mere act, on the part of the user, of removing the receiver from, or placing it upon, a conveniently arranged hook or fork projecting from the side of the telephone casing.

Automatic Operation. It may be taken as a fundamental principle in the design of any piece of telephone apparatus that is to be generally used by the public, that the necessary acts which a person must perform in order to use the device must, as far as possible, follow as a natural result from some other act which it is perfectly obvious to the user that he must perform. So in the case of the switch hook, the user of a telephone knows that he must take the receiver from its normal support and hold it to his ear; and likewise, when he is through with it, that he must dispose of it by hanging it upon a support obviously provided for that purpose.

In its usual form a forked hook is provided for supporting the receiver in a convenient place. This hook is at the free end of a pivoted lever, which is normally pressed upward by a spring when the receiver is not supported on it. When, however, the receiver is supported on it, the lever is depressed by its weight. The motion of the lever is mechanically imparted to the members of the switch proper, the contacts of which are usually enclosed so as to be out of reach of the user. This switch is so arranged that when the hook is depressed the circuits are held in such condition that the talking apparatus will be cut out, the battery circuit opened, and the signaling apparatus connected with the line. On the other hand, when the hook is in its raised position, the signaling apparatus is cut out, the talking apparatus switched into proper working relation with the line, and the battery circuit closed through the transmitter.

In the so-called common-battery telephones, where no magneto generator or local battery is included in the equipment at the subscriber's station, the mere raising of the hook serves another important function. It acts, not only to complete the circuit through the substation talking apparatus, but, by virtue of the closure of the line circuit, permits a current to flow over the line from the central-office battery which energizes a signal associated with the line at the central office. This use of the hook switch in the case of the common-battery telephone is a good illustration of the principle just laid down as to making all the functions which the subscriber has to perform depend, as far as possible, on acts which his common sense alone tells him he must do. Thus, in the common-battery telephone the subscriber has only to place the receiver at his ear and ask for what he wants. This operation automatically displays a signal at the central office and he does nothing further until the operator inquires for the number that he wants. He has then nothing to do but wait until the called-for party responds, and after the conversation his own personal convenience demands that he shall dispose of the receiver in some way, so he hangs it up on the most convenient object, the hook switch, and thereby not only places the apparatus at his telephone in proper condition to receive another call, but also conveys to the central office the signal for disconnection.

Likewise in the case of telephones operating in connection with automatic exchanges, the hook switch performs a number of functions automatically, of which the subscriber has no conception; and while, in automatic telephones, there are more acts required of the user than in the manual, yet a study of these acts will show that they all follow in a way naturally suggested to the user, so that he need have but the barest fundamental knowledge in order to properly make use of the instrument. In all cases, in properly designed apparatus, the arrangement is such that the failure of the subscriber to do a certain required act will do no damage to the apparatus or to the system, and, therefore, will inconvenience only himself.

Design. The hook switch is in reality a two-position switch, and while at present it is a simple affair, yet its development to its high state of perfection has been slow, and its imperfections in the past have been the cause of much annoyance.

Several important points must be borne in mind in the design of the hook switch. The spring provided to lift the hook must be sufficiently strong to accomplish this purpose and yet must not be strong enough to prevent the weight of the receiver from moving the switch to its other position. The movement of this spring must be somewhat limited in order that it will not break when used a great many times, and also it must be of such material and shape that it will not lose its elasticity with use. The shape and material of the restoring spring are, of course, determined to a considerable extent by the length of the lever arm which acts on the spring, and on the space which is available for the spring.

The various contacts by which the circuit changes are brought about upon the movement of the hook-switch lever usually take the form of springs of German silver or phosphor-bronze, hard rolled so as to have the necessary resiliency, and these are usually tipped with platinum at the points of contact so as to assure the necessary character of surface at the points where the electric circuits are made or broken. A slight sliding movement between each pair of contacts as they are brought together is considered desirable, in that it tends to rub off any dirt that may have accumulated, yet this sliding movement should not be great, as the surfaces will then cut each other and, therefore, reduce the life of the switch.

Contact Material. On account of the high cost of platinum, much experimental work has been done to find a substitute metal suitable for the contact points in hook switches and similar uses in the manufacture of telephone apparatus. Platinum is unquestionably the best known material, on account of its non-corrosive and heat-resisting qualities. Hard silver is the next best and is found in some first-class apparatus. The various cheap alloys intended as substitutes for platinum or silver in contact points may be dismissed as worthless, so far as the writers' somewhat extensive investigations have shown.

In the more recent forms of hook switches, the switch lever itself does not form a part of the electrical circuit, but serves merely as the means by which the springs that are concerned in the switching functions are moved into their alternate coöperative relations. One advantage in thus insulating the switch lever from the current-carrying portions of the apparatus and circuits is that, since it necessarily projects from the box or cabinet, it is thus liable to come in contact with the person of the user. By insulating it, all liability of the user receiving shocks by contact with it is eliminated.

Wall Telephone Hooks. *Kellogg.* A typical form of hook switch, as employed in the ordinary wall telephone sets, is shown in Fig. 75, this being the standard hook of the Kellogg Switchboard and Supply Company. In this the lever *1* is pivoted at the point *3* in a bracket *5* that forms the base of all the working parts and the means of securing the entire hook switch to the box or framework of the telephone. This switch lever is normally pressed upward by a spring *2*, mounted on the bracket *5*, and engaging the under side of the hook lever at the point *4*. Attached to the lever arm *1* is an insulated pin *6*. The contact springs by which the various electrical circuits are made and broken are shown at *7*, *8*, *9*, *10*, and *11*, these being mounted in one group with insulated bushings between them; the entire group is secured by machine screws to a lug projecting horizontally from the bracket *5*. The center spring *9* is provided with a forked extension which embraces the pin *6* on the hook lever. It is obvious that an up-and-down motion of the hook lever will move the long spring *9* in such manner as to cause electrical contact either between it and the two upper springs *7* and *8*, or between it and the two lower springs *10* and *11*. The hook is shown in its raised position, which

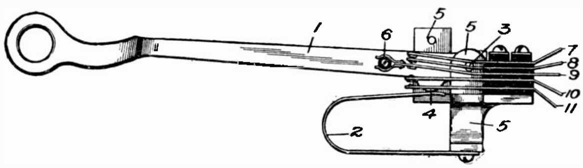
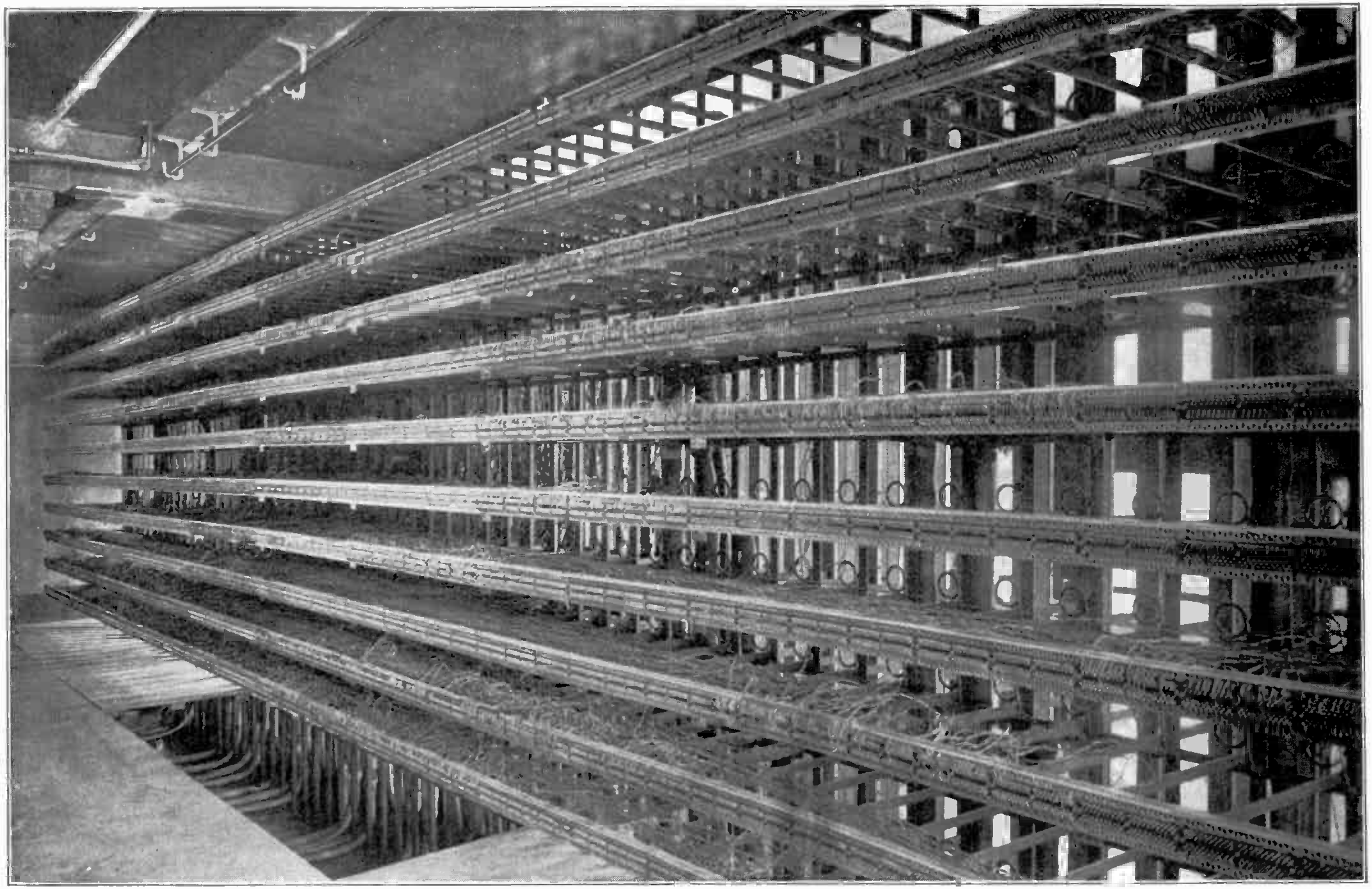


Fig. 75. Long Lever Hook Switch

is the position required for talking. When lowered the two springs *7* and *8* are disengaged from the long spring *9* and from each other, and the three springs *9*, *10*, and *11* are brought into electrical engagement, thus establishing the necessary signaling conditions.

The right-hand ends of the contact springs are shown projecting beyond the insulating supports. This is for the purpose of facilitating making electrical joints between these springs and the various wires which lead from them. These projecting ends are commonly referred to as ears, and are usually provided with holes or notches into which the connecting wire is fastened by soldering.

Western Electric. Fig. 76 shows the type of hook switch quite extensively employed by the Western Electric Company in wall telephone sets where the space is somewhat limited and a compact arrangement is desired. It will readily be seen that the principle on which this hook switch operates is similar to that employed in Fig. 75, although the mechanical arrangement of the parts differs radically. The hook lever *1* is pivoted at *3* on a bracket *2*, which serves to support all the other parts of the switch. The contact springs are shown at *4*, *5*, and *6*, and this latter spring *6* is so designed as to make it serve as an actuating spring for the hook. This is accomplished by having the curved end of this spring press against the lug *7* of the hook and thus tend to raise the hook when it is relieved of the weight of the receiver. The two shorter springs *8* and *9* have no electrical function but merely serve as supports against which the springs *4* and *5* may rest when the receiver is on the



LINE SIDE OF LARGE MAIN DISTRIBUTING FRAME hook, these springs *4* and *5* being given a light normal tension toward the stop springs *8* and *9*. It is obvious that in the particular arrangement of the springs in this switch no contacts are closed when the receiver is on the hook.

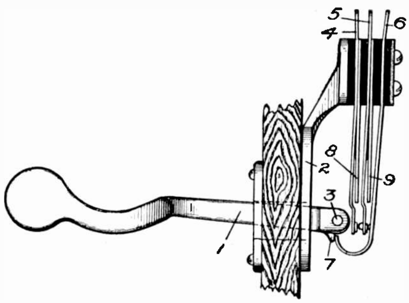


Fig. 76. Short Lever Hook Switch

Concerning this latter feature, it will be noted that the particular form of Kellogg hook switch, shown in Fig. 75, makes two contacts and breaks two when it is raised. Similarly the Western Electric Company's makes two contacts but does not break any when raised. From such considerations it is customary to speak of a hook such as that shown in Fig. 75 as having two make and two break contacts, and such a hook as that shown in Fig. 76 as having two make contacts.

It will be seen from either of these switches that the modification of the spring arrangement, so as to make them include a varying number of make-and-break contacts, is a simple matter, and switches of almost any type are readily modified in this respect.

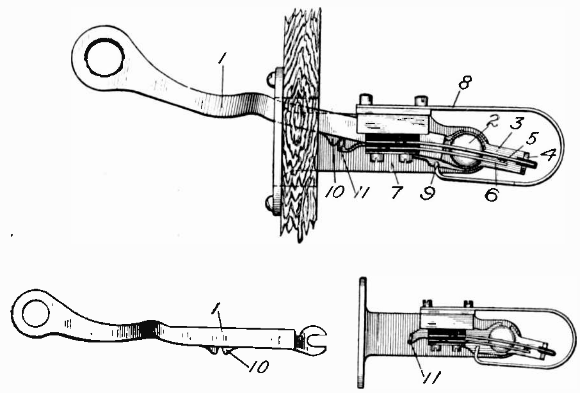


Fig. 77. Removable Lever Hook Switch

Dean. In Fig. 77 is shown a decidedly unique hook switch for wall telephone sets which forms the standard equipment of the Dean Electric Company. The hook lever *1* is pivoted at *2*, an auxiliary lever *3* also being pivoted at the same point. The auxiliary lever *3* carries at its rear end a slotted lug *4*, which engages the long contact spring *5*, and serves to move it up and down so as to engage and disengage the spring *6*, these two springs being mounted on a base lug extending from the base plate *7*, upon which the entire hook-switch mechanism is mounted. The curved spring *8*, also mounted on this same base, engages the auxiliary lever *3* at the point *9* and normally serves to press this up so as to maintain the contact springs *5* in engagement with contact spring *6*. The switch springs are moved entirely by the auxiliary lever *3*, but in order that this lever *3* may be moved as required by the hook lever *1*, this lever is provided with a notched lug *10* on its lower side, which notch is engaged by a forwardly projecting lug *11* that is integral with the auxiliary lever *3*. The switch lever may be bodily removed from the remaining parts of the hook switch by depressing the lug *11* with the finger, so that it disengages the notch in lug *10*, and then drawing the hook lever out of engagement with the pivot stud *2*, as shown in the lower portion of the figure. It will be noted that the pivotal end of the hook lever is made with a slot instead of a hole as is the customary practice.

The advantage of being able to remove the hook switch bodily from the other portions arises mainly in connection with the shipment or transportation of instruments. The projecting hooks cause the instruments to take up more room and thus make larger packing boxes necessary than would otherwise be used. Moreover, in handling the telephones in store houses or transporting them to the places where they are to be used, the projecting hook switch is particularly liable to become damaged. It is for convenience under such conditions that the Dean hook switch is made so that the switch lever may be removed bodily and placed, for instance, inside the telephone box for transportation.

Desk-Stand Hooks. The problem of hook-switch design for portable desk telephones, while presenting the same general characteristics, differs in the details of construction on account of the necessarily restricted space available for the switch contacts in the desk telephone.

Western Electric. In Fig. 78 is shown an excellent example of hook-switch design as applied to the requirements of the ordinary portable desk set. This figure is a cross-sectional view of the base and standard of a familiar type of desk telephone. The base itself is of stamped metal construction, as indicated, and the standard which supports the transmitter and the switch hook for the receiver is composed of a black enameled or nickel-plated brass tube *1*, attached to the base by a screw-threaded joint, as shown. The switch lever *2* is pivoted at *3* in a brass plug *4*, closing the upper end of the tube forming the standard. This brass plug supports also the transmitter, which is not shown in this figure. Attached to the plug *4* by the screw *5* is a heavy strip *6*, which reaches down through the tube to the base plate of the standard and is held therein by a screw *7*. The plug *4*, carrying with it the switch-hook lever *2* and the brass strip *6*, may be lifted bodily out of the standard *1* by taking out the screw *7* which holds the strip *6* in place, as is clearly indicated. On the strip *6* there is mounted the group of switch springs by which the circuit changes of the instrument are brought about when the hook is raised or lowered. The spring *8* is longer than the others, and projects upwardly far enough to engage the lug on the switch-hook lever *2*. This spring, which is so bent as to close the contacts at the right when not prevented by the switch lever, also serves as an actuating spring to raise the lever *2* when the receiver is removed from it. This spring, when the receiver is removed from the hook, engages the two springs at the right, as shown, or when the receiver is placed on the hook, breaks contact with the two right-hand springs and makes contact respectively with the left-hand spring and also with the contact *9* which forms the transmitter terminal.

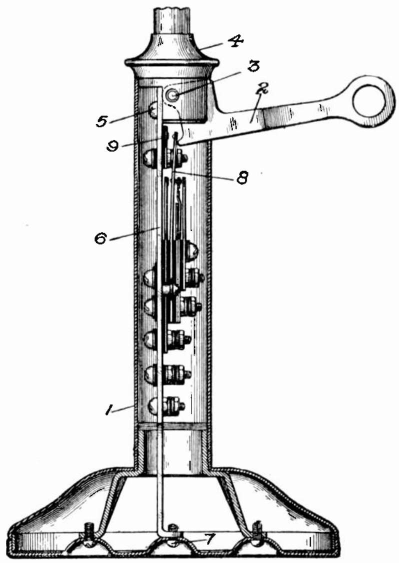


Fig. 78. Desk-Stand Hook Switch

It is seen from an inspection of this switch hook that it has two make and two break contacts. The various contact springs are connected with the several binding posts shown, these forming the connectors for the flexible cord conductors leading into the base and up through the standard of the desk stand. By means of the conductors in this cord the circuits are led to the other parts of the instrument, such as the induction coil, call bell, and generator, if there is one, which, in the case of the Western Electric Company's desk set, are all mounted separately from the portable desk stand proper.

This hook switch is accessible in an easy manner and yet not subject to the tampering of idle or mischievous persons. By taking out the screw 7 the entire hook switch may be lifted out of the tube forming the standard, the cords leading to the various binding posts being slid along through the tube. By this means the connections to the hook switch, as well as the contact of the switch itself, are readily inspected or repaired by those whose duty it is to perform such operations.

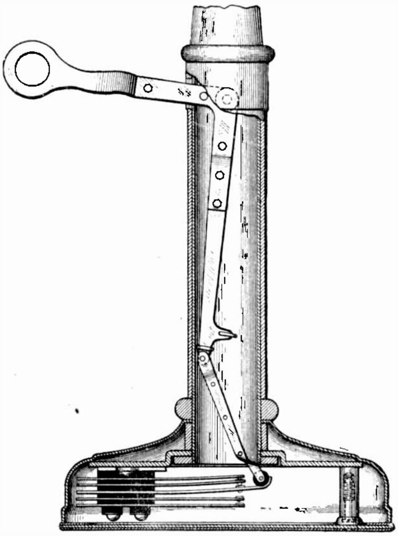


Fig. 79. Desk-Stand Hook Switch

Kellogg. In Fig. 79 is shown a sectional view of the desk-stand hook switch of the Kellogg Switchboard and Supply Company. In this it will be seen that instead of placing the switch-hook springs within the standard or tube, as in the case of the Western Electric Company, they are mounted in the base where they are readily accessible by merely taking off the base plate from the bottom of the stand. The hook lever operates on the long spring of the group of switch springs by means of a toggle joint in an obvious manner. This switch spring itself serves by its own strength to raise the hook lever when released from the weight of the receiver.

In this switch, the hook lever, and in fact the entire exposed metal portions of the instrument, are insulated from all of the contact springs and, therefore, there is little liability of shocks on the part of the person using the instrument.

Conventional Symbols. The hook switch plays a very important part in the operation of telephone circuits; for this reason readily understood conventional symbols, by which they may be conveniently represented in drawings of circuits, are desirable. In Fig. 80 are shown several symbols such as would apply to almost any circuit, regardless of the actual mechanical details of the particular hook switch which happened to be employed. Thus diagram *A* in Fig. 80 shows a hook switch having a single make contact and this diagram might be used to refer to the hook switch of the Dean Electric Company shown in Fig. 77 in which only a single contact is made when the receiver is removed, and none is made when it is on the hook. Similarly, diagram *B* might be used to represent the hook switch of the Kellogg Company, shown in Fig. 75, the arrangement being for two make and two break contacts. Likewise diagram *C* might be used to represent the hook switch of the Western Electric Company, shown in Fig. 76, which, as before stated, has two make contacts only. Diagram *D* shows another modification in which contacts made by the hook switch, when the receiver is removed, control two separate circuits. Assuming that the solid black portion represents insulation, it is obvious that the contacts are divided into two groups, one insulated from the other.

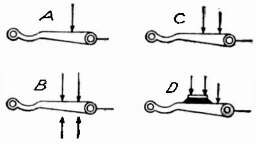


Fig. 80. Hook Switch Symbols

ONE WING OF OPERATING ROOM, BERLIN, GERMANY
Ultimate Capacity 24,000 Subscribers' Lines and 2,100 Trunk Lines. Siemens-Halske Equipment. Note Horizontal Disposal of Multiple

CHAPTER IX

GENERAL FEATURES OF THE TELEPHONE EXCHANGE

Up to this point only those classes of telephone service which could be given between two or more stations on a single line have been considered. Very soon after the practical conception of the telephone, came the conception of the telephone exchange; that is, the conception of centering a number of lines at a common point and there terminating them in apparatus to facilitate their interconnection, so that any subscriber on any line could talk with any subscriber on any other line.

The complete equipment of lines, telephone instruments, and switching facilities by which the telephone stations of the community are given telephone service is called a telephone exchange.

The building where a group of telephone lines center for interconnection is called a central office, and its telephonic equipment the central-office equipment. The terms telephone office and telephone exchange are frequently confused. Although a telephone office building may be properly referred to as a telephone exchange building, it is hardly proper to refer to the telephone office as a telephone exchange, as is frequently done. In modern parlance the telephone exchange refers not only to the central office and its equipment but to the lines and instruments connected therewith as well; furthermore, a telephone exchange may embrace a number of telephone offices that are interconnected by means of so-called trunk lines for permitting the communication of subscribers whose lines terminate in one office with those subscribers whose lines terminate in any other office.

Since a given telephone exchange may contain one or more central offices, it is proper to distinguish between them by referring to an exchange which contains but a single central office as a single office exchange, and to an exchange which contains a plurality of central offices as a multi-office exchange.

In telephone exchange working, three classes of lines are dealt with—subscribers' lines, trunk lines, and toll lines.

Subscribers' Lines. The term subscriber is commonly applied to the patron of the telephone service. His station is, therefore, referred to as a subscriber's station, and the telephone equipment at any subscriber's station is referred to as a subscriber's station equipment. Likewise, a line leading from a central office to one or more subscribers' stations is called a subscriber's line. A subscriber's line may, as has been shown in a previous chapter, be an individual line if it serves but one station, or a party line if it serves to connect more than one station with the central office.

Trunk Lines. A trunk line is a line which is not devoted to the service of any particular subscriber, but which may form a connecting link between any one of a group of subscribers' lines which terminate in one place and any one of a group of subscribers' lines which terminate in another place. If the two groups of subscribers' lines terminate in the same building or in the same switchboard, so that the trunk line forming the connecting link between them is entirely within the central-office building, it is called a local trunk line, or a local trunk. If, on the other hand, the trunk line is for connecting groups of subscribers' lines which terminate in different central offices, it is called an inter-office trunk.

Toll Lines. A toll line is a telephone line for the use of which a special fee or toll is charged; that is, a fee that is not included in the charges made to the subscriber for his regular local exchange service. Toll lines extend from one exchange district to another, more or less remote, and they are commonly termed *local* toll and *long-distance* toll lines according to the degree of remoteness. A toll line, whether local or long-distance, may be looked upon in the nature of an inter-exchange trunk.

Districts. The district in a given community which is served by a single central office is called an office district. Likewise, the district which is served by a complete exchange is called an exchange district. An exchange district may, therefore, consist of a number of central-office districts, just as an exchange may comprise a number of central offices. To illustrate, the entire area served by the exchange of the Chicago Telephone Company in Chicago, embracing the entire city and some of its suburbs, is the Chicago exchange district. The area served by one of the central offices, such as the Hyde Park office, the Oakland office, the Harrison office, or any of the others, is an office district.

Switchboards. The apparatus at the central office by which the telephone lines are connected for conversation and afterwards disconnected, and by which the various other functions necessary to the giving of complete telephone service are performed, is called a switchboard. This may be simple in the case of small exchanges, or of vast complexity in the case of the larger exchanges.

Sometimes the switchboards are of such nature as to require the presence of operators, usually girls, to connect and disconnect the line and perform the other necessary functions, and such switchboards, whether large or small, are termed *manual.*

Sometimes the switchboards are of such a nature as not to require the presence of operators, the various functions of connection, disconnection, and signaling being performed by the aid of special forms of apparatus which are under the control of the subscriber who makes the call. Such switchboards are termed *automatic.*

Of recent years there has appeared another class of switchboards, employing in some measure the features of the automatic and in some measure those of the manual switchboard. These boards are commonly referred to as *semi-automatic* switchboards, presumably because they are supposed to be half automatic and half manual.

Manual. Manual switchboards may be subdivided into two classes according to the method of distributing energy for talking purposes. Thus we may have *magneto* switchboards, which are those capable of serving lines equipped with magneto telephones, local batteries being used for talking purposes. On the other hand, we may have *common-battery* switchboards, adapted to connect lines employing common-battery telephones in which all the current for both talking and signaling is furnished from the central office. In still another way we may classify manual switchboards if the method of distributing the energy for talking and signaling purposes is ignored. Thus, entirely irrespective of whether the switchboards are adapted to serve common-battery or local-battery lines, we may have non-multiple switchboards and multiple switchboards.

The term *multiple* switchboard is applied to that class of switchboards in which the connection terminals or jacks for all the lines are repeated at intervals along the face of the switchboard, so that each operator may have within her reach a terminal for each line and may thus be able to complete by herself any connection between two lines terminating in the switchboard.

The term *non-multiple* switchboard is applied to that class of boards where the provision for repeating the line terminals at intervals along the face of the board is not employed, but where, as a consequence, each line has but a single terminal on the face of the board. Non-multiple switchboards have their main use in small exchanges where not more than a few hundred lines terminate. Where such is the case, it is an easy matter to handle all the traffic by one, two, or three operators, and as all of these operators may reach all over the face of the switchboard, there is no need for giving any line any more than one connection terminal. Such boards may be called *simple* switchboards.

There is another type of non-multiple switchboard adaptable for use in larger exchanges than the simple switchboard. A correct idea of the fundamental principle involved in these may be had by imagining a row of simple switchboards each containing terminals or jacks for its own group of lines. In order to provide for the connection of a line in one of these simple switchboards with a line in another one, out of reach of the operator at the first, short connecting lines extending between the two switchboards are provided, these being called *transfer* or *trunk* lines. In order that connections may be made between any two of the simple boards, a group of transfer lines is run from each board to every other one.

In such switchboards an operator at one of the boards or positions may complete the connection herself between any two lines terminating at her own board. If, however, the line called for terminates at another one of the boards, the operator makes use of the transfer or trunk line extending to that board, and the operator at this latter board completes the connection, so that the two subscribers' lines are connected through the trunk or transfer line. A distinguishing feature, therefore, in the operation of so-called transfer switchboards, is that an operator can not always complete a connection herself, the connection frequently requiring the attention of two operators.

Transfer systems are not now largely used, the multiple switchboard having almost entirely supplanted them in manual exchanges of such size as to be beyond the limitation of the simple switchboard. At multi-office manual exchanges, however, where there are a number of multiple switchboards employed at various central offices, the same sort of a requirement exists as that which was met by the provision of trunk lines between the various simple switchboards in a transfer system. Obviously, the lines in one central office must be connected to those of another in order to give universal service in the community in which the exchange operates. For this purpose inter-office trunk lines are used, the arrangement being such that when an operator at one office receives a call for a subscriber in another office, she will proceed to connect the calling subscriber's line, not directly with the line of the called subscriber because that particular line is not within her reach, but rather with a trunk line leading to the office in which the called-for subscriber's line terminates; having done this she will then inform an operator at that second office of the connection desired, usually by means of a so-called order-wire circuit. The connection between the trunk line so used and the line of the called-for subscriber will then be completed by the connecting link or trunk line extending between the two offices.

In such cases the multiple switchboard at each office is divided into two portions, termed respectively the *A* board and the *B* board. Each of these boards, with the exception that will be pointed out in a subsequent chapter, is provided with a full complement of multiple jacks for all of the lines entering that office. At the *A* board are located operators, called *A* operators, who answer all the calls from the subscribers whose lines terminate in that office. In the case of calls for lines in that same office, they complete the connection themselves without the assistance of the other operators. On the other hand, the calls for lines in another office are handled through trunk lines leading to that other office, as before described, and these trunk lines always terminate in the *B* board at that office. The *B* operators are, therefore, those operators who receive the calls over trunk lines and complete the connection with the line of the subscriber desired.

To define these terms more specifically, an *A* board is a multiple switchboard in which the subscriber's lines of a given office district terminate. For this reason the *A* board is frequently referred to as a subscribers' board, and the operators who work at these boards and who answer the calls of the subscribers are called *A* operators or subscribers' operators. *B* boards are switchboards in which terminate the incoming ends of the trunk lines leading from other offices in the same exchange. These boards are frequently called incoming trunk boards, or merely trunk boards, and the operators who work at them and who receive the directions from the *A* operators at the other boards are called *B* operators, or incoming trunk operators.

The circuits which are confined wholly to the use of operators and over which the instructions from one operator to another are sent, as in the case of the *A* operator giving an order for a connection to a *B* operator at another switchboard, are designated *call circuits* or *order wire circuits.*

Sometimes trunk lines are so arranged that connections may be originated at either of their ends. In other cases they are so arranged that one group of trunk lines connecting two offices is for the traffic in one direction only, while another group leading between the same two offices is for handling only the traffic in the other direction. Trunk lines are called *one-way* or *two-way* trunks, according to whether they handle the traffic in one direction or in two. A trunking system, where the same trunks handle traffic both ways, is called a *single-track system;* and, on the other hand, a system in which there are two groups of trunks, one handling traffic in one direction and the other in the other, is called a *double-track system.* This nomenclature is obviously borrowed from railroad practice.

There is still another class of manual switchboards called the *toll board* of which it will be necessary to treat. Telephone calls made by one person for another within the limits of the same exchange district are usually charged for either by a flat rate per month, or by a certain charge for each call. This is usually regardless of the duration of the conversation following the call. On the other hand, where a call is made by one party for another outside of the limits of the exchange district and, therefore, in some other exchange district, a charge is usually made, based on the time that the connecting long-distance line is employed. Such calls and their ensuing conversations are charged for at a very much higher rate than the purely local calls, this rate depending on the distance between the stations involved. The making up of connections between a long-distance and a local line is usually done by means of operators other than those employed in handling the local calls, who work either by means of special equipment located on the local board, or by means of a separate board. Such equipments for handling long-distance or toll traffic are commonly termed toll switchboards.

They differ from local boards (*a*) in that they are arranged for a very much smaller number of lines; (*b*) in that they have facilities by which the toll operator may make up the connections with a minimum amount of labor on the part of the assisting local operators; and (*c*) in that they have facilities for recording the identification of the parties and timing the conversations taking place over the toll lines, so that the proper charge may be made to the proper subscriber.

CHAPTER X

THE SIMPLE MAGNETO SWITCHBOARD

Definitions. As already stated those switchboards which are adapted to work in conjunction with magneto telephones are called magneto switchboards. The signals on such switchboards are electromagnetic devices capable of responding to the currents of the magneto generators at the subscribers' stations. Since, as a rule, magneto telephones are equipped with local batteries, it follows that the magneto switchboard does not need to be arranged for supplying the subscribers' stations with talking current. This fact is accountable for magneto switchboards often being referred to as local-battery switchboards, in contradistinction to common-battery switchboards which are equipped so as to supply the connected subscribers' stations with talking current.

The term *simple* as applied in the headings of this and the next chapter, is employed to designate switchboards adapted for so small a number of lines that they may be served by a single or a very small group of operators; each line is provided with but a single connection terminal and all of them, without special provision, are placed directly within the reach of the operator, or operators if there are more than one. This distinction will be more apparent under the discussion of transfer and multiple switchboards.

Mode of Operation. The cycle of operation of any simple manual switchboard may be briefly outlined as follows: The subscriber desiring a connection transmits a signal to the central office, the operator seeing the signal makes connection with the calling line and places herself in telephonic communication with the calling subscriber to receive his orders; the operator then completes the connection with the line of the called subscriber and sends ringing current out on that line so as to ring the bell of that subscriber; the two subscribers then converse over the connected lines and when the conversation is finished either one or both of them may send a signal to the central office for disconnection, this signal being called a clearing-out signal; upon receipt of the clearing-out signal, the operator disconnects the two lines and restores all of the central-office apparatus involved in the connection to its normal position.

Component Parts. Before considering further the operation of manual switchboards it will be well to refer briefly to the component pieces of apparatus which go to make up a switchboard.

Line Signal. The line signal in magneto switchboards is practically always in the form of an electromagnetic annunciator or drop. It consists in an electromagnet adapted to be included in the line circuit, its armature controlling a latch, which serves to hold the drop or shutter or target in its raised position when the magnet is not energized, and to release the drop or shutter or target so as to permit the display of the signal when the magnet is energized. The symbolic representation of such an electromagnetic drop is shown in Fig. 81.

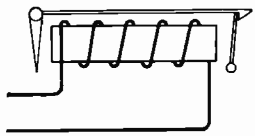


Fig. 81. Drop Symbol

Jacks and Plugs. Each line is also provided with a connection terminal in the form of a switch socket. This assumes many forms, but always consists in a cylindrical opening behind which are arranged one or more spring contacts. The opening forms a receptacle for plugs which have one or more metallic terminals for the conductors in the flexible cord in which the plug terminates. The arrangement is such that when a plug is inserted into a jack the contacts on the plug will register with certain of the contacts in the jack and thus continue the line conductors, which terminate in the jack contacts, to the cord conductors, which terminate in the plug contacts. Usually also when a plug is inserted certain of the spring contacts in the jack are made to engage with or disengage other contacts in the jack so as to make or break auxiliary circuits.

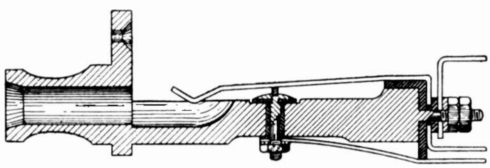


Fig. 82. Spring Jack

A simple form of spring jack is shown in section in Fig. 82. In Fig. 83 is shown a sectional view of a plug adapted to co-operate with the jack of Fig. 82. In Fig. 84 the plug is shown inserted into the jack. The cylindrical portion of the jack is commonly

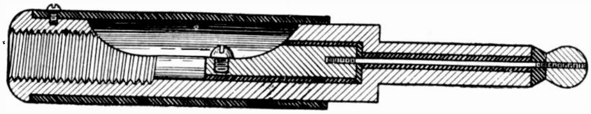


Fig. 83. Plug

called the *sleeve* or *thimble* and it usually forms one of the main terminals of the jack; the spring, forming the other principal terminal,

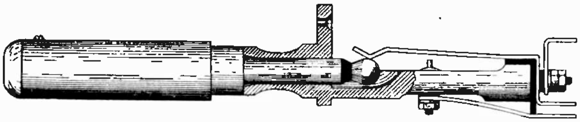


Fig. 84. Plug and Jack

is called the *tip spring,* since it engages the tip of the plug. The tip spring usually rests on another contact which may be termed the *anvil.* When the plug is inserted into the jack as shown in Fig. 84, the tip spring is raised from contact with this anvil and thus breaks the circuit leading through it. It will be understood that spring jacks are not limited to three contacts such as shown in these figures nor are plugs limited to two contacts. Sometimes the plugs have three, and even more, contacts, and frequently the jacks corresponding to such plugs have not only a contact spring adapted to register with each of the contacts of the plug, but several other auxiliary contacts also, which will be made or broken according to whether the plug is inserted or withdrawn from the jack. Symbolic representations of plugs and jacks are shown in Fig. 85. These are employed in diagrammatic representations of circuits and are supposd to represent the essential elements of the plugs and jacks in such a way as to be suggestive of their operation. It will be understood that such symbols may be greatly modified to express the various peculiarities of the plugs and jacks which they represent.

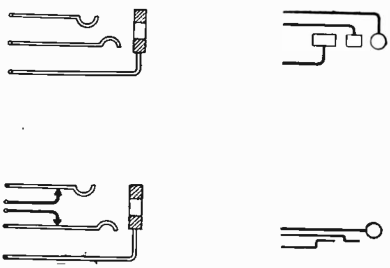
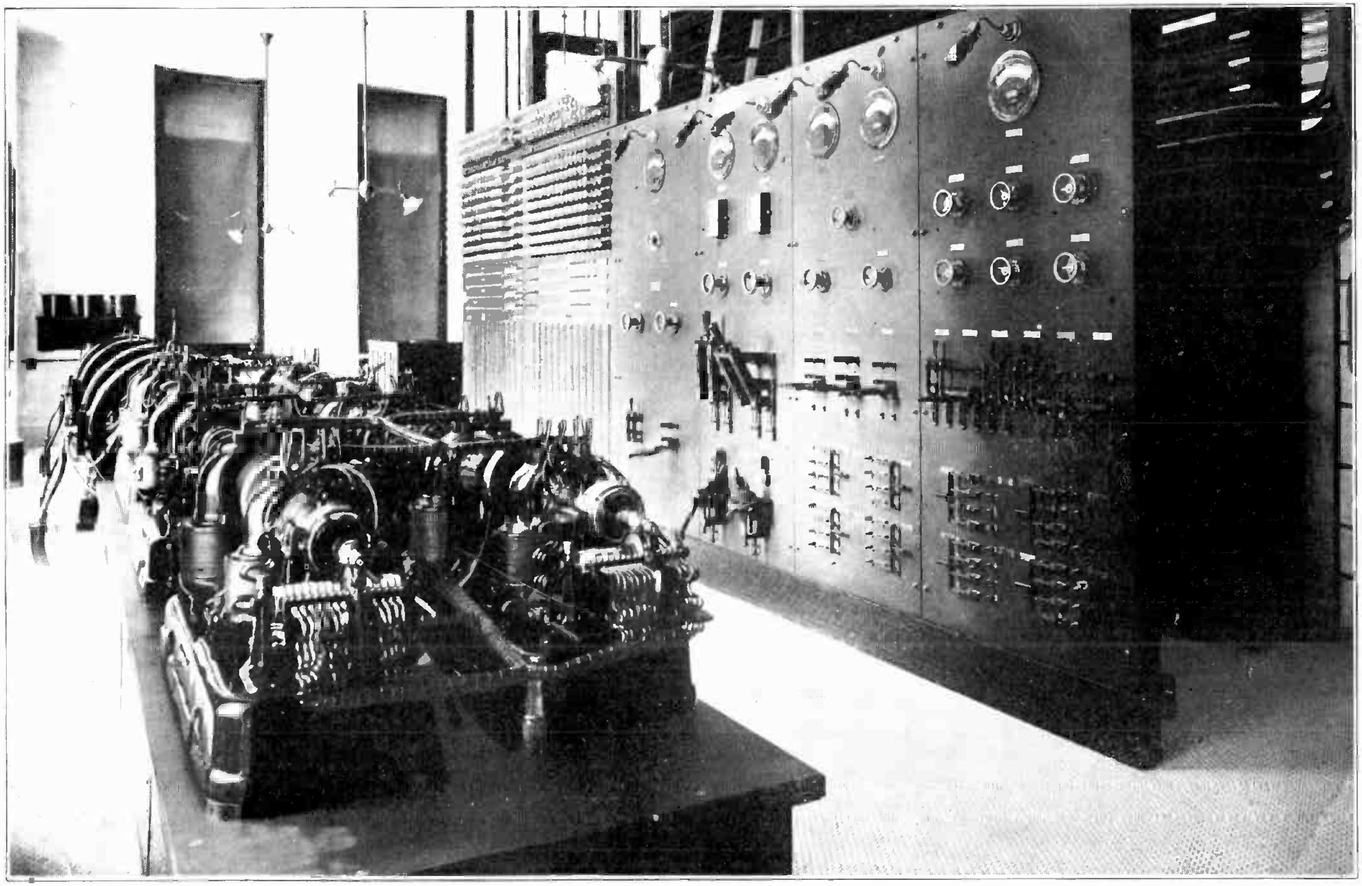


Fig. 85. Jack and Plug Symbols



RINGING AND CHARGING MACHINES AND POWER BOARD
Plaza Office, New York Telephone Co.

Keys. Other important elements of manual switchboards are ringing and listening keys. These are the devices by means of which the operator may switch the central-office generator or her telephone set into or out of the circuit of the connected lines. The details of a simple ringing and listening key are shown in Fig. 86. This con-

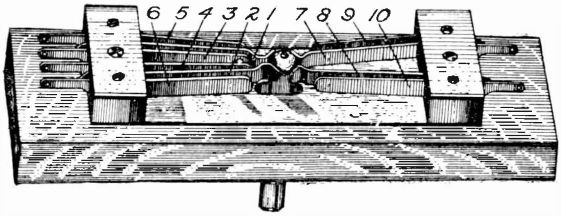


Fig. 86. Ringing and Listening Key

sists of two groups of springs, one of four and one of six, the springs in each group being insulated from each other at their points of mounting. Two of these springs *1* and *2* in one group—the ringing group—are longer than the others, and act as movable levers engaging the inner pair of springs *3* and *4* when in their normal positions, and the outer pair *5* and *6* when forced into their alternate positions. Movement is imparted to these springs by the action of a cam which is mounted on a lever, manipulated by the operator. When this lever is moved in one direction the cam presses the two springs *1* and *2* apart, thus causing them to disengage the springs *3* and *4* and to engage the springs *5* and *6*.

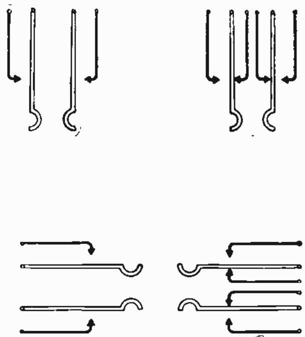


Fig. 87. Ringing- and Listening-Key Symbols

The springs of the other group constitute the switching element of the listening key and are very similar in their action to those of the ringing key, differing in the fact that they have no inner pair of springs such as *3* and *4*. The two long springs *7* and *8*, therefore, normally do not rest against anything, but when the key lever is pressed, so as to force the cam between them, they are made to engage the two outer springs *9* and *10*.

The design and construction of ringing and listening keys assume many different forms. In general, however, they are adapted to do exactly the same sort of switching operations as that of which the device of Fig. 86 is capable. Easily understood symbols of ringing and listening keys are shown in Fig. 87; the cam member which operates on the two long springs is usually omitted for ease of illustration. It will be understood in considering these symbols, therefore, that the two long curved springs usually rest against a pair of inner contacts in case of the ringing key or against nothing at all in case of the listening key, and that when the key is operated the two springs are assumed to be spread apart so as to engage the outer pair of contacts with which they are respectively normally disconnected.

Line and Cord Equipments. The parts of the switchboard that are individual to the subscriber's line are termed the *line equipment;* this, in the case of a magneto switchboard, consists of the line drop and the jack together with the associated wiring necessary to connect them properly in the line circuit. The parts of the switchboard that are associated with a connecting link—consisting of a pair of plugs and associated cords with their ringing and listening keys and clearing-out drop—are referred to as a *cord equipment.* The circuit of a complete pair of cords and plugs with their associated apparatus is called a *cord circuit.* In order that there may be a number of simultaneous connections between different pairs of lines terminating in a switchboard, a number of cord circuits are provided, this number depending on the amount of traffic at the busiest time of the day.

Operator's Equipment. A part of the equipment that is not individual to the lines or to the cord circuits, but which may, as occasion requires, be associated with any of them is called the *operator's equipment.* This consists of the operator's transmitter and receiver, induction coil, and battery connections together with the wiring and other associated parts necessary to co-ordinate them with the rest of the apparatus. Still another part of the equipment that is not individual to the lines nor to the cord circuits is the calling-current generator. This may be common to the entire office or a separate one may be provided for each operator's position.

Operation in Detail. With these general statements in mind we may take up in some detail the various operations of a telephone system wherein the lines center in a magneto switchboard. This may best be done by considering the circuits involved, without special regard to the details of the apparatus.

The series of figures showing the cycle of operations of the magneto switchboard about to be discussed are typical of this type of switchboard almost regardless of make. The apparatus is in each case represented symbolically, the representations indicating type rather than any particular kind of apparatus within the general class to which it belongs.

Normal Condition of Line. In Fig. 88 is shown the circuit of an ordinary magneto line. The subscriber's sub-station apparatus, shown at the left, consists of the ordinary bridging telephone but might with equal propriety be indicated as a series telephone. The subscriber's station is shown connected with the central office by the two limbs of a metallic-circuit line. One limb of the line terminates

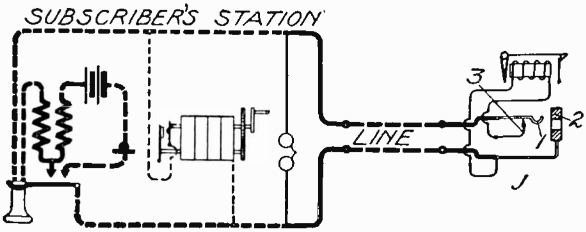


Fig. 88. Normal Condition of Line

in the spring *1* of the jack, and the other limb in the sleeve or thimble *2* of the jack. The spring *1* normally rests on the third contact or anvil *3* in the jack, its construction being such that when a plug is inserted this spring will be raised by the plug so as to break contact with the anvil *3*. It is understood, of course, that the plug associated with this jack has two contacts, referred to respectively as the tip and the sleeve; the tip makes contact with the tip spring *1* and the sleeve with the sleeve or thimble *2*.

The drop or line signal is permanently connected between the jack sleeve and the anvil *3*. As a result, the drop is normally bridged across the circuit of the line so as to be in a receptive condition to signaling current sent out by the subscriber. It is evident, however, that when the plug is inserted into the jack this connection between the line and the drop will be broken.

In this normal condition of the line, therefore, the drop stands ready at the central office to receive the signal from the subscriber and the generator at the sub-station stands ready to be bridged across the circuit of the line as soon as the subscriber turns its handle. Similarly the ringer—the call-receiving device at the sub-station—is permanently bridged across the line so as to be responsive to any signal that may be sent out from the central office in order to call the subscriber. The subscriber's talking apparatus is, in this normal condition of the line, cut out of the circuit by the switch hook.

Subscriber Calling. Fig. 89 shows the condition of the line when the subscriber at the sub-station is making a call. In turning his generator the two springs which control the connection of the generator with the line are brought into engagement with each other

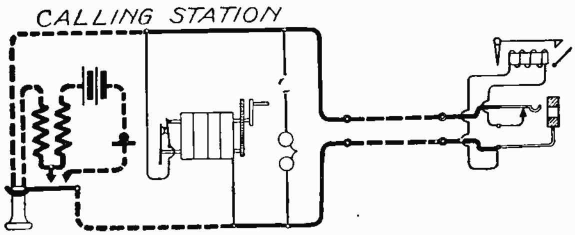


Fig. 89. Subscriber Calling

so that the generator currents may pass out over the line. The condition at the central office is the same as that of Fig. 88 except that the drop is shown with its shutter fallen so as to indicate a call.

Operator Answering. The next step is for the operator to answer the call and this is shown in Fig. 90. The subscriber has released the handle of his generator and the generator has, therefore, been automatically cut out of the circuit. He also has removed his receiver from its hook, thus bringing his talking apparatus into the line circuit. The operator on the other hand has inserted one of the plugs P_a into the jack. This action has resulted in the breaking of the circuit through the drop by the raising of the spring *1* from the anvil *3*, and also in the continuance of the line circuit through the conductors of the cord circuits. Thus, the upper limb of the line is continued by means of the engagement of the tip spring *1* with the tip *4* of the plug to the conducting strand *6* of the cord circuit; likewise the lower limb of the line is continued by the engagement of the thimble *2* of the jack with the sleeve contact *5* of the plug P_a to the strand *7* of the cord circuit. The operator has also closed her listening key *L.K.* In doing so she has brought the springs *8* and *9* into engagement with the anvils *10* and *11* and has thus bridged her head telephone receiver with the secondary of her induction coil across the two strands *6* and *7* of the cord. Associated with the secondary winding of her receiver is a primary circuit containing a transmitter, battery, and the primary of the induction coil. It will be seen that the conditions are now such as to permit the subscriber at the calling station to converse with the operator and this conversation consists in the familiar "Number Please" on the part of the operator and the response of the subscriber giving the number of the line that is desired.

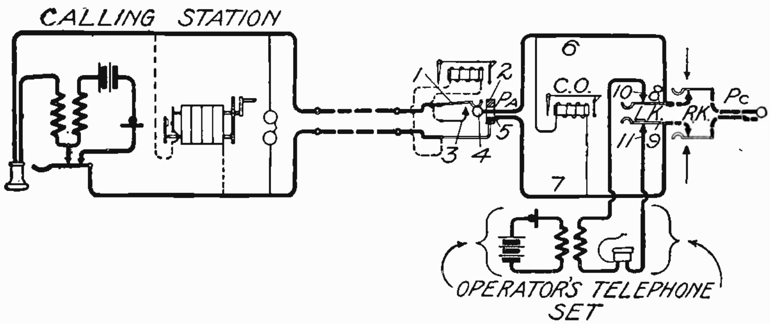


Fig. 90. Operator Answering

Neither the plug P_c, nor the ringing key *R.K.*, shown in Fig. 90, is used in this operation. The clearing-out drop *C.O.* is bridged permanently across the strands *6-7* of the cord, but is without function at this time; the fact that it is wound to a high resistance and impedance prevents its having a harmful effect on the transmission.

It may be stated at this point that the two plugs of an associated pair are commonly referred to as the answering and calling plugs. The answering plug is the one which the operator always uses in answering a call as just described in connection with Fig. 90. The calling plug is the one which she next uses in connecting with the line of the called subscriber. It lies idle during the answering of a call and is only brought into play after the order of the calling subscriber has been given, in which case it is used in establishing connection with the called subscriber.

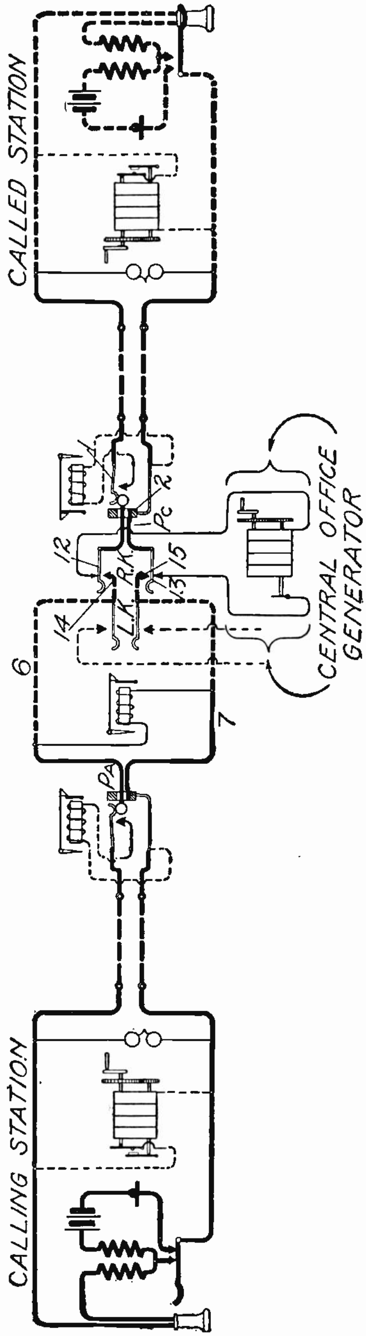


Fig. 91. Operator Calling

Operator Calling. We may now consider how the operator calls the called subscriber. The condition existing for this operation is shown in Fig. 91. The operator after receiving the order from the calling subscriber inserts the calling plug P_c into the jack of the line of the called station. This act at once connects the limbs of the line with the strands *6* and *7* of the cord circuit, and also cuts out the line drop of the called station, as already explained. The operator is shown in this figure as having opened her listening key *L.K.* and closed her ringing key *R.K.* As a result, ringing current from the central-office generator will flow out over the two ringing key springs *12* and *13* to the tip and sleeve contacts of the calling plug P_c, then to the tip spring *1* and the sleeve or thimble *2* of the jack, and then to the two sides of the metallic-circuit line to the sub-station and through the bell there. This causes the ringing of the called subscriber's bell, after which the operator releases the ringing key and thereby allows the two springs *12* and *13* of that key to again engage their normal contacts *14* and *15*, thus making the two strands *6* and *7* of the cord circuit continuous from the contacts of the answering plug P_a to the contacts of the calling plug P_c. This establishes the condition at the central office for conversation between the two subscribers.

Subscribers Conversing. The only other thing necessary to establish a complete set of talking conditions between the two subscribers is for the called subscriber to remove his receiver from its hook, which he does as soon as he responds to the call. The conditions for conversation between the two subscribers are shown in Fig. 92. It is seen that the two limbs of the calling line are connected respectively to the two limbs of the called line by the two strands of the cord circuit, both the operator's receiver and the central-office generator being cut out by the listening and ringing keys, respectively. Likewise the two line drops are cut out of circuit and the only thing left associated with the circuit at the central office is the clearing-out drop *C. O.*, which remains bridged across the cord circuit. This, like the two ringers at the respective connected stations, which also remain bridged across the circuit when bridging instruments are used, is of such high resistance and impedance that it offers practically no path to the rapidly fluctuating voice currents to leak from one side of the line circuit to the other. Fluctuating currents generated by the transmitter at the calling station, for instance, are converted by means of the induction coil into alternating currents flowing in the secondary of the induction coil at that station. Considering a momentary current as passing up through the secondary winding of the induc-

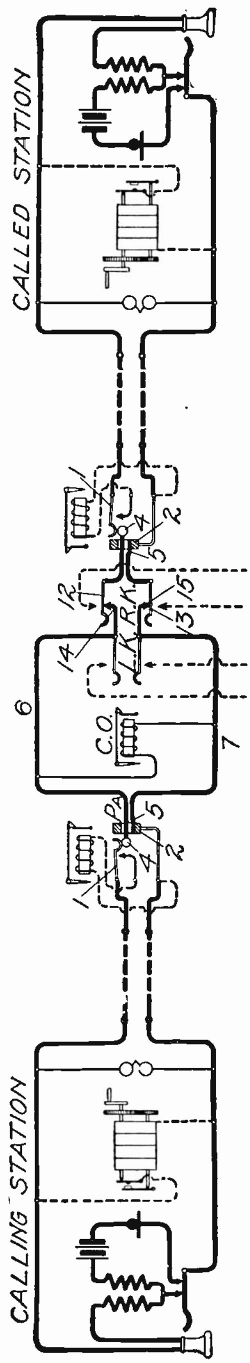


Fig. 92. Subscribers Connected for Conversation

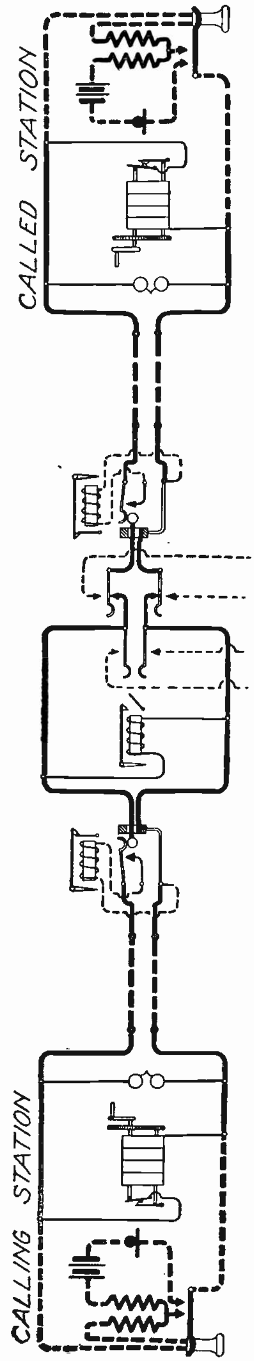


Fig. 93. Clearing-Out Signal

tion coil at the calling station, it passes through the receiver of that station through the upper limb of the line to the spring *1* of the line jack belonging to that line at the central office; thence through the tip *4* of the answering plug to the conductor *6* of the cord; thence through the pair of contacts *14* and *12* forming one side of the ringing key to the tip *4* of the calling plug; thence to the tip spring *1* of the jack of the called subscriber's line; thence over the upper limb of his line through his receiver and through the secondary of the induction to one of the upper switch-hook contacts; thence through the hook lever to the lower side of the line, back to the central office and through the sleeve contact *2* of the jack and the sleeve contact *5* of the plug; thence through the other ringing key contacts *13* and *15*; thence through the strand *7* of the cord to the sleeve contact *5* and the sleeve contact *2* of the answering plug and jack, respectively; thence through the lower limb of the calling subscriber's line to the hook lever at his station; thence through one of the upper contacts of this hook to the secondary of the induction coil, from which point the current started.

Obviously, when the called subscriber is talking to the calling subscriber the same path is followed. It will be seen that at any time the operator may press her listening key *L.K.*, bridge her telephone set across the circuit of the two connected lines, and listen to the conversation or converse with either of the subscribers in case of necessity.

Clearing Out. At the close of the conversation, either one or both of the subscribers may send a clearing-out signal by turning their generators after hanging up their receivers. This condition is shown in Fig. 93. The apparatus at the central office remains in exactly the same position during conversation as that of Fig. 92, except that the clearing-out drop shutter is shown as having fallen. The two subscribers are shown as having hung up their receivers, thus cutting out their talking apparatus, and as operating their generators for the purpose of sending the clearing-out signals. In response to this act the operator pulls down both the calling and the answering plug, thus restoring them to their normal seats, and bringing both lines to the normal condition as shown in Fig. 88. The line drops are again brought into operative relation with their respective lines so as to be receptive to subsequent calls and the calling generators at the sub-stations are removed from the bridge circuits across the line by the opening of the automatic switch contacts associated with those generators.

Essentials of Operation. The foregoing sequence of operations while described particularly with respect to magneto switchboards is, with certain modifications, typical of the operation of nearly all manual switchboards. In the more advanced types of manual switchboards, certain of the functions described are sometimes done automatically, and certain other functions, not necessary in connection with the simple switchboard, are added. The essential mode of operation, however, remains the same in practically all manual switchboards, and for this reason the student should thoroughly familiarize himself with the operation and circuits of the simple switchboard as a foundation for the more complex and consequently more-difficult-to-understand switchboards that will be described later on.

Commercial Types of Drops and Jacks. *Early Drops.* Coming now to the commercial types of switchboard apparatus, the first subject that presents itself is that of magneto line signals or drops. The very early forms of switchboard drops had, in most cases, two-coil magnets, the cores of which were connected at their forward ends by an iron yoke and the armature of which was pivoted opposite the rear end of the two cores. To the armature was attached a latch rod which projected forwardly to the front of the device and was there adapted to engage the upper edge of the hinged shutter, so as to hold it in its raised or undisplayed position when the armature was unattracted. Such a drop, of Western Electric manufacture, is shown in Fig. 94.

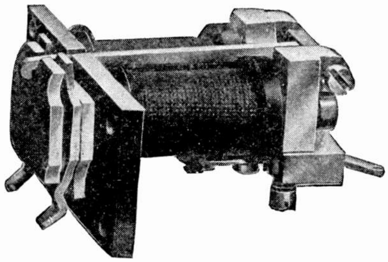


Fig. 94. Old-Style Drop

Liability to Cross-Talk:—This type of drop is suitable for use only on small switchboards where space is not an important consideration, and even then only when the drop is entirely cut out of the circuit during conversation. The reason for this latter requirement will be obvious when it is considered that there is no magnetic shield around the winding of the magnet and no means for preventing the stray field set up by the talking currents in one of the magnets from affecting by induction the windings of adjacent magnets contained in other talking circuits. Unless the drops are entirely cut out of the talking circuit, therefore, they are very likely to produce cross-talk between adjacent circuits. Furthermore, such form of drop is obviously not economical of space, two coils placed side by side consuming practically twice as much room as in the case of later drops wherein single magnet coils have been made to answer the purpose.

Tubular Drops. In the case of line drops, which usually can readily be cut out of the circuit during conversation, this cross-talk feature is not serious, but sometimes the line drops, and always the clearing-out drops, must be left in connection with the talking circuit. On account of economy in space and also on account of this cross-talk feature, there has come into existence the so-called tubular or iron-clad drop, one of which is shown in section in Fig. 95. This was developed a good many years ago by Mr. E. P. Warner of the Western Electric Company, and has since, with modifications, become standard with practically all the manufacturing companies. In this there is but a single bobbin, and this is enclosed in a shell of soft Norway iron, which is closed at its front end and joined to the end of the core as indicated, so as to form a complete return magnetic path for the lines of force generated in the coil. The rear end of the shell and core are both cut off in the same plane and the armature is made in such form as to practically close this end of the shell. The armature carries a latch rod extending the entire length of the

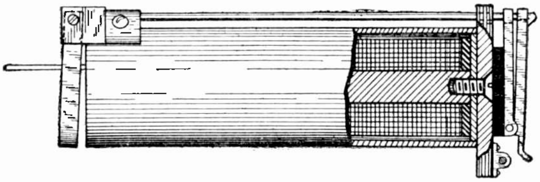


Fig. 95. Tubular Drop

shell to the front portion of the structure, where it engages the upper edge of the pivoted shutter; this, when released by the latch upon the attraction of the armature, falls so as to display a target behind it.

These drops may be mounted individually on the face of the switchboard, but it is more usual to mount them in strips of five or ten. A strip of five drops, as manufactured by the Kellogg Switchboard and Supply Company, is shown in Fig. 96. The front strip on which these drops are mounted is usually of brass or steel, copper plated, and is sufficiently heavy to provide a rigid support for the entire group of drops that are mounted on it. This construction

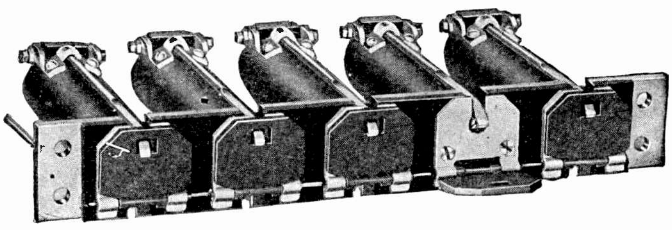


Fig. 96. Strip of Tubular Drops

greatly facilitates the assembling of the switchboard and also serves to economize space—obviously, the thing to economize on the face of a switchboard is space as defined by vertical and horizontal dimensions. These tubular drops, having but one coil, are readily mounted on 1-inch centers, both vertically and horizontally. Sometimes even smaller dimensions than this are secured. The greatest advantage of this form of construction, however, is in the absolute freedom from cross-talk between two adjacent drops. So completely is the magnetic field of force kept within the material of the shell, that there is practically no stray field and two such drops may be included in two different talking circuits and the drops mounted immediately adjacent to each other without producing any cross-talk whatever.

Night Alarm. Switchboard drops in falling make but little noise, and during the day time, while the operator is supposed to be needed continually at the board, the visual signal which they display is sufficient to attract her attention. In small exchanges, however, it is frequently not practicable to keep an operator at the switchboard at night or during other comparatively idle periods, and yet calls that do arrive during such periods must be attended to. For this reason some other than a visual signal is necessary, and this need is met by the so-called night-alarm attachment. This is merely an arrangement by which the shutter in falling closes a pair of contacts and thus completes the circuit of an ordinary vibrating bell or buzzer which will sound until the shutter is restored to its normal position. Such contacts are shown

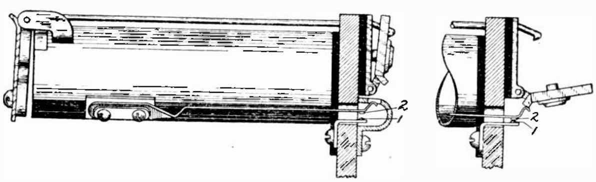


Fig. 97. Drop with Night-Alarm Contacts

in Fig. 97 at *1* and *2*. Night-alarm contacts have assumed a variety of forms, some of which will be referred to in the discussion of other types of drops and jacks.

Jack Mounting. Jacks, like drops, though frequently individually mounted are more often mounted in strips. An individually mounted jack is shown in figure 98, and a strip of ten jacks in Fig. 99. In such a strip of jacks, the strips supporting the metallic parts of the various jacks are usually of hard rubber reinforced by brass so as to give sufficient strength. Various forms of supports for these strips are used by different manufacturers, the means for fastening them in the switchboard frame usually consisting of brass lugs on the end of

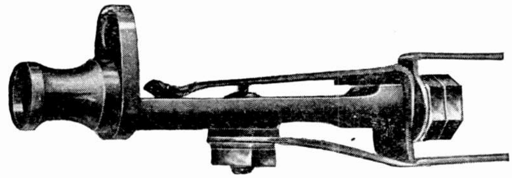


Fig. 98. Individual Jack

the jack strip adapted to be engaged by screws entering the stationary portion of the iron framework; or sometimes pins are fixed in the framework, and the jack is held in place by nuts engaging screw-threaded ends on such pins.

Methods of Associating Jacks and Drops. There are two general methods of arranging the drops and jacks in a switchboard. One of these is to place all of the jacks in a group together at the lower portion of the panel in front of the operator and all of the drops together in another group above the group of jacks. The other way is to locate each jack in immediate proximity to

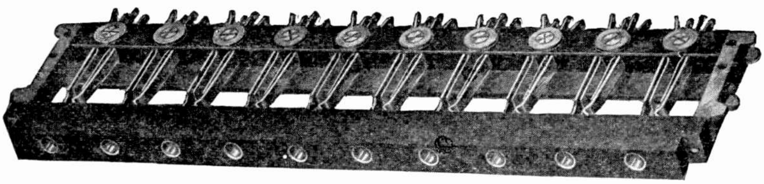


Fig. 99. Strip of Jacks

the drop belonging to the same line so that the operator's attention will always be called immediately to the jack into which she must insert her plug in response to the display of a drop. This latter practice has several advantages over the former. Where the drops are all mounted in one group and the jacks in another, an operator seeing a drop fall must make mental note of it and pick out the corresponding jack in the group of jacks. On the other hand, where the jacks and drops are mounted immediately adjacent to each other, the falling of a drop attracts the attention of the operator to the corresponding jack without further mental effort on her part.

The immediate association of the drops and jacks has another advantage—it makes possible such a mechanical relation between the drop and its associated jack that the act of inserting the plug into the jack in making the connection will automatically and mechanically restore the drop to its raised position. Such drops are termed *self-restoring drops*, and, since a drop and jack are often made structurally a unitary piece of apparatus, they are frequently called *combined* drops and jacks.

Manual vs. Automatic Restoration. There has been much difference of opinion on the question of manual versus automatic restoration of drops. Some have contended that there is no advantage in having the drops restored automatically, claiming that the operator has plenty of time to restore the drops by hand while receiving the order from the calling subscriber or performing some of her other work. Those who think this way have claimed that the only place where an automatically restored drop is really desirable is where, on account of the lack of space on the front of the switchboard, the drops are placed on such a portion of the board as to be not readily reached by the operator. This resulted in the electrically restored drop, mention of which will be made later.

Others have contended that even though the drop is mounted within easy reach of the operator, it is advantageous that the operator should be relieved of the burden of restoring it, claiming that even though there are times in the regular performance of the operator's duties when she may without interfering with other work restore the drops manually, such requirement results in a double use of her attention and in a useless strain on her which might better be devoted to the actual making of connections.

Until recently the various Bell operating companies have adhered, in their small exchange work, to the manual restoring method, while most of the so-called independent operating companies have adhered to the automatic self-restoring drops.

Methods of Automatic Restoration. Two general methods present themselves for bringing about the automatic restoration of the drop. First, the mechanical method, which is accomplished by having some moving part of the jack or of the plug as it enters the jack force the drop mechanically into its restored position. This usually means the mounting of the drop and the corresponding jack in juxtaposition, and this, in turn, has usually resulted in the unitary structure containing both the drop and the jack. Second, the electrical method wherein the plug in entering the jack controls a restoring circuit, which includes a battery or other source of energy and a restoring coil on the drop, the result being that the insertion of the plug into the jack closes this auxiliary circuit and thus energizes the restoring magnet, the armature of which pulls the shutter back into its restored position. This practice has been followed by Bell operating companies whenever conditions require the drop to be mounted out of easy reach of the operator; not otherwise.

