MODERN AMERICAN TELEPHONY

IN ALL ITS BRANCHES

The Installation, Operation, and Maintenance of Telephones; Including Electro Motive Force — Sound and Sound Waves— Induction, Strength and Direction of Induced Currents — Direct and Alternating Electrical Currents—Pressure, Resistance —Capacity—Magneto System—Transmitter—Magneto Generators—Batteries—Common Battery Systems— Power Plants for Common Battery Systems — Magneto Switch Boards — Switchboard Installation — Multiple Switchboards — Common Battery Non-Multiple Exchanges without Central Office Connections—Test Boards, Distributing Boards, Testing Apparatus —Protective Devices — Measuring Instruments, The Wheatstone Bridge—Telephonic Troubles, How to Find and Remedy Them—Line Construction—Rural Line Construction—Electrical Conduit Construction—The Latest Automatic Systems— Wireless Telephony—Etc., Etc.

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PREFACE

The widespread interest in the telephone and the usefulness of viewing the art from various standpoints are sufficient reasons for the appearance of this book.

This is an age in which self help and mutual assistance are rightly prominent. In former years, the skilled workman kept his information to himself. "I had to work hard to learn my business. Let others do the same." Though it originated in selfishness, such an attitude is partly good in its results.

Part of a man's equipment for life is his manual and mental dexterity and skill, which can neither be taught nor imparted to others. For this reason, each man must bravely attack the work and "learn to do by doing." If he does not, he is doomed to mediocrity or failure.

The other part of a man's equipment, his knowledge, can be passed on for the benefit of others. He can teach the novice what he knows. He can direct him in the best ways of acquiring dexterity. Fortunately the spirit of mutual helpfulness is prevalent in these days and every man who will can learn.

A good book, written by a man of experience, and studied in connection with one's work is an exceedingly valuable means of acquiring a knowledge of the art. Without waiting to "graduate" the reader-student can at once begin to apply his information and to gain that dexterity which comes only from intelligent work. In some respects the man who follows a home course of reading has an advantage over his brother in college. This advantage lies in the live and immediate interest with which he follows his studies, for he realizes their importance at every step.

In this book have been brought together the best things from many sources. Although it is impossible to treat the whole theory, science, and art of the telephone in one volume, this work will be found to be fairly comprehensive. It will answer a host of questions which come to every worker and will prove stimulating to his ambition to excell.

The rise of wireless telephony is of enough importance to justify a chapter on that interesting subject. Though it is in its infancy, much has already been done and a good foundation laid for the future. The field is wide and must ultimately be filled by practical and reliable apparatus and methods. This book is fortunate in being able to record the advance of the art to the latest moment.

The automatic switchboard has come into widespread use. In eighty cities in America it is serving the daily needs of the public, while abroad the preparations for its use are going on rapidly. Many of the readers of this book will doubtless be workers on automatic exchanges. For these reasons the chapter on the automatic telephone has been prepared. The descriptions of the switches and trunking are full and up to date.

It is the hope of the author that this book will prove to be of interest and practical help to the man who "shoots trouble" as well as to those whose duties call them into other relations with the plant.

TELEPHONY

CHAPTER I

THE INVENTION AND FIRST PRINCIPLES OF THE TELEPHONE

In the year 1876 Alexander Graham Bell and Elisha Gray, two American scientists, invented independently the electromagnetic telephone. With these inventions the practical application of electrical transmission of speech over wires was for the first time introduced to the world as an established scientific achievement. The telephone soon became an indispensable auxiliary to the expeditious dispatch of affairs in the great field of commerce, in both the civil and military branches of government, in the complex relations of social life and in all other departments of human activity. Previous to the inventions of Bell and Graham, other experimenters had succeeded in transmitting sounds by means of mechanical telephones, which were crude devices, consisting of wooden rods and strings, or wires, stretched between points separated by short distances. Such types of apparatus were known at as early a period as the seventeenth century, but were of no practical value and served only as a source of amusement and entertainment to those interested in the discovery of new phenomena in the transmission of sounds.

The basic principle of all telephone practice, as well as the foundation of all other applied elec-

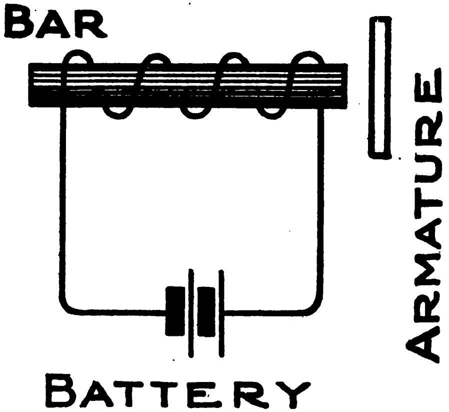


FIG. 1

trical science, is inherently involved with, and dependent upon, the two laws relating to the transformation of electric into magnetic energy and conversely magnetic into electric energy.

An iron or steel bar wound with a coil of wire, as shown in Fig. 1, becomes a magnet when placed in circuit with a battery, and the electric current is made to flow through the coil. If an iron armature be placed in proximity to either of the poles of this magnetized bar it will be attracted so long as the current continues to flow through the coil of wire; the attractive power of the magnet varying as the strength of the current varies, and losing its magnetic attraction when the circuit is opened and the current ceases to flow. If, however, the bar be of steel and is magnetized permanently, an attractive force, independent of the current, will be exerted upon the armature; but the current will, according to its direction, modify this attractive force by increasing or diminishing it, as the case may be.

MAGNETIC LINES OF FORCE. Surrounding every magnet is a field of force known as the *magnetic field* which exerts an influence of attraction or repulsion upon bodies susceptible to magnetization, and which is represented by curved lines radiating from the poles of the magnet. These lines are termed, *magnetic lines of force,* and usually the strength of a magnet is referred to in terms of the number of lines which radiate from one of its poles. These lines merely indicate the *direction* in which the magnetism acts at any point and do not actually exist as *lines.* The expressions "5,000 lines per square inch" and "10,000 lines per square inch" simply mean that the second is twice as strong as the first. The radiation and direction of these lines may be demonstrated visibly by the simple experiment of holding a bar magnet horizontally under a sheet of paper and sprinkling the paper with iron filings. The moment the iron filings touch the paper they will arrange themselves on its surface in lines corresponding to the magnetic lines of force, as illustrated in Fig. 2, which shows the bar magnet, N. S., and the curved lines of radiation described by the iron filings; and which are supposed to represent the direction of

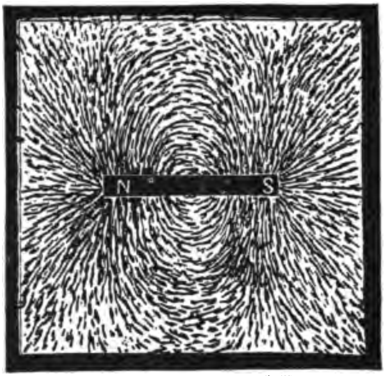


FIG. 2

the flux as it leaves the north pole and re-enters at the south.

When a current indicator—a galvanometer for example—is placed in circuit with a coil, as shown in Fig. 3, and a magnet is moved close to the coil in such manner as to change the number of lines of force passing through the coil, the galvanometer will indicate that a current has been generated in the coil, and also that the current flows only while such movement of the magnet is continued.

The direction of the lines of force through the coil, and the increase or decrease of their number, will govern the direction of the current; and the rate at which the number of lines change will determine the strength of the current.

When a body of iron is moved into the field of a magnet, a greater number of lines pass through the space filled by the iron than if the same space were filled with air, which causes the field to be-

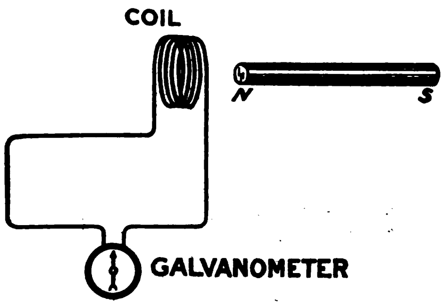


FIG. 3

come distorted. Hence currents of electricity will flow in a closed coil, if it be placed about the pole of a magnet, and the mass of iron be moved to and from the pole, as this movement will cause a variation in the intensity of the field.

THE ELECTROMAGNET. When a current is flowing through a conductor, as A, B, in Fig. 4, it is surrounded by lines of force, as shown at C, C′, C″ and the center of these lines is coincident with the axis of the wire. These lines of force increase or decrease in number with the strength of the current flowing through the wire. By winding

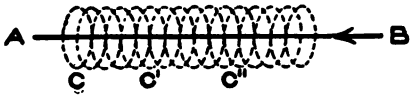


FIG. 4

the wire around a soft iron core the same flow of current will produce a very much stronger mag-

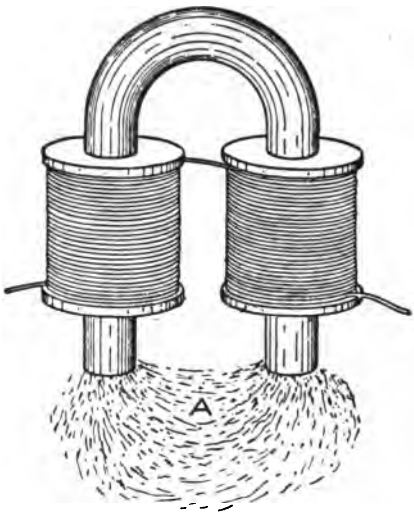


FIG. 5

netic field. The amount of magnetization for a given kind of iron core is proportional to the product of the number of turns by the current divided by the length of the iron core; and if, as shown in Fig. 5, the iron core be extended, bringing the poles in close proximity, a given current strength will produce still greater magnetization. This arrangement constitutes an electro-magnet.

ELECTROMOTIVE FORCE. The three initial letters, E. M. F. are usually employed to indicate *electromotive force.* This refers to the force or intensity with which a battery or other generator *tends* to cause a flow of current. We must distinguish carefully between this force or tendency and the actual flow of current. A dry cell may have an electromotive force of 1.5 volts, yet if the circuit be open, no current will be flowing. But if the circuit be closed, the pressure of 1.5 volts will cause the movement of electricity through the connecting wire.

THE DYNAMO OR GENERATOR. By causing a closed conductor to revolve between the poles of the electro-magnet at A, (See Fig. 5), the lines of force in the magnetic field will be cut and an E. M. F. will be generated in the conductor, producing a flow of current. But the amount of current generated in a given strength of field will be greater in proportion to the number of turns of the conductor and will be still greater if the wire is wound around a soft iron core; since the number of convolutions are increased and the magnetic resistance is decreased by the presence of the soft iron armature. A dynamo or generator, in its simplest form, is illustrated in Fig. 6. The product of the strength of field, the number of turns on one half of the armature and the speed per second in turns is pro-

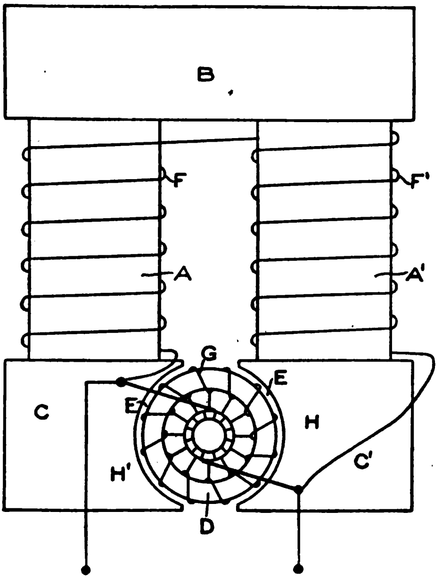


FIG. 6
SIMPLE FORM OF DYNAMO

portional to the E. M. F. generated by a dynamo. To some extent the resistance of the armature reduces the effective E. M. F. when a dynamo delivers current. The compound winding of a dynamo is generally used when a constant potential from open circuit to full load is required, as by this means the current, by passing through the series coils, assists the shunt coils, increasing the magnetic density and tending to maintain a constant E. M. F.

THE DYNAMOTOR. A combination machine called a motor-generator is constructed with a dynamo and motor mounted on one shaft, each having independent fields and armatures; but for small machines one field and one armature suffices; the armature being provided with two windings, one being used for the dynamo and the other for the motor. This is called a dynamotor. At one end of the shaft is the commutator of one winding and at the other end of the shaft is the commutator of the other winding.

SOUND

The phenomenon of sound, like heat, is caused by molecular motion. When a sounding body is moved to and fro, or vibrated, the air in contact with it takes up the vibrations and transmits the motion from one portion of air to another in undulations or waves as shown in Fig. 7. These waves consist of two parts, one in which the particles of air are pressed more closely together, called *condensation,* A. or B., and one where they are further apart, called rarefaction, C. or D. The distance between two consecutive points of condensation or rarefaction is called the *length* of the wave. These air waves set up corresponding vibrations in the drum of the ear, which are thence conveyed through the auditory nerve to the brain, producing the sensation which we know as sound. The magnitude, or amount of disturbance given to the particles of air, is known as the *amplitude* of the wave. The *intensity* of the sound is proportional to the square of the amplitude, and like all emanations from a central point in a free medium, varies inversely as the square of the distance from

FIG. 7
ILLUSTRATION OF SOUND WAVES

the center, which is, in this case, the position of the sounding body.

Sound possesses three qualities—*pitch,* which depends on the *frequency* of the vibrations; *loudness,* which depends on the *amplitude* of the vibrations, and *timbre,* or *quality,* which depends upon the *form* of vibration. The number of vibrations per second determines the pitch. A note from a tuning fork giving out 250 vibrations is referred to as having a "lower pitch" than one giving out 500 vibrations per second.

Quality (German, *Klangfarbe* or *Clang-tint;* French, *timbre*) is the characteristic by which sounds having the same pitch are distinguished—i.e. the distinguishing between the same musical note produced by different instruments or voices. The difference between noise and music is that noise is heard as an irregular succession of sounds, but if the sounds become periodic and sufficiently rapid, a musical note is obtained. The motion of a pendulum is periodic, but too slow to affect the auditory nerve; but if the number of vibrations were increased to 32 per second a deep low note would be produced, and as the number of vibrations increase, the higher would become the pitch. Vibrations of the pendulum at the rate of 66 per second would produce the lowest C of the piano, and at the rate of 528 the middle C would be obtained, and so on. The *quality* is due to overtones or harmonics superimposed upon or blended with the fundamental tones. These overtones have the effect of altering or modifying the form of the sound wave. In the case of articulate speech, the fundamental is accompanied by higher frequencies. When from any cause they become displaced articulation becomes more or less indistinct. In telephony *inductance* and *capacity* are the chief causes of imperfect articulation. If a circuit is free from both, the articulation is practically perfect; but if both are present they have the effect of distorting and displacing the harmonics.

THE HUMAN VOICE. The most complicated sound waves are those produced by articulate speech, and in their production the vocal chords, throat, mouth, tongue and teeth, are all factors, and the result is—unlike the simple series of vibrations produced by a musical instrument—an extraordinary combination of very rapid vibrations upon which other vibrations are superimposed. Sound waves produced by human voices are of inconceivable variety, as no two voices are exactly alike. Fig. 8 illustrates the movement of sound waves or vibrations as they are recorded by the phonautograph, and which represent musical

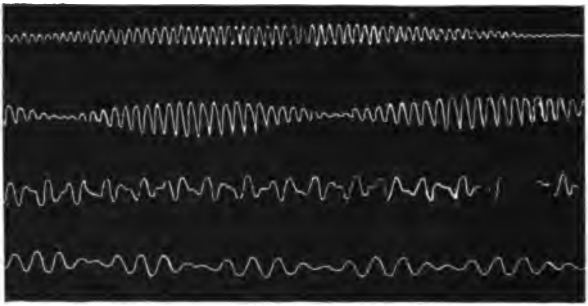


Fig. 8

MUSICAL SOUND WAVES AS RECORDED BY THE PHONAUTOGRAPH

sounds, and Fig. 9 represents the extremely irregular form of wave produced by articulate speech.

The Vocal Chords. The sound of the human voice is produced by the larynx forcing the air from the lungs through the "vocal chords," which consist of two membranes divided by a narrow aperture or slit. The high or low notes, as desired, are produced by the tightening or relaxing of these

FIG. 9
IRREGULAR SOUND WAVE PRODUCED BY ARTICULATE SPEECH

membranes which are controlled by a set of delicate muscles.

THE PHONAUTOGRAPH. By an ingenious instrument invented by Leon Scott, the wave motion of sound has been visibly demonstrated and re-

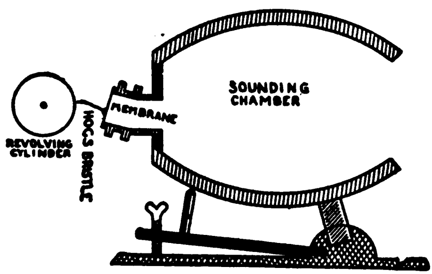


FIG. 10
LEON SCOTT'S PHONAUTOGRAPH

corded. This instrument, Fig. 10, consists of a sounding chamber which is open at one end to admit the sound, and a brass tube at the opposite end closed by a flexible membrane stretched across its mouth, and to which a hog's bristle is attached at right angles. The bristle rests upon soot-covered paper wound upon a cylinder which is mounted upon an axis and revolved by a crank handle. As the sound enters the chamber it causes the membrane to vibrate and the vibrations are traced upon the paper, as the cylinder revolves, forming lines not dissimilar to the lines indicating

FIG. 11
MANOMETRIC FLAMES

the pulsation of the blood as traced by the sphygmograph.

KOENIG'S MANOMETER. Another apparatus for observing and recording the wave motion of sound is the ingenious mechanical contrivance invented by Koenig, and which consists of a metal box containing two compartments, an elastic diaphragm forming the dividing partition. Sounds from the voice or an instrument are admitted through an orifice at one end of the box and to the other end, by means of rubber tubes, a gas fixture is connected, the supply of gas for which is admitted into the compartment in front of the diaphragm. The variations in the sound waves are indicated by the changes in the strength and steadiness of the flame; effects which are produced by the impinging of the waves against the diaphragm. A square box with mirrors on four sides, mounted on a vertical shaft and rapidly revolved before the flame by means of a crank handle, exhibits the different variations in the image of the flame, which corrspond with the different characteristics of the sound wave, as shown in Fig. 11.

THE MUSICAL SCALE. As the consensus of belief is that sound and light are governed by the same law, the conclusion of science is that they are both manifestations of the same force in nature, i.e.: both are manifestations of vibrations in solid substances, in the air or in that highly attenuated universal ether which pervades all matter. The musical scale as compared with the solar spectrum is a convincing illustration of this truth. This scale consists of a series of seven sounds designated by the letters A, B, C, D, E, F, G, and when this scale is mounted or descended in order, every eighth note, or *"octave,"* is the same as the initial one, varying only in pitch according to its proximity to base or treble. A note which is an octave above another note has twice its frequency. The seven sounds, or full notes, are known in musical terminology as *"naturals."* There are also five other notes, termed half tones or *"sharps"* and *"flats,"*—notes which come between certain naturals as a vibratory modification or connecting link between two well defined simple sounds, analogous to the vibratory variation of sun light, which in the seven colors of the solar spectrum, cause the effect of colors blending into one another, that would otherwise be sharply separated.

Octaves of Force. To vibration, slow or rapid, is due the difference between any two notes in one octave and between the same notes in different octaves. Perceptible to the sense of hearing, as "one tone," are sounds consisting of less than 32

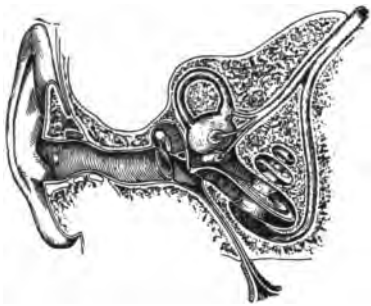


Fig. 12

THE HUMAN EAR

vibrations per second, or as many as 32,000 vibrations per second; representing a difference of fifteen octaves. Between the "sense" perception of sound and light, in regular scale of increasing vibratory intensity in multiples of 2, there are thirty-five octaves, the light area computed by scientists from the number of vibrations of the faintest ray, being termed the *"fiftieth octave."*

The Human Ear. A good sectional view of the human ear is shown in Fig. 12. A membranous diaphragm, called the tympanum or *"drum,"* is stretched across the inner end of the external canal. Three minute bones, or "ossicles," forming a series, are named the *"malleus"* (hammer), the *"incus"* (anvil) and the *"stapes"* (stirrup), and are shown respectively at a, b, c, Fig. 13. The malleus and stapes close the passage to the inner ear; the former by pressing against the inner side

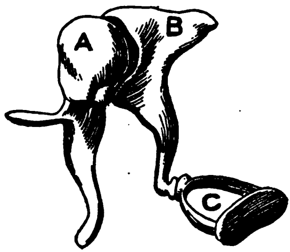


FIG 13

THE "MALLEUS," THE "INCUS," THE "STAPES" OF THE EAR

of the tympanum or drum, and the stapes by pressing against another membrane. The *"labyrinth"* and the *"cochlea"* (snail shell), a and b Fig. 14, are bony structures threaded by a series of small, tortuous canals; the former, a, being filled with nerve fibers to which the auditory nerve is connected, and which also runs through the turns and convolutions of the latter, b. The nerve fibers, some 3,000 in number, which line the inner membrane of the cochlea, and connect with the brain, are the terminals of the auditory nerve and are known as "Corti's Fibres" or "Rods of Corti." These fibres appear, each one, to be attuned to a certain note or tone, and when such note is sounded on a musical instrument, and the sound wave enters the ear, it causes one of these fibres or rods to vibrate in unison with it, and this vibration, being transmitted to the brain, the sensation of sound is experienced. A harmonious

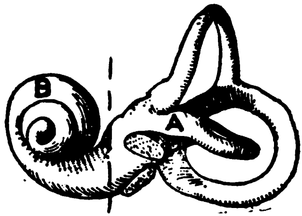


FIG. 14
THE "LABYRINTH" AND "COCHLEA"

sound would be produced if a chord or combination of musical sounds were made, as a corresponding vibration would be produced in several fibres or rods; each fibre responding to the note to which it is attuned, and no two fibres are responsive to the same note; but the complex system of nerve fibres, considered as a whole, is capable of responding, not only to notes of different tone; but also to sounds of different form, such as articulate speech. This phenomenon has never yet been satisfactorily explained.

The acuteness of hearing and the distinguishing between sounds varies in different persons, depending entirely upon the number of nerves possessed and normally performing their functions. The majority of people have substantially the same number of nerves and consequently an equal capacity for hearing. In others some fibres may be undeveloped, diseased or lacking altogether, in which cases there is imperfect vibratory response, or none at all, to the corresponding vibration of the external source carried to the ear drum by the sound wave. When the functional performance of any of these nerve fibres is defective from disease or any cause whatsoever, and they are not responsive, this causes a condition known as "tone-deafness," and total or partial deafness, either congenital or acquired, accompanies respectively the total impotency or partial impairment of this system of nerves. Many theories have been advanced and attempts at explanation made to account for the transmission of articulate sounds by the process of interrupted currents; but no interrupted current has been successful in securing results. It requires an undulating or an alternating wave of definite characteristics to transmit speech. This wave must correspond to the sound wave in all particulars, in the same way as do the undulations in the groove of a phonograph record.

So far as the nature of sound is understood, concisely stated, it consists in vibrations set up in the air, in solids and in liquids, and is a molecular motion produced in varying degrees in all material things, and the characteristics of sound, i. e.: loudness, tone and timbre, are all transmitted as far as the sound will go, and combine to create upon the brain, through the medium of the ear and auditory nerve, a single impression, and the theory upon which rests the electric telephone is that these combined characteristics of sound create impressions, which in a similar manner, vary the electric current. That the carrying distance of sound in the air or other medium, by virtue of its own vibrations is very limited and dependent upon various conditions, is a fact which would not escape the most careless observer. The sound of the woodsman's axe, which under favorable atmospheric conditions would be heard at a considerable distance in a given direction, would fall far short of its reach should the wind be wrong.

The phenomenon which we know as wind is but a body of air moving in a certain direction, and when sound waves are set up in it, those waves which are coincident or approximately coincident with its direction, travel further than if the air were not in motion. This may be illustrated by a simple analogy. Sound waves like water waves will travel a distance in ratio to the initial energy imparted to them at the point of disturbance.

If a pebble be thrown into a pond of still water —and assuming that no obstructions are in the path of the resulting wave—it will begin at the point of impact and travel in all directions in an ever enlarging circle; the energy becoming constantly distributed, and hence decreasing as the circle enlarges, until it becomes completely exhausted and is absorbed by the body of water. If a large rock be thrown into the water the disturbance or initial energy imparted, and the amplitude of the wave, will be greater than that caused by the impact of the pebble and it will travel further proportionately.

In this case the distance traveled by the wave represents only the molecular motion created in the body of water proper; but let it be assumed that the body of water is contained in an immense basin and is moving at a certain rate of speed on a mammoth flat car; then should a wave be caused by the impact of some object cast upon the surface of the water, its progress, as referred to immobile objects on the earth's surface, would be determined by two distinct motions, viz., the molecular motion of the water itself and the motion through space of the water as an entire body. As in this case the wave is an integral part of a moving body of water, likewise is the sound wave an integral part of a moving body of air—or the wind.

In the above illustration the motion of the water carried along on the car is analagous to the motion of a body of moving air, or the wind; and the movement of the wave on the surface of the water is analogous to the sound wave set up in a body of moving air.

It is a common-place fact observed by nearly everyone, that sound does not travel so far when moving against the wind as when moving with it, and the reason is apparent when the illustration given above is considered in its reverse application. As sound waves travel at a very much higher rate of speed than the wind, this fact must be borne in mind and allowed for in all illustrations of comparison; for were it not true that sound travels faster than wind, it could not be heard at all in a direction against the wind, as the progress of that part of the sound wave traveling in the opposite direction to the direction of the

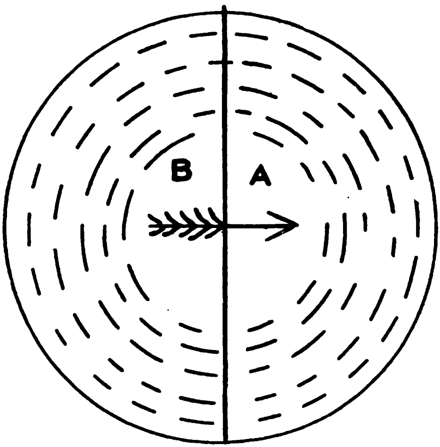


Fig. 15
ANALOGY OF SOUND WAVES

wind would be slower than the velocity of the wind and consequently would move in the direction of the wind at a rate equal to the wind's velocity less its own speed in the opposite direction.

A simple illustration of this may be given by pursuing further the analogue of the moving basin or pond and the water waves. The circle, Fig. 15, represents the pond, moving in the direction indicated by the arrow, at the rate of one mile per hour. The broken lines represent the water waves moving in every direction at the rate of three miles per hour.* Obviously then, the segments of the semicircle A, moving directly or approximately in the same direction as the pond, will travel a certain distance in a certain length of time until they become exhausted and absorbed; but the total distance covered in this length of time, will be the distance traveled by the wave *plus* the distance traveled by the pond; or, in one hour the waves will have covered a distance of four miles—three miles with their own motion and one mile with the motion of the pond. Obversely then, the waves in the semicircle B, would have traveled but two miles—three miles at their own rate of speed in one direction, less one mile covered by the moving body of water in the opposite direction.

When sound waves are confined as within long tubes, such as the speaking tubes, which were once in common use, the sound is conveyed to a greater distance and speech is more distinctly heard than when the sound waves spread through the air, and sound may be conducted along a definite line or conduit such as the "lovers' telegraph" heretofore described; but all transmission of sound, whether by waves in the air or vibrations communicated to

* For convenience of illustration this calculation has been made regardless of the variation in distances traveled by segments of wave circle, due to differences in angles of radiation from true direction.

a taut string, is very limited, and both the waves in the air and the molecular vibrations in a solid conductor soon suffer dissolution by atmospheric or other resistance. Therefore, for practical purposes, no agencies for the transmission of sound to distant points were ever known to the scientific world until the discovery was made that the electric current could take up the impulses of the sound wave and transmit them to the distant end of a line where they could be reproduced with all of their characteristics.

CHAPTER II

INDUCTION

As a comprehensive treatment of the subject of *Telephone Practice* is contemplated principally in the preparation of this volume, a knowledge of the fundamentals of magnetism and electricity is presupposed, and therefore only cursory reference is made to such elementary features of the subject as the "attraction by unlike poles and the repulsion by like poles" of the magnet; or to the "Ohm's law," and other features contained and elucidated in the usual preparatory curriculum of electrical study, familiar to advanced students and practical workers. But the subject of induction, being one of such paramount importance, and its thorough comprehension so indispensable to a clear understanding of the principle upon which all telephones of practical utility are constructed and operated, a concise survey or summary of its salient points may be advantageously reviewed, and reassimilated, before entering into the technology and applied theory of this great branch of electrical science.

Induction is the inevitable concomitant of magnetic and electric disturbances. A current will circulate in a coil of wire in a certain direction whenever a magnet is made to approach the coil or enter it, and if a galvanometer be placed in circuit with the coil the needle will be deflected in one direction, as shown in Fig. 16; but when the magnet is withdrawn the path of the current will be reversed and the deflection of the needle will also be in the opposite direction. This current is a transient one, lasting only during the motion

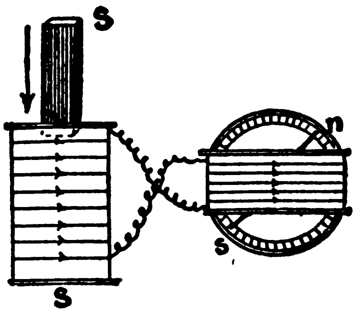


FIG 16

DEFLECTION OF NEEDLE CAUSED BY BRINGING MAGNET NEAR WINDING

of the magnet, and when this motion ceases inside or outside, the needle will remain at zero.

The same effect may be obtained by winding a shorter coil of thicker wire around a soft iron core, connecting its terminals to the poles of a battery and bringing it to the larger coil or introducing it inside, as shown in Fig. 17. This contrivance embodies the essential features of the induction coil.

THE INDUCTION COIL. This apparatus, Fig. 18, is constructed by winding two coils on the same spool or bobbin instead of winding them separately. The shorter coil of wire is wound on the bobbin first and over that the thinner wire composing the longer coil. The shorter coil is called the *primary* wire, and is much thicker than that of the longer coil to enable it to carry a strong current without overheating. The longer coil is

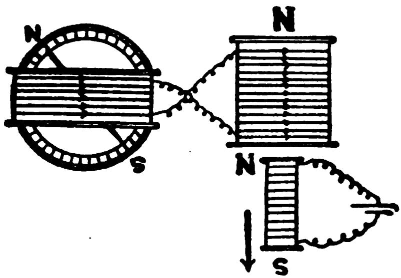


FIG. 17

SECOND METHOD OF ILLUSTRATING THE RISE OF CURRENT CAUSED BY VARYING DISTANCE OF MAGNETIC FIELD FROM WINDING

called the *secondary* wire. To close and open the circuit the primary wire is provided with a key or commutator. A current passes through the primary wire, when the circuit is closed, and the curving lines of force which flow around that wire cut or pass through the wires of the secondary coil at right angles to their length. As this is one of the conditions of an induced current such a current will flow in the secondary wire. When the current of the primary is broken, a current flows through the secondary in the opposite direction. If a current is already flowing in the primary, and it is suddenly increased, a current will flow in the same direction as the former, and when the current is decreased a current will flow in the same direction as the latter.

The first current is referred to as *inverse* and the second as *direct*, for the reason that the direction of the first current is opposed to that of the

FIG. 18
INDUCTION COIL

primary and the direction of the second current coincides with it.

One of the conditions of an induced current, it has been maintained, is that the lines of force of the magnet or primary wire, must be projected at right angles to the winding of the secondary coil, when they are then supposed to cut the coil. The current, however, is not caused by the lines of force proper cutting the coil; but rather by the turning of the molecules of the wire whereby they place themselves *in* the lines of force; in action, similar to the movement of the tangent galvanometer's magnet, which seeks a position in the lines of force of the coil. The molecules assume their former position with the cessation of the current and a current is then produced in the contrary direction.

The *intensity* of the magnetic field, and consequent strength of current; the *number* of turns of wire in the secondary coil; the *rapidity* in the variation of the magnetic field produced by the current in the primary wire, by either making or breaking the circuit or by increasing or decreasing the current, are the three conditions upon which the E.M.F. depends. If the number of lines of force cutting the secondary coil is at first N′, where induced currents are created by increasing and decreasing the current in the primary wire, and N′ is increased to N″, in a time T, and R being the resistance of the coil, then the strength of the induced current may be deduced from the formula: $I = K\frac{N' - N''}{RT}$. The numerator in which I = the current and K = some constant number will be minus and the current an *inverse* one since N″ is greater than N′. But a direct current will be had if the current in the primary is reduced since N″ will be less than N′.

Directions of Induced Currents. The direction of induced currents may be determined by Lenz's law, which concisely stated is, that induced currents will follow a direction opposite to the motion producing them. For example: If a coil be approached by the south pole of a bar magnet a current will be induced in the coil in such direction that the near end of the coil will be a *south* pole and will tend to repel the magnet—as like poles repel each other; but if the south pole is removed suddenly, the end of the coil will become a north pole, it will attract and tend to resist the removal of the receding pole. The introduction of a coil into, and its removal from, a hollow coil, will produce the same effect.

STRENGTH OF CURRENTS IN COILS. Within certain limits a current of high E.M.F. can be produced at will. The E.M.F. and current in the secondary coil will be nearly equal to that in the primary coil when the number of turns of wire on the former is equal to that on the latter; but as the number of turns in the secondary coil is increased, the strong current and low E.M.F. of the primary is transformed into a high E.M.F., with a comparatively weak current in the secondary.

Energy, being a constant quantity, is not created or destroyed, but may be transformed, as in these cases. For instance, muscular energy is transformed into electrical energy when the magnet is advanced by hand. The energy W in the primary, when the induced current is produced, is approximately equal to the product of the current and the E.M.F., or $E' \times I'$. In the secondary the energy likewise is approximately equal to the product of the E.M.F. and current or $E'' \times I''$. But $E'' \times I''$ will always be somewhat less than $E' \times I'$ as in any case of the transformation of energy more or less will disappear in heat or other ways and to transform the entire energy in the primary is not possible.

As the number of turns of wire in the secondary coil is the second cause of the high induced E.M.F., then likewise, $E' : E'' :: N' : N''$, one and two respectively in each case refers to the primary and secondary coils. This holds true only if all the magnetic flux cuts both coils.

When the galvanometer is connected to the secondary coil the third cause of the high induced E.M.F. may be verified by observing the deflections of the needle, when the magnet or coil is suddenly or slowly inserted or withdrawn, or when a current is suddenly or slowly increased or decreased.

ENERGY LOST THROUGH INDUCTANCE. To the magnetic inertia or inductance of the wire in both coils is due the loss of as much of the transformed energy as is expended in overcoming it. A part of the energy is lost in a long straight wire because of the retardation of current and the time required to form a signal at the remote end, In addition to this retardation, when the wire is in the form of a coil a force is created in opposition to the current, as in passing through the secondary wire, it induces a current in the opposite direction in all the adjacent convolutions. The collapse of the magnetic field produces an induced current when the original current ceases. Theoretically this should restore to the circuit all the energy lost when the current was started but practically it is lost in the spark produced at the contact. Not only does it act as a drag, but the first part of the current is absorbed by it. Assuming that there are ten turns in a coil, the inductance would be proportional, i. e., to 10^2 or 100; because the current passing through any one turn in the secondary wire would induce a current in every other turn, and also a current before itself, and every other turn would act likewise, from which may be deduced the rule that the action varies, not as the number of turns, but *as the square of the number of turns.* Inertia or self-induction is denoted by the symbol L, and R denoting the resistance of the coil or circuit, L R would denote its *time constant,* from which, to ascertain its effects, the calculations may be made.

LOSS OF PART OF TRANSFORMED ENERGY DUE TO HEAT. The heat in any wire is $H = 1^2 \, R \, T = E^2 \, T/R = EIT$, therefore it is inversely proportional to the resistance for a given E.M.F., and directly proportional to the square of E.M.F. for a given resistance. Consequently the heat is reduced by one-half when the resistance is doubled, and it is quadrupled when the E.M.F. is doubled. The unit of heat or the caloric represents a quantity of heat which will raise 1 gramme of water 1° C.

CHAPTER III

BELL'S TELEPHONE

The Early Types of Bell's Telephone. The first forms of telephone invented by Professor Graham Bell were of no value so far as their utility related to public service, as they were com-

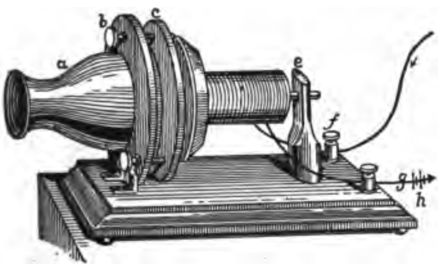


Fig. 19
EARLY TYPE OF BELL TELEPHONE

plicated in construction and inefficient in performance. The earliest practical apparatus which he finally evolved was constructed upon the essential principle and possessed all of the cardinal features of the highly developed and perfected type in present use. It was of much simpler construction than the first forms and far easier to understand and has undergone practically no change since it was first exhibited in 1876. One of the first forms constructed by Professor Bell is shown in Fig. 19 and was on exhibition in 1876 at the Centennial Exposition at Philadelphia. This apparatus, although suitable only for laboratory purposes, was nevertheless considered an achievement of transcendent scientific interest, as

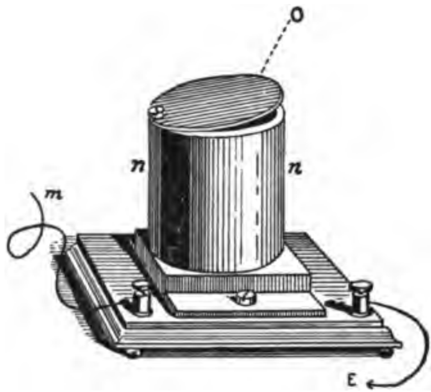


FIG. 20
RECEIVING END

it accomplished the astounding result of transmitting spoken words through a telegraph wire by means of electric currents. The result was obtained by producing a variation of strength of current in exact proportion to the velocity of a particle of air moved by the sound, and the method of accomplishing this was by means of a piece of iron attached to a membrane and moved back and forth in proximity to an electro-magnet shown at *d* in Fig. 19, and in the same figure the battery and wire, *g* and *h,* are in circuit with the telegraph wire *f* and *l,* and also with the wire of another electro-magnet at the receiving station, as shown at *m* in Fig. 20. There is a solid iron bar core in this second electro-magnet which at one end is connected by a thick iron disc to an iron tube surrounding the coil and bar *n,* Fig. 20. One pole of this electro-magnet is the free circular end of the tube and the other pole is the free end of the adjacent bar core. The sounder *o,* by which the electric effect is reconverted into sound, consists of a thin circular iron disc held pressed against the end of the tube by the attraction of the electro-magnet, with freedom for very limited vibratory movement without contact with the central pole. The mouthpiece of this apparatus for collecting the sound is shown at *a,* Fig. 19, and in the same figure *b b* are the screws which serve to tighten or slacken the diaphragm, composed of gold-beater's skin, and in the center of which a small piece of watch spring is fixed, the skin being stretched over the collar *c c* and retained by it in position. At *d* the electro-magnet is shown, the iron core of which is supported at one end by the pillar *e,* while the other end is immediately opposite the diaphragm. The original diaphragm of gold-beater's skin was later on superseded by a thin iron disc.