Mechanical—Direct Contact with Plug. One widely used method of mechanical restoration of drops, once employed by the Western Telephone Construction Company with considerable success, was to hang the shutter in such position that it would fall immediately in front of the jack so that the operator in order to reach the jack with the plug would have to push the plug directly against the shutter and thus restore it to its normal or raised position. In this construction the coil of the drop magnet was mounted directly behind the jack, the latch rod controlled by the armature reaching forward, parallel with the jack, to the shutter, which, as stated, was hung in front of the jack. This resulted in a most compact arrangement so far as the space utilization on the front of the board was concerned and such combined drops and jacks were mounted on about 1-inch centers, so that a bank of one hundred combined drops and jacks occupied a space only a little over 10 inches square.

A modification of this scheme, as used by the American Electric Telephone Company, was to mount the drop immediately over the jack so that its shutter, when down, occupied a position almost in front of, but above, the jack opening. The plug was provided with a collar, which, as it entered the jack, engaged a cam on the base of the shutter and forced the latter mechanically into its raised position.

Neither of these methods of restoring—*i. e*, by direct contact between the shutter or part of it and the plug or part of it—is now as widely used as formerly. It has been found that there is no real need in magneto switchboards for the very great compactness which the hanging of the shutter directly in front of the drop resulted in, and the tendency in later years has been to make the combined drops and jacks more substantial in construction at the expense of some space on the face of the switchboard.

Kellogg Type:—A very widely used scheme of mechanical restoration is that employed in the Miller drop and jack manufactured by the Kellogg Switchboard and Supply Company, the principles of which may be understood in connection with Fig. 100. In this figure views of one of these combined drops and jacks in three different positions are shown. The jack is composed of the framework *B* and the hollow screw *A*, the latter forming the sleeve or thimble of the jack and being externally screw-threaded so as to engage and bind in place the front end of the framework *B*. The jack is mounted on the lower part of the brass mounting strip *C* but insulated therefrom. The tip spring of the jack is bent down as usual to engage the tip of the plug, as better shown in the lower cut of Fig. 100, and then continues in an extension *D*, which passes through a hole in the mounting plate *C*. This tip spring in its normal position rests against another spring as shown, which latter spring forms one terminal of the drop winding.

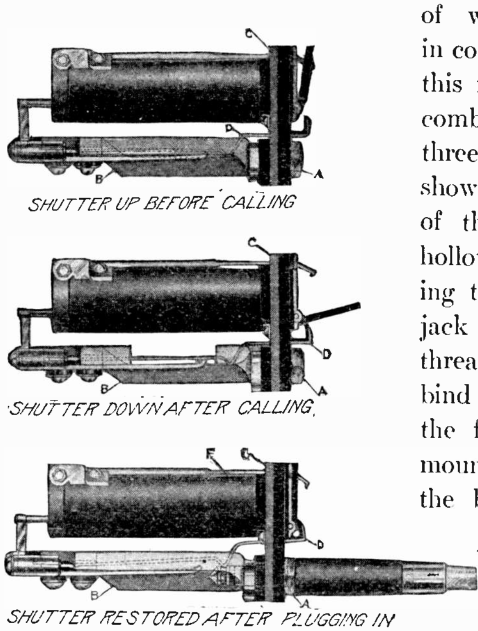
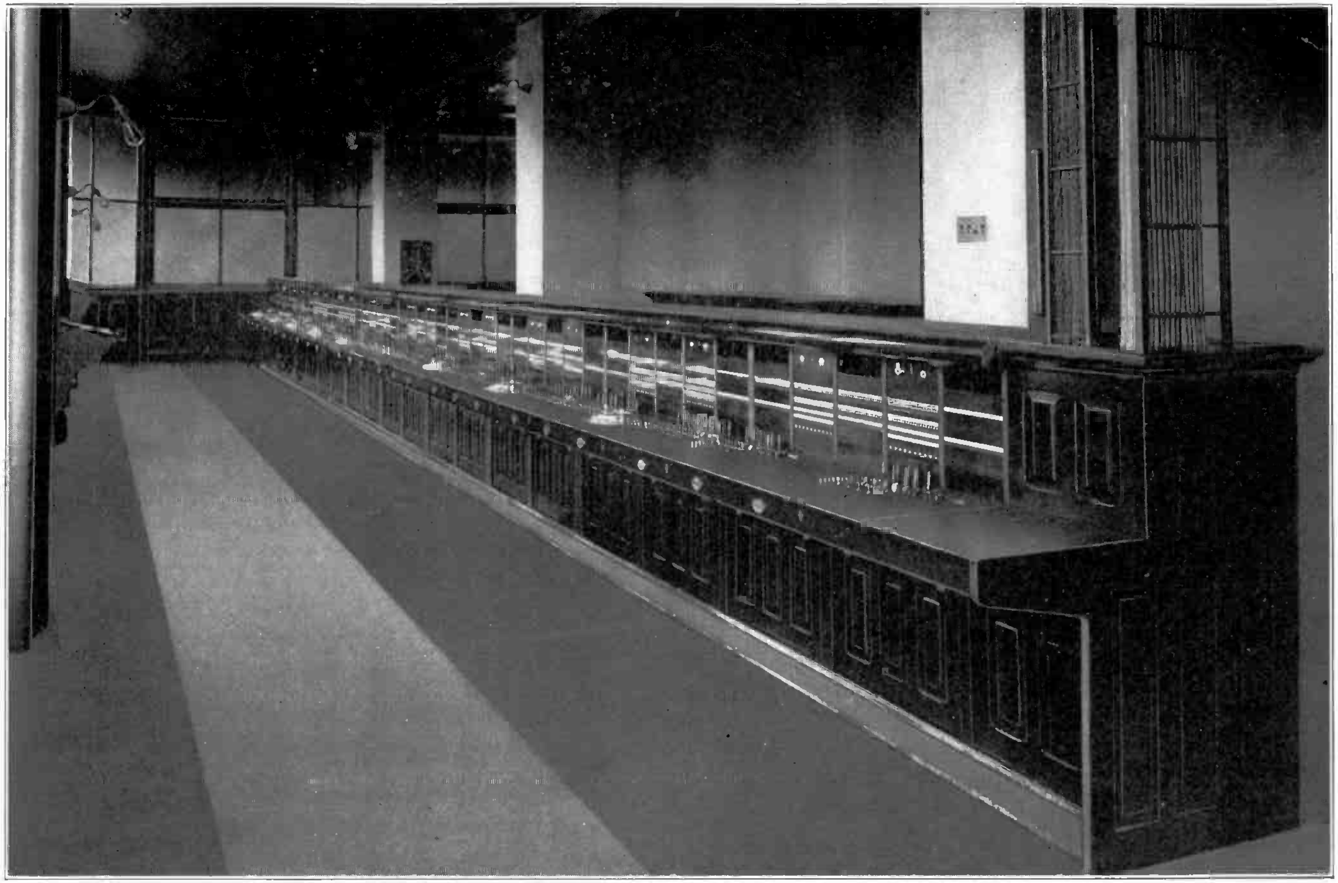


Fig. 100. Kellogg Drop and Jack



TOLL BOARD
U. S. Telephone Company, Cleveland, Ohio,
The Dean Electric Co.

The drop or annunciator is of tubular form, and the shutter is so arranged on the front of the mounting strip *C* as to fall directly above the extension *D* of the tip spring. As a result, when the plug is inserted into the jack, the upward motion of the tip spring forces

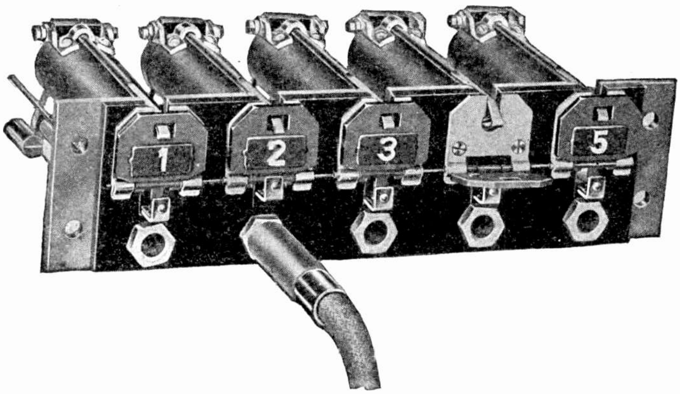


Fig. 101 Strip of Kellogg Drops and Jacks

the drop into its restored position, as indicated in the lower cut of the figure. These drops and jacks are usually mounted in banks of five, as shown in Fig. 101.

Western Electric Type:—The combined drop and jack of the Western Electric Company recently put on the market to meet the demands of the independent trade, differs from others principally in that it employs a spherical drop or target instead of the ordinary flat shutter. This piece of apparatus is shown in its three possible positions in Fig. 102. The shutter or target normally displays a black surface through a hole in the mounting plate. The sphere forming the target is out of balance, and when the latch is withdrawn from it by the action of the electromagnet it falls into the position shown in the middle cut of Fig. 102, thus displaying a red instead of a black surface to the view of the operator. When the operator plugs in, the plug engages the lower part of an **S**-shaped lever which acts on the pivoted sphere to restore it to its normal position. A perspective view of one of these combined line signals and jacks is shown in Fig. 103.

A feature that is made much of in recently designed drops and jacks for magneto service is that which provides for the ready removal of the drop coil, from the rest of the structure, for repair. The drop and jack of the Western Electric Company, just described, embodies this feature, a single screw being so arranged that its removal will permit the withdrawal of the coil without disturbing any of the other parts or connections. The coil windings terminate in two projections on the front head of the spool, and these register with spring clips on the inside of the shell so that the proper connections for the coil are automatically made by the mere insertion of the coil into the shell.

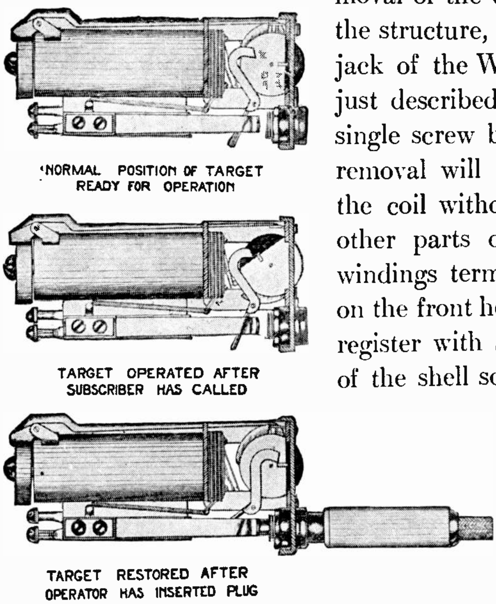


Fig. 102. Western Electric Drop and Jack

Dean Type:—The combined drop and jack of the Dean Electric Company is illustrated in Figs. 104 and 105. The two perspective views show the general features of the drop and jack and the method by which the magnet

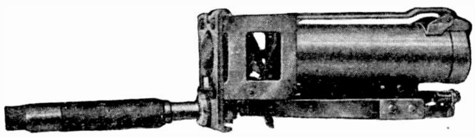


Fig. 103. Western Electric Drop and Jack

coil may be withdrawn from the shell. As will be seen the magnet is wound on a hollow core which slides over the iron core, the latter remaining permanently fixed in the shell, even though the coil be withdrawn.

Fig. 106 shows the structural details of the jack employed in this combination and it will be seen that the restoring spring for the drop is not the tip spring itself, but another spring located above and insulated from it and mechanically connected therewith.

Monarch Type:—Still another combined drop and jack is that of the Monarch Telephone Manufacturing Company of Chicago, shown in sectional view in Fig. 107. This differs from the usual type in that the armature is mounted on the front end of the electromagnet, its latch arm retaining the shutter in its normal position when raised, and releasing it when depressed by the attraction of the armature. As is shown, there is within the core of the magnet an adjustable spiral spring which presses forward against the armature and which spring is compressed by the attraction of the armature of the

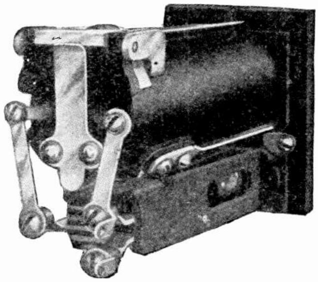


Fig. 104. Dean Drop and Jack

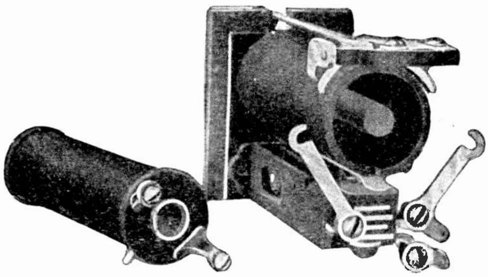


Fig. 105. Dean Drop and Jack

magnet. The night-alarm contact is clearly shown immediately below the strip which supports the drop, this consisting of a spring

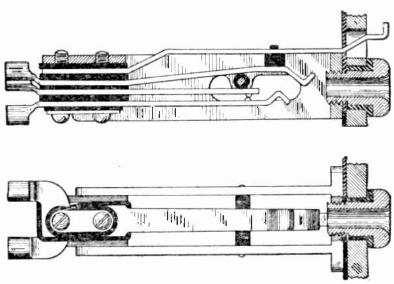


Fig. 106. Details of Dean Jack

adapted to be engaged by a lug on the shutter and pressed upwardly against a stationary contact when the shutter falls. The method of restoration of the shutter in this case is by means of an auxiliary spring bent up so as to engage the shutter and restore it when the spring is raised by the insertion of a plug into the jack.

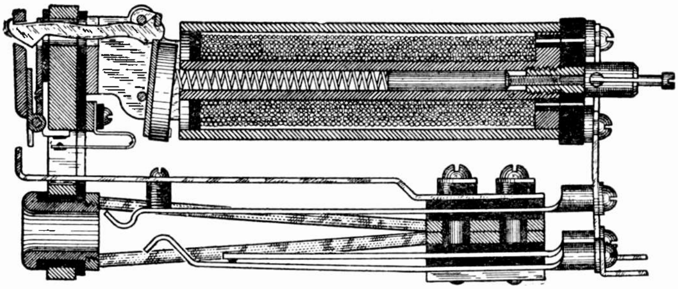


Fig. 107. Monarch Drop and Jack

Code Signaling. On bridging party lines, where the subscribers sometimes call other subscribers on the same line and sometimes call the switchboard so as to obtain a connection with another line, it is not always easy for the operator at the switchboard to distinguish whether the call is for her or for some other party on the line. On such lines, of course, code ringing is used and in most cases the operator's only way of distinguishing between calls for her and those for some sub-station parties on the line is by listening to the rattling noise which the drop armature makes. In the case of the Monarch drop the adjustable spring tension on the armature is intended to provide for such an adjustment as will permit the armature to give a satisfactory buzz in response to the alternating ringing currents, whether the line be long or short.

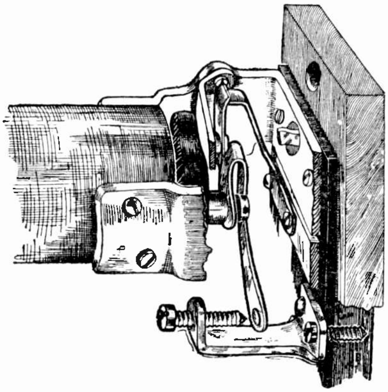


Fig. 108. Code Signal Attachment

The Monarch Company provides in another way for code signaling at the switchboard. In some cases there is a special attachment, shown in Fig. 108, by means of which the code signals are repeated on the night-alarm bell. This is in the nature of a special attachment placed on the drop, which consists of a light, flat spring attached to the armature and forming one side of a local circuit. The other side of the circuit terminates in a fixture which is mounted on the drop frame and is provided with a screw, having a platinum point forming the other contact point; this allows of considerable adjustment. At the point where the screw comes in contact with the spring there is a platinum rivet. When an operator is not always in attendance, this code-signaling attachment has some advantages

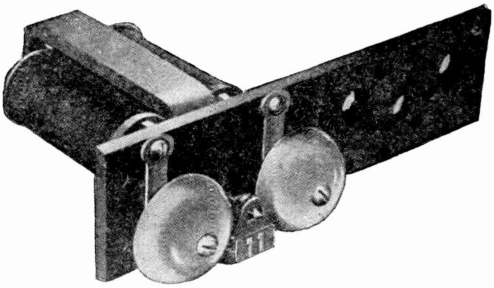


Fig. 109. Combined Drop and Ringer

over the drop as a signal interpreter, in that it permits the code signals to be heard from a distance. Of course, the addition of spring contacts to the drop armature tends to complicate the structure and perhaps to cut down the sensitiveness of the drop, which are offsetting disadvantages.

For really long lines, this code signaling by means of the drop is best provided for by employing a combined drop and ringer, although in this case whatever advantages are secured by the mechanical restoration of the shutter upon plugging in are lost. Such a device as manufactured by the Dean Electric Company is shown in Fig. 109. In this the ordinary polarized ringer is used, but in addition the tapper rod carries a latch which, when vibrated by the ringing of the bell, releases a shutter and causes it to fall, thus giving a visual as well as an audible signal.

Electrical. Coming now to the electrical restoration of drop shutters, reference is made to Fig. 110, which shows in side section the electrical restoring drop employed by the Bell companies and manufactured by the Western Electric Company. In this the coil *1* is a line coil, and it operates on the armature *2* to raise the latch lever

3 in just the same manner as in the ordinary tubular drop. The latch lever *3* acts, however, to release another armature *4* instead of a shutter. This armature *4* is pivoted at its lower end at the

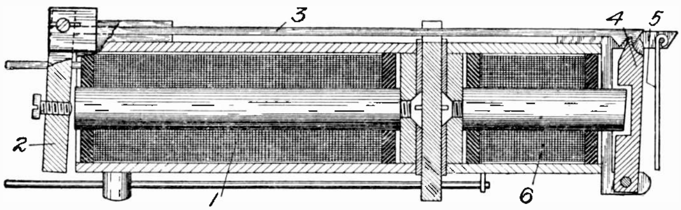


Fig. 110. Electrically Restored Drop

opposite end of the device from the armature *2* and, by falling outwardly when released, it serves to raise the light shutter *5*. The restoring coil of this device is shown at *6*, and when energized it attracts the armature *4* so as to pull it back under the catch of the latch lever *3* and also so as to allow the shutter *5* to fall into its normal position. The method of closing the restoring circuit is by placing coil *6* in circuit with a local battery and with a pair of contacts in the jack, which latter contacts are normally open but are bridged across by the plug when it enters the jack, thus energizing the restoring coil and restoring the shutter.

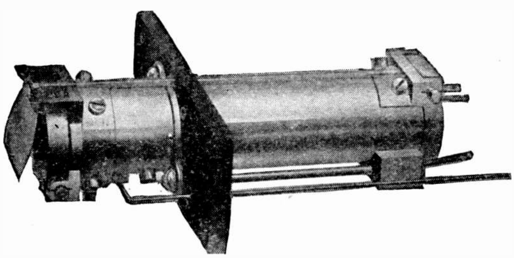


Fig. 111. Electrically Restored Drop

A perspective view of this Western Electric electrical restoring drop is shown in Fig. 111, a more complete mention being made of this feature under the discussion of magneto multiple switchboards, wherein it found its chief use. It is mentioned here to round out the methods that have been employed for accomplishing the automatic restoration of shutters by the insertion of the plug.

Switchboard Plugs. A switchboard plug such as is commonly used in simple magneto switchboards is shown in Fig. 112 and also in Fig. 83. The tip contact is usually of brass and is connected to a slender steel rod which runs through the center of the plug and terminates near the rear end of the plug in a connector for the tip conductor of the cord. This central core of steel is carefully insulated from the outer shell of the plug by means of hard rubber bushings, the parts being forced tightly together. The outer shell, of course, forms the other conductor of the plug, called the sleeve contact. A handle of tough fiber tubing is fitted over the rear end of the plug and this also serves to close the opening formed by cutting away a portion of the plug shell, thus exposing the connector for the tip conductor.

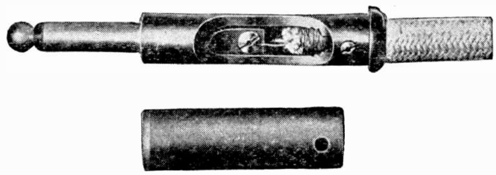


Fig. 112. Switchboard Plug

Cord Attachment. The rear end of the plug shell is usually bored out just about the size of the outer covering of the switchboard cord, and it is provided with a coarse internal screw thread, as shown. The cord is attached by screwing it tightly into this screw-threaded chamber, the screw threads in the brass being sufficiently coarse and of sufficiently small internal diameter to afford a very secure mechanical connection between the outer braiding of the cord and the plug. The connection between the tip conductor of the cord and the tip of the plug is made by a small machine screw connection as shown, while the connection between the sleeve conductor of the plug and the sleeve conductor of the cord is made by bending back the latter over the outer braiding of the cord before it is screwed into the shank of the plug. This results in the close electrical contact between the sleeve conductor of the cord and the inner metal surface of the shank of the plug.

Switchboard Cords. A great deal of ingenuity has been exerted toward the end of producing a reliable and durable switchboard cord. While great improvement has resulted, the fact remains that the cords of manual switchboards are today probably the most troublesome element, and they need constant attention and repairs. While no two manufacturers build their cords exactly alike, descriptions of a few commonly used and successful cords may be here given.

Concentric Conductors. In one the core is made from a double strand of strong lock stitch twine, over which is placed a linen braid. Then the tip conductor, which is of stranded copper tinsel, is braided on. This is then covered with two layers of tussah silk, laid in reverse wrappings, then there is a heavy cotton braid, and over the latter a linen braid. The sleeve conductor, which is also of copper tinsel, is then braided over the structure so formed, after which two reverse wrappings of tussah silk are served on, and this is covered by a cotton braid and this in turn by a heavy linen or polished

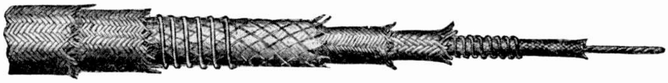


Fig. 113. Switchboard Cord

cotton braid. The plug end of the cord is reinforced for a length of from 12 to 18 inches by another braiding of linen or polished cotton, and the whole cord is treated with melted beeswax to make it moisture-proof and durable.

Steel Spiral Conductors. In another cord that has found much favor the two conductors are formed mainly by two concentric spiral wrappings of steel wire, the conductivity being reinforced by adjacent braidings of tinsel. The structure of such a cord is well shown in Fig. 113. Beginning at the right, the different elements shown are, in the order named, a strand of lock stitch twine, a linen braiding, into the strands of which are intermingled tinsel strands, the inner spiral steel wrapping, a braiding of tussah silk, a linen braiding, a loose tinsel braiding, the outer conductor of round spiral steel, a cotton braid, and an outside linen or polished cotton braid. The inner tinsel braiding and the inner spiral together form the tip conductor while the outer braiding and spiral together form the sleeve conductor. The cord is reinforced at the plug end for a length of about 14 inches by another braiding of linen. The tinsel used is, in each case, for the purpose of cutting down the resistance of the main steel conductor. These wrappings of steel wire forming the tip and sleeve conductors respectively, have the advantage of affording great flexibility, and also of making it certain that whatever strain the cord is subjected to will fall on the insulated braiding rather than on the spiral steel which has in itself no power to resist tensile strains.

Parallel Tinsel Conductors. Another standard two-conductor switchboard cord is manufactured as follows: One conductor is of very heavy copper tinsel insulated with one wrapping of sea island cotton, which prevents broken ends of the tinsel or knots from piercing through and short-circuiting with the other conductor. Over this is placed one braid of tussah silk and an outer braid of cotton. This combines high insulation with considerable strength. The other conductor is of copper tinsel, not insulated, and this is laid parallel to the thrice insulated conductor already described. Around these two conductors is placed an armor of spring brass wire in spiral form, and over this a close, stout braid of glazed cotton. This like the others is reinforced by an extra braid at the plug end.

Ringing and Listening Keys. The general principles of the ringing key have already been referred to. Ringing keys are of two general types, one having horizontal springs and the other vertical.

Horizontal Spring Type. Various Bell operating companies have generally adhered to the horizontal spring type except in

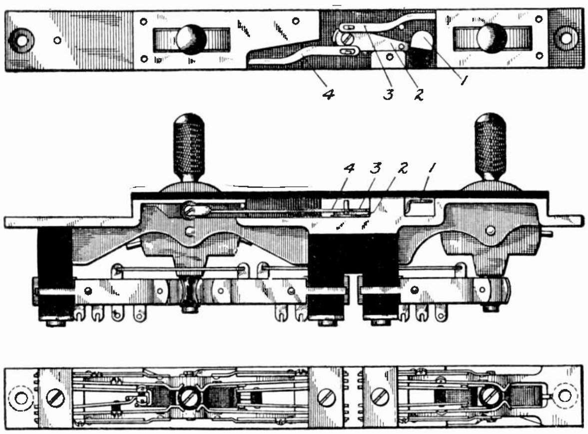


Fig. 114. Horizontal-Spring Listening and Ringing Key

individual and four-party-line keys. The construction of a Western Electric Company horizontal spring key is shown in Fig. 114. In this particular key, as illustrated, there are two cam levers operating upon three sets of springs. The cam lever at the left operates the ordinary ringing and listening set of springs according to whether it is pushed one way or the other. In ringing on single-party lines the cam lever at the left is the one to be used; while on two-party lines the lever at the left serves to ring the first party and the ringing key at the right the second party.

In order that the operator may have an indication as to which station on a two-party line she has called, a small target *1* carried on a lever *2* is provided. This target may display a black or a white field, according to which of its positions it occupies. The lever *2* is connected by the links *3* and *4* with the two key levers and the target is thus moved into one position or the other, according to which lever was last thrown into ringing position.

It will be noticed that the springs are mounted horizontally and on edge. This on-edge feature has the advantage of permitting ready inspection of the contacts and of avoiding the liability of dust gathering between the contacts. As will be seen, at the lower end of each switch lever there is a roller of insulating material which serves as a wedge, when forced between the two long springs of any set, to force them apart and into engagement with their respective outer springs.

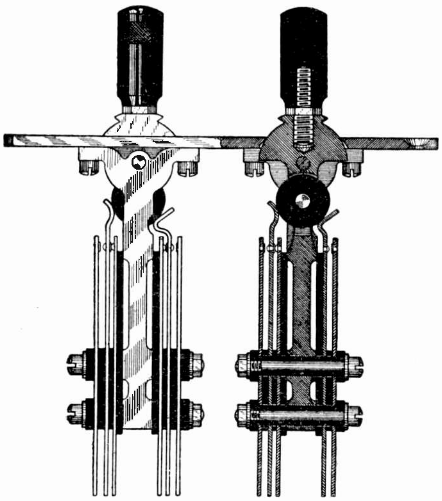


Fig. 115. Vertical-Spring Listening and Ringing Key

Vertical Spring Type. The other type of ringing and listening key employing vertical springs is almost universally used by the various independent manufacturing companies. A good example of this is shown in Fig. 115, which shows partly in elevation and partly in section a double key of the Monarch Company. The operation of this is obvious from its mode of construction. The right-hand set of springs of the right-hand key in this cut are the springs of the listening key, while the left-hand set of the right-hand key are those of the calling-plug ringing key. The left-hand set of the left-hand key may be those of a ring-back key on the answering plug, while the right-hand set of the left-hand key may be for any special purpose. It is obvious that these groups of springs may be grouped in different combinations or omitted in part, as required. This same general form of key is also manufactured by the Kellogg Company and the Dean Company, that of the Kellogg Company being illustrated in perspective, Fig. 116. The keys of this general type have the same advantages as those of the horizontal on-edge arrangement with respect to the gathering of dust, and while perhaps the contacts are not so readily get-at-able for inspection, yet they have the advantage of being somewhat more simple, and of taking up less horizontal space on the key shelf.

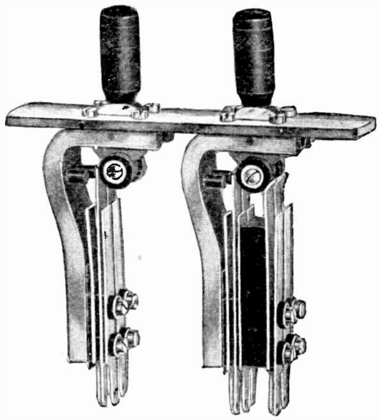


Fig. 116. Vertical Listening and Ringing Key

Party-Line Ringing Keys. For party-line ringing the key matter becomes somewhat more complicated. Usually the arrangement is such that in connection with each calling plug there are a number of keys, each arranged with respect to the circuits of the plug so as to send out the proper combination and direction of current, if the polarity system is used; or the proper frequency of current if the harmonic system is used; or the proper number of impulses if the step-by-step or broken-line system is used. The number of different kinds of arrangements and combinations is legion, and we will here illustrate only an example of a four-party line ringing key adapted for harmonic ringing. A Kellogg party-

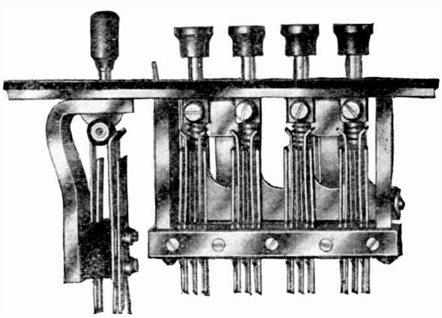


Fig. 117. Four-Party Listening and Ringing Key

line listening and ringing key is shown in Fig. 117. In this, besides the regular listening key, are shown four push-button keys, each adapted, when depressed, to break the connection back of the key, and at the same time connect the proper calling generator with the calling plug.

Self-Indicating Keys. A complication that has given a good deal of trouble in the matter of party-line ringing is due to the fact that it is sometimes necessary to ring a second or a third time on a party-line connection, because the party called may not respond the first time. The operator is not always able to remember which one of the four keys associated with the plug connected with the desired party she has pressed on the first occasion and, therefore, when it becomes necessary to ring again, she may ring the wrong party. This is provided for in a very ingenious way in the key shown in Fig. 117, by making the arrangement such that after a given key has been depressed to its full extent in ringing, and then released, it does not come quite back to its normal position but remains slightly depressed. This always serves as an indication to the operator, therefore, as to which key she depressed last, and in the case of a re-ring, she merely presses the key that is already down a little way. On the next call if she is required to press another one of the four keys, the one which remained down a slight distance on the last call will be released and the one that is fully depressed will be the one that remains down as an indication.

Such keys, where the key that was last used leaves an indication to that effect, are called *indicating* ringing keys. In other forms the indication is given by causing the key lever to move a little target which remains exposed until some other key in the same set is moved. The key shown in Fig. 114 is an example of this type.

NOTE. The matter of automatic ringing and other special forms of ringing will be referred to and discussed at their proper places in this work, but at this point they are not pertinent as they are not employed in simple switchboards.

Operator's Telephone Equipment. Little need be said concerning the matter of the operator's talking apparatus, *i. e.*, the operator's transmitter and receiver, since as transmitters and receivers they are practically the same as those in ordinary use for other purposes. The watch-case receiver is nearly always employed for operators' purposes on account of its lightness and compactness. It is used in connection with a head band so as to be held continually at the operator's ear, allowing both of her hands to be free.

The transmitter used by operators does not in itself differ from the transmitters employed by subscribers, but the methods by which it is supported differ, two general practices being followed. One of these is to suspend the transmitter by flexible conducting cords so as to be adjustable in a vertical direction. A good illustration of this is given in Fig. 118. The other method, and one that is coming into more and more favor, is to mount the transmitter on a

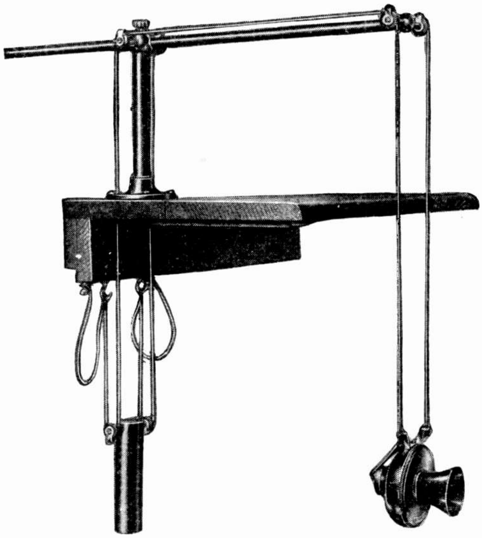


Fig. 118. Operator's Transmitter Suspension

light bracket suspended by a flexible band from the neck of the operator, a breast plate being furnished so that the transmitter will rest on her breast and be at all times within proper position to receive her speech. To facilitate this, a long curved mouthpiece is commonly employed, as shown clearly in Fig. 47.

Cut-in Jack. It is common to terminate that portion of the apparatus which is worn on the operator's person—that is, the receiver only if the suspended type of transmitter is employed, and the receiver and transmitter if the breast plate type of transmitter is employed—in a plug, and a flexible cord connecting the plug terminates with the apparatus. The portions of the operator's talking circuit that are located permanently in the switchboard cabinet are in such cases terminated in a jack, called an operator's *cut-in jack.* This is usually mounted on the front rail of the switchboard cabinet just below the key shelf. Such a cut-in jack is shown in Fig. 119 and it is merely a specialized form of spring jack adapted to receive the short, stout plug in which the operator's transmitter, or transmitter and receiver, terminate. By this arrangement the operator is enabled readily to connect or disconnect her talking apparatus, which is worn on her person, whenever she comes to the board for work or leaves it at the end of her work. A complete operator's telephone set, or that portion that is carried on the person of the operator, together with the cut-in plug, is shown in Fig. 120.

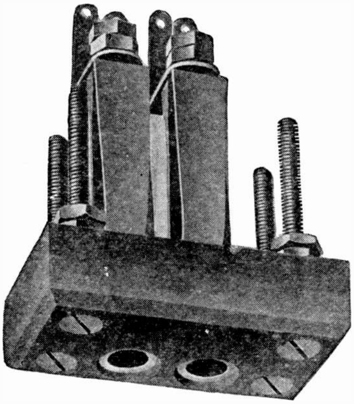


Fig. 119. Operator's Cut-In Jack

Circuits of Complete Switchboard. We may now discuss the circuits of a complete simple magneto switchboard. The one shown in Fig. 121 is typical. Before going into the details of this, it is well to inform the student that this general form of circuit representation is one that is commonly employed in showing the complete circuits of any switchboard. Ordinarily two subscribers' lines are shown, these connecting their respective subscribers' stations with two different line equipments at the central office. The jacks and signals of these line equipments are turned around so as to face each other, in order to clearly represent how the connection between them

Fig. 120. Operator's Talking Set

may be made by means of the cord circuit. The elements of the cord circuit are also spread out, so that the various parts occupy relative positions which they do not assume at all in practice. In other words it must be remembered that, in circuit diagrams, the relative positions of the parts are sacrificed in order to make clear the circuit connections. However, this does not mean that it is often not possible to so locate the pieces of apparatus that they will in a certain way indicate relative positions, as may be seen in the case

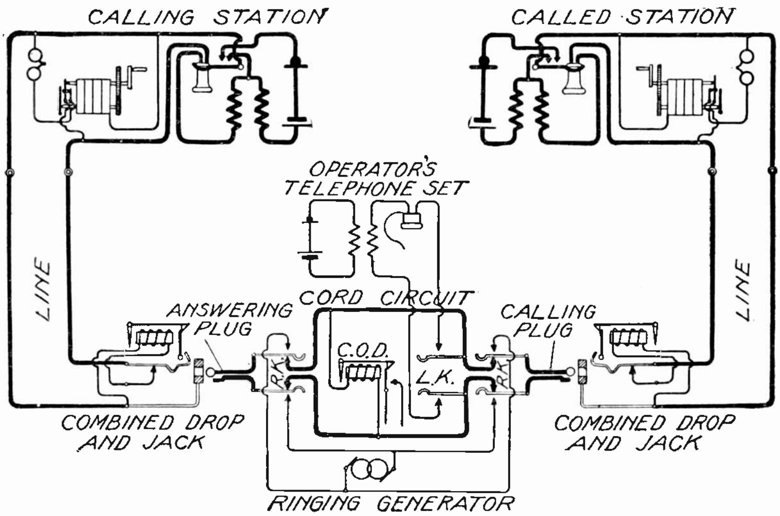


Fig. 121. Circuit of Simple Magneto Switchboard

of the drop and jack in Fig. 121, the drop being shown immediately above the jack, which is the position in which these parts are located in practice.

Little need be said concerning this circuit in view of what has already been said in connection with Figs. 88 to 93. It will be seen in the particular sub-station circuit here represented, that the talking apparatus is arranged in the usual manner and that the ringer and generator are so arranged that when the generator is operated the ringer will be cut out of circuit, while the generator will be placed across the circuit; while, when the generator is idle, the ringer is bridged across the circuit and the generator is cut out.

The line terminates in each case in the tip and sleeve contacts of the jack, and in the normal condition of the jack the line drop is bridged across the line. The arrangement by which the drop is restored and at the same time cut out of circuit when the operator plugs in the jack, is obvious from the diagrammatic illustration. The cord circuit is the same as that already discussed, with the exception that two ringing keys are provided, one in connection with the calling plug, as is universal practice, and the other in connection with the answering plug as is sometimes practiced in order that the operator may, when occasion requires, ring back the calling subscriber without the necessity of changing the plug in the jack. The outer contacts of these two ringing keys are connected to the terminals of the ringing generator and, when either key is operated, the connection between the plug, on which the ringing is to be done, and the rest of the cord circuit will be broken, while the generator will be connected with the terminals of the plug. The listening key and talking apparatus need no further explanation, it being obvious that when the key is operated the subscriber's telephone set will be bridged across the cord circuit and, therefore, connected with either or both of the talking subscribers.

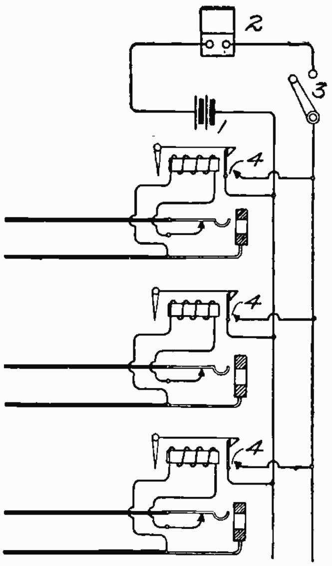
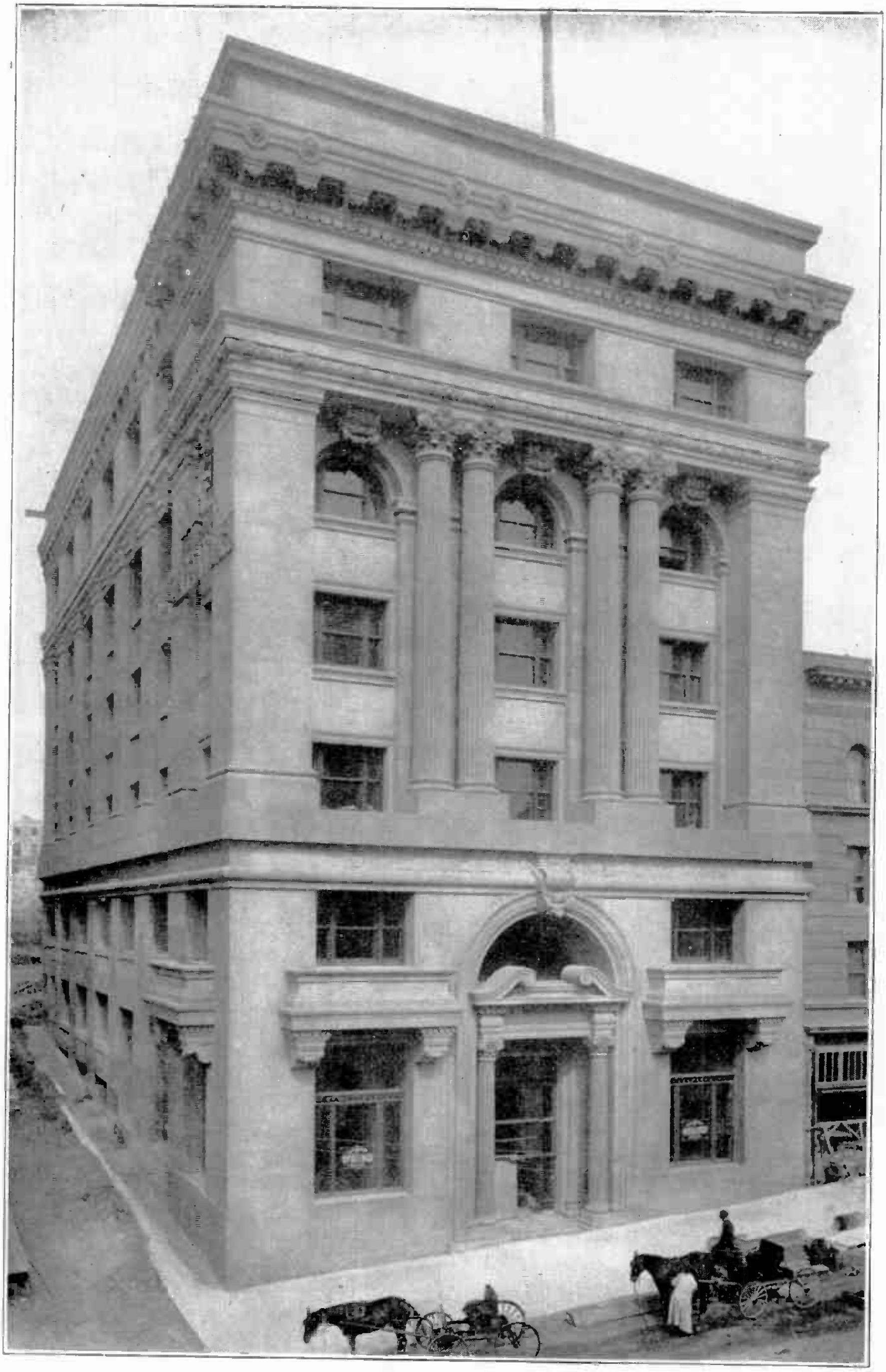


Fig. 122. Night-Alarm Circuit

Night-Alarm Circuits. The circuit of Fig. 121, while referred to as a complete circuit, is not quite that. The night-alarm circuit is not shown. In order to clearly indicate how a single battery and bell, or buzzer, may serve in connecting a number of line drops, reference is made to Fig. 122 which shows the connection between three different line drops and the night-alarm circuit. The night-alarm apparatus consists in the battery *1* and the buzzer, or bell, *2*. A switch *3* adapted to be manually operated is connected in the circuit with the battery and the buzzer so as to open this circuit when the night alarm is not needed, thus making it inoperative. During the portions of the day when the operator is needed constantly at



GRANT AVENUE OFFICE OF HOME TELEPHONE COMPANY, SAN FRANCISCO, CAL.
A Type of Central-Office Buildings in Down-Town Districts of Large Cities.

the board it is customary to leave this switch *3* open, but during the night period when she is not required constantly at the board this switch is closed so that an audible signal will be given whenever a drop falls. The night-alarm contact *4* on each of the drops will be closed whenever a shutter falls, and as the two members of this contact, in the case of each drop, are connected respectively with the two sides of the night-alarm circuit, any one shutter falling will complete the necessary conditions for causing the buzzer to sound, assuming of course that the switch *3* is closed.

Night Alarm with Relay. A good deal of trouble has been caused in the past by uncertainty in the closure of the night-alarm circuit at the drop contact. Some of the companies have employed the form of circuit shown in Fig. 123 to overcome this. Instead of the night-alarm buzzer being placed directly in the circuit that is closed by the drop, a relay *5* and a high-voltage battery *6* are placed in this circuit. The buzzer and the battery for operating it are placed in a local circuit controlled by this relay. It will be seen by reference to Fig. 123 that when the shutter falls, it will, by closing the contact *4*, complete the circuit from the battery *6* through the relay *5*—assuming switch *3* to be closed—and thus cause the operation of the relay. The relay, in turn, by pulling up its armature, will close the circuit of the buzzer *2* through the battery *7* and cause the buzzer to sound.

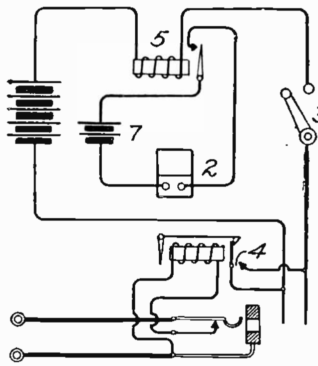


Fig. 123. Night-Alarm Circuit with Relay

The advantage of this method over the direct method of operating the buzzer is that any imperfection in the night-alarm contact at the drop is much less likely to prevent the flow of current of the high-voltage battery *6* than of the low-voltage battery *1*, shown in connection with Fig. 122. This is because the higher voltage is much more likely to break down any very thin bit of insulation, such as might be caused by a minute particle of dust or oxide between contacts that are supposed to be closed by the falling of the shutter. It has been common to employ for battery *6* a dry-cell battery giving about 20 or 24 volts, and for the operation of the buzzer itself, a similar battery of about two cells giving approximately 3 volts.

Night-Alarm Contacts. The night-alarm contact *4* of the drop shown diagrammatically in Figs. 122 and 123 would, if taken literally, indicate that the shutter itself actually forms one terminal of the circuit and the contact against which it falls, the other. This has not been found to be a reliable way of closing the night-alarm contacts and this method is indicated in these figures and in other figures in this work merely as a convenient way of representing the matter diagrammatically. As a matter of fact the night-alarm contacts are ordinarily closed by having the shutter fall against one spring, which is thereby pressed into engagement with another spring or contact, as shown in Fig. 97. This method employs the shutter only as a means for mechanically causing the one spring to press against the other, the shutter itself forming no part of the circuit. The reason why it is not a good plan to have the shutter itself act as one terminal of the circuit is that this necessitates the circuit connections being led to the shutter through the trunnions on which the shutter is pivoted. This is bad because, obviously, the shutter must be loosely supported on its trunnions in order to give it sufficiently free movement, and, as is well known, loose connections are not conducive to good electrical contacts.

Grounded- and Metallic-Circuit Lines. When grounded circuits were the rule rather than the exception, many of the switchboards were particularly adapted for their use and could not be used with metallic-circuit lines. These grounded-circuit switchboards provided but a single contact in the jack and a single contact on the plug, the cords having but a single strand reaching from one plug to the other. The ringing keys and listening keys were likewise single-contact keys rather than double. The clearing-out drop and the operator's talking circuit and the ringing generator were connected between the single strand of the cord and the ground as was required.

The grounded-circuit switchboard has practically passed out of existence, and while a few of them may be in use, they are not manufactured at present. The reason for this is that while many grounded circuits are still in use, there are very few places where there are not some metallic-circuit lines, and while the grounded-circuit switchboard will not serve for metallic-circuit lines, the metallic-circuit switchboard will serve equally well for either metallic-circuit or grounded lines, and will interconnect them with equal facility. This fact will be made clear by a consideration of Figs. 124, 125, and 126.

Connection between Two Similar Lines. In Fig. 124 a common magneto cord circuit is shown connecting two metallic-circuit lines;

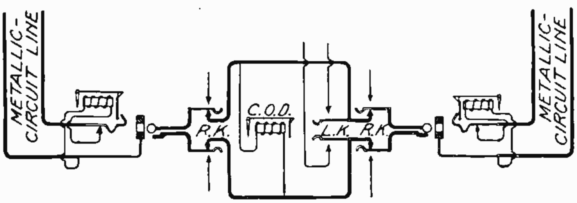


Fig. 124. Connection Between Metallic Lines

in Fig. 125 the same cord circuit is shown connecting two grounded lines. In this case the line wire *1* of the left-hand line is, when the plugs are inserted, continued to the tip of the answering plug, thence through the tip strand of the cord circuit to the tip of the calling plug, then to the tip spring of the right-hand jack and out to the single con-

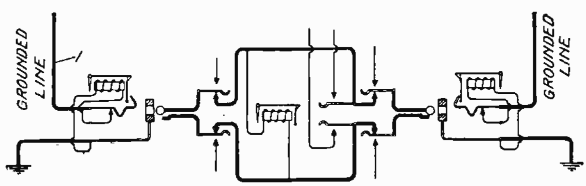


Fig. 125. Connection Between Grounded Lines

ductor of that line. The entire sleeve portion of the cord circuit becomes grounded as soon as the plugs are inserted in the jacks of such a line. Hence, we see that the sleeve contacts of the plug and the sleeve conductor of the cord are connected to ground through the permanent ground connection of the sleeve conductors of the jack as soon as the plug is inserted into the jack. Thus, when the cord circuit of a metallic-circuit switchboard is used to connect two grounded circuits together, the tip strand of the cord is the connecting link between the two conductors, while the sleeve strand of the cord merely serves to ground one side of the clearing-out drop and one side each of the operator's telephone set and the ringing generator when their respective keys are operated.

Connection between Dissimilar Lines. Fig. 126 shows how the same cord circuit and the same arrangement of line equipment may be used for connecting a grounded line to a metallic-circuit line. The metallic circuit line is shown on the left and the grounded line on the right. When the two plugs are inserted into the respective jacks of this figure, the right-hand conductor of the metallic circuit shown on the left will be continued through the tip strand of the cord circuit to the line conductor of the grounded line shown on the right. The left-hand conductor of the metallic-circuit line will be connected to ground because it will be continued through the sleeve strand of the cord circuit to the sleeve contact of the calling plug and thence to the sleeve contact of the jack of the grounded line, which sleeve contact is shown to be grounded. The talking circuit between the two connected lines in this case may be traced as follows: From the subscriber's station at the left through the right-hand limb of the metallic-circuit line, through the tip contact and tip conductor of the cord circuit, to the single limb of the grounded-circuit line, thence to the sub-station of that line and through the talking apparatus there to ground. The return path from the right-hand

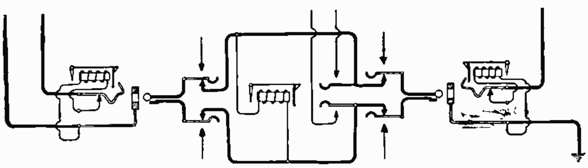


Fig. 126. Connection Between Dissimilar Lines

station is by way of ground to the ground connection at the central office, thence to the sleeve contact of the grounded line jack, through the sleeve conductor of the cord circuit, to the sleeve contact of the metallic-circuit line jack, and thence by the left-hand limb of the metallic-circuit line to the subscriber's station.

A better way of connecting a metallic-circuit line to a grounded line is by the use of a special cord circuit involving a repeating coil, such a connection being shown in Fig. 127. The cord circuit in this case differs in no respect from those already shown except that a repeating coil is associated with it in such a way as to conductively divide the answering side from the calling side. Obviously, whatever currents come over the line connected with the answering plug will pass through the windings *1* and *2* of this coil and will induce corresponding currents in the windings *3* and *4*, which latter currents

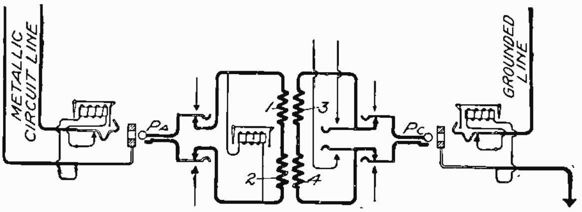


Fig. 127. Connection of Dissimilar Lines through Repeating Coil

will pass out over the circuit of the line connected with the calling plug. When a grounded circuit is connected to a metallic circuit in this manner, no ground is thrown onto the metallic circuit. The balance of the metallic circuit is, therefore, maintained.

To ground one side of a metallic circuit frequently so unbalances it as to cause it to become noisy, that is, to have currents flowing in it, by induction or from other causes, other than the currents which are supposed to be there for the purpose of conveying speech.

Convertible Cord Circuits. The consideration of Fig. 127 brings us to the subject of so-called convertible cord circuits. Some switchboards, serving a mixture of metallic and grounded lines, are provided with cord circuits which may be converted at will by the operator from the ordinary type shown in Fig. 124 to the type shown in Fig. 127. The advantage of this will be obvious from the following consideration. When a call originates on any line, either grounded or metallic, the operator does not know which kind of a line is to be called for. She, therefore, plugs into this line with any one of her answering plugs and completes the connection in the usual way. If the call is for the same kind of a circuit as that over which the call originated, she places the converting key in such a position as will connect the conductors of the cord circuit straight through; while if the connection is for a different kind of a line than that on which the call originated she throws the converting key into such a position as to include the repeating coil. A study of Fig. 128 will show that when the converting key, which is commonly referred to as the repeating-coil key, is in one position, the cord conductors will be cut straight through, the repeating coil being left open in both its windings; and when it is thrown to its other position, the connection be-

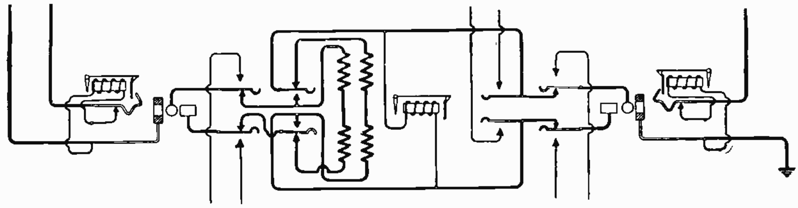


Fig. 128. Convertible Cord Circuit

tween the answering and calling sides of the cord circuit will be severed and the repeating coil inserted so as to bring about the same effects and circuit arrangements as are shown in Fig. 127.

Cord-Circuit Considerations. *Simple Bridging Drop Type.* The matter of cord circuits in magneto switchboards is deserving of much attention. So far as talking requirements are concerned, the ordinary form of cord circuit with a clearing-out drop bridged across the two strands is adequate for nearly all conditions except those where a grounded- and a metallic-circuit line are connected together, in which case the inclusion of a repeating coil has some advantages.

From the standpoint of signaling, however, this type of cord circuit has some disadvantages under certain conditions. In order to simplify the discussion of this and other cord-circuit matters, reference will be made to some diagrams from which the ringing and listening keys and talking apparatus have been entirely omitted. In Fig. 129 the regular bridging type of clearing-out drop-cord circuit is shown, this being the type already discussed as standard. For ordinary practice it is all right. Certain difficulties are experienced with it, however, where lines of various lengths and various types of sub-station apparatus are connected. For instance, if a long

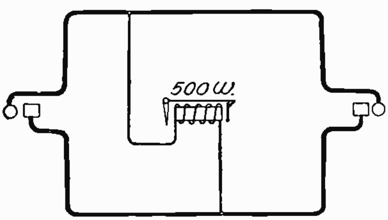


Fig. 129. Bridging Drop-Cord Circuit

bridging line be connected with one end of this cord circuit and a short line having a low-resistance series ringer be connected with the other end, then a station on the long line may have some difficulty in throwing the clearing-out drop, because of the low-resistance shunt that is placed around it through the short line and the low-resistance ringer. In other words, the clearing-out drop is shunted by a comparatively low-resistance line and ringer and the feeble currents arriving from a distant station over the long line are not sufficient to operate the drop thus handicapped. The advent of the various forms of party-line selective signaling and the use of such systems in connection with magneto switchboards has brought in another difficulty that sometimes manifests itself with this type of cord circuit. If two ordinary magneto telephones are connected to the two ends of this cord circuit, it is obvious that when one of the subscribers has hung up his receiver and the other subscriber rings off, the bell of the other subscriber will very likely be rung even though the clearing-out drop operates properly; it would be better in any event not to have this other subscriber's bell rung, for he may understand it to be a recall to his telephone. When, however, a party line is connected through such a cord circuit to an ordinary line having bridging instruments, for instance, the difficulty due to ringing off becomes even greater. When the subscriber on the magneto line operates his generator to give the clearing-out signal, he is very likely to ring some of the bells on the other line and this, of course, is an undesirable thing. This may happen even in the case of harmonic bells on the party line, since it is possible that the subscriber on the magneto line in turning his generator will, at some phase of the operation, strike just the proper frequency to ring some one of the bells on the harmonic party line. It is obvious, therefore, that there is a real need for a cord circuit that will prevent *through ringing.*

One way of eliminating the through-ringing difficulty in the type of cord circuit shown in Fig. 129 would be to use such a very low-wound clearing-out drop that it would practically short-circuit the line with respect to ringing currents and prevent them from passing on to the other line. This, however, is not a good thing to do, since a winding sufficiently low to shunt the effective ringing current would also be too low for good telephone transmission.

Series Drop Type. Another type of cord circuit that was largely used by the Stromberg-Carlson Telephone Manufacturing Company at one time is shown in Fig. 130. In this the clearing-out drop was not bridged but was placed in series in the tip side of the line and was shunted by a condenser. The resistance of the clearing-out drop was 1,000 ohms and the capacity of the condenser was 2 microfarads. It is obvious that this way of connecting the clearing-out drop was subject to the *ringing-through* difficulty, since the circuit through which the clearing-out current necessarily passed included the telephone instrument of the line that was not sending the clearing-out signal. This form was also objectionable because it was necessary for the subscriber to ring through the combined resistance of two lines, and in case the other line happened to be open, no clearing-out signal would be received. While this circuit, therefore, was perhaps not quite so likely as the other to tie up the subscriber, that is, to leave him connected without the ability to send a clearing-out signal, yet it was sure to ring through, for the clearing-out drop could not be thrown without the current passing through the other subscriber's station.

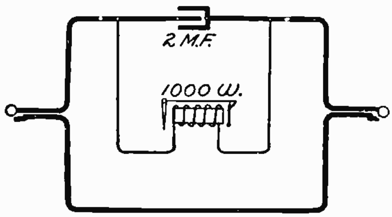


Fig. 130. Series Drop-Cord Circuit

Non-Ring-Through Type. An early attempt at a non-ring-through cord is shown in Fig. 131, this having once been standard with the Dean Electric Company. It made use of two condensers of 1 microfarad each, one in each side of the cord circuit. The clearing-out drop was of 500 ohms resistance and was connected from the answering side of the tip conductor to the calling side of the sleeve conductor. In this way whatever clearing-out current reached the central office passed through at least one of the condensers and the clearing-out drop. In order for the clearing-out current to pass on

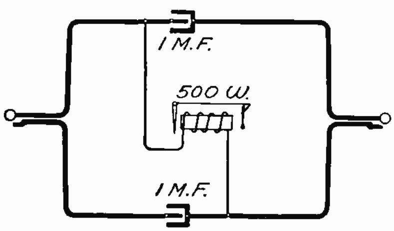


Fig. 131. Dean Non-Ring-Through Cord Circuit

beyond the central office it was necessary for it to pass through the two condensers in series. This arrangement had the advantage of giving a positive ring-off, regardless of the condition of the connected line. Obviously, even if the line was short-circuited, the ringing currents from the other line would still be forced through the clearing-out drop on account of the high effective resistance of the 1-microfarad condenser connected in series with the short-circuited line. Also the clearing-out signal would be properly received if the connected line were open, since the clearing-out drop would still be directly across the cord circuit. This arrangement also largely prevented through ringing, since the currents would pass through the 1-microfarad condenser and the 500-ohm drop more readily than through the two condensers connected in series.

In Fig. 132 is shown the non-ring-through arrangement of cord circuit adopted by the Monarch Company. In this system the clearing-out drop has two windings, either of which will operate the armature. The two windings are bridged across the cord circuit, with a ½-microfarad condenser in series in the tip strand between the two winding connections. While the low-capacity condenser will allow the high-frequency talking current to pass readily without affecting it to any appreciable extent, it offers a high resistance to a low-frequency ringing current, thus preventing it from passing out on a connected line and forcing it through one of the windings of the coil. There is a tendency to transformer action in this arrangement, one of the windings serving as a primary and the other as a secondary, but this has not prevented the device from being highly successful.

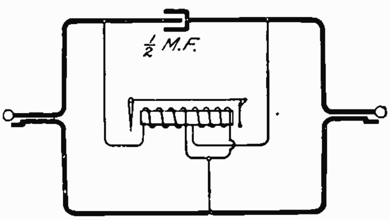


Fig. 132. Monarch Non-Ring-Through Cord Circuit

A modification of this arrangement is shown in Fig. 133, wherein a double-wound clearing-out drop is used, and a ½-microfarad condenser is placed in series in each side of the cord circuit between the winding connections of the clearing-out drop. This circuit should give a positive ring-off under all conditions and should prevent through ringing except as it may be provided by the transformer action between the two windings on the same core.

Another rather ingenious method of securing a positive ring-off and yet of preventing in a certain degree the undesirable ringing-through feature is shown in the cord circuit, Fig. 134. In this two non-inductive coils *1* and *2* are shown connected in series in the tip and sleeve strands of the coils, respectively. Between. the neutral point of these two non-inductive windings is connected the clearing-out drop circuit. Voice currents find ready path through these non-inductive windings because of the fact that, being non-inductive, they present only their straight ohmic resistance. The impedance of the clearing-out drop prevents the windings being shunted across the two sides of the cord circuit. With this circuit a positive ring-off is assured even though the line connected with the one sending the clearing-out signal is short-circuited or open. If it is short-circuited, the shunt around the clearing-out drop will still have the resistance of two of the non-inductive windings included in it, and thus the drop will never be short-circuited by a very low-resistance path. Obviously, an open circuit in the line will not prevent the clearing-out signal being received. While this is an ingenious scheme, it is not one to be highly recommended since the non-inductive windings, in order to be effective so far as signaling is concerned, must be of considerable resistance and this resistance is in series in the talking circuit. Even non-inductive resistance is to be avoided in the talking circuit when it is of considerable magnitude and where there are other ways of solving the problem.

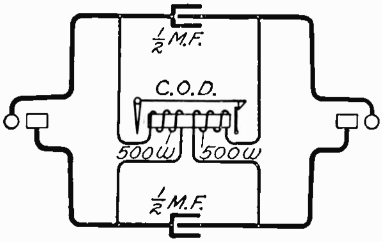


Fig. 133. Non-Ring-Through Cord Circuit

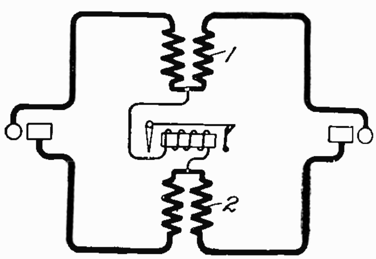


Fig. 134. Cord Circuit with Differential Windings

Double Clearing-out Type. Some people prefer two clearing-out drops in each cord circuit, so arranged that the one will be responsive to currents sent from the line with which the answering plug is connected and the other responsive only to currents sent from the line with which the calling plug is connected. Such a scheme, shown in Fig. 135, is sometimes employed by the Dean, the Monarch, and the Kellogg companies. Two 500-ohm clearing-out drops of ordinary construction are bridged across the cord circuit and in each side of the cord circuit there is included between the drop connections a 1-microfarad condenser. Ringing currents originating on the line with which the answering plug is connected will pass through the clearing-out drop, which is across that side of the cord circuit, without having to pass through any condensers. In order to reach the other clearing-out drop the ringing current must pass through the two 1-microfarad condensers in series, this making in effect only ½-microfarad. As is well known, a ½-microfarad condenser not only transmits voice currents with ease but also offers a very high apparent resistance to ringing currents. With the double clearing-out drop system the operator is enabled to tell which subscriber is ringing off. If both shutters fall she knows that both subscribers have sent clearing-out signals and she, therefore, pulls down the connection without the usual precaution of listening to see whether one of the subscribers may be waiting for another connection. This double clearing-out system is analogous to the complete double-lamp supervision that will be referred to more fully in connection with common-battery circuits. There is not the need for double supervision in magneto work, however, that there is in common-battery work because of the fact that in magneto work the subscribers frequently fail to remember to ring off, this act being entirely voluntary on their part, while in common-battery work, the clearing-out signal is given automatically by the subscriber when he hangs up his receiver, thus accomplishing the desired end without the necessity of thoughtfulness on his part.

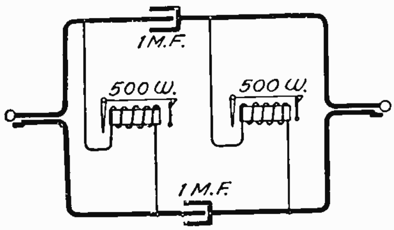


Fig. 135. Double Clearing-Out Drops

Another form of double clearing-out cord circuit is shown in Fig. 136. In this the calling and the answering plugs are separated by repeating coils, a condenser of 1-microfarad capacity being inserted between each pair of windings on the two ends of the circuit.

The clearing-out drops are placed across the calling and answering cords in the usual manner. The condenser in this case prevents the drop being short-circuited with respect to ringing currents and yet

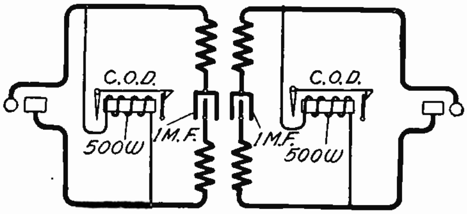


Fig. 136. Double Clearing-Out Drops

permits the voice currents to flow readily through it. The high impedance of the drop forces the voice currents to take the path through the repeating coil rather than through the drop. This circuit has the advantage of a repeating-coil cord circuit in permitting the connection of metallic and grounded lines without causing the unbalancing of the metallic circuits by the connection to them of the grounded circuits.

Recently there has been a growing tendency on the part of some manufacturers to control their clearing-out signals by means of relays associated with cord circuits, these signals sometimes being ordinary clearing-out drops and sometimes incandescent lamps.

In Fig. 137 is shown the cord circuit sometimes used by the L. M. Ericsson Telephone Manufacturing Company. A high-wound

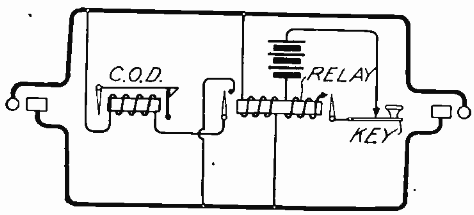


Fig. 137. Relay-Controlled Clearing-Out Drop

relay is normally placed across the cord and this, besides having a high-resistance and impedance winding has a low-resistance locking winding so arranged that when the relay pulls up its armature it will close a local circuit including this locking winding, and local battery. When once pulled up the relay will, therefore, stay up due to the energizing of this locking coil. Another contact operated by the relay closes the circuit of a low-wound clearing-out drop placed across the line, thus bridging it across the line. The condition of high impedance is maintained across the cord circuit normally while the subscribers are talking; but when either of them rings off, the high-wound relay pulls up and locks, thus completing the circuit of the clearing-out drop across the cords. The subsequent impulses sent from the subscribers' generators operate this drop. The relay is restored or unlocked and the clearing-out drop disconnected from the cord circuit by means of a key which opens the locking circuit of the relay. This key is really a part of the listening key and serves to open this locking circuit whenever the listening key is operated. The clearing-out drop is also automatically restored by the action of the listening key, this connection being mechanical rather than electrical.

Recall Lamp:—The Monarch Company sometimes furnishes what it terms a recall lamp in connection with the clearing-out drops on its magneto switchboards. The circuit arrangement is shown in Fig. 138, wherein the drop is the regular double-wound clearing-out drop like that of Fig. 132. The armature carries a contact spring adapted to close the local circuit of a lamp whenever it is attracted. The object of this is to give the subscriber, whose line still remains connected by a cord circuit, opportunity to recall the central office if the operator has not restored the clearing-out drop.

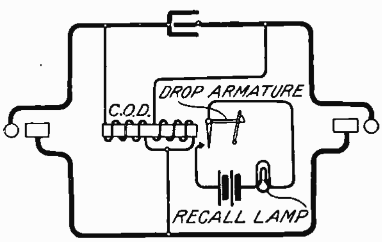


Fig. 138. Cord Circuit with Recall Lamp

Lamp-Signal Type. There has been a tendency on the part of some manufacturing companies to advocate, instead of drop signals, incandescent lamp signals for the cord circuits, and sometimes for the line circuits on magneto boards. In most cases this may be looked upon as a "frill." Where line lamps instead of drops have been used on magneto switchboards, it has been the practice to employ, instead of a drop, a locking relay associated with each lamp, which was so arranged that when the relay was energized by the magneto current from the subscriber's station, it would pull up and lock, thus closing the lamp circuit.