The wire leading from the transmitter is shown at *m* in Fig. 20, and is connected with a vertical bar electro-magnet located inside of the iron tube *n.* The diaphragm or thin iron disc *o* is caused to vibrate by the attraction of the electro-magnet.

THE MODERN BELL TELEPHONE. After much experimental work Professor Bell finally devised a form of telephone in which the electro-magnet

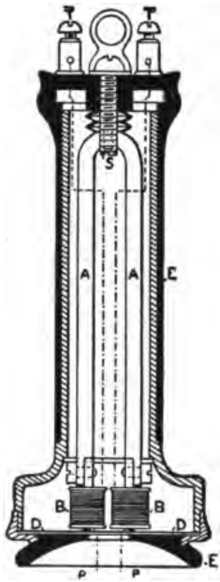


FIG. 21

MODERN TYPE BELL RECEIVER

and battery were dispensed with, and a permanent magnet substituted; the latter having been found to answer the same purpose. In this apparatus he employed a compound horse shoe magnet, having a small bobbin of fine insulated copper wire fixed on each pole, the two inner ends of the wire being joined together, one of the outer ends leading to the distant telephone and the other being connected with the earth or the other line. Immediately in front of the magnet a thin iron disc or diaphragm was mounted. Fig. 21 illustrates in sectional view, the modern form of this instrument, which is known as a double pole Bell telephone or receiver. A permanent horse shoe magnet,

FIG. 22

EXTERNAL VIEW OF BELL RECEIVER

aa, of the best tungsten steel is mounted inside of an ebonite metal case *ee.* Screwed on to the poles of the magnet are soft iron pole pieces, *pp,* forming the cores of the coils *b. b.,* which are wound to a resistance of 60 to 80 ohms. The ferrotype plate is indicated by *dd,* the regulating screw by *s,* and the terminals which connect with the wires from the coils by *t. t.* The dotted lines show the connection of the coil wires and the terminals. Fig. 22 is an external illustration of the double pole receiver.

In the diagram, Fig. 23, is shown the means sometimes used by which calling attention is effected. The bell *l* is connected with the line when the telephone *t* is hung on the hook of the automatic switch *s*. The bell is cut out of circuit when the telephone is taken from the hook. The path of the current operating the bell starts at the positive pole of the battery at A when the ringing key P is depressed and proceeds in the direction indicated

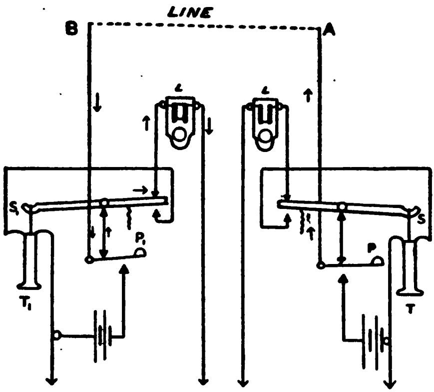


FIG. 23
SIMPLE TELEPHONE CIRCUIT

by the arrow to B, whence it passes to earth after traversing the coils of the trembler bell. In like manner the bell at A is rung when the key is depressed at B. It is obvious, then, that after a conversation is closed the telephone should always be replaced on the hook.

THEORY OF BELL TELEPHONE

The nearest path, or path of least magnetic resistance in the magnetic circuit tends to be taken by the lines of force which constantly stream from the pole of the magnet. The greater part of these lines will pass through the iron disc which has a resistance about 1400 times less than air. By bringing the disc nearer still more of the lines will flow through it, and by removing the disc from the magnet fewer lines will pass through it, and the remaining lines will return by the air path. As the disc approaches and withdraws from the magnet under the influence of the vibrations of the air due to the voice, the distribution of the magnetic field constantly varies, and currents circulate in the coil and line wire in alternate directions. The rate of motion of the disc causes a variation of the rate of increase and decrease of the number of lines of force passing through it, and the change of number of the lines of force produces undulatory currents in the coil and wire. Therefore the number of currents is determined by the number of vibrations, and their form and intensity, by the rate and amplitude of the vibrations.

The low, deep notes of a man's voice cause about 100 complete vibrations per second, and the high notes of a woman's voice cause from 1000 to 1500 for the fundamental tones, and up to 5000 for the superimposed tones necessary to the *quality* of the sound.

It has been estimated that the successive transformations which take place in the inappreciable interval between the moment when the sound leaves the disc of the transmitter and the moment that it strikes the ear of the listener are seven:

First. The vibrations of the air set the disc of the transmitter in motion.

Second. This motion changes the magnetic condition of the magnet.

Third. This change induces currents in the coil.

Fourth. These induced currents traverse the line and coil of the distant receiver.

Fifth. These currents produce changes in the magnet of the receiver.

Sixth. These changes of magnetism act on the disc and cause it to vibrate.

Seventh. These vibrations are communicated to the air and strike the tympanum of the ear.

The Strength of the Current. The currents generated in the Bell telephone are so very weak that no ordinary instrument is capable of measuring them. It has been authoritatively asserted that a current of .000,000,000,6 (six ten-thousand-millionths) of a milliampere will produce a vibration of the disc, and also that currents produce audible effects when reversed 500 times per second, though their strength be only equal to two volts, acting through a resistance of a million megohms. The instrument is so sensitive that it is estimated the energy contained in one heat unit would maintain a continuous sound for 10,000 years.

Amplitude of Vibration.—The vibrations of the disc are very slight and in order to produce the desired result, an amplitude of vibration of the 400-millionth of an inch is sufficient.

PROPORTION OF SOUND REPRODUCED.—The quantity of sound reproduced is only a small fraction of the sound of the voice. The experiments of some scientists have led them to the conclusion that the sound transmitted may be 1,500,000 times weaker than that emitted by the speaker. A wide difference, however, in the figures is given by different authorities, as the difficulty of making such delicate tests renders the results uncertain. Of the sound which the transmitter receives, it is believed that not more than the 10,000th part is reproduced.

NATURE OF MATERIAL OF DISC. From a large number of experiments with various kinds of discs, the theory has been advanced and generally accepted that telephones with iron discs are much louder than others, and that the effect is chiefly due to magnetic induction. Copper and aluminum discs (also those of iron) show alternate maxima and minima of intensity, and their effect is chiefly due to electro-dynamic induction. These discs reproduce the timbre very much better than those of iron. Without affecting the clearness of speech, it has been found that iron an inch in thickness reduces the intensity. Wood also reproduces the sound, and its thickness up to 1.5 inches increases the intensity. Also discs made of thick pieces of lead, glass, zinc and steel have been tried, all of which act. An empty wooden box has served the purpose of a diaphragm, and also a piece of ½-inch cork; and a razorstone two inches in thickness. A faint sound has been heard by dispensing with the disc and placing the ear very close to the pole of the magnet, thus proving that the magnet and coil also take part in the vibrations which reproduce the sound. Edison, Blyth and others have also shown that sound may be reproduced although the disc is non-magnetic. To prove whether or not the discs really vibrated mercury and water were tried on the discs, but no signs of vibration were perceptible, even when luminous reflections were employed to detect them. But the more sensitive photographer's plate has shown that vibrations are produced in the disc of the receiving telephone. By stretching an India-rubber membrane over the end of a speaking tube, with a small mirror cemented in the center, the vibrations of thin discs under the influence of sounds can be made optically visible. On singing into the tube a spot of light reflected from the mirror will describe on a screen the most extraordinary figures. A beautiful experiment is to pierce a small hole in the tube and close it by a film of soap. On singing into the tube all the variations can be seen in the film producing the most intricate and complicated figures which change with every note.

Strength of the Magnet. With the increase of strength of the magnet of the telephone, up to a certain limit the amplitude of the vibrations also increase and then fall off. The strength of the magnet should be in proportion to the other parts of the instrument, but it is absolutely necessary that the disc should be in a magnetic field.

UNDULATORY CURRENTS. The undulatory currents which make the transmission of speech possible, Bell claims to have been the first to employ. Intermittent, A, or pulsatory, B, currents, Fig. 24,

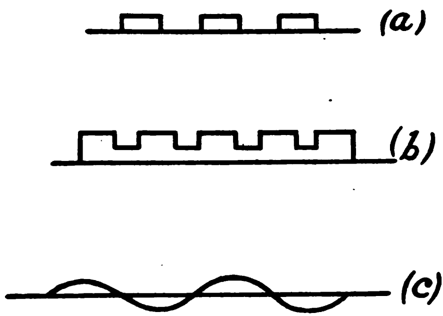


FIG. 24

CLASSES OF CURRENTS

are employed in the Tone telephones. The current is broken, suddenly raised or lowered, or reversed in direction, between each emission. Such currents can transmit the periodic vibrations of music, but not the more complex sounds of the human voice. *Undulatory* currents are indispensable for the reproduction of speech. To produce these, the current must not be broken, but must be alternately reversed, and gradually rise and fall, C, Fig. 24. Such currents can be produced in two ways:

First. By producing a varying electromotive force, as in the Bell telephone.

Second. By varying the resistance of the circuit as is done in all carbon transmitters.

CHAPTER IV

ELECTRICAL CURRENT

The electrical current, in its practical application, may be described as a force which is derived from and readily converted into other forms of energy and by means of which the transmission of energy is effected more readily than by direct mechanical application of power. For example, work can, by means of the proper apparatus, be recovered at a distant place from the initial point where a current has been generated or modified. The light of an incandescent or arc lamp is but the latent energy of fuel or the chemical energy of a battery converted into such by the intermediate means of the electrical current. In like manner sound waves which are very limited in range of transmission, may be converted into electrical waves by means of a telephone transmitter at a given point and at a very remote point these waves may be re-converted into sound waves by means of a telephone receiver.

As the electrical current has become the paramount factor in the present phenomenal development of industrial life and all of the activities which make for a higher civilization, a close scrutiny into its known characteristics will afford a useful working knowledge of its variance of effects under different conditions, and such knowledge is indispensable to the intelligent and successful prosecution of any branch of electrical science. Values and measurements constitute an important essential in the study of currents. A voltameter may be formed by running two wires from the terminals of a battery into a solution of silver nitrate or zinc sulphate or copper or acidulated water. If this is connected in series with an electro-magnet, a galvanometer and a piece of thin wire the effects will be: the production of chemical decomposition to a certain extent in the *voltameter*, heating of the wire, electro-magnetic attraction and deflection of the galvanometer needle, and these effects will increase by strengthening the battery. This increase, however, will not be respectively in the same ratio, as the attraction of the electro-magnet and deflection of the needle may become less or greater than the increase of chemical action in the *voltameter*—assuming it to be doubled—whereas the degree of heat in the wire will be more than twice as great. The only effect which is practicable for obtaining measurement without complex preparation and calculation is that of chemical decomposition which provides a reliable and uniform standard. Other apparatus, diverging widely in design and form, may be employed to demonstrate accurately the effect which indicates the proportional variation in strength of current and the same result will be obtained showing chemical decomposition to be the only effect maintaining the same value in the different sets of measuring apparatus. The demonstrated and established fact that a flow of current of one coulomb per second or one ampere of current will deposit exactly 0.017253 grain of silver per second, furnishes a standard by which the amount of current may be readily determined with a galvanometer suitably arranged for comparison with a silver voltameter. The actual values of the galvanometer's deflections may be determined by this comparison and when its scale is marked to record the results, an instrument is evolved, known as an ammeter (*abbreviation of ampere meter*) by means of which the amount of current in a circuit to which it is connected is immediately indicated on the scale.

In common battery exchanges about 0.1 ampere or 100 milliamperes is the average transmitter current. This varies from 30 to 40 on long lines and 200 or a little more on short lines. Transmission depends primarily upon the fluctuations in the current caused by the transmitter, and while it is not proportional to the amount of current, 30 or 40 milliamperes is not sufficient to insure the best results. In branch exchange work this difficulty is presented in a somewhat aggravated form because the retardation coil cord circuit is subject to varying conditions and also because the branch exchange battery is some volts lower when charged from the office battery. By various methods of boosting, usually by increasing the E.M.F., the transmitter current is maintained; this being an important requirement, as it is used both for signaling and talking.

The adoption of the current method of relay adjustment has invested the electric current with greater importance. All other essentials being equal the force of a magnet depends upon the number of ampere turns; or otherwise stated, the number of amperes through its windings, multiplied by the number of turns of wire around its core determines the strength of an electro-magnet.

The attractive force of the electro-magnet is approximately doubled by doubling the current—the carrying capacity of the wire and the quality and amount of iron, however, determining the limits of increase. To obtain the standard adjustment of battery relays a milliammeter and variable resistance are cut in series with them and the current is adjusted by varying the resistance. When the milliammeter records the required value, the relay on that current is then adjusted by using three varying strengths, viz., *operating, non-operating* and *releasing*. The adjustment of the relay then causes it to pull up on the first current strength; on the second not to pull up; and when pulled up to fall back on the third current.

The old resistance method is still employed to adjust trip relays which are used on trunks to cut the ringing off when the answer of the called subscriber is effected by operating on the increase of ringing current following the removal of the receiver from the hook. This is due to the difficulty which an ordinary direct current milliammeter entails in the accurate measurement of this type of current. The adjustment of the trip relay is such that when ringing through a certain adjustment it does not operate; but when this resistance is reduced to a point at which more current is allowed to pass through it the relay operates.

DAMAGE BY CURRENTS.—One plate of a zinc or copper voltameter becomes eroded by the same chemical effects of a current which causes the other plate to increase in bulk. In like manner and by the same action metallic substances such as iron pipes and wires in the ground are eroded because of water or any damp material forming a part of a circuit and causing erosion of the positive pole where the electricity leaves it, the metal being dissolved and carried off with the current. Therefore in order to prevent erosion at the ground connection in common battery circuits, the positive pole of the office battery should always be grounded, and the negative running to line, so that if a line should be grounded at a subscriber's station, the path of the current will not be from the line to the ground. Where dampness must be reckoned with, it is of signal importance in electrical work, in order to prevent electrolysis and consequent erosion of wires, that all connections should be made and kept as tight as possible. Stray currents of every description—and of which there are countless numbers—are a constant menace to cables, which are to a great extent laid under the surface of the ground, and often in streets along which the tracks of railway systems are laid. Return currents, escaping from the track rails, seek a path through the cable armor and where they leave it the erosion occurs. This causes serious damage in time, and if not provided against, as far as possible, by bonding to the track circuit, contiguous cables or a local ground, the flow of electricity from the cable armor into the damp earth will invariably occur, with the attending results of damage to the cable and interruption of service.

The heating effect of the electrical current in some branches of applied electricity, such as heating and electric lighting systems, welding and soldering of metals, etc., is the prime essential, and without which the object sought could not be attained; but in those branches where the transmission of energy is the sole desideratum, it sometimes becomes a source of danger and expense, causing disastrous fires by defective wiring, and damage to costly machinery by the burning out of windings. Familiar to all operatives in telephone service is the occasional damage wrought by the burning out of the windings of relays, receivers and induction coils when the strength of the current exceeds the carrying capacity of the wire. Although the heat is often too slight to be detected by measuring instruments there is always some rise in temperature produced by the electrical current in all parts of the circuit.

THE FUSE. (See Protective Devices.) For telephone practice, fuses are manufactured in many different designs. These fuses whilst rated at a given safe carrying capacity cannot always be depended upon to give uniform results under every possible variation of current action. Small fuses frequently will stand a current considerably in excess of their rated carrying capacity and in such case considerable damage is liable to follow the passage of a momentary rush of current greater than the circuit will stand. The surest protection to a circuit is the insertion of a short strip of some easily fusible metal or short wire, which will not fail to melt or fuse and open the circuit a little before the current reaches the point of danger. To over-fuse, i. e. to fuse by the use of any of the various designs of fuses which carry more current than the circuit which it is intended to protect, will invariably lead to damaging results.

In most cases, however, the fuse, whilst it may not be possible to assign to it an absolutely accurate carrying capacity, is adequate to perform the office of protection where care and good judgment are exercised in its selection.

To reduce the risk of accident to a minimum, in the selection of a fuse with reference to its protective quality, the carrying capacity of the weakest point in the circuit which it is expected to protect should be determined and the capacity of the fuse selected should be well below this point. This precaution calls for special care in providing fuses for fuse boards using different sizes, as for instance, in exchanges where any variation from it materially increases the danger of fire.

THE CIRCUIT BREAKER. (See Protective Devices.) The office of protection performed by the fuse is not confined alone to that device. Two other devices—the circuit breaker and the heat coil—are in common use and exclusively employed where greater accuracy is required or where certain conditions render the use of the fuse unavailable.

The circuit breaker is considered a most efficient protective device for heavy currents, its operation and that of the trip relay being very similar, consisting of a solenoid or electro-magnet and an iron armature which is held away from the magnet by a spring or weight until the current reaches a point which affords the magnet sufficient strength to attract it. It then moves up striking a trigger which releases a switch and the latter is then thrown open by a spring.

The circuit breaker is much valued for its accuracy and its simplicity of manipulation, being readily restored by merely closing the switch, and for that reason meets with much favor as an effective and convenient device for use in the charging leads on telephone power boards and other power circuits.

THE HEAT COIL. (See Protective Devices.) This device, whilst largely varying in form of construction in actual practice, embodies in every instance the same essential principle. It consists of a thin metallic tube wound with a non-inductive German silver wire of very slight ohmic resistance. Inside of the tube a small pin is held in position by a drop of solder fusible at a very low degree of temperature. When the current passing through the wire accumulates sufficient heat it causes the drop of solder to melt, which releases the pin, and this in turn allows a spring, which has been held off by the pin, to come in contact with a ground plate.

The heat coil is usually employed as a protective device where the circuit breaker or fuse is impracticable or ineffective because of too small current; but it can operate on almost any current if suitably constructed, and is fully as accurate as the circuit breaker and much less expensive. A variation of this device, consisting of a combination which permits the line to be opened in one direction and grounded in another, is employed in some instances.

Common Causes of Damage to Switchboards by Fire. Constant vigilance is the only safeguard against the danger of fire caused by loose connections or cords with broken strands of tinsel which may become dangerously heated with normal current, and no automatic protection has yet been devised to guard against this risk of fire. It is in the 110 or 220 volt nickel or lighting leads that this trouble usually occurs followed by the destruction of defective parts and the exact nature of the origin of the trouble is very difficult to determine. That dampness aggravates or increases these troubles, both to switchboards and the outside plant is a familiar fact, though not in the same manner in both cases. In switchboards the weak points in the insulation of relays, keys and wires are developed by the leakage, and often result in the burning out of relays besides largely increasing the risk of serious fires, whereas aerial troubles due to dampness affect only a line or group of lines while the dampness lasts, the cause being due simply to grounds and short circuits. In the more serious cases resulting from the leakage in switchboards—and in which the destruction of the evidence by fire is almost inevitable—the trouble occurs principally on the circuits of higher voltage, i. e. the nickel or generator.

Insulation of adequate quantity and quality, and proper fusing in initial construction, together with constant vigilance to maintain these elements at the highest standard of efficiency are the only means by which these troubles can be provided against. On most switchboard wires exposed to these troubles an insulation may be obtained sufficiently high and water proof to insure the desired result, by the use of double wrappings of silk and cotton on the wire, and where unprotected by the braided covering of a cable it should be well coated with wax and shellac. But whilst providing against one source of trouble great care should be exercised to safeguard against another; for this method of insulation involves material of a highly inflammable nature and which once ignited rapidly develops into a fire of serious proportions.

The different directions which the electrical current is known to take, has, for greater exactitude of description and meaning, caused it to be designated or qualified by two distinguishing technical terms, viz.: *direct* and *alternating*.

DIRECT CURRENT. A direct current flows in one direction only; but differs in characteristic as its value is either constant or fluctuating. Where

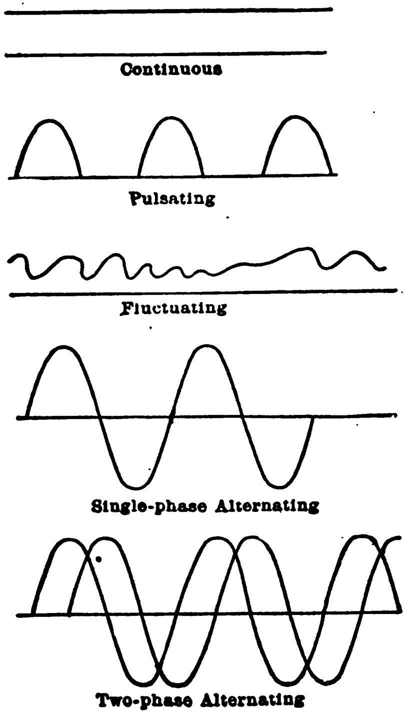


FIG. 25
DIFFERENT KINDS OF CURRENTS

the value is constant the current is said to be *continuous*, as shown in Fig. 25, and where the value changes constantly it is said to be *fluctuat-*

ing or *pulsating*. A still further fine distinction may be made between the fluctuating and the pulsating current. In the former the value changes constantly without regular sequence, whereas in the latter there is a regular succession of equal impulses in one direction with sometimes intervals between them of equal length and apparent cessation of flow.

The forms of impulses constituting the difference between these two currents are shown in Fig. 25, the base line in each diagram representing the point of zero current.

ALTERNATING CURRENT. An alternating current flows first in one direction and then in the opposite. This reversal of direction occurs many times in a second. The alternating current is also subdivided into phases exhibiting characteristics by which they are distinguished. The single phase alternating current consists of successive regular impulses first in one direction and then in the other, as illustrated in Fig. 25, and the polyphase or multiphase alternating current consists of two or more currents, the regular impulses of which and the direction of flow are the same as in the single phase. When two or more of these currents are flowing combined into one circuit, the change of reversal in one occurs at a fixed interval later in the rotation of generator armature. Fig. 25 shows the impulses of a two-phase alternating current as one impulse follows the other. The pulsating curves alternate in position above and below the base line indicating the reversal of direction.

QUESTIONS

1. What is an electrical current in its practical application?

2. How does the electric current convey sound waves between distant points?

3. Are values and measurements important in the study of currents?

4. What is the function of a voltmeter and how can one be made?

5. What is an ammeter?

6. By what standard may the amount of current be determined?

7. What is the average transmitter current in common battery exchanges expressed in milliamperes?

8. What is meant by "boosting" a telephone line?

9. What is the function of a trip relay on a trunk?

10. How are buried iron pipes, wires, etc., damaged by currents?

11. How is electrolysis guarded against in electric work?

12. What are stray currents, and what do they endanger?

13. How is the damage done to cables by stray currents provided against?

14. When is the heating effect of the electrical current an advantage and when a disadvantage?

15. What causes the burning out of windings?

16. What is a fuse?

17. What is the proper type of fuse to use and how should it be selected to protect a circuit?

18. What other devices are used besides the fuse to protect circuits?

19. What is a circuit breaker and what is its use?

20. What is a heat coil and what is its use?

21. Why can a heat coil be used when a fuse or circuit breaker cannot?

22. Name some of the common causes of damage to switchboards by fire.

23. Name a good insulation for switchboards.

24. What is a direct current?

25. Name the different kinds of direct currents and state what characteristics distinguish one from another.

26. What is an alternating current?

27. Name the different kinds of alternating currents and state what characteristics distinguish one from another.

CHAPTER V

ELECTRICAL PRESSURE

All physical phenomena, so far as experience has enabled our understanding to grasp them, are governed in their actions by certain fundamental principles or laws, and electrical phenomena are no exceptions in subjection to the universality of these natural laws.

In mutable physical phenomena nothing can be accomplished without the expenditure of energy. The inertia of matter cannot be overcome without the agency of some other force or power, but all of the known forces of nature exist everywhere, latent and inactive, when not subject to the conditions or laws which bring them into motion thereby causing them to exert energy through the medium of matter.

Matter and the forces which exert energy through the medium of it are coeternal. Therefore, electricity and all the other forces of nature are not generated or created, but are made to manifest themselves and exert mechanical action through the instrumentality of the laws which govern them. To illustrate: Electricity is a force already existing in one form or another everywhere upon the globe;* as for instance in the form of earth currents or in the static form, as in storm clouds. In the opinion of many scientists all parts of the earth and the atmospheric envelope which surrounds it are, in varying degrees, charged with the electric fluid. Therefore, when in practice, the process by which an electric current is made to flow, is referred to as *"generating electricity,"* or when the aparatus or machine performing the function is said to be a *"generator,"* these terms should not be taken in their literal sense; but rather as a convenient terminology sanctioned by custom.

The principle upon which a current of electricity is made to flow is precisely the same as that which causes water to seek its level, or which sets up a current of air in a long tube through which a piston is being moved. The principle is that of pressure, or more exactly stated: *Nature's effort to restore equilibrium or an equal distribution.* So long as pressure continues the flow of current will continue when the pressure is exerted upon any elastic fluid, and although electricity is not a tangible material substance or chemically perceptible, it is, with respect to its flow, subject to the same law of pressure as are grosser material fluids. A practical demonstration of the principle of pressure may be found in the simple experiment of connecting two tanks together at the

* In all probability electricity as a force of nature exists everywhere throughout the universe.

bottom by a length of pipe with a stop cock in the pipe between the two tanks. If one tank contains a quantity of water and the other be empty, the moment the stop cock is opened between the two tanks the water will begin to flow from the tank containing it into the empty one, and will continue to flow so long as the pressure lasts, or until the height of water in each tank is equal. When the equilibrium between the two tanks is established the pressure ceases. From which it may be rationally inferred that all forces in nature are, when inactive, normally in a state of equilibrium and that motion and the manifestation of energy is the effect of disturbing the equilibrium.

An electric battery, a dynamo or any other form of electrical generator, used to cause a current, is simply an apparatus for disturbing the equilibrium of the normal charge of electricity diffused throughout all substances, i. e., by raising its potential at one point and lowering it at another. *"Potential"* in electrical terminology is the equivalent of *"Pressure"* as referred to material substances such as air, water and other elastic fluids. A current of electricity, then, is caused by a difference of potential and so long as means are provided to maintain that difference—as for example by the operation of a generator—the current will flow through a suitable conductor; but when a difference of potential is established in two bodies without any means for maintaining it—as, for instance in static electricity, or where two thunder clouds are unequally charged—there will follow a sudden discharge of electricity from one body to the other, which will bring them both to the same potential. This discharge or impulse is not a current; but a restoration of equilibrium by a sudden rush. The generation of a current or continuous flow, on the contrary, is the continuous *effort* of the law to assert itself, i. e., perform its function of equalization of potential, and this effort is maintained, manifested as an electrical current, just so long as the disturbing element (battery, dynamo or any other cause of currents) continues to operate.

This principle may readily be demonstrated by dipping a plate of copper and one of zinc in dilute sulphuric acid. The affinity of the acid for the zinc will be much greater than for the copper and the effect of this difference in affinity will be to lower the electrical potential of the zinc and raise that of the copper. The potential of the copper will be shown by a voltmeter to be about one volt higher than that of the zinc. By connecting the two plates through an ammeter or galvanometer this difference of potential will cause a current to flow from the copper to the zinc and the current will continue to flow as long as the chemical action is continuous; and which is needed to maintain the difference of potential; its continuance being indicated by the rising of bubbles from the copper. In this case the inequality of the chemical action upon the two different metals becomes the disturbing element by establishing and maintaining a difference of potential and the current will continue to flow—that is, continue its effort to equalize potential—as long as the chemical action lasts. If, however, the circuit between the two plates be opened the bubbles will cease, because there is no longer any current to relieve the pressure, although the pressure is still there, as will be shown by a test with the voltmeter. The principle demonstrated in this simple experiment forms the basis of the chemical action in all the countless types of batteries.

The potential of one end of a wire will be raised and that of the other end lowered by simply passing the wire rapidly across a magnetic field. A wire wound in a coil and rotated in a magnetic field becomes a simple dynamo or generator when connection with its terminals is established. By the difference of potential a current will be made to flow through a circuit connecting the poles.

Considered from a commercially economical view, the current set up by rotating in a magnetic field windings of wire or coils, or the device, which in the course of electrical motive power evolution has developed into what is known as the armature of a dynamo, is the only practical means of obtaining the electircal current on any extensive scale. Therefore, the engine driven generator has supplanted all other means of setting up electrical currents for the performance of work in the industrial world. Because of the greater cost of operation due to the wide difference in the cost of coal and zinc, and also because of the more convenient generating units available with the engine driven generator, the use of the primary battery is limited to isolated cases where only a small or intermittent current is required. The great extension of telephone systems and the equally large reduction in the price for service, made possible by the common battery system, may very justly be, to a great extent, attributed to the comparative economy of operation by means of the engine driven generator.

"Electromotive force" (e. m. f.), *"difference of potential"* (p. d.) and *"electrical pressure"* are all various terms applied to the impelling force which sets up a current of electricity when the circuit is closed and exerts a pressure which tends to force an electrical charge to a lower level. *"Voltage"* is sometimes erroneously used in the same sense with reference to this impelling force, but strictly interpreted *"voltage"* is a term derived from *"volt,"* the unit of measurement, and which, for general practice, has been defined and accepted as $\frac{1000}{1434}$ of the e. m. f. of a standard Clark's cell prepared in accord with certain definite specifications. In modern practice, however, an approximation serving all requirements of value is to place the unit at about two-thirds the voltage of a new dry cell, or one-half of a storage cell on discharge, or one one-hundred-and-tenth the voltage across the ordinary incandescent lighting leads.

The volt has been technically defined in various phraseology, the idea of the essential principle conveyed in each definition, however, being identical when carried to its final analysis. Several of the most lucidly stated definitions are as follows:

1. The practical unit of electromotive force or difference of potential.

2. An electromotive force which would cause a current of one ampere to flow through a resistance of one ohm.

3. The electromotive force induced in a conductor by its cutting 100,000,000 lines of force per second.

4. Such a rise of potential as would be produced by charging a condenser of one farad capacity with one coulomb.

5. An electro motive force equal to 10^8 absolute electromagnetic units, or to the one three-hundredth electrostatic unit.

There is nowhere in nature a point of actual zero potential, as all substances are to some degree charged with electricity—a fact which may be demonstrated by setting up a difference of potential, and which will invariably develop into the form of current when the circuit is closed. If such a condition as zero potential existed anywhere in nature an equilibrium would immediately be established by the flowing to it of electricity from all directions. But for working purposes a definite standard has been arbitrarily established in computing electrical pressure, and for this arbitrary point the potential of the earth has been taken; all potentials above it being termed *"posi-*

tive" (represented by the plus sign, +) and all potentials below it being termed negative (represented by the minus sign, —). The arbitrary electrical point of computation answers to or may be claimed analogous to the arbitrary zero point of the thermometer which does not actually indicate a point of *no heat;* but has been adopted merely for convenience of computation. The absolute interpretation, however, of the terms "positive" and "negative" become merely relative considered in relation to metallic circuits which have no connection with the ground—the points are only positive or negative as compared with each other.

The erroneous impression at one time to a considerable extent prevalent among investigators of electric phenomena was that static and dynamic electricity were intrinsically different, whereas, in fact, the only differences between the electrical conditions of two bodies oppositely charged and that of the terminals of a battery, are, that the difference in the potential between the charged bodies is much higher than that across battery terminals, and, that the current produced when the circuit is closed is very much smaller, consisting only of a single impulse—not of a steady flow; but oscillating for a fraction of a second—there being no means provided to maintain the difference of potential. The only general distinction between static and dynamic electricity may be stated as follows: Static electricity is that which is contained under pressure in a charged body and unable to discharge itself because of an open circuit. Dynamic electricity is the same charge flowing in the form of a current through a closed circuit. The question of low or high potential is in no wise involved in this distinction; and although the lightning flash is a spectacular manifestation of static electricity at high potential, the applications of static electricity in common practice are at low voltages, as may be observed in telephone condensers where less than ten volts often constitutes the difference of potential. Approximately stated, to cause a spark one inch long an e. m. f. of 100,000 volts is required.

It is not necessary to have opposite polarities to produce a current if the current is produced by a difference of potential between two points in a circuit.

Polarity, technically defined, is that quality of a body by virtue of which it exhibits opposite properties in opposite directions. It also signifies the possession of poles.

If two points, both of which are positive, but one at a higher potential than the other, be connected, the effort to equalize them will establish a current, and it will not be necessary to know the absolute value of the two potentials to determine the energy of the current; but only the difference between them. For instance, in the charging of branch exchange batteries from an office battery, the connection is made through a charging lead and the ground in a manner to oppose each other, but the office battery will establish a charging current through the branch battery in opposition to its e. m. f,. as the office battery is at a higher voltage, having a larger number of cells.

Earth currents, usually resulting from defective return circuits of street railway systems often cause complications in the charging of branch batteries and all other methods of grounded signaling.

Central office and branch batteries are always negative in polarity as their positive poles are grounded. If then the potential of the earth has been disturbed by a street railway system, raising its potential to a negative polarity of eight volts more at the branch exchange than at the office, the difference between the two batteries will be neutralized, and both ends of the charging lead will be brought to the same potential, and there will flow no current through it to charge the branch battery. The branch end of the charging lead would become more negative than the office end and the branch battery would discharge back through the office battery, should the difference of potential between the two grounds be still greater. But should the branch ground be negative to the office ground, the difference of potential between the two ends of the charging lead would be greater than eight volts and a heavier charge than intended would be conveyed to the branch battery.

To remedy charging trouble due to earth current a return wire instead of the branch exchange ground should be used or the battery should be charged from a local lighting system or some other source.

The system of grounded signaling formerly used on all trunk lines in exchanges of large cities has been practically abandoned on account of the great increase in earth currents and for it has been substituted a system of metallic signaling. The great variations in the value of earth currents at different hours of the day rendered any attempt at compensation for them ineffective.

A *"counter e. m. f."* is an e. m. f. in a circuit which opposes the "impressed" or original e. m. f. Rapid trolley developments in recent times afford a marked example of this effect of earth currents, but there are other causes even more formidable which must be reckoned with. Very few circuits used in electrical work are free from capacity or retardation, consequently in almost every circuit, the counter e. m. f. which exists in some form must be allowed for or utilized.

The battery voltage, in the charging circuit itself, of both office and branch exchange batteries, is an e. m. f. opposed or *"counter"* to that of the charging machine or lead. To find the net or *"effectual"* e. m. f. which is available to force a current through the circuits the *"counter"* e. m. f. must be substracted from the *"impressed"* e. m. f.

The relative affinities of the two plates for the electrolyte determines the difference of potential between the terminals of a cell of battery and this difference depends in no measure upon the size of the cell. The immense cells used in large exchanges and power houses and having a capacity of many thousand ampere-hours have no greater e. m. f. than a small storage cell having a surface of but a few square inches and a capacity of very few ampere-hours.

Following are several technical definitions for the ampere:

1. The accepted unit of electric current.

2. A flow of electricity at a rate which transmits one coulomb per second.

3. The current which could pass through a circuit that offered a resistance of one ohm under a one-volt electromotive force.

The amount of current which can be drawn from a cell safely, providing there is sufficient electrolyte, is in exact proportion to the size of the cell or to the surface of the plates, because the chemical action necessary to maintain the initial difference of potential, when a current exists, depends directly upon the value of that current.

When the current is too small for effective transmission of signaling the necessity of *"boosting"* common battery lines arises, and in general practice the most effective and simplest method is by adding the voltage of an additional battery to that of the office battery by cutting it into the line. The number of lines to be boosted usually determines whether this battery should be made up of dry or storage cells. Dry cells are cheaper where only a few lines need boosting, and a sufficient number of them should be looped in series with the battery side of each line, so that the total e. m. f. on the line may be raised to a point where the desired value of current in the circuit can be maintained. So far as a line as just above referred to is concerned, it simply means adding a certain number of cells to the office battery, and in all series battery connections, the positive side of the booster battery being conected to the negative side of the office battery while the booster's negative side runs to line, the same rule applies.

Fig. 26 shows this arrangement by which each line must be provided with its own booster battery; therefore, where quite a number of lines are to be boosted the expense of using the dry cell

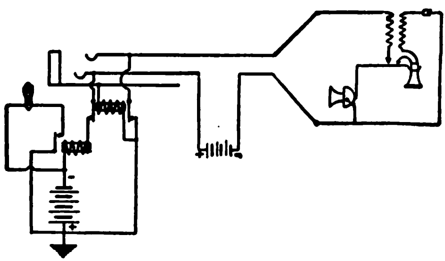


FIG. 26
"BOOSTER" CIRCUIT

method renders it unsatisfactory. The current through the line relay and instruments in a storage battery booster is based upon the same principle as in the dry cell method; both booster and office batteries being in series directly to ground, as shown in Fig. 27. For convenience in construction and operation only the instrument is cut in between the two batteries. The attention of the reader is especially directed to the combination of retardation coil and condenser shown in this figure. It is well to have one side of the booster permanently grounded; admissible to signal grounded providing the location of the booster ground be such as to prevent any trouble from earth current; but it is not at all desirable to talk grounded. The voltage of a storage battery being constant, it will deliver a uniform continuous cur-

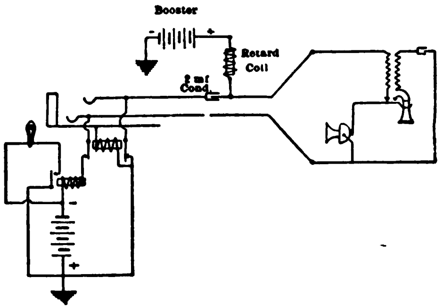


FIG. 27

SECOND PLAN FOR "BOOSTER" CIRCUIT

rent under uniform conditions, and this continuous current, in a telephone circuit, is altered by the varying resistance of the transmitter into a fluctuating current, which, in many respects acts as a continuous and an alternating current combined. In practice a condenser is not considered to impede an alternating current; but a retardation coil offers great impedance to it, and while a condenser acts like an open circuit to a continuous current a retardation coil offers little resistance to it.

The fluctuating current in a storage battery booster circuit, which is increased in volume or amplitude by the two batteries in series assisting each other, divides into its two component parts when it reaches the junction of the retardation coil and condenser. The portion which controls the signaling—i. e., the continuous portion—follows a path to ground through the retardation coil and booster battery. The alternating portion follows a path back to the tip of the jack through the condenser, and at this point becomes available for transmission.

The different lines connected to the same booster being provided each with a retardation coil, cross talk between them is obviated.

However the best practice is not to use a booster, but to design the live relay to be sensitive enough to act over the longest lines. Modern boards require no boosters except for toll conversations. This is described in the chapter on toll work.

ELECTROSTATIC INDUCTION. In telephony the disturbing elements of "cross talk" and other noises are principally due, not to electromagnetic induction, but to electro-static induction, similar to that which is observed in the process of charging a condenser. The series of original experiments which has established this discovery as a scientific truth consisted in running two grounded circuits of equal length at equal distances apart, arranging an ordinary transmitter apparatus at the line extremity of the first, and three receivers, one at either end and one in the middle, in the second. Words spoken into the transmitter on the first circuit could be distinctly heard in the two end receivers of the sècond circuit, but not at all in the middle one, thus proving that the inducing current moved either to or from the middle and neutral point, which is an ascertained characteristic of electrostatic charges, and not at all from either end through the whole length of the circuit, as is the case in such electro-magnetic induction devices as the ordinary induction coil. The problem of overcoming the condition is then a simple one, involving merely an observance of the laws governing induction of this variety.