The local circuit, or locking circuit, which included the lamp was carried through a pair of contacts in the corresponding jacks so arranged that when the plug was inserted in answer to the call, this locking lamp circuit would be open, thereby extinguishing the lamp and also unlocking the relay. There seems to be absolutely no good reason why lamp signals should be substituted for mechanical drops in magneto switchboards. There is no need for the economy in space which the lamp signal affords, and the complications brought in by the locking relays, and the requirements for maintaining a local battery suitable for energizing the lamps are not warranted for ordinary cases.

In Fig. 139 is shown a cord circuit, adaptable to magneto switchboards, provided with double lamp signals instead of clearing-out

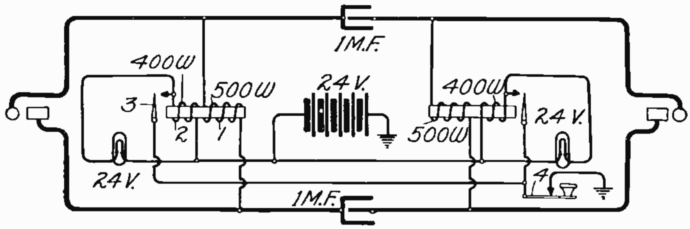


Fig. 139. Cord Circuit with Double Lamp Signals

drops. Two high-wound locking relays are bridged across the line, the cord strands being divided by 1-microfarad condensers. When the high-wound coil of either relay is energized by the magneto current from the subscriber's station, the relay pulls up and closes a locking circuit including a battery and a coil *2*, the contact *3* of the locking relay, and also the contact *4* of a restoring key. This circuit may be traced from the ground through battery, coil *2*, contact *3* controlled by the relay, and contact *4* controlled by the restoring key, and back to ground. In multiple with the locking coil *2* is the lamp, which is illuminated, therefore, whenever the locking circuit is closed. Pressure on the restoring key breaks the locking circuit of either of the lamps, thereby putting out the lamp and at the same time restoring the locking relay to its normal position.

Lamps vs. Drops in Cord Circuits. So much has been said and written about the advantages of incandescent lamps as signals in switchboards and about the merits of the common-battery method of supplying current to the subscribers, that there has been a tendency for people in charge of the operation of small exchanges to substitute the lamp for the drop in a magneto switchboard in order to give the general appearance of common-battery operations. There has also been a tendency to employ the common-battery system of operation in many places where magneto service should have been used, a mistake which has now been realized and corrected. In places where the simple magneto switchboard is the thing to use, the simpler it is the better, and the employment of locking relays and lamp signals and the complications which they carry with them, is not warranted.

Switchboard Assembly. The assembly of all the parts of a simple magneto switchboard into a complete whole deserves final consideration. The structure in which the various parts are mounted, referred to as the cabinet, is usually of wood.

Functions of Cabinet. The purpose of the cabinet is not only to form a support for the various pieces of apparatus but also to protect them from dust and mechanical injury, and to hold those parts that must be manipulated by the operator in such relation that they may be most convenient for use, and thus best adapted for carrying out their various functions. Other points to be provided for in the design of the cabinet and the arrangement of the various parts within are: that all the apparatus that is in any way liable to get out of order may be readily accessible for inspection and repairs; and that provision shall be made whereby the wiring of these various pieces of apparatus may be done in a systematic and simple way so as to minimize the danger of crossed, grounded, or open circuits, and so as to provide for ready repair in case any of these injuries do occur.

Wall-Type Switchboards. The simplest form of switchboard is that for serving small communities in rural districts. Ordinarily the telephone industry in such a community begins by a group of farmers along a certain road building a line connecting the houses of several of them and installing their own instruments. This line is liable to be extended to some store at the village or settlement, thus affording communication between these farmers and the center of their community. Later on those residing on other roads do the same thing and connect their lines to the same store or central point. Then it is that some form of switchboard is established, and perhaps the storekeeper's daughter or wife is paid a small fee for attendance.

A switchboard well-adapted for this class of service where the number of lines is small, is shown in Fig. 140. In this the operator's

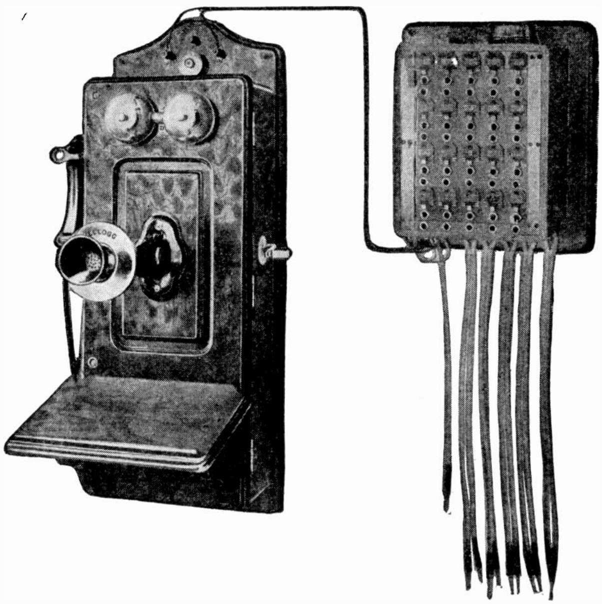
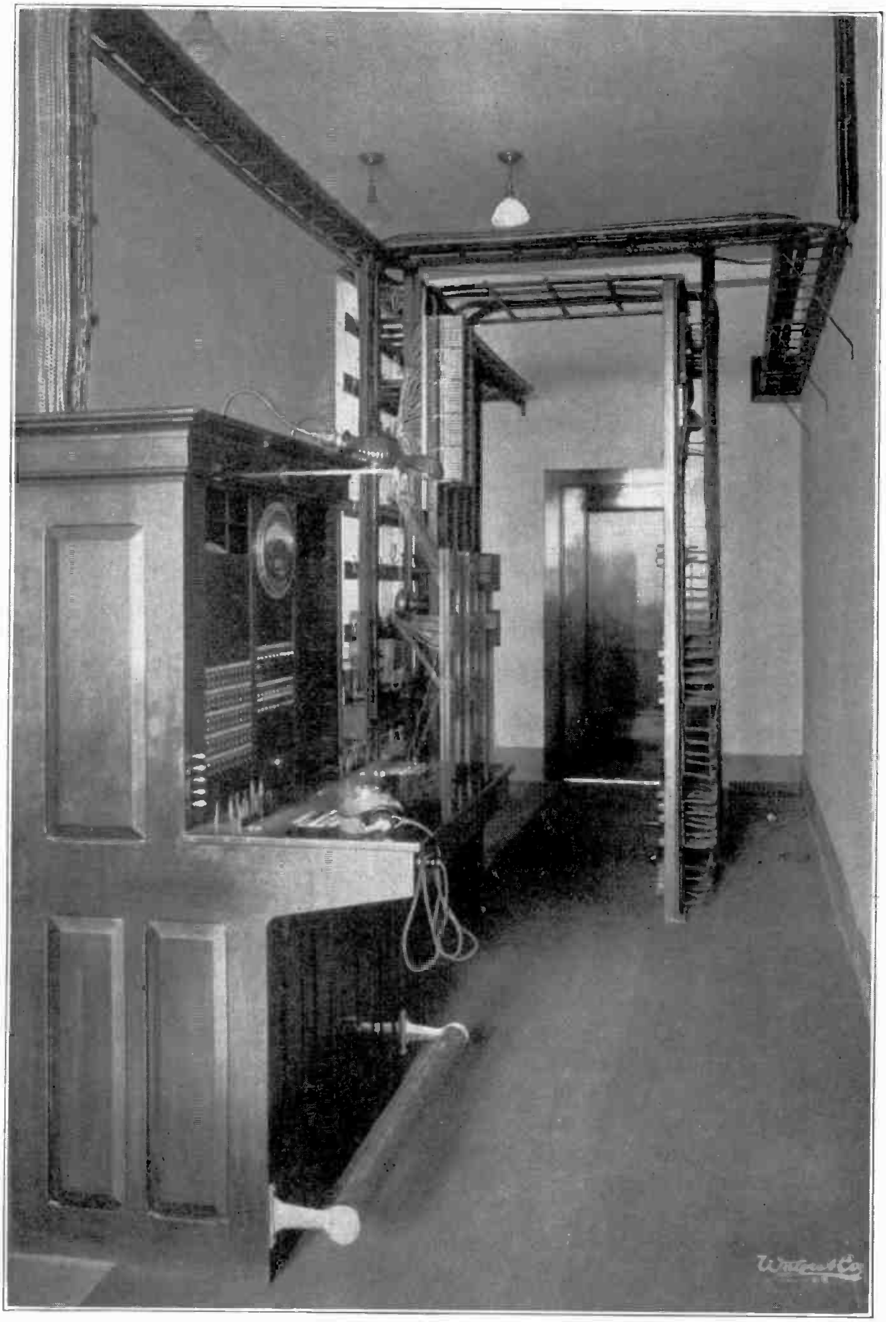


Fig. 140. Wall Switchboard with Telephone

talking apparatus and her calling apparatus are embodied in an ordinary magneto wall telephone. The switchboard proper is mounted alongside of this, and the two line binding posts of the telephone are connected by a pair of wires to terminals of the operator's plug, which plug is shown hanging from the left-hand portion of the switchboard. The various lines centering at this point terminate in the combined drops and jacks on the switchboard, of which there are 20 shown in this illustration. Beside the operator's plug there are a number of pairs of plugs shown hanging from the switchboard cabinet. These are connected straight through in pairs,



LONG-DISTANCE TEST BOARD OF SAN FRANCISCO HOME TELEPHONE COMPANY
Distributing Frame and Testing Appliances for Long-Distance Lines.

there being no clearing-out drops or keys associated with them in the arrangement. Each line shown is provided with an extra jack, the purpose of which will be presently understood.

The method of operation is as follows: When a subscriber on a certain line desires to get connection through the switchboard he turns his generator and throws the drop. The operator in order to communicate with him inserts the plug in which her telephone terminates into the jack, and removes her receiver from its hook. Having learned that it is for a certain subscriber on another line, she withdraws her plug from the jack of the calling line and inserts it into the jack of the called line, then, hanging up her receiver, she turns the generator crank in accordance with the proper code to call that subscriber. When that subscriber responds she connects the two lines by inserting the two plugs of a pair into their respective jacks, and the subscribers are thus placed in communication. The extra jack associated with each line is merely an open jack having its terminals connected respectively with the two sides of the line. Whenever an operator desires to listen in on two connected lines she does so by inserting the operator's plug into one of these extra jacks of the connected lines, and she may thus find out whether the subscribers are through talking or whether either one of them desires another connection. The drops in such switchboards are commonly high wound and left permanently bridged across the line so as to serve as clearing-out drops. The usual night-alarm attachment is provided, the buzzer being shown at the upper right-hand portion of the cabinet.

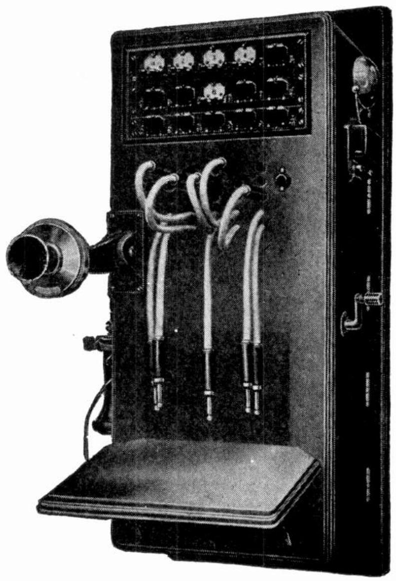


Fig. 141. Combined Telephone and Switchboard

Another type of switchboard commonly employed for this kind of service is shown in Fig. 141, in which the telephone and the switchboard cabinet are combined. The operation of this board is practically the same as that of Fig. 140, although it has manually-restored drops instead of self-restoring drops; the difference between these two types, however, is not material for this class of service. For such work the operator has ample time to attend to the restoring of the

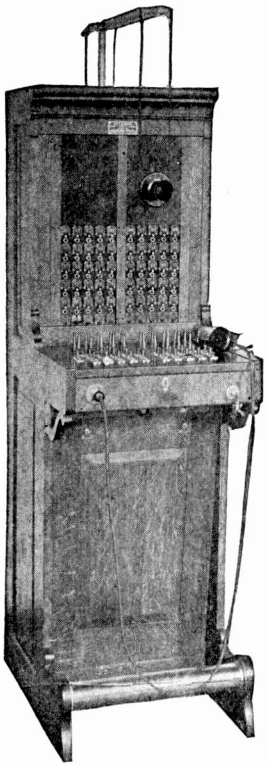


Fig. 142. Upright Magneto Switchboard

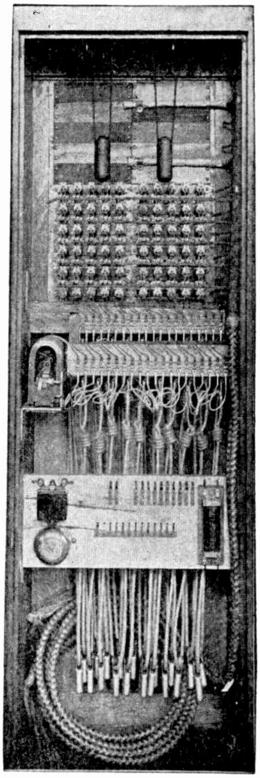


Fig. 143. Upright Magneto Switchboard—Rear View

drop and the only possible advantage in the combined drop-and-jack for this class of work is that it prevents the operator from forgetting to restore the drops. However, she is not likely to do this with the night-alarm circuit in operation, since the buzzer or bell would continue to ring as long as the drop was down.

Upright Type Switchboard. By far the most common type of magneto switchboard is the so-called upright type, wherein the drops and jacks are mounted on the face of upright panels rising from a horizontal shelf, which shelf contains the plugs, the keys, and any other apparatus which the operator must manipulate. Front and rear views of such a switchboard, as manufactured by the Kellogg Company, are shown in Figs. 142 and 143. This particular board is provided with fifty combined drops and jacks and, therefore,

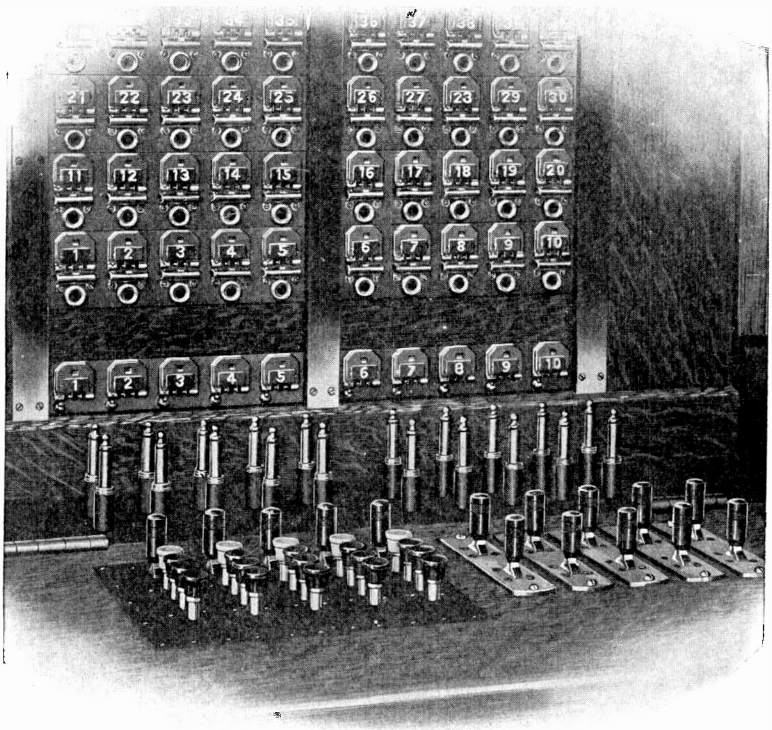


Fig. 144. Details of Drop, Jack, Plug, and Key Arrangement

equipped for fifty subscribers' lines. The drops and jacks are mounted in strips of five, and arranged in two panels. The clearing-out drops, of which there are ten, are arranged at the bottom of the two panels in a single row and may be seen immediately above the switchboard plugs. There are ten pairs of cords and plugs with their associated ringing and listening keys, the plugs being

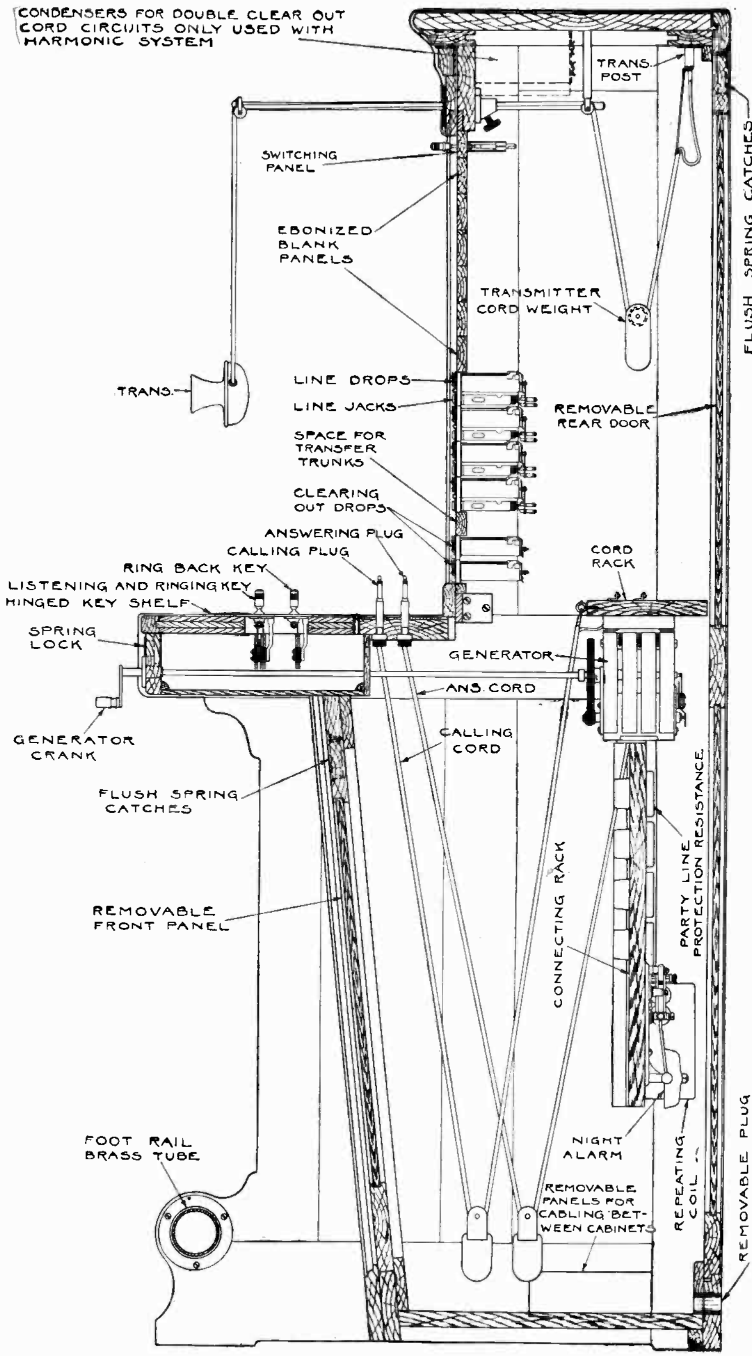


Fig. 145. Cross-Section of Upright Switchboard

mounted on the rear portion of the shelf, while the ringing and listening keys are mounted on the hinged portion of the shelf in front of the plugs.

A better idea of the arrangement of drops, jacks, plugs, and keys may be had from an illustration of a Dean magneto switchboard shown in Fig. 144. The clearing-out drops and the arrangement of the plugs and keys are clearly shown. The portion of the switchboard on which the plugs are mounted is always immovable, the plugs being provided with seats through which holes are bored of sufficient size to permit the switchboard cord to pass beneath the shelf. When one of these plugs is raised, the cord is pulled up through this hole thus allowing the plug to be placed in any of the jacks.

The key arrangement shown in this particular cut is instructive. It will be noticed that the right-hand five pairs of plugs are provided with ordinary ringing and listening keys, while the left-hand five are provided with party-line ringing keys and listening keys. The listening key in each case is the one in the rear and is alike for all of the cord pairs. The right-hand five ringing keys are so arranged that pressing the lever to the rear will ring on the answering cord, while pressing it toward the front will cause ringing current to flow on the calling plug. In the left-hand five pairs of cords shown in this cut, the pressure of any one of the keys causes a ringing current of a certain frequency to flow on the calling cord, this frequency depending upon which one of the keys is pressed.

Fig. 146. Cord Weight

An excellent idea of the grouping of the various pieces of apparatus in a complete simple magneto switchboard may be had from Fig. 145. While the arrangement here shown is applicable particularly to the apparatus of the Dean Electric Company, the structure indicated is none-the-less generally instructive, since it represents good practice in this respect. In this drawing the stationary plug shelf with the plug seat is clearly shown and also the hinged key shelf. The hinge of the key shelf is an important feature and is universally found in all switchboards of this general type. The key shelf may be raised and thus expose all of the wiring leading to the keys, as well as the various contacts of the keys themselves, to inspection.

As will be seen, the switchboard cords leading from the plugs extend down to a point near the bottom of the cabinet where they pass through pulley weights and then up to a stationary cord rack. On this cord rack are provided terminals for the various conduc-

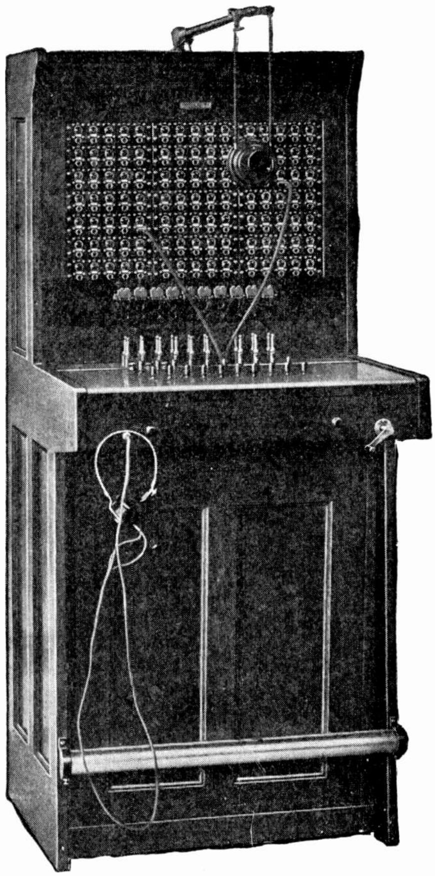


Fig. 147. Magneto Switchboard, Target Signals

tors in the cord, and it is at this point that the cord conductors join the other wires leading to the other portions of the apparatus as required. A good form of cord weight is shown in Fig. 146; and obviously the function of these weights is to keep the cords taut at all times and to prevent their tangling.

The drawing, Fig. 145, also gives a good idea of the method of mounting the hand generator that is ordinarily employed with such magneto switchboards. The shaft of the generator is merely continued out to the front of the key shelf where the usual crank is provided, by means of which the operator is able to generate the

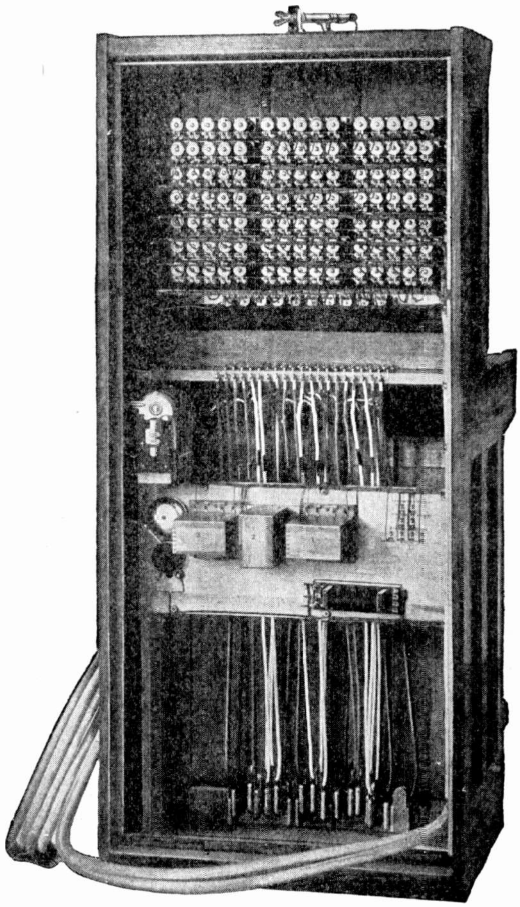


Fig. 148. Rear View of Target Signal, Magneto Switchboard

necessary ringing current. Beside the hand generator at each operator's position, it is quite common in magneto boards, of other than the smallest sizes, to employ some form of ringing generator, either a power-driven generator or a pole changer driven by battery current for furnishing ringing current without effort on the part of the operator.

Switchboards as shown in Figs. 142 and 143, are called single-position switchboards because they afford room for a single operator. Ordinarily for this class of work a single operator may handle from one to two hundred lines, although of course this depends on the

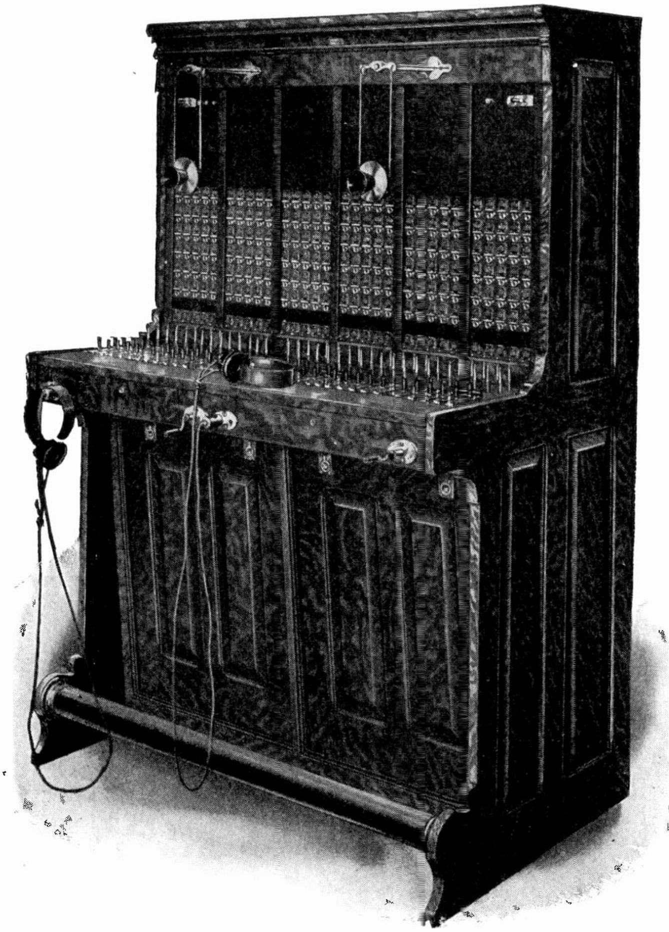


Fig. 149. Dean Two-Position Switchboard

amount of traffic on the line, and this, in turn, depends on the character of the subscribers served, and also on the average number of stations on a line. Another single-position switchboard is shown in Figs. 147 and 148, being a front and rear view of the simple magneto switchboard of the Western Electric Company, which is provided with the target signals of that company rather than the usual form of drop.

Where a switchboard must accommodate more lines than can be handled by a single operator, the cabinet is made wider so as to afford

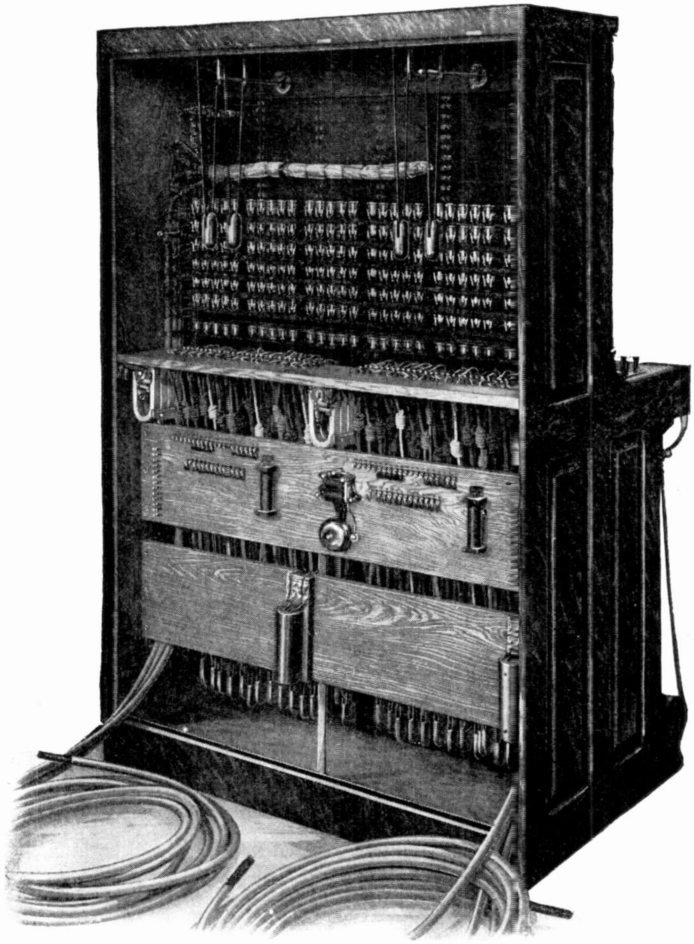


Fig. 150. Rear View of Dean Two-Position Switchboard

room for more than one operator to be seated before it. Sometimes this is accomplished by building the cabinet wider, or by putting two such switchboard sections as are shown in Figs. 142 or 147 side by side. A two-position switchboard section is shown in front and rear views in Figs. 149 and 150.

Sectional Switchboards. The problem of providing for growth in a switchboard is very much the same as that which confronts one in buying a bookcase for his library. The Western Electric Company has met this problem, for very small rural exchanges, in much the same way that the sectional bookcase manufacturers have provided for the possible increase in bookcase capacity. Like the sectional bookcase, this sectional switchboard may start with the smallest of equipment—a single sectional unit—and may be added to vertically

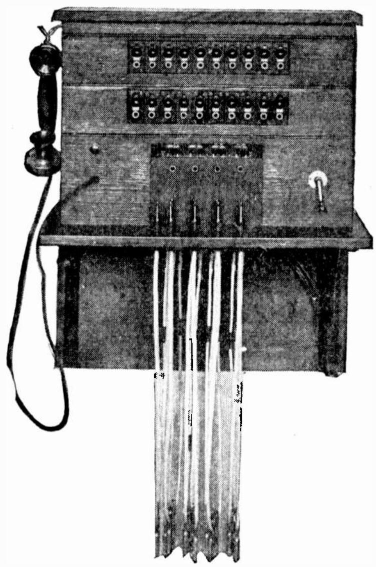


Fig. 151. Sectional Switchboard—Wall Type

as the requirements increase, the original equipment being usable in its more extended surroundings.

This line of switchboards is illustrated in Figs. 151 to 154. The beginning may be made with either a wall type or an upright type of switchboard, the former being mounted on brackets secured to the wall, and the latter on a table. A good idea of the wall type is shown in Fig. 151. Three different kinds of sectional units are involved in this: first, the unit which includes the cords, plugs, clearing-out drops, listening jacks, operator's telephone set and generator; second, the unit containing the line equipment, including a strip of ten magneto line signals and their corresponding jacks; third, the finishing top, which includes no equipment except the support for the operator's talking apparatus.

The first of the units in Fig. 151 forms the foundation on which the others are built. Two of the line-equipment units are shown; these provide for a total of twenty lines. The top rests on the upper line-equipment unit, and when it becomes necessary to add one or more line-equipment units as the switchboard grows, this

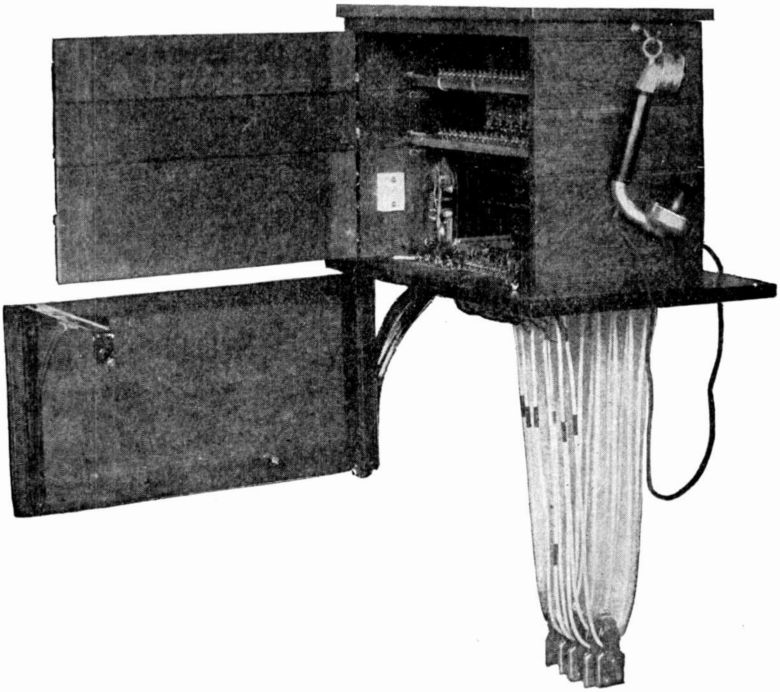


Fig. 152. Sectional Switchboard—Wall Type

top is merely taken off, the other line-equipment units put in place on top of those already existing, and the top replaced. The wall type of sectional switchboard is so arranged that the entire structure may be swung out from the wall, as indicated in Fig. 152, exposing all of the apparatus and wiring for inspection. Each of the sectional units is provided with a separate door, as indicated, so that the rear door equipment is added to automatically as the sections are added. In the embodiment of the sectional switchboard idea shown in these two figures just referred to, no ringing and listening keys are provided, but the operator's telephone and generator terminate in a special plug—the left-hand one shown in Fig. 151—and when the operator desires to converse with the connected subscribers, she does so by inserting the operator's plug into one of the jacks immediately below the clearing-out drop corresponding to the pair of plugs used in making the connection. The arrangement in this case is exactly the same in principle as that described in Fig. 140. The operator's generator is so arranged in connection with this left-hand operator's plug that the turning of the generator crank automatically switches the operator's telephone set off and switches the generator on, just the same as a switch hook may do in a subscriber's series telephone.

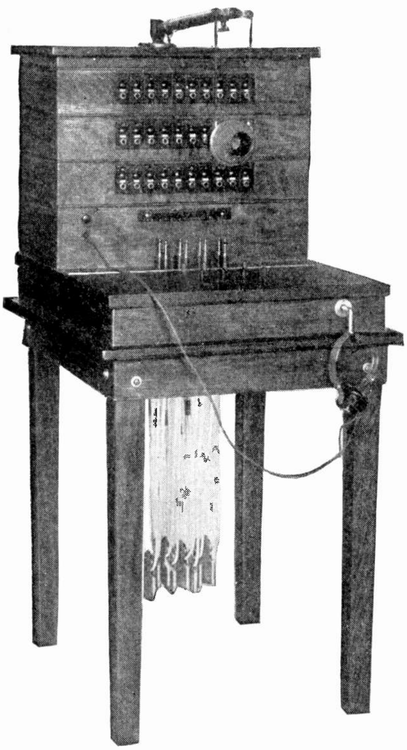


Fig. 153. Sectional Switchboard—Table Type

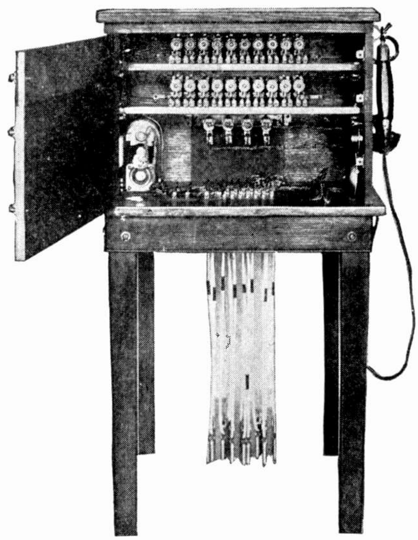


Fig. 154. Sectional Switchboard—Table Type

The upright type of sectional switchboard is shown in Figs. 153 and 154, which need no explanation in view of the foregoing, except to say that, in the particular instrument illustrated, ringing and listening keys are provided instead of the jack-and-plug arrangement of the wall type. In this case also, the top section carries an arm for supporting a swinging transmitter instead of the hook support for the combined transmitter and receiver.

CHAPTER XI

THE SIMPLE COMMON-BATTERY SWITCHBOARD

Advantages of Common-Battery Operation. The advantages of the common-battery system of operation of a telephone exchange may be briefly summarized here. The main gain in the common-battery system of supply is the simplification of the subscribers' instruments, doing away with the local batteries and the magneto generators, and the concentration of all these many sources of current into one single source at the central office. A considerable saving is thus effected from the standpoint of maintenance, since the simpler common-battery instrument is not so likely to get out of order and, therefore, does not have to be visited so often for repairs, and the absence of local batteries, of course, makes the renewal of the battery parts by members of the maintenance department, unnecessary. Another decided advantage in the common-battery system is the fact that the centralized battery stands ready always to send current over the line when the subscriber completes the circuit of the line at his station by removing his receiver from its hook. The common-battery system, therefore, lends itself naturally to the purposes of automatic signaling, since it is only necessary to place at the central office a device in the circuit of each line that will be responsive to the current which flows from the central battery when the subscriber removes his receiver from its hook. It is thus that the subscriber is enabled automatically to signal the central office when he desires a connection; and as will be shown, it is by the same sort of means, associated with the cord circuits used in connecting his line with some other line, that the operator is automatically notified when a disconnection is desired, the cessation of current through the subscriber's line when he hangs up his receiver being made to actuate certain responsive devices which are associated with the cord at that time connected with his line, and which convey the proper disconnect signal to the operator.

Concentration of sources of energy into a single large unit, the simplification of the subscriber's station equipment, and the ready adaptability to automatic signaling from the subscriber to the central office are, therefore, the reasons for the existence of the common-battery system.

Common Battery vs. Magneto. It must not be supposed, however, that the common-battery system always has advantages over the magneto system, and that it is superior to the magneto or local-battery system for all purposes. It is the outward attractiveness of the common-battery system and the arguments in its favor, so readily made by over-zealous salesmen, that has led, in many cases, to the adoption of this system when the magneto system would better have served the purpose of utility and economy.

To say the least, the telephone transmission to be had from common-battery systems is no better than that to be had from local-battery systems, and as a rule, assuming equality in other respects, it is not as good. It is perhaps true, however, that under average conditions common-battery transmission is somewhat better, because whereas the local batteries at the subscribers' stations in the local-battery system are not likely to be in uniformly first-class condition, the battery in a common-battery system will be kept up to its full voltage except under the grossest neglect.

The places in which the magneto, or local-battery, system is to be preferred to the common-battery system, in the opinion of the writers, are to be found in the small rural communities where the lines have a rather great average length; where a good many subscribers are likely to be found on some of the lines; where the sources of electrical power available for charging storage batteries are likely either not to exist, or to be of a very uncertain nature; and where it is not commercially feasible to employ a high-grade class of attendants, or, in fact, any attendant at all other than the operator at the central office.

In large or medium-sized exchanges it is always possible to procure suitable current for charging the storage batteries required in common-battery systems, and it is frequently economical, on account of the considerable quantity of energy that is thus used, to establish a generating plant in connection with the central office for developing the necessary electrical energy. In very small rural places there are frequently no available sources of electrical energy, and the expense of establishing a power plant for the purpose cannot be justified. But even if there is an electric light or railway system in the small town, so that the problem of available current supply does not exist, the establishment of a common-battery system with its storage battery and the necessary charging machinery requires the daily attendance at the central office of some one to watch and care for this battery, and this, on account of the small gross revenue that may be derived from a small telephone system, often involves a serious financial burden.

There is no royal road to a proper decision in the matter, and no sharp line of demarcation may be drawn between the places where common-battery systems are superior to magneto and *vice versâ*. It may be said, however, that in the building of all new telephone plants having over about 500 local subscribers, the common-battery system is undoubtedly superior to the magneto. If the plant is an old one, however, and is to be re-equipped, the continuance of magneto apparatus might be justified for considerably larger exchanges than those having 500 subscribers.

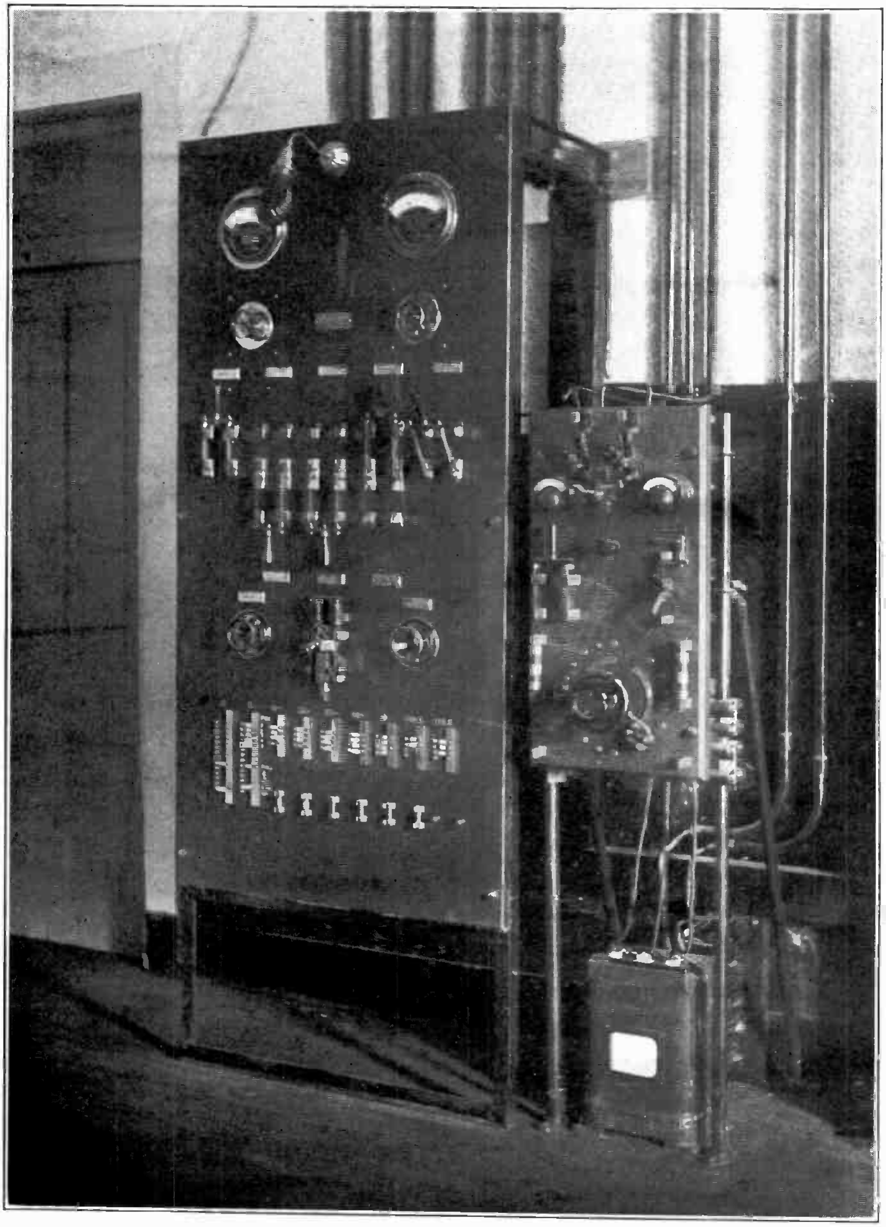
Telephone operating companies who have changed over the equipment of old plants from magneto to common battery have sometimes been led into rather serious difficulty, owing to the fact that their lines, while serving tolerably well for magneto work, were found inadequate to meet the more exacting demands of common-battery work. Again in an old plant the change from magneto to common-battery equipment involves not only the change of switchboards, but also the change of subscribers' instruments that are otherwise good, and this consideration alone often, in our opinion, justifies the replacing of an old magneto board with a new magneto board, even if the exchange is of such size as to demand a small multiple board.

Where the plant to be established is of such size as to leave doubt as to whether a magneto or a common-battery switchboard should be employed, the questions of availability of the proper kind of power for charging the batteries, the proper kind of help for maintaining the batteries and the more elaborate central-office equipment, the demands and previous education of the public to be served, all are factors which must be considered in reaching the decision.

It is not proper to say that anything like all exchanges having fewer than 500 local lines, should be equipped with magneto service. Where all the lines are short, where suitable power is available, and where a good grade of attendants is available—as, for instance, in the case of private telephone exchanges that serve some business establishment or other institution located in one building or a group of buildings—the common-battery system is to be recommended and is largely used, even though it may have but a dozen or so subscribers' lines. It is for such uses, and for use in those regular public-service exchange systems where the conditions are such as to warrant the common-battery system, and yet where the number of lines and the traffic are small enough to be handled by such a small group of operators that any one of them may reach over the entire face of the board, that the simple non-multiple common-battery system finds its proper field of usefulness.

Line Signals. The principles and means by which the subscriber is enabled to call the central-office operator in a common-battery system have been referred to briefly in Chapter III. We will review these at this point and also consider briefly the way in which the line signals are associated with the connective devices in the subscribers' lines.

Direct-Line Lamp. The simplest possible way is to put the line signal directly in the circuit of the line in series with the central-office battery, and so to arrange the jack of the corresponding line that the circuit through the line signal will be open when the operator inserts a plug into that jack. This arrangement is shown in Fig. 155 where the subscriber's station at the left is indicated in the simplest of its forms. It is well to repeat here that in all common-battery manual systems, the subscriber's station equipment, regardless of the arrangement or type of its talking and signaling apparatus, must have these features: First, that the line shall be normally open to direct currents at the subscriber's station; second, that the line shall be closed to direct currents when the subscriber removes his receiver from its hook in making or in answering a call; third, that the line normally, although open to direct currents, shall afford a proper path for alternating or varying currents through the signal receiving device at the sub-station. The subscriber's station arrangement shown in Fig. 155, and those immediately following,



POWER SWITCHBOARD FOR MEDIUM-SIZED OFFICE
Mercury Arc Rectifier Panel and Transformer at Right.

is the simplest arrangement that possesses these three necessary features for common-battery service.

Considering the arrangement at the central office, Fig. 155, the two limbs of the line are permanently connected to the tip and sleeve contacts of the jack. These two main contacts of the jack normally engage two anvils so connected that the tip of the jack is ordinarily connected through its anvil to ground, while the sleeve of the jack is normally connected through its anvil to a circuit leading through the line signal—in this case a lamp—and the

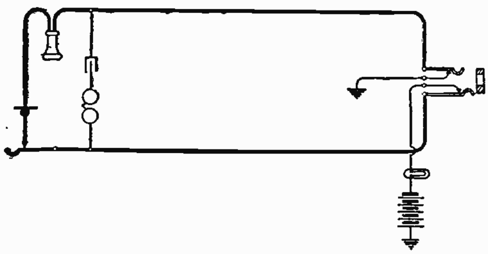


Fig. 155. Direct-Line Lamp

common battery, and thence to ground. The operation is obvious. Normally no current may flow from the common battery through the signal because the line is open at the subscriber's station. The removal of the subscriber's receiver from its hook closes the circuit of the line and allows the current to flow through the lamp, causing it to glow. When the operator inserts the plug into the jack, in response to the call, the circuit through the lamp is cut off at the jack and the lamp goes out.

This arrangement, termed the direct-line lamp arrangement, is largely used in small common-battery telephone systems where the lines are very short, such as those found in factories or other places where the confines of the exchange are those of a building or a group of neighboring buildings. Many of the so-called private-branch exchanges, which will be considered more in detail in a later chapter, employ this direct-line lamp arrangement.

Direct-Line Lamp with Ballast. Obviously, however, this direct-line lamp arrangement is not a good one where the lines vary widely in length and resistance. An incandescent lamp, as is well known, must not be subjected to too great a variation in current. If the current that is just right in amount to bring it to its intended degree of illumination is increased by a comparatively small amount, the life of the lamp will be greatly shortened, and too great an increase will result in the lamp burning out immediately. On the other hand, a current that is too small will not result in the proper illumination of the lamp, and a current of one-half the proper normal value will just suffice to bring the lamp to a dull red glow. With lines that are not approximately uniform in length and resistance the shorter lines would afford too great a flow of current to the lamps and the longer lines too little, and there is always the danger present, unless means are taken to prevent it, that if a line becomes short-circuited or grounded near the central office, the lamp will be subjected to practically the full battery potential and, therefore, to such a current as will burn it out. One of the very ingenious and, we believe, promising methods that has been proposed to overcome this difficulty is that of the iron-wire ballast, alluded to in Chapter III. This, it will be remembered, consists of an iron-wire resistance enclosed in a vacuum chamber and so proportioned with respect to the flow of current that it will be subjected to a considerable heating effect by the amount of current that is proper to illuminate the lamp. As has already been pointed out, carbon has a negative temperature coefficient, that is, its resistance decreases when heated. Iron, on the other hand, has a positive temperature coefficient, its resistance in-

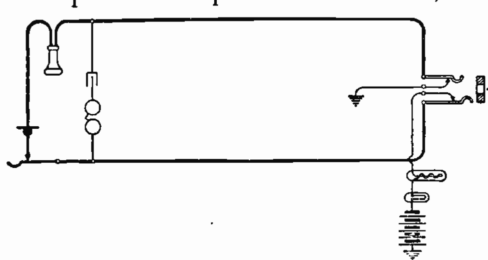


Fig. 156. Direct-Line Lamp with Ballast

creasing when heated. When such an iron-wire ballast is put in series with the incandescent lamp forming the line signal, as shown in Fig. 156, it is seen that the resistance of the carbon in the lamp filament and of the iron in the ballast will act in opposite ways when the current increases or decreases. An increase of current will tend to heat up the iron wire of the ballast and, therefore, increase its resistance, and the ballast is so proportioned that it will hold the current that may flow through the lamp within the proper maximum and minimum limits, regardless of the resistance of the line in which the lamp is used. This arrangement has not gone into wide use up to the present time.

Line Lamp with Relay. By far the most common method of associating the line lamp with the line is to employ a relay, of

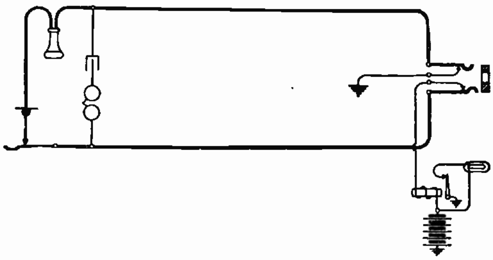


Fig. 157. Line Lamp with Relay

which the actuating coil is in the line circuit, this relay serving to control a local circuit containing the battery and the lamp. This arrangement and the way in which these parts are associated with the jack are clearly indicated in Fig. 157. Here the relay may receive any amount of current, from the smallest which will cause it to pull up its armature, to the largest which will not injure its winding by overheat. Relays may be made which will attract their armatures at a certain minimum current and which will not burn out when energized by currents about ten times as large, and it is thus seen that a very large range of current through the relay winding is permissible, and that, therefore, a very great latitude as to line resistance is secured. On the other hand, it is obvious that the lamp circuit, being entirely local, is of uniform resistance, the lamp always being subjected, in the arrangement shown, to practically the full battery potential, the lamp being selected to operate on that potential.

Pilot Signals. In the circuits of Figs. 155, 156, and 157, but a single line and its associated apparatus is shown, and it may not be altogether clear to the uninitiated how it is that the battery shown in those figures may serve, without interference of any function, a larger number of lines than one. It is to be remembered that this battery is the one which serves not only to operate the line signals, but also to supply talking current to the subscribers and to supply current for the operation of the cord-circuit signals after the cord circuits are connected with the lines.

In Fig. 158 this matter is made clear with respect to the association of this common battery with the lines for operating the line signals, and also another important feature of common-battery work is brought out, viz., the pilot lamp and its association with a group of line lamps. Three subscribers' lines only are shown, but this serves clearly to illustrate the association of any larger number of lines with the common battery. Ignoring at first the pilot relay and the pilot lamp, it will be seen that each of the tip-spring anvils of the jacks is connected to a common wire *1* which is grounded. Each of the sleeve-contact anvils is connected through the coil of the line relay to another common wire *2*, which connects with the live side of the common battery. Obviously, therefore, this arrangement corresponds with that of Fig. 157, since the battery may furnish current to energize any one of the line relays upon the closure of the circuit of the corresponding line. Each of the relay armatures in Fig. 158 is connected to ground.

Here we wish to bring out an important thing about telephone circuit diagrams which is sometimes confusing to the beginner, but which really, when understood, tends to prevent confusion. The showing of a separate ground for each of the line-relay armatures does not mean that literally each one of these armatures is connected by a separate wire to earth, and it is to be understood that the three separate grounds shown in connection with these relay armatures is meant to indicate just such a set of affairs as is shown in connection with the tip-spring anvils of the jacks, all of which are connected to a common wire which, in turn, is grounded. Obviously, the result is the same, but in the case of this particular diagram it is seen that a great deal of crossing of lines is prevented by showing a separate ground at each one of the relay armatures. The same practice is followed in connection with the common battery. Sometimes it is very inconvenient in a complicated diagram to run all of the wires that are supposed to connect with one terminal of the battery across the diagram to represent this connection. It is permissible, therefore, and in fact desirable, that separate battery symbols be shown wherever by so doing the diagram will be simplified, the understanding being, in the absence of other information or of other indications, that the same battery is referred to, just as the same ground is referred to in connection with the relay armatures in the figure under discussion.

Each line lamp in Fig. 158 is shown connected on one hand to its corresponding line relay contact and on the other hand to a common wire which leads through the winding of the pilot relay to the live side of the battery. It is obvious here that whenever any one of the line relays attracts its armature the local circuit containing the corresponding lamp and the common battery will be closed and the lamp illuminated.

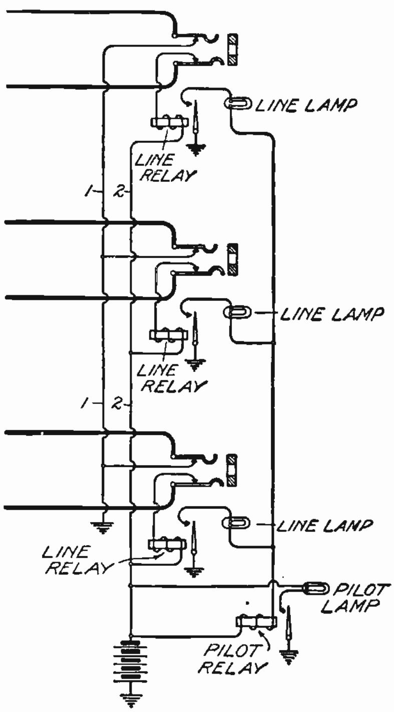


Fig. 158. Pilot-Lamp Operation

Whenever any line relay operates, the current, which is supplied to its lamp, must come through the pilot-relay winding, and if a number of line relays are energized, then the current flow of the corresponding lamps must flow through this relay winding. Therefore, this relay winding must be of low resistance, so that the drop through its winding may not be sufficient to interfere with the proper burning of the lamps, even though a large number of lamps be fed simultaneously through it. The pilot relay must be so sensitive that the current, even through one lamp, will cause it to attract its armature. When it does attract its armature it causes illumination of the pilot lamp in the same way that the line relays cause the illumination of the line lamps.

The pilot lamp, which is commonly associated with a group of line lamps that are placed on any one operator's position of the switchboard, is located in a conspicuous place in the switchboard cabinet and is provided with a larger lens so as to make a more striking signal. As a result, whenever any line lamp on a given position lights, the pilot lamp does also and serves to attract the attention, even of those located in distant portions of the room, to the fact that a call exists on that position of the board, the line lamp itself, which is simultaneously lighted, pointing out the particular line on which the call exists.

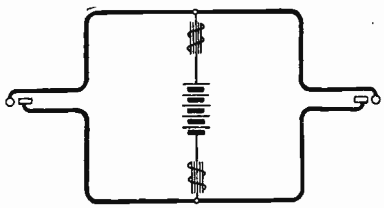


Fig. 159. Battery Supply Through Impedance Coils

Pilot lamps, in effect, perform similar service to the night alarm in magneto boards, but, of course, they are silent and do not attract attention unless within the range of vision of the operator. They are used not only in connection with line lamps, but also in connection with the cord-circuit lamps or signals, as will be pointed out.

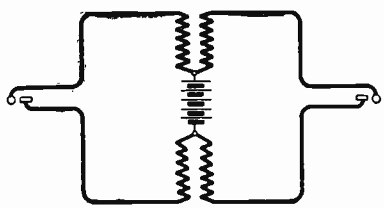


Fig. 160. Battery Supply through Repeating Coils

Cord Circuit. *Battery Supply.* Were it not for the necessity of providing for cord-circuit signals in common-battery switchboards, the common-battery cord circuit would be scarcely more complex than that for magneto working. Stripped of all details, such as signals, ringing and listening keys, and operator's equipment, cord circuits of three different types are shown in Figs. 159, 160, and 161. These merely illustrate the way in which the battery is associated with the cord circuits and through them with the line circuits for supplying current for talking purposes to the subscribers. It is thought that this matter will be clear in view of the discussion of the methods by which current is supplied to the subscribers' transmitters in common-battery systems. The methods of using various impedance devices are shown in Figs. 159, 160, and 161; while these illustrate

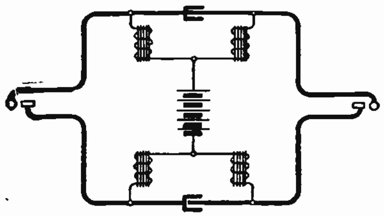


Fig. 161. Battery Supply with Impedance Coils and Condensers

only three of the methods, these three are the ones that have been most widely and successfully used.

Supervisory Signals. The signals that are associated with the cord circuits are termed supervisory signals because of the fact that by their means the operator is enabled to supervise the condition of the lines during times when they are connected for conversation. The operation of these supervisory signals may be best understood by considering the complete circuits of a simple switchboard and must be studied in conjunction with the circuits of the lines as well as those of the cords.

Complete Circuit. Such complete circuits are shown in Fig. 162. The particular arrangement indicated is that employed by the Kel-

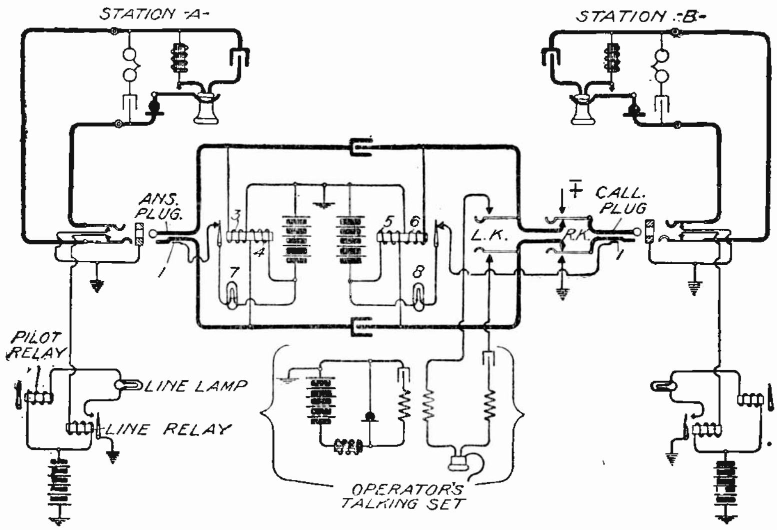


Fig. 162. Simple Common-Battery Switchboard

logg Company, and except for minor details may be considered as typical of other makes also. Two subscribers' lines are shown extending from Station *A* and Station *B*, respectively, to the central office. The line wires are shown terminating in jacks in the same manner as indicated in Figs. 155, 156, and 157, and their circuits are normally continued from these jacks to the ground on one side and to the line relay and battery on the other. The jack in this case has three contacts adapted to register with three corresponding contacts in each of the plugs. The thimble of the jack in this case forms no part of the talking circuit and is distinct from the two jack springs which form the line terminals. It and the auxiliary contact *1* in each of the plugs with which it registers, are solely for the purpose of co-operating in the control of the supervisory signals.

The tip and sleeve strands of the cord are continuous from one plug to the other except for the condensers. The two batteries indicated in connection with the cord circuit are separate batteries, a characteristic of the Kellogg system. One of these batteries serves to supply current to the tip and sleeve strand of the cord circuit through the two windings *3* and *4*, respectively, of the supervisory relay connected with the answering side of the cord circuit, while the other battery similarly supplies current through the windings *5* and *6* of the supervisory relay associated with the calling side of the cord circuit. The windings of these relays, therefore, act as impedance coils and the arrangement by which battery current is supplied to the cord circuits and, therefore, to the lines of the connected subscribers, is seen to be an ordinary combined impedance coil and condenser arrangement.

As soon as a plug is inserted into the jack of a line, the line relay will be removed from the control of the line, and since the two strands of the cord circuit now form continuations of the two line conductors, the supervisory relay will be substituted for the line relay and will be under control of the line. Since all of the current which passes to the line after a plug is inserted must pass through the cord-circuit connection and through the relay windings, and since current can only flow through the line when the subscriber's receiver is off its hook, it follows that the supervisory relays will only be energized after the corresponding plug has been inserted into a jack of the line and after the subscriber has removed his receiver. Unlike the line relays, the supervisory relays open their contacts to break the local circuits of the supervisory lamps *7* and *8* when the relay coils are energized, and to close them when de-energized; but the armatures of the supervisory relays do alone control the circuits of the supervisory lamps. These circuits are normally held open in another place, that is, between the plug contacts *1* and the jack thimbles. It is only, therefore, when a plug is inserted into a jack and when the supervisory relay is de-energized, that the supervisory lamp may be lighted. When a plug is inserted into a jack and when the corresponding supervisory relay is de-energized, the circuit may be traced from ground at the cord-circuit batteries through the left-hand battery, for instance, through lamp *7*, thence through the contacts of the supervisory relay to the contact *1* of the plug, thence through the thimble of the jack to ground. When a plug is inserted into the jack, therefore, the necessary arrangements are completed for the supervisory lamp to be under the control of the subscriber. Under this condition, whenever the subscriber's receiver is on its hook, the circuit of the line will be broken, the supervisory relay will be de-energized, and the supervisory lamp will be lighted. When, on the other hand, the subscriber's receiver is off its hook, the circuit of the line will be complete, the supervisory relay will be energized, and the supervisory lamp will be extinguished.

Salient Features of Supervisory Operation. It will facilitate the student's understanding of the requirements and mode of operation of common-battery supervisory signals in manual systems, whether simple or multiple, if he will firmly fix the following facts in his mind. In order that the supervisory signal may become operative at all, some act must be performed by the operator—this being usually the act of plugging into a jack—and then, until the connection is taken down, the supervisory signal is under the control of the subscriber, and it is displayed only when the subscriber's receiver is placed on its hook.

Cycle of Operations. We may now trace through the complete cycle of operations of the simple common-battery switchboard, the circuits of which are shown in Fig. 162. Assume all apparatus in its normal condition, and then assume that the subscriber at Station *A* removes his receiver from its hook. This pulls up the line relay and lights the line lamp, the pilot relay also pulling up and lighting the common pilot lamp which is not shown. In response to this call, the operator inserts the answering plug and throws her listening key *L.K.* The operator's talking set is thus bridged across the cord circuit and she is enabled to converse with the calling subscriber. The answering supervisory lamp *7* did not light when the operator inserted the answering plug into the jack, because, although the contacts in the lamp circuit were closed by the plug contact *1* engaging the thimble of the jack, the lamp circuit was held open by the attraction of the supervisory relay armature, the subscriber's receiver being off its hook. Learning that the called-for subscriber is the one at Station *B*, the operator inserts the calling plug into the jack at that station and presses the ringing key *R.K.*, in order to ring the bell. The act of plugging in, it will be remembered, cuts off the line-signaling apparatus from connection with that line. As the subscriber at Station *B* was not at his telephone when called and his receiver was, therefore, on its hook, the insertion of the calling plug did not energize the supervisory relay coils *5* and *6*, and, therefore, that relay did not attract its armature. The supervisory lamp *8* was thus lighted, the circuit being from ground through the right-hand cord-circuit battery, lamp *8*, back contacts of the supervisory relay, third strand of the cord to contact *1* of the calling plug, and thence to ground through the thimble of the jack. The lighting of this lamp is continued until the party at Station *B* responds by removing his receiver from its hook, which completes the line circuit, energizes relay windings *5* and *6*, causes that relay to attract its armature, and thus break the circuit of the lamp *8*. Both supervisory lamps remain out as long as the two subscribers are conversing, but when either one of them hangs up his receiver the corresponding supervisory relay becomes de-energized and the corresponding lamp lights. When both of the lamps become illuminated, the operator knows that both subscribers are through talking and she takes down the connection.

Countless variations have been worked in the arrangement of the line and cord circuits, but the general mode of operation of this particular circuit chosen for illustration is standard and should be thoroughly mastered. The operation of other arrangements will be readily understood from an inspection of the circuits, once the fundamental mode of operation that is common to all of them is well in mind.

Lamps. The incandescent lamps used in connection with line and supervisory signals are specially manufactured, but differ in no sense from the larger lamps employed for general lighting purposes, save in the details of size, form, and method of mounting. Usually these lamps are rated at about one-third candle-power, although they have a somewhat larger candle-power as a rule. They are manufactured to operate on various voltages, the most usual operating pressures being 12, 24, and 48 volts. The 24-volt lamp consumes about one-tenth of an ampere when fully illuminated, the lamp thus consuming about 2.4 watts. The 12- and 48-volt lamps consume about the same amount of energy and corresponding amounts of current.

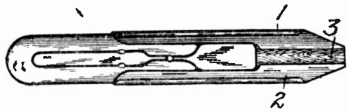


Fig. 163. Switchboard Lamp

Lamp Mounting. The usual form of screw-threaded mounting employed in lamps for commercial lighting was at first applied to the miniature lamps used for switchboard work, but this was found unsatisfactory and these lamps are now practically always provided with two contact strips, one on each side of the glass bulb, these strips forming respectively the terminals for the two ends of the filament within. Such a construction of a common form of lamp is shown in Fig. 163, where these terminals are indicated by the numerals *1* and *2*, *3* being a dry wooden block arranged between the terminals at one end for securing greater rigidity between them.

The method of mounting these lamps is subject to a good deal of variation in detail, but the arrangement is always such that the lamp is slid in between two metallic contacts forming terminals of the circuit in which the lamp is to operate. Such an arrangement

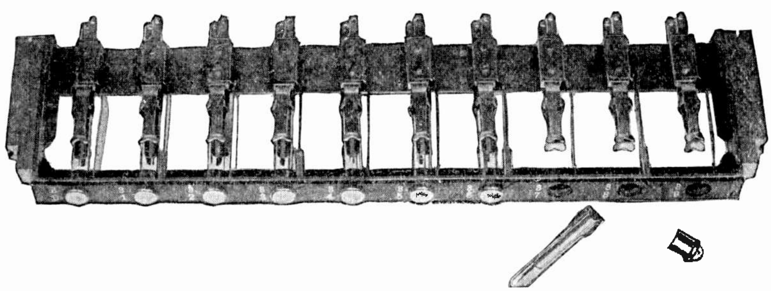


Fig. 164 Line Lamp Mounting

of springs and the co-operating mounting forming a sort of socket for the reception of switchboard lamps is referred to as a *lamp jack.* These are sometimes individually mounted and sometimes mounted in strips in much the same way that jacks are mounted in strips. A strip of lamp jacks as manufactured by the Kellogg Company is shown in Fig. 164. The opalescent lens is adapted to be fitted in front of the lamp after it has been inserted into the jack. Fig. 165 gives an excellent view of an individually-mounted lamp jack with its lamp and lens, this also being of Kellogg manufacture. This figure shows a section of the plug shelf which is bored to receive a lamp. In order to protect the lamps and lenses from breakage, due to the striking of the plugs against them, a metal shield is placed over the lens, as shown in this figure, this being so cut away as to allow sufficient openings for the light to shine through. Sometimes instead of employing lenses in front of the lamps, a flat piece of translucent material is used to cover the openings of the lamp, this being protected by suitable perforated strips of metal. A strip of lamp jacks employing this feature is shown in Fig. 166, this being of Dean manufacture. An advantage of this for certain types of work is that the flat translucent plate in front of the lamp may readily carry designating marks, such as the number of the line or something to indicate the character of the line, which marks may be readily changed as required.