Assuming a noisy telephone line with a distribution of charges as shown in Fig. 28, the straight line in the upper part of the figure representing a disturbing wire, such as one side of an electric lighting circuit with alternating current, and the lower part of the figure representing the two sides of a telephone circuit provided at each end with a receiver. The polarity of the wire in the lighting circuit is constantly reversing as the current is produced by an alternating e.m.f. While the polarity of the wire is positive, it attracts a negative charge to the nearer side of the telephone circuit, and rebels an equally positive charge to the farther side. This action is reversed at the next alternation; the disturbing wire, becoming negative, repels the negative charge to the farther side and attracts the positive charge to the nearer side of the telephone circuit. By passing through the receivers at each end and causing an alternating current through them of the same frequency as that on the lighting circuit is the only way that these charges on the telephone circuit can exchange sides. Reversing or transposing the two sides of the telephone circuit in the center of the zone of disturbance, another path is opened, Fig. 29, for the charges through which there will be a much larger undulating current than through the receivers, as through this path the impedence or resistance is negligible. The noise will be still fur-

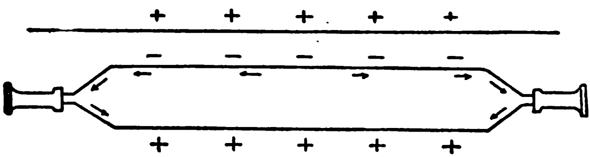


FIG. 28

ILLUSTRATING INDUCTION ON A TELEPHONE LINE

ther decreased if these sections are again divided by a transposition in the center. Hence a line under almost any disturbing conditions, may be rendered practically quiet by sufficiently multiplying the transpositions.

For preventing induction disturbances, besides the employment of mechanical means, twisted pairs in inside wire and cable conductors are most efficient as each half twist acts as a transposition.

TO MEASURE POTENTIAL DIFFERENCES. Two methods are generally employed to measure potential differences; the more usual one being by means of a voltmeter, which depends for its action upon the force developed in a coil by the passage of a very small current. It is the current through its winding that it actually measures, and this may be calibrated in volts as it is proportional to the difference of potential or pressure across its terminals. To measure the current in a circuit an ammeter is connected in series with the circuit,

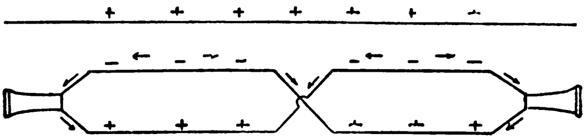


FIG. 29

METHOD FOR CUTTING IN TRANSPOSITION

while a voltmeter or electrometer is bridged across a circuit or connected across the two parts, whose difference of potential is to be ascertained.

QUESTIONS

1. Define the volt and the ampere.

2. What are the terms for which e. m. f. and p. d. are abbreviations?

3. What does the term "counter" e. m. f. signify?

4. What is the distinction between dynamic and static electricity?

5. State the principle of the booster battery.

6. When a dry cell booster battery is used,

state which side should be connected to the line and the reason for it.

7. State the principle of line transposition.

8. How many methods are there in general use to measure potential differences? What are they? How are they applied?

CHAPTER VI

RESISTANCE

In electrical work the three principal factors are the current, the pressure and the resistance. The first performs the work and is measured in amperes; the second produces the current and is measured in volts, and the third is measured in ohms. Every circuit offers more or less resistance to a current. Resistance, concisely stated, is the obstruction offered to a continuous current of electricity in its passage through a circuit; but in alternating or fluctuating currents there are elements aside from simple resistance which obstruct their passage. The phenomena of current and resistance may, for purposes of elucidation, be compared to analogous phenomena familiar in mechanics and physics. To illustrate: All mechanical movement is more or less impeded by friction and the energy exerted in overcoming friction is converted into heat. To this extent electrical resistance may be considered analagous to friction. All substances possess, in widely varying degrees, according to the nature of the substance and temperature, the property of opposing an electrical current, and this opposition converts into heat the energy exerted in maintaining the current. Matter and energy, being indestructible, the loss in a circuit does not indicate that the energy has been destroyed, but merely that it has escaped and been dissipated in the form of heat into space.

The electrical resistance of a circuit may be readily computed if the length, material, size and temperature of the conductor be known, as, unlike friction, it is independent of its shape. The resistance of a wire is in no wise affected by bending or coiling providing its cross section is not mechanically changed and even the temperature within certain limits need not be considered for most practical purposes.

Materials termed insulators are those which, because of their very high resistance, permit very little flow of current through them at ordinary pressures. There is no such thing as a perfect insulator, as there is no substance in nature which has absolute resistance, nor is there any substance which has absolutely no resistance; hence there cannot exist a perfect conductor, but as an arbitrary standard of low resistance, silver has been adopted, because it has been found to oppose to the electrical current the least resistance of any known substance. Between silver and the numerous materials, which, because of their high resistance, are used as insulators, there is a wide variance of difference in resistance. What is termed the *"specific resistance"* of any substance is the resistance of one cubic centimeter of that substance. However it is instructive to notice the resistances of various metals as compared with the resistance of silver. These differences of resistances may be ascertained by testing against a silver wire having a resistance of one ohm, the resistances of a number of wires of different substances having the same length and cross section as the silver wire, taken as a standard. Among the materials contained in published tables, and which may vary slightly by reason of impurities in the tested specimens, the following specific resistances may be mentioned: Mercury, about 62.73; German silver, 13.92; wrought iron, 6.46; copper, 1.063.

Resistance, being a fixed property of a material substance, is more readily measured than a current or electromotive force. Resistance is determined only by its effect upon a current as manifested by the pressure maintaining the current. Here exists a very intimate relationship between the three elementary factors in electrical work, and as before mentioned, resistance is measured in ohms and the ohm is defined as the amount of *"resistance which requires a pressure of one volt to force a current of one ampere through it."*

The result obtained in every field of action depends upon the amount of effort exerted, and the greater the difficulty the smaller the result, except where the effort is greater than the difficulties opposed.

As applied to continuous current electricity, these two fundamental principles are embodied in Ohm's law: *"The value of current, expressed in amperes, is invariably equal to the electromotive force, expressed in volts, divided by the resistance* *in ohms.*" For practical purposes it is usually expressed by the equation

$$\text{“Current} = \frac{\text{Electromotive force”}}{\text{Resistance}}.$$

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

or, in abbreviated form, $I = \frac{E}{R}$, I representing *current,* E electromotive force, and R resistance. This equation is also correctly written in two other forms as follows:

$$R = \frac{E}{I} \text{ and } E = I \text{ times } R; \text{ or } E = IR.$$

With this equation, it becomes a simple operation in arithmetic to find the third factor—the other two being known—by substituting the known values for the letters in the second term of whichever form of the equation applies to the case.

In actual practice there is, however, a still simpler method which is to take the reciprocal of the sum of the several resistances. A fraction having 1 for its numerator is the reciprocal of the same number as its denominator; thus: $\frac{1}{X}$ is the reciprocal of X.

The value of current in any circuit, according to Ohm's law, is at a given voltage, inversely proportioned to its resistance. A circuit with a resistance of 40 ohms will permit one-half as much current to flow through it at a given pressure as will one of 20 ohms, while its resistance is twice as much. $\frac{1}{2}$ is the reciprocal of 2. In the two paths the relative current values are termed their relative conductivities. In each case the conductivity is the reciprocal of the resistance, the total conductivity of the circuit being the sum of the conductivities of the several parallel paths. By inverting this total or taking its reciprocal, the combined resistance may be obtained. A variable resistance or rheostat is employed when it is required to regulate the value of the current in a circuit and the e.m.f. is fixed.

The ohmic value of a resistance being equal to the difference of potential across its terminals, divided by the current through it, the direct method of measuring it is to bridge a voltmeter across it, cut an ammeter in series with it, and divide the reading of one instrument by that of the other,

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

In an exchange where a milliammeter is in series with the test cord, its reading taken in connection with the approximately known voltage of the office battery will give a sufficiently correct idea of the resistance of the circuit, but for greater accuracy the battery voltage should be measured at the power board or bus-bar and an ammeter reading taken through the circuit while another is taken through the office wiring alone. These readings should then be reduced to ohms, and from the total the resistance of the office wiring should be substracted. As electricity flows through a circuit its pressure falls in proportion to the resistance it flows over. If a ten-volt battery be connected to a ten-ohm resistance the current will be $\frac{10}{10}$ or one ampere ($I = \frac{E}{R}$), and this current will be the same in value, although not in pressure, at all points in the circuit. If a voltmeter be bridged across the resistance it will indicate the full battery voltage, or that the total fall of potential through the circuit is ten volts. If it be bridged across one-half of the resistance, or five ohms, then, since E = I times R it will read 1 (ampere) times (5 ohms) or five (volts); which shows that one-half of the total difference of potential has been consumed in forcing the current through one-half of the resistance. If eight-tenths of the resistance, or eight ohms, be bridged across, the reading will be, 1 (ampere) times 8 (ohms) or eight (volts). The action of a voltmeter, then, depends upon the principle that if $I = \frac{E}{R}$ the value of current through a given resistance is proportional to the difference of potential across its terminals. Therefore the scale can be marked to indicate a difference of potential directly in volts, inasmuch as the indications of the voltmeter depend upon the value of current which can be maintained through it by the difference of potential across its terminals.

The most accurate method, however, and the easiest of application for resistance measurements generally in telephone practice, is shown in Fig. 30 where the three known resistances and the unknown one are arranged in the form of a bridge. In order to appreciate the possibilities of this in-

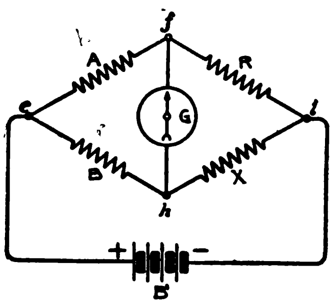


FIG. 30

SIMPLE ILLUSTRATION OF WHEATSTONE BRIDGE

strument its underlying principles should be understood. In Fig. 30, A, B, R, and X represent resistances. G is a galvanometer or instrument for detecting the flow of current. The four resistances are connected together as shown, the galvanometer being connected in the "bridge" between the junctures of A and R, and B and X. A battery, B′, is connected between the junctures of A and B, and of R and X. Each resistance, A.

B. R. and X forms what is termed an arm of the bridge.

The action of the bridge is based upon two fundamental laws which may be stated as follows:

FIRST—*No current will flow betwen points of equal potential.*

SECOND—*The drop in potential along the various parts of a conductor is proportional respectively to the resistance of those parts.*

Referring to diagram Fig. 30, it is shown that a current flows from the battery to e and at that point it divides, a part flowing through AR and a part through BX, after which the two parts unite and pass to the negative pole of the battery. But what of the galvanometer? Evidently by Rule 1 the only time at which no current will pass through it will be at the time when the points, *f* and *h*, are at the same potential. By Rule 2 these points will be at the same potential only when A bears the same relation to R as B does to X.

That is

$$A : R :: B : X, \text{ or, by alternation,}$$

$$\frac{A}{B} = \frac{R}{X}.$$

A little algebra will render the above evident if not so already.

Call a the drop of potential between the points e and i, b that between e and f, and c that between e and h.

Then

$$b : a :: A : A + R \text{ by Rule 2.}$$

$$\therefore b = \frac{A}{A + R} a.$$

Likewise

$$c = \frac{B}{B + X} a.$$

For a condition of equal potentials at f and h so that no current will flow through the galvanometer, b must equal c.

Hence

$$\frac{A}{A + R} a = \frac{B}{B + X} a.$$

whence: $AB + AX = AB + BR$

and $AX = BR.$

Dividing by BX, gives

$$\frac{A}{B} = \frac{R}{X},$$

the equation of the ratios between the resistances of the arms of the bridge, to insure no flow of current through the galvanometer.

The arm X of the bridge represents the resistance to be measured and the resistances in the various arms are adjusted till no current flows through the galvanometer in order to determine the value of this resistance. Then the equation just derived holds good and may be solved for X,

$$\text{thus } X = \frac{B}{A} R.$$

The arms A and B are best termed the "ratio arms" of the bridge and arm R the rheostat arm.

In commercial forms of the bridge, A and B are usually so arranged that each may be given the values, 10, 100 and 1000 ohms, and in some cases 1 ohm and 10,000 ohms also. The ratio arms, A and B, may therefore be adjusted to bear any convenient ratio to each other from $\frac{10}{1000}$ to $\frac{1000}{10}$, or, in some instances, from $\frac{1}{10,000}$ to $\frac{10,000}{1}$. The rheostat arm is in reality a rheostat capable of being adjusted to any value from 1 to about 11,000 ohms.

In bridges having resistances of 10, 100, and 1000 ohms in the ratio arms, the following values in arms A and B will give the best results:

Under 100 ohms, ...	1000	10
100 to 1000 ohms, ...	1000	100
1000 to 10,000 ohms, ...	1000	1000
10,000 to 100,000 ohms, . .	100	1000
100,000 to 1,000,000 ohms, .	10	1000

As to the accuracy of measurements attainable by the use of the Wheatstone bridge, the following table represents the claim of one reliable manufacturer:

.01	of an ohm to an accuracy of	1 %
.1	of an ohm to an accuracy of	½ %
1	ohm to an accuracy of	½ %
10	ohms to an accuracy of	1/5 %
100	ohms to an accuracy of	⅛ %
1,000	ohms to an accuracy of	⅛ %
10,000	ohms to an accuracy of	1/5 %
100,000	ohms to an accuracy of	¼ %
1,000,000	ohms to an accuracy of	5 %

The box type bridge has been made up in a multitude of widely varying designs; but for accu-

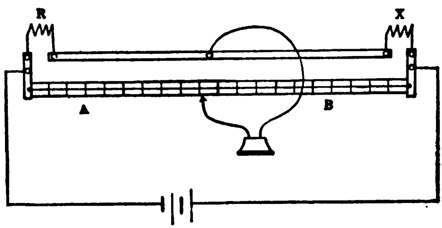


FIG. 31

SLIDE WIRE TYPE OF WHEATSTONE BRIDGE

racy of all attainable measurements the plug type of Wheatstone bridge seems to be the most used. The slide wire type of bridge, illustrated in Fig. 31 is much used by students because of its simplicity of construction and small cost, while the accuracy possible to attain with it places it in the laboratories of the most advanced investigators. In its simplest form it consists of a scale of any convenient length—often one meter, whence the name "meter bridge"—divided into one hundred or one thousand equal parts, mounted on a board; of a heavy wire or strip of copper parallel to it and two or three inches away; of two short similar wires or strips placed across the ends of the scale, leaving an opening of convenient size between their ends and the ends of the longer strip; and of a bare German silver platinoid or manganin wire, as small as possible without sacrificing the necessary mechanical strength, stretched over the scale and connected by clamps or by soldering to the short copper strips, *exactly* at the ends of the scale. The last point is important, because if the connection is made, for example, one-eighth inch beyond the end of the scale, a serious error will be introduced when taking readings near one end of the scale. Suitable binding posts are mounted on the copper strips for making the necessary connections.

A resistance of any known value is connected across the left hand opening, and X or the unknown, across the right hand. The battery is connected across the two short strips, one side of a head telephone is connected to the long strip and the other ends in a tip which is touched to the slide wire at different points until a balance is obtained as shown by the absence of a click. Applying the skeleton, A is the portion of the slide wire between the tip of the receiver cord and the left hand end of the scale, B is the portion between it and the right hand end, R is the known resistance, and X the unknown. As an illustration of its use:

Let R = 100 ohms
and A = 450 (Scale divisions)
Then B = 1000 — 450 = 550.

Applying the formula, $X = 100 \text{ times } \frac{550}{450} =$ 122.2 ohms.

The box form of bridge employs fixed resistances, cut in and out by means of plugs, and a galvanometer instead of a receiver. There are three precautions which must be observed when using a bridge, in order to secure accurate results; first, to set all plugs in firmly; second, to close the battery about one second before the galvanometer; and third, to use no stronger battery than is actually necessary in order to prevent altering the resistance of the coils by raising their temperature. The effect of temperature on resistance is far less understood than the conversion of the energy of an electric current into heat by resistance, a fact which is often liable to cause serious errors in electrical measurements. In Fig. 32 are shown curves illustrating the measurements taken on two incandescent lamps through a broad range of current with varying temperatures up to incandescence. One lamp was of the tantulum filament and the other of the common carbon filament type. The resistance in the tantulum shows a decided increase while that of the carbon shows just the reverse. Ordinarily as the temperature rises the resistance of metals increase while that of liquids, gases and of carbon decreases.

This increase however is practically uniform at about 0.4 per cent for every rise of one degree centrigrade with pure metals such as iron, copper and silver, while it varies widely with alloys.

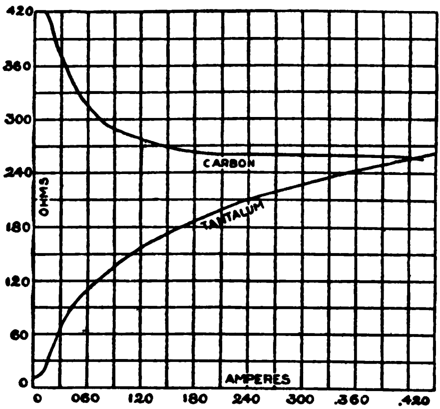


FIG. 32

INCREASE AND DECREASE IN RESISTANCE OF CARBON AND TANTALUM LAMPS

German silver has a resistance of 0.04 per cent and platinoid 0.02 per cent for each degree of rise in temperature.

CHAPTER VII

CAPACITY

The farad is the unit of capacity, or, that capacity possessed by a conductor which is capable of holding one coulomb of elecrticity at one volt potential. A condenser is a contrivance for augmenting the capacity of an insulated conductor by placing it in contiguity to another conductor, but from which it is separated by any intervening body which will allow electrostatic induction to occur through it. To more clearly illustrate: If there should be set up by a one-volt battery a difference of potential of one volt across the terminals of a condenser of one farad capacity, one coulomb of electricity would be transferred from the negative to the positive plate. For practical purposes this unit would prove very awkward; consequently it has, for general uses, been divided into microfarads (abbreviated M. F.) or millionths, precisely as the ampere has been divided into milliamperes, or thousandths.

It is only on the surface and never on the inside of a conductor that a static charge is found. The reason for this is that a charge is self-repulsive, the different parts of it having a tendency to force each other apart, which results in the charge being driven to the surface of the conductor or charged body, and when the surface of this is uniform the distribution of the charge over it is also uniform.

The thickness of the plates does not in any way determine the capacity of a condenser, but the surface represents the capacity in varying degrees.

In the operation of a condenser, electrostatic induction depends to a great extent upon the distance between the two bodies, and experiment has shown that the capacity of a plate condenser is in inverse proportion to the space between the plates.

A great difference would be found in the intensity of inductive effect by interposing insulating substances of various materials.

A dielectric is any substance through whose mass electrostatic induction is allowed to occur. It is not only upon the thickness of the dielectric, but also upon its material composition that the effect produced by electrostatic induction, and in consequence, the capacity of a condenser, depends. The term *"Specific inductive capacity,"* is used to express the various lesser degrees of opposition as compared with air which the different kinds of dielectrics offer to the action of electrostatic induction through them. For example: Glass shows a specific inductive capacity of about six and one-half to ten; shellac, about three; paraffin, about two. Where in both cases the surface of the plates and the distance between them is the same, paraffin paper used as a dielectric with a condenser will show twice the capacity of a condenser with which air is used.

Concisely stated, then: the quantity of charge which a condenser will hold at a potential difference of one volt between its terminals, is its capacity, and which depends upon the nature of the dielectric and varies also directly with the surface of its plates, and in inverse proportion to the distance between them.

Although the capacity of a condenser may be measured in farads and a quantity of electricity in coulombs, a one-farad condenser will hold more than one coulomb if greater pressure is maintained. In an ordinary condenser the actual quantity of the charge is very small as contrasted with the potential difference across its terminals; there being only 0.000002 of a coulomb per volt in a 2 m.f. condenser and unless there is very high resistance in the circuit, the current produced on closing it, is virtually an instantaneous impulse and the impulse, when a voltmeter or galvanometer is introduced into the circuit, produces the effect of a flow or what is known as the "condenser kick" of the needle. The amount of the discharge and also of the charge is accurately indicated by the extent of this kick. A good voltmeter, therefore, may be depended upon with approximate accuracy in comparing these condenser charges and capacities. To illustrate: A 2 m.f. condenser will be charged twice as heavily by 220 than by 110 volts, as the swing of the needle with a given condenser, is nearly in proportion to the amount of the charge. The capacities of two condensers may very easily be compared by charging or discharging them through a voltmeter, because, with a given potential difference, the volume of the charge is proportional to the capacity.

Mutual attraction holds the opposite charges on the plates of a condenser and this keeps the dielectric under constant stress, which causes a deformation of the particles of the dielectric, turning them in the direction of the lines of induction. This deformation increases with the increase of potential difference, finally breaking down the dielectric, when the condenser discharges through it. In case of a high tension cross or lightning discharge the condenser in an unprotected telephone acts exactly in similar manner and likewise in carbon plate arresters, where a small air gap separates the two carbon plates, one plate being connected with the line and the other with the ground.

When a condenser discharges through an air gap the particles of air resume their normal position immediately; but not so in the case of a discharge through any other dielectric. When charging or discharging a condenser by tapping a telephone receiver a succession of gradually diminishing clicks follow. This effect is termed *"soaking in"* and *"residual charge"* in each case respectively, and is caused by the particles, which were gradually displaced on the charge, gradually assuming their normal positions on the discharge, or, technically expressed, to the *"deformation of the dielectric."* The two sides of a telephone circuit constitute the two plates of a condenser; being conductors separated by insulation and have very perceptible capacity. The capacity, then, of this telephone condenser depends upon the extent of surface, the nature of the dielectric and the distance between the wires, which answer to the plates in other condensers. In making a test on a testing desk, it is the practice to charge and discharge the line through a voltmeter, the line answering to one plate of a condenser while the ground answers to the other. Thus the capacity of the line may be estimated and the distance to the fault by the kick of the voltmeter be ascertained. The capacity of the open conductor, in cable testing, is, by means of a bridge, compared directly with that of a good one in the same cable. The same principle applies to the sound test used by repair men, which consists of introducing a telephone receiver between line and ground by means of which the noise on both sides of the line may be compared.

To charge and discharge the line through the head telephone, in this test, the constantly varying earth potential is utilized. A quicker and more sensitive test than that with the voltmeter may be had with a ground key on the testing desk by means of which the telephone may be connected in the same manner. In the case of continuous current, when a dielectric separates the two plates of a condenser cut in series with a circuit it will be opened; but a different set of conditions are established in the case of fluctuating or alternating currents. Should an alternating current generator be connected to the two sides of a short open line, the difference of potential across the terminals of the machine and that across the ends of the wire forming the line, would be simultaneously alike—there would be no current through the circuit, it being open. That is to say, there would be no appreciable current, as the capacity of the two wires and the quantity of electricity which they would hold, except under extraordinary pressures, would be ineffective in producing perceptible current. When, however, the wires are connected to the terminals of a condenser the capacity of the two sides of the open circuit is no longer inappreciable, and to maintain the difference of potential across the ends of the circuit, the current necessary to transfer a sufficient amount of electricity through it increases in proportion to the capacity. There is a current flowing into the condenser as the potential of the machine rises, charging the condenser and raising its potential correspondingly with that of the machine and the rapidity with which the potential rises determines the value of the current. The potential at the terminals or ends of the wires is at its greatest height when the potential of the machine is at maximum, and here the current drops to zero, since there is no further rise of potential and consequently nothing to cause any further flow of electricity.

In Fig. 33 may be seen the connections with the pressure curve (e.m.f.) at its maximum and the current curve at zero. The potential across the terminals of the condenser falls with the potential of the machine since they are connected; but it is the pressure which directly determines what any charged body will hold. Hence, now, the original charge at the condenser cannot be held; for if it could, the potential of the condenser would be higher than that of the machine and the excess charge would flow back out of the condenser through the machine, and since its direction is opposed to the e.m.f. of the machine, and in the

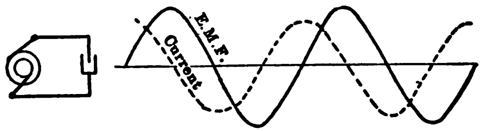


FIG. 33
PRESSURE AND CURRENT CURVES THROUGH CONDENSER

reverse direction to that which it had been, the current curve drops below the line. This reversed current will continue until it reaches the point of lowest potential and will then cease to flow, if the change in the potential of the machine from positive to negative maximum be taken as merely a fall of pressure from the highest point to the lowest; for, the moment that the potential of the machine attains its negative maximum the current curve falls back to the zero line. From this point the potential of the machine begins to rise and electricty must flow from the machine to the condenser, charging it, in order that the potential of the condenser may rise with that of the machine. When the condenser is fully charged—the potential of both machine and condenser, having reached the positive maximum—this current will cease to exist. The rate of change in the potential of the machine, determines the value of current required to keep the potential of the condenser in step with that of the machine, consequently the current attains its maximum value in either direction when the change of potential is most rapid. This. in the case of the *sine* wave, occurs when the curve crosses the line. When the potential of the machine is downward, the current is in one direction and it is in the contrary direction when the potential of the machine is upward; the maximum value, in both instances, being attained as the potential crosses the line. The foregoing explanation refers to only one side of the circuit as it can be readily inferred that analagous changes have occurred in an opposite direction in the other side.

The curve of the current through the circuit, to and from the condenser terminals, and through the ringers, when ringing through a condenser, is approximately alike in shape, though differing in phase, to one with the condenser left out. It must, however, be borne in mind that very high self-induction characterizes a pair of ringers, and the lag behind the e.m.f., because of this, is considerable. This lag is partly neutralized by the leading effect of the condenser, which is opposed to it in direction, so that the current is brought in more approximate phase with the e.m.f. By cutting a condenser into a circuit a pronounced improvement in ringing may be obtained in some cases. If a pair of 1,000-ohm ringers be operated on an ordinary 20-cycle generator or current, a reduction in the impedence of the combination may be effected equal to the resistance of the ringers by raising, in accordance with the inductance of the ringers, the capacity of the condenser from two to eight microfarads. For most practical purposes it may be assumed that a condenser allows alternating current through it, as it represents closely enough the to and fro motion of electricity. The assumption, however, is not, strictly speaking, correct.

The element of capacity in electrical science becomes more complicated when considering the fluctuating or pulsating e.m.f.'s which are constantly changing in value although they are only in one direction. This subject alone offers a very broad field for investigation and study, and it would require a special and voluminous work to cover it fully; but in the foregoing pages the subject has been sufficiently treated to afford the reader a clear understanding of electrical capacity and its practical application to telephone work.

CHAPTER VIII

FACTS ABOUT THE MAGNETO SYSTEM

A small dynamo, contained in a magneto bell box, generates the current which causes the bells in another box to ring. The bell box also contains polarized ringers, which when actuated by its own generator or that of another box, rings its own bells; and a switch is adjusted in the box by means of which the bell or speaking apparatus, as desired, may be connected to the line. When the receiver is hung up, this switch, in every type of bell box, connects the bell apparatus with the line wire, and connects the speaking apparatus with the line when the receiver is taken off the hook. The hook, which holds the receiver when not in use, operates this switch; it being practically an integral part of the hook.

Two wires, one from each extremity of the generator coils, and which connect or make contact with each other, thereby forming a shorter path for the current around than through the generator, short-circuits the generator in all bells when not in use, except in bridging bells where the generator circuit, when not in use is open; for in that case the resistance of the generator coil and its inductive effects are removed from the line. The operation of a telephone line is much improved by cutting these coils from circuit in the manner described. This cut-off or shunt wire is, in some kinds of bells, broken with a push button, when ringing, but with a bridging bell it is closed. In others it is done by an automatic attachment to the crank shaft, so that while the crank is being turned the shunt wire is broken, or closed if bridged, allowing the current generated by the generator to flow to line. As soon as the crank motion ceases, the generator is then cut out by the shunt wire.

The switch which the receiver hook operates,

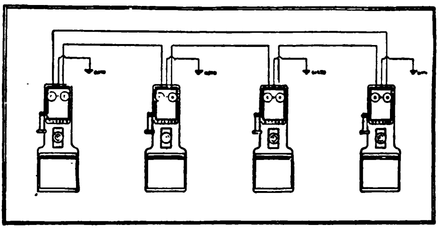


FIG. 34

METHOD USED FOR CONNECTING UP SERIES TELEPHONES

besides connecting the line alternately to the ringing and the speaking apparatus, also closes and opens the circuit of the local battery by which the transmitter is operated.

Most all forms of battery used with the transmitter, such as the Leclanché, dry and others, become weak and useless in a short time if the circuit is kept constantly closed and the battery continuously at work, entailing unnecessary waste of material. One of the battery wires is made to pass through the bell box and is connected to the switch in such a manner that, when the re-

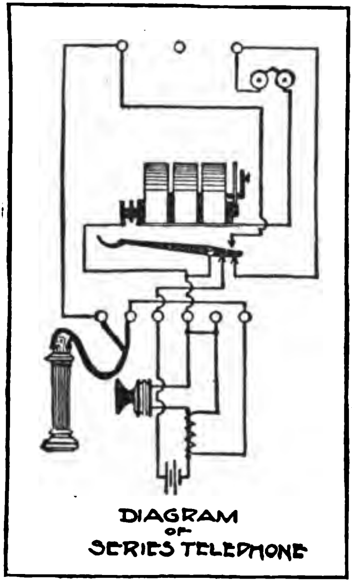


Fig. 35

ceiver is hanging on the hook, the battery wire is broken, and the battery is in a state of absolute rest. But the switch connects the receiver to the line wire when the receiver is taken down, and also closes the local battery circuit, thereby bringing the local battery into action.

Magneto bells are of both the series and bridging type. The series bell is looped in on the circuit and the bridging bell connected or "bridged" directly across the circuit as shown in Figs. 34, 35, 36, 37.

As the ringers of a series bell form part of a circuit they are necessarily low wound and are usually of about 80 ohms resistance.

The Wiring of a Series Apparatus.—The wiring of a series circuit party line station telephone apparatus is substantially the same as that of the

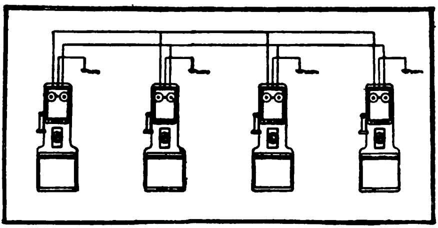


FIG. 36

METHOD USED FOR CONNECTING UP BRIDGING TELEPHONES

ordinary exchange circuit apparatus, as may be seen by reference to Fig. 35. As in the latter instrument, the hook makes two contacts when the receiver is removed, thus making the talking circuit, and but one when the hook is down, thus making the calling circuit.

The bad effects observed by retardation in the ringer coils when bells are connected in series can, to a certain extent, be reduced by shunting the ringer coils with a resistance coil having four or five times the resistance that the ringers have.

The resistance of bridging bell ringers ranges from 1,000 to 2,500 ohms. Bridging bells are

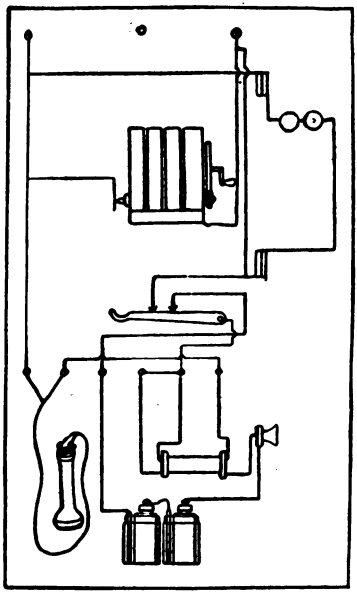


FIG. 37

CIRCUIT OF BRIDGING TELEPHONE

largely used on metallic circuits and grounded lines, when two or more subscribers are placed on the same circuit. When used on metallic circuits the bells are "bridged" across the two wires of the circuit, and when used in ground lines, bridged to ground at each station, making it possible to operate a number of instruments on one circuit with negligible loss.

TOLL LINE OR PARTY LINE—BRIDGING BELL

An alternating current may be used in ringing this type of bell. The current it generates, how-

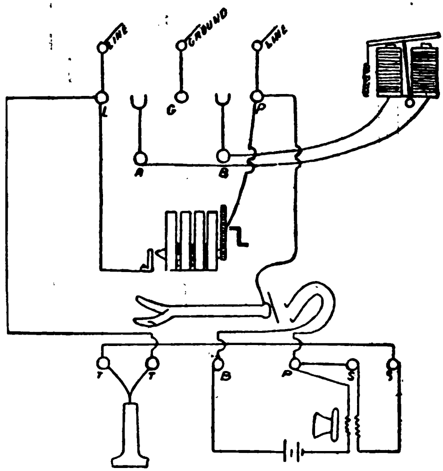


FIG. 38

CIRCUIT OF SELECTIVE TELEPHONE

ever is a pulsating one which will operate signal at *exchange* but will not actuate its own ringers or other biased ones on the line.

The method is by means of a split commutator and brush placed on the generator and connecting one-half with armature coil, which connects the coil with the line during one-half of each revolution, producing an interrupted direct or pulsating current. Subscribers or toll stations on the same line are enabled, by using this bell, to signal central other bells on the line. This prevents unnecessary ringing of subscribers' bells and also affords main office an opportunity to check up business, as toll stations cannot call each other directly.

FOUR PARTY SELECTIVE BELL

This type of bell, operated by positive or negative current, has 2,500-ohm ringers. A spring holds the armature of the ringer to one side and an adjusting screw regulates the pressure. See Fig. 38.

The ringers are bridged to earth, two from each side of the circuit, and the bell is equipped with a low voltage generator so that it will throw the drop at the central office, but will not actuate the high-wound ringers of the bells.

A combination alternating and direct pulsating current generator or pole changer is used at the central office, which provides for the application to either side of the line of negative or positive current as required. Impulses of current applied to one side of line in such a direction as to cause the armature to move in the opposite direction to the spring will ring the bell. Impulses in the same direction will not.

Only one of the four bells will be rung at one time when the two bells on each side of the circuit

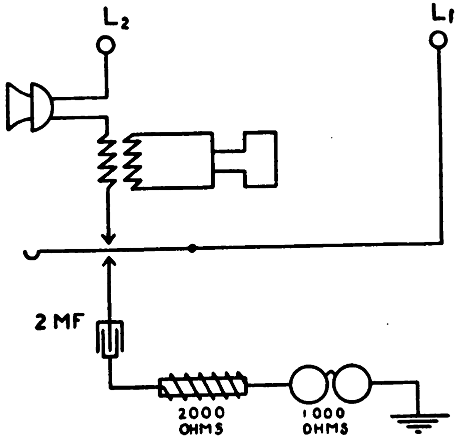


FIG. 39

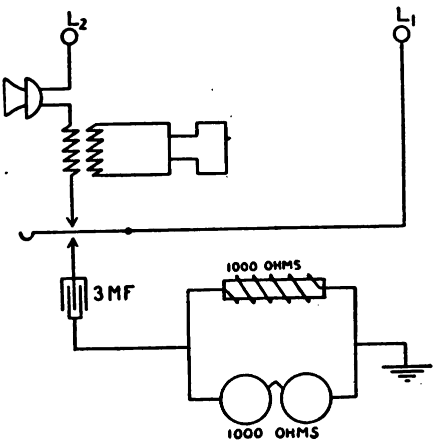


FIG. 39A.

SELECTIVE TELEPHONES, HIGH AND LOW FREQUENCY are arranged so as to be affected by opposite currents.

Two different frequencies of alternating current are required for ringing purposes in the operation of the high and low frequency system (see diagrams, Figs. 39 and 39[a]. Taking under consideration two frequencies of the alternating ringing current of 20 and 60 cycles per second, the first, or 20-cycle per second frequency, may be obtained from the regular alternating two-pole ringing machine revolving at a rate of 1,200 revolutions per minute, giving 2,400 alternations per minute. A generator operating at 1,000, or one running at even a speed of 800 revolutions is efficient.

The low frequency current of 20 cycles may also be obtained by the use of an efficient low frequency pole changer, such as a hand generator if not turned too rapidly.

A regular ringing machine delivering a 60-cycle current will supply the high frequency alternating ringing current, i. e.: a machine having 7,200 alternations per minute. This would be either a two-pole machine running at 3,600 revolutions per minute, a four-pole machine running at 1,800 revolutions per minute, or a six-pole machine at 1,200 revolutions.

A power magneto may be safely used, providing it is driven at a proper speed and the voltage is not permitted to rise too high. The most practical method to obtain the high frequency ringing current in cities having a 60-cycle alternating current incandescent light system, is to use this current direct through a transformer without the use of any motor-generator. The pressure or voltage should not exceed 90 volts.

In the practical operation of the system as a four-party selective line, four instruments are connected to one metallic line (with talking circuits metallic); two of these instruments have their ringing circuits connected between one line wire and the ground, and the other pair of instruments

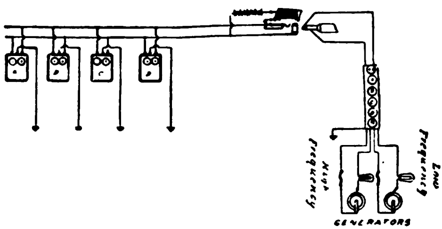


FIG. 40

TELEPHONES CONNECTED ON FOUR PARTY SELECTIVE LINE

have their ringing circuits connected between the other line wire and the ground. Each pair of instruments comprises a high and a low frequency instrument. A selective key having the requisite number of buttons is used at the switchboard for ringing the bells, this selective key serving the purpose of connecting either high or low frequency current between either one of the line wires and the ground, that is, sending high or low frequency ringing current over either the tip or sleeve of the plug and the ground. The general arrangement of the four telephones on one line is shown in diagram Fig. 40. The low frequency machine is shown together with the association of the ringing key, plug, and generators as delivering 2,400 alternations per minute, and the high frequency machine as delivering 7,200 alternations. The keys "A," "B," "C," "D" when depressed operate either of the telephones marked "A," "B," "C," or "D" accordingly as either button is actuated.

"A" and "C" are low frequency instruments, and their line connections are reversed. The same is true of the two high frequency instruments "B" and "D." If ringing current of either class is sent over either line wire to ground, that current is sent through the ringing circuits of both a high and a low instrument, but on account of the construction of these ringing circuits, only one bell will respond, either the high or the low, depending upon whether high or low frequency current is used.

THE RECEIVER

There are two types of receivers, viz.: Single pole and bi-polar, the latter signifying *two poles*. The single pole receiver consists of a spool or bobbin, wound with fine, insulated copper wire, upon an iron core. One end of this core is inserted in the end of a steel bar magnet, by which the iron core is magnetized. A small circular sheet of thin iron, called a diaphragm, is placed across the free end of the coil and about .015-inch from the end of magnet.

The two ends of the wire from the electro-magnet bobbin are attached to the two binding posts outside or the binding screws inside, depending on the type of receiver used, and the tips or terminals of the flexible cords are screwed into these posts, or terminal screws.

The bi-polar receiver has a horseshoe shaped magnet with two electro-magnetic bobbins connected in series. This is much stronger than the single pole type of receiver. A cover with a hole in the center and a funnel-shaped cup screwed onto the free end of the case is used to hold the diaphragm in place across the face of the electro-magnet.

CHAPTER IX

THE TRANSMITTER

It is often said that the transmitter, makes the telephone, and to a large extent, this is true. It is certainly the most important part to the subscriber,

FIG. 41
FRONT VIEW OF TELEPHONE TRANSMITTER

and, consequently, is the most important to the operating company.