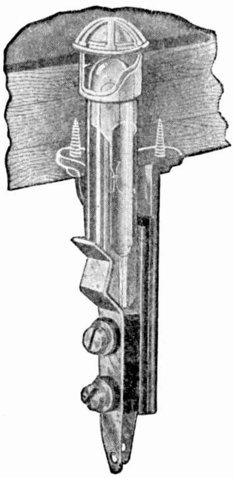


Fig. 165. Supervisory Lamp Mounting

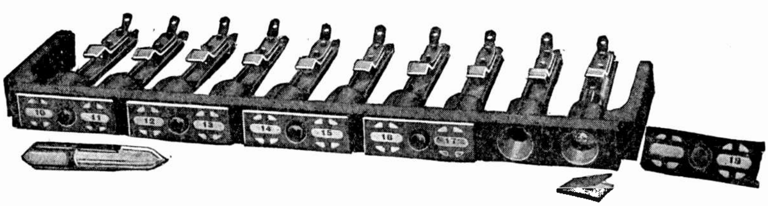


Fig. 166. Line Lamp Mounting

In the types made by some manufacturers the only difference between the pilot lamp and the line lamp is in the size of the lens in front of it, the jack and the lamp itself being the same for each, while others use a larger lamp for the pilot. In Fig. 167 are shown two individual lamp jacks, the one at the top being for supervisory lamps and the one at the bottom being provided with a large lens for serving as a pilot lamp.

Mechanical Signals. As has been stated the so-called mechanical signals are sometimes used in small common-battery switchboards instead of lamps. Where this is done the coil of the signal,

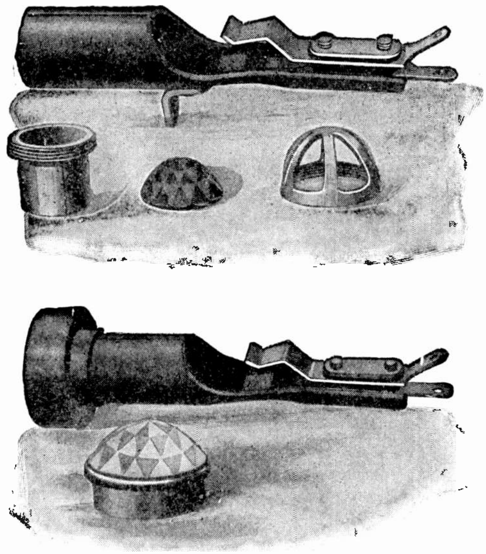


Fig. 167. Individual Lamp Jacks

if it is a line signal, is substituted in the line circuit in place of the relay coil. If the signals are used in connection with cord circuits for supervisory signals, their coils are put in the circuit in place of the supervisory relay coils. (These signals are referred to in Chapter III in connection with Fig. 23.) They are so arranged that the attraction of the armature lifts a target on the end of a lever, and this causes a display of color or form. The release of the armature allows this target to drop back, thus obliterating the display. Such signals, often called *visual signals* and *electromagnet signals*, should be distinguished from the drops considered in connection with magneto switchboards in which the attraction of the armature causes the display of the signal by the falling of a drop, the signal remaining displayed until restored by some other means, the restoration depending in no wise on when the armature is released.

Western Electric. The mechanical signal of the Western Electric Company, shown in Fig. 168, has a target similar to that shown in Fig. 102 but without a latch. It is turned to show a different color by the attraction of the armature and allowed to resume its normal position when the armature is released.

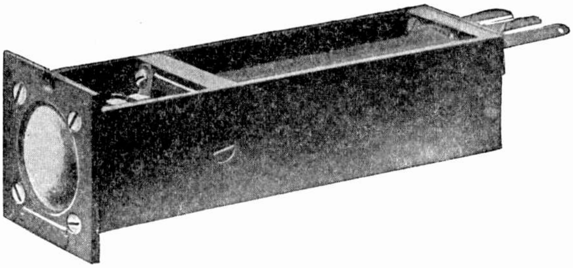


Fig. 168. Mechanical Signal

Kellogg. Fig. 169 gives a good idea of a strip of mechanical signals as manufactured by the Kellogg Company. This is known as the *gridiron* signal on account of the cross-bar striping of its target. The white bars on the target normally lie just behind the cross-bars on the shield in front, but a slight raising of the target—

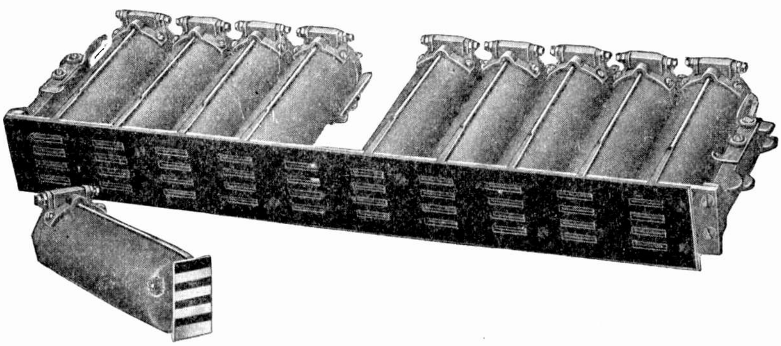


Fig. 169. Strip of Gridiron Signals

about one-eighth of an inch—exposes these white bars to view, opposite the rectangular openings in the front shield.

Monarch. In Fig 170 is shown the visual signal manufactured by the Monarch Telephone Company.

Relays. The line relays for common-battery switchboards likewise assume a great variety of forms. The well-known type of relay employed in telegraphy would answer the purpose well but for the amount of room that it occupies, as it is sometimes necessary to group a large number of relays in a very small space. Nearly all present-day relays are of the single-coil type, and in nearly all cases the movement of the armature causes the movement of one or more switching springs, which are thus made to engage or disengage their

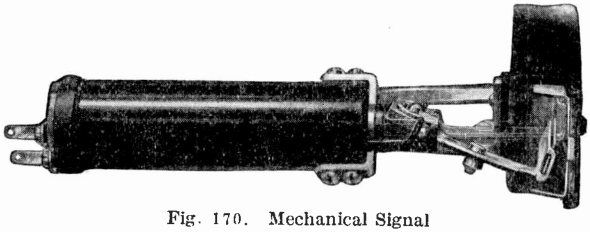


Fig. 170. Mechanical Signal

associated spring or springs. One of the most widely used forms of relays has an L-shaped armature hung across the front of a forwardly projecting arm of iron. The corner of this arm is knife-edge shaped and the armature is mounted so as to rock about this corner as it is moved by the attraction of the magnet. Sometimes this relay is made up in single units and frequently a large number of such single units are mounted on a single mounting plate. This matter will be dealt with more in detail in the discussion of common-battery multiple switchboards. In other cases these relays are built *en bloc,* a rectangular strip of soft iron long enough to afford space for ten relays side by side being bored out with ten cylindrical holes to

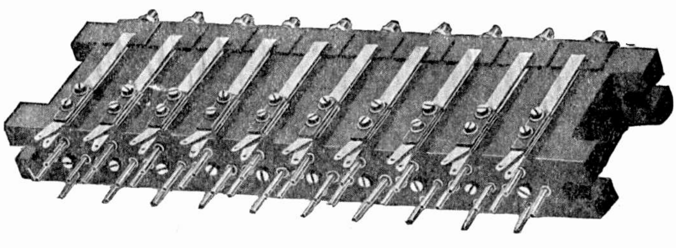


Fig. 171. Strip of Relays

receive the electromagnets. The iron of the block affords a return path for the lines of force. The L-shaped armatures are hung over the front edge of this block, so that their free ends lie opposite the magnet cores within the block. This arrangement as employed by the Kellogg Company is shown in two views in Figs. 171 and 172.

A bank of line relays especially adapted for small common-battery switchboards as made by the Dean Company, is shown in Fig. 173.

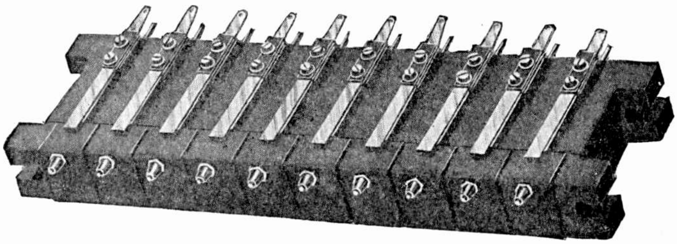


Fig. 172. Strip of Relays

Jacks. The jacks in common-battery switchboards are almost always mounted in groups of ten or twenty, the arrangement being similar to that discussed in connection with lamp strips. Ordinarily in common-battery work the jack is provided with two inner contacts so as to cut off both sides of the signaling circuit when the operator plugs in. A strip of such jacks is shown in Fig. 174.

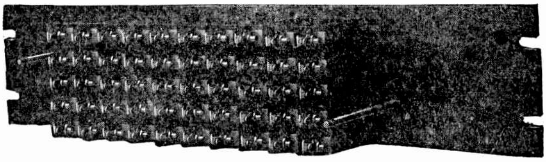


Fig. 173. Bank of Relays

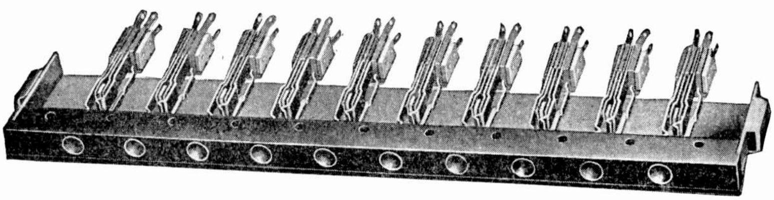
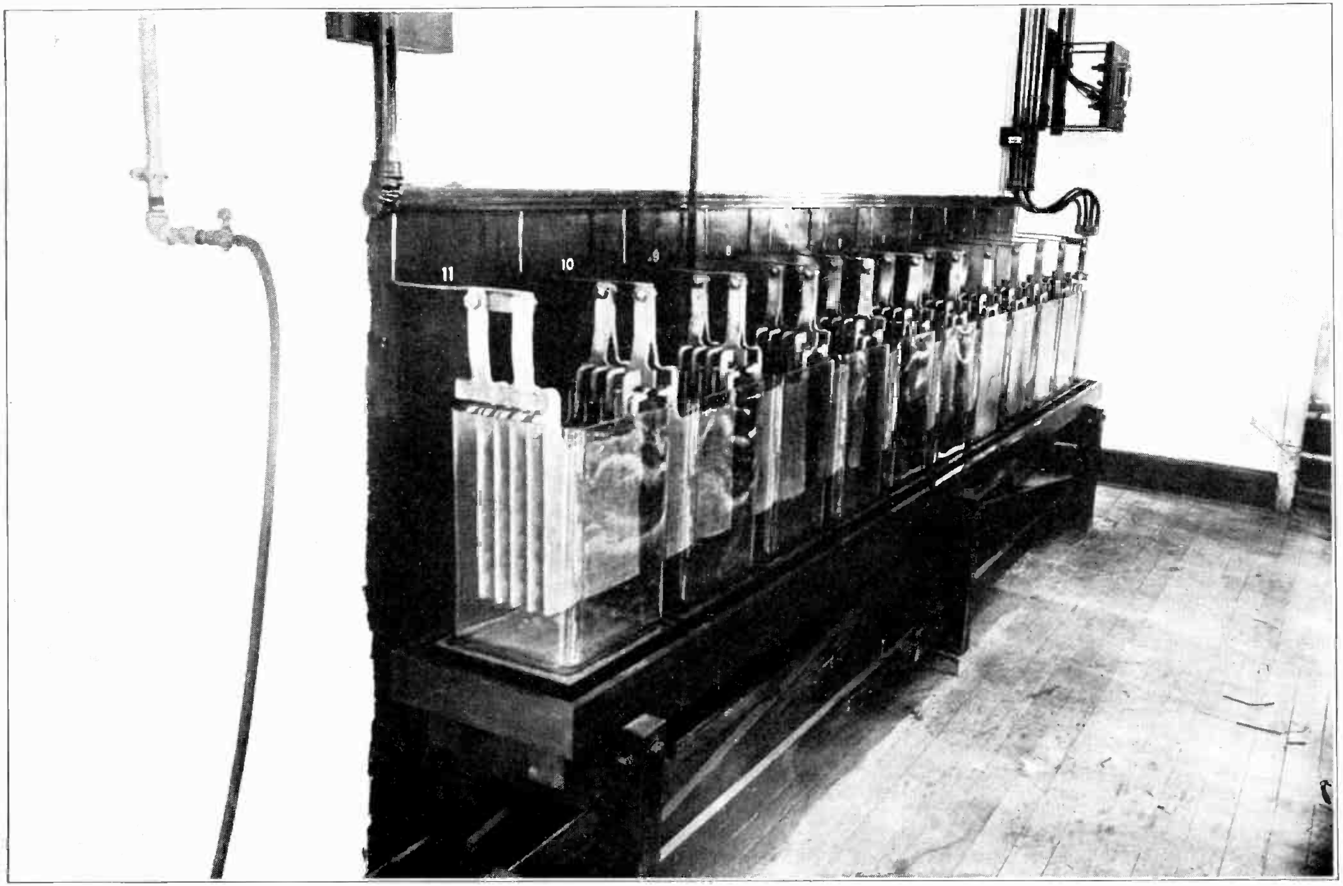


Fig. 174. Strip of Cut-Off Jacks

Ringing and listening keys for simple common-battery switchboards differ in no essential respect from those employed in magneto boards.



WESTERN ELECTRIC COMPANY BATTERY ROOM AT MONMOUTH, ILLINOIS

Switchboard Assembly. The general assembly of the parts of a simple common-battery switchboard deserves some attention. The form of the switchboard need not differ essentially from that employed in magneto work, but ordinarily the cabinet is somewhat smaller on account of the smaller amount of room required by its lamps and jacks. An excellent idea of the line jacks and lamps, plugs, keys, and supervisory signals may be obtained from Fig. 175,

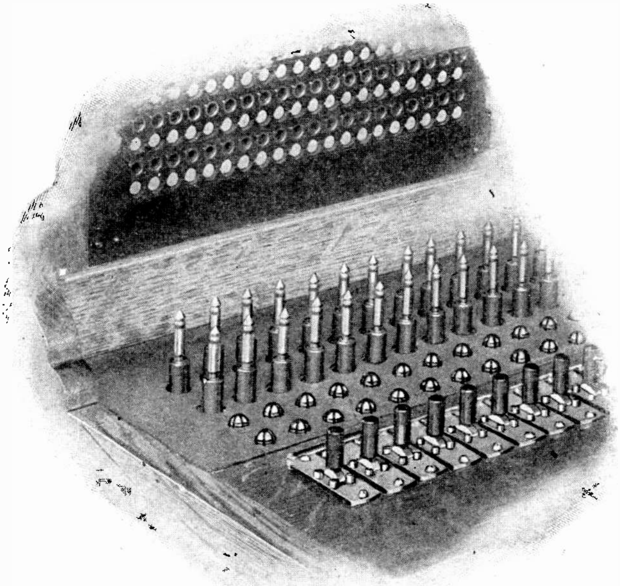


Fig. 175 Details of Lamp, Plug, and Key Mounting

which is a detail view taken from a Kellogg board. In the vertical panel of the board above the plug shelf are arranged the line jacks and the lamps in rows of twenty each, each lamp being immediately beneath its corresponding jack. Such jacks are ordinarily mounted on $\frac{1}{2}$-inch centers both vertically and horizontally, so that a group of one hundred lamps and line jacks will occupy a space only slightly over 10 by 5 inches. Such economy of space is not required in the simple magneto board, because the space might easily be made larger without in any way taxing the reach of the operator. The reason for this comparatively close mounting is a result, not of the requirements of the simple non-multiple common-battery board itself, but of the fact that the jack strips and lamp strips, which are required in very large numbers in multiple boards, have to be mounted extremely close together, and as the same lamp strips and jack strips are often available for simple switchboards, an economy in manufacture is effected by adherence to the same general dimensions.

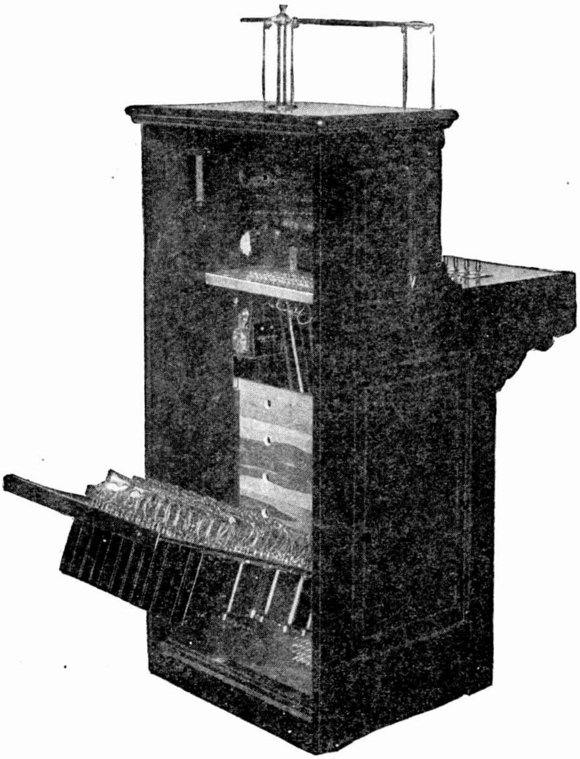


Fig. 176. Simple Common-Battery Switchboard with Removable Relay Panel

A rear view of a common form of switchboard cabinet, known as the *upright type* and manufactured by the Dean Company, is shown in Fig. 176. In this all the relays are mounted on a hinged rack, which, when opened out as indicated, exposes the wiring to view for inspection or repairs. Access to both sides of the relays is thus given to the repairman who may do all his work from the rear of the board without disturbing the operator.

Fig. 177 shows a three-position cabinet of Kellogg manufacture, this being about the limit in size of boards that could properly be called simple. Obviously, where a switchboard cabinet must be made of greater length than this, *i.e.*, than is required to accommodate three operators, it becomes too long for the operators to reach all over it without undue effort or without moving from their

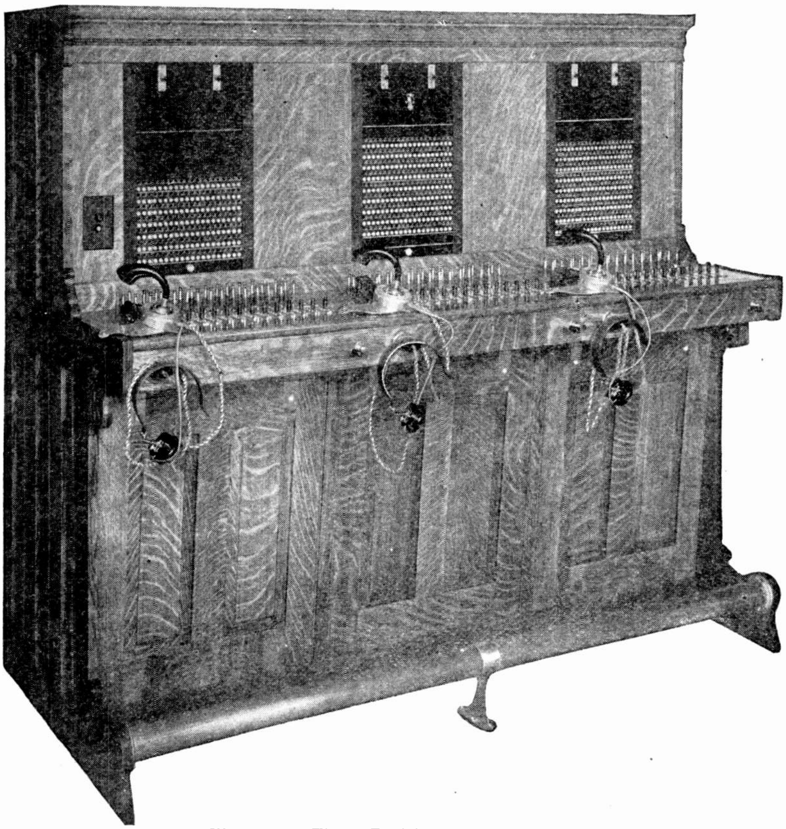


Fig. 177. Three-Position Lamp Board

seats. The so-called *transfer board* and the *multiple board* (to be considered in subsequent chapters), constitute methods of relief from such a condition in larger exchanges.

ONE OF THE FOUR WINGS OF THE OLD KELLOGG DIVIDED MULTIPLE BOARD OF THE CUYAHOGA TELEPHONE COMPANY, CLEVELAND, OHIO

Ultimate Capacity, 24,000 Lines. One of the Two Examples in the United States of a Multiple Switchboard Having an Ultimate Capacity over 18,000 Lines. Replaced Recently by a Kellogg Straight Multiple Board Having an Ultimate Capacity of 18,000 Lines and a Present Capacity of 10,000 Lines.

CHAPTER XII

PRINCIPLES OF THE MULTIPLE SWITCHBOARD

Field of Utility. The multiple switchboard, unlike the transfer board, provides means for each operator to complete, without assistance, a connection with any subscriber's line terminating in the switchboard no matter how great the number of lines may be. It is used only where the simple switchboard will not suffice; that is, where the number of lines and the consequent traffic is so great as to require so many operators and, therefore, so great a length of board as to make it impossible for any one operator to reach all over the face of the board without moving from her position.

The Multiple Feature. The fundamental feature of the multiple switchboard is the placing of a jack for every line served by the switchboard within the reach of every operator. This idea underlying the multiple switchboard may be best grasped by merely considering the mechanical arrangement and grouping of parts without regard to their details of operation. The idea is sometimes elusive, but it is really very simple. If the student at the outset will not be frightened by the very large number of parts that are sometimes involved in multiple switchboards, and by the great complexity which is apparent in the wiring and in the action of these parts; and will remember that this apparent complexity results from the great number of repetitions of the same comparatively simple group of apparatus and circuits, much will be done toward a mastery of the subject.

The multiple switchboard is divided into sections, each section being about the width and height that will permit an ordinary operator to reach conveniently all over its face. The usual width of a section brought about by this limitation is from five and one-half to six feet. Such a section affords room for three operators to sit side by side before it. Now each line, instead of having a single jack as in the simple switchboard, is provided with a number of jacks and one of these is placed on each of the sections, so that each one of the operators may have within her reach a jack for each line. It is from the fact that each line has a multiplicity of jacks, that the term multiple switchboard arises.

Number of Sections. Since there is a jack for each line on each section of the switchboard, it follows that on each section there are as many jacks as there are lines; that is, if the board were serving 5,000 lines there would be 5,000 jacks. Let us see now what it is that determines the number of sections in a multiple switchboard. In the final analysis, it is the amount of traffic that arises in the busiest period of the day. Assume that in a particular office serving 5,000 lines, the subscribers call at such a very low rate that even at the busiest time of the day only enough calls are made to keep, say, three operators busy. In this case there would be no need for the multiple switchboard, for a single section would suffice. The three operators seated before that section would be able to answer and complete the connections for all of the calls that arose. But subscribers do not call at this exceedingly low rate. A great many more calls would arise on 5,000 lines during the busiest hour than could be handled by three operators and, therefore, a great many more operators would be required. Space has to be provided for these operators to work in, and as each section accommodates three operators the total number of sections must be at least equal to the total number of required operators divided by three.

Let us assume, for instance, that each operator can handle 200 calls during the busy hour. Assume further that during the busy hour the average number of calls made by each subscriber is two. One hundred subscribers would, therefore, originate 200 calls within this busy hour and this would be just sufficient to keep one operator busy. Since one operator can handle only the calls of one hundred subscribers during the busy hour, it follows that as many operators must be employed as there are hundreds of subscribers whose lines are served in a switchboard, and this means that in an exchange of 5,000 subscribers, 50 operators' positions would be required, or $16\frac{2}{3}$ sections. Each of these sections would be equipped with the full 5,000 jacks, so that each operator could have a connection terminal for each line.

The Multiple. These groups of 5,000 jacks, repeated on each of the sections, are termed multiple jacks, and the entire equipment of these multiple jacks and their wiring is referred to as the multiple. It will be shown presently that the multiple jacks are only used for enabling the operator to connect with the called subscriber. In other words these jacks are for the purpose of enabling each operator to have within her reach any line that may be called for regardless of what line originates the call. We will now consider what arrangements are provided for enabling the operator to receive the signal indicating a call and what provisions are made for her to answer the call in response to such a signal.

Line Signals. Obviously it is not necessary to have the line signals repeated on each section of the board as are the multiple jacks. If a line has one definite place on the switchboard where its signal may be received and its call may be answered, that suffices. Each line, therefore, in addition to having its multiple jacks distributed one on each section of the switchboard, has a line signal and an individual jack immediately associated with it, located on one only of the sections. This signal usually is in the form of a lamp and is termed the line signal, and this jack is termed the answering jack since it is by means of it that the operator always answers a call in response to the line signal.

Distribution of Line Signals. It is evident that it would not do to have all of these line signals and answering jacks located at one section of the board for then they would not be available to all of the operators. They are, therefore, distributed along the board in such a way that one group of them will be available to one operator, another group to another operator, and so on; the number of answering jacks and signals in any one group being so proportioned with respect to the number of calls that come in over them during the busy hour that it will afford just about enough calls to keep the operator at that position busy.

We may summarize these conditions with respect to the jack and line-signal equipment of the multiple switchboard by saying that each line has a multiple jack on each section of the board and in addition to this has on one section of the board an answering jack and a line signal. These answering jacks and line signals are distributed in groups along the face of the board so that each operator will receive her proper quota of the originating calls which she will answer and, by virtue of the multiple jack, be able to complete the connections with the desired subscribers without moving from her position.

Cord Circuits. Each operator is also provided with a number of pairs of cords and plugs with proper supervisory or clearing-out signals and ringing and listening keys, the arrangement in this respect being similar to that already described in connection with the simple switchboard.

Guarding against Double Connections. From what has been said it is seen that a call originating on a given line may be answered at one place only, but an outgoing connection with that line may be made at any position. This fact that a line may be connected with when called for at any one of the sections of the switchboard. makes necessary the provision that two or more connections will not be made with the same line at the same time. For instance, if a call came in over a line whose signal was located on the first position of the switchboard for a connection with line No. 1,000, the operator at the first position would connect this calling line with No. 1,000 through the multiple jack on the first section of the switchboard Assume now that some line, whose signal was located on the 39th position of the switchboard, should call also for line No. 1,000 while that line was still connected with the first calling subscriber. Obviously confusion would result if the operator at the 39th position, not knowing that line No. 1,000 was already busy, should connect this second line with it, thereby leaving both of the calling subscribers connected with line No. 1,000, and as a result all of these three subscribers connected together.

The provisions for suitable means for preventing the making of a connection with a line that is already switched at some other section of the switchboard, has offered one of the most fertile fields for invention in the whole telephone art. The ways that have been proposed for accomplishing this are legion. Fortunately common practice has settled on one general plan of action and that is to so arrange the circuits that whenever a line is switched at one section, such an electrical condition will be established on the forward contacts of all of its multiple jacks that any operator at any other section in attempting to make a connection with that line will be notified of the fact that it is already switched by an audible signal, which she will receive in her head receiver. On the other hand the arrangement is such that when a line is not busy, *i. e.*, it is not switched at any of the positions of the switchboard, the operator on attempting to make a connection with such a line will receive no such guarding signal and will, therefore, proceed with the connection.

We may liken a line in a multiple switchboard to a lane having a number of gates giving access to it. One of these gates—the answering jack—is for the exclusive use of the proprietor of that lane. All of the other gates to the lane—the multiple jacks—are for affording means for the public to enter. But whenever any person enters one of these gates, a signal is automatically put up at all of the other gates forbidding any other person to enter the lane as long as the first person is still within.

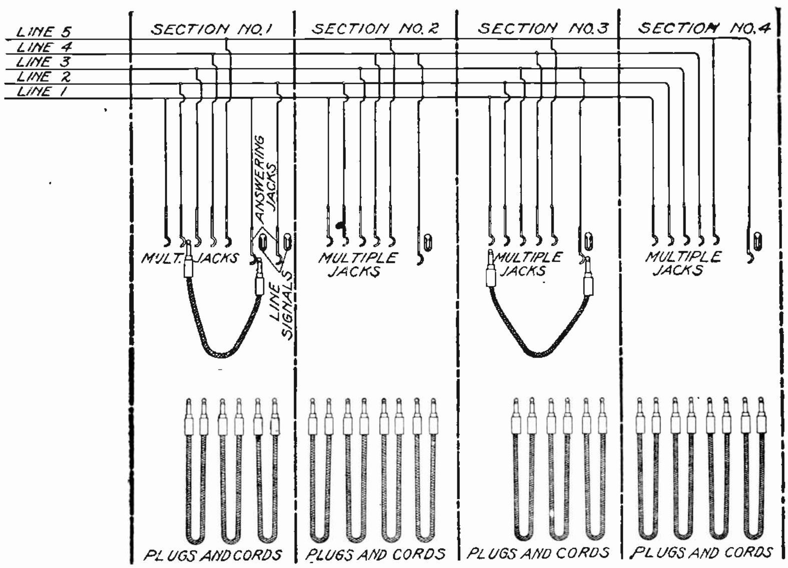


Fig. 178. Principle of Multiple Switchboard

Diagram Showing Multiple Board Principle. For those to whom the foregoing description of the multiple board is not altogether clear, the diagram of Fig. 178 may offer some assistance. Five subscribers' lines are shown running through four sections of a switchboard. Each of these lines is provided with a multiple jack on each section of the board. Each line is also provided with an answering jack and a line signal on one of the sections of the board. Thus the answering jacks and the line signals of lines *1* and *2* are shown in Section I, that of line *4* is shown in Section II, that of line *3* in Section III, and that of line *5* in Section IV. At Section I, line *1* is shown in the condition of having made a call and having had this call answered by the operator inserting one of her plugs into its answering jack. In response to the instructions given by the subscriber, the operator has inserted the other plug of this same pair in the multiple jack of line *2*, thus connecting these two lines for conversation. At Section III, line *3* is shown as having made a call, and the operator as having answered by inserting one of her plugs into the answering jack. It happens that the subscriber on line *3* requests a connection with line *1*, and the condition at Section III is that where the operator is about to apply the tip of the calling plug to the jack of line *1* to ascertain whether or not that line is busy. As before stated, when the contact is made between the tip of the calling plug and the forward contact of the multiple jack, the operator will receive a click in the ear (by means that will be more fully discussed in later chapters), this click indicating to her that line *1* is not available for connection because it is already switched at some other section of the switchboard.

Busy Test. The busy signal, by which an operator in attempting to make a connection is informed that the line is already busy, has assumed a great variety of forms and has brought forth many inventions. It has been proposed by some that the insertion of a plug into any one of the jacks of a line would automatically close a little door in front of each of the other jacks of the line, therefore making it impossible for any other operator to insert a plug as long as the line is in use. It has been proposed by others to ring bells or to operate buzzers whenever the attempt was made by an operator to plug into a line that was already in use. Still others have proposed to so arrange the circuits that the operator would get an electric shock whenever she attempted to plug into a busy line. The scheme that has met with universal adoption, however, is that the operator shall, when the tip of her calling plug touches the forward contact of the jack of a line that is already switched, receive a click in her telephone which will forbid her to insert the plug. The absence of this click, or silence in her telephone, informs her that she may safely make the connection.

Principle. The means by which the operator receives or fails to receive this click, according to whether the line is busy or idle, vary widely, but so far as the writers are aware they all have one fundamental feature in common. The tip of the calling plug and the test contact of all of the multiple jacks of an idle line must be absolutely at the same potential before the test, so that no current will flow through the test circuit when the test is actually made. The test thimbles of all the jacks of a busy line must be at a different potential from the tip of the test plug so that a current will flow and a click result when the test is made.

Potential of Test Thimbles. It has been found an easy matter to so arrange the contacts in the jacks of a multiple switchboard that whenever the line is idle the test thimbles of that line will be a certain potential, the same as that of all the unused calling plug tips. It has also been easy to so arrange these contacts that the insertion of a plug into any one of the jacks will, by virtue of the contacts established, change the potential of all the test thimbles of that line so that they will be at a different potential from that of the tips of the calling plugs. It has not been so easy, however, to provide that these conditions shall exist under all conditions of practice. A great many busy tests that looked well on paper have been found faulty in practice. As is always the case in such instances, this has been true because the people who considered the scheme on paper did not foresee all of the conditions that would arise in practice. Many busy-test systems will operate properly while everything connected with the switchboard and the lines served by it remains in proper order. But no such condition as this can be depended on in practice. Switchboards, no matter how perfectly made and no matter with how great care they may be installed and maintained, will get out of order. Telephone lines will become grounded or short-circuited or crossed or opened. Such conditions, in a faulty busy-test system, may result in a line that is really idle presenting a busy test, and thus barring the subscriber on that line from receiving calls from other lines just as completely as if his line were broken. On the other hand, faulty conditions either in the switchboard or in the line may make a line that is really busy, test idle, and thus result in the confusion of having two or more subscribers connected to the same line at the same time.

Busy-Test Faults. To show how elusive some of the faults of a busy test may be, when considered on paper, it has come within the observation of the writers that a new busy-test system was thought well enough of by a group of experienced engineers to warrant its installation in a group of very large multiple switchboards, the cost of which amounted to hundreds of thousands of dollars, and yet when so installed it developed that a single short-circuited cord in a position would make the test inoperative on all the cords of that position —obviously an intolerable condition. Luckily the remedy was simple and easily applied.

In a well-designed busy-test system there should be complete silence when the test is made of an idle line, and always a well-defined click when the test is made of a busy line. The test on busy lines should result in a uniform click regardless of length of lines or the condition of the apparatus. It does not suffice to have a little click for an idle line and a big click for a busy line, as practice has shown that this results in frequent errors on the part of the operators.

Good operating requires that the tip of the calling plug be tapped against the test thimble several times in order to make sure of the state of the called line.

In some multiple switchboards the arrangement has been such that the jacks of a line would test busy as soon as the subscriber on that line removed his receiver from its hook to make a call, as well as while any plug was in any jack of that line. The advocates of this added feature, in connection with the busy test, have claimed that the receiver, when removed from its hook in making a call, should make the line test busy and that a line should not be connected with when the subscriber's receiver was off its hook any more than it should be when it was already connected with at some other section of the switchboard. While it is true that a line may be properly termed busy when the subscriber has removed his receiver in order to make a call, it is not true that there is any real necessity for guarding against a connection with it while he is waiting for the operator to answer. Leaving the line unguarded for this brief period may result in the subscriber, who intended to make the call, having to defer his call until he has conversed with the party who is trying to reach him. This cannot be said to be a detriment to the service, however, since the second party gets the connection he desires much sooner than he otherwise would, and the first party may still make his first intended call as soon as he has disposed of the party who reached him while he was waiting for his own operator to answer. It may be said, therefore, in connection with this matter of making the line test busy as soon as a subscriber has removed his receiver from the hook, that it is not considered an essential, and in case of those switchboard systems which naturally work out that way it is not considered a disadvantage.

Field of Each Operator. It was stated earlier in this chapter that as each section accommodated three operators, the total number of sections in a switchboard will be at least one-third the total number of required operators. This thought needs further development, for to stop at that statement is to arrive somewhat short of the truth. In order to do this it is necessary to consider the field in the multiple, reached by each operator. The section is of such size, or should be, that an operator seated in the center position of it may, without undue effort, reach all over the multiple. But the operator at the right-hand position cannot reach the extreme left portion of the multiple of that section, nor can the operator at the left reach the extreme right. How then may each operator reach a jack for every line? Remembering that the multiple jacks are arranged exactly the same in each section, each jack always occupying the same relative position, it is easy to see that while the operator at a right-hand position of a section cannot reach the left-hand third of the multiple in her own section, she may reach the left-hand third of the multiple in the section at her right, and this, together with the center and right-hand thirds of her own section, represents the entire number of lines. So it is with the left-hand operator at any section, she reaches two-thirds of all the lines in the multiple of her own section and one-third in that of the section at her left.

End Positions. This makes it necessary to inquire about the operators at the end positions of the entire board. To provide for these the multiple is extended one-third of a section beyond them, so as to supply at the ends of the switchboard jacks for those lines which the end operators cannot reach on their own sections. Sometimes instead of adding these end sections to the multiple for the end operators, the same result is accomplished by using only the full and regular sections of the multiple, and leaving the end positions without operators' equipment, as well as without answering jacks, line signals, and cords and plugs, so that in reality the end operator is at the middle position of the end section. This, in our opinion, is the better practice, since it leaves the sections standard, and makes it easier to extend the switchboard in length, as it grows, by the mere addition of new sections without disturbing any of the old multiple.

Influence of Traffic. We wish again to emphasize the fact that it is the traffic during the busiest time of day and not the number of lines that determine the size of a multiple switchboard so far as its length is concerned. The number of lines determines the size of the multiple in any one section, but it is the amount of traffic, the number of calls that are made in the busiest period, that determines the number of operators required, and thus the number of positions. Had this now very obvious fact been more fully realized in the past, some companies would be operating at less expense, and some manufacturers would have sold less expensive switchboards.

The whole question as to the number of positions boils down to how many answering jacks and line signals may be placed at each operator's position without overburdening the operator with incoming traffic at the busy time of day. Obviously, some lines will call more frequently than others, and hence the proper number of answering jacks at the different positions will vary. Obviously, also, due to changes in the personnel of the subscribers, the rates of calling of different groups of lines will change from time to time, and this may necessitate a regrouping of the line signals and answering jacks on the positions; and changes in the personnel of the operators or in their skill also demand such regrouping.

Intermediate Frame. The intermediate distributing frame is provided for this purpose, and will be more fully discussed in subsequent chapters. Suffice it to say here that the intermediate distributing frame permits the answering jacks and line signals to be shifted about among the operators' positions, so that each position will have just enough originating traffic to keep each of the operators economically busy during the busiest time of the day.

CHAPTER XIII

THE MAGNETO MULTIPLE SWITCHBOARD

Field of Utility. The principles of the multiple switchboard set forth in the last chapter were all developed long before the common-battery system came into existence, and consequently all of the first multiple switchboards were of the magneto type. Although once very widely used, the magneto multiple switchboard has almost passed out of existence, since it has become almost universal practice to equip exchanges large enough to employ multiple boards with common-battery systems. Nevertheless there is a field for magneto multiple switchboards, and in this field it has recently been coming into increasing favor. In those towns equipped with magneto systems employing simple switchboards or transfer switchboards, and which require new switchboards by virtue of having outgrown or worn out their old ones, the magneto multiple switchboard is frequently found to best fit the requirements of economy and good practice. The reason for this is that by its use the magneto telephones already in service may be continued, no change being required outside of the central office. Furthermore, with the magneto multiple switchboard no provision need be made for a power plant, which, in towns of small size, is often an important consideration. Again, many companies operate over a considerable area, involving a collection of towns and hamlets. It may be that all of these towns except one are clearly of a size to demand magneto equipment and that magneto equipment is the standard throughout the entire territory of the company. If, however, one of the towns, by virtue of growth, demands a multiple switchboard, this condition affords an additional argument for the employment of the magneto multiple switchboard, since the same standards of equipment and construction may be maintained throughout the entire territory of the operating company, a manifest advantage. On the other hand, it may be said that the magneto multiple switchboard has no proper place in modern exchanges of considerable size—say, having upward of one thousand subscribers—at least under conditions found in the United States.

Notwithstanding the obsolescence of the magneto multiple switchboard for large exchanges, a brief discussion of some of the early magneto multiple switchboards, and particularly of one of the large ones, is worth while, in that a consideration of the defects of those early efforts will give one a better understanding and appreciation of the modern multiple switchboard, and particularly of the modern multiple common-battery switchboard, the most highly organized of all the manual switching systems. Brief reference will, therefore, be made to the so-called series multiple switchboard, and then to the branch terminal multiple switchboard, which latter was the highest type of switchboard development at the time of the advent of common-battery working.

Series-Multiple Board. In Fig. 179 are shown the circuits of a series magneto multiple switchboard as developed by the engineers of the Western Electric Company during the eighties. As is usual, two subscribers' lines and a single cord circuit are shown. One side of each line passes directly from the subscriber's station to one side of the drop, and also branches off to the sleeve contact of each of the jacks. The other side of the line passes first to the tip spring of the first jack, thence to the anvil of that jack and to the tip spring of the next jack, and so on in series through all of the jacks belonging in that line to the other terminal of the drop coil. Normally, therefore, the drop is connected across the line ready to be responsive to the signal sent from the subscriber's generator. The cord circuit is of the two-conductor type, the plugs being provided with tip and sleeve contacts, the tips being connected by one of the flexible conductors through the proper ringing and listening key springs, and the sleeve being likewise connected through the other flexible conductor and the other springs of the ringing and listening keys. It is obvious that when any plug is inserted into a jack, the circuit of the line will be continued to the cord circuit and at the same time the line drop will be cut out of the circuit, because of the lifting of the tip spring of the jack from its anvil. Permanently connected between the sleeve side of the cord circuit and ground is a retardation coil *1* and a battery. Another retardation coil *2* is connected between the ground and a point on the operator's telephone circuit between the operator's head receiver and the secondary of her induction coil. These two retardation coils have to do with the busy test, the action of which is as follows: normally, or when a line is not switched at the central office, the test thimbles will all be at substantially ground potential, *i. e.*, they are supposed to be. The point on the operator's receiver circuit which is grounded through the retardation coil *2* will also be of ground potential because of that connection to ground. In order to test, the operator always has to throw her

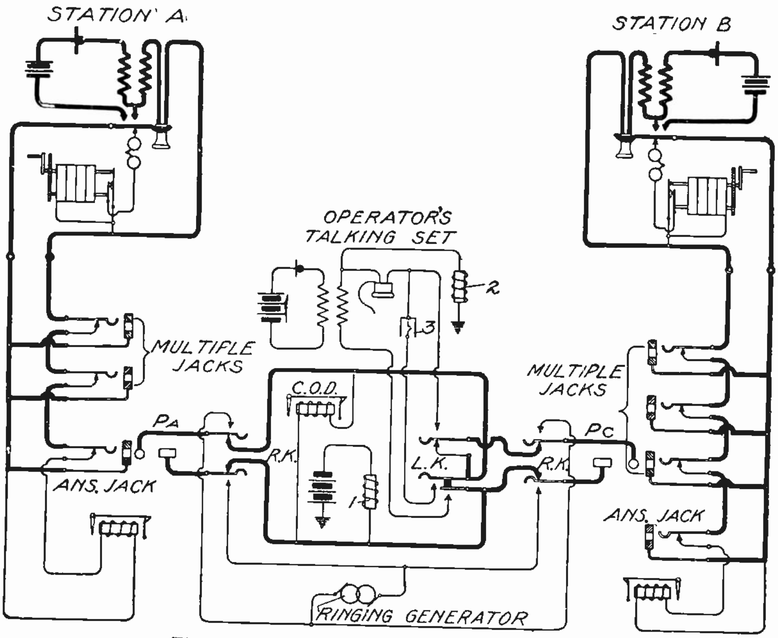


Fig. 119. Series Magneto Multiple Switchboard

listening key *L.K.* into the listening position. She also has to touch the tip of the calling plug P_c to a sleeve or jack of the line that is being tested. If, therefore, a test is made of an idle or non-busy line, the touching of the tip of the calling plug with the test thimble of that line will result in no flow of current through the operator's receiver, because there will be no difference of potential anywhere in the test circuit, which test circuit may be traced from the test thimble of the line under test to the tip of the calling plug, thence through the tip strand of the cord to the listening key, thence to the outer anvil of the listening key on that side, through the operator's receiver to ground through the impedance coil *2*. If, however, the line had already been switched at some other section by the insertion of either a calling or answering plug, all of the test thimbles of that line would have been raised to a potential above that of the ground, by virtue of the battery connected with the sleeve side of the cord circuit through the retardation coil *1*. If the operator had made a test of such a line, the tip of her testing plug would have found the thimble raised to the potential of the battery and, therefore, a flow of current would occur which would give her the busy click. The complete test circuit thus formed in testing a busy line would be from the ungrounded pole of the battery through the impedance coil *1* associated with the cord that was already in connection with the line, thence to the sleeve strand of that cord to the sleeve of the jack at which the line was already switched, thence through that portion of the line circuit to which all of the sleeve contacts were connected, and therefore to the sleeve or test thimble of the jack at which the test is made, thence through the tip of the calling plug employed in making the test through the tip side of that cord circuit to the outer listening key contact of the operator making the test, and thence to ground through the operator's receiver and the impedance coil *2*. The resultant click would be an indication to the operator that the line was already in use and that, therefore, she must not make the connection.

The condenser *3* is associated with the operator's talking set and with the extra spring in the listening key *L.K.* in such a manner that when the listening key is thrown, the tip strand of the cord circuit is divided and the condenser included between them. This is for the purpose of preventing any potentials, which might exist on the line with which the answering plug P_a was connected, from affecting the busy-test conditions.

Operation. The operation of the system aside from the busy-test feature is just like that described in connection with the simple magneto switchboard. Assuming that the subscriber at Station *A* makes the call, he turns his hand generator, which throws the drop on his line at the central office. The operator, seeing the signal, inserts the answering plug of one of her idle pairs of cords into the answering jack and throws her listening key *L.K.* This enables the operator to talk with the calling subscriber, and having found that he desires a connection with the line extending to Station *B*, she touches the tip of her calling plug to the multiple jack of that line that is within her reach, it being remembered that each one of the multiple jacks shown is on a different section. She leaves the listening key in the listening position when she does this. If the line is busy, the click will notify her that she must not make the connection, in which case she informs the calling subscriber that the line is busy and requests him to call again. If, however, she received no click, she would insert the calling plug into the jack, thus completing the connection between the two lines. She would then press the ringing key associated with the calling plug and that momentarily disconnects the calling plug from the answering plug and at the same time establishes connection between the ringing generator and the called line. The release of the ringing key again connects the calling and answering plugs and, therefore, connects the two subscribers' lines ready for conversation. All that is then necessary is that the called subscriber shall respond and remove his receiver from its hook, the calling subscriber already having done this. When the conversation is finished, both of the subscribers (if they remember it) will operate their ringing generators, which will throw the clearing-out drop as a signal to the operator for disconnection. If it should become necessary for the operator to ring back on the line of the calling subscriber, she may do so by pressing the ringing key associated with the calling plug.

Frequently this multiple switchboard arrangement was used with grounded lines, in which case the single line wire extending from the subscriber's station to the switchboard was connected with the tip spring of the first jack, the circuit being continued in series through the jack to the drop and thence to ground through a high non-inductive resistance.

Defects. This series multiple magneto system was used with a great many variations, and it had a good many defects. One of these defects was due to the necessary extending of one limb of the line through a large number of series contacts in the jacks. This is not to be desired in any case, but it was particularly objectionable in the early days before jacks had been developed to their present high state of perfection. A particle of dust or other insulating matter, lodging between the tip spring and its anvil in any one of the jacks, would leave the line open, thus disabling the line to incoming signals, and also for conversation in case the break happened to occur between the subscriber and the jack that was used in connecting with the line. Another defect due to the same cause was that the line through the switchboard was always unbalanced by the insertion of a plug, one limb of the line always extending clear through the switchboard to the drop and the other, when the plug was inserted, extending only part way through the switchboard and being cut off at the jack where the connection was made. The objection will be apparent when it is remembered that the wires in the line circuit connecting the multiple jacks are necessarily very closely bunched together and, therefore, there is very likely to be cross-talk between two adjacent lines unless the two limbs of each line are exactly balanced throughout their entire length.

Again the busy-test conditions of this circuit were not ideal. The fact that the test rings of the line were connected permanently with the outside line circuit subjected these test rings to whatever potentials might exist on the outside lines, due to any causes whatever, such as a cross with some other wire; thus the test rings of an idle line might by some exterior cause be raised to such a potential that the line would test busy. It may be laid down as a fundamental principle in good multiple switchboard practice that the busy-test condition should be made independent of any conditions on the line circuit outside of the central office, and such is not the case in this circuit just described.

Branch-Terminal Multiple Board. The next important step in the development of the magneto multiple switchboard was that which produced the so-called branch-terminal board. This came into wide use in the various Bell operating companies before the advent of the common-battery systems. Its circuits and the principles of operation may be understood in connection with Fig. 180. In the branch-terminal system there are no series contacts in the jacks and no unbalancing of the line due to a cutting off of a portion of the line circuit when a connection was made with it. Furthermore, the test circuits were entirely local to the central office and were not likely to be affected by outside conditions on the line. This switchboard also added the feature of the automatic restoration of the drops, thus relieving the operator of the burden of doing that manually, and also permitting the drops to be mounted on a portion of the switchboard that was not available for the mounting of jacks, and thus permitting a greater capacity in jack equipment.

Each jack has five contacts, and the answering and multiple jacks are alike, both in respect to their construction and their connection with the line. The drops are the electrically self-restoring type shown in Fig. 111. The line circuits extended permanently from the subscriber's station to the line winding of the drop and the

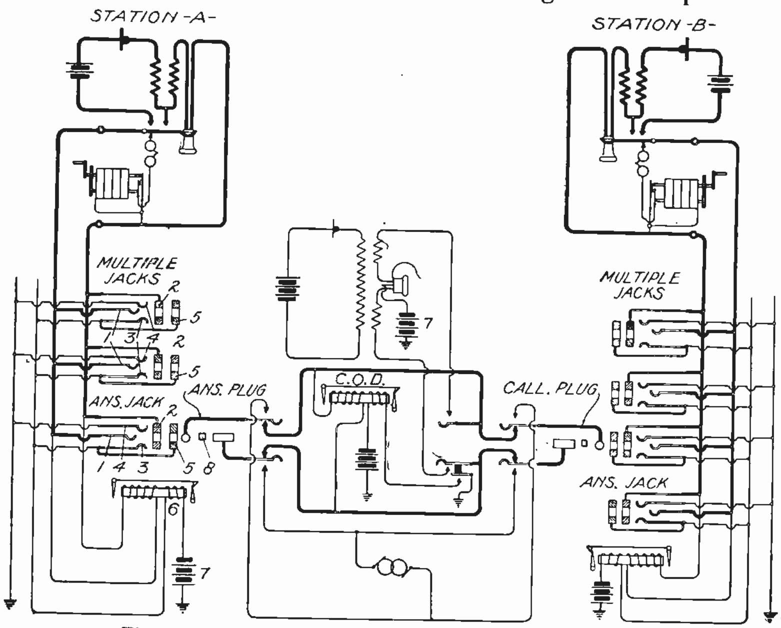


Fig. 180. Branch-Terminal Magneto Multiple Switchboard

two limbs of the line branched off to the tip and sleeve contacts *1* and *2* respectively of each jack. Another pair of wires extended through the multiple parallel to the line wires and these branched off respectively to the contact springs *3* and *4* of each of the jacks. This pair of wires formed portions of the drop-restoring circuit, including the restoring coil *6* and the battery *7*, as indicated. The test thimble *5* of each of the jacks is connected permanently with the spring *3* of the corresponding jack and, therefore, with the wire which connects through the restoring coil *6* of the corresponding drop to ground through the battery *7*.

The plugs were each provided with three contacts. Two of these were the usual tip and sleeve contacts connected with the two strands of the cord circuit. The third contact *8* was not connected with any portion of the cord circuit, being merely an insulated contact on the plug adapted, when the plug was fully inserted, to connect together the springs *3* and *4*. The cord circuit itself is readily understood from the drawing, having two features, however, which merit attention. One is the establishing of a grounded battery connection to the center portion of the winding of the receiver for the purposes of the busy test, and the other is the provision of a restoring coil and restoring circuit for the clearing-out drop, this circuit being closed by an additional contact on the listening key so as to restore the clearing-out drop whenever the listening key was operated.

Operation. An understanding of the operation of this system is easy. The turning of the subscriber's generator, when the line was in its normal condition, caused the display of the line signal. The insertion of the answering plug, in response to this call, did three things: (1) It extended the line circuit to the tip and sleeve strand of the cord circuit. (2) It energized the restoring coil *6* of the drop by establishing the circuit from the contact spring *3* through the plug contact *8* to the other contact spring *4*, thus completing the circuit between the two normally open auxiliary wires. (3) The connecting of the springs *3* and *4* established a connection from ground to the test thimbles of all the jacks on a line, the spring *4* being always grounded and the spring *3* being always connected to the test thimble *5*.

It is to be noted that on idle lines the test rings are always at the same potential as the ungrounded pole of the battery *7*, being connected thereto through the winding *6* of the restoring coil. On all busy lines, however, the test rings are dead grounded through the contact *8* of the plug that is connected with the line.

The tip of the testing plug at the time of making a test will also be at the same potential as that of the ungrounded pole of the battery *7*, since this pole of the battery *7* is always connected to the center portion of the operator's receiver winding, and when the listening key is thrown the tip of the calling plug is connected therewith and is at the same potential. When, therefore, the operator touches the tip of the calling plug to the test thimble of an idle line, she will get no click, since the tip of the plug and the test thimble will be at the same potential. If, however, the line has already been switched at another section of the board, there will be a difference of potential, because the test thimble will be grounded, and the circuit, through which the current which causes the click flows, may be traced from the ungrounded pole of the battery *7* to the center portion of the operator's receiver, thence through one-half of the winding to the tip of the calling plug, thence to the test thimble of the jack under test, thence to the spring *3* of the jack on another section at which the connection exists, through the contact *8* on the plug of that jack to the spring *4*, and thence to ground and back to the other terminal of the battery *7*.

Magnet Windings. Coils of the line and clearing-out drops by which these drops are thrown, are wound to such high resistance and impedance as to make it proper to leave them permanently bridged across the talking circuit. The necessity for cutting them out is, therefore, done away with, with a consequent avoidance, in the case of the line drops, of the provision of series contacts in the jacks.

Arrangement of Apparatus. In boards of this type the line and clearing-out drops were mounted in the extreme upper portion of the switchboard face so as to be within the range of vision of the operator, but yet out of her reach. Therefore, the whole face of the board that was within the limit of the operator's reach was available for the answering and multiple jacks. A front view of a little over one of the sections of the switchboard, involving three complete operator's positions, is shown in Fig. 181, which is a portion of the switchboard installed by the Western Electric Company in one of the large exchanges in Paris, France. (This has recently been replaced by a common-battery multiple board.) In this the line drops may be seen at the extreme top of the face of the switchboard, and immediately beneath these the clearing-out drops. Beneath these are the multiple jacks arranged in banks of one hundred, each hundred consisting of five strips of twenty. At the extreme lower portion of the jack space are shown the answering jacks and beneath these on the horizontal shelf, the plugs and keys. These jacks were mounted on $\frac{1}{2}$-inch centers, both vertically and horizontally, and each section had in multiple 90 banks of 100 each, making 9,000 in all. Subsequent practice has shown that this involves too large a reach for the operators and that, therefore, 9,000 is too large a num-

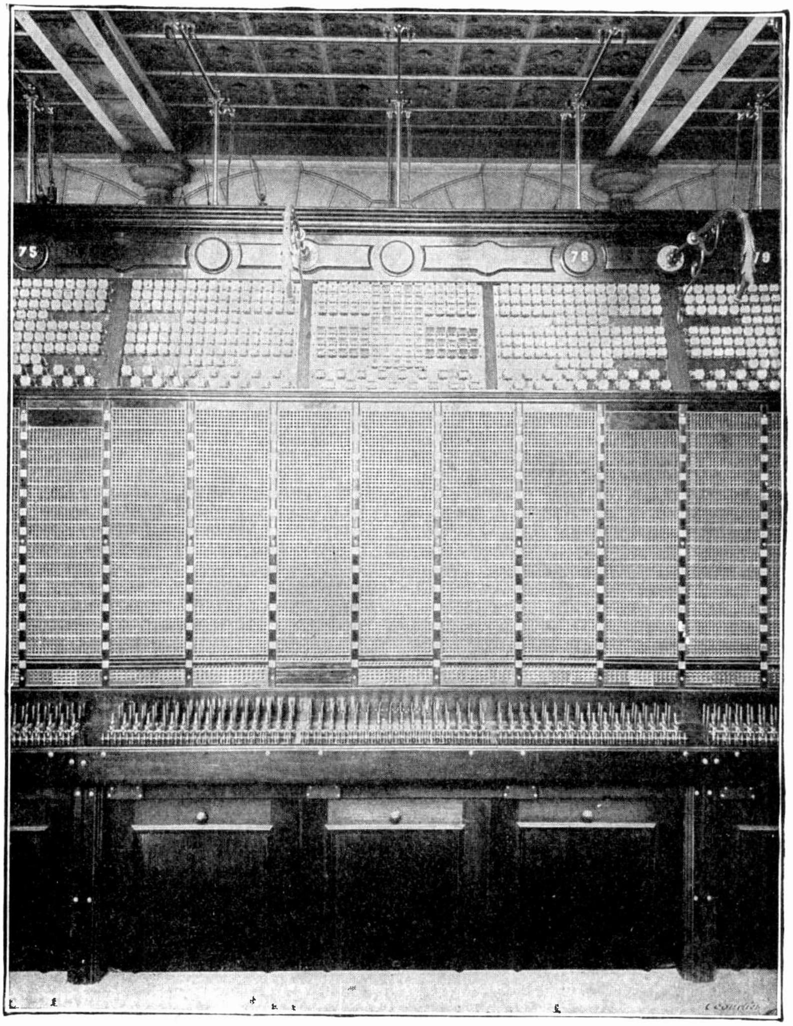


Fig. 181. Face of Magneto Multiple Switchboard

ber of jacks to place on one section if the jacks are not spaced closer than on ½-inch centers. With the jack involving as many parts as that required by this branch terminal system, it was hardly feasible to make them smaller than this without sacrificing their durability, and one of the important features of the common-battery multiple system which has supplanted this branch-terminal magneto system is that the jacks are of such a simple nature as to lend themselves to mounting on $\frac{3}{8}$-inch centers, and in some cases on $\frac{3}{10}$-inch centers.

Modern Magneto Multiple Board. Coming now to a consideration of modern magneto multiple switchboards, and bearing in mind that such boards are to be found in modern practice only in comparatively small installations and then only under rather peculiar conditions, as already set forth, we will consider the switchboard of the Monarch Telephone Manufacturing Company as typical of good practice in this respect.

Line Circuit. The line and cord circuits of the Monarch system are shown in Fig. 182. It will be seen that each jack has in all five contacts, numbered from *1* to *5* respectively, of which *1* and *4* are the springs which register with the tip and ring contacts of the plug and through which the talking circuit is continued, while *2* and *3* are series contacts for cutting off the line drop when a plug is inserted,

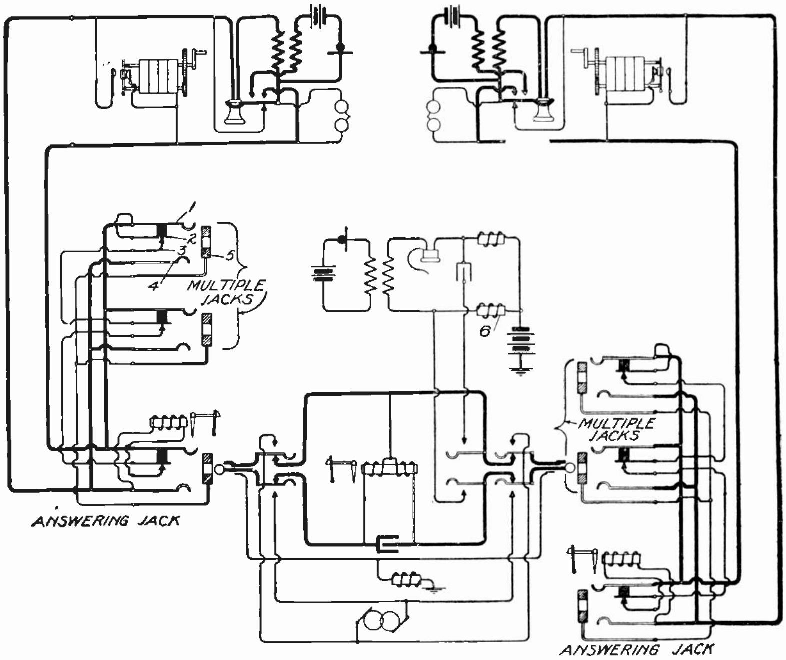


Fig. 182. Monarch Magneto Multiple Switchboard Circuits

and *5* is the test contact or thimble adapted to register with the sleeve contact on the plug when the plug is fully inserted. The line circuit through the drop may be traced normally from one side of the line through the drop coil, thence through all of the pairs of springs *2* and *3* in the jacks of that line, and thence to spring *1* of the last jack, this spring always being strapped to the spring *2* in the last jack, and thence to the other side of the line. All the ring springs *1* are permanently tapped on to one side of the line, and all of the tip springs *4* are permanently tapped to the other side of the line. This system may, therefore, properly be called a branch-terminal system. It is seen that as soon as a plug is inserted into any of the jacks, the circuit through the drop will be broken by the opening of the springs *2* and *3* in that jack. The drop shown immediately above the answering jack is so associated mechanically with that jack as to be mechanically self-restored when the answering plug is inserted into the answering jack in response to a call. The arrangement in this respect is the same as that shown in Fig. 107, illustrating the Monarch combined drop and jack.

Cord Circuit. The cord circuit needs little explanation. The tip and ring strands are the ones which carry the talking current and across these is bridged the double-wound clearing-out drop, a condenser being included in series in the tip strand between the two drop windings in the manner already explained in connection with Fig. 132. The third or sleeve strand of the cord is continuous from plug to plug, and between it and the ground there is permanently connected a retardation coil.

Test. The test is dependent on the presence or absence of a path to ground from the test thimbles through some retardation coil associated with a cord circuit. Obviously, in the case of an idle line there will be no path to ground from the test thimbles, since normally they are merely connected to each other and are insulated from everything else. When, however, a plug is inserted into a multiple or answering jack, the test thimbles of that line are connected to ground through the retardation coil associated with the third strand of the plug used in making the connection. When the operator applies the tip of the calling plug to a test contact of a multiple jack there will be no path to ground afforded if the line is idle, while if it is busy the potential of the tip of the test plug will cause a current to flow to ground through the impedance coil associated with the plug used in making the connection. This will be made clearer by tracing the test circuit. With the listening key thrown this may be traced from the live side of the battery through the retardation coil *6*, which is common to an operator's position, thence through the tip side of the listening key to the tip conductor of the calling cord, and thence to the tip of the calling plug and the thimble of the jack under test. If the line is idle there will be no path to ground from

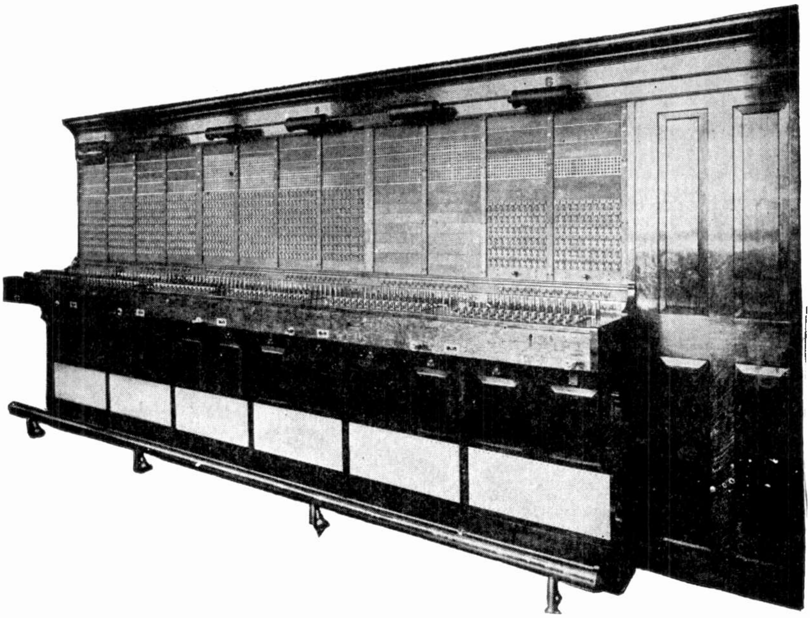


Fig. 183. Magneto Multiple Switchboard

this point and no click will result, but if the line is busy, current will flow from the tip of the test plug to the thimble of the jack tested, thence by the test wire in the multiple to the thimble of the jack at which a connection already exists, and thence to ground through the third strand of the cord used in making that connection and the impedance coil associated therewith. The current which flows in this test circuit changes momentarily the potential of the tip side of the operator's telephone circuit, thus unbalancing her talking circuit and causing a click.

If this test system were used in a very large board where the multiple would extend through a great many sections, there would be some liability of a false test due to the static capacity of the test contacts and the test wire running through the multiple. For small boards, however, where the multiple is short, this system has proven reliable. A multiple magneto switchboard employing the form of circuits just described is shown in Fig. 183. This switchboard consists of three sections of two positions each. The combined answering jacks and drops may be seen at the lower part of the face of the switchboard and occupying somewhat over one-half of the jack and drop space. The multiple jacks are above the answering jacks and drops and it may be noted that the same arrangement and number of these jacks is repeated in each section. This switchboard may be extended by adding more sections and increasing the multiple in those already installed to serve 1,600 lines.

Assembly. In connection with the assembly of these magneto multiple switchboards, as installed by the Monarch Company, Fig. 184 shows the details of the cord rack at the back of the board. It shows how the ends of the switchboard cords opposite to the ends that are fastened to the plugs are connected permanently to terminals on the cord rack, at which point the flexible conductors are brought out to terminal clips or binding posts, to which the wires leading from the other portions of the cord circuit are led. In order to relieve the conductors in the cords from strain, the outer braiding of the cord at the rack end is usually extended to form what is called a *strain cord*, and this attached to an eyelet under the cord rack, so that the weight of the cord and the cord weights will be borne by the braiding rather than by the conductors. This leaves the insulated conductors extending from the ends of the cords free to hang loose without strain and be connected to the terminals as shown. This method of connecting cords, with variations in form and detail, is practically universal in all types of switchboards.

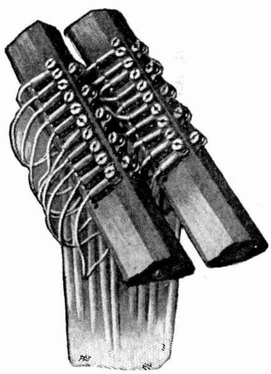


Fig. 184. Cord-Rack Connectors

A detail of the assembly of the drops and jacks in such a switchboard is shown in Fig. 185. The single pair of clearing-out drops is mounted in the lower part of the vertical face of the switchboard just above the space occupied by the plug shelf. Vertical stile strips extend above the clearing-out drop space for supporting the drops

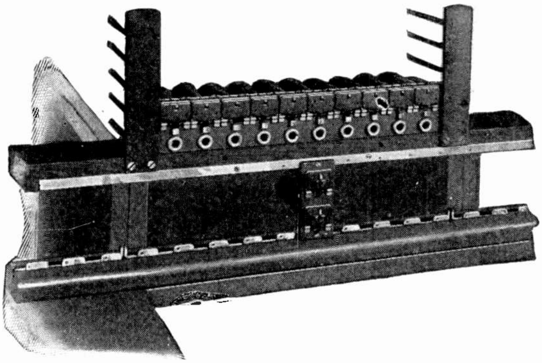


Fig. 185. Drop and Jack Mounting

and jacks. A single row of 10 answering jacks and the corresponding line drops are shown in place. Above these there would be placed, in the completely assembled board, the other answering jacks and line signals that were to occupy this panel, and above these the

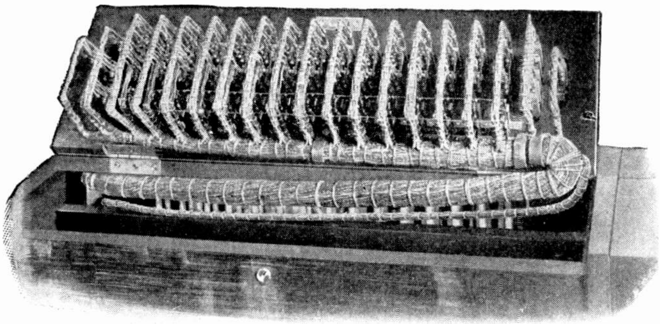


Fig. 186. Keyboard Wiring

strips of multiple jacks. The rearwardly projecting pins from the stile strips are for the support of the multiple jack strips, these pins supporting the strips horizontally by suitable multiple clips at the ends of the jack strips; the jack strips being fastened from the rear by means of nuts engaging the screw threads on these pins. This method of supporting drops and jacks is one that is equally adaptable for use in other forms of boards, such as the simple magneto switchboard.