The essential principle upon which all transmitters are constructed is the same; but with the rapid improvement in telephone construction generally there are recent types of transmitters which have out-distanced, with respect to several advantages, the Bell instrument, although they may resemble the well known White solid back. Among recent forms and types of improved telephone parts

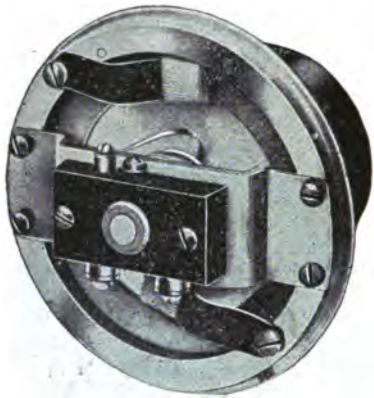


FIG. 42

BACK VIEW OF TRANSMITTER

some standard ones are described in the following pages:

The outer casing of this instrument (Fig. 41) consists of a heavy cast brass front and a drawn sheet metal back. These two parts are firmly fastened together by four machine screws. A very heavy brass bridge is supported by the front, and affords a most solid mounting for the working parts, which lie between the front and bridge. Fig. 42 shows this construction.

The carbon chamber is formed by two mica diaphragms supporting the electrodes and a brass ring or collar. A cross section of the chamber is shown in Fig. 43, and it will be seen that each electrode is fastened to a brass disc. The carbon is attached to the disk without the use of solder, by spinning the edge of the disc over the edge of

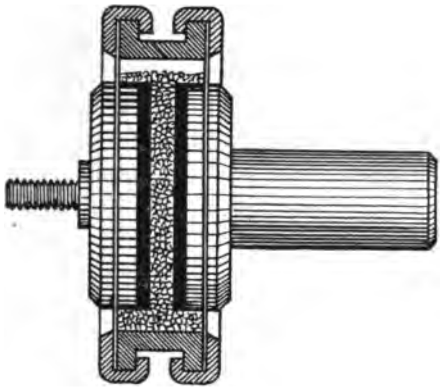


Fig. 43
CARBON CHAMBER

the carbon similar to the mounting of a stone in a ring. The absence of solder and soldering salts leaves no chance of corrosion on either surface, and thus keeps a perfect contact for all time. Immediately behind the supporting brass disc is placed a mica diaphragm, and behind this another brass disc to lock the diaphragm and further support the electrode. The hubs upon which these discs are screwed serve another purpose. The front hub is threaded and passes through a hole in the center of the aluminum diaphragm, where it is held by a nut, while the rear hub extends through the bridge to an insulating block, and is there locked in place by a setscrew. As will be noticed by reference to Fig. 43 these hubs are of different size and shape. The brass collar forming the other part of the chamber is clamped to the mica diaphragm by brass rings having lugs or ears, which are bent over the edges of the collar. These rings and the collar fit so exact as to make an absolutely moisture-proof carbon chamber. The granular carbon is sealed within the chamber so that it is never necessary to tamper with this part of the transmitter. The only adjustment provided is the setscrew holding the hub of the rear electrode in the insulating block on the bridge. By moving this hub forward or backward, a slight adjustment can be secured in case the transmitter is too sensitive or is not quite as sensitive as desired.

The use of two mica diaphragms in the construction of the carbon chamber provides that any vibration of the front electrode is transmitted through the granular carbon to the rear electrode, but at the same time the whole chamber is caused to vibrate. This keeps the carbon granules alive, and precludes all chance of their becoming packed and thus deadening the vibrations transmitted through them.

In order to have no electrical connections with the frame of the transmitter, the connection from the front electrode is brought to the rubber insulating block on the bridge by means of a German silver strip, which is fastened to a binding post. A second binding post connects directly to the hub of the rear electrode. A double conductor cord then carries the connections through a hollow

FIG. 44

TRANSMITTER DISASSEMBLED

transmitter arm to the interior of the telephone cabinet. Insulation at every point of contact keeps the talking circuit free from the transmitter case and the arm.

The diaphragm used to take up the voice vibrations is made of sheet aluminum. Around its outer edge is a rubber gasket which softens the tones by keeping out all metallic harshness. Two damping springs clamped against the diaphragm reduce the sensitiveness just enough to eliminate side tones which would otherwise occur. The theory upon which the mechanical construction is based, and the excellence of the workmanship, are not the only considerations in building a transmitter. The quality of the material used plays a very important part in the success of the

FIG. 45
TRANSMITTER MOUNTING

instrument. The carbon especially must be perfect. The electrodes should be extremely hard, and polished until their surfaces are as smooth and even as glass plate.

Fig. 44 shows the various parts of a transmitter disassembled.

Another important feature of a transmitter is the amount of battery consumed, or the amount of current required to operate it clearly and distinctly. Telephone companies are beginning to realize this important feature, and are now demanding a transmitter which will operate on much less current than those designed and manufactured four or five years ago.

Transmitters equipped with high resistance car-

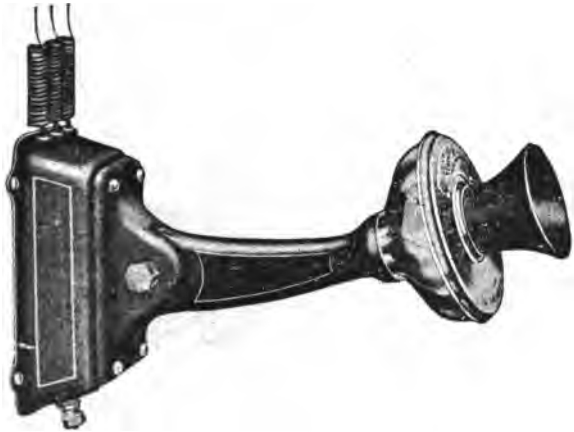


FIG. 46
TRANSMITTER MOUNTING WITH INDUCTION COIL IN BASE

bon electrodes require a great deal less current than those equipped with metal electrodes and the carbon electrodes reduce the battery consumption without affecting the transmission, whereas a corresponding reduction of battery flow in a transmitter having metal electrodes would greatly reduce its efficiency.

TRANSMITTER MOUNTINGS

Three standard telephone transmitter mountings are shown in Figs. 45, 46 and 47. The first is the "Pony" arm, used on compact type telephones and on wide and single battery box instruments. The arm is formed up of sheet steel, and

FIG. 47
TRANSMITTER MOUNTED ON HOTEL AND RESIDENCE TELEPHONES

is hollow for the accommodation of the cords. The construction is such as to allow a considerable freedom of vertical movement. The method of connecting the base to the arm is such as to preclude all chance of excessive wear. The old trouble of the arm wearing at the base so that it could not be tightened enough to support the weight of the transmitter is entirely eliminated.

Fig. 46 shows the "Box" arm with the induction coil in the base. This arm is, as a rule, used on all wide and single battery box telephones. The vertical movement is the same as the pony arm.

A knuckle joint arm for hotel or residence sets

FIG. 48
OUTSIDE VIEW OF RECEIVER

is illustrated in Fig. 47. This arm accommodates a double conductor transmitter cord, and is so constructed that there is no chance of the cord wearing. While the vertical movement is considerable, stops are provided so that the transmitter cannot be placed in such a position that it will not operate properly.

THE RECEIVER.—Following the transmitter, the receiver, which is shown complete in Fig. 48 and exposed in Fig. 49, is the next important part of the talking circuit of any telephone. The requirements are easily determined. It must be

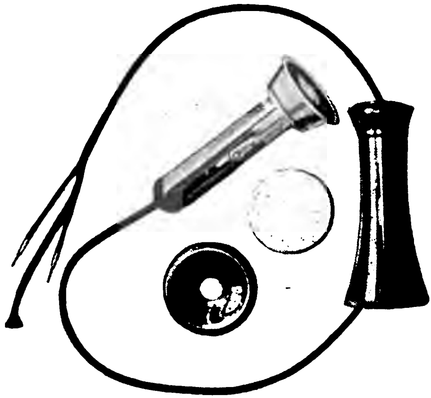


FIG. 49
EXPOSED VIEW OF RECEIVER

efficient and positive in reproducing the voice vibrations transmitted to it. It must be of such stability as to stand the hard usage to which it is often subjected, and the change of air and temperature. It must be easily handled and neat in appearance.

It is generally conceded now that no receiver needs a method of adjustment. If properly made in the beginning, there should be no occasion to adjust it even after years of service under varying conditions.

By referring to Fig. 50 it will be seen that a casting forms the mounting for the various parts.

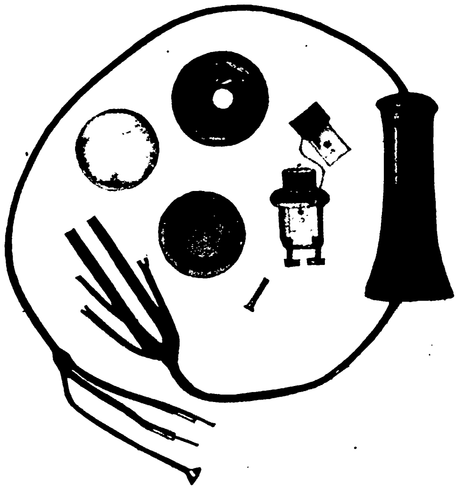


FIG. 50

DISASSEMBLED PARTS OF TELEPHONE RECEIVER

The elongated cores of the electro-magnets fit into slots in this casting. A hole is drilled in each core, and dowel pins fastened in the casting fit into these holes. The diaphragm is supported by a cup which in turn is fastened by four screws to the casting above mentioned.

The winding of the coils is done with silk covered copper magnet wire, and the resistance is uniform. The outside terminals are soldered to strips which are insulated and extend to the cord terminals within the shell. Small coils of wire between these strips and the coils allow plenty of

FIG. 51
MODERN TYPE OF RINGER

slack so that a coil can be removed and inspected without breaking the soldered connections.

The magnet is a single piece, being formed up from a bar of magnet steel. It slips over the casting which forms a support for all of the parts, and is held by a large brass machine screw. This screw passes completely through both sides of the magnet, the casting and both of the coil cores. All these parts are firmly clamped together, while the screw plays no part in the adjustment.

The German silver strips which bring the coil connections to the interior of the receiver, terminate in a brass support to which are fastened the

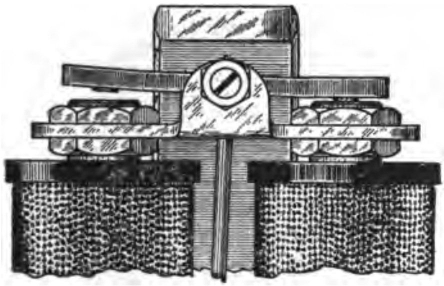


FIG. 52

SHOWING RELATION OF ARMATURE CORES

cord terminals. Means are provided for fastening either spade or solid tips, so that these receivers can be used by any exchange without the necessity of keeping two kinds of cords.

THE RINGER.—A modern type of ringer is shown in Fig. 51. In Fig. 52 the armature and its relation to the cores is shown and Fig. 53 shows the bell. The cores of the coils extend beyond the heads and are threaded on the ends. On each core are two lock nuts between which rests a yoke supporting the armature. If the lock nuts on one core are turned in one direction, that end of the yoke is brought closer to the coil, and if turned in the opposite direction, that end of the yoke is carried away from the coil. As the yoke supports the armature, any change in the position of the yoke causes a like change in the position of the armature.

The armature is pivoted in the middle between

FIG. 53
GONG OF RINGER

two lugs on the yoke. On one side is a pivot point, while on the other is a screw which affords a support as well as a means of adjustment. This screw is fitted with a lock nut so there can be no chance of its working loose. With a pivot point on one side and a sharp pointed screw on the other, there need be no pressure against the armature to hold it firmly. Fig. 54 shows the screw, lock nut and pivot point ready to mount in the yoke. To the armature is riveted a striker rod of brass with a brass striker ball at the end.

Referring to Fig. 52 it will be seen that the ends of the armature are formed so that they lie parallel to the ends of the cores. This construction greatly increases the efficiency of the ringer,

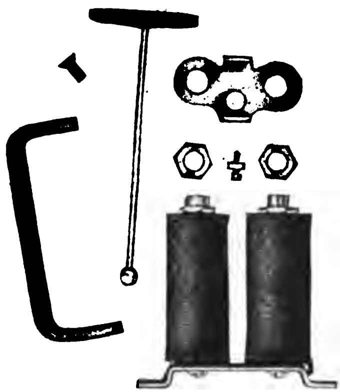


FIG. 54
DISASSEMBLED PARTS OF RINGER MOVEMENT

as the air gap between the armature and coil cores is uniform. Consequently, the greatest possible area is presented to be affected by the magnetizing of the cores.

Brass studs inserted in the armature keep it from coming into direct contact with the cores. These studs project but a few thousandths of an inch.

The heads of the cores are made of heavy black fiber, and are securely fastened to the cores. The coils are wound with silk covered copper magnet wire.

This ringer has recently been improved by the addition of a solder clip fastened in the head. The winding of the coil terminates in this clip and therefore there is no wire connection brought out of the coil. The fine wire terminals on ringer coils have caused a great deal of trouble.

The magnet is made of magnet steel and is firmly fastened to the ringer mounting by a machine screw.

These ringers are made for both series and bridging work and are of almost any desired resistance because of the construction of the coil which allows a large winding space. For series or town lines 80 ohm ringers are preferable, and 1000 or 1600 ohm for bridging or farm lines.

THE GENERATOR.—If, as already stated, mechanical construction is an essential feature in the perfection of the different pieces of telephone apparatus, the fact may further be emphasized as particularly true in relation to the generator. One thing that largely determines the efficiency of a generator is the distance from the armature to the field pieces. The air gap between these parts should be as small as possible, and should be uniform the entire length of the machine. To insure this the field pieces may be cast in soft iron and then milled on their concave surfaces so that each and every one will be exactly the same shape.

See Fig. 59. These field pieces being fastened to brass heads by four machine screws and four

FIG. 55
GENERATOR ARMATURE

dowel pins, there is no chance of their working loose. An approved type of generator much in

FIG. 56
THREE BAR GENERATOR

use has its armature placed between the field pieces and it revolves on a shaft extending through the brass heads. At one end this shaft supports a pinion which engages the large gear wheel to which the crank is attached. At the other end the shaft is insulated from the brass head and then passes through the head to come into contact with the armature spring of the shunt. The fact that

FIG. 57
FOUR BAR GENERATOR

the armature shaft is supported between the same two heads that hold the field pieces allows no variation in the distance between these parts.

Fig. 55 shows an armature of a four bar generator. It is composed of laminations or segments placed side by side so as to form a single unit. These segments are punched out of soft sheet steel, and are so uniform in size that a smooth surface is presented when they are assembled. The object of the laminated armature is to eliminate eddy currents which would reduce the efficiency of the whole generator. However, this loss is by many manufacturers considered allowable and excellent generators are made with solid armature cores.

The running gear is made up of a steel pinion

FIG. 58
FIVE BAR GENERATOR

and a brass gear wheel. These two different metals work together with little friction.

The shunts of both the series and bridging generators are very simple. In the series instrument there are two springs. Normally the armature is shunted out of the circuit by the two springs being in contact. The turning of the crank forces the crank shaft out against the longer spring, thus breaking the short circuit.

The bridging shunt consists of three springs arranged so that the armature is short circuited when the instrument is not in use. The turning of the crank breaks the short circuit and bridges the instrument across the line.

FIG. 59
GENERATOR PARTS

Short circuiting the armature practically eliminates lightning trouble, as it is almost impossible for lightning to burn out a generator.

Figs. 56, 57 and 58, which show the three, four and five magnet generators complete, and Fig. 59, which shows a four magnet generator dissected.

THE HOOK SWITCH

A hook switch of recent type is shown in Fig. 60. The long lever actuated by a coil spring of phosphor-bronze wire mounted in the base controls the action of the contact springs.

The lever is made in two pieces so it is possible to remove the hook from the telephone cabinet without disturbing the contact springs or altering

FIG. 60
TELEPHONE HOOK SWITCH

the adjustment in any way. A slot in the lower half of the lever accommodates the other portion, and the two pieces are securely fastened together by machine screws.

The contact points are pure platinum rivets, which pass through the springs, and are riveted on both sides. Hard rubber bushings and separators insulate the springs and mounting screws from each other and from the iron mounting. The master or line spring attached to the lever by a stirrup is also insulated by a hard rubber bushing. There are no electrical connections between the contact springs and the lever or mounting, thus precluding any chance of a subscriber receiving a shock from touching the hook.

Each spring has a clip for connecting the wires conveniently. These clips extend forward so as to bring the connectors into plain view. The base or mounting is cast of iron and is fastened by two screws put in from beneath to the shelf of the telephone.

THE INDUCTION COIL.—There are actually no minor parts in a telephone, and yet the induction coil, (See Fig. 18), is often referred to as such. The coil should be as efficient as it can be made, as it has an important function to perform. It is placed in the talking circuit to increase the voltage of the talking current, so that it may overcome the resistance of long distance lines. Unless properly designed and carefully made, it will only partially fulfill its purpose, as it will distort the sound waves so as to make the voice unrecognizable.

There are various ideas regarding the proper resistance of the primary and secondary windings. A series of experiments and tests in laboratories and actual practice have led to the use by many companies of a coil with a primary wound to 1.3 to 1.75 ohms and a secondary wound to 20 to 50 ohms.

The material used in the core has a great deal to do with the efficiency of an induction coil. Soft Norway iron wires which have been annealed twice in order to absolutely eliminate all hard spots are highly efficient. The wires may be held within a

Fig. 61

TELEPHONE WITH REMOVABLE SHELVES

paper shell, and the whole core supported by two heavy blocks.

The best grade of copper magnet wire should be used for the winding.

Mounting of Telephone Parts.—In Fig. 63 is shown one manner of mounting a telephone.

The two 5-ply shelves supporting the hook switch, induction coil and generator are removable, they being fitted into slots in the sides of the cabinet. The parts are mounted upon the shelves in the usual manner, and the wiring is carried to binding posts on the front edges. Silk and cotton insulated wire is used, and at all connections enough slack is left for reconnecting in case it is necessary to remove a part from the shelf.

Referring to Fig. 61, it will be seen that the cabinet is fitted with contact bars. These bars are the terminals of the permanent wiring, the circuits being carried along the back of the back board and soldered to the contact bars which extend through. Immediately beneath the top shelf are five of these bars, and beneath the lower shelf are two. They are so situated as to engage the binding posts on the shelves, and thus the connections from the cabinet to the parts on the shelves are made. Each of the contact bars is fitted with a solder clip which extends through the back board, and a clip which engages the binding post, which is fitted with a lock nut.

A shelf may be removed in order to inspect any of the parts without breaking any soldered connection, and without removing the telephone from the wall. All shelves for one type of telephone are interchangeable, and defective or damaged parts can be replaced by exchanging shelves. This feature is especially desirable in bridging telephones, as a repair man can remove the damaged parts, and by inserting a new shelf, can leave the instrument in order without the loss of time. The old shelf can then be repaired at the exchange where facilities are at hand.

THE GONG DAMPER.—The purpose of the gong

FIG. 62
BELL WITH GONG DAMPER

damper is to stop the vibrations of the ringer gongs as soon as the receiver is removed from the hook. A sensitive transmitter will take up these vibrations and magnify them to such an extent that it is impossible to carry on a conversation. This is particularly true with a compact type telephone. It has become customary to place the hand on the gongs when calling or answering a call, but the gong damper obviates this necessity.

FIG. 63
COMPLETE TELEPHONE

In Fig. 62 is shown the device attached to the door of a compact type telephone. A lever formed of heavy wire is secured to the door by hinges, just beneath the ringer and in such a position as to rest upon the switch hook when the door is closed. When the receiver is removed, the hook is raised and the lever is tilted upward. Two prongs of the lever extend through the door, one into the inside of each gong. The tilting of the lever throws these prongs downward and leather discs on their ends strike the gongs and deaden their vibrations. When the receiver is replaced, the lever falls back and removes the discs so that the next ring is not affected.