In Fig. 186 is shown a detail photograph of the key shelf wiring in one of these Monarch magneto switchboards. In this the under side of the keys is shown, the key shelf being raised on its hinge for that purpose. The cable, containing all of the insulated wires leading to these keys, enters the space under the key shelf at the extreme left and from the rear. It then passes to the right of this space where a "knee" is formed, after which the cable is securely strapped to the under side of the key shelf. By this construction sufficient flexibility is provided for in the cable to permit the raising and lowering of the key shelf, the long reach of the cable between the "knee" and the point of entry at the left serving as a torsion member, so that the raising of the shelf will give the cable a slight twist rather than bend it at a sharp angle.

CHAPTER XIV

THE COMMON-BATTERY MULTIPLE SWITCHBOARD

Western Electric No. 1 Relay Board. The common-battery multiple switchboard differs from the simple or non-multiple common-battery switchboard mainly in the provision of multiple jacks and in the added features which are involved in the provision for a busy test. The principles of signaling and of supplying current to the subscribers for talking are the same as in the non-multiple common-battery board. For purposes of illustrating the practical workings of the common-battery multiple switchboard, we will take the standard form of the Western Electric Company, choosing this only because it is the standard with nearly all the Bell operating companies throughout the United States.

Line Circuit. We will first consider the line circuit in simplified form, as shown in Fig. 187. At the left in this figure the com-

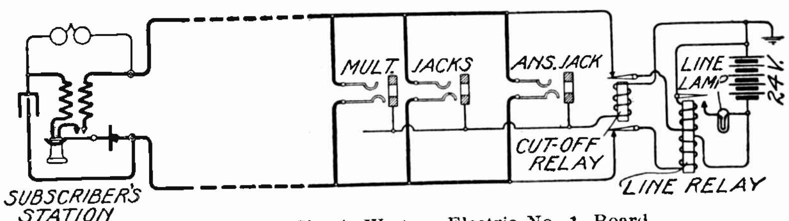


Fig. 187. Line Circuit Western Electric No. 1. Board

mon-battery circuit is shown at the subscriber's station, and at the right the central-office apparatus is indicated so far as equipment of a single line is concerned. In this simplified diagram no attempt has been made to show the relative positions of the various parts, these having been grouped in this figure in such a way as to give as clear and simple an idea as possible of the circuit arrangements. It is seen at a glance that this is a branch terminal board, the three contacts of each jack being connected by separate taps or legs to three wires running throughout the length of the board, these three wires being individual to the jacks of one line. On this account this line circuit is commonly referred to as a three-wire circuit. By the same considerations it will be seen that the switchboard line circuit of the branch-terminal multiple magneto system, shown in Fig. 180, would be called a four-wire circuit. It will be shown later that other multiple switchboards in wide use have a still further reduction in the number of wires running through the jacks, or through the multiple as it is called, such being referred to as two-wire switchboards.

The two limbs of the line which extend from the subscriber's circuit, besides being connected by taps to the tip and sleeve contacts of the jack, respectively, connect with the two back contacts of a cut-off relay, and when this relay is in its normal or unenergized condition, these two limbs of the line are continued through the windings of the line relay and thence one to the ungrounded or negative side of the common-battery and the other to the grounded side. The subscriber's station circuit being normally open, no current flows through the line, but when the subscriber removes his receiver for the purpose of making a call the line circuit is completed and current flows through the coil of the line relay, thus energizing that relay and causing it to complete the circuit of the line lamp. The cut-off relay plays no part in the operation of the subscriber's calling, but merely leaves the circuit of the line connected through to the calling relay and battery. The coil of the cut-off relay is connected to ground on one side and on the other side to the third wire running through the switchboard multiple and which is tapped off to each of the test rings on the jacks. As will be shown later, when the operator plugs into the jack of a line, such a connection is established that the test ring of that jack will be connected to the live or negative pole of the common battery, which will cause current to flow through the coil of the cut-off relay, which will then operate to *cut off* both of the limbs of the line from their normal connection with ground and the battery and the line relay. Hence the name *cut-off relay.*

The use of the cut-off relay to sever the calling apparatus from the line at all times when the line is switched serves to make possible a very much simpler jack than would otherwise be required, as will be obvious to anyone who tries to design a common-battery multiple system without a cut-off relay. The additional complication introduced by the cut-off relay is more than offset by the saving in complexity of the jacks. It is desirable, on account of the great number of jacks necessarily employed in a multiple switchboard, that the jacks be of the simplest possible construction, thus reducing to a minimum their first cost and making them much less likely to get out of order.

Cord Circuit. The cord circuit of the Western Electric standard multiple common-battery switchboard is shown in Fig. 188, This cord circuit involves the use of three strands in the flexible cords of both the calling and the answering plugs. Two of these are the ordinary tip and ring conductors over which speech is transmitted to the connected subscriber's wire. The third, the sleeve strand, carries the supervisory lamps and has associated with it other apparatus for the control of these lamps and of the test circuit.

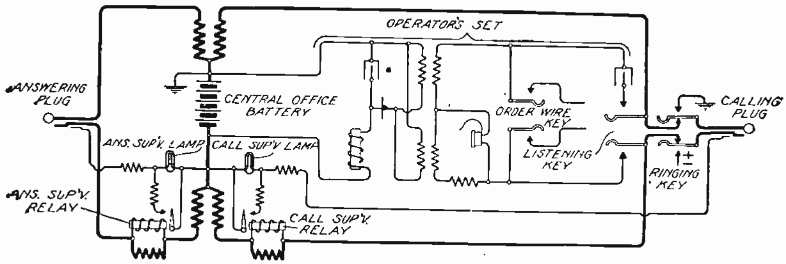


Fig. 188. Cord Circuit Western Electric No. 1 Board

The system of battery feed is the well-known split repeating-coil arrangement already discussed. The tip strand runs straight through to the repeating coil, while the ring strand contains, in each case, the winding of the supervisory relay corresponding to either the calling or the answering plug. In order that the presence in the talking circuit of a magnet winding possessing considerable impedance may not interfere with the talking efficiency, each of these supervisory relay windings is shunted by a non-inductive resistance. In practice the supervisory relay windings have each a resistance of about 20 ohms and the shunt around them each a resistance of about 31 ohms. In the third strand of each cord is placed a 12-volt supervisory lamp, and in series with it a resistance of about 80 ohms. Each supervisory relay is adapted, when energized, to close a 40-ohm shunt about its supervisory lamp. The arrangement and proportion of these resistances is such that when a plug is inserted into the jack of a line the lamp will receive current from a circuit traced from the negative pole of the battery in the center of the cord circuit through the lamp and the 80-ohm series resistance, through the third strand of the cord to the test thimble of the jack, and thence to the positive or grounded pole of the battery through the third conductor in the multiple and the winding of the cut-off relay. This current always flows as long as the plug is inserted, and it is just sufficient to illuminate the lamp when the supervisory relay armature is not attracted. When, however, the supervisory relay armature is attracted, the shunting of the lamp by the 40-ohm resistance cuts down the current to such a degree as to prevent the illumination of the lamp, although some current still flows through it.

The usual ringing and listening key is associated with the calling plug, and in some cases a ring-back key is associated with the answering plug, but this is not standard practice.

Operation. The operation of this cord circuit in conjunction with the line circuit of Fig. 187 may best be understood by reference to Fig. 189. This figure employs a little different arrangement of the line circuit in order more clearly to indicate how the two lines may be connected by a cord; a study of the two line circuits, however, will show that they are identical in actual connections. It is to be remembered that all of the battery symbols shown in this figure represent in reality the same battery, separate symbols being shown for greater simplicity in circuit connections.

We will assume the subscriber at Station *A* calls for the subscriber at Station *B*. The operation of the line relay and the consequent lighting of the line lamp, and also the operation of the pilot relay will be obvious from what has been stated. The response of the operator by inserting the answering plug into the answering jack, and the throwing of her listening key so as to bridge her talking circuit across the cord in order to place herself in communication with the subscriber, is also obvious. The insertion of the answering plug into the answering jack completed the circuit through the third strand of the cord and the winding of the cut-off relay of the calling line, and this accomplishes three desirable results. The circuit so completed may be traced from the negative or ungrounded side of the battery to the center portion of the cord circuit, thence through the supervisory lamp *1*, resistance *2*, to the third conductor on the plug, test thimble on the jack, thence through the winding of the cut-off relay to ground, which forms the other terminal of the battery. The results accomplished by the closing of this circuit are: first, the energizing of the cut-off relay to cut off the signaling portion of the line; second, the flowing of current through the lamp that

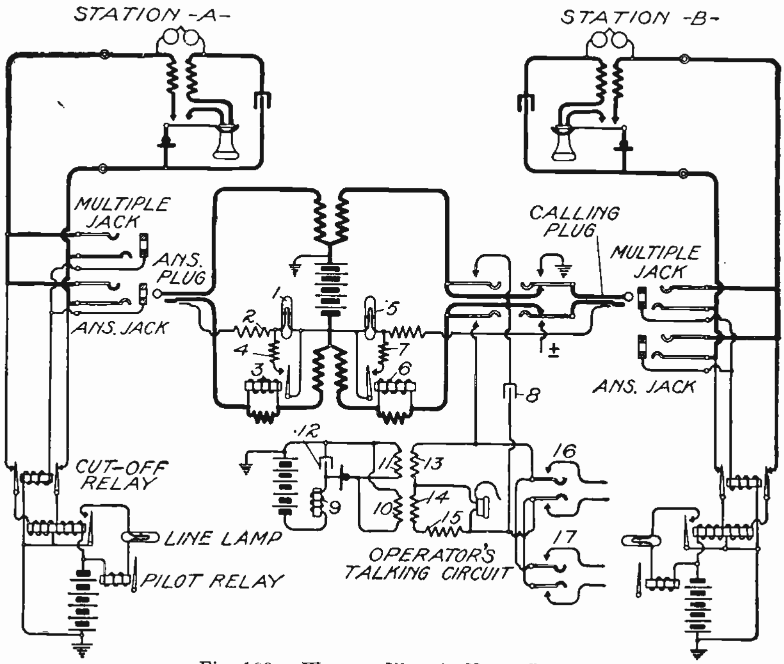


Fig. 189. Western Electric No. 1 Board

is almost sufficient to illuminate it, but not quite so because of the closure of the shunt about it, for the reason that will be described; third, the raising of the potential of all the contact thimbles on the jacks from zero to a potential different from that of the ground and equal in amount to the fall of potential through the winding of the cut-off relay. A condition is thus established at the test rings such that some other operator at some other section in testing the line will find it busy and will not connect with it.

The reason why the lamp *1*, connected with the answering plug, was not lighted was that the supervisory relay *3*, associated with the answering plug, became energized when the operator plugged in, due to the flow of current from the battery through the calling subscriber's talking apparatus, this flow of current being permitted by the removal of the calling subscriber's receiver from its hook. The energizing of this relay magnet by causing the attraction of its armature, closed the shunt about the lamp *1*, which shunt contains the 40-ohm resistance *4*, and thus prevents the lamp from receiving enough current to illuminate it. Obviously, as soon as the calling subscriber replaces his receiver on its hook, the supervisory relay *3* will be de-energized, the shunt around the lamp will be broken, and the lamp will be illuminated to indicate to the operator the fact that the subscriber with whose line her calling plug is connected has replaced his receiver on its hook.

Testing—Called Line Idle. Having now shown how the operator connects with the calling subscriber's line and how that line automatically becomes guarded as soon as it is connected with, so that no other operator will connect with it, we will discuss how the operator tests the called line and subsequently connects with that line, if it is found proper to do so. If, on making the test with one of the multiple jacks of the line leading to Station *B*, that line is idle and free to be connected with, its test rings will all be at zero potential because of the fact that they are connected with ground through the cut-off relay winding with no source of current connected with them. The tip of the calling plug will also be at zero potential in making this test, because it is connected to ground through the tip side of the calling-plug circuit and one winding of the cord-circuit repeating coil. As a result no flow of current will occur, the operator will receive no click, and she will know that she is free to connect with the line. As soon as she does so, by inserting the plug, the third strand of the cord will be connected with the test thimble of the calling line and the resulting flow of current will bring about three results, two of which are the same, and one of which is slightly different from those described as resulting from the insertion of the answering plug into the jack of the calling line. First, the cut-off relay will be operated and cut off the line-signaling apparatus from the called line; second, a flow of current will result through the calling supervisory lamp *5*, which in this case will be sufficient to illuminate that lamp for the reason that the called subscriber has not yet responded, the calling supervisory relay *6* has, therefore, not yet been energized, and the lamp has not, therefore, been shunted by its associated resistance *7;* third, the test thimbles of the called line will be raised to a potential above that of the earth, and thus the line will be guarded against connection at another section of the switchboard. As soon as the called subscriber responds to the ringing current sent out by the operator, current will flow over the cord circuit and over his line through his transmitter. This will cause the calling supervisory relay to be energized and the calling lamp to be extinguished. Both lamps *1* and *5* remain extinguished as long as the connected subscribers are in conversation, but as soon as either one of them hangs up his receiver the corresponding lamp will be lighted, due to the deenergization of the supervisory relay and the breaking of the shunt around the lamp. The lighting of both lamps associated with a cord circuit is a signal to the operator for disconnection.

Testing—Called Line Busy. If we now assume that the called line was already busy, by virtue of being connected with at another section, the test rings of that line would accordingly all be raised to a potential above that of the earth. As a result, when the operator applied the tip of her calling plug to a test thimble on that line, current would flow from this test thimble through the tip of the calling plug and tip strand of the cord and through one winding of the cord-circuit repeating coil to ground. This would cause a slight raising of potential of the entire tip side of the cord circuit and a consequent momentary flow of current through the secondary of the operator's circuit bridged across the cord circuit at that time.

Operator's Circuit Details. The details of the operator's talking circuit shown in Fig. 189 deserve some attention. The battery supply to the operator's transmitter is through an impedance coil *9*. The condenser *12* is bridged around the transmitter and the two primary windings *10* and *11*, which windings are in parallel so as to afford a local circuit for the passage of fluctuating currents set up by the transmitter. The two primary windings *10* and *11* are on separate induction coils, the secondary windings *13* and *14* being, therefore, on separate cores. The winding *15*, in circuit with the secondary winding *14* and the receiver, is a non-inductive winding and is supposed to have a resistance about equal to the effective resistance to fluctuating currents of a subscriber's line of average length. Owing to the respective directions of the primary and secondary windings *10* and *11*, *13* and *14*, the result is that the outgoing currents set up by the operator's transmitter are largely neutralized in the operator's receiver. Incoming currents from either of the connected subscribers, however, pass, in the main, through the secondary coil *13* and the operator's receiver, rather than through the shunt path formed by the secondary *14*, and the non-inductive resistance *15*. This is known as an "anti-side tone" arrangement, and its object is to prevent the operator from receiving her own voice transmission so loudly as to make her ear insensitive to the feebler voice currents coming in from the subscribers.

Order-Wire Circuits. The two keys *16* and *17*, shown in connection with the operator's talking circuit in Fig. 189, play no part in the regular operation of connecting two local lines, as described above. They are order-wire keys, and the circuits with which they connect lead to the telephone sets of other operators at distant central offices, and by pressing either one of these keys the operator is enabled to place herself in communication over these so-called order-wire circuits with such other operators. The function and mode of operation of these order-wire circuits will be described in the next chapter, wherein inter-office connections will be discussed.

Wiring of Line Circuit. The line circuits shown in Figs. 187 and 189 are, as stated, simplified to facilitate understanding, although the connections shown are those which actually exist. The more complete wiring of a single line circuit is shown in Fig. 190. The line wires are shown entering at the left. They pass immediately, upon entering the central office, through the main distributing frame, the functions and construction of which will be considered in detail in a subsequent chapter. The dotted portions of the circuit shown in connection with this main distributing frame indicate the path from the terminals on one side of the frame to those on the other through so-called jumper wires. The two limbs of the line then pass to terminals *1* and *2* on one side of the so-called intermediate distributing frame. Here the circuit of each limb of the line divides, passing, on the one hand, to the tip and sleeve springs of all the multiple jacks belonging to that line; and, on the other hand, through the jumper wires indicated by dotted lines on the intermediate distributing frame, and thence to the tip and ring contacts of the answering jack. A consideration of this connection will show that the actual electrical connections so far as already described are exactly those of Figs. 187 and 189, although those figures omitted the main and intermediate distributing frames. Only two limbs of the line are involved in the main frame. In the intermediate frame the test wire running through the multiple is also involved. This test wire, it will be seen, leads from the test thimbles of all the multiple jacks to the terminal *3* on the intermediate frame, thence through the jumper wire to the terminal *6* of this frame, and to the test thimble of the answering jack. Here again the electrical connections are exactly those represented in Figs. 187 and 189, although those figures do not show the intermediate frame.

The two terminals *4* and *5* of the intermediate frame, besides being connected to the tip and sleeve springs of the answering jack, are connected to the contacts of the cut-off relay, and thence through the coils of the line relay to ground on one side and to battery on the other. Thus the line relay and battery are normally included in the circuit of the line. The contact *6* on the intermediate distributing frame, besides being connected to the test thimble of all the jacks, is connected through the coil of the cut-off relay to ground, thus establishing a path by which current is supplied to the cut-off relay when connection is made to the line at any jack. There is another contact *7* on the intermediate distributing frame which merely forms a terminal for joining one side of the line lamp to the back contact of the line relay.

Functions of Distributing Frames. Since the line circuit thus far described in connection with Fig. 190 is exactly the same as that of Fig. 187 in its electrical connections, it becomes obvious that the main and intermediate distributing frames play no part in the operation of the circuit any more than a binding post of a telephone plays a part in its operation. These frames carry terminals for facilitating the connection of the various wires in the line circuit and, as will be shown later, for facilitating certain changes in the line connection.

Remembering that the dotted lines in Fig. 190 indicate jumper wires of the main and intermediate distributing frames, and that these are in the nature of temporary or readily changeable connections, and that the full lines, whether heavy or light, are permanent connections not readily changeable, it will be seen that the wires leading through the multiple jacks of a certain line are permanently associated with each other, and with certain terminals on the main distributing frame and certain other terminals on the intermediate

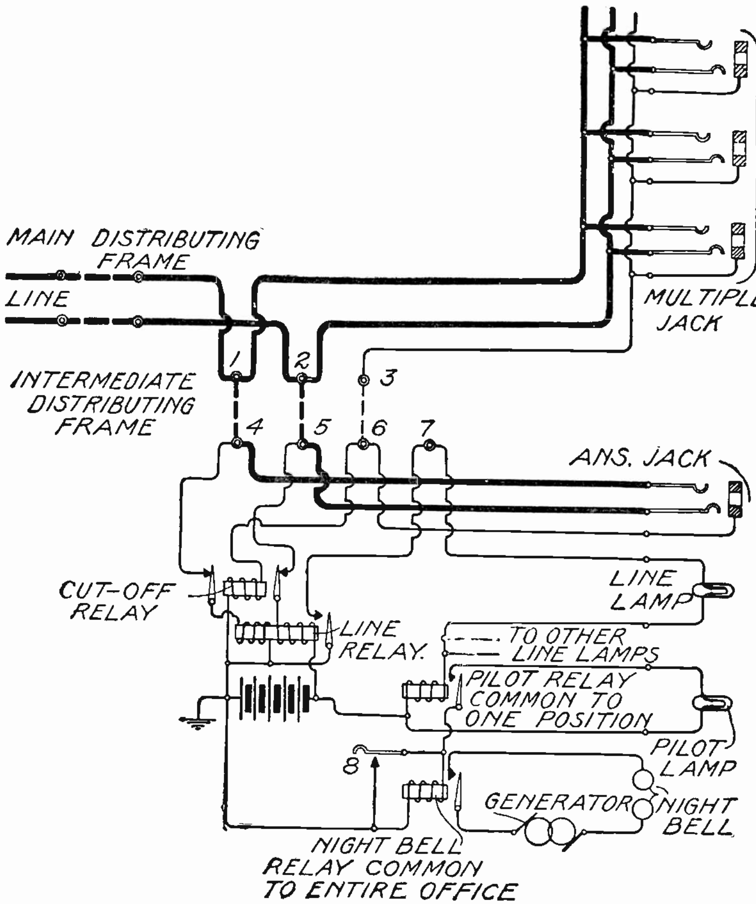


Fig. 190. Line Circuit No. 1 Board

distributing frame. It will also be seen that the line lamp and the answering jack, together with the cut-off relay and line relay, are permanently associated with each other and with another group of terminals *4*, *5*, *6*, and *7* on the intermediate distributing frame. It will also be apparent that by changing the jumper wires on the main frame, any outside line may be connected with any different set of line switchboard equipment, and also that by making changes in the jumper wires on the intermediate frame, any given answering jack and line lamp with its associated line cut-off relay may be associated with any set of multiple jacks.

Pilot Signals. In a portion of the circuit leading from the battery that is common to a group of line lamps is the winding of the pilot relay, which is common to this group of line lamps. This controls, as already described, the circuit of the pilot lamp common to the same group of line lamps. In addition, a night-bell circuit is sometimes provided, this usually being in the form of an ordinary polarized ringer, the circuit of which is controlled by a night-bell relay common to the entire office. Normally, this relay is shunted out of the circuit of the common portion of the lead to the pilot relay contacts by the key *8*, but when the key *8* is opened all current that is fed to the pilot lamps passes through the night-bell relay, and thus, whenever any pilot lamp is lighted, the night-bell relay will attract its armature and thus close the circuit of the calling generator through the night bell.

A study of this figure will make clear to the student how the portions of the circuit that are individual to the line are associated with such things as the battery, that are common to the entire office, and such as the pilot relay and lamp, that are common to a group of lines terminating in one position.

Modified Relay Windings. In some cases, the line relay instead of being double wound, as shown, is made with a single winding, this winding being normally included between the ring side of the cut-off relay and the battery, the tip side of the cut-off relay being run direct to ground. The present practice of the Western Electric Company is toward the double-wound relay, however, and that is considered standard in all of their large No. 1 multiple boards, except where the customer, owing to special reasons, demands a single wound relay on the ring side of the line. The prime reason for the two-winding line relay is the lessened click in the calling-subscriber's receiver which occurs when the operator answers. All line relays prior to 1902 were single-wound, but after that they were made double and used some turns of resistance wire to limit the normal calling current.

Relay Mounting. In the standard No. 1 relay board of the Western Electric Company and, in fact, in nearly all common-battery multiple boards that are manufactured by other companies, the line and cut-off relays are mounted on separate racks outside the switchboard room and adjacent to the main and intermediate distributing frames, the wiring being extended from the relays to the jacks and lamps on the switchboard proper by means of suitable cables. The Western Electric Company has recently instituted a departure from this practice in the case of some of their smaller No. 1 switchboard installations. Where it is thought that the ultimate capacity required by the board will not be above 3,000 lines, the relay rack is dispensed with and all of the line and cut-off relays, as well as the supervisory relays, are mounted in the rear of the switchboard frame. For this purpose the line and cut-off relays are specially made with the view to securing the utmost compactness. In still other cases, in switchboards of relatively small ultimate capacity, they use this small line and cut-off relay mounted on a separate relay rack, in which case the board is the standard No. 1 board except for the type of relays. In all of these modifications of the No. 1 board adapted for the use of the smaller and cheaper relays, the line relay has but a single winding, the small size of the relay winding not lending itself readily to double winding with the added necessary coil terminals.

Capacity Range. The No. 1 Western Electric board is made in standard sizes up to an ultimate capacity of 9,600 lines. For all capacities above 4,900 lines, a $\frac{3}{8}$-inch jack, vertical and horizontal face dimensions, is employed. For this capacity the smaller types of cut-off and line relays are not employed. Up to ultimate capacities of 4,900 lines, $\frac{1}{2}$-inch jacks are employed, and either the small or the large relays mounted on a separate rack are available. Up to 3,000 lines ultimate capacity, the $\frac{1}{2}$-inch jack is employed, and either the small or the large cut-off and line relays are available, but in case the small type is used the purchaser has the option of mounting them on a separate relay rack, as in ordinary practice, or mounting them in the switchboard cabinet and dispensing with the relay rack.

Western Electric No. 10 Board. The No. 1 common-battery multiple switchboard, regardless of its size and type of arrangement of line and cut-off relays, involves two relays for each line, the line relay energized by the taking of the receiver off its hook, and the cut-off relay energized by the act of the operator on plugging in and serving to remove the line relay from the circuit whenever and as long as a plug is inserted into any jack of the line. This seems to involve a considerable expense in relays, but this, as has been stated, is warranted by the greater simplicity in jacks which the use of the cut-off relay makes possible. In addition to this expense of investment in the line and cut-off relays, the amount of current required to hold up the cut-off relays during conversations foots up to a considerable item of expense, particularly as the system of supervisory signals is one in which the supervisory lamp takes current not only while burning, but its circuit takes even more current when the lamp is extinguished during the time of a connection. For all of these reasons, and some other minor ones, it was deemed expedient by the engineers of the Western Electric Company to design a common-battery multiple switchboard for small and medium-sized exchanges in which certain sacrifices might be made to the end of accomplishing certain savings. The result has been a type of switchboard, designated the No. 10, which may be found in a number of Bell exchanges, it being considered particularly adaptable to installations of from 500 to 3,000 lines. Although this board has been subject to a good deal of adverse criticism, and although it seems probable that even for the cheaper boards the No. 1 type with some of the modifications just described will eventually supersede this No. 10 board, yet the present extent of use of the No. 10 board and the instructive features which its type displays warrant its discussion here.

Circuits. The circuits of this switchboard are shown in Fig. 191, this indicating two-line circuits and a connecting cord circuit, together with the auxiliary apparatus employed in connection with the operator's telephone circuit, the pilot and night alarm circuits. The most noticeable feature is that cut-off jacks are employed, the circuit of the line normally extending through the sets of jack springs in the multiple, and answering jacks to the line relay and battery on one side of the line, and to ground on the other side. Obviously, the additional complexity of the jack saves the use of a cut-off relay and the relay equipment of each line consists, therefore, of but a single line relay, which controls the lamp in an obvious manner.

The cord circuit is of the three-conductor type, the two talking strands extending to the usual split repeating-coil arrangement, and battery current for talking purposes being fed through these windings as in the standard No. 1 board. The supervisory relay is included in the ring strand of the cord circuit and is shunted by a non-inductive

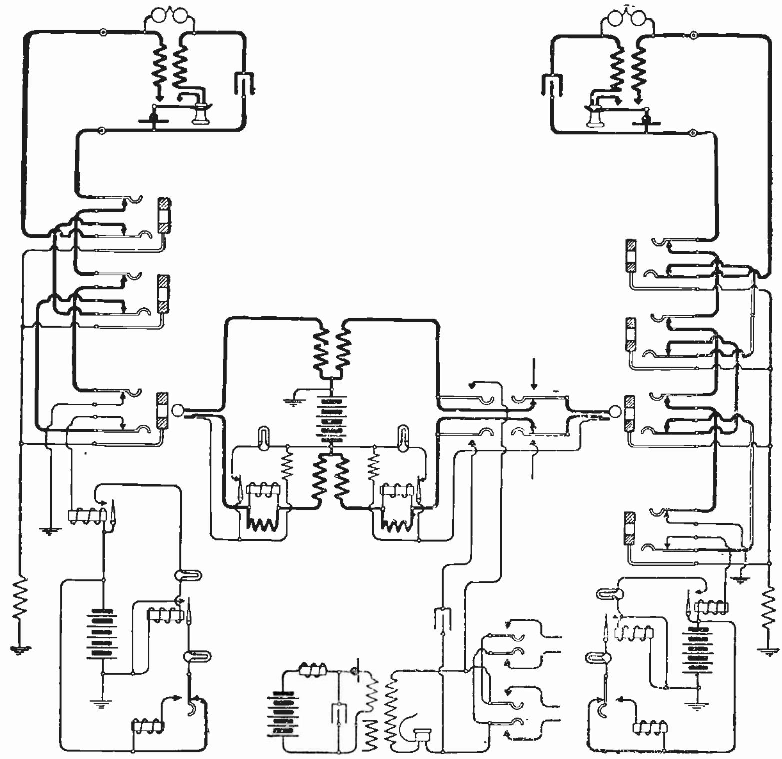


Fig. 191. Western Electric No. 10 Board

resistance, so that its impedance will not interfere with the talking currents. The armature of the supervisory relay closes the lamp contact on its back stroke, so that the lamp is always held extinguished when the relay is energized. The supervisory lamp is included in a connection between the back contact of the supervisory relay and ground, this connection including the central-office battery. As a result, the illumination of the supervisory lamp is impossible until a plug has been inserted into a jack, in which case, assuming the supervisory relay to be de-energized, the lamp circuit is completed through the wire connecting all of the test thimbles and the resistance permanently bridged to ground from that wire.

Test. For purposes of the test it is evident that the test rings of an idle line are always at ground potential, due to their connection to ground through the resistance coil. It is also evident that the tip of an unused calling plug will always be at ground potential and, therefore, that the testing of an idle line will result in no click in the operator's receiver. When a line is switched, however, the potential of all the test rings will be raised due to their being connected with the live pole of the battery through the third strand of the cord. When the operator in testing touches the test contact of the jack of a busy line, a current will, therefore, flow from this test contact to the tip strand of the cord and thence to ground through one of the repeating coil windings. The potential of the tip side of the cord will, therefore, be momentarily altered, and this will result in a click in the operator's receiver bridged across the cord circuit at the time. The details of the operator's cord circuit and of the pilot lamp and night alarm circuits will be clear from the diagram.

Operation. A brief summary of the operation of this system is as follows:

The subscriber removes his receiver from its hook, thus drawing up the armature of the line relay and lighting his line lamp. The operator answers. The line lamp is extinguished by the falling back of the line-relay armature, due to the breaking of the relay circuit at the jack contacts. The subscriber then receives current for his transmitter through the cord-circuit battery connections. The supervisory relay connected with the answering cord is not lighted, because, although the lamp-circuit connection is completed at the jack, the supervisory relay is operated to hold the lamp circuit open. Conversation ensues between the operator and the subscriber, after which the operator tests the line called for with the tip of the calling plug of the pair used in answering. If the called line is not busy, no click will ensue, because both the tested ring and the calling plug are at the same potential. Finding no click, the operator will insert the plug and ring by means of the ringing key. When the operator plugs in, the supervisory lamp, associated with the calling plug, becomes lighted because the circuit is completed at the jack and the supervisory relay remains de-energized, since the line circuit is open at the subscriber's station. When the called subscriber responds, the calling supervisory lamp goes out because of the energization of the supervisory relay. Both lamps remain out during the conversation, but when either subscriber hangs up, the corresponding supervisory lamp will be lighted because of the falling back of the supervisory relay armature.

If the called line is busy, a click will be heard, for the reason described, and the operator will so inform the calling subscriber. It goes without saying, that in any multiple-switchboard system a plug may be found in the actual multiple jack that is reached for, in which case, although no test will be made, the busy condition will be reported back to the calling subscriber.

Economy. It has been the belief of the Western Electric engineers that a real economy is accomplished in this type of board by the saving in relay equipment. It is, of course, apparent at a glance that with a switchboard long enough and of sections enough, the cost of extra jack springs and their platinum contacts must become great enough to offset the saving accomplished by omitting the cut-off relay. This makes it apparent that if there is any economy in this type of multiple switchboard, it must be found in the very small boards where there are but few jacks per line and where the extra cost of the cut-off jack is not enough to offset the extra cost of an added relay. It is the growing belief, however, among engineers, that the multiple switchboard must be very small indeed in order that the added complexity of the cut-off jacks and wiring may be able to save anything over the two-relay type of line; and it is believed that where economy is necessary in small boards, it may be best effected by employing cheaper and more compact forms of relays and mounting them, if necessary, directly in the switchboard cabinet.

NOTE. These two standard types of common-battery multiple switchboards of the Western Electric Company represent the development through long years of careful work on the part of the Western Electric and Bell engineers, credit being particularly due to Scribner, McBerty, and McQuarrie of the Western Electric Company, and Hayes of the American Telephone and Telegraph Company.

Kellogg Two-Wire Multiple Board. The simplicity in the jacks permitted by the use of the cut-off relay in the Western Electric common-battery multiple switchboard for larger exchanges was carried a step further by Dunbar and Miller in the development of the so-called two-wire common-battery multiple switchboard, which for many years has been the standard of the Kellogg Switchboard and Supply Company. The particular condition which led to the development of the two-wire system was the demand at that time on the Kellogg Company for certain very large multiple switchboards, involving as many as 18,000 lines in the multiple. Obviously, this necessitated a small jack, and obviously a jack having only two contacts, a tip spring and a sleeve, could be made more easily and with greater durability of this very small size than a jack requiring three or more contacts. Other reasons that were considered were, of course, cheapness in cost of construction and extreme simplicity, which, other things being equal, lends itself to low cost of maintenance.

Line Circuit. Like the standard Western Electric board for large offices, the Kellogg two-wire board employs two relays for each line, the line relay under the control of the subscriber and in turn controlling the lamp, and a cut-off relay under the control of the operator and in turn controlling the connection of the line relay with the line. The line circuit as originally developed and as widely used by the Kellogg Company is shown in Fig. 192. The extreme simplicity of the jacks is apparent, as is also the fact that but two wires lead through the multiple. Another distinguishing feature is, that all of the multiple and answering jacks are normally cut off from the line at the cut-off relay, but when the cut-off relay operates it serves, in addition to cutting off the line relay, to attach the two limbs of the line to the two wires leading through the multiple and answering jacks. The control of the line relay by the subscriber's switch hook is clear from the figure. The control of the cut-off relay is secured by attaching one terminal of the cut-off relay winding permanently to that wire leading through the multiple which connects with the sleeve contacts of the jack, the other terminal of the cut-off relay being grounded. The way in which this relay is operated will be understood when it is stated that the sleeve contacts of both the answering and calling plugs always carry full battery potential and, therefore, whenever any plug is inserted into any jack, current flows from the sleeve of the jack through the sleeve contact of the jack to ground, through the winding of the cut-off relay, which relay becomes energized and performs the functions just stated. It is seen that the wire running through the multiple to which the sleeve jack contacts are attached, is thus made to serve the double purpose of answering as one side of the talking circuit, and also of performing the functions carried out by the separate or third wire in the three-wire system.

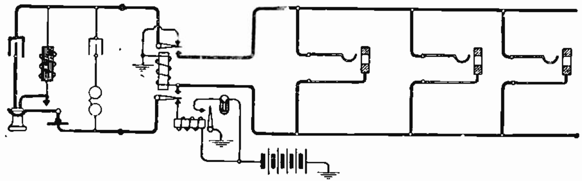


Fig. 192. Two-Wire Line Circuit

It will be shown also that, in addition, this wire is made to lend itself to the purposes of the busy test without any of these functions interfering with each other in any way.

Cord Circuit. The cord circuit in somewhat simplified form is shown in Fig. 193. Here again there are but two conductors to the plugs and two strands to the cords. This greater simplicity is in some measure offset by the fact that four relays are required, two for each plug. This so-called four-relay cord circuit may be most readily understood by considering half of it at a time, since the two relays associated with the answering plug act in exactly the same way as those connected with the calling plug.

Associated with each plug of a pair are two relays *1* and *2*, in the case of the answering cord, and *3* and *4* in the case of the calling cord. The coils of the relays *1* and *2* are connected in series and

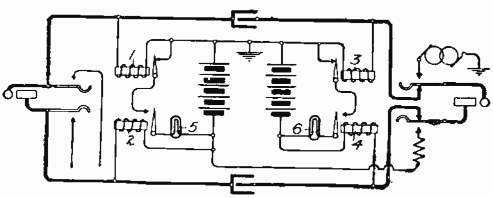


Fig. 193. Two-Wire Cord Circuit

bridged across the answering cord, a battery being included between the coils in this circuit. The coils of the relays *3* and *4* are similarly connected across the calling cord. A peculiar feature of the Kellogg system is that two batteries are used in connection with the cord circuit, one of them being common to all answering cords and the other to all calling cords. The operation of the system would, however, be exactly the same if a single battery were substituted for the two.

Supervisory Signals. Considering the relays associated with the answering cord, it is obvious that these two relays *1* and *2* together control the circuit of the supervisory lamp *5*, the circuit of this lamp being closed only when the relay *1* is de-energized and the relay *2* is energized. We will find in discussing the operation of these that the relay *2* is wholly under the control of the operator, and that the relay *1*, after its plug has been connected with a line, is wholly under the control of the subscriber on that line. It is through the windings of these two relays that current is fed to the line of the subscriber connected with the corresponding cord

When a plug—the answering plug, for instance—is inserted into a jack, current at once flows from the positive pole of the left-hand battery through the winding of the relay *2* to the sleeve of the plug, thence to the sleeve of the jack and through the cut-off relay to ground. This at once energizes the supervisory relay *2* and the cut-off relay associated with the line. The cut-off relay acts, as stated, to continue the tip and sleeve wires associated with the jacks to the line leading to the subscriber, and also to cut off the line relay. The supervisory relay *2* acts at the same time to attract its armature and thus complete its part in closing the circuit of the supervisory lamp. Whether or not the lamp will be lighted at this time depends on whether the relay *1* is energized or not, and this, it will be seen, depends on whether the subscriber's receiver is off or on its hook. If off its hook, current will flow through the metallic circuit of the line for energizing the subscriber's transmitter, and as whatever current goes to the subscriber's line must flow through the relay *1*, that relay will be energized and prevent the lighting of the supervisory lamp *5*. If, on the other hand, the subscriber's receiver is on its hook, no current will flow through the line, the supervisory relay will not be energized, and the lamp *5* will be lighted.

In a nutshell, the sleeve supervisory relay normally prevents the lighting of the corresponding supervisory lamp, but as soon as the operator inserts a plug into the jack of the line, the relay *2* establishes such a condition as to make possible the lighting of the supervisory lamp, and the lighting of this lamp is then controlled entirely by the relay *1*, which is, in turn, controlled by the position of the subscriber's switch-hook.

Battery Feed. A 2-microfarad condenser is included in each strand of the cord, and battery is fed through the relay windings to the calling and called subscribers on opposite sides of these condensers, in accordance with the usual method of combining impedance coils and condensers. Here the relay windings do double duty, serving as magnets for operating the relays and as retardation coils in the system of battery supply.

Complete Cord and Line Circuits. The complete cord and line circuits of the Kellogg two-wire system are shown in Fig. 194. In the more recent installations of the Kellogg Company the cord and line circuits have been slightly changed from those shown in Figs. 192 and 193, and these changes have been incorporated in Fig. 194. The principles of operation described in connection with the simplified figures remain, however, exactly the same. One of the changes is, that the tip side of the lines is permanently connected to the tips of the jacks instead of being normally cut off by the cut-off relay, as was done in the system as originally developed. Another change is, that the line relay is associated with the tip side of the line, rather than with the sleeve side, as was formerly done. The cord circuit shown in Fig. 194 shows exactly the same arrangement of supervisory relays and exactly the same method of battery feed as in the simplified cord circuit of Fig. 193, but in addition to this the detailed connections of the operator's talking set and of her order-wire keys are indicated, and also the ringing equipment is indicated as being adapted for four-party harmonic work.

In connection with this ringing key it may be stated that the springs *7*, *8*, *9*, and *10* are individually operated by the pressure of one of the ringing key buttons, while the spring *17*, connected with the sleeve side of the calling plug, is always operated simultaneously with the operation of any one of the other springs. As a result the proper ringing circuit is established, it being understood that the upper contacts of the springs *7*, *8*, *9*, and *10* lead to the terminals of their respective ringing generators, the other terminals of which are grounded. The circuit is, therefore, from the generator, through the ringing key, out through the tip side of the line, back over

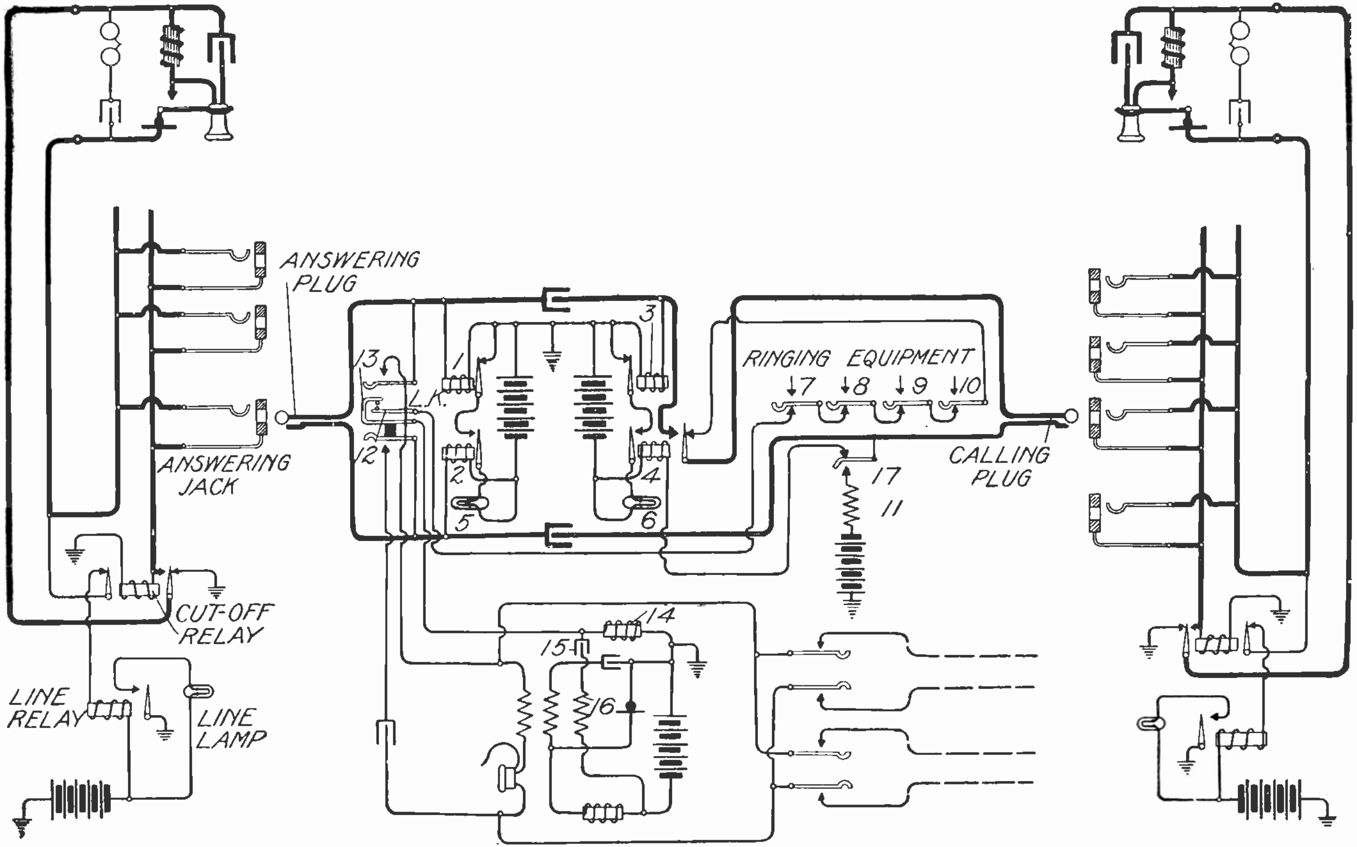


Fig. 194. Kellogg Two-Wire Board

the sleeve side of the line, and to ground through the spring *17*, resistance *11*, and the battery, which is one of the cord-circuit batteries. The object of this coil *11* and the battery connection through it to the ringing-key spring is to prevent the falling back of the cut-off relay when the ringing key is operated. This will be clear when it is remembered that the cut-off relay is energized by battery current fed over the sleeve strand of the cord, and obviously, since it is necessary when the ringing key is operated to cut off the supply wire back of the key, this would de-energize the cut-off relay when the ringing key was depressed, and the falling back of the cut-off relay contacts would make it impossible to ring because the sleeve side of the line would be cut off. The battery supply through the resistance *11* is, therefore, substituted on the sleeve strand of the cord for the battery supply through the normal connection.

Busy Test. The busy test depends on all of the test rings being at zero potential on an idle line and at a higher potential on a busy line. Obviously, when the line is not switched, the test rings are at zero potential on account of a ground through the cut-off relay. When, however, a plug is inserted in either the answering or multiple jacks, the test rings will all be raised in potential due to being connected with the live side of the battery through the sleeve strand of the cord. Conditions on the line external to the central office cannot make an idle line test busy because, owing to the presence of the cut-off relay, the sleeve contacts of all the jacks are disconnected from the line when it is idle. The test circuit from the tip of the calling plug to ground at the operator's set passes through the tip strand of the cord, thence through a pair of normally closed extra contacts on the supervisory relay *4*, thence in series through all the ringing key springs *10*, *9*, *8*, and *7*, thence through an extra pair of springs *12* and *13* on the listening key—closed only when the listening key is operated—and thence to ground through a retardation coil *14*. No battery or other source of potential exists in this circuit between ground and the tip of the calling plug and, therefore, the tip is normally at ground potential. The sleeve ring of the jack being at ground potential if the line is idle, no current will flow and no click will be produced in testing such a line. If, however, the line is busy, the test ring will be at a higher potential and, therefore, current will flow from the tip of the calling plug to ground over the path just traced, and this will cause a rise in potential at the terminal of the condenser *15* and a momentary flow of current through the tertiary winding *16* of the operator's induction coil; hence the click.

Obviously the testing circuit from the tip of the calling plug to ground at the operator's set is only useful during the time when the calling plug is not in a jack, and as the tip strand of the calling plug has to do double duty in testing and in serving as a part of the talking circuit, the arrangement is made that the testing circuit will be automatically broken and the talking circuit through the tip strand automatically completed when the plug is inserted into a jack in establishing a connection. This is accomplished by means of the extra contact on the relay *4*, which relay, it will be remembered, is held energized when its corresponding plug is inserted in a jack. During the time when the plug is not inserted, this relay is not energized and the test circuit is completed through the back contact of its right-hand armature. When connection is made at the jack, this relay becomes energized and the tip strand of the cord circuit is made complete by the right-hand lever being pulled against the front contact of this relay. The keys shown to the right of the operator's set are order-wire keys.

Summary of Operation. We may give a brief summary of the operation of this system as shown in Fig. 194. The left-hand station calls and the line relay pulls up, lighting the lamp. The operator inserts an answering plug in the answering jack, thus energizing the cut-off relay which operates to cut off the line relay and to complete the connection between the jacks and the external line. The act of plugging in by the operator also raises the potential of all the test rings so as to guard the line against intrusion by other callers. The supervisory lamp *5* remains unlighted because, although the relay *2* is operated, the relay *1* is also operated, due to the calling subscriber's receiver being off its hook. The operator throws her listening key, communicates with the subscriber, and, learning that the right-hand station is wanted, proceeds to test that line. If the line is idle, she will get no click, because the tip of her calling plug and the tested ring will be at the same ground potential. She then plugs in and presses the proper ringing-key button to send out the proper frequency to ring the particular subscriber on the line—if there be more than one—the current from the battery through the coil *11* and spring *17* serving during this operation to hold up the cut-off relay.

As soon as the operator plugs in with the calling plug, the supervisory lamp *6* lights, assuming that the called subscriber had not already removed his receiver from its hook, due to the fact that the relay *4* is energized and the relay *3* is not. As soon as the called subscriber responds, the relay *3* becomes energized and the supervisory lamp goes out. If the line called for had been busy by virtue of being plugged at another section, the tip of the operator's plug in testing would have found the test ring raised to a potential above the ground, and, as a consequence, current would have flowed from the tip of this plug through the back contact of the right-hand lever of relay *4*, thence through the ringing key springs and the auxiliary listening-key springs to ground through the retardation coil *14*. This would have produced a click by causing a momentary flow of current through the tertiary winding *16* of the operator's set.

Wiring of Line Circuit. The more complete wiring diagram of a single subscriber's line, Fig. 195, shows the placing in the circuits of the terminals and jumper wires of the main distributing frame and of the intermediate distributing frame, and also shows how the pilot lamps and night-alarm circuits are associated with a group of lines. The main distributing frame occupies the same relative position in this line circuit as in the Western Electric, being located in the main line circuit outside of all the switchboard apparatus. The intermediate distributing frame occupies a different relative position from that in the Western Electric line. It will be recalled by reference to Fig. 190 that the line lamp and the answering jack were permanently associated with the line and cut-off relays, such mutations of arrangement as were possible at the intermediate distributing frame serving only to vary the connection between the multiple of a line and one of the various groups of apparatus consisting of an answering jack and line lamp and associated relays. In the Kellogg arrangement, Fig. 195, the line and cut-off relays, instead of being permanently associated with the answering jack and line lamp, are permanently associated with the multiple jacks, no changes, of which the intermediate or main frames are capable, being able to alter the relation between a group of multiple jacks and its associated line and cut-off relays. In this Kellogg arrangement the intermediate distributing frame may only alter the connection of an answering jack and line lamp with the multiple and its permanently associated relays. The pilot and night alarm arrangements of Fig. 195 should be obvious from the description already given of other similar systems.

Dean Multiple Board. In Fig. 196 are shown the circuits of the multiple switchboard of the Dean Electric Company. The subscrib-

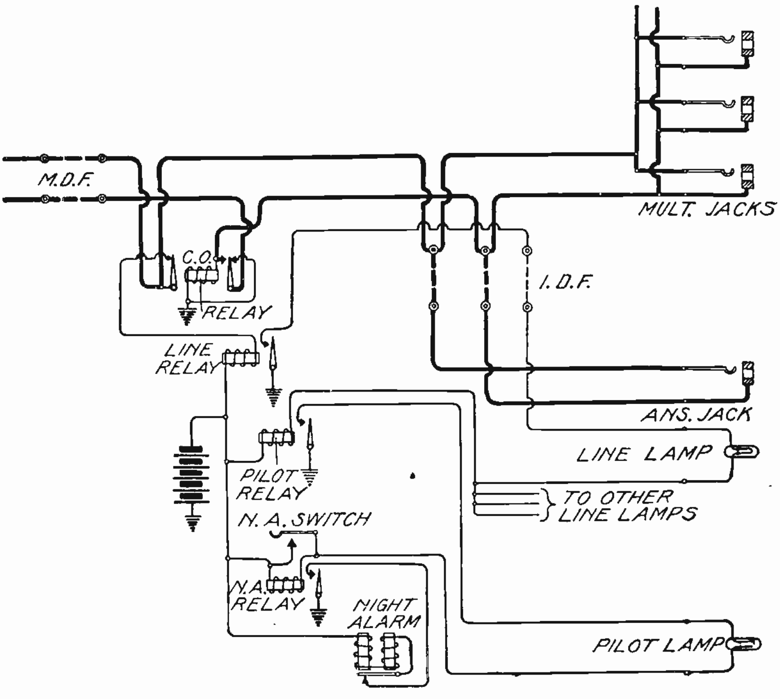


Fig. 195. Kellogg Two-Wire Line Circuit

er's station equipment shown at Station *A* and Station *B* will be recognized as the Wheatstone-bridge circuit of the Dean Company.

Line Circuit. The line circuit is easily understood in view of what has been said concerning the Western Electric line circuit, the line relay *1* being single wound and between the live side of the battery and the ring side of the line. The cut-off relay *2* is operated whenever a plug is inserted in a jack and serves to sever the connection of the line with the normal line signaling apparatus.

Cord Circuit. The cord circuit is of the four-relay type, but employs three conductors instead of two, as in the two-wire system. The relay *3*, being in series between the battery and the sleeve contact on the plug, is energized whenever a plug is inserted in the jack, its winding being placed in series with the cut-off relay of the line with which the plug is connected. This completes the circuit through the associated supervisory lamp unless the relay *4* is energized, the local lamp circuit being controlled by the back contact of relay *4* and the front contact of relay *3*. It is through the two windings of the relay *4* that current is fed to the subscriber's station, and, therefore, the armature of this relay is responsive to the movements of the subscriber's hook. As the relay *3* holds the supervisory lamp circuit closed as long as a plug is inserted in a jack of the line, it follows that during a connection the relay *4* will have entire control of the supervisory lamp.

Listening Key. The listening key, as usual, serves to connect the operator's set across the talking strands of the cord circuit, and the action of this in connection with the operator's set needs no further explanation.

Ringing Keys. The ringing-key arrangement illustrated is adapted for use with harmonic ringing, the single springs *5*, *6*, *7*, and *8* each being controlled by a separate button and serving to select the particular frequency that is to be sent to line. The two springs *9* and *10* always act to open the cord circuit back of the ringing keys, whenever any one of the selective buttons is depressed, in order to prevent interference by ringing current with the other operations of the circuit.

Two views of these ringing keys are shown in Figs. 197 and 198, Fig. 198 is an end view of the entire set. In Fig. 197 the listening key is shown at the extreme right and the four selective buttons at the left. When a button is released it rises far enough to cause the disengagement of the contacts, but remains partially depressed to serve as an indication that it was last used. The group of springs at the extreme left of Fig. 197 are the ones represented at *9* and *10* in Fig. 196 and by the anvils with which those springs co-operate.

Test. The test in this Dean system is simple, and, like the Western Electric and Kellogg systems, it depends on the raising of the potential of the test thimbles of all the line jacks of a line when

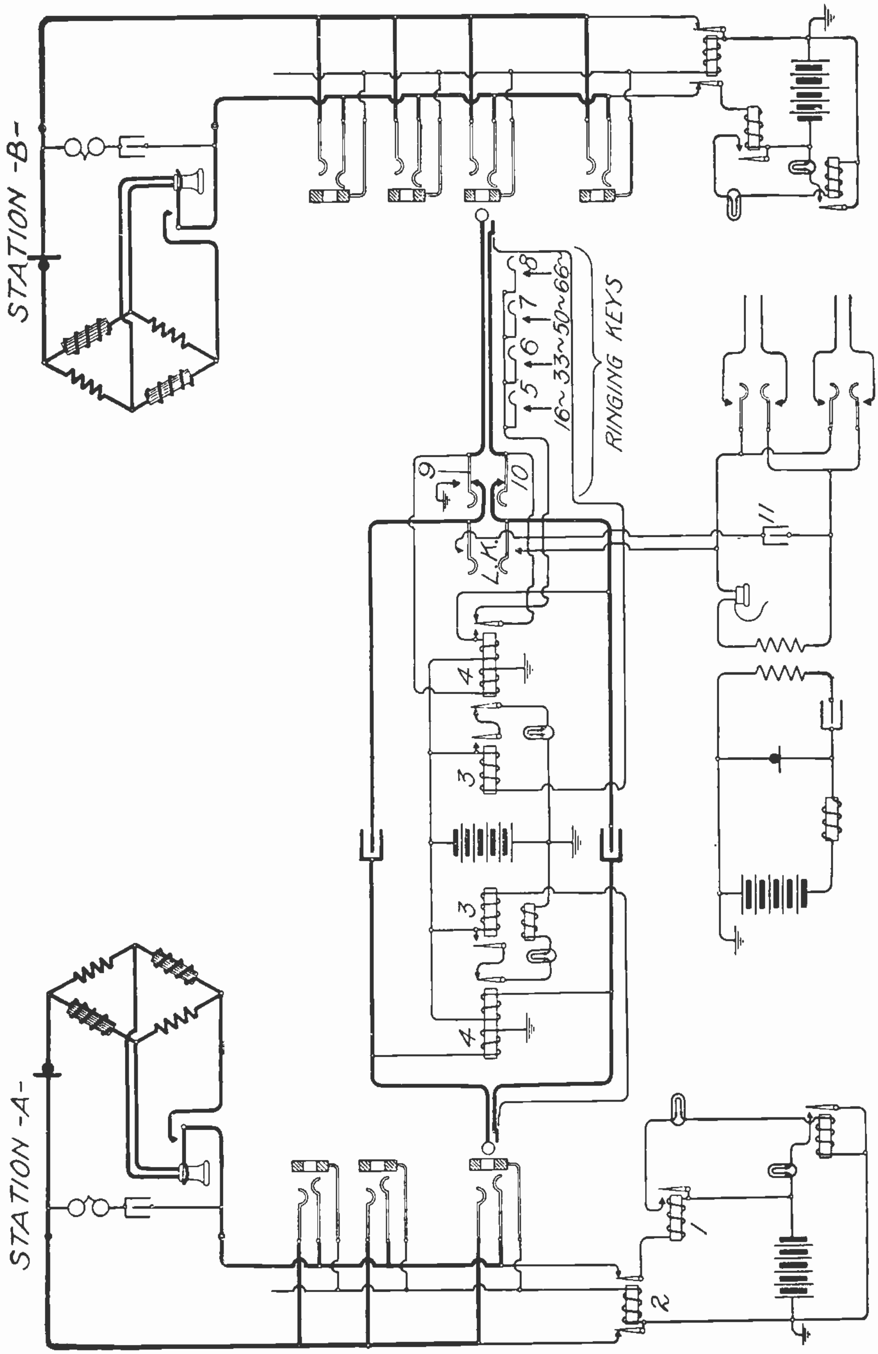


Fig. 196. Dean Multiple Board Circuits

a connection is made with that line by a plug at any position. When an operator makes a test by applying the tip of the calling plug to the test thimble of a busy line, current passes from the test thimble

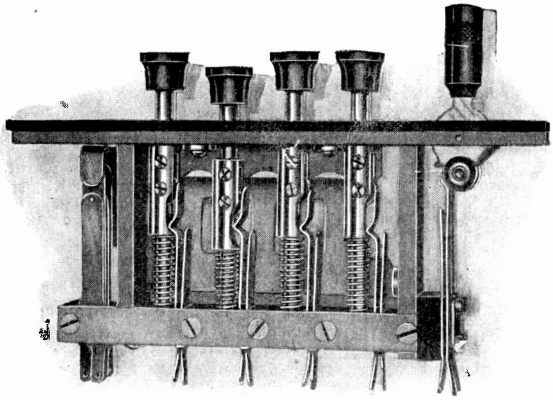


Fig. 197. Dean Party Line Ringing Key

through the tip strand of the cord to ground through the left-hand winding of the calling supervisory relay *4*. The drop of potential through this winding causes the tip strand of the cord to be raised to a higher potential than it was before, and as a result the upper plate of the condenser *11* is thus altered in potential and this change in potential across the condenser results in a click in the operator's ear.

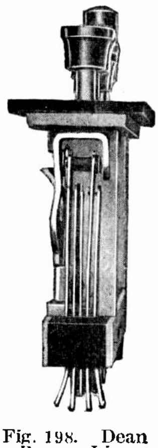


Fig. 198. Dean Party Line Ringing Key

Stromberg-Carlson Multiple Board. *Line Circuit.* In Fig. 199 is shown the multiple common-battery switchboard circuits employed by the Stromberg-Carlson Telephone Manufacturing Company. The subscriber's line circuits shown in this drawing are of the three-wire type and, with the exception of the subscriber's station, are the same as already described for the Western Electric Company's system.

Cord Circuit. The cord circuit employed is of the two-conductor type, the plugs being so constructed as to connect the ring and thimble contacts of the jack when inserted. This cord circuit is somewhat similar to that employed by the Kellogg Switchboard and Supply Company, shown in Fig. 194, except that only one battery is employed, and that certain functions of this circuit are performed mechanically by the inter-action of the armatures of the relays.

Supervisory Signals. When the answering plug is inserted in a jack, in response to a call, the current passing to the subscriber's station and also through the cut-off relay must flow through the relay *1*, thus energizing it. As the calling subscriber's receiver is at this time removed from the hook switch, the path for current will be completed through the tip of the jack, thence through the tip of the plug, through relay *2* to ground, causing relay *2* to be operated and to break the circuit of the answering supervisory lamp. The two relays *1* and *2* are so associated mechanically that the armature of *1* controls the armature of *2* in such a manner as to normally hold the circuit of the answering supervisory lamp open. But, however, when the plug is inserted in a jack, relay *1* is operated and allows the operation of relay *2* to be controlled by the hook switch at the subscriber's station. The supervisory relay *3* associated with the calling cord is operated when the calling plug is placed in a jack, and this relay normally holds the armature of relay *4* in an operated position in a similar manner as the armature of relay *1* controlled that of relay *2*. Supervisory relay *4* is under the control of the hook switch at the called subscriber's station.

Test. In this circuit, as in several previously described, when a plug is inserted in a jack of a line, the thimble contacts of the jacks associated with that line are raised to a higher potential than that which they normally have. The operator in testing a busy line, of course having previously moved the listening key to the listening position, closes a path from the test thimble of the jack, through the tip of the calling plug, through the contacts of the relay *4*, the inside springs of the listening key, thence through a winding of the induction coil associated with her set to ground. The circuit thus established allows current to flow from the test thimble of the jack through the winding of her induction coil to ground, causing a click in her telephone receiver. The arrangement of the ringing circuit does not differ materially from that already described for other systems and, therefore, needs no further explanation.

Multiple Switchboard Apparatus. Coming now to a discussion of the details of apparatus employed in multiple switchboards, it may

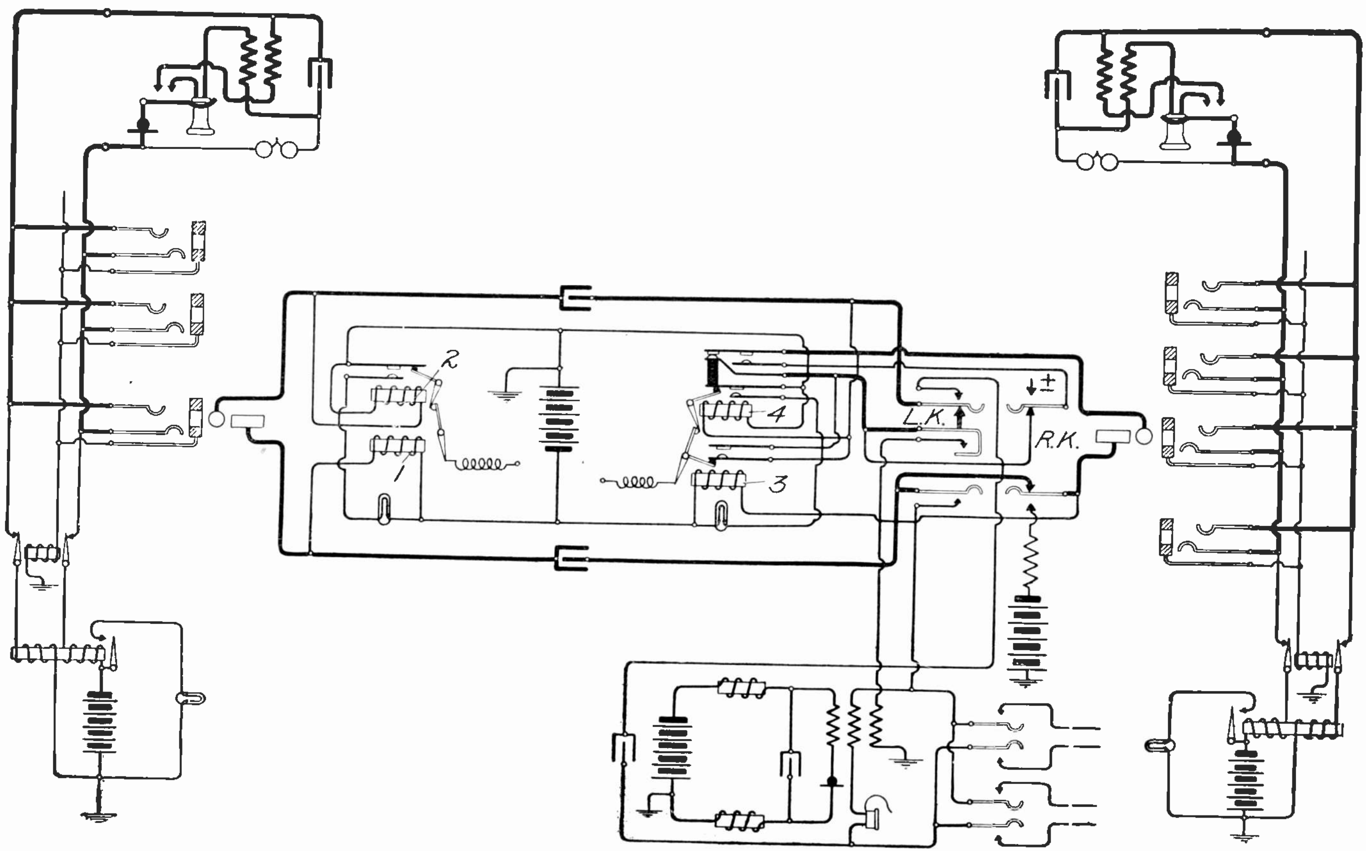


Fig. 199. Stromberg-Carlson Multiple Board Circuits

be stated that much of the apparatus used in the simpler types is capable of doing duty in multiple switchboards, although, of course, modification in detail is often necessary to make the apparatus fit the particular demands of the system in which it is to be used.

Jacks. Probably the most important piece of apparatus in the multiple switchboard is the jack, its importance being increased by the fact that such very large numbers of them are sometimes necessary. Switchboards having hundreds of thousands of jacks are not uncommon. The multiple jacks are nearly always mounted in strips of twenty and the answering jacks usually in strips of ten, the length of the jack strip being the same in each case in the same board and, therefore, giving twice as wide a spacing in the answering as in the multiple jacks. The distance between centers in the multiple jacks varies from a quarter of an inch—which is perhaps the extreme minimum—to half an inch, beyond which larger limit there seems to be no need of going in any case. It is customary that the jack strip shall be made of the same total thickness as the distance between the centers of two of its jacks, and from this it follows that the strips when piled one upon the other give the same vertical distance between jack centers as the horizontal distance.

In Fig. 200 is shown a strip of multiple and a strip of answering jacks of Western Electric make, this being the type employed in the No. 1 standard switchboards for large exchanges. In Fig. 201 are shown the multiple and answering jacks employed in the No. 10 Western Electric switchboard. The multiple jacks in the No. 1 switchboard are mounted on $\frac{3}{8}$-inch centers, the jacks having three branch terminal contacts. The multiple jacks of the No. 10 switchboard indicated in Fig. 201 are mounted on $\frac{1}{2}$-inch centers, each jack having five contacts as indicated by the requirement of the circuits in Fig. 191.

In Fig. 202 are shown the answering and multiple jacks of the Kellogg Switchboard and Supply Company's two-wire system. The extreme simplicity of these is particularly well shown in the cut of the answering jack, and these figures also show clearly the customary method of numbering jacks. In very large multiple boards it has been the practice of the Kellogg Company to space the multiple jacks on $\frac{3}{10}$-inch centers, and in their smaller multiple work, they employ the $\frac{1}{2}$-inch spacing. With the $\frac{3}{10}$-inch spacing that company has been able to build boards having a capacity of 18,000 lines, that many jacks being placed within the reach of each operator.

In all modern multiple switchboards the test thimble or sleeve contacts are drawn up from sheet brass or German silver into tubular form and inserted in properly spaced borings in strips of hard rubber forming the faces of the jacks. These strips sometimes are reinforced by brass strips on their under sides. The springs forming the other terminals of the jack are mounted in milled slots in another

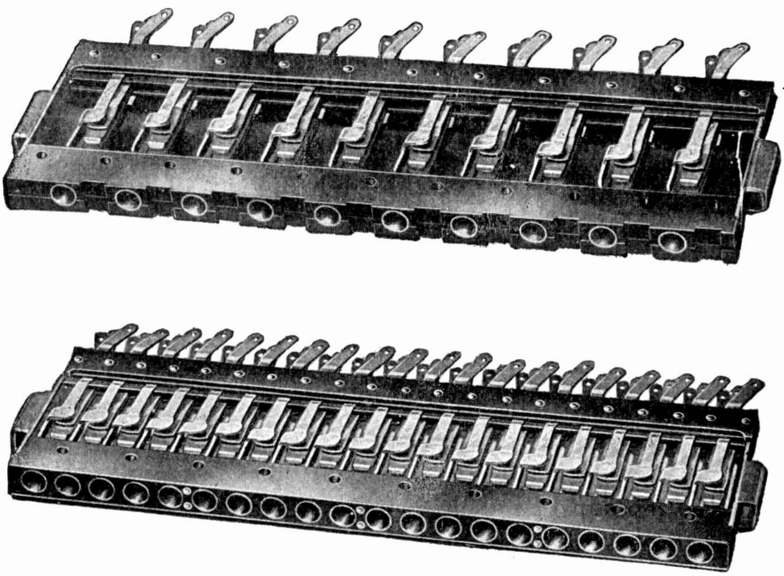


Fig. 200. Answering and Multiple Jacks for No. 1 Board

strip of hard rubber mounted in the rear of and parallel to the front strip and rigidly attached thereto by a suitable metal framework. In this way desired rigidity and high insulation between the various parts is secured.

Lamp Jacks. The lamp jacks employed in multiple work need no further description in view of what has been said in connection with lamp jacks for simple common-battery boards. The lamp jack spacing is always the same as the answering jack spacing, so that the lamps will come in the same vertical alignment as their corresponding answering jacks when the lamp strips and answering jack strips are mounted in alternate layers.

Relays. Next in order of importance in the matter of individual parts for multiple switchboards is the relay. The necessity for reliability of action in these is apparent, and this means that they

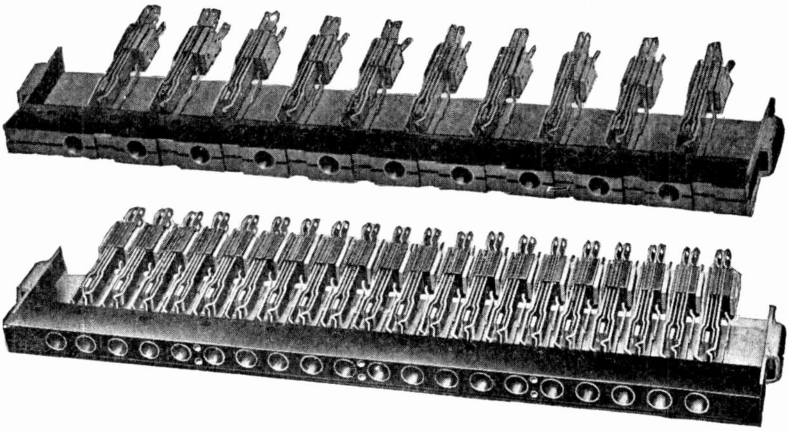


Fig. 201. Answering and Multiple Jacks for No 10 Board

must not only be well constructed, but that they must be protected from dust and moisture and must have contact points of such a nature as not to corrode even in the presence of considerable sparking

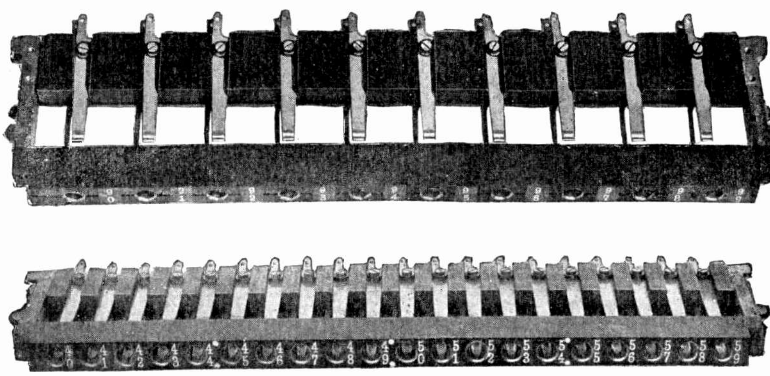


Fig. 202. Answering and Multiple Jacks for Kellogg Two-Wire Board

and of the most adverse atmospheric conditions. Economy of space is also a factor and has led to the almost universal adoption of the single-magnet type of relay for line and cut-off as well as supervisory purposes.

The Western Electric Company employs different types of relays for line, cut-off, and supervisory purposes. This is contrary to the practice of most of the other companies who make the same general type of relay serve for all of these purposes. A good idea of the type of Western Electric line relay, as employed in its No. 1 board, may be had from Fig. 203. As is seen this is of the tilting armature

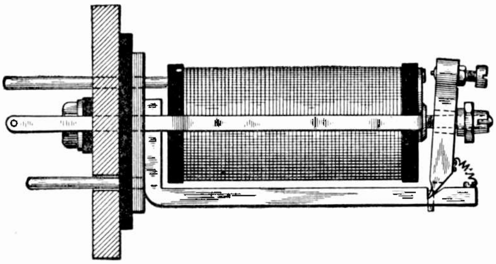


Fig. 203. Type of Line Relay

type, the armature rocking back and forth on a knife-edge contact at its base, the part on which it rests being of iron and of such form as to practically complete, with the armature and core, the magnetic circuit. The cut-off relay, Fig. 204, is of an entirely different type. The armature in this is loosely suspended by means of a flexible

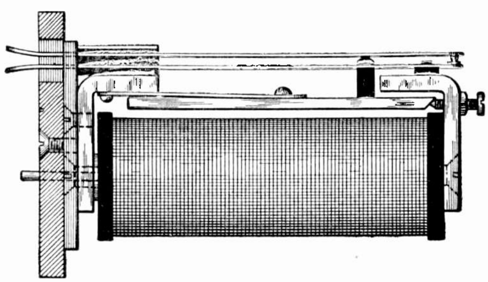


Fig. 204. Type of Cut-Off Relay

spring underneath two L-shaped polar extensions, one extending up from the rear end of the core and the other from the front end. When energized this armature is pulled away from the core by these L-shaped pieces and imparts its motion through a hard-rubber pin to the upper pair of springs so as to effect the necessary changes in the circuit.

Much economy in space and in wiring is secured in the type of switchboards employing cut-off as well as line relays by mounting the two relays together and in making of them, in fact, a unitary

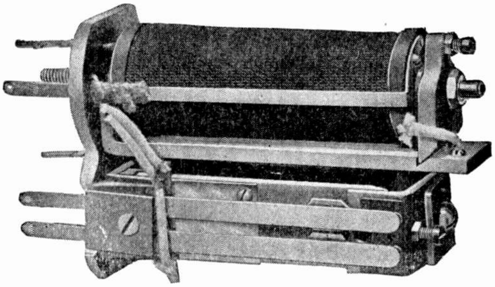


Fig. 205. Western Electric Combined Line and Cut-off Relay

piece of apparatus. Since the line relay is always associated with the cut-off relay of the same line and with no other, it is obvious that this unitary arrangement effects a great saving in wiring and

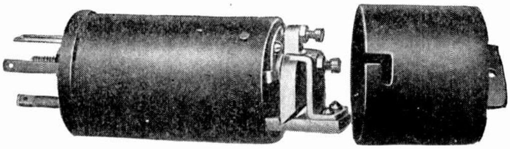


Fig. 206. Western Electric Supervisory Relay

also secures a great advantage in the matter of convenience of inspection. Such a combined cut-off and line relay, employed in the Western Electric No. 1 relay board, is shown in Fig. 205.

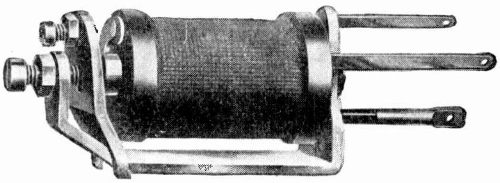


Fig. 207. Line Relay No. 10 Board

These are mounted in banks of ten pairs, a common dust cap of sheet iron covering the entire group.

The Western Electric supervisory relay, Fig. 206, is of the tilting armature type and is copper clad. The dust cap in this case fits on with a bayonet joint as clearly indicated. In Fig. 207 is shown the line relay employed in the Western Electric No. 10 board.

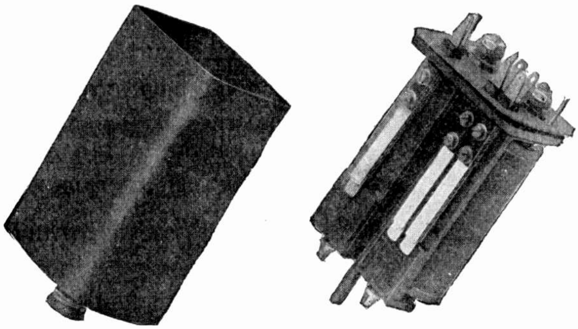


Fig. 208. Kellogg Line and Cut-off Relays

The Kellogg Company employs the special horseshoe type of relay commonly used in telephone circuits. In its multiple boards it commonly mounts the line and cut-off relays together, as shown in Fig. 208. A single, soft iron shell is used to cover both of these, thus serving as a dust shield and also as a magnetic shield to prevent cross-talk between adjacent relays—an important feature, since it will be remembered the cut-off relays are left permanently connected with the talking circuit. Fig. 209, which shows a strip of twenty such pairs of relays, from five of which the covers have been

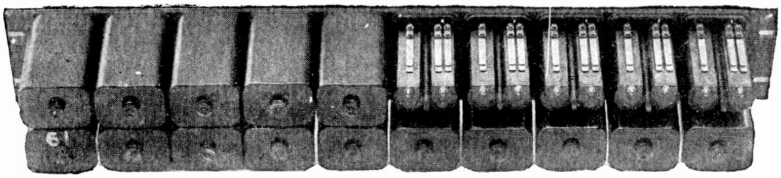


Fig. 209. Strip of Kellogg Line and Cut-Off Relays

removed, is an excellent detail view of the general practice in this respect; obviously, a very large number of such relays may be mounted in a comparatively small space. The mounting strip shown in this cut is of heavy rolled iron and is provided with openings through which the connection terminals—shown more clearly in Fig. 208—project. On the back of this mounting strip all the wiring is done and much of this wiring—that connecting adjacent terminals on the back of the relay strip—is made by means of thin copper wires without insulation, the wires being so short as to support themselves without danger of crossing with other wires. When these wires are adjacent to ground or battery wires they may be protected by sleeving, so as to prevent crosses.

An interesting feature in relay construction is found in the relay of the Monarch Telephone Manufacturing Company shown

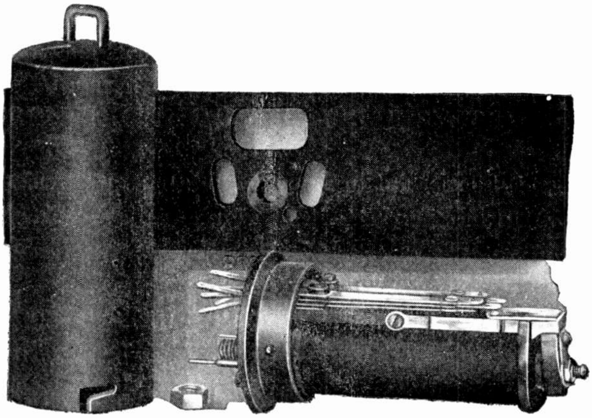


Fig. 210. Monarch Relay

in Figs. 210 and 211. The assembled relay and its mounting strip and cap are shown in Fig. 210. This relay is so constructed that by the lifting of a single latch not only the armature but the coil may be bodily removed, as shown in Fig. 211, in which the latch is shown in its raised position. As seen, the armature has an L-shaped projection which serves to operate the contact springs lying on the iron plate above the coil. The simplicity of this device is attractive, and it is of convenience not only from the standpoint of easy repairs but also from the standpoint of factory assembly, since by manufacturing standard coils with different characters of windings and standard groups of springs, it is possible to produce without special manufacture almost any combination of relay.

Assembly. The arrangement of the key and jack equipment in complete multiple switchboard sections is clearly shown in Fig. 212, which shows a single three-position section of one of the small multiple switchboards of the Kellogg Switchboard and Supply Company. The arrangement of keys and plugs on the key shelf is substantially the same as in simple common-battery boards. As in the simple switchboards the supervisory lamps are usually mounted on the hinged key shelf immediately in the rear of the listening and ringing keys and with such spacing as to lie immediately in front of

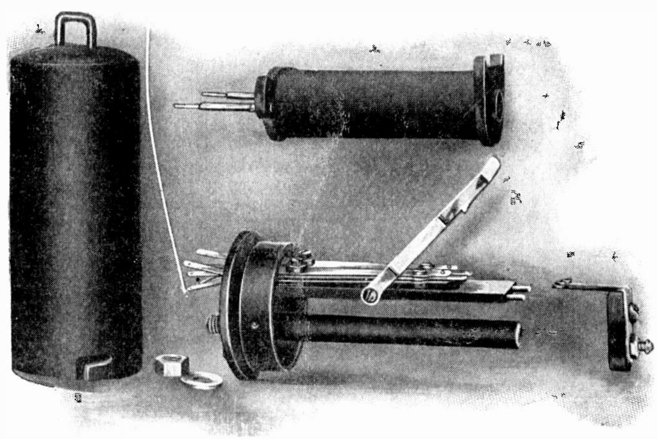


Fig. 211. Monarch Relay

the plugs to which they correspond. The reason for mounting the supervisory lamps on the key shelf is to make them easy of access in case of the necessity of lamp renewals or repairs on the wiring The space at the bottom of the vertical panels, containing the jacks, is left blank, as this space is obstructed by the standing plugs in front of it. Above the plugs, however, are seen the alternate strips of line lamps and answering jacks, the lamps in each case being directly below the corresponding answering jacks. Above the line lamps and answering jacks in the two positions at the right there are blank strips into which additional line lamps and jacks may be placed in case the future needs of the system demand it. The space above these is the multiple jack space, and it is evident from the small number of multiple jacks in this little switchboard that the present equipment of the board is small. It is also evident from the amount of blank space left for future installations of multiple jacks that a considerable growth is expected. Thus, while there are but four banks of 100 multiple jacks, or 400 in all, there is room in the multiple for 300 banks of 100 multiple jacks, or 3,000 in all. The method of grouping the jacks in banks of 100 and of providing for their future growth is clearly indicated in this figure. The next section at the right of the one shown would contain a duplicate set of multiple jacks and also an additional equipment of answering jacks and lamps.

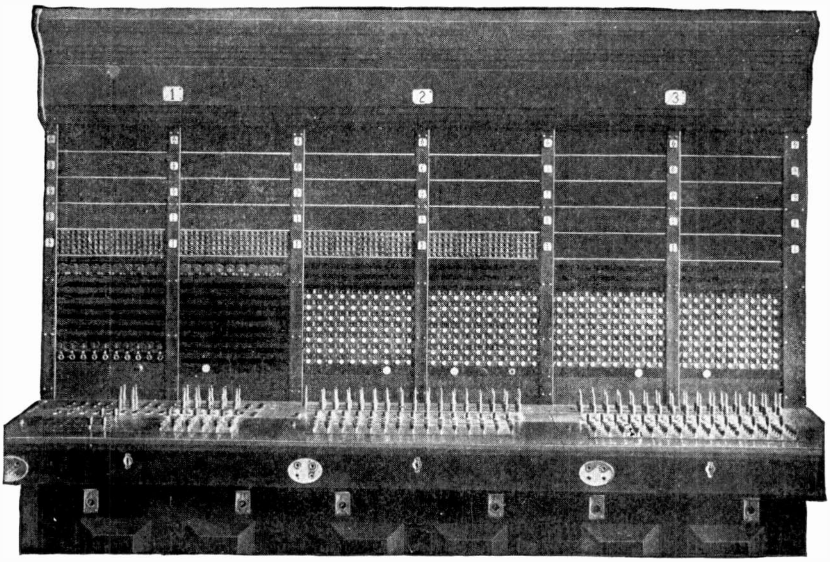


Fig. 212. Small Multiple Board Section

For ordinary local service no operator would sit at the left-hand position of the section shown, that being the end position, since the operator there would not be able easily to reach the extreme right-hand portion of the third position and would have nothing to reach at her left. This end position in this particular board illustrated is provided with toll-line equipment, a practice not uncommon in small multiple boards. To prevent confusion let us assume that the multiple jack space contains its full equipment of 3,000 jacks on each section. The operator in the center position of the section shown could easily reach any one of the jacks on that section. The operator at the third position could reach any jack on the second and third position of her section, but could not well reach multiple jacks in the first position. She would, however, have a duplicate of the multiple jacks in this first position in the section at her right, *i. e.*, in the fourth position, and it makes no difference on what portion of the switchboard she plugs into the multiple so long as she plugs into a jack of the right line.

CHAPTER XV

TRUNKING IN MULTI-OFFICE SYSTEMS

It has been stated that a single exchange may involve a number of offices, in which case it is termed a multi-office exchange. In a multi-office exchange, switchboards are necessary at each office in which the subscribers' lines of the corresponding office district terminate. Means for intercommunication between the subscribers in one office and those in any other office are afforded by inter-office trunks extended between each office and each of the other offices.

If the character of the community is such that each of the offices has so few lines as to make the simple switchboard suffice for its local connections, then the trunking between the offices may be carried out in exactly the same way as explained between the various simple switchboards in a transfer system, the only difference being that the trunks are long enough to reach from one office to another instead of being short and entirely local to a single office. Such a condition of affairs would only be found in cases where several small communities were grouped closely enough together to make them operate as a single exchange district, and that is rather unusual.

The subject of inter-office trunking so far as manual switchboards are concerned is, therefore, confined mainly to trunking between a number of offices each equipped with a manual multiple switchboard.

Necessity for Multi-Office Exchanges. Before taking up the details of the methods and circuits employed in trunking in multi-office systems, it may be well to discuss briefly why the multi-office exchange is a necessity, and why it would not be just as well to serve all of the subscribers in a large city from a single huge switchboard in which all of the subscribers' lines would terminate. It cannot be denied, when other things are equal, that it is better to have only one operator involved in any connection which means less labor and less liability of error.

The reasons, however, why this is not feasible in really large exchanges are several. The main one is that of the larger investment required. Considering the investment first from the standpoint of the subscriber's line, it is quite clear that the average length of subscriber's line will be very much greater in a given community if all of the lines are run to a single office, than will be the case if the exchange district is divided into smaller office districts and the lines run merely from the subscribers to the nearest office. There is a direct and very large gain in this respect, in the multi-office system over the single office system in large cities, but this is not a net gain, since there is an offsetting investment necessary in the trunk lines between the offices, which of course are separate from the subscribers' lines.

Approaching the matter from the standpoint of switchboard construction and operation, another strong reason becomes apparent for the employment of more than one office in large exchange districts. Both the difficulties of operation and the expense of construction and maintenance increase very rapidly when switchboards grow beyond a certain rather well-defined limit. Obviously, the limitation of the multiple switchboard as to size involves the number of multiple jacks that it is feasible to place on a section. Multiple switchboards have been constructed in this country in which the sections had a capacity of 18,000 jacks. Schemes have been proposed and put into effect with varying success, for doubling and quadrupling the capacity of multiple switchboards, one of these being the so-called divided multiple board devised by the late Milo G. Kellogg, and once used in Cleveland, Ohio, and St. Louis, Missouri. Each of these boards had an ultimate capacity of 24,000 lines, and each has been replaced by a "straight" multiple board of smaller capacity. In general, the present practice in America does not sanction the building of multiple boards of more than about 10,000 lines capacity, and as an example of this it may be cited that the largest standard section manufactured for the Bell companies has an ultimate capacity of 9,600 lines.

European engineers have shown a tendency towards the opposite practice, and an example of the extreme in this case is the multiple switchboard manufactured by the Ericsson Company, and installed in Stockholm, in which the jacks have been reduced to such small dimensions as to permit an ultimate capacity of 60,000 lines.

The reasons governing the decision of American engineers in establishing the practice of employing no multiple switchboards of greater capacity than about 10,000 lines, briefly outlined, are as follows: The building of switchboards with larger capacity, while perfectly possible, makes necessary either a very small jack or some added complexity, such as that of the divided multiple switchboard, either of which is considered objectionable. Extremely small jacks and large multiples introduce difficulties as to the durability of the jacks and the plugs, and also they tend to slow down the work of operators and to introduce errors. They also introduce the necessity of a smaller gauge of wire through the multiple than it has been found desirable to employ. Considered from the standpoint of expense, it is evident that as a multiple switchboard increases in number of lines, its size increases in two dimensions, *i. e.*, in length of board and height of section, and this element of expense, therefore, is a function of the square of the number of lines.

The matter of insurance, both with respect to the risk as to property loss and the risk as to breakdown of the service, also points distinctly in the direction of a plurality of offices rather than one. Both from the standpoint of risk against fire and other hazards, which might damage the physical property, and of risk against interruption to service due to a breakdown of the switchboard itself, or a failure of its sources of current, or an accident to the cable approaches, the single office practice is like putting all one's eggs in one basket.

Another factor that has contributed to the adoption of smaller switchboard capacities is the fact that in the very large cities even a 40,000 line multiple switchboard would still not remove the necessity of multi-office exchanges with the consequent certainty that a large proportion of the calls would have to be trunked anyway.

Undoubtedly, one of the reasons for the difference between American and European practice is the better results that American operating companies have been able to secure in the handling of calls at the incoming end of trunks. This is due, no doubt, in part to the differences in social and economic conditions under which exchanges are operated in this country and abroad, and also in part to the characteristics of the English tongue when compared to some of the other tongues in the matter of ease with which numbers may be spoken. In America it has been found possible to so perfect the operation of trunking under proper operating conditions and with good equipment as to relieve multi-office practice of many of the disadvantages which have been urged against it.

Classification. Broadly speaking there are two general methods that may be employed in trunking between exchanges. The first and simplest of these methods is to employ so-called *two-way trunks*. These, as their name indicates, may be used for completing connections between offices in either direction, that is, whether the call originates at one end or the other. The other way is by the use of *one-way trunks*, wherein each trunk carries traffic in one direction only. Where such is the case, one end of the trunk is always used for connecting with the calling subscriber's line and is termed the *outgoing* end, and the other end is always used in completing the connection with the called subscriber's line, and is referred to as the *incoming* end. Traffic in the other direction is handled by another set of trunks differing from the first set only in that their outgoing and incoming ends are reversed.

As has already been pointed out, a system of trunks employing two-way trunks is called a *single-track system*, and a system involving two sets of one-way trunks is called a *double-track system*. It is to be noted that the terms outgoing and incoming, as applied to the ends of trunks and also as applied to traffic, always refer to the direction in which the trunk handles traffic or the direction in which the traffic is flowing with respect to the particular office under consideration at the time. Thus an *incoming trunk* at one office is an *outgoing trunk* at the other.

Two-Way Trunks. Two-way trunks are nearly always employed where the traffic is very small and they are nearly always operated by having the *A*-operator plug directly into the jack at her end of the trunk and displaying a signal at the other end by ringing over the trunk as she would over an ordinary subscriber's line. The operator at the distant exchange answers as she would on an ordinary line, by plugging into the jack of that trunk, and receives her orders over the trunk either from the originating operator or from the subscriber, and then completes the connection with the called subscriber. Such trunks are often referred to as "ring-down" trunks, and their equipment consists in a drop and jack at each end. In case there is a multiple board at either or both of the offices, then the equipment at each end of the trunk would consist of a drop and answering jack, together with the full quota of multiple jacks. It is readily seen that this mode of operation is slow, as the work that each operator has to do is the same as that in connecting two local subscribers, plus the time that it takes for the operators to communicate with each other over the trunk.

One-Way Trunks. Where one-way trunks are employed in the double-track system, the trunks, assuming that they connect multiple boards, are provided with multiple jacks only at their outgoing ends, so that any operator may reach them for an outgoing connection, and at their incoming ends they terminate each in a single plug and in suitable signals and ringing keys, the purpose of which will be explained later. Over such trunks there is no verbal communication between the operators, the instructions passing between the operators over separate order-wire circuits. This is done in order that the trunk may be available as much as possible for actual conversation between the subscribers. It may be stated at this point that the duration of the period from the time when a trunk is appropriated by the operators for the making of a certain connection until the time when the trunk is finally released and made available for another connection is called the *holding time*, and this holding time includes not only the period while the subscribers are in actual conversation over it, but also the periods while the operators are making the connection and afterwards while they are taking it down. It may be said, therefore, that the purpose of employing separate order wires for communication between the operators is to make the holding time on the trunks as small as possible and, therefore, for the purpose of enabling a given trunk to take part in as many connections in a given time as possible.

In outline the operation of a one-way trunk between common-battery, manual, multiple switchboards is, with modifications that will be pointed out afterwards, as follows: When a subscriber's line signal is displayed at one office, the operator in attendance at that position answers and finding that the call is for a subscriber in another office, she presses an order-wire key and thereby connects her telephone set directly with that of a *B*-operator at the proper other office. Unless she finds that other operators are talking over the order wire, she merely states the number of the called subscriber, and the *B*-operator whose telephone set is permanently connected with that order wire merely repeats the number of the called subscriber and follows this by designating the number of the trunk which the *A*-operator is to employ in making the connection. The *A*-operator, thereupon, immediately and without testing, inserts the calling plug of the pair used in answering the call into the trunk jack designated by the *B*-operator; the *B*-operator simultaneously tests the multiple jack of the called subscriber and, if she finds it not busy, inserts the plug of the designated trunk into the multiple jack of the called subscriber and rings his bell by pressing the ringing key associated with the trunk cord used. The work on the part of the *A*-operator in connecting with the outgoing end of the trunk and on the part of the *B*-operator in connecting the incoming end of the trunk with the line goes on simultaneously, and it makes no difference which of these operators completes the connection first.

It is the common practice of the Bell operating companies in this country to employ what is called automatic or machine ringing in connection with the *B*-operator's work. When the *B*-operator presses the ringing key associated with the incoming trunk cord, she pays no further attention to it, and she has no supervisory lamp to inform her as to whether or not the subscriber has answered. The ringing key is held down, after its depression by the operator, either by an electromagnet or by a magnet-controlled latch, and the ringing of the subscriber's bell continues at periodic intervals as controlled by the ringing commutator associated with the ringing machine. When the subscriber answers, however, the closure of his line circuit results in such an operation of the magnet associated with the ringing key as to release the ringing key and thus to automatically discontinue the ringing current.

When a connection is established between two subscribers through such a trunk the supervision of the connection falls entirely upon the *A*-operator who established it. This means that the calling supervisory lamp at the *A*-operator's position is controlled over the trunk from the station of the called subscriber, the answering supervisory lamp being, of course, under the control of the calling subscriber as in the case of a local connection. It is, therefore, the *A*-operator who always initiates the taking down of a trunk connection, and when, in response to the lighting of the two lamps, she withdraws her calling plug from the trunk jack, the supervisory lamp associated with the incoming end of the trunk at the other office is lighted, and the *B*-operator obeys it by pulling down the plug.

If, upon testing the multiple jack of the called subscriber's line, the *B*-operator finds the line to be busy, she at once inserts the trunk plug into a so-called "busy-back" jack, which is merely a jack whose terminals are permanently connected to a circuit that is intermittently opened and closed, and which also has impressed upon it an alternating current of such a nature as to produce the familiar "buzz-buzz" in a telephone receiver. The opening and closing of this circuit causes the calling supervisory lamp of the *A*-operator to flash at periodic intervals just as if the called subscriber had raised and lowered his receiver, but more regularly. This is the indication to the *A*-operator that the line called for is busy. The buzzing sound is repeated back through the cord circuit of the *A*-operator to the calling subscriber and is a notification to him that the line is busy.

Sometimes, as is practiced in New York City, for instance, the buzzing feature is omitted, and the only indication that the calling subscriber receives that the called-for line is busy is being told so by the *A*-operator. This may be considered a special feature and it is employed in New York because there the custom exists of telling a calling subscriber, when the line he has called for has been found busy, that the party will be secured for him and that he, the calling subscriber, will be called, if he desires.

A modification of this busy-back feature that has been employed in Boston, and perhaps in other places, is to associate with the busy-back jack at the *B*-operator's position a phonograph which, like a parrot, keeps repeating "Line busy—please call again." Where this is done the calling subscriber, *if he understands what the phonograph says*, is supposed to hang up his receiver, at which time the *A*-operator takes down the connection and the *B*-operator follows in response to the notification of her supervisory lamp. The phonograph busy-back scheme, while ingenious, has not been a success and has generally been abandoned.

As a rule the independent operating companies in this country have not employed automatic ringing, and in this case the *B*-operators have been required to operate their ringing keys and to watch for the response of the called subscriber. In order to arrange for this, another supervisory lamp, termed the *ringing lamp*, is associated with each incoming trunk plug, the going out of this lamp being a notification to the *B*-operator to discontinue ringing.

Western Electric Trunk Circuits. The principles involved in inter-office trunking with automatic ringing, are well illustrated in the trunk circuit employed by the Western Electric Company in connection with its No. 1 relay boards. The dotted dividing line through the center of Fig. 213 represents the separating space between two offices. The calling subscriber's line in the first office is shown at the extreme left and the called subscriber's line in the second office is shown at the extreme right. Both of these lines are standard multiple switchboard lines of the form already discussed. The equipment illustrated in the first office is that of an *A*-board, the cord circuit shown being that of the regular *A*-operator. The outgoing trunk jacks connecting with the trunk leading to the other office are, it will be understood, multipled through the *A*-sections of the board and contain no relay equipment, but the test rings are connected to ground through a resistance coil *1*, which takes the place of the cut-off relay winding of a regular line so far as test conditions and supervisory relay operation are concerned. The equipment illustrated in the second office is that of a *B*-board, it being understood that the called subscriber's line is multipled through both the *A*- and *B*-boards at that office. The part of the equipment that is at this point unfamiliar to the reader is, therefore, the cord circuit at the *B*-operator's board. This includes, broadly speaking, the means: (1) for furnishing battery current to the called subscriber; (2) for accomplishing the ringing of the called subscriber and for automatically stopping the ringing when he shall respond; (3) for performing the ordinary switching functions in connection with the relays of the called subscriber's line in just the same way that an *A*-operator's cord carries out these functions; and (4) for causing the operation of the calling supervisory relay of the *A*-operator's cord circuit in just the same manner, under control of the connected called subscriber, as if that subscriber's line had been connected directly to the *A*-operator's cord circuit.

The operation of these devices in the *B*-operator's cord circuit

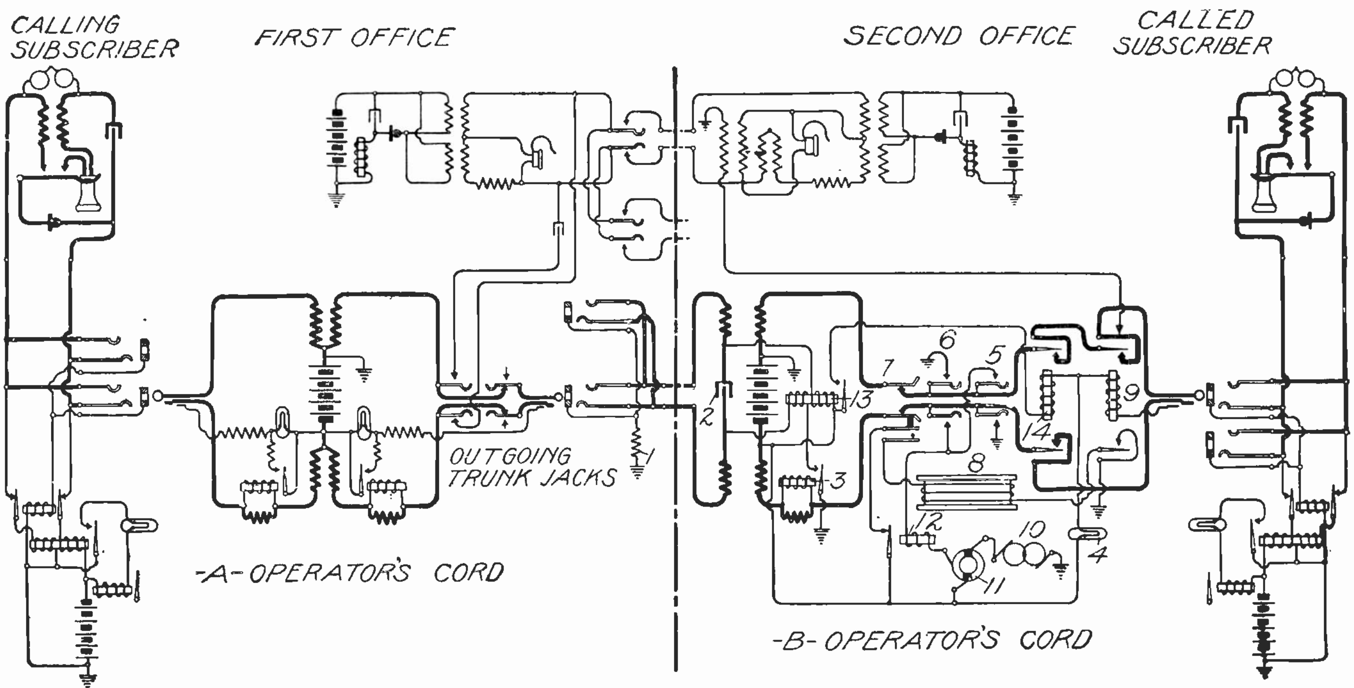
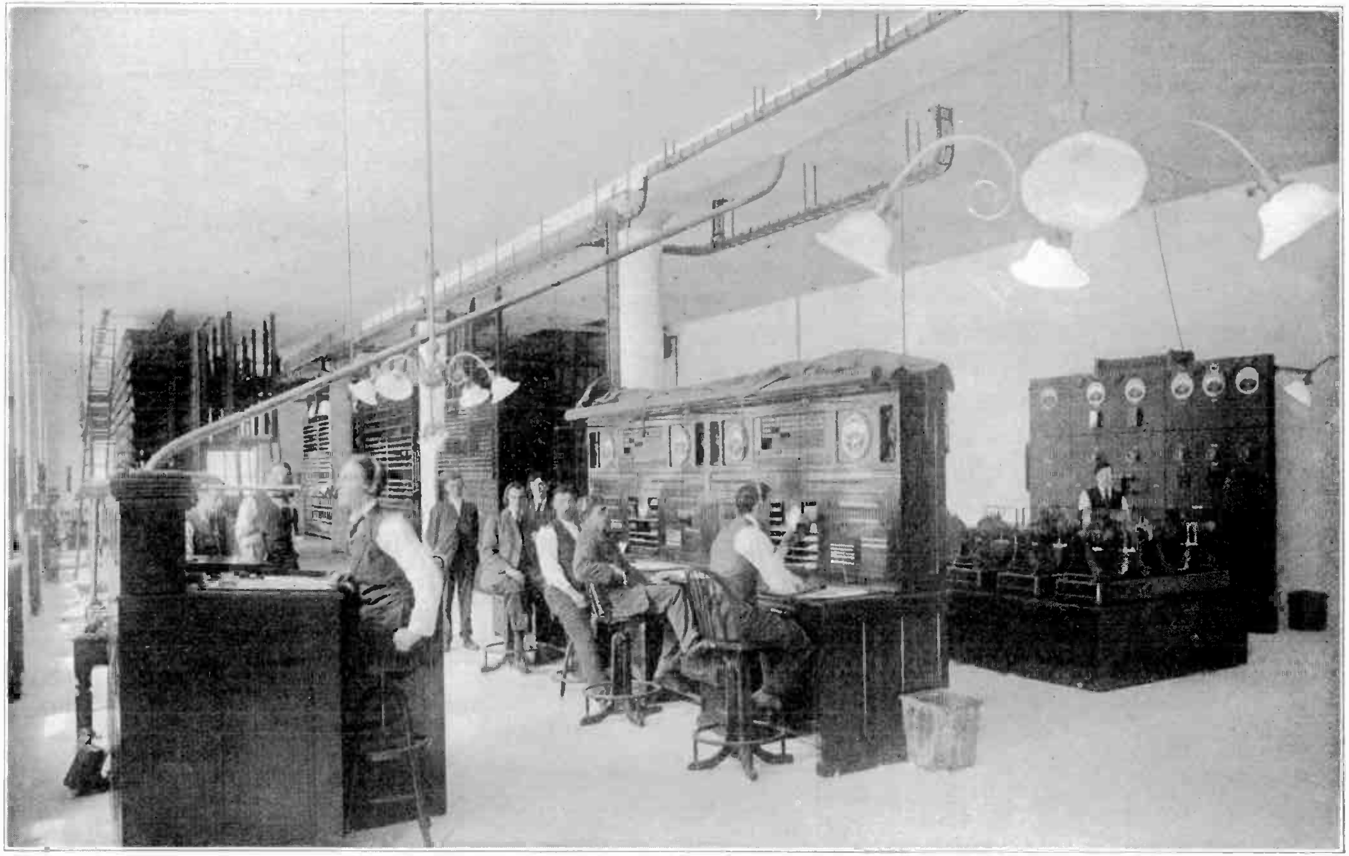


Fig. 213. Inter-Office Connection—Western Electric System

may be best understood by following the establishment of the connection. Assuming that the calling subscriber in the first office desires a connection with the subscriber's line shown in the second office, and that the *A*-operator at the first office has answered the call, she will then communicate by order wire with the *B*-operator at the second office, stating the number of the called subscriber and receiving from that operator in return the number of the trunk to be employed. The two operators will then proceed simultaneously to establish the connection, the *A*-operator inserting the calling plug into the outgoing trunk jack, and the *B*-operator inserting the trunk plug into the multiple jack of the called subscriber's line after testing. We will assume at first that the called subscriber's line is found idle and that both of the operators complete their respective portions of the work at the same time and we will consider first the condition of the calling supervisory relay at the *A*-operator's position.

The circuit of the calling supervisory lamp will have been closed through the resistance coil *1* connected with the outgoing trunk jacks and the lamp will be lighted because, as will be shown, it is not yet shunted out by the operation of its associated supervisory relay. Tracing the circuit of the calling supervisory relay of the *A*-operator's circuit, it will be found to pass from the live side of the battery to the ring side of the trunk circuit through one winding of the repeating coil of the *B*-operator's cord; beyond this the circuit is open, since no path exists through the condenser *2* bridged across the trunk circuit or through the normally open contacts of the relay *3* connected in the talking circuit of the trunk. The association of this relay *3* with the repeating coil and the battery of the trunk is seen to be just the same as that of a supervisory relay in the *A*-operator's cord, and it is clear, therefore, that this relay *3* will not be energized until the called subscriber has responded. When it is energized it will complete the path to ground through the *A*-operator's calling supervisory relay and operate to shunt out the *A*-operator's calling supervisory lamp in just the same manner as if the *A*-operator's calling plug had been connected directly with the line of the calling subscriber. In other words, the called subscriber in the second office controls the relay *3*, which, in turn, controls the calling supervisory relay of the *A*-operator, which, in turn, shunts out its lamp.



TERMINAL ROOM, SHOWING WIRE CHIEF'S EQUIPMENT
Bedford Office, New York Telephone Co.

The connection being completed between the two subscribers, the *B*-operator depresses one or the other of the ringing keys *5* or *6*, according to which party on the line is called, assuming that it is a two-party line. It will be noticed that the springs of these ringing keys are not serially arranged in the talking circuit, but the cutting off of the trunk circuit back of the ringing keys is accomplished by the set of springs shown just at the left of the ringing keys, which set of springs *7* is operated whenever either one of the ringing keys is depressed. An auxiliary pair of contacts, shown just below the group of springs *7*, is also operated mechanically whenever either one of the ringing keys is depressed, and this serves to close one of two normally open points in the circuit of the ringing-key holding magnet *8*. This holding magnet *8* is so arranged with respect to the contacts of the ringing key that whenever any one of them is depressed by the operator, it will be held depressed as long as the magnet is energized just the same as if the operator kept her finger on the key. The other normally open point in the circuit of the holding magnet *8* is at the lower pair of contacts of the test and holding relay *9*. This relay is operated whenever the trunk plug is inserted in the jack of a called line, regardless of the position of the subscriber's equipment on that line. The circuit may be traced from the live side of the battery through the trunk disconnect lamp *4*, coil *9*, sleeve strand of cord, and to ground through the cut-off relay of the line. The insertion of the trunk plug into the jack thus leaves the completion of the holding-magnet circuit dependent only upon the auxiliary contact on the ringing key, and, therefore, as soon as the operator presses either one of these keys, the clutch magnet is energized and the key is held down, so that ringing current continues to flow at regular intervals to the called subscriber's station.

The ringing current issues from the generator *10*, but the supply circuit from it is periodically interrupted by the commutator *11* geared to the ringing-machine shaft. This periodically interrupted ringing current passes to the ringing-key contacts through the coil of the ringing cut-off relay *12*, and thence to the subscriber's line. The ringing current is, however, insufficient to cause the operation of this relay *12* as long as the high resistance and impedance of the subscriber's bell and condenser are in the circuit. It is, however, sufficiently sensitive to be operated by this ringing current when the subscriber responds and thus substitutes the comparatively low resistance and impedance path of his talking apparatus for the previous path through his bell. The pulling up of the ringing cut-off relay *12* breaks a third normally closed contact in the circuit of the holding coil *8*, de-energizing that coil and releasing the ringing key, thus cutting off ringing current. There is a third brush on the commutator *11* connected with the live side of the central battery, and this is merely for the purpose of assuring the energizing of the ringing cut-off relay *12*, should the subscriber respond during the interval while the commutator *11* held the ringing current cut off. The relay *12* may thus be energized either from the battery, if the subscriber responds during a period of silence of his ringer, or from the generator *10*, if the subscriber responds during a period while his bell is sounding; in either case the ringing current will be promptly cut off by the release of the ringing key.

The trunk operator's "disconnect lamp" is shown at *4*, and it is to be remembered that this lamp is lighted only when the *A*-operator takes down the connection at her end, and also that this lamp is entirely out of the control of the subscribers, the conditions which determine its illumination being dependent on the positions of the operators' plugs at the two ends of the trunk. With both plugs up, the lamp *4* will receive current, but will be shunted to prevent its illumination. The path over which it receives this current may be traced from battery through the lamp *4*, thence through the coil of the relay *9* and the cut-off relay of the called subscriber's line. This current would be sufficient to illuminate the lamp, but the lamp is shunted by a circuit which may be traced from the live side of battery through the contact of the relay *13*, closed at the time, and through the coil of the trunk cut-off relay coil *14*. The resistance of this coil is so proportioned to the other parts of the circuit as to prevent the illumination of the lamp just exactly as in the case of the shunting resistances of the lamps in the *A*-operator's cord. It will be seen, therefore, that the supply of current to the trunk disconnect lamp is dependent on the trunk plug being inserted into the jack of the subscriber's line and that the shunting out of this lamp is dependent on the energization of the relay *13*. This relay *13* is energized as long as the *A*-operator's plug is inserted into the outgoing trunk jack, the path of the energizing circuit being traced from the live side of the battery at the second office through the right-hand winding of this relay, thence over the tip side of the trunk to ground at the first office. From this it follows that as long as both plugs are up, the disconnect lamp will receive current but will be shunted out, and as soon as the *A*-operator pulls down the connection, the relay *13* will be de-energized and will thus remove the shunt from about the lamp, allowing its illumination. The left-hand winding of the relay *13* performs no operating function, but is merely to maintain the balance of the talking circuit, it being bridged during the connection from the ring side of the trunk to ground in order to balance the bridge connection of the right-hand coil from the live side of battery to the tip side of the trunk circuit.

The relay *14*, already referred to as forming a shunt for the trunk disconnect lamp, has for its function the keeping of the talking circuit through the trunk open until such time as the relay *13* operates, this being purely an insurance against unnecessary ringing of a subscriber in case the *A*-operator should by mistake plug into the wrong trunk. It is not, therefore, until the *A*-operator has plugged into the trunk and the relay *13* has been operated to cause the energization of the relay *14* that the ringing of the called subscriber can occur, regardless of what the *B*-operator may have done.

The relay *9* has an additional function to that of helping to control the circuit of the ringing-key holding magnet. This is the holding of the test circuit complete until the operator has tested and made a connection and then automatically opening it. The test circuit of the *B*-operator's trunk may be traced, at the time of testing, from the thimble of the multiple jack under test, through the tip of the cord, thence through the uppermost pair of contacts of the relay *9* to ground through a winding of the *B*-operator's induction coil. After the test has been made and the plug inserted, the relay *9*, which is operated by the insertion of the plug, acts to open this test circuit and at the same time complete the tip side of the cord circuit.

In the upper portion of Fig. 213 the order-wire connections, by which the *A*-operator and the *B*-operator communicate, are indicated. It must be remembered in connection with these that the *A*-operator only has control of this connection, the *B*-operator being compelled necessarily to hear whatever the A-operators have to say when the A-operators come in on the circuit.

The incoming trunk circuit employed by the Western Electric Company for four-party line ringing is shown in Fig. 214, it being

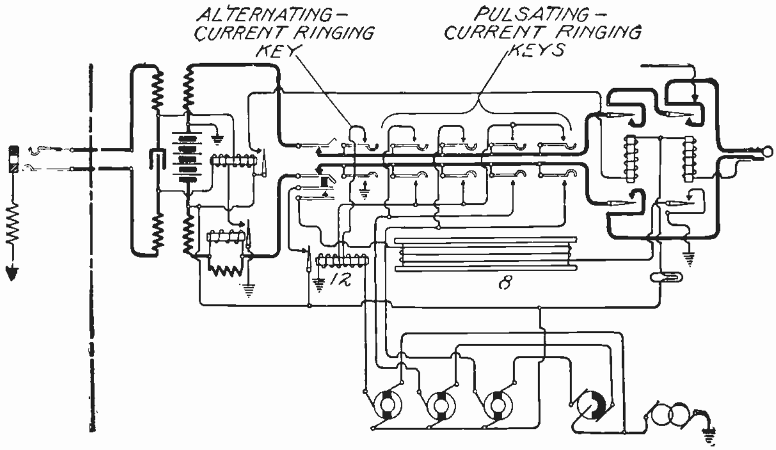


Fig. 214. Incoming Trunk Circuit

necessarily somewhat modified from that shown in Fig. 213, which is adapted for two-party line ringing only. In addition to the provision of the four-party line ringing keys, by which positive or negative pulsating current is received over either limb of the line, and to

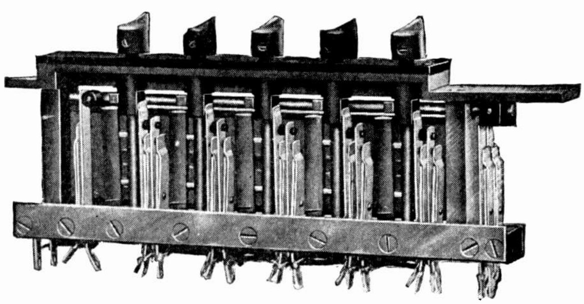


Fig 215. Western Electric Trunk Ringing Key

the provision of the regular alternating current ringing key for ringing on single party lines, it is necessary in the ringing cut-off relay to provide for keeping the alternating and the pulsating ringing currents entirely separate. For this reason, the ringing cut-off relay *12* is provided with two windings, that at the right being in the path of the alternating ringing currents that are supplied to the alternating current key, and that at the left being in the

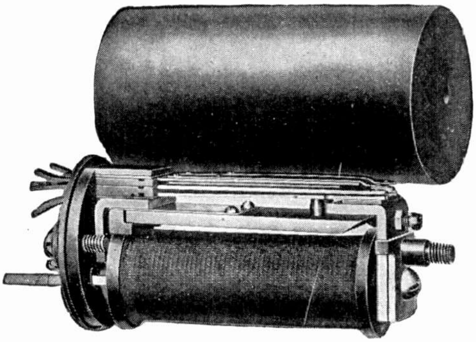


Fig. 216. Trunk Relay

ground return path for all of the pulsating ringing currents supplied to the pulsating keys. With this explanation it is believed that this circuit will be understood from what has been said in connection with Fig. 213. The operation of the holding coil *8* is the same in each case, the holding magnet in Fig. 214 serving to hold depressed any one of the five ringing keys that may have been used in calling the subscriber.

The standard four-party line, trunk ringing key of the Western Electric Company is shown in Fig. 215. In this the various keys

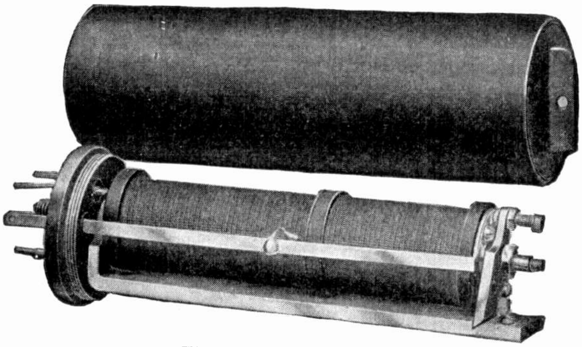


Fig. 217. Trunk Relay

operate not by pressure but rather by being pulled by the finger of the operator in such a way as to subject the key shaft to a twisting movement. The holding magnet lies on the side opposite to that shown in the figure and extends along the full length of the set of keys, each key shaft being provided with an armature which is held by this magnet until the magnet is de-energized by the action of the ringing cut-off relay.

The standard trunk relays employed by the Western Electric Company in connection with the circuits just described are shown in Figs. 216 and 217. In each case the dust-cap or shield is also shown. The relay of Fig. 216 is similar to the regular cut-off relay and is the one used for relays *9* and *14* of Figs. 213 and 214. The relay of Fig. 217 is somewhat similar to the subscriber's line relay in that it has a tilting armature, and is the one used at *13* in Figs. 213 and 214. The trunk relay *3* in Figs. 213 and 214 is the same as the *A*-operator's supervisory relays already discussed.

It has been stated that under certain circumstances *B*-operator's trunk circuits devoid of ringing keys, and consequently of all keys, may be employed. This, so far as the practice of the Bell companies

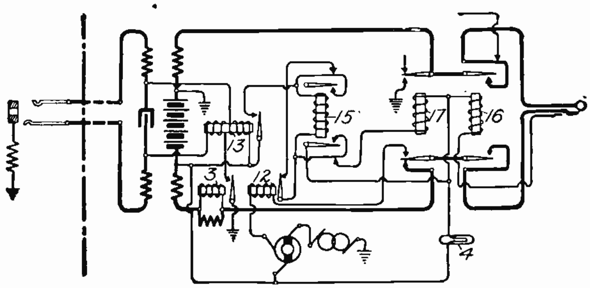


Fig. 218. Keyless Trunk

is concerned, is true only in offices where there are no party lines, or where, as in many of the Chicago offices, the party lines are worked on the "jack per station" basis. In "jack per station" working, the selection of the station on a party line is determined by the jack on which the plug is put, rather than by a ringing key, and hence the keyless trunk may be employed.

A keyless trunk as used in New York is shown in Fig. 218 This has no manually operated keys whatever, and the relay *17*, when it is operated, establishes connection between the ringing generator and the conductors of the trunk plug. The relays *3*, *13*, and *12* operate in a manner identical with those bearing corresponding numbers in Fig. 213. As soon as the trunk operator plugs into the multiple jack of the called subscriber, the relay *16* will operate for the same reason that the relay *9* operated in connection with Fig. 213. The trunk disconnect lamp will receive current, but if the operator has already established connection with the other end of the trunk, this lamp will not be lighted because shunted by the relay *17*, due to the pulling up of the armature of the relay *13*. The relay *15* plays no part in the operation so far described, because of the fact that its winding is short-circuited by its own contacts and those of relay *12*, when the latter is not energized. As a result of the operation of the relay *17*, ringing current is sent to line, the supply circuit including the coil of the relay *12*. As soon as the subscriber responds to this ringing current, the armature of the relay *12* is pulled up, thus breaking the shunt about the relay *15*, which, therefore, starts to operate in series with the relay *17*, but as its armatures assume their attracted position, the relay *17* is cut out of the circuit, the coil of the relay *15* being substituted for that of the relay *17* in the shunt path around the lamp *4*. The relay *17* falls back and cuts off the ringing current. The relay *15* now occupies the place with respect to the shunt around the lamp *4* that the relay *17* formerly did, the continuity of this shunt being determined by the energization of the relay *13*. When the *A*-operator at the distant exchange withdraws the calling plug from the trunk jack, this relay *13* becomes de-energized, breaking the shunt about the lamp *4* and permitting the display of that lamp as a signal to the operator to take down the connection. It may be asked why the falling back of relay *15* will not again energize relay *17* and thus cause a false ring on the called subscriber. This will not occur because both the relays *15* and *17* depend for their energization on the closure of the contacts of the relay *13*, and when this falls back the relay *17* cannot again be energized even though the relay *15* assumes its normal position.

Kellogg Trunk Circuits. The provision for proper working of trunk circuits in connection with the two-wire multiple switchboards is not an altogether easy matter, owing particularly to the smaller number of wires available in the plug circuits. It has been worked out in a highly ingenious way, however, by the Kellogg Company, and a diagram of their incoming trunk circuit, together with the associated circuits involved in an inter-office connection, is shown in Fig. 219.

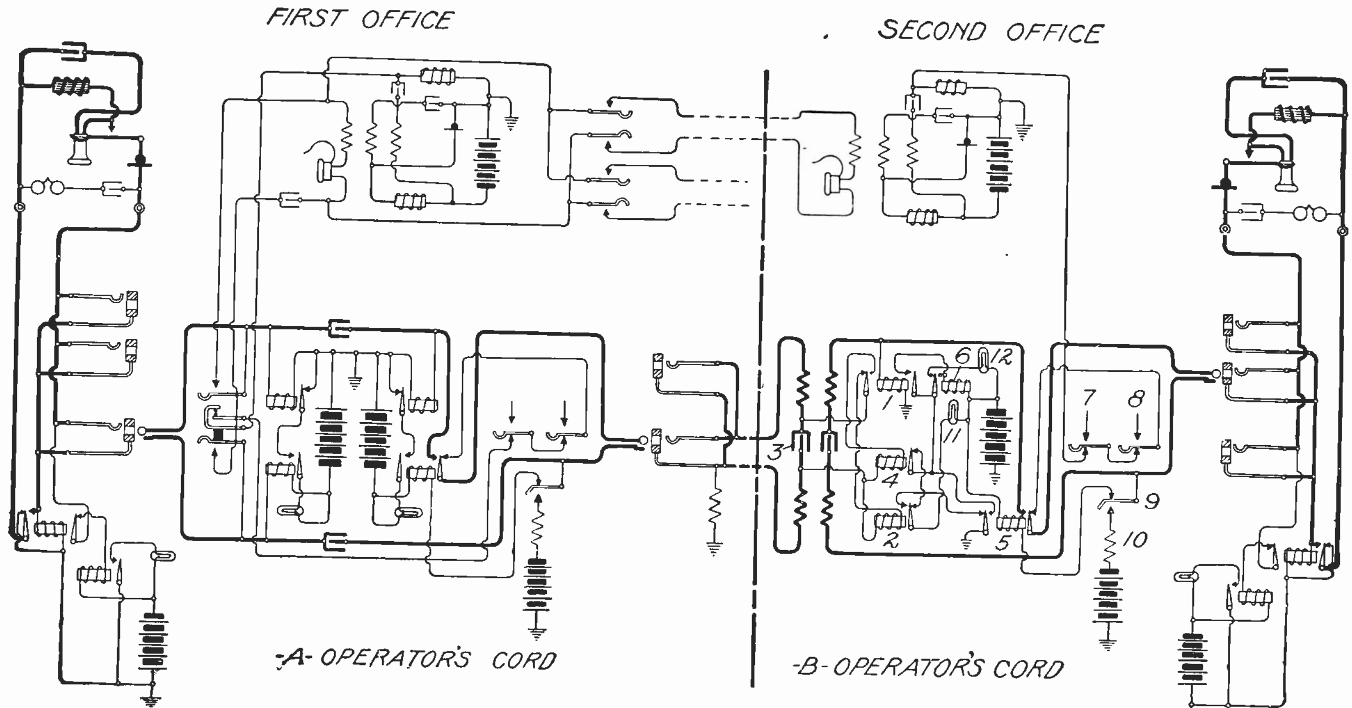


Fig. 219. Inter-Office Connection—Kellogg System

This figure illustrates a connection from a regular two-wire multiple subscriber's line in one office, through an *A*-operator's cord circuit there, to the outgoing trunk jacks at that office, thence through the incoming trunk circuit at the other office to the regular two-wire multiple subscriber's line at that second office. The portion of this diagram to be particularly considered is that of the *B*-operator's cord circuit. The trunk circuit terminates in the multipled outgoing trunk jacks at the first office, the trunk extending between offices consisting, of course, of but two wires. We will first consider the control of the calling supervisory lamp in the *A*-operator's cord circuit, it being remembered that this control must be from the called subscriber's station. It will be noticed that the left-hand armature of the relay *1* serves normally to bridge the winding of relay *2* across the cord circuit around the condenser *3*. When, however, the relay *1* pulls up, the coil of relay *4* is substituted in this bridge connection across the trunk. The relay *2* has a very high resistance winding—about 15,000 ohms—and this resistance is so great that the tip supervisory relay of the *A*-operator's cord will not pull up through it. As a result, when this relay is bridged across the trunk circuit, the tip relay on the calling side of the *A*-operator's cord circuit is de-energized, just as if the trunk circuit were open, and this results in the lighting of the *A*-operator's calling supervisory lamp. The winding of the relay *4*, however, is of low resistance—about 50 ohms—and when this is substituted for the high-resistance winding of the relay *2*, the tip relay on the calling side of the *A*-operator's cord is energized, resulting in the extinguishing of the calling supervisory lamp. The illumination of the *A*-operator's calling supervisory lamp depends, therefore, on whether the high-resistance relay *2*, or the low-resistance relay *4*, is bridged across the trunk, and this depends on whether the relay *1* is energized or not. The relay *1*, being bridged from the tip side of the trunk circuit to ground and serving as the means of supply of battery current to the called subscriber, is operated whenever the called subscriber's receiver is removed from its hook. Therefore, the called subscriber's hook controls the operation of this relay *1*, which, in turn, controls the conditions which cause the illumination or darkness of the calling supervisory lamp at the distant office.

Assuming that the *A*-operator has received and answered a call, and has communicated with the *B*-operator, telling her the number of the called subscriber, and has received, in turn, the number of the trunk to be used, and that both operators have put up the connection, then it will be clear from what has been said that the calling supervisory lamp of the *A*-operator will be lighted until the called subscriber removes his receiver from its hook, because the tip relay in the *A*-operator's cord circuit will not pull up through the 15,000-ohm resistance winding of the relay *2*. As soon as the subscriber responds, however, the relay *1* will be operated by the current which supplies his transmitter. This will substitute the low-resistance winding of the relay *4* for the high-resistance winding of the relay *2*, and this will permit the energizing of the tip supervisory relay of the *A*-operator and put out the calling supervisory lamp at her position. As in the Western Electric circuit, therefore, the control of the *A*-operator's calling supervisory lamp is from the called subscriber's station and is relayed back over the trunk to the originating office.

In this circuit, manual instead of automatic ringing is employed, therefore, unlike the Western Electric circuit, means must be provided for notifying the *B*-operator when the calling subscriber has answered. This is done by placing at the *B*-operator's position a ringing lamp associated with each trunk cord, which is illuminated when the *B*-operator places the plug of the incoming trunk into the multiple jack of the subscriber's line, and remains illuminated until the subscriber has answered. This is accomplished in the following manner: when the operator plugs into the jack of the line called, relay *5* is energized but is immediately de-energized by the disconnecting of the circuit of this relay from the sleeve conductor of the cord when the ringing key is depressed, the selection of the ringing key being determined by the particular party on the line desired. These ringing keys have associated with them a set of springs *9*, which springs are operated when any one of the ringing keys is depressed. Thus, with a ringing key depressed and the relay *5* de-energized, the ringing lamp will be illuminated by means of a circuit as follows: from the live side of the battery, through the ringing lamp *12*, through the back contact and armature of the relay *6*, through the armature and contact of relay *4*, then through the armature and front contact of relay *2*—which at this time is the relay bridged across the trunk and, therefore, energized—and thence through the back contact and armature of relay *5* to ground. When the subscriber removes his receiver from the hook, the relay *1* will become energized as previously described, and will, therefore, operate relay *6* to break the circuit of the ringing lamp. The circuit thus established by the operation of relay *1* is as follows: from the live side of battery, through the winding of relay *6*, through the armature and contact of relay *1*, through the armature and contact of relay *4*, through the armature and front contact of relay *2*, thence through the armature and back contact of relay *5* to ground. As soon as the *B*-operator notes that the ringing lamp has gone out, she knows that no further ringing is required on that line, thus allowing the operation of relay *5* and accomplishing the locking out of the ringing lamp during the remainder of that connection. The relay *6*, after having once pulled up, remains locked up through the rear contact of the left-hand armature of relay *5* and ground, until the plug is removed from the jack.

At the end of the conversation, when the *A*-operator has disconnected her cord circuit on the illumination of the supervisory signals, both relays *2* and *4* will be in an unoperated condition and will provide a circuit for illuminating the disconnect lamp associated with the *B*-operator's cord. This circuit may be traced as follows: from battery through the disconnect lamp, through the armatures and contacts of relays *2* and *4*, thence through the front contact and armature of relay *5* to ground, thus illuminating the disconnect lamp. The ringing lamp will not be re-illuminated at this time, due to the fact that it has been previously locked out by relay *6*. The operator then removes the plug from the jack of the line called, and the apparatus in the trunk circuit is restored to normal condition.

In the circuit shown only keys are provided for ringing two parties. This circuit, however, is not confined to the use of two-party lines, but may be extended to four parties by simply duplicating the ringing keys and by connecting them with the proper current for selectively ringing the other stations.

The method of determining as to whether the called line is free or busy is similar to that previously described for the *A*-operator's cord circuit when making a local connection, and differs only in the fact that in the case of the trunk cord the test circuit is controlled through the contacts of a relay, whereas in the case of the *A*-operator's cord, the test circuit was controlled through the contacts of the listening key. The function of the resistance *10* and the battery connected thereto is the same as has been previously described.

The general make-up of trunking switchboard sections is not greatly different from that of the ordinary switchboard sections where no trunking is involved. In small exchanges where ring-down trunks are employed, the trunk line equipment is merely added to the regular jack and drop equipment of the switchboard. In common-battery multiple switchboards the *A*-boards differ in no respect from the standard single office multiple boards, except that immediately above the answering jacks and below the multiple there are arranged in suitable numbers the jacks of the outgoing trunks.

Where the offices are comparatively small, the incoming trunk portions of the *B*-boards are usually merely a continuance of the *A*-boards, the subscriber's multiple being continuous with and differing in no respect from that on the *A*-sections. Instead of the usual pairs of *A*-operators' plugs, cords, and supervisory equipment, there are on the key and plug shelves of these *B*-sections the incoming trunk plugs and their associated equipment.

In large offices it is customary to make the *B*-board entirely separate from the *A*-board, although the general characteristics of construction remain the same. The reason for separate *A*- and *B*-switchboards in large exchanges is to provide for independent growth of each without the growth of either interfering with the other.

A portion of an incoming trunk, or *B*-board, is shown in Fig. 220. The multiple is as usual, and, of course, there are no outgoing trunk jacks nor regular cord pairs. Instead the key and plug shelves are provided with the incoming-trunk plug equipments, thirty of these being about the usual quota assigned to each operator's position.

In multi-office exchanges, employing many central offices, such, for instance, as those in New York or Chicago, it is frequently found that nearly all of the calls that originate in one office are for subscribers whose lines terminate in some other office. In other words, the number of calls that have to be trunked to other offices is greatly in excess of the number of calls that may be handled through the multiple of the *A*-board in which they originate. It is

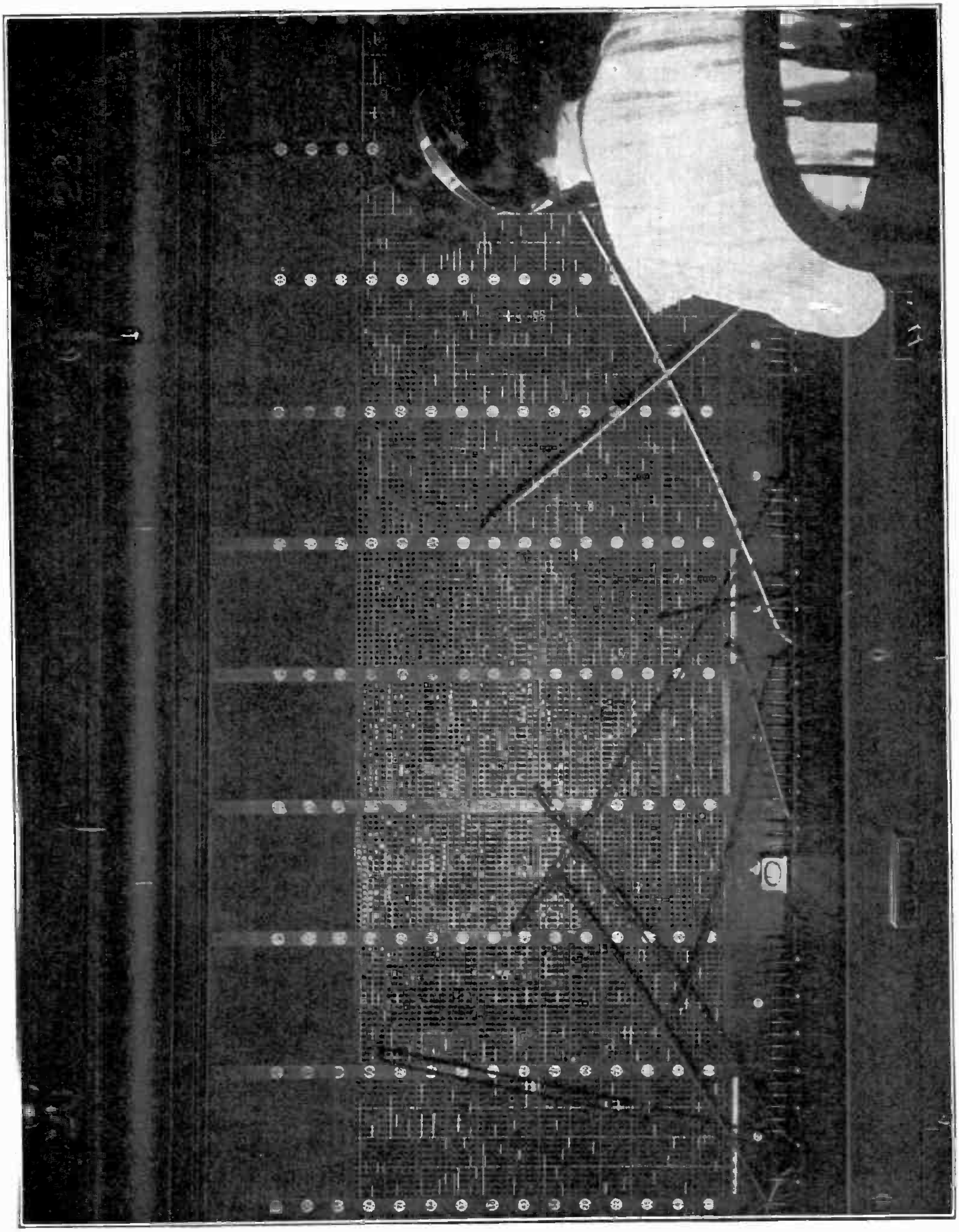


Fig. 220. Section of Trunk Switchboard

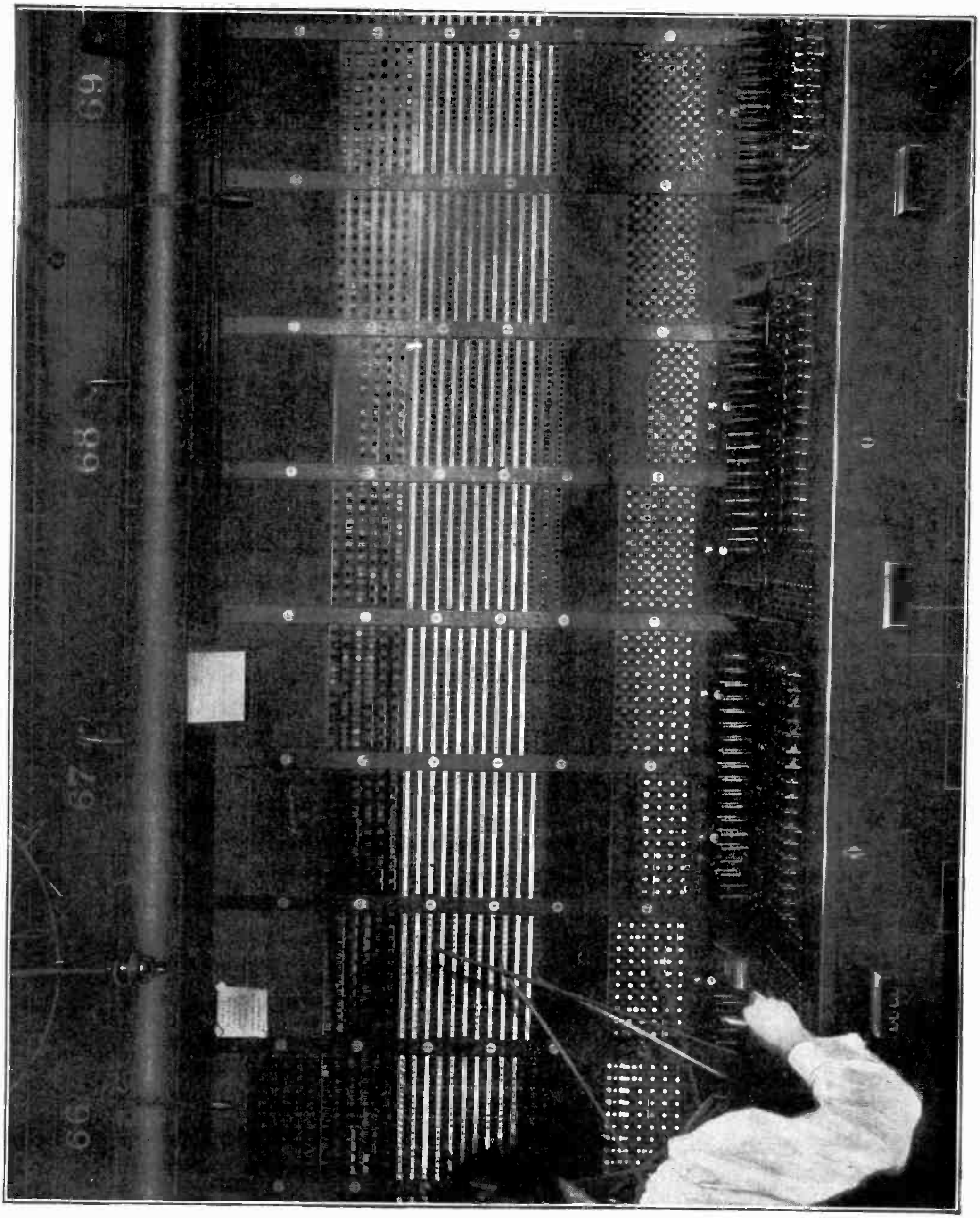


Fig. 221. Section of Partial Multiple Switchboard

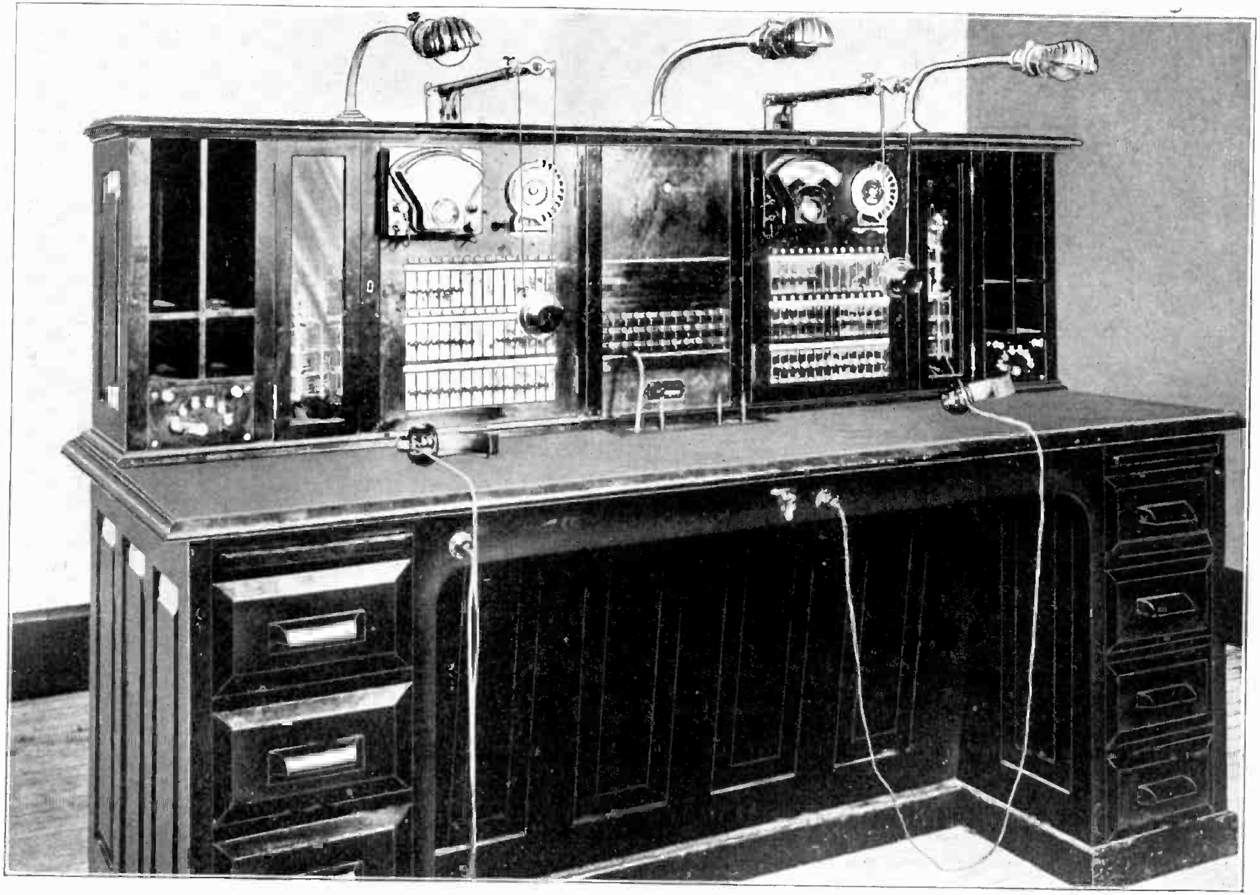
not infrequent to have the percentage of trunked calls run as high as 75 per cent of the total number of calls originating in any one office, and in some of the offices in the larger cities this percentage runs higher than 90 per cent.

This fact has brought up for consideration the problem as to whether, when the nature of the traffic is such that only a very small portion of the calls can be handled in the office where they originate, it is worth while to employ the multiple terminals for the subscribers' lines on the *A*-boards. In other words, if so great a proportion as 90 per cent of the calls have to be trunked any way, is it worth while to provide the great expense of a full multiple on all the sections of the *A*-board in order to make it possible to handle the remaining 10 per cent of the calls directly by the *A*-operators?

As a result of this consideration it has been generally conceded that where such a very great percentage of trunking was necessary, the full multiple of the subscribers' lines on each section was not warranted, and what is known as the partial multiple board has come into existence in large manual exchanges. In these the regular subscribers' multiple is entirely omitted from the *A*-board, all subscribers' calls being handled through outgoing trunk jacks connected by trunks to *B*-boards in the same as well as other offices. In these partial multiple *A*-boards, the answering jacks are multipled a few times, usually twice, so that calls on each line may be answered from more than one position. This multipling of answering jacks does not in any way take the place of the regular multipling in full multiple boards, since in no case are the calls completed through the multiple jacks. It is done merely for the purpose of contributing to team work between the operators.

A portion of such a partial multiple *A*-board is shown in Fig. 221. This view shows slightly more than one section, and the regular answering jacks and lamps may be seen at the bottom of the jack space just above the plugs. Above these are placed the outgoing trunk jacks, those that are in use being indicated with white designation strips. Above the outgoing trunk jacks are placed the multiples of the answering jacks, these not being provided with lamps.

The partial multiple *A*-section of Fig. 221 is a portion of the switchboard equipment of the same office to which the trunking section shown in Fig. 220 belongs. That this is a large multiple board may be gathered from the number of multiple jacks in the trunking section, 8,400 being installed with room for 10,500. That the board is a portion of an equipment belonging to an exchange of enormous proportions may be gathered from the number of outgoing trunk jacks shown in the *A*-board, and in the great number of order-wire keys shown between each of the sets of regular cord-circuit keys. The switchboards illustrated in these two figures are those of one of the large offices of the New York Telephone Company on Manhattan Island, and were especially taken for this work by the Western Electric Company.



WIRE CHIEF'S DESK FOR AUTOMATIC EQUIPMENT

CHAPTER XVI

FUNDAMENTAL CONSIDERATIONS OF AUTOMATIC SYSTEMS

Definition. The term automatic, as applied to telephone systems, has come to refer to those systems in which machines at the central office, under the guidance of the subscribers, do the work that is done by operators in manual systems. In all automatic telephone systems, the work of connecting and disconnecting the lines, of ringing the called subscriber, even though he must be selected from among those on a party line, of refusing to connect with a line that is already in use, and informing the calling subscriber that such line is busy, of making connections to trunk lines and through them to lines in other offices and doing the same sort of things there, of counting and recording the successful calls made by a subscriber, rejecting the unsuccessful, and nearly all the thousand and one other acts necessary in telephone service, are performed without the presence of any guiding intelligence at the central office.

The fundamental object of the automatic system is to do away with the central-office operator. In order that each subscriber may control the making of his own connections there is added to his station equipment a call transmitting device by the manipulation of which he causes the central-office mechanisms to establish the connections he desires.

We think that the automatic system is one of the most astonishing developments of human ingenuity. The workers in this development are worthy of particular notice. From occupying a position in popular regard in common with long-haired men and short-haired women they have recently appeared as sane, reasonable men with the courage of their convictions and, better yet, with the ability to make their convictions come true. The scoffers have remained to pray.

Arguments Against Automatic Idea. Naturally there has been a bitter fight against the automatic. Those who have opposed it have contended:

First: that it is too complicated and, therefore, could be neither reliable nor economical.

Second: that it is too expensive, and that the necessary first cost could not be justified.

Third: that it is too inflexible and could not adapt itself to special kinds of service.

Fourth: that it is all wrong from the subscribers' point of view as the public will not tolerate "doing its own operating."

Complexity. This first objection as to complexity, and consequent alleged unreliability and lack of economy should be carefully analyzed. It too often happens that a new invention is cast into outer darkness by those whose opinions carry weight by such words as "it cannot work; it is too complicated." Fortunately for the world, the patience and fortitude which men must possess before they can produce meritorious, though intricate inventions, are usually sufficient to prevent their being crushed by any such offhand condemnation, and the test of time and service is allowed to become the real criterion.

It would be difficult to find an art that has gone forward as rapidly as telephony. Within its short life of a little over thirty years it has grown from the phase of trifling with a mere toy to an affair of momentous importance to civilization. There has been a tendency, particularly marked during recent years, toward greater complexity; and probably every complicated new system or piece of apparatus has been roundly condemned, by those versed in the art as it was, as being unable to survive on account of its complication.

To illustrate: A prominent telephone man, in arguing against the nickel-in-the-slot method of charging for telephone service, once said, partly in jest, "The Lord never intended telephone service to be given in that way." This, while a little off the point, is akin to the sweeping aside of new telephone systems on the sole ground that they are complicated. These are not real reasons, but rather convenient ways of disposing of vexing problems with a minimum amount of labor. Important questions lying at the very root of the development of a great industry may not be put aside permanently in this offhand way. The Lord has never, so far as we know, indicated just what his intentions were in the matter of nickel service; and no one has ever shown yet just what degree of complexity will prevent a telephone system from working.

It is safe to say that, if other things are equal, the simpler a machine is, the better; but simplicity, though desirable, is not all-important. Complexity is warranted if it can show enough advantages.

If one takes a narrow view of the development of things mechanical and electrical, he will say that the trend is toward simplicity. The mechanic in designing a machine to perform certain functions tries to make it as simple as possible. He designs and re-designs, making one part do the work of two and contriving schemes for reducing the complexity of action and form of each remaining part. His whole trend is away from complication, and this is as it should be. Other things being equal, the simpler the better. A broad view, however, will show that the arts are becoming more and more complicated. Take the implements of the art of writing: The typewriter is vastly more complicated than the pen, whether of steel or quill, yet most of the writing of today is done on the typewriter, and is done better and more economically. The art of printing affords even more striking examples.

In telephony, while every effort has been made to simplify the component parts of the system, the system itself has ever developed from the simple toward the complex. The adoption of the multiple switchboard, of automatic ringing, of selective ringing on party lines, of measured-service appliances, and of automatic systems have all constituted steps in this direction. The adoption of more complicated devices and systems in telephony has nearly always followed a demand for the performance by the machinery of the system of additional or different functions. As in animal and plant life, so in mechanics—the higher the organism functionally the more complex it becomes physically.

Greater intricacy in apparatus and in methods is warranted when it is found desirable to make the machine perform added functions. Once the functions are determined upon, then the whole trend of the development of the machine for carrying them out should be toward simplicity. When the machine has reached its highest stage of development some one proposes that it be required to do something that has hitherto been done manually, or by a separate machine, or not at all. With this added function a vast added complication may come, after which, if it develops that the new function may with economy be performed by the machine, the process of simplification again begins, the whole design finally taking on an indefinable elegance which appears only when each part is so made as to be best adapted in composition, form, and strength to the work it is to perform.

Achievements in the past teach us that a machine may be made to do almost anything automatically if only the time, patience, skill, and money be brought to bear. This is also true of a telephone system. The primal question to decide is, what functions the system is to perform within itself, automatically, and what is to be done manually or with manual aid. Sometimes great complications are brought into the system in an attempt to do something which may very easily and cheaply be done by hand. Cases might be pointed out in which fortunes and life-works have been wasted in perfecting machines for which there was no real economic need. It is needless to cite cases where the reverse is true. The matter of wisely choosing the functions of the system is of fundamental importance. In choosing these the question of complication is only one of many factors to be considered.

One of the strongest arguments against intricacy in telephone apparatus is its greater initial cost, its greater cost of maintenance, and its liability to get out of order. Greater complexity of apparatus usually means greater first cost, but it does not necessarily mean greater cost of up-keep or lessened reliability. A dollar watch is more simple than an expensive one. The one, however, does its work passably and is thrown away in a year or so; the other does its work marvelously well and may last generations, being handed down from father to son. Merely reducing the number of parts in a machine does not necessarily mean greater reliability. Frequently the attempt to make one part do several diverse things results in such a sacrifice in the simplicity of action of that part as to cause undue strain, or wear, or unreliable action. Better results may be attained by adding parts, so that each may have a comparatively simple thing to do.

The stage of development of an art is a factor in determining the degree of complexity that may be allowed in the machinery of that art. A linotype machine, if constructed by miracle several hundred years ago, would have been of no value to the printer's art then. The skill was not available to operate and maintain it, nor was the need of the public sufficiently developed to make it of use. Similarly the automatic telephone exchange would have been of little value thirty years ago. The knowledge of telephone men was not sufficiently developed to maintain it, telephone users were not sufficiently numerous to warrant it, and the public was not sufficiently trained to use it. Industries, like human beings, must learn to creep before they can walk.

Another factor which must be considered in determining the allowable degree of complexity in a telephone system is the character of the labor available to care for and manage it. Usually the conditions which make for unskilled labor also lend themselves to the use of comparatively simple systems. Thus, in a small village remote from large cities the complexity inherent in a common-battery multiple switchboard would be objectionable. The village would probably not afford a man adequately skilled to care for it, and the size of the exchange would not warrant the expense of keeping such a man. Fortunately no such switchboard is needed. A far simpler device, the plain magneto switchboard—so simple that the girl who manipulates it may also often care for its troubles—is admirably adapted to the purpose. So it is with the automatic telephone system; even its most enthusiastic advocate would be foolish indeed to contend that for all places and purposes it was superior to the manual.

These remarks are far from being intended as a plea for complex telephone apparatus and systems; every device, every machine, and every system should be of the simplest possible nature consistent with the functions it has to perform. They are rather a protest against the broadcast condemnation of complex apparatus and systems just because they are complicated, and without regard to other factors. Such condemnation is detrimental to the progress of telephony. Where would the printing art be today if the linotype, the cylinder press, and other modern printing machinery of marvelous intricacy had been put aside on account of the fact that they were more complicated than the printing machinery of our forefathers?

That the automatic telephone system is complex, exceedingly complex, cannot be denied, but experience has amply proven that its complexity does not prevent it from giving reliable service, nor from being maintained at a reasonable cost.

Expense. The second argument against the automatic—that it is too expensive—is one that must be analyzed before it means anything. It is true that for small and medium-sized exchanges the total first cost of the central office and subscribers' station equipment, is greater than that for manual exchanges of corresponding sizes. The prices at which various sizes of automatic exchange equipments may be purchased vary, however, almost in direct proportion to the number of lines, whereas in manual equipment the price per line increases very rapidly as the number of lines increases. From this it follows that for very large exchanges the cost of automatic apparatus becomes as low, and may be even lower than for manual. Roughly speaking the cost of telephones and central-office equipment for small exchanges is about twice as great for automatic as for manual, and for very large exchanges, of about 10,000 lines, the cost of the two for switchboards and telephones is about equal.

For all except the largest exchanges, therefore, the greater first cost of automatic apparatus must be put down as one of the factors to be weighed in making the choice between automatic and manual, this factor being less and less objectionable as the size of the equipment increases and finally disappearing altogether for very large equipments. Greater first cost is, of course, warranted if the fixed charges on the greater investment are more than offset by the economy resulting. The automatic screw machine, for instance, costs many times more than the hand screw machine, but it has largely displaced the hand machine nevertheless.

Flexibility. The third argument against the automatic telephone system—its flexibility—is one that only time and experience has been able to answer. Enough time has elapsed and enough experience has been gained, however, to disprove the validity of this argument. In fact, the great flexibility of the automatic system has been one of its surprising developments. No sooner has the statement been made that the automatic system could not do a certain thing than forthwith it has done it. It was once quite clear that the automatic system was not practicable for party-line selective ringing; yet today many automatic systems are working successfully with this feature; the selection between the parties on a line being accomplished with just as great certainty as in manual systems. Again it has seemed quite obvious that the automatic system could not hope to cope with the reverting call problem, *i. e.*, enabling a subscriber on a party line to call back to reach another subscriber on the same line; yet today the automatic system may do this in a way that is perhaps even more satisfactory than the way in which it is done in multiple manual switchboards. It is true that the automatic system has not done away with the toll operator and it probably never will be advantageous to require it to do so for the simple reason that the work of the toll operator in recording the connections and in bringing together the subscribers is a matter that requires not only accuracy but judgment, and the latter, of course, no machine can supply. It is probable also that the private branch-exchange operator will survive in automatic systems. This is not because the automatic system cannot readily perform the switching duties, but the private branch-exchange operator has other duties than the mere building up and taking down of connections. She is, as it were, a door-keeper guarding the telephone door of a business establishment; like the toll operator she must be possessed of judgment and of courtesy in large degree, neither of which can be supplied by machinery.

In respect to toll service and private branch-exchange service where, as just stated, operators are required on account of the nature of the service, the automatic system has again shown its adaptability and flexibility. It has shown its capability of working in harmony with manual switchboards, of whatever nature, and there is a growing tendency to apply automatic devices and automatic principles of operation to manual switchboards, whether toll or private branch or other kinds, even though the services of an operator are required, the idea being to do by machinery that portion of the work which a machine is able to do better or more economically than a human being.

Attitude of Public. The attitude of the public toward the automatic is one that is still open to discussion; at least there is still much discussion on it. A few years ago it did seem reasonable to suppose that the general telephone user would prefer to get his connection by merely asking for it rather than to make it himself by "spelling" it out on the dial of his telephone instrument. We have studied this point carefully in a good many different communities and it is our opinion that the public finds no fault with being required to make its own connections. To our minds it is proven beyond question that either the method employed in the automatic or that in the manual system is satisfactory to the public as long as good service results, and it is beyond question that the public may get this with either.

Subscriber's Station Equipment. The added complexity of the mechanism at the subscriber's station is in our opinion the most valid objection that can be urged against the automatic system as it exists today. This objection has, however, been much reduced by the greater simplicity and greater excellence of material and workmanship that is employed in the controlling devices in modern automatic systems. However, the automatic system must always suffer in comparison with the manual in respect of simplicity of the subscriber's equipment. The simplest conceivable thing to meet all of the requirements of telephone service at a subscriber's station is the modern common-battery manual telephone. The automatic telephone differs from this only in the addition of the mechanism for enabling the subscriber to control the central-office apparatus in the making of calls. From the standpoint of maintenance, simplicity at the subscriber's station is, of course, to be striven for since the proper care of complex devices scattered all over a community is a much more serious matter than where the devices are centered at one point, as in the central office. Nevertheless, as pointed out, complexity is not fatal, and it is possible, as has been proven, to so design and construct the required apparatus in connection with the subscribers' telephones as to make them subject to an amount of trouble that is not serious.

Comparative Costs. A comparison of the total costs of owning, operating, and maintaining manual and automatic systems usually results in favor of the automatic, except in small exchanges. This seems to be the consensus of opinion among those who have studied the matter deeply. Although the automatic usually requires a larger investment, and consequently a larger annual charge for interest and depreciation, assuming the same rates for each case, and although the automatic requires a somewhat higher degree of skill to maintain it and to keep it working properly than the manual, the elimination of operators or the reduction in their number and the consequent saving of salaries and contributory expenses together with other items of saving that will be mentioned serves to throw the balance in favor of the automatic.

The ease with which the automatic system lends itself to inter-office trunking makes feasible a greater subdivision of exchange districts into office districts and particularly makes it economical, where such would not be warranted in manual working. All this tends toward a reduction in average length of subscribers' lines and it seems probable that this possibility will be worked upon in the future, more than it has been in the past, to effect a considerable saving in the cost of the wire plant, which is the part of a telephone plant that shows least and costs most.

Automatic vs. Manual. Taking it all in all the question of automatic versus manual may not and can not be disposed of by a consideration of any single one of the alleged features of superiority or inferiority of either. Each must be looked at as a practical way of giving telephone service, and a decision can be reached only by a careful weighing of all the factors which contribute to economy, reliability, and general desirability from the standpoint of the public. Public sentiment must neither be overlooked nor taken lightly, since, in the final analysis, it is the public that must be satisfied.

Methods of Operation. In all of the automatic telephone systems that have achieved any success whatever, the selection of the desired subscriber's line by the calling subscriber is accomplished by means of step-by-step mechanism at the central office, controlled by impulses sent or caused to be sent by the acts of the subscriber.

Strowger System. In the so-called Strowger system, manufactured by the Automatic Electric Company of Chicago, the subscriber, in calling, manipulates a dial by which the central-office switching mechanism is made to build up the connection he wants. The dial is moved as many times as there are digits in the called subscriber's number and each movement sends a series of impulses to the central office corresponding in number respectively to the digits in the called subscriber's number. During each pause, except the last one, between these series of impulses, the central-office mechanism operates to shift the control of the calling subscriber's line from one set of switching apparatus at the central office to another.

In case a four-digit number is being selected first, the movement of the dial by the calling subscriber will correspond to the thousands digit of the number being called, and the resulting movement of the central-office apparatus will continue the calling subscriber's line through a trunk to a piece of apparatus capable of further extending his line toward the line terminals of the thousand subscribers whose numbers begin with the digit chosen. The next movement of the dial corresponding to the hundreds digit of the called number will operate this piece of apparatus to again extend the calling subscriber's line through another trunk to apparatus representing the particular hundred in which the called subscriber's number is. The third movement of the dial corresponding to the tens digit will pick out the group of ten containing the called subscriber's line, and the fourth movement corresponding to the units digit will pick out and connect with the particular line called.

Lorimer System. In the Lorimer automatic system invented by the Lorimer Brothers, and now being manufactured by the Canadian Machine Telephone Company of Toronto, Canada, the subscriber sets up the number he desires complete by moving four levers on his telephone so that the desired number appears visibly before him. He then turns a handle and the central-office apparatus, under the control of the electrical conditions thus set up by the subscriber, establishes the connection. In this system, unlike the Strowger system, the controlling impulses are not caused by the movement of the subscriber's apparatus in returning to its normal position after being set by the subscriber. Instead, the conditions established at the subscriber's station by the subscriber in setting up the desired number, merely determine the point in the series of impulses corresponding to each digit at which the stepping impulses local to the central office shall cease, and in this way the proper number of impulses in the series corresponding to each digit is determined.

Magnet- vs. Power-Driven Switches. These two systems differ radically in another respect. In the Strowger system it is the electrical impulses initiated at the subscriber's apparatus that actually cause the movement of the switching parts at the central office, these impulses energizing electromagnets which move the central-office switching devices a step at a time the desired number of steps. In the Lorimer system the switches are all power-driven and the impulses under the control of the subscriber's instrument merely serve to control the application of this power to the various switching mechanisms. These details will be more fully dealt with in subsequent chapters.

Multiple vs. Trunking. It has been shown in the preceding portion of this work that the tendency in manual switchboard practice has been away from trunking between the various sections or positions of a board, and toward the multiple idea of operating, wherein each operator is able to complete the connection with any line in the same office without resorting to trunks or to the aid of other operators. Strangely enough the reverse has been true in the development of the automatic system. As long as the inventors tried to follow the most successful practice in manual working, failure resulted. The automatic systems of today are essentially trunking systems and while they all involve multiple connections in greater or less degree, all of them depend fundamentally upon the extending of the calling line by separate lengths until it finally reaches and connects with the called line.

Grouping of Subscribers. In this connection we wish to point out here two very essential features without which, so far as we are aware, no automatic telephone system has been able to operate successfully. The first of these is the division of the total number of lines in any office of the exchange into comparatively small groups and the employment of correspondingly small switch units for each group. Many of the early automatic systems that were proposed involved the idea of having each switch capable in itself of making connection with any line in the entire office. As long as the number of lines was small—one hundred or thereabouts—this might be all right, but where the lines number in the thousands, it is readily seen that the switches would be of prohibitive size and cost.

Trunking between Groups. This feature made necessary the employment of trunk connections between groups. By means of these the lines are extended a step at a time, first entering a large group of groups, containing the desired subscriber; then entering the smaller group containing that subscriber; and lastly entering into connection with the line itself. The carrying out of this idea was greatly complicated by the necessity of providing for many simultaneous connections through the switchboard. It was comparatively easy to accomplish the extension of one line through a series of links or trunks to another line, but it was not so easy to do this and still leave it possible for any other line to pick out and connect with any other idle line without interference with the first connection. A number of parallel paths must be provided for each possible connection. Groups of trunks are, therefore, provided instead of single trunks between common points to be connected. The subscriber who operates his instrument in making a call knows nothing of this and it is, of course, impossible for him to give any thought to the matter as to which one of the possible paths he shall choose. It was by a realization of these facts that the failures of the past were turned into the successes of the present. The subscriber by setting his signal transmitter was made to govern the action of the central-office apparatus in the selection of the proper *group* of trunks. The group being selected, the central-office apparatus was made to act at once *automatically* to pick out and connect with *the first idle trunk of such group.* Thus, we may say *that the subscriber by the act performed on his signal transmitter, voluntarily chooses the group of trunks, and immediately thereafter the central-office apparatus without the volition of the subscriber picks out the first idle one of this group of trunks so chosen.* This fundamental idea, so far as we are aware, underlies all of the successful automatic telephone-exchange systems. It provides for the possibility of many simultaneous connections through the switchboard, and it provides against the simultaneous appropriation of the same path by two or more calling subscribers and thus assures against interference in the choice of the paths.

Outline of Action. In order to illustrate this point we may briefly outline the action of the Strowger automatic system in the making of a connection. Assume that the calling subscriber desires a connection with a subscriber whose line bears the number 9,567. The subscriber in making the call will, by the first movement of his dial, transmit nine impulses over his line. This will cause the selective apparatus at the central office, that is at the time associated with the calling subscriber's line, to move its selecting fingers opposite a group of terminals representing the ends of a group of trunk lines leading to apparatus employed in connecting with the ninth thousand of the subscribers' lines.

While the calling subscriber is getting ready to transmit the next digit, the automatic apparatus, without his volition, starts to pick out the first idle one of the group of trunks so chosen. Having found this it connects with it and the calling subscriber's line is thus extended to another selective apparatus capable of performing the same sort of function in choosing the proper hundreds group.

In the next movement of his dial the calling subscriber will send five impulses. This will cause the last chosen selective switch to move its selective fingers opposite a group of terminals representing the ends of a group of trunks each leading to a switch that is capable of making connection with any one of the lines in the fifth hundred of the ninth thousand. Again during the pause by the subscriber, the switch that chose this group of trunks will start automatically to pick out and connect with the first idle one of them, and will thus extend the line to a selective switch that is capable of reaching the desired line, since it has access to all of the lines in the chosen hundred. The third movement of the dial sends six impulses and this causes this last chosen switch to move opposite the sixth group of ten terminals, so that there has now been chosen the nine hundred and fifty-sixth group of ten lines. The final movement of the dial sends seven impulses and the last mentioned switch connects with the seventh line terminal in the group of ten previously chosen and the connection is complete, assuming that the called line was not already engaged. If it had been found busy, the final switch would have been prevented from connecting with it by the electrical condition of certain of its contacts and the busy signal would have been transmitted back to the calling subscriber.

Fundamental Idea. This idea of subdividing the subscribers' lines in an automatic exchange, of providing different groups of trunks so arranged as to afford by combination a number of possible parallel paths between any two lines, of having the calling subscriber select, by the manipulation of his instrument, the proper group of trunks any one of which might be used to establish the connection he desires, and of having the central-office apparatus act automatically to choose and connect with an idle one in this chosen group, should be firmly grasped. It appears, as we have said, in every successful automatic system capable of serving more than one small group of lines, and until it was evolved automatic telephony was not a success.

Testing. As each trunk is chosen and connected with, conditions are established, by means not unlike the busy test in multiple manual switchboards, which will guard that trunk and its associated apparatus against appropriation by any other line or apparatus as long as it is held in use. Likewise, as soon as any subscriber's line is put into use, either by virtue of a call being originated on it, or by virtue of its being connected with as a called line, conditions are automatically established which guard it against being connected with any other line as long as it is busy. These guarding conditions of both trunks and lines, as in the manual board, are established by making certain contacts, associated with the trunks or lines, assume a certain electrical condition when busy that is different from their electrical condition when idle; but unlike the manual switchboard this different electrical condition does not act to cause a click in any one's ear, but rather to energize or de-energize certain electromagnets which will establish or fail to establish the connection according to whether it is proper or improper to do so.

Local and Inter-Office Trunks. The groups of trunks that are used in building up connections between subscribers' lines may be local to the central office, or they may extend between different offices. The action of the two kinds of trunks, local or inter-office, is broadly the same.

CHAPTER XVII

PRIVATE BRANCH EXCHANGES

Definitions. A telephone exchange devoted to the purely local uses of a private establishment such as a store, factory, or business office, is a private exchange. If, in addition to being used for such local communication, it serves also for communication with the subscribers of a city exchange, it becomes in effect a branch of the city exchange and, therefore, a private branch exchange. The term "P. B. X." has become a part of the telephone man's vocabulary as an abbreviation for private branch exchange.

Private exchanges for purely local use require no separate treatment as any of the types of switching equipments for interconnecting the lines for communication, that have been or that will be described herein, may be used. The problem becomes a special one, however, when communication must also be had with the subscribers of a public exchange, since then trunking is involved in which the conditions differ materially from those encountered in trunking between the several offices in a multi-office exchange.

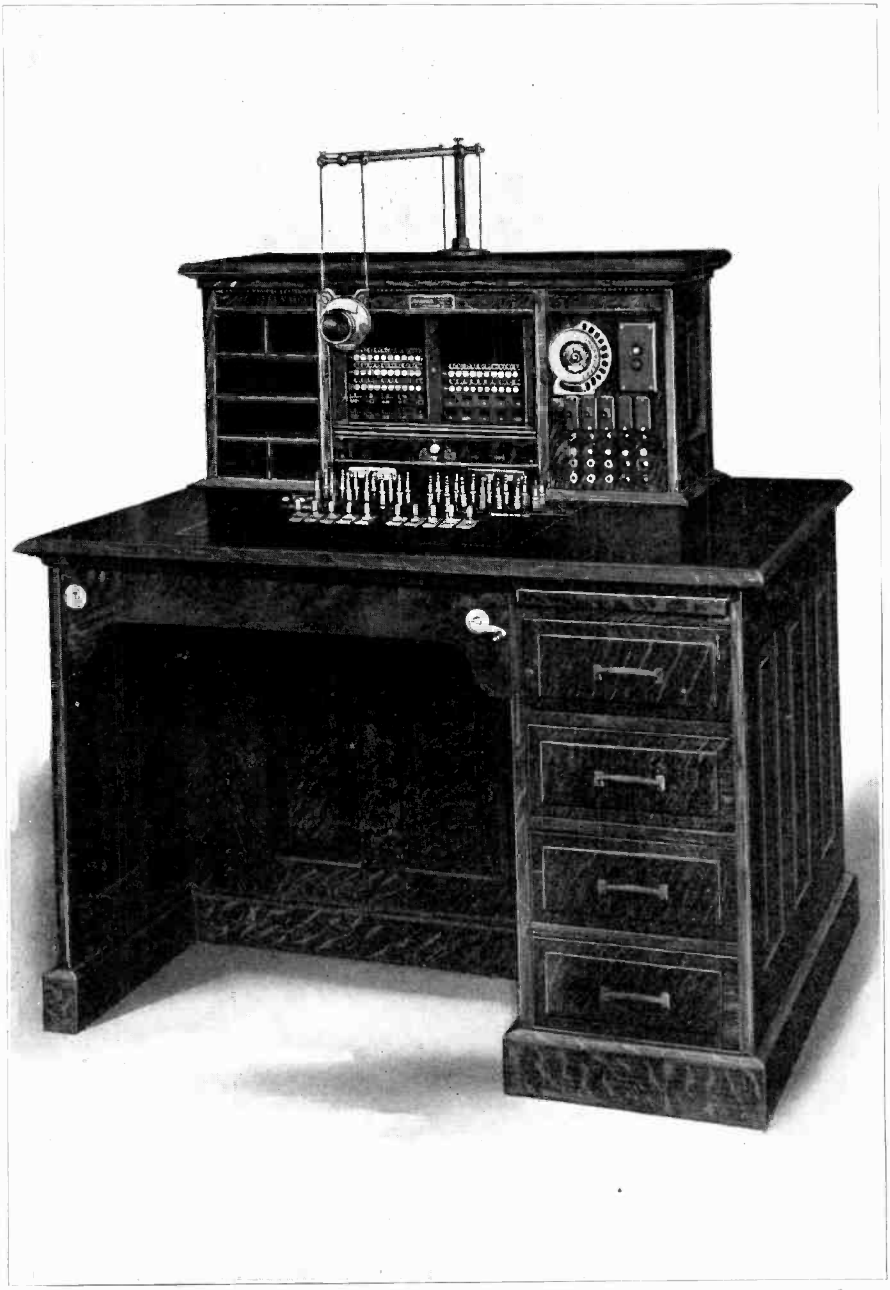
For such communication one or more trunk lines are led from the private branch office usually to the nearest central office of the public exchange and such trunks are called private branch-exchange trunks. They are the paths for communication between the private exchange and the public exchange. For establishing the connections either between the local lines themselves or between the local lines and the trunks, and for performing other duties that will be referred to, one or more private branch-exchange operators are employed at the switchboard of the private establishment.

The private branch exchange may operate in conjunction with a manual or an automatic public exchange, but whether manual or automatic, the private exchange is usually manually operated, although it is quite possible to make a private branch exchange that is wholly automatic and will, therefore, involve no operator at all.

Functions of the Private Branch-Exchange Operator. It is possible, as just stated, entirely to dispense with the private branch-exchange operator so far as the mere connection and disconnection of the lines is concerned. But the real function of the private branch-exchange operator is a broader one than this, and it is for this reason that even in connection with automatic public exchanges, operators are desirable at the private branches. The private branch-exchange operator is, as it were, the doorkeeper of the telephone entrance to the private establishment. She is the person first met by the public in entering this telephone door. There is the same reason, therefore, why she should be intelligent, courteous, and obliging as that the ordinary doorkeeper should possess these characteristics.

As to incoming traffic to a private branch exchange, an intelligent operator may do much toward directing the calls to the proper department or person, even though the person calling may have little idea as to whom he desires to reach. This saves the time of the person who makes the call as well as that of the people at the private branch stations, since it prevents their being unnecessarily called.

The functions of the private branch-exchange operator are no less important with respect to outgoing calls. It is the duty of the operator to obtain connections through the city exchange for the private branch subscriber, who merely asks for a certain connection and hangs up his receiver to await her call when she shall have obtained it. This saving of time of busy people by having the branch-exchange operator make their calls for them has one attending disadvantage, which is that the person in the city exchange who is called does not, when he answers his telephone, find the real party with whom he is to converse, but has to wait until that party responds to the private branch operator's call. This is akin to asking a person to call at one's office and then being out when he gets there. This drawback is greatly accentuated where both the parties that are to be involved in the connection are people high in authority in certain establishments at private branch exchanges. Some business houses have made the rule that the private branch operator shall not connect with their lines until she has actually heard the voice of the proper party at the other end. When two subscribers in two different private branch exchanges where this rule is enforced, attempt to get



MONARCH PRIVATE BRANCH BOARD
Equipped with Both Lamp and Visual Signals and with an Automatic Selector

into communication with each other, the possibilities of trouble are obvious.

All that may be said on this matter is that the person who calls another by telephone should extend that person the same courtesies that he would had he called him in person to his office; and that a person who is called by telephone by another should meet him with the same consideration as if he had received a personal call at his office or home. The arbitrary ruling made by some corporations and persons, which results always in the "other fellow's" doing the waiting, is not ethically correct nor is it good policy.

Private Branch Switchboards. Private branch switchboards may be of common-battery or magneto types regardless of whether they work in conjunction with main office equipments having common-battery or magneto equipments. Usually a magneto private branch exchange works in conjunction with a magneto main office, but this is not always true. There are cases where the private branch equipment of modern common-battery type works in conjunction with main office equipment of the magneto type; and in some of these cases the private branch exchange has a much larger number of subscribers than the main office. This is likely to be true in large summer resort hotels located in small and otherwise unimportant rural districts. In one such case within our knowledge the private branch exchange has a larger number of stations than the total census population of the town, resulting in an apparent telephone development considerably greater than one hundred per cent.

Magneto Type. Where both the private branch and the main office equipments are of the magneto type, the private branch requirements are met by a simple magneto switchboard of the requisite size, and the trunking conditions are met by ring-down trunks extending to the main office. In this case the supervision is that of the ordinary clearing-out drop type, the operators working together as best they may.

Common-Battery Type. The cases where the private branch board is of common-battery type and the main office of magneto type are comparatively so few that they need not be treated here. Where they do occur they demand special treatment because the main portion of the traffic over the trunk lines to the city or town central office is likely to be toll traffic through that office over long-distance lines. The principal reason why the equipment of the town offices under such conditions is magneto rather than common battery is that the traffic conditions are those of short season and heavy toll, and common-battery switching equipment at the main office has no especial advantages for toll work.

For small private branch exchanges the desk type of switch board, shown in Fig. 222, is largely used. The operator frequently

Fig. 222. Desk Type, Private Branch Board

has other work to do and the desk is, therefore, a convenience. In larger private exchanges, such as those requiring more than one operator, some form of upright cabinet is employed, and if, as sometimes occurs, the branch exchange is of such size as to demand a multiple board, then the general form of the board does not differ materially from the standard types of multiple board employed in regular central office work. The most common private branch-exchange condition is that of a common-battery branch working into a common-battery main office. In such the main point to be considered is that of supervision of trunk-line connections.

Cord Type. For the larger sizes of branch exchange switchboards, the switching apparatus is practically the same as that of ordinary manual switchboards wherein the connections are made between the various lines by means of pairs of cords and plugs. The private branch-exchange trunk lines usually terminate on the private branch board in jacks but in some cases plug-ended trunks are used.

The line signals may consist in mechanical visual signals or in lamps, the choice between these depending largely on the source

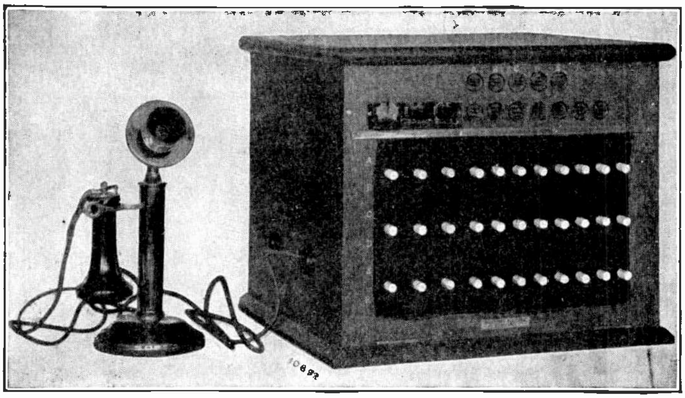


Fig. 223. Key Type, Private Branch Board

of battery supply at the branch exchange, a matter which will be considered later. The trunk-line signals at the private branch board are usually ordinary drops which are thrown when the main-exchange operator rings on the line as she would on an ordinary subscriber's line. Frequently, however, lamp signals are used for this purpose, being operated by locking relays energized when the main-office operator rings or, in some cases, operated at the time when the main-office operator plugs into the trunk-line jack.

Key Type. For small private branch-exchange switchboards, a type employing no cords and plugs has come into great favor during recent years. Instead of connecting the lines by jacks and plugs, they are connected by means of keys closely resembling ordinary ringing and listening keys. Such a switchboard is shown in Fig. 223, this having a capacity of three trunks, seven local lines, and the equivalent of five cord circuits. The drops associated with the three trunks may be seen in the upper left-hand side of the face of the switchboard. Immediately below these in three vertical rows are the keys which are used in connecting the trunks with the "cord circuits" or connecting bus wires. At the right of the drop associated

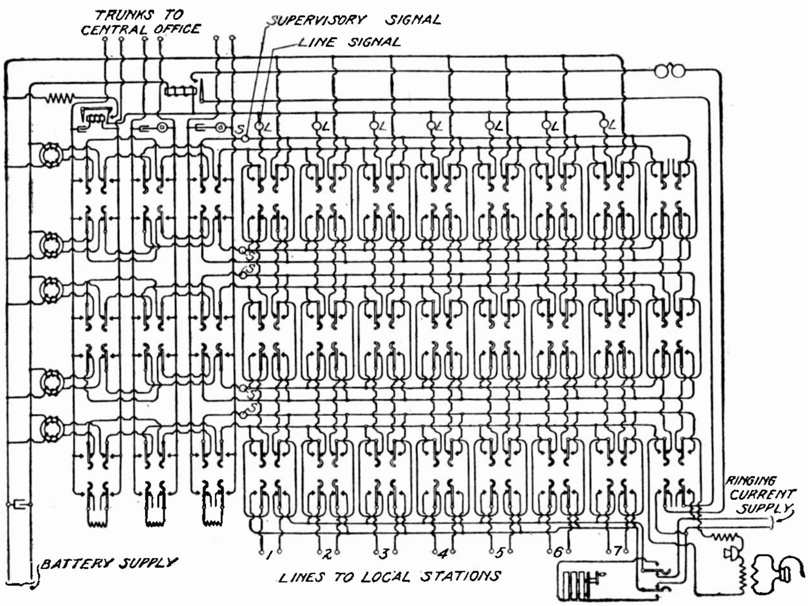


Fig. 224. Circuits, Key-Type Board

with the trunks are seven visual signals, these being the calling signals of the local lines. The seven vertical rows of keys, immediately to the right of the three trunk-line rows, are the line keys. The throwing of any one of these keys and of a trunk-line key in the same horizontal row in the same direction will connect a line with a trunk through the corresponding bus wires, leaving one of the supervisory visual signals, shown at the extreme top of the board, connected with the circuit. The keys in a single row at the right are those by means of which the operator may bridge her talking set across any of the "cord circuits." The circuits of this particular board are shown in Fig. 224. This is equipped for common-battery working, the battery feed wires being shown at the left.

Supervision of Private Branch Connections. At the main office where common-battery equipment is used, the private branch trunks terminate before the *A*-operators exactly in the same way as ordinary subscribers' lines, *i. e.*, each in an answering jack and lamp at one position and in a multiple jack on each section. It goes without saying, therefore, that the handling of a private branch call, either incoming or outgoing, should be done by the *A*-operator in the same manner as a call on an ordinary subscriber's line, and that the supervision of the connection should impose no special duties on the *A*-operator.

There has been much discussion, and no final agreement, as to the proper method of controlling the supervisory lamp at the main office of a cord that is, at the time, connected to a private branch trunk. Three general methods have been practiced:

The first method is to have the private branch subscriber directly control the supervisory lamp at the main office without producing any effect upon the private branch supervisory signal; this latter signal being displayed only after the connection has been taken down at the main office and in response to the withdrawal of the main office plug from the private branch jack. This is good practice so far as the main-office discipline is concerned but it results in a considerable disadvantage to both the city and private branch subscribers in that it is impossible for the private branch subscriber, when connected to the other, to re-signal the private branch operator without the connection being first taken down.

The second method is to have the private branch subscriber control both the supervisory signal at the private branch board and at the main board. This has the disadvantage of bringing both operators in on the circuit when the private branch subscriber signals.

The third method, and one that seems best, is to place the supervisory lamp of the private branch board alone under the control of the private branch subscriber, so that he may attract the attention of the private branch operator without disturbing the supervisory signal at the main office. The supervisory signal at the main office in this case is displayed only when the private branch operator takes down the connection. This practice results in a method of operation at the main office that involves no special action on the part of the

A-operator. She takes down the connection only when the main-office subscriber has hung up his telephone and the private branch subscriber has disconnected from the trunk.

Whatever method is employed, private branch disconnection is usually slow, and for this reason many operating companies instruct the *A*-operators to disconnect on the lighting of the supervisory lamp of the city subscriber.

With Automatic Offices. Private branch exchanges most used in connection with automatic offices employ manual switchboards, with the cord circuits of which is associated a signal transmitting device by which the operator instead of the subscriber may manipulate the automatic apparatus of the public exchange by impulses sent over the private branch-exchange trunk lines. The subscriber's equipment at the private branch stations may be either automatic or manual. Frequently the same private branch exchange will contain both kinds. With the manual sub-station equipment the operation is exactly the same as in a private branch of a manual exchange, except that the private branch operator by means of her dial makes the central-office connection instead of telling the main-office operator to do so for her. With automatic sub-station equipment at the private branch the subscribers, by removing their receivers from their hooks, call the attention of the private branch operator, who may receive their orders and make the desired central-office connection for them, or who may plug their lines through to the central office and allow the subscribers to make the connection themselves with their own dials.

In automatic equipment of the common-battery type, some change always takes place in the calling line at the time the called subscriber answers. In the three-wire system during the time of calling, both wires are of the same polarity with respect to earth. At the time of the answering of the called subscriber, the two wires assume different polarities, one being positive to the other. Such a change is sufficient for the actuation of devices local to the private exchange switchboard and may be interpreted through the calling supervisory signal in such a way as to allow it to glow during calling and not to glow after the called subscriber has answered. In the two-wire automatic system a similar change can be arranged for, with similar advantageous results.

Secrecy. In private exchanges operating in connection with automatic central offices, the secret feature of individual lines may or may not be carried into the private exchange equipment. Some patrons of automatic exchanges set a high value on the absence of any operator in a connection and transact business over such lines which they would not transact at all over manual lines or would not transact in the same way over manual lines. To some such patrons, the presence of a private exchange operator, even though employed and supervised by themselves, seems to be a disadvantage. To meet such a feeling, it is not difficult to arrange the circuits of a private exchange switchboard so that the operator may listen in upon a cord circuit at any time and overhear what is being said upon it *so long as two subscribers are not in communication on that cord circuit.* That is, she may answer a call and may speak to the calling person at any time she wishes until the called person answers. When he does answer and conversation can take place, some device operates to disconnect her listening circuit from the cord circuit, not to be connected again until at least one of the subscribers has hung up his receiver. With private exchange apparatus so arranged, the secrecy of the system is complete.

Battery Supply. There are three available methods of supplying direct current for talking and signaling purposes to private branch exchanges, each of which represents good practice under certain conditions. First, by means of pairs of wires extended from the central-office battery; second, by means of a local storage battery at the private branch exchange charged over wires from the central office; and third, by means of a local storage battery at the private exchange charged from a local source.

The choice of these three methods depends always on the local conditions and it is a desirable feature, to be employed by large operating companies, to have all private branch-exchange switchboards provided with simple convertible features contained within the switchboard for adapting it to any one cf these methods of supplying current.

If a direct-current power circuit is available at the private branch exchange, it may be used for charging the local storage battery by inserting mere resistance devices in the charging leads. If the local power circuit carries alternating current, a converting device of some sort must be used and for this purpose, if the exchange is large enough to warrant it, a mercury rectifier is an economical and simple device.

The supply of current to private branch exchanges over wires leading to the central-office battery has the disadvantage of requiring one or several pairs of wires in the cables carrying the trunk wires. No special wires are run, regular pairs in the paper insulated line or trunk cables being admirably suited for the purpose. Sufficient conductivity may be provided by placing several such pairs in multiple.

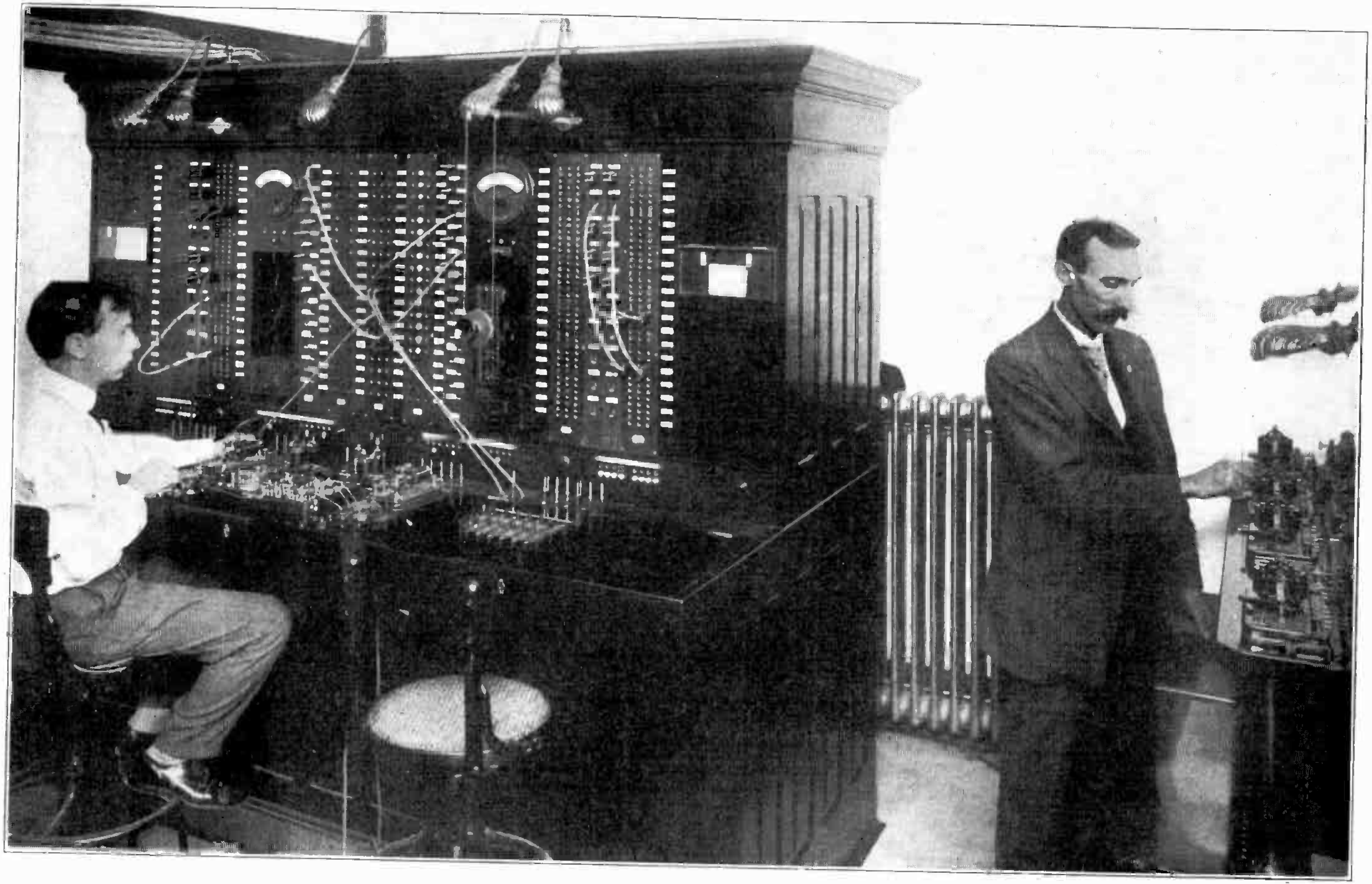
If the amount of current required by the private exchange warrants it, pairs of charging wires from the central office may be fewer if a battery is charged over them than if they are used direct to the bus bars of the private exchange switchboard. If they are used in the latter way, and this is simpler for reasons of maintenance, some means must be provided to prevent the considerable resistance of the supply wires from introducing cross-talk into the circuit of the private exchange. The usual method of avoiding this difficulty is by bridging a considerable capacity across the supply pairs at the private exchange—ten to twelve microfarads capacity will, as a rule, suffice.

The number of pairs of wires, or, in other words, the amount of copper in the battery lead between the central office and the private branch-exchange switchboard needs to be properly determined not only to eliminate cross-talk when the proper condensers are used with them, but to furnish the proper difference of potential at the private exchange bus bars, so that the line and supervisory signals will receive the proper current. It is a convenience in installing and maintaining private exchange switchboards of this kind to prepare tables showing the number of pairs of No. 19 gauge and No. 22 gauge wires required for a private exchange at a given distance from its central office and of a probable amount of traffic. The traffic may be expressed in the maximum number of pairs of cords which will be in use at one time. With this fact and the distance, the number of pairs of wires required may be determined.

Ringing Current. The ringing current may be provided in two ways: over pairs of wires from the city-office ringing machines or by means of a local hand generator, or both. A key should enable either of these sources of ringing current to be chosen at will.

Marking of Apparatus. All apparatus should be marked with permanent and clear labels. That private exchange switchboard is best at which an almost uninformed operator could sit and operate it at once. It is not difficult to lay out a scheme of labels which will enable such a board to be operated without any detailed instructions being given.

Desirable Features. The board should contain means of connecting certain of the local private exchange lines to the central-office trunks when the board is unattended. Also, it is desirable that it should contain means whereby any local private exchange line may be connected to the trunk so that its station will act as an ordinary subscriber's station. Whether the trunks of the private exchange lead to a manual or an automatic equipment, it often is desired to connect a local line through in that way, either so that the calling person may make his calls without the knowledge of the private exchange operator, because he wishes to make a large number of calls in succession, or because for some other reason he prefers to transact his business directly with or through the exchange than to entrust it to his operator.



PHANTOM AND MORSE TEST BOARD
Long-Distance Telephone and Telegraph Co., Lincoln, Neb.

CHAPTER XVIII

PHANTOM, SIMPLEX, AND COMPOSITE CIRCUITS

Definitions. Phantom circuits are arrangements of telephone wires whereby more working, non-interfering telephone lines exist than there are sets of actual wires. When four wires are arranged to provide three metallic circuits for telephone purposes, two of the lines are physical circuits and one is a phantom circuit.

Simplex and composite circuits are arrangements of wires whereby telephony and telegraphy can take place at the same time over the same wires without interference.

Phantom. In Fig. 225 four wires join two offices. *RR* are repeating coils, designed for efficient transforming of both talking

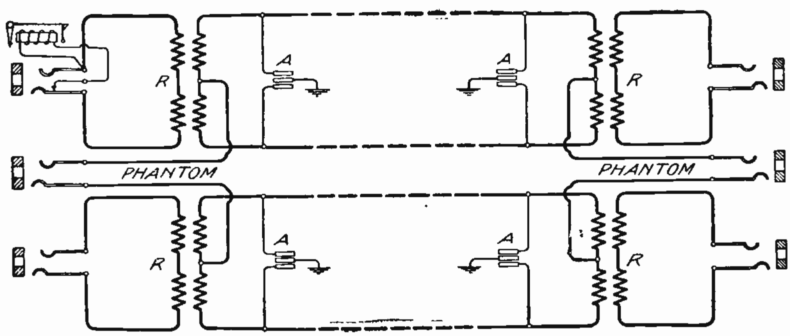


Fig. 225. Phantom Circuit

and ringing currents. The devices marked *A* in this and the following figures are air-gap arresters. Currents from the telephones connected to either physical pair of wires pass, at any instant, in opposite directions in the two wires of the pair. The phantom circuit uses one of the physical pairs as a *wire* of its line. It does this by tapping the middle point of the line side of each of the repeating coils. The impedance of the repeating-coil winding is lowered because, all the windings being on the same core, the phantom line currents pass from the middle to the outer connections so as to neutralize each other's influence. The currents of the phantom circuit, unlike those of the physical circuits, are *in the same direction* in both wires of a pair at any instant. Their potentials, therefore, are equal and simultaneous.

A phantom circuit is formed most simply when both physical lines end in the same two offices. If one physical line is longer than

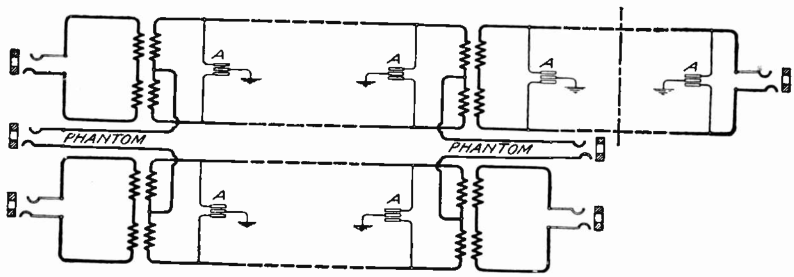


Fig. 226. Phantom from Two Physical Circuits of Unequal Length

the other, a phantom circuit may be formed as in Fig. 226, wherein the repeating coil is inserted in the longer line where it passes through a terminal station of the shorter.

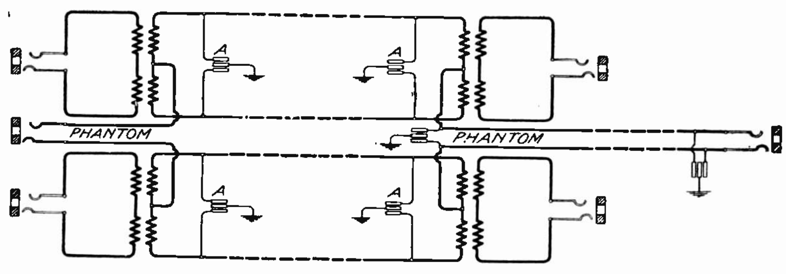


Fig. 227. Phantom Extended by Physical Circuit

A circuit may be built up by adding a physical circuit to a phantom. A circuit may be made up of two or more phantom circuits, joined by physical ones. In Fig. 227 a phantom circuit is extended by the use of a physical circuit, while in Fig. 228, two phantom circuits are joined by placing between them a physical circuit.

Transpositions. In phantom circuits formed merely by inserting repeating coils in physical circuits and doing nothing else, an exact balance of the sides of the phantom circuit is lacking. The

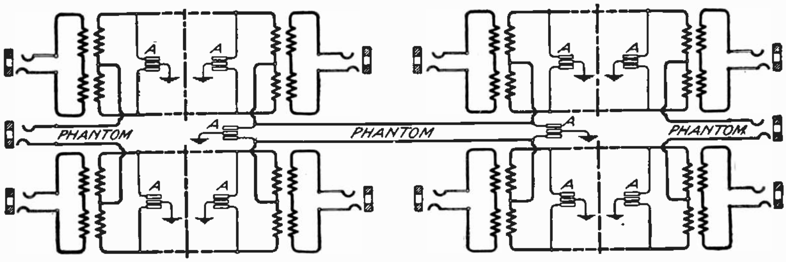


Fig. 228. Two Phantoms Joined by Physical Circuit

resistances, insulations, and capacities to earth of the sides may be equal, but the exposures to adjacent telephone and telegraph circuits and to power circuits will not be equal unless the phantom circuits are transposed.

To transpose a set of lines of two physical wires each, is not complicated, though it must be done with care and in accordance

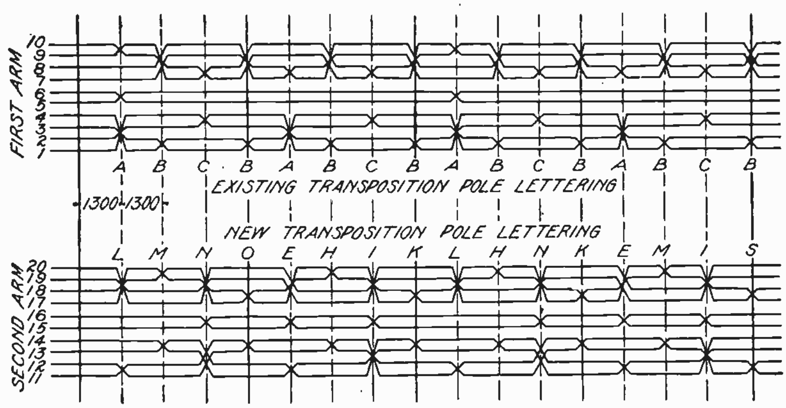


Fig. 229. Transposition of Phantom Circuits

with a definite, foreknown plan. Transposing phantom circuits is less simple, however, as four wires per circuit have to be transposed, instead of two.

In Fig. 229, the general spacing of transposition sections is the usual one, 1,300 feet, of the *ABCB* system widely in use. The pole circuit, on pins *5* and *6* of the upper arm, is transposed once each two miles. The pole circuit of the second arm transposes either once or twice a mile. But neither pole circuit differs in transposition from any other regular scheme except in the frequency of transposition. All the other wires of each arm, however, are so arranged that each wire on either side of the pole circuit moves from pin to pin at section-ends, till it has completed a cycle of changes over all four of the pins on its side. In doing so, each phantom circuit is transposed with proper regard to each of the other three on that twenty-wire line.

The "new transposition" lettering in Fig. 229 is for the purpose of identifying the exact scheme of wiring each transposition pole. The complication of wiring at each transposition pole is increased by the adoption of phantom circuits. Maintenance of all the circuits is made more costly and less easy unless the work at points of transposition is done with care and skill. Phantom circuits, to be always successful, require that the physical circuits be balanced and kept so.

Transmission over Phantom Circuits. Under proper conditions phantom circuits are better than physical circuits, and in this respect it may be noted that some long-distance operating companies instruct their operators always to give preference to phantom circuits, because of the better transmission over them. The use of phantom circuits is confined almost wholly to open-wire circuits; and while the capacity of the phantom circuit is somewhat greater than that of the physical circuit, its resistance is considerably smaller. In the actual wire the phantom loop is only half the resistance of either of the physical lines from which it is made, for it contains twice as much copper. The resistance of the repeating coils, however, is to be added.

Simplex. Simplex telegraph circuits are made from metallic circuit telephone lines, as shown in Fig. 230. The principle is identical with that of phantom telephone circuits. The potentials placed on the telephone line by the telegraph operations are equal and simultaneous. They cause no current to flow *around* the telephone loop, only *along* it. If all qualities of the loop are balanced, the telephones will not overhear the telegraph impulses. In the figure, *AA* are arresters, as before, *GG* are Morse relays; a 2-microfarad condenser is shunted around the contact of each Morse key *F* to quench the noises due to the sudden changes on opening the keys between dots and dashes.

A simplex arrangement even more simple substitutes impedance coils for the repeating coils of Fig. 230. The operation of

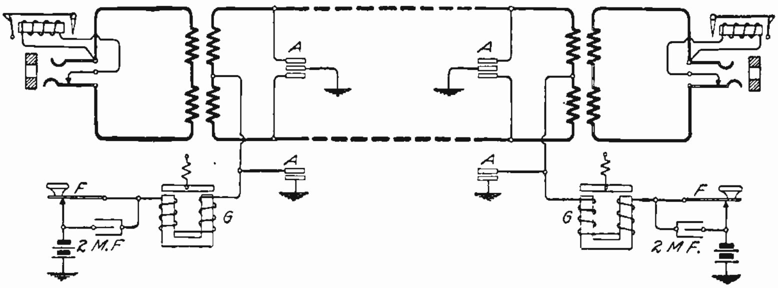


Fig. 230. Simplex Telegraph Circuit

the Morse circuit is the same. An advantage of such a circuit, as shown in Fig. 231, is that the telephone circuit does not suffer from the two repeating-coil losses in series. A disadvantage is, that

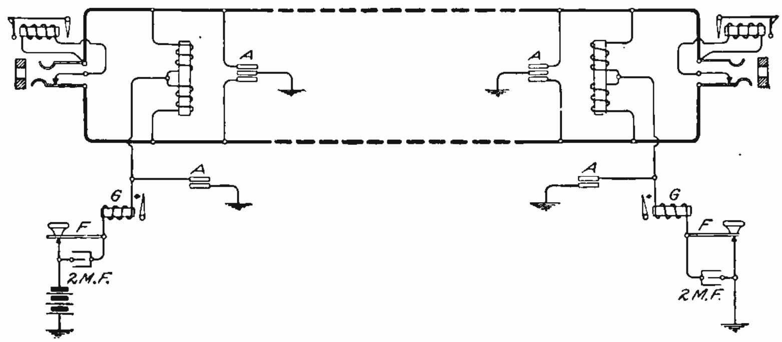


Fig. 231: Simplex Telegraph Circuit

in ringing on such a line with a grounded generator, the Morse relays are caused to chatter.

The circuit of Fig. 230 may be made to fit the condition of a through telephone line and a way telegraph station. The midway Morse apparatus of Fig. 232 is looped in by a combination of impedance coils and condensers. The plans of Figs. 230 and 231 here are combined, with the further idea of stopping direct and passing alternating currents, as is so well accomplished by the use of condensers.

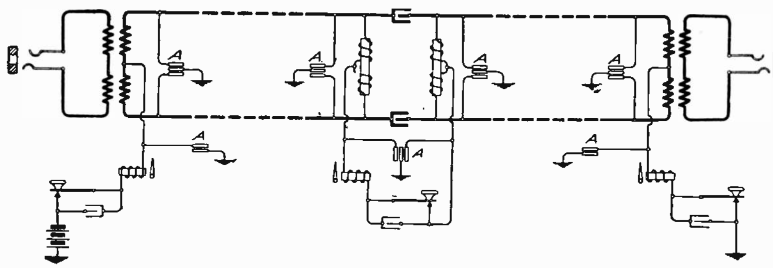


Fig. 232. Simplex Circuit with Waystation

Composite. Composite circuits depend on another principle than that of producing equal and simultaneous potentials on the two wires of the telephone loop. The opposition of impedance coils to alternating currents and of condensers to direct currents are the fundamentals. The early work in this art was done by Van Rysselberghe, of Belgium. In Fig. 233, one telephone circuit

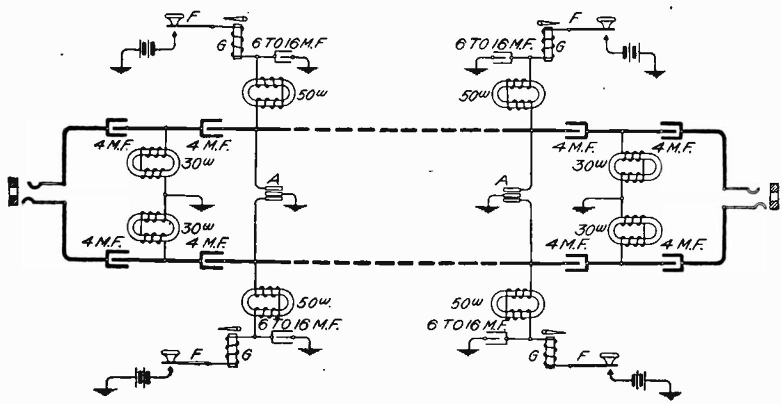
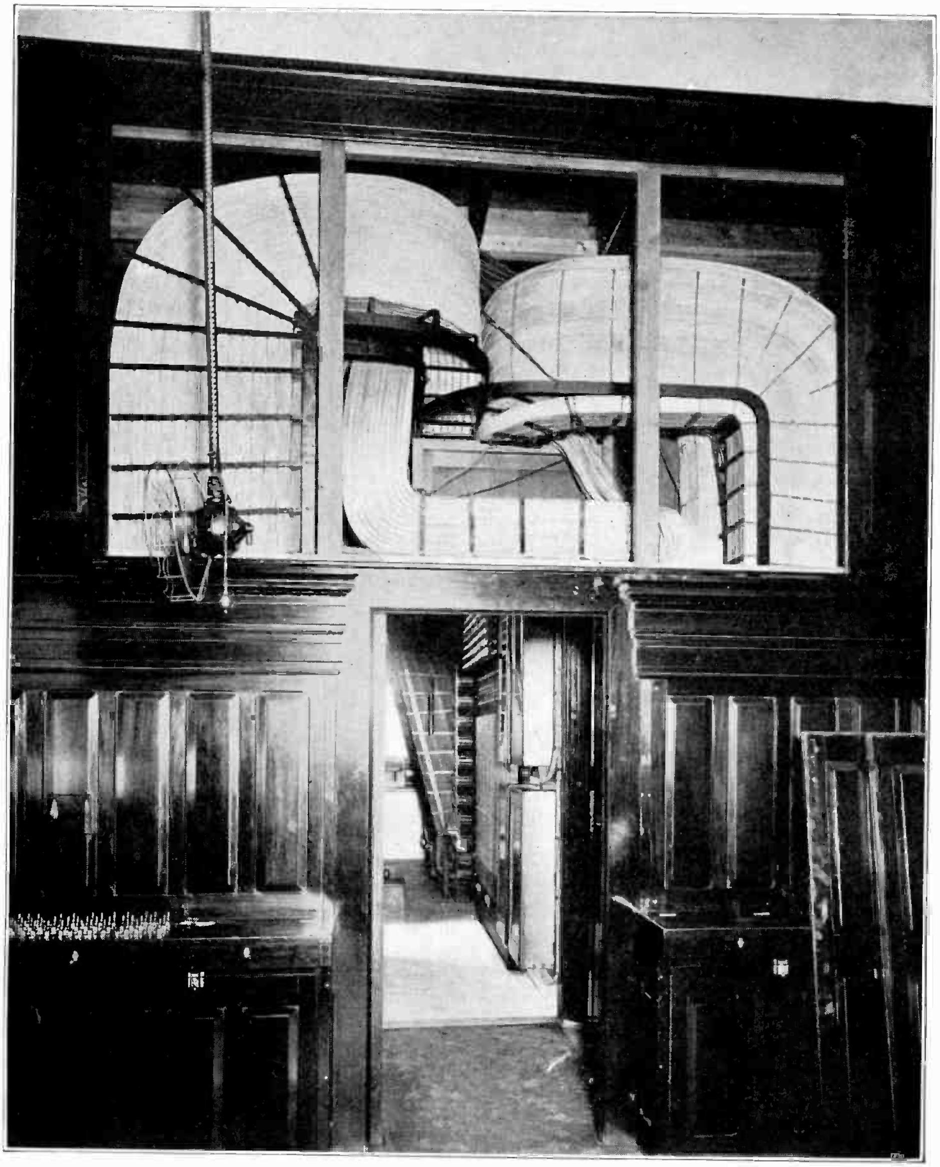


Fig. 233. Composite Circuit

forms two Morse circuits, two wires carrying three services. Each Morse circuit will be seen to include, serially, two 50-ohm impedance coils, and to have shunts through condensers to ground. The 50-



CABLE TURNING SECTIONS, BETWEEN A AND B BOARDS
Cortlandt Office, New York Telephone Co.

ohm coils are connected differentially, offering low consequent impedance to Morse impulses, whose frequency of interruption is not great. As the impedance coils are large, have cores of considerable length, and are wound with two separate though serially connected windings each, their impedance to voice currents is great. They act as though they were not connected differentially, so far as voice currents are concerned.

Because of the condensers serially in the telephone line, voice currents can pass through it, but direct currents can not. Impulses due to discharges of cores, coils, and capacities in the Morse circuit *could* make sounds in the telephones, but these are choked out, or led to earth by the 30-ohm impedance coils and the heavy Morse condensers.

Ringing. Ringing over simplex circuits is done in the way usual where no telegraph service is added. Both telegraphy and telephony over simplex circuits follow their usual practice in the way of calling and conversing. In composite working, however, ringing by usual methods either is impossible because of heavy grounds and shunts, or if it is possible to get ringing signals through at all, the relays of the Morse apparatus will chatter, interfering with the proper use of the telegraph portion of the service.

It is customary, therefore, either to equip composite circuits with special signaling devices by which high-frequency currents pass over the telephone circuits, operating relays which in turn operate local ringing signals; or to refrain from ringing on composite circuits and to transmit orders for connections by telegraph. The latter is wholly satisfactory over composite lines between points having heavy telegraph traffic, and it is between such points as these that composite practice is most general.

Phantoms from Simplex and Composite Circuits. Phantom and simplex principles are identical, and by adding the composite principle, two simplex circuits may have a phantom superadded, as in Fig. 234. Similarly, as in Fig. 235, two composite circuits can be phantomed. This case gives seven distinct services over four wires: three telephone loops—two physical and one phantom—and four Morse lines.

Railway Composite. The foregoing are problems of making telegraphy a by-product of telephony. With so many telegraph

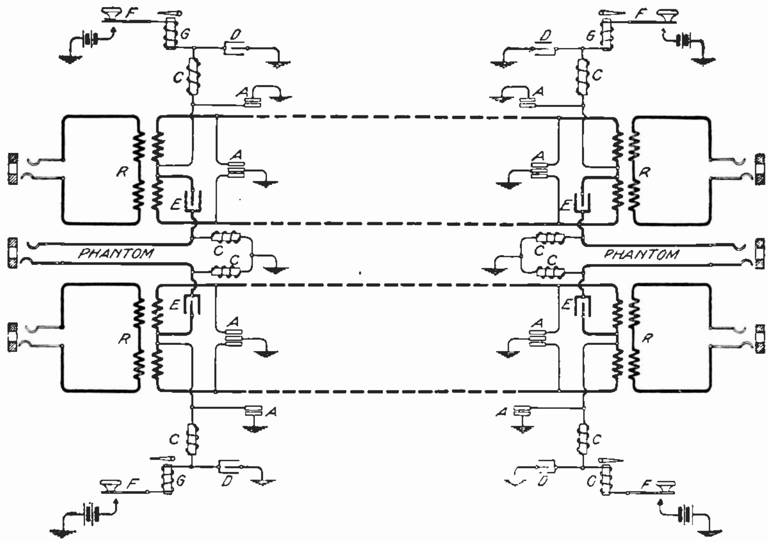


Fig. 234. Phantom of Two Simplex Circuits

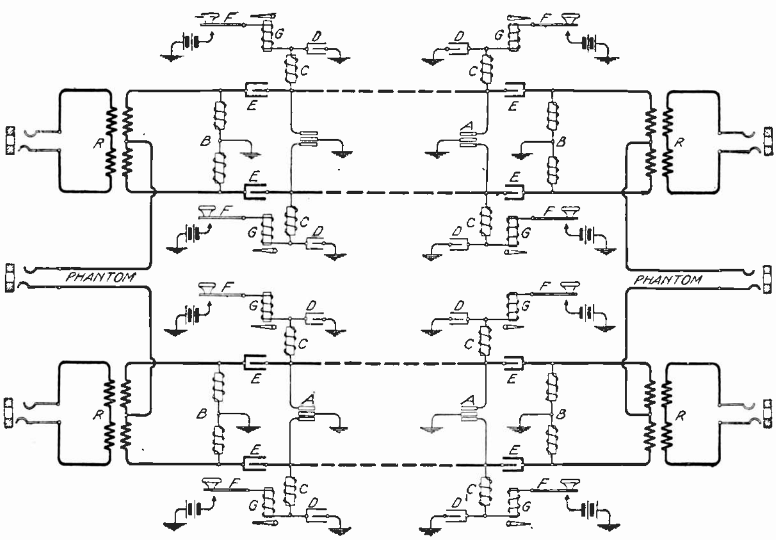


Fig. 235. Phantom of Two Composite Circuits

wires on poles over the country, it has seemed a pity not to turn the thing around and provide for telephony as a by-product of telegraphy. This has been accomplished, and the result is called a railway composite system. For the reason that the telegraph circuits are not in pairs, accurately matched one wire against another, and are not always uniform as to material, it has not been possible to secure as good telephone circuits from telegraph wires as telegraph circuits from telephone wires.

Practical results are secured by adaptation of the original principle of different frequencies. A study of Fig. 233 shows that over such a composite circuit the usual method of ringing from station to station over the telephone circuit by an alternating current of a frequency of about sixteen per second is practically impossible. This is because of the heavy short-circuit provided by the two 30-ohm choke coils at each of the stations, the heavy shunt of the large condensers, and the grounding through the 50-ohm choke coils. If high-frequency speech currents can pass over these circuits with a very small loss, other high-frequency circuits should find a good path. There are many easy ways of making such currents, but formerly none very simple for receiving them. Fig. 236 shows one simple observer of such high-frequency currents, it being merely an adaptation of the familiar polarized ringer used in every subscriber's telephone. In either position of the armature it makes contact with one or the other of two studs connected to the battery, so that in all times of rest the relay *A* is energized. When a high-frequency current passes through this polarized relay, however, there is enough time in which the armature is out of contact with either stud to reduce the total energy through the relay *A* and allow its armature to fall away, ringing a vibrating bell or giving some other signal.

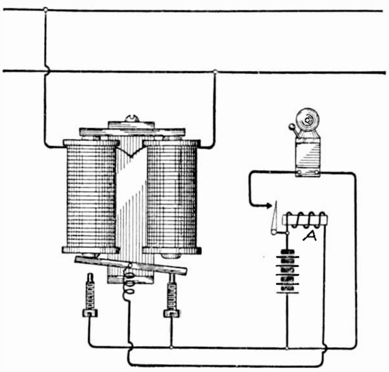


Fig. 236. Ringing Device for Composite Circuits

Fig. 237 shows a form of apparatus for producing the high-frequency current necessary for signaling. It is evident that if a magneto generator, such as is used in ordinary magneto telephones, could be made to drive its armature fast enough, it also might furnish the high-frequency current necessary for signaling through condensers and past heavy impedances.

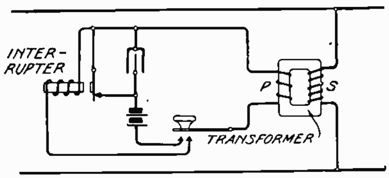


Fig. 237 Ringing Current Device

Applying these principles of high-frequency signals sent and received to a single-wire telegraph circuit, the arrangement shown in Fig. 238 results, this being a type of railway composite circuit. The principal points of interest herein are the insertion of impedances in series with the telegraph lines, the shunting of the telegraph relays by small condensers, the further shunting of the whole telegraph mechanism of a station by another condenser, and thus keeping out of the line circuit changes in current values which would be heard in the telephones if violent, and might be inaudible if otherwise.

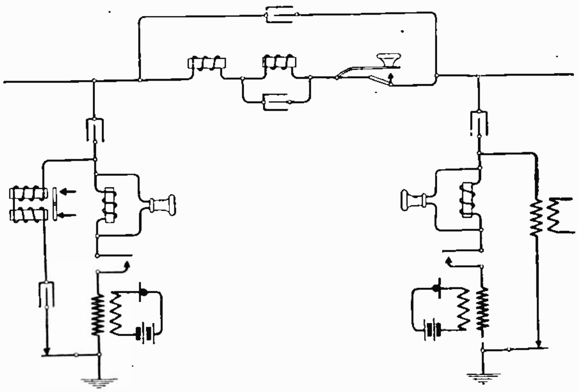


Fig. 238: Railway Composite Circuit

A further interesting element is the very heavy shunting of the telephone receiver by means of an inductive coil. This shunt is applied for by-path purposes so that heavy disturbing currents may be kept out of the receiver while a sufficient amount of voice current is diverted through the receiver. It is well to have the inductance of this shunt made adjustable by providing a movable iron core for the shunt winding. When the core is drawn out of the coil, its impedance is diminished because the inductance is diminished. This reduces the amount of disturbing noise in the receiver. The core should be withdrawn as little as the amount of disturbance permits, as this also diminishes the loudness of the received speech.

Because the signaling over lines equipped with this form of composite working results in the ringing of a bell by means of local current, it is of particular advantage in cases where the bell needs to ring loudly. Switch stations, crossings, and similar places where the attendant is not constantly near the telephone can be equipped with this type of composite apparatus and it so offers a valuable substitute for regular railway telegraph equipment, with which the attendant may not be familiar. The success of the local bell-ringing arrangement, however, depends on accurate relay adjustment and on the maintenance of a primary battery. The drain on the ringing battery is greater than on the talking battery.

A good substitute for the bell signal on railway composite circuits is a telephone receiver responding directly to high-frequency currents over the line. The receiver is designed specially for the purpose and is known as a "howler." Its signal can be easily heard through a large room. The condenser in series with it is of small capacity, limiting the drain upon the line. Usually the howler is detached by the switch hook during conversation from a station.

Railway Composite Set. The circuit of a set utilizing such an arrangement together with other details of a complete railway composite set is shown in Fig. 239. The drawing is arranged thus, in the hope of simplifying the understanding of its principles. It will be seen that the induction coil serves as an interrupter as well as for transmission. All of the contacts are shown in the position they have during conversation. The letters *Hc1*, *Hc 2*, etc., and *Kc 1*, *Kc 2*, etc., refer to hook contacts and key contacts, respectively, of the numbers given. The arrangements of the hook and key springs are shown at the right of the figure. *RR* represent impedance coils connected serially in the line and placed at terminal stations. The composite telephone sets are bridged from the line to ground at any points between the terminal impedance coils.

The direct currents of telegraphy are prevented from passing to ground through the telephone set during conversation by the 2-

microfarad condenser which is in series with the receiver. They are prevented from passing to ground through the telephone set when the receiver is on the hook by a .05 microfarad condenser in series with the howler. The alternating currents of speech and interrupter signaling are kept from passing to ground at terminals by the impedance coils.

Signals are sent from the set by pressing the key *K*. This operates the vibrator by closing contacts *Kc 6* and *Kc 7*. The howler is cut off and the receiver is short-circuited by the same operation of the key. The impedance of the coil *I* is changed by moving its adjustable core.

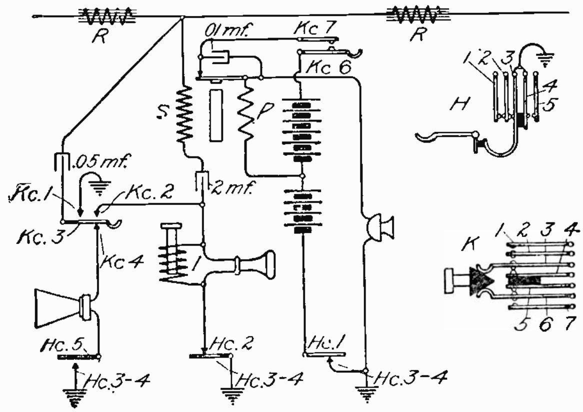


Fig. 239. Railway Composite Set

Applications. A chief use of composite and simplex circuits is for ticket wire purposes. These are circuits over which long-distance operators instruct each other as to connecting and disconnecting lines, the routing of calls, and the making of appointments. One such wire will care for all the business of many long-distance trunks. The public also absorbs the telegraph product of telephone lines. Such telegraph service is leased to brokers, manufacturers, merchants, and newspapers. Railway companies use portable telephone adjuncts to telegraph circuits on trains for service from stations not able to support telegraph attendants, and in a limited degree for the dispatching of trains. Telephone train dispatching, however, merits better equipment than a railway composite system affords.

CHAPTER XIX

*TELEPHONE TRAIN DISPATCHING

It has been only within the past three years that the telephone has begun to replace the telegraph for handling train movements. The telegraph and the railroads have grown up together in this country since 1850, and in view of the excellent results that the telegraph has given in train dispatching and of the close alliance that has always naturally existed between the railway and the telegraph, it has been difficult for the telephone, which came much later, to enter the field.

Rapid Growth. The telephone has been in general use among the railroads for many years, but only on a few short lines has it been used for dispatching trains. In these cases the ordinary magneto circuit and instruments have been employed, differing in no respect from those used in commercial service at the present time. Code ringing was used and the number of stations on a circuit was limited by the same causes that limit the telephones on commercial party lines at present.

The present type of telephone dispatching systems, however, differs essentially from the systems used in commercial work, and is, in fact, a highly specialized party-line system, arranged for selective ringing and *many stations*. The first of the present type was installed by the New York Central and Hudson River Railroad in October, 1907, between Albany and Fonda, New York, a distance of 40 miles. This section of the road is on them ain line and has four tracks controlled by block signals.

The Chicago, Burlington, and Quincy Railroad was the second to install train-dispatching circuits. In December, 1907, a portion of the main line from Aurora to Mendota, Illinois, a distance of 46 miles, was equipped. This was followed in quick succession by various

*We wish particularly to acknowledge the courtesy of the Western Electric Company in their generous assistance in the preparation of this chapter.

other circuits ranging, in general, in lengths over 100 miles. At the present time there are over 20 train-dispatching circuits on the Chicago, Burlington, and Quincy Railroad covering 125 miles of double track, 28 miles of multi-track, and 1,381 miles of single track, and connecting with 286 stations.

Other railroads entered this field in quick order after the initial installations, and at the present time nearly every large railroad system in the United States is equipped with several telephone train-dispatching circuits and all of these seem to be extending their systems.

In 1910, several railroads, including the Delaware, Lackawanna, and Western, had their total mileage equipped with telephone dispatching circuits. The Atchison, Topeka, and Santa Fe Railroad is equipping its whole system as rapidly as possible and already is the largest user of this equipment in this country. From latest information, over 55 railroads have entered this field, with the result that the telephone is now in use in railroad service on over 29,000 miles of line.

Causes of Its Introduction. The reasons leading to the introduction of the telephone into the dispatching field were of this nature: First, and most important, was the enactment of State and Federal Laws limiting to nine hours the working day of railroad employes transmitting or receiving orders pertaining to the movement of trains. The second, which is directly dependent upon the first, was the inability of the railroads to obtain the additional number of telegraph operators which were required under the provisions of the new laws. It was estimated that 15,000 additional operators would be required to maintain service in the same fashion after the new laws went into effect in 1907. The increased annual expense occasioned by the employment of these additional operators was roughly estimated at $10,000,000. A third reason is found in the decreased efficiency of the average railway and commercial telegraph operator. There is a very general complaint among the railroads today regarding this particular point, and many of them welcome the telephone, because, if for no other reason, it renders them independent of the telegrapher. What has occasioned this decrease in efficiency it is not easy to say, but there is a strong tendency to lay it, in part, to the attitude of the telegraphers' organization toward the student operator. It is a fact, too, that the limits which these organizations have placed on student operators were directly responsible for the lack of available men when they were needed.

Advantages. In making this radical change, railroad officials were most cautious, and yet we know of no case where the introduction of the telephone has been followed by its abandonment, the tendency having been in all cases toward further installations and more equipment of the modern type. The reasons for this are clear, for where the telephone is used it does not require a highly specialized man as station operator and consequently a much broader field is open to the railroads from which to draw operators. This, we think, is the most far-reaching advantage.

The telephone method also is faster. On an ordinary train-dispatching circuit it now requires from 0.1 of a second to 5 seconds to call any station. In case a plurality of calls is desired, the dispatcher calls one station after another, getting the answer from one while the next is being called, and so on. By speaking into a telephone many more words may be transmitted in a given time than by Morse telegraphy. It is possible to send fifty words a minute by Morse, but such speed is exceptional. Less than half that is the rule. The gain in high speed, therefore, which is obtained is obvious and it has been found that this is a most important feature on busy divisions. It is true that in the issuance of "orders," the speed, in telephonic train dispatching, is limited to that required to write the words in longhand. But all directions of a collateral character, the receipt of important information, and the instantaneous descriptions of emergency situations can be given and received at a speed limited only by that of human speech.

The dispatcher is also brought into a closer personal relation with the station men and trainmen, and this feature of direct personal communication has been found to be of importance in bringing about a higher degree of co-operation and better discipline in the service.

Telephone dispatching has features peculiar to itself which are important in improving the class of service. One of these is the "answer-back" automatically given to the dispatcher by the way-station bell. This informs the dispatcher whether or not the bell at the station rang, and excuses by the operators that it did not, are eliminated.

Anyone can answer a telephone call in an emergency. The station operator is frequently agent also, and his duties often take him out of hearing of the telegraph sounder. The selector bell used with the telephone can be heard for a distance of several hundred feet. In addition, it is quite likely that anyone in the neighborhood would recognize that the station was wanted and either notify the operator or answer the call.

In cases of emergency the train crews can get into direct communication with the dispatcher immediately, by means of portable telephone sets which are carried on the trains. It is a well-known fact that every minute a main line is blocked by a wreck can be reckoned as great loss to the railroad.

It is also possible to install siding telephone sets located either in booths or on poles along the right-of-way. These are in general service today at sidings, crossings, drawbridges, water tanks, and such places, where it may be essential for a train crew to reach the nearest waystation to give or receive information.

The advantage of these siding sets is coming more and more to be realized. With the telegraph method of dispatching, a train is ordered to pass another train at a certain siding, let us say. It reaches this point, and to use a railroad expression, "goes into the hole." Now, if anything happens to the second train whereby it is delayed, the first train remains tied up at that siding without the possibility of either reaching the dispatcher or being reached by him. With the telephone station at the siding, which requires no operator, this is avoided. If a train finds itself waiting too long, the conductor goes to the siding telephone and talks to the dispatcher, possibly getting orders which will advance him many miles that would otherwise have been lost.

It is no longer necessary for a waystation operator to call the dispatcher. When one of these operators wishes to talk to the dispatcher, he merely takes his telephone receiver off the hook, presses a button, and speaks to the dispatcher.

With the telephone it is a simple matter to arrange for provision so that the chief dispatcher, the superintendent, or any other official may listen in at will upon a train circuit to observe the character of the service. The fact that this can be done and that the operators know it can be done has a very strong tendency to improve the discipline.

The dispatchers are so relieved, by the elimination of the strain of continuous telegraphing, and can handle their work so much more quickly with the telephone, that in many cases it has been found possible to increase the length of their divisions from 30 to 50 per cent.

Railroad Conditions. One of the main reasons that delayed the telephone for so many years in its entrance to the dispatching field is that the conditions in this field are like nothing which has yet been met with in commercial telephony. There was no system developed for meeting them, although the elements were at hand. A railroad is divided up into a number of divisions or dispatchers' districts of varying lengths. These lengths are dependent on the density of the traffic over the division. In some cases a dispatcher will handle not more than 25 miles of line. In other cases this district may be 300 miles long. Over the length of one of these divisions the telephone circuit extends, and this circuit may have upon it 5 or 50 stations, *all of which may be required to listen upon the line at the same time.*

It will be seen from this that the telephone dispatching circuit partakes somewhat of the nature of a long-distance commercial circuit in its length, and it also resembles a rural line in that it has a large number of telephones upon it. Regarding three other characteristics, namely, that many of these stations may be required to be in on the circuit simultaneously, that they must all be signaled selectively, and that it must also be possible to talk and signal on the circuit simultaneously, a telephone train-dispatching circuit resembles nothing in the commercial field. These requirements are the ones which have necessitated the development of special equipment.

Transmitting Orders. The method of giving orders is the same as that followed with the telegraph, with one important exception. When the dispatcher transmits a train order by telephone, he writes out the order as he speaks it into his transmitter. In this way the speed at which the order is given is regulated so that everyone receiving it can easily get it all down, and a copy of the transmitted order is retained by the dispatcher. All figures and proper names are spelled out. Then after an order has been given, it is repeated to the dispatcher by each man receiving it, and he underlines each word as it comes in. This is now done so rapidly that a man can repeat an order more quickly than the dispatcher can underline. The doubt as to the accuracy with which it is possible to transmit information by telephone has been dispelled by this method of procedure, and the safety of telephone dispatching has been fully established.

Apparatus. The apparatus which is employed at waystations may be divided into two groups—the selector equipment and the telephone equipment. The selector is an electro-mechanical device for ringing a bell at a waystation when the dispatcher operates a key corresponding to that station. At first, as in telegraphy, the selector magnets were connected in series in the line, but today all systems bridge the selectors across the telephone circuit in the same way and for the same reasons that it is done in bridging party-line work. There are at the present time three types of selectors in general use, and the mileage operated by means of these is probably considerably over 95 per cent of the total mileage so operated in the country.

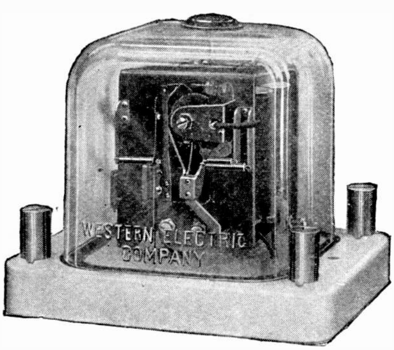


Fig. 240. Western Electric Selector

The Western Electric Selector. This selector is the latest and perhaps the simplest. Fig. 240 shows it with its glass dust-proof cover on, and Fig. 241 shows it with the cover removed. This selector is adapted for operating at high speed, stations being called at the rate of ten per second.

The operating mechanism, which is mounted on the front of the selector so as to be readily accessible, works on the central-energy principle—the battery for its operation, as well as for the operation of the bell used in connection with it, both being located at the dispatcher's office. The bell battery may, however, be placed at the waystation if this is desired.

The selector consists of two electromagnets which are bridged in series across the telephone circuit and are of very high impedance. It is possible to place as many of these selectors as may be desired across a circuit without seriously affecting the telephonic transmission. Direct-current impulses sent out by the dispatcher operate these magnets, one of which is slow and the other quick-acting. The first impulse sent out is a long impulse and pulls up both arma-

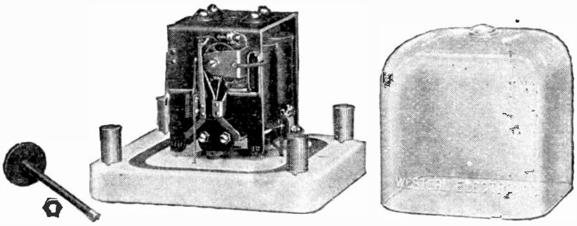


Fig 241. Western Electric Selector

tures, thereby causing the pawls above and below the small ratchet wheel, shown in Fig. 241, to engage with this wheel. The remaining impulses operate the quick-acting magnet and step the wheel

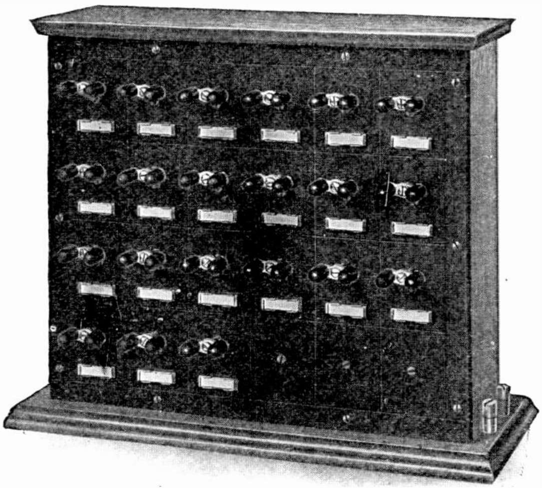


Fig. 242. Dispatcher's Keys

around the proper number of teeth, but do not affect the slow-acting magnet which remains held up by them. The pawl connected to the slow-acting magnet merely serves to prevent the ratchet wheel from turning back. Attached to the ratchet wheel is a contact whose position can be varied in relation to the stationary contact on the left of the selector with which this engages. This contact is set so that when the wheel has been rotated the desired number of teeth, the two contacts will make and the bell be rung. Any selector may thus be adjusted for any station, and the selectors are thus interchangeable. When the current is removed from the line at the dispatcher's office, the armatures fall back and everything is restored to normal. An "answer-back" signal is provided with this selector dependent upon the operation of the bell. When the selector at a

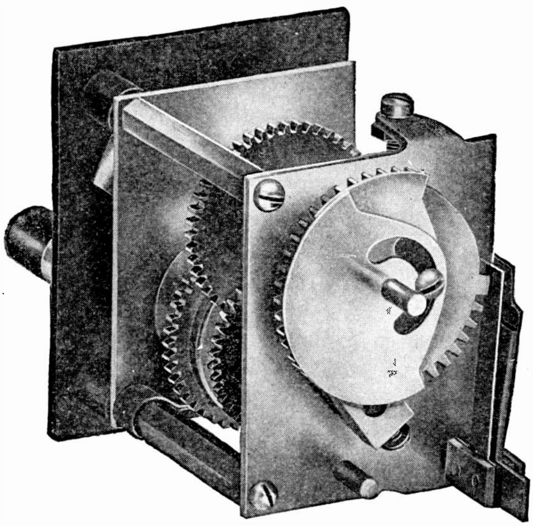


Fig. 243. Dispatcher's Key Mechanism

station operates, the bell normally rings for a few seconds. The dispatcher, however, can hold this ring for any length of time desired.

The keys employed at the dispatcher's office for operating selectors are shown in Fig. 242. There is one key for each way-station on the line and the dispatcher calls any station by merely giving the corresponding key a quarter turn to the right. Fig. 243 shows the mechanism of one of these keys and the means employed for sending out current impulses over the circuit. The key is adjustable and may be arranged for any station desired by means of the movable cams shown on the rear in Fig. 243, these cams, when occupying different positions, serving to cover different numbers of the teeth of the impulse wheel which operate the impulse contacts.

The Gill Selector. The second type of selector in extensive use throughout the country today is known as the Gill, after its inventor. It is manufactured for both local-battery and central-energy types, the latter being the latest development of this selector. With the local-battery type, the waystation bell rings until stopped by the dispatcher. With the central-energy type it rings a definite length of time and can be held for a longer period as is the case with the Western Electric selector. The selector is operated by combinations of direct-current impulses which are sent out over the line by keys in the dispatcher's office.

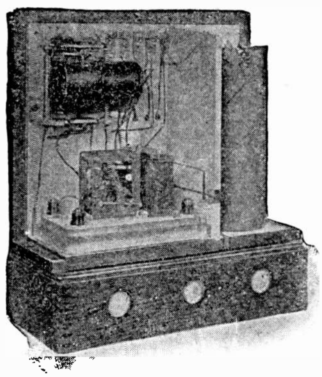


Fig. 244. Gill Selector

The dispatcher has a key cabinet, and calls in the same way as already described, but these keys, instead of sending a series of quick impulses, send a succession of impulses with intervals between corresponding to the particular arrangement of teeth in the corresponding waystation selector wheel. Each key, therefore, belongs definitely with a certain selector and can be used in connection with no other.

A concrete example may make this clearer. The dispatcher may operate key No. 1421. This key starts a clockwork mechanism which impresses at regular intervals, on the telephone line, direct-current impulses, with intervals between as follows: 1-4-2-1. There is on the line one selector corresponding to this combination and it alone, of all the selectors on the circuit, will step its wheel clear around so that contact is made and the bell is rung. In all the others, the pawls will have slipped out at some point of the revolution and the wheels will have returned to their normal positions.

The Gill selector is shown in Fig. 244. It contains a double-wound relay which is bridged across the telephone circuit and operates the selector. This relay has a resistance of 4,500 ohms and a high impedance, and operates the selector mechanism which is a special modification of the ratchet and pawl principle. The essential features of this selector are the "step-up" selector wheel and a time wheel, normally held at the bottom of an inclined track.

The operation of the selector magnet pushes the time wheel up the track and allows it to roll down. If the magnet is operated rapidly, the wheel does not get clear down before being pushed back again. A small pin on the side of the pawl, engaging the selector wheel normally, opposes the selector wheel teeth near their outer points. When the time wheel rolls to the bottom of the track, however, the pawl is allowed to drop to the bottom of the tooth. Some of the teeth on the selector wheel are formed so that they will effectually engage with the pawl only when the latter is in normal position, while others will engage only while the pawl is at the bottom position; thus innumerable combinations can be made which will respond to certain combinations of rapid impulses with intervals between. The correct combination of impulses and intervals steps

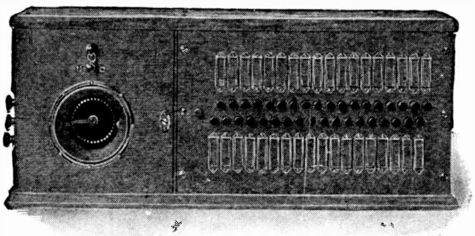


Fig. 245. Cummings-Wray Dispatcher's Sender

the selector wheel clear around so that a contact is made. The selector wheels at all other stations fail to reach their contact position because at some point or points in their revolution the pawls have slipped out, allowing the selector wheels to return "home."

The "answer-back" is provided in this selector by means of a few inductive turns of the bell circuit which are wound on the selector relay. The operation of the bell through these turns induces an alternating current in the selector winding which flows out on the line and is heard as a distinctive buzzing noise by the dispatcher.

The Cummings-Wray Selector. Both of the selectors already described are of a type known as the *individual-call* selectors, meaning that only one station at a time can be called. If a plurality of calls is desired, the dispatcher calls one station after another. The third type of selector in use today is of a type known as the *multiple-call*, in which the dispatcher can call simultaneously as many stations as he desires.

The Cummings-Wray selector and that of the Kellogg Switchboard and Supply Company are of this type and operate on the principle of synchronous clocks. When the dispatcher wishes to put through a call, he throws the keys of all the stations that he desires and then operates a starting key. The bells at all these stations are rung by one operation.

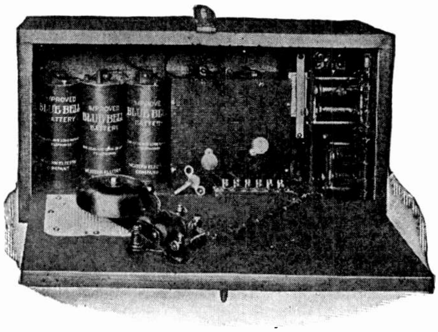


Fig. 246. Cummings-Wray Selector

The dispatcher's sending equipment of the Cummings-Wray system is shown in Fig. 245, and the waystation selector in Fig. 246. It is necessary with this system for the clocks at all stations to be wound every eight days.

In the dispatcher's master sender the clock-work mechanism operates a contact arm which shows on the face of the sender in Fig. 245. There is one contact for every station on the line. The clock at this office and the clocks at all the waystation offices start together, and it is by this means that the stations are signaled, as will be described later, when the detailed operation of the circuits is taken up.

Telephone Equipment. Of no less importance than the selective devices is the telephone apparatus. That which is here illustrated is the product of the Western Electric Company, to whom we are indebted for all the illustrations in this chapter.

Dispatcher's Transmitter. The dispatcher, in most cases, uses the chest transmitter similar to that employed by switchboard operators in every-day service. He is connected at all times to the telephone circuit, and for this reason equipment easy for him to wear is essential. In very noisy locations he is equipped with a double head receiver. On account of the dispatcher being connected across the line permanently and of his being required to talk a large part of the time, there is a severe drain on the transmitter battery. For this reason storage batteries are generally used.

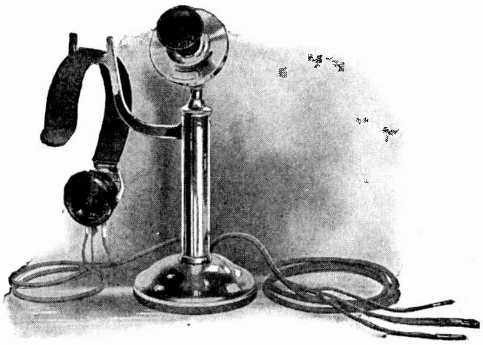


Fig. 247. Waystation Desk Telephone

Waystation Telephones. At the waystations various types of telephone equipment may be used. Perhaps the most common is the familiar desk stand shown in Fig. 247, which, for railroad service, is arranged with a special hook-switch lever for use with a head receiver.

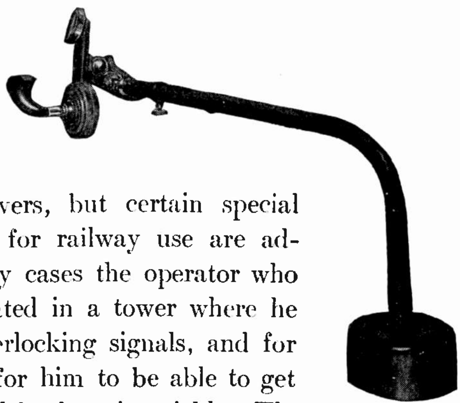


Fig. 248. Telephone Arm

Often some of the familiar swinging-arm telephone supports are used, in connection with head receivers, but certain special types developed particularly for railway use are advantageous, because in many cases the operator who handles train orders is located in a tower where he must also attend to the interlocking signals, and for such service it is necessary for him to be able to get away from the telephone and back to it quickly. The Western Electric telephone arm developed for this use is shown in Fig. 248. In this the transmitter and the receiver are so disposed as to conform approximately to the shape of the operator's head. When the arm is thrown back out of the way it opens the transmitter circuit by means of a commutator in its base.

Siding Telephones. Two types of sets are employed for siding purposes. The first is an ordinary magneto wall instrument, which embodies the special apparatus and circuit features employed in the standard waystation sets. These are used only where it is possible to

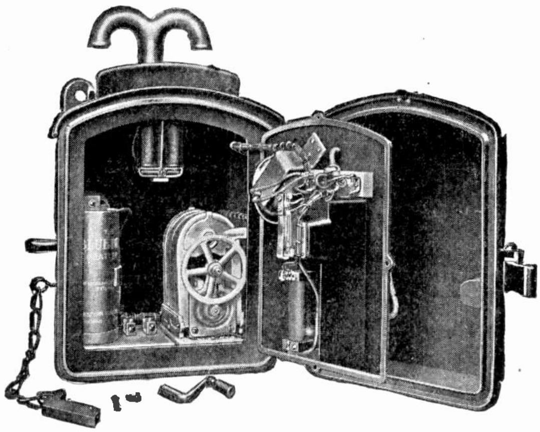


Fig. 249. Weather-Proof Telephone Set

locate them indoors or in booths along the line. These sets are permanently connected to the train wire, and since the chances are small that more than one of them will be in use at a time, they are rung by the dispatcher, by means of a regular hand generator, when it is necessary for him to signal a switching.

In certain cases it is not feasible to locate these siding telephone sets indoors, and to meet these conditions an iron weather-proof set is employed, as shown in Figs. 249 and 250. The apparatus in this set is treated with a moisture-proofing compound, and the casing itself is impervious to weather conditions.

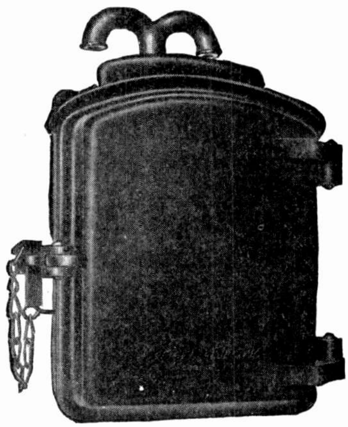


Fig. 250. Weather-Proof Telephone Set

Portable Train Sets. Portable telephone sets are being carried regularly on wrecking trains and their use is coming into more and more general acceptance on freight and passenger trains. Fig. 251 shows one of these sets equipped with a five-bar generator for calling

Fig. 251 Portable Telephone Set

the dispatcher. Fig. 252 shows a small set without generator for conductors' and inspectors' use on lines where the dispatcher is at all times connected in the circuit.

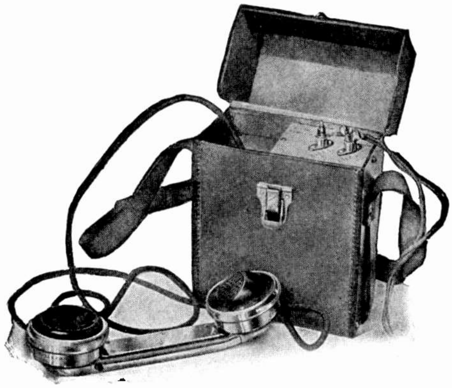


Fig. 252. Portable Telephone Set

These sets are connected to the telephone circuit at any point on the line by means of a light portable pole arranged with terminals at its outer extremity for hooking over the line wires, and with flexible conducting cords leading to the portable set. The use of these sets among officials on their private cars, among construction and bridge gangs working on the line, and among telephone inspectors and repairmen for reporting trouble, is becoming more and more general.

Western Electric Circuits. As already stated, a telephone train-dispatching circuit may be from 25 to 300 miles in length, and upon this may be as many stations as can be handled by one dispatcher. The largest known number of stations upon an existing circuit of this character is 65.

Dispatcher's Circuit Arrangement. The circuits of the dispatcher's station in the Western Electric system are shown in Fig. 253, the operation of which is briefly as follows: When the dispatcher wishes to call any particular station, he gives the key corresponding to that station a quarter turn. This sends out a series of rapid

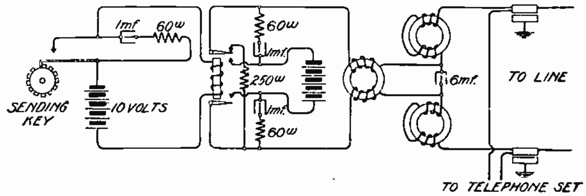


Fig. 253. Dispatcher's Station—Western Electric System

direct-current impulses on the telephone line through the contact of a special telegraph relay which is operated by the key in a local circuit. The telegraph relay is equipped with spark-eliminating condensers around its contacts and is of heavy construction throughout in order to carry properly the sending current.

Voltage. The voltage of the sending battery is dependent on the length of the line and the number of stations upon it. It ranges from 100 to 300 volts in most cases. When higher voltages are required in order successfully to operate the circuit, it is generally customary to install a telegraph repeater circuit at the center of the line, in order to keep the voltage within safe limits. One reason for limiting the voltage employed is that the condensers used in the circuit will not stand much higher potentials without danger of burning out. It is also possible to halve the voltage by placing the dispatcher in the center of the line, from which position he may signal in two directions instead of from one end.

Simultaneous Talking and Signaling. Retardation coils and condensers will be noticed in series with the circuit through which the signaling current must pass before going out on the line. These are for the purpose of absorbing the noise which is caused by high-voltage battery, thus enabling the dispatcher to talk and signal simultaneously. The 250-ohm resistance connected across the circuit through one back contact of the telegraph relay absorbs the discharge of the 6-microfarad condenser.

Waystation Circuit. The complete selector set for the waystations is shown in Fig. 254, and the wiring diagram of its apparatus in Fig. 255. The first impulse sent out by the key in the dispatch-

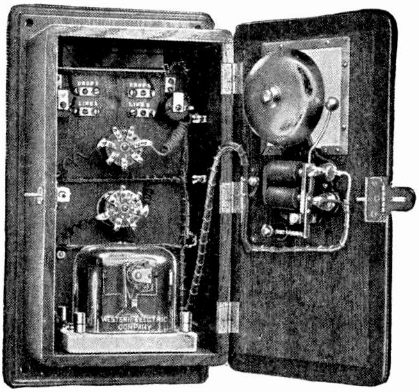


Fig. 254. Selector Set—Western Electric System

er's office is a long direct-current impulse, the first tooth being three or four times as wide as the other teeth. This impulse operates both magnets of the selector and attracts their armatures, which, in turn, cause two pawls to engage with the ratchet wheel, while the remaining quick impulses operate the "stepping-up" pawl and rotate the wheel the requisite number of teeth. Retardation coils are placed in series with the selector in order to choke back any lightning discharges which might come in over the line. The selector contact, when operated, closes a bell circuit, and it will be noted that both the selector, and the bell are operated from battery current coming over the main line through variable resistances. There are, of course, a number of selectors bridged across the circuit, and the variable resistance at each station is so adjusted as to give each approximately 10 milliamperes, which allows a large factor of safety for line leakage in wet weather. The drop across the coils at 10 milliamperes is 38 volts. If these coils were not employed, it is clear

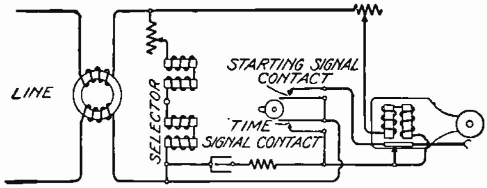


Fig. 255. Selector Set—Western Electric System

that the selectors nearer the dispatcher would get most of the current and those further away very little.

A time-signal contact is also indicated on the selector-circuit diagram of Fig. 255. This is common to all offices and may be operated by a special key in the dispatcher's office, thereby enabling him to send out time signals over the telephone circuit.

Gill Circuits. The circuit arrangement for the dispatcher's outfit of the Gill system is shown in Fig. 256. This is similar to that of the Western Electric system just described. The method of operation also is similar, the mechanical means of accomplishing

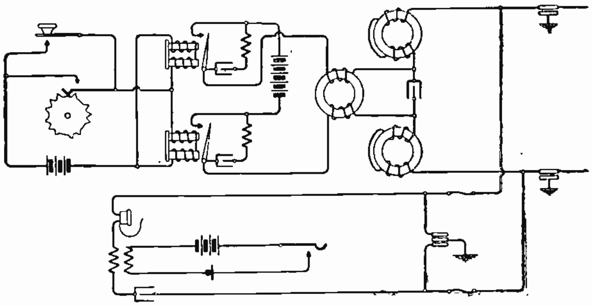


Fig. 256. Gill Dispatcher's Station

the selection being the main point of difference. In Fig. 257 the wiring of the Gill selector at a waystation for local-battery service is shown. The selector contact closes the bell circuit in the station and a few windings of this circuit are located on the selector magnets, as shown. These provide the "answer-back" by inductive means.

Fig. 258 shows the wiring of the waystation, central-energy Gill selector. In this case, the local battery for the operation of the bell is omitted and the bell is rung, as is the case of the Western Electric selector, by the main sending battery in the dispatcher's office.

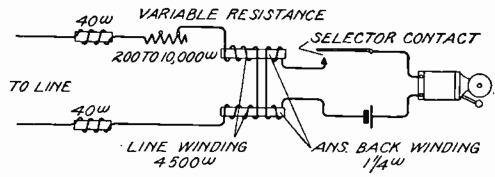


Fig. 257. Gill Selector—Local Battery

The sending keys of these two types of circuits differ, in that with the local-battery selector the key contact is open after the selector has operated, and the ringing of the bell must be stopped by the dispatcher pressing a button or calling another station. Either of these operations sends out a new current impulse which releases the selector and opens its circuit.

With the central-energy selector, however, the contacts of the sending key at the dispatcher's office remain closed after operation for a definite length of time. This is obviously necessary in order that battery may be kept on the line for the operation of the bell. In this case the contacts remain closed during a certain portion of the revolution of the key, and the bell stops ringing when that portion of the

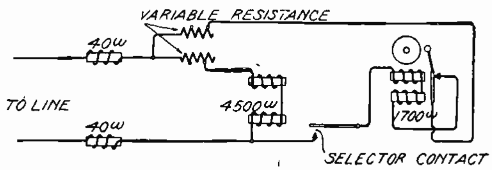


Fig. 258. Gill Selector—Central Energy

revolution is completed. If, however, the dispatcher desires to give any station a longer ring, he may do so by keeping the key contacts closed through an auxiliary strap key as soon as he hears the "answer-back" signal from the called station.

Cummings-Wray Circuits. The Cummings-Wray system, as previously stated, is of the multiple-call type, operating with synchronous clocks. Instead of operating one key after another in order to call a number of stations, all the keys are operated at once and a starting key sets the mechanism in motion which calls all these stations with one operation. Fig. 259 shows the circuit arrangement of this system.

In order to ring one or more stations, the dispatcher presses the corresponding key or keys and then operates the starting key. This starting key maintains its contact for an appreciable length of time to allow the clock mechanism to get under way and get clear of the releasing magnet clutch. Closing the starting key operates the clock-releasing magnet and also operates the two telegraph-line relays. These send out an impulse of battery on the line operating

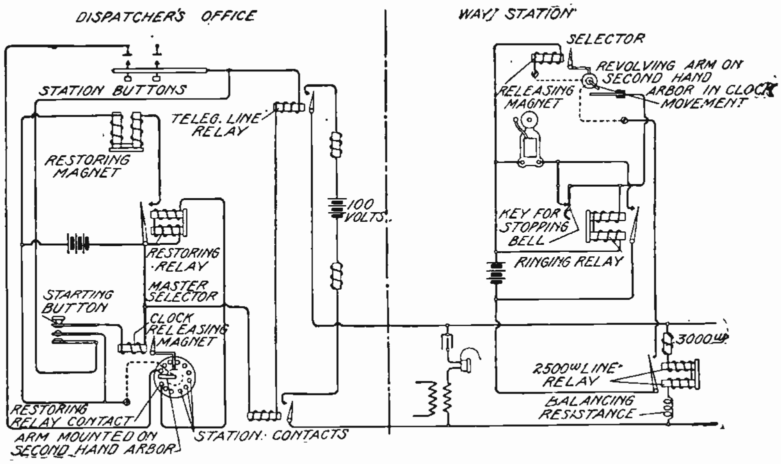


Fig. 259. Cummings-Wray System

the bridged 2,500-ohm line relays and, in turn, the selector releasing magnets; thus, all the waystation clocks start in unison with the master clock. The second hand arbor of each clock carries an arm, which at each waystation is set at a different angle with the normal position than that at any other station. Each of these arms makes contact precisely at the moment the master-clock arm is passing over the contact corresponding to that station.

If, now, a given station key is pressed in the master sender, the telegraph-line relays will again operate when the master-clock arm reaches that point, sending out another impulse of battery over the line. The selector contact at the waystation is closed at this moment;

therefore, the closing of the relay contact operates the ringing relay through a local circuit, as shown. The ringing relay is immediately locked through its own contact, thus maintaining the bell circuit closed until it is opened by the key and the ringing is stopped.

As the master-clock arm passes the last point on the contact dial, the current flows through the restoring relay operating the restoring magnet which releases all the keys. A push button is provided by means of which the keys may be manually released, if desired. This is used in case the dispatcher presses a key by mistake. Retardation coils and variable resistances are provided at the waystation just as with the other selector systems which have been described and for the same reasons.

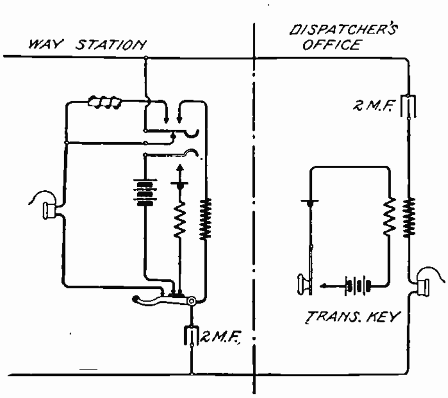


Fig. 260. Telephone Circuits

The circuits of the operator's telephone equipment shown in Fig. 260, are also bridged across the line. This apparatus is of high impedance and of a special design adapted to railroad service. There may be any number of telephones listening in upon a railroad train wire at the same time, and often a dispatcher calls in five or six at once to give orders. These conditions have necessitated the special circuit arrangement shown in Fig. 260.

The receivers used at the waystations are of high impedance and are normally connected, through the hook switch, directly across the line in series with a condenser. When the operator, at a waystation wishes to talk, however, he presses the key shown. This puts the receiver across the line in series with the retardation coil and in parallel with the secondary of the induction coil. It closes the transmitter battery circuit at the same time through the primary of the induction coil.

The retardation coil is for the purpose of preventing excessive side tone, and it also increases the impedance of the receiver circuit, which is a shunt on the induction coil. This latter coil, however, is of a special design which permits just enough current to flow through the receiver to allow the dispatcher to interrupt a way-station operator when he is talking.

The key used to close the transmitter battery is operated by hand and is of a non-locking type. In some cases, where the operators are very busy, a foot switch is used in place of this key. The use of such a key or switch in practical operation has been found perfectly satisfactory, and it takes the operators but a short time to become used to it.

The circuits of the dispatcher's office are similarly arranged, Fig. 260, being designed especially to facilitate their operation. In other words, as the dispatcher is doing most of the work on the circuit, his receiver is of a low-impedance type, which gives him slightly better transmission than the way-stations obtain. The key in his transmitter circuit is of the locking type, so that he does not have to hold it in while talking. This is for the reason that the dispatcher does most of the talking on this circuit. Foot switches are also employed in some cases by the dispatchers.

Fig. 261. Test Board

Test Boards. It is becoming quite a general practice among the railroads to install more than one telephone circuit along their rights-of-way. In many cases in addition to the train wire, a message circuit is also equipped, and quite frequently a block wire also operated by telephone, parallels these two. It is desirable on these circuits to be able to make simple tests and also to be able to patch one circuit with another in cases of emergency.

Test boards have been designed for facilitating this work. These consist of simple plug and jack boxes, the general appearance of which is shown in Fig. 261. The circuit arrangement of one of these is shown in Fig. 262. Each wire comes into an individual jack as will be noted on one side of the board, and passes through the inside contact of this jack, out through a similar jack on the opposite side. The selector and telephone set at an office are taken off these inside contacts through a key, as shown. The outside contacts of this key are wired across two pairs of cords. Now, assume the train wire comes in on jacks *1* and *3*, and the message wire on jacks *9* and *11*. In case of an accident to the train wire between two stations, it is desirable to patch this connection with a message wire in order to keep the all-important train wire working. The dispatcher instructs the operator at the last station which he can obtain, to insert plugs *1* and *2* in jacks *1* and *10*, and plugs *3* and *4* in jacks *3* and *12*, at the same time throwing the left-hand key. Then, obtaining an operator beyond the break by any available means, he instructs

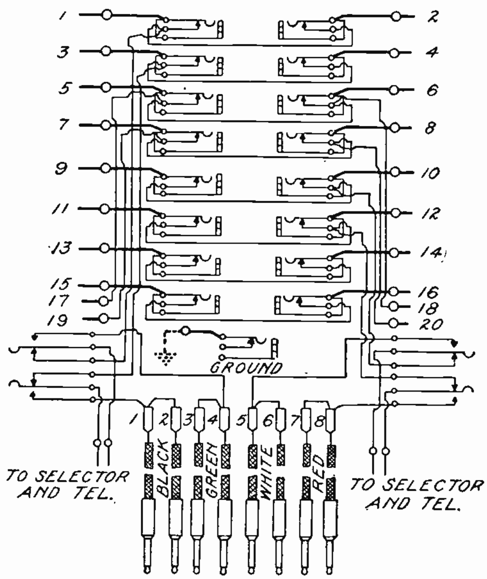


Fig. 262. Circuits of Test Board

him likewise to insert plugs *1* and *2* in jacks *9* and *2*, and plugs *3* and *4* in jacks *11* and *4*, similarly throwing the left-hand key. By tracing this out, it will be observed that the train wire is patched over the disabled section by means of the message circuit, and that the selector and the telephone equipment are cut over on to the patched connections; in other words, bridged across the patching cords.

It will also be seen that with this board it is possible to open any circuit merely by plugging into a jack. Two wires can be short-circuited or a loop made by plugging two cords of corresponding colors into the two jacks. A ground jack is provided for grounding any wire. In this way, a very flexible arrangement of circuits is obtained, and it is possible to make any of the simple tests which are all that are usually required on this type of circuit.

Blocking Sets. As was just mentioned, quite frequently in addition to train wires and message circuits, block wires are also operated by telephone. In some cases separate telephone instruments are used for the blocking service, but in others the same man handles all three circuits over the same telephone. The block wire is generally a converted telegraph wire between stations, usually of iron and usually grounded. It seldom ranges in length over six miles.

Where the block wires are operated as individual units with their own instruments, it is unnecessary to have any auxiliary ap-

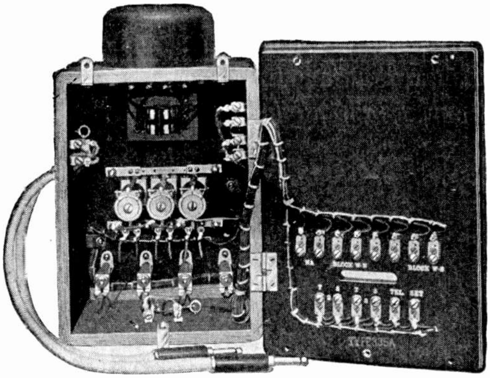


Fig. 263. Blocking Set

paratus to be used in connection with them. Where, however, they are operated as part of a system and the same telephone is used on these that is used on the train wire and message wire, additional apparatus, called a blocking set, is required. This blocking set, shown in Figs. 263 and 264, was developed especially for this service by the Western Electric Company. As will be noted, a repeating coil at the top and a key on the front of the set are wired in connection with a pair of train wire cords. This repeating coil is for use in connecting a grounded circuit to a metallic circuit, as, for instance, connecting a block wire to the train wire, and is, of course, for the purpose of eliminating noise. Below the key are three combined jacks and signals. One block wire comes into each of these and a private line may be brought into the middle one. When the next block rings up, a visual signal is displayed which operates a bell in the office by means of a local circuit. The operator answers by plugging the telephone cord extending from the bottom of the set into the proper jack. This automatically restores the signal and stops the bell.

Below these signals appear four jacks. One is wired across the train wire; one across the message wire; and the other two are bridged across the two pairs of patching cords on each side of the set. The operator answers a call on any circuit by plugging his telephone cord into the proper jack.

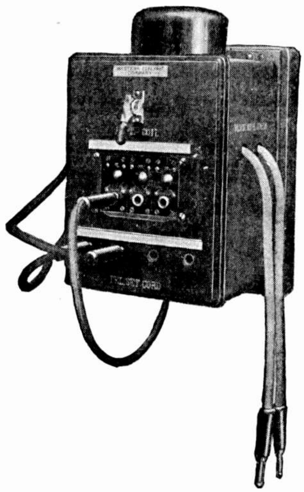


Fig. 264. Blocking Set

If a waystation is not kept open in the evening, or the operator leaves it for any reason and locks up, he can connect two blocks together by means of the block-wire cords. These are arranged simply for connecting two grounded circuits together and serve to join two adjacent blocks, thereby eliminating one station. A jack is wired across these cords, so that the waystation operator can listen in on the connection if he so desires.

In some cases not only are the telephone circuits brought into the test board, but also two telegraph wires are looped through this board before going to the peg switchboard. This is becoming quite a frequent practice and, in times of great emergency, enables patches to be made to the telegraph wires as well as to the telephone wires.

Dispatching on Electric Railways. As interurban electric railways are becoming more extended, and as their traffic is becoming heavier, they approximate more closely to steam methods of operation. It is not unusual for an electric railway to dispatch its cars exactly as in the case of a steam road. There is a tendency, however, in this class of work, toward slightly different methods, and these will be briefly outlined.

On those electric railways where the traffic is not especially heavy, an ordinary magneto telephone line is frequently employed with standard magneto instruments. In some cases the telephone sets are placed in waiting rooms or booths along the line of the road. In other cases it is not feasible to locate the telephone indoors and then iron weatherproof sets, such as are shown in Figs. 249 and 250, are mounted directly on the poles along the line of railway. With a line of this character there is usually some central point from which orders are issued and the trainmen call this number when arriving at sidings or wherever they may need to do so.

Another method of installing a telephone system upon electric railways is as follows: Instead of instruments being mounted in booths or on poles along the line, portable telephone sets are carried on the cars and jacks are located at regular intervals along the right-of-way on the poles. The crew of the car wishing to get in touch with the central office or the dispatcher, plugs into one of these jacks and uses the portable telephone set. At indoor stations, in offices or buildings belonging to the railroad, the regular magneto sets may be employed, as in the first case outlined.

On electric railway systems where the traffic is heavy, the train or car movements may be handled by a dispatcher just as on the steam railroad. There is usually one difference, however. On a steam road, the operators who give the train crews their orders and manipulate the semaphore signals are located at regular intervals in the different waystations. No such operators are usually found on electric railways, except, perhaps, at very important points, and, therefore, it is necessary for the dispatcher to be able to signal cars at any point and to get into communication with the crews of these cars. He does this by means of semaphores operated by telephone selectors over the telephone line. The telephone circuit may be equipped with any number of selectors desired, and the dispatcher can operate any particular one without operating any other one on the circuit. Each selector, when operated, closes a pair of contacts. This completes a local circuit which throws the semaphore arm to the "danger" position, at the same time giving the dispatcher a distinctive buzz in his ear, which informs him that the arm has actually moved to this position. He can get this signal only by the operation of the arm.

Each semaphore is located adjacent to a telephone booth in which is also placed the restoring lever, by means of which the semaphore is set in the "clear" position by the crew of the car which has been signaled. The wall-type telephone set is usually employed for this class of service, but if desired, desk stands or any of the various transmitter arms may be used.

It is necessary for the crew of the car which first approaches a semaphore set at "danger," to get out, communicate with the dispatcher, and restore the signal to the "clear" position. The dispatcher can not restore the signal. The signal is set only in order that the train crew may get into telephonic communication with the dispatcher, and in order to do this, it is necessary for them to go into the booth in any case.

REVIEW QUESTIONS

REVIEW QUESTIONS

ON THE SUBJECT OF

TELEPHONY

PAGES 11—54

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1. When was the telephone invented and by whom?

2. State the velocity of sound in air. Is it higher in air than in a denser medium?

3. State and define the characteristics of sound.

4. Make sketch of Bell's original magneto telephone without permanent magnets.

5. Describe and sketch Hughes' microphone.

6. Which is, at present, the best material for varying the resistance in transmitters?

7. Give the fundamental differences between the magneto transmitter and the carbon transmitter.

8. What is the function of the induction coil in the telephone circuit?

9. Describe and sketch the different kinds of visible signals.

10. What should be the diameter of hard drawn copper wire in order to allow economical spacing of poles?

11. State the four principal properties of a telephone line.

12. If in testing a line the capacity is changed what are the results found on the receiver and transmitter end?

13. Why is paper used as an insulator of telephone cables?

14. How does a conductor behave in connection with direct current and how with alternating current?

15. What influence has inductance on the telephone?

16. Define impedance and give the formula for it.

17. What is the usual specification for insulation of resistance in telephone cables?

18. If 750 feet of cable have an insulation resistance of 9,135

megohms, how great is the insulation resistance for 7 miles and 1,744 feet of cable?

19. What is the practical limiting conversation distance for No. 10 B. and S. wire?

20. Describe Professor Pupin's method of inserting inductance into the telephone line.

21. What does *mho* denote?

22. Why are Pupin's coils not so successful on open wires?

23. What is a repeater?

24. Define *reactive interference.*

25. State the frequencies of the pitches of the human voice.

26. What is the office of a diaphragm in a telephone apparatus?

27. What transmitter material has greatly increased the ranges of speech?

28. Describe the different methods of measurements of telephone circuits.

29. What are the two kinds of *electric calls?*

30. How many conductors has a telephone line?

31. Give formula for capacity reactance and the meaning of the symbols.

32. Which American cities are joined by underground lines at present?

33. State the two practical ways of improving telephone transmission.

REVIEW QUESTIONS

ON THE SUBJECT OF

TELEPHONY

PAGES 55—111

1. On what general principle are most of the telephone transmitters of today constructed?

2. Make sketch of the new Western Electric transmitter and describe its working.

3. Make sketch and describe the Kellogg transmitter.

4. What troubles were encountered in the earlier forms of granular carbon transmitters and how were they overcome?

5. What limits the current-carrying capacity of the transmitter? How may this capacity be increased?

6. State in what kind of transmitters a maximum degree of sensitiveness is desirable.

7. Show the conventional symbols for transmitters.

8. Describe a telephone receiver.

9. Sketch a Western Electric receiver and point out its deficiencies.

10. Make a diagram of the Kellogg receiver.

11. Describe the direct-current receiver of the Automatic Electric Company.

12. Describe and sketch the Dean receiver.

13. Show the conventional symbols of a receiver.

14. Describe exactly how, in a cell composed of a tin and a silver plate with dilute sulphuric acid as electrolyte, the current inside and outside of the cell will flow.

15. Describe the phenomenon of polarization.

16. What is *local action* of a cell? How may it be prevented?

17. Into how many classes may cells be divided? Which class is most used in telephony?

18. Describe the LeClanché cell.

19. Sketch and describe an excellent form of dry cell.

20. Show the conventional symbols for batteries.

21. Sketch and describe the generator shunt switch and the generator cut-in switch.

22. How may a pulsating current be derived from a magneto generator?

23. Show conventional symbols for magneto generators.

24. Sketch and describe the Western Electric polarized bell.

25. Give conventional ringer symbols.

26. What is the purpose of the hook switch?

27. Make sketch and give description of Kellogg's long lever hook switch.

28. Describe and sketch the Western Electric short lever hook switch.

29. Point out the principal difference between the desk stand hook switches of the Western Electric Company and of the Kellogg Switchboard and Supply Company.

30. Give conventional symbols of hook switches.

REVIEW QUESTIONS

ON THE SUBJECT OF

TELEPHONY

PAGES 113—182

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1. What is a central office?

2. What are (*a*) subscriber's lines? (*b*) Trunk lines? (*c*) Toll lines?

3. For what purpose is the switchboard?

4. Give short descriptions of the different classes of switchboards.

5. How are manual switchboards subdivided? Describe briefly the different types.

6. Define A and B boards.

7. What is a call circuit?

8. What kind of calls are handled on a toll switchboard?

9. Give drop symbol and describe its principles.

10. What is a jack?

11. Make a sketch of a plug inserted into a jack.

12. Give jack and plug symbols.

13. What are ringing and listening keys?

14. Show symbols for ringing and listening keys.

15. State the parts of which a cord equipment consists.

16. Show step by step the various operations of a telephone system wherein the lines center in a magneto switchboard. Make all the necessary diagrams and give brief descriptions to show that you understand each operation.

17. On what principle does a drop with night-alarm contact operate?

18. What is the advantage of associating jacks and drops?

REVIEW QUESTIONS

ON THE SUBJECT OF

TELEPHONY

PAGES 183—232

1. What are the advantages of a common-battery system?
2. When is the local battery to be preferred to the common-battery?
3. Enumerate the different kinds of line signals.
4. Make a diagram of the arrangement of a direct line lamp signal.
5. What is a direct line lamp with ballast? Give sketch.
6. Describe a line lamp with relay.
7. What is a pilot lamp and what are its functions?
8. Sketch three different kinds of batteries applied to cord circuits.
9. What is a supervisory signal?
10. Make diagram of a complete simple common-battery switchboard circuit.
11. When will the supervisory signal become operative?
12. What is the candle-power of incandescent lamps used for line and supervisory signals?
13. At what voltages do they operate?
14. What are visual signals?
15. Describe the mechanical signal of the Western Electric Company.
16. Give a short description of the general assembly of the parts of a simple common-battery switchboard.
17. What is a transfer switchboard?
18. Outline the limitations of a simple switchboard.
19. Describe and sketch a plug-ended transfer line.

REVIEW QUESTIONS

ON THE SUBJECT OF

TELEPHONY

PAGES 233—312

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1. Sketch and describe the line circuit of the common-battery multiple switchboard of the Bell companies.

2. Make a diagram of the cord circuit of the Western Electric standard multiple common-battery switchboard.

3. Describe the busy test in this system.

4. What is the function of the order-wire circuits?

5. What is jumper wire?

6. Give a short description of the relay mounting in the standard No. 1 relay board of the Western Electric Company.

7. What is the ultimate capacity of the No. 1 Western Electric switchboard?

8. What is the capacity of the No. 10 Western Electric switchboard?

9. How does this switchboard No. 10 differ from No. 1?

10. Give a diagram of the two-wire line circuit of the Kellogg Company.

11. What is the capacity of the condenser of the cord circuit in the foregoing system?

12. Give a complete diagram of the Kellogg two-wire board.

13. Describe the busy test in this system.

14. Give diagram of the Stromberg-Carlson multiple-board circuit.

15. What is the most important piece of apparatus in a multiple switchboard?

16. What is the spacing of the multiple jacks in the No. 1 Western Electric switchboard?

REVIEW QUESTIONS

ON THE SUBJECT OF

TELEPHONY

PAGES 313—362

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1. Describe a phantom circuit with diagram.
2. Explain how two phantoms may be joined by a physical circuit.
3. Which are the better, phantom or physical circuits, and why?
4. Explain how the simplex circuit differs from the phantom telephone circuit.
5. Why are not telegraph wires as serviceable for telephone work as telephone wires are for telegraph work?
6. Give the names of the different parts of a railway composite set and explain method of operating.
7. State the causes of the introduction of the telephone into the train dispatching field and explain the advantages it has over the telegraph for this work.
8. In transmitting orders for train dispatching, how are mistakes avoided?
9. Describe the Western Electric selector and explain its use.
10. In what way does the Gill selector differ from the Western Electric?
11. What special feature does the multiple coil selector possess?
12. What special arrangement is provided for the train dispatcher in noisy locations?
13. How can a man on a wrecking train get connection with the train dispatcher?
14. What is the usual limit in length of a telephone train dispatching circuit and what is the largest number of stations at present existing on such a circuit?

GENERAL INDEX

In this index the *Volume number* appears in Roman numerals—thus, I, II, III, IV, etc.; and the *Page number* in Arabic numerals—thus, 1, 2, 3, 4, etc. For example, Volume IV, Page 327, is written IV, 327.

In addition to this "General Index," the reader is referred to the more exhaustive analytical index to be found in each volume.

The page numbers of each volume will be found at the bottom of the pages; the numbers at the top refer only to the section.

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