COMPACT TYPE TELEPHONES

The compact type of telephone is used to a greater extent than all other types of magneto telephones combined. The reason for this is that it satisfies a greater number of conditions than any other yet produced. The apparatus is easy of access, it is neat in appearance; its wiring is simple. As all the apparatus is enclosed in a single cabinet, it utilizes a comparatively small amount of space, as the name implies and is easy to handle and install.

COMPACT TYPE SERIES TELEPHONES.—A Series telephone of the compact type is shown in Fig. 63, It is equipped with a 3-bar generator and 80-ohm ringer. Some exchanges prefer to use 250-ohm or even 500-ohm ringers, but, although this is good practice, 80-ohm ringers are extensively and satisfactorily used for all classes of individual lines. The bridging telephone has replaced the series set for practically all party line work.

A diagram of the wiring used in a standard series compact set is shown in Fig. 65. The various lines show the connections between the different pieces of apparatus; for example, the line numbered 44 represents the wire connecting the receiver binding post with the line binding

FIG. 64

COMPLETE TELEPHONE, KELLOGG TYPE

post. The small simplified diagram to the left in Fig. 65 is given so that one can see at a glance the circuit used, but does not show the actual wiring employed.

COMPACT TYPE BRIDGING TELEPHONES.—In Fig. 64 is shown a five-bar bridging telephone of the compact type. This instrument may be equipped with a ringer of any desired resistance

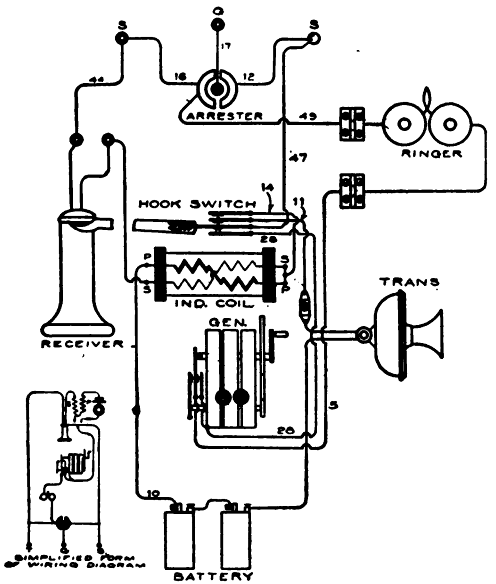


FIG. 65

COMPLETE CIRCUIT FOR SERIES INSTRUMENT

for bridging work; usually either 1,000 ohms or 1,600 ohms, according to the length of the line and the number of telephones on the line. Higher resistances can be obtained, but an efficient 1,600 ohm ringer will give satisfactory service on any ordinary heavily loaded bridging line.

Fig. 64 reveals the arrangement of the equipment as well as a portion of the wiring. The transmitter connections are made of stranded copper wire with a double insulation. These wires lead from the transmitter through the hollow arm to the inside of the door and here they are held in place by a suitable clamp.

From here one wire goes to one terminal of the battery and the other is soldered to a connector to which is already attached a wire that is carried through a slot in the backboard to the primary of the induction coil.

These compact sets are also made with all parts of the circuit highly insulated for use on lines near high tension circuits.

The hinges form no part of the talking circuit which is an important feature in the design of a telephone for the reason that a poor contact quite frequently occurs at this point. The presence of the hinges in the ringer circuit presents no serious obstacle to the high potential current such as is used for ringing.

The wiring of a standard bridging compact set is shown in Figs. 66 and 67. Upon turning the generator crank the ringer is automatically cut out of the circuit.

The five-bar generator and high wound ringer sets are admirably adapted for use on the longest heavily loaded farmers' lines, while a four-bar, 1,000-ohm set will work satisfactorily on a line of moderate length with 10 or 12 phones depending entirely upon the condition of the line.

It frequently happens that on heavily loaded lines some party fails to hang his receiver on the hook. This not only allows the batteries to run down but leaves the receiver bridged across the

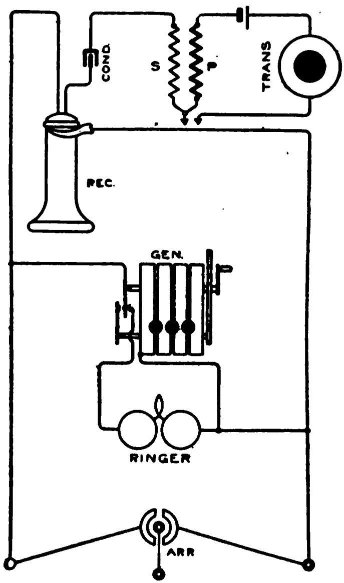


Fig. 66

line in series with the secondary of the induction coil.

This forms a very low resistance path for the generator current, consequently such a small portion of the same passes through the ringers of the other telephones on the line that they fail to respond. To overcome this difficulty and in accord with an essential principle of electricity—that "a condenser offers a small resistance to high frequency alternating current and a high resistance

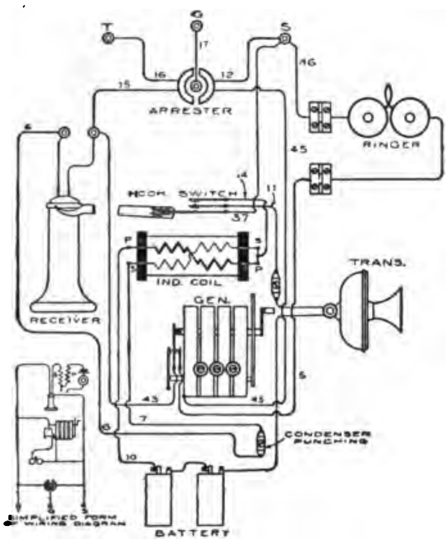


Fig. 67

to a low frequency alternating current"—a low capacity condenser may be in the secondary circuit.

This offers ample resistance to the low frequency ringing current to cause a sufficient flow through the ringers to operate them satisfactorily and at the same time the resistance offered to the high frequency talking current is negligible.

A simplified diagram of such a circuit is shown in Fig. 66.

The actual wiring of the set is the same as shown in Fig. 67 with a condenser inserted in the place of the condenser punching.

In all the sets wired with this circuit a condenser punching should be provided so that a condenser can be installed at any future time without

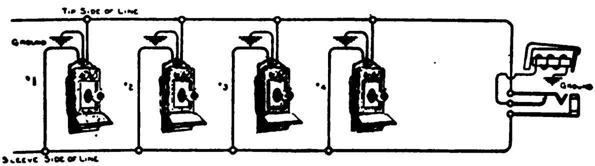


FIG. 68

METHOD FOR CONNECTING TELEPHONES WITH GROUNDED CALLING PUSH BUTTON

changing the wiring of the set in any way. All that is necessary to install the condenser, is to remove the wires from the punching and connect them to the condenser terminals. With the ordinary telephone it is necessary to procure a special condenser and place it on the outside of the telephone or on the wall near by.

In rural telephone service it has always been considered, that, to be able to ring central without ringing the other parties on the line and to ring any party on the line without ringing central, is a great advance in telephony.

This has been accomplished on metallic lines in the following manner: In addition to the two line wires a ground connection is provided at each telephone as indicated in Fig. 68 which shows the complete system with four telephones connected.

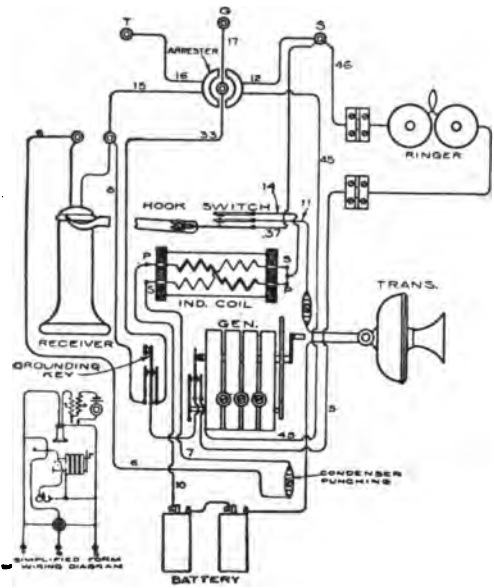


Fig. 69

CIRCUIT OF BRIDGING TELEPHONE WITH GROUNDING KEY FOR CALLING CENTRAL

With this type of telephone the left post is connected to the sleeve and the right post to the tip of the line which is just the reverse arrangement used for standard instruments. This arrangement is used to avoid complications in the wiring of the set.

The diagram of the circuit employed in wiring these telephones is shown in Fig. 69. The only piece of apparatus required in addition to that used in a standard bridging telephone is the grounding key. Normally the generator is bridged across the line through the break contact in the grounding key.

To ring any party on the line, all that is necessary is to turn the generator crank using the proper code of rings. This will not affect the drop at the switchboard as it is connected to ground from one side of the line.

When the subscriber desires to call central, he presses the grounding key which completes a circuit through the switchboard drop and at the same time breaks the circuit with the other telephones on the line. Now upon giving the generator a turn the drop is thrown and the other parties on the line are not aware of the fact.

It often happens that telephone companies desire to change some of their old bridging instruments for use with a grounding key. To provide for this and obviate the considerable work which is necessary to install this key in the telephone as it is done in factories, a key, has come into noticeable practice. This key is mounted in an oak block together with all the necessary wiring for making the changes. No change is required in the telephone. The method of connecting is shown in the diagram, Fig. 70. To ring central secretly on grounded lines is a far more difficult thing to accomplish than on metallic lines as on grounded lines the complications at the switchboard render the problem a most difficult one, and while there has been introduced such apparatus, it is doubtful if entire satisfaction can yet be

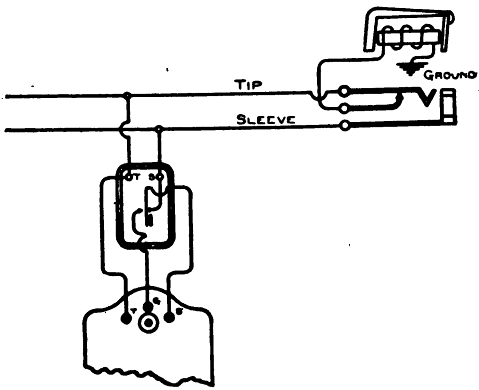


FIG. 70
METHOD OF CONNECTING GROUNDING KEY TO A BRIDGING TELEPHONE

given under very trying conditions, although, like all the other difficult problems which have been solved in practical telephony, this difficulty will be surmounted in the course of time, and this class of service may also be given with most satisfactory results.

However, in the interim the essential want is practically provided for by the type of telephone with which central can be called secretly and also the parties on the line can be called, but in doing this the switchboard drop is operated. The operator can usually tell if the party on the line is

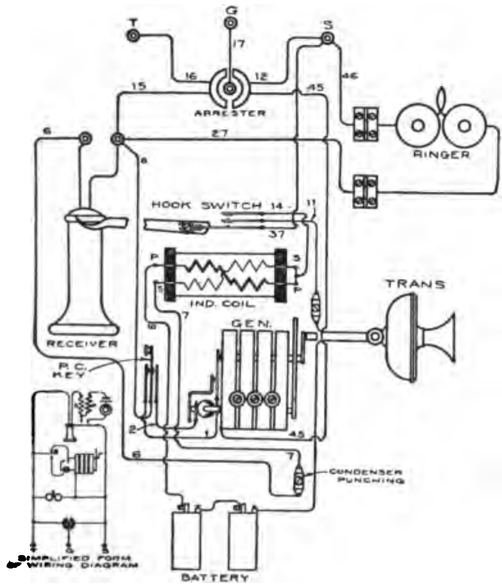


FIG. 71

CIRCUIT OF INSTRUMENT WITH GENERATOR DESIGNED TO GIVE ALTERNATING AND PULSATING CURRENTS

being called by the number of rings and consequently restores the drop without listening in. To aid in discerning a coded call a combined ringer and drop is often used on such lines.

The wiring used in this type of set is shown in Fig. 71. The peculiar feature in the equipment being in the construction of the generator. This is designed to give both alternating and pulsating

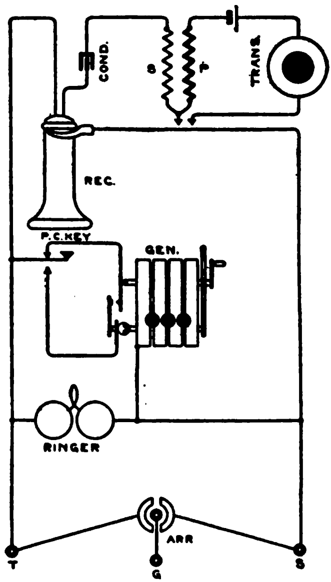


FIG. 72

current. The alternating current is used for ringing other parties on the same line and is normally connected. To call central the subscriber presses the key which connects the pulsating current to the line. This will operate the drop but will not affect the ringers on the line as they respond only to alternating current. The pulsating current tends to pull the tapper over in the same direction all the time and as it is held over to the proper side by a small spring there can be no action.

The condenser can be used to advantage in this

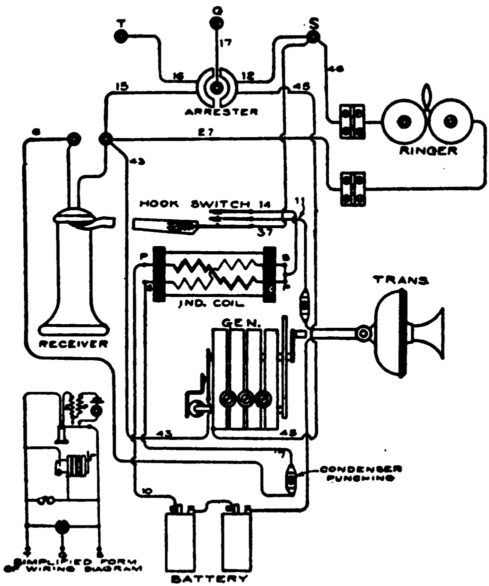
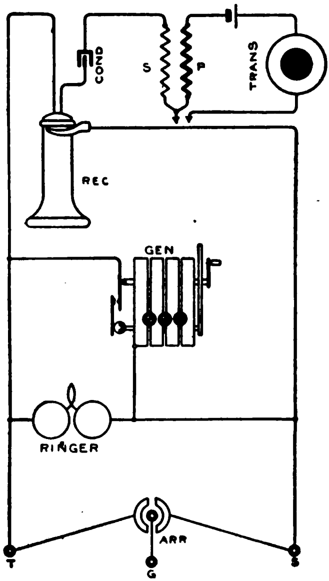


Fig. 73

COMPLETE CIRCUIT FOR CENTRAL CHECKING INSTRUMENT

type of telephone and a sketch of the circuit for the same is shown in Fig. 72, and for the actual wiring reference can be made to the preceding diagram, Fig. 71.

Some telephone companies desire to give service in which the subscribers on a line are not per-



Equipment

Selective Ringing

FIG. 74

SIMPLIFIED DIAGRAM OF TELEPHONE CENTRAL CHECKING

mitted to call one another, but must first call central and she will call the desired party in the usual way. A telephone to satisfy this class of service is equipped with a generator producing pulsating current only. This will cause the drop at central to fall but will not affect the ringers on the line. Instruments of this type are frequently spoken of as "central checking telephones."

Fig. 73 shows a wiring diagram of such a telephone. It is very similar to the standard bridging circuit shown in Fig. 67, the only difference being that the ringer in the latter circuit is not cut out

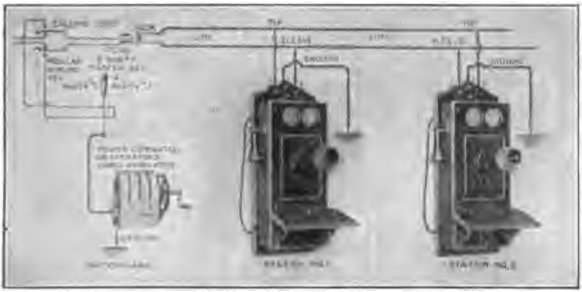


FIG. 75
TWO PARTY SYSTEM

by the generator shunt for the reason that the subscriber is not able to ring his own bell due to the fact that his telephone is equipped with a pulsating current generator.

Fig. 74 shows a simplified diagram of the circuit for this kind of telephone equipped with a condenser in the secondary circuit.

The code system of ringing telephone bells is one of the disagreeable features of party line service. Many times the wrong party answers the call due sometimes to careless ringing and other times to a misunderstanding of the signal. To overcome this trouble several selective ringing systems for magneto exchanges are in use.

The two party systems is extremely simple, em-

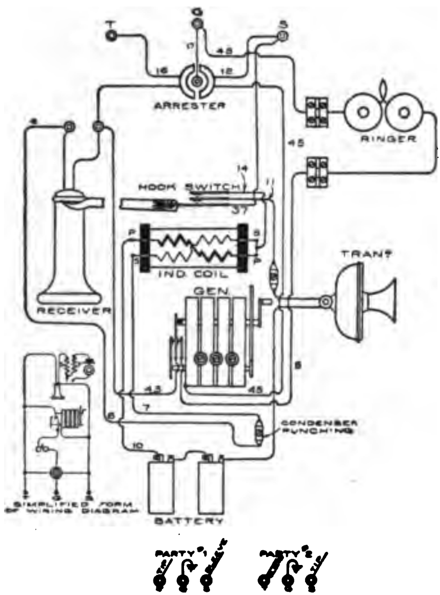
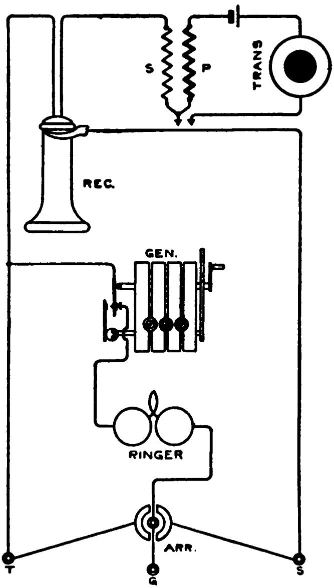


FIG. 76

COMPLETE CIRCUIT OF TWO PARTY INSTRUMENT WITH ALTERNATING CURRENT GENERATOR

ploying the divided circuit scheme as illustrated in Fig. 75. In this diagram a "master-key" common to all the ringing keys in an operator's position, is used for switching the generator to either side of the line. To ring the first party the operator connects the generator to the tip side of the line by means of her "master key" and rings in the usual way. This causes the ringing current to



Biased Ringer

FIG. 77

SIMPLIFIED CIRCUIT OF TWO PARTY INSTRUMENT WITH PULSATING GENERATOR

flow over the tip of the line through the ringer, in the first party's telephone to ground. The binding posts of the second party's instrument are connected to the line in the opposite way from those of the first party—that is, the tip post is connected to the sleeve instead of the tip side of the line, etc.

Any number of telephones may be bridged across the line with one-half of the ringers connected from either side of the line to ground. By this divided circuit arrangement only one-half of the subscribers will be disturbed when a party is signaled, which for a heavily loaded line is great advantage.

In Fig. 76 is shown the wiring diagram of a regular two party set with an alternating current generator and in Fig. 77 is shown a simplified diagram of a circuit for the same type of set equipped with a pulsating current generator. Either set is equally satisfactory for this service.

FOUR PARTY SELECTIVE WITH BIASED BELLS

Referring to Fig. 78 which shows a complete diagram of a four party selective ringing magneto system, it can be seen that each subscriber's instrument consists of a regular talking circuit, differing in no way from that of the standard bridging subscriber's set, and a signaling outfit which consists of a bridging generator with an automatic switch to cut it out of circuit when not in use, and a special high wound ringer.

This ringer is preferably wound to a resistance of 2,500 ohms, and is provided with an adjustable biasing spring to hold the armature against one of the pole pieces, thereby making it possible to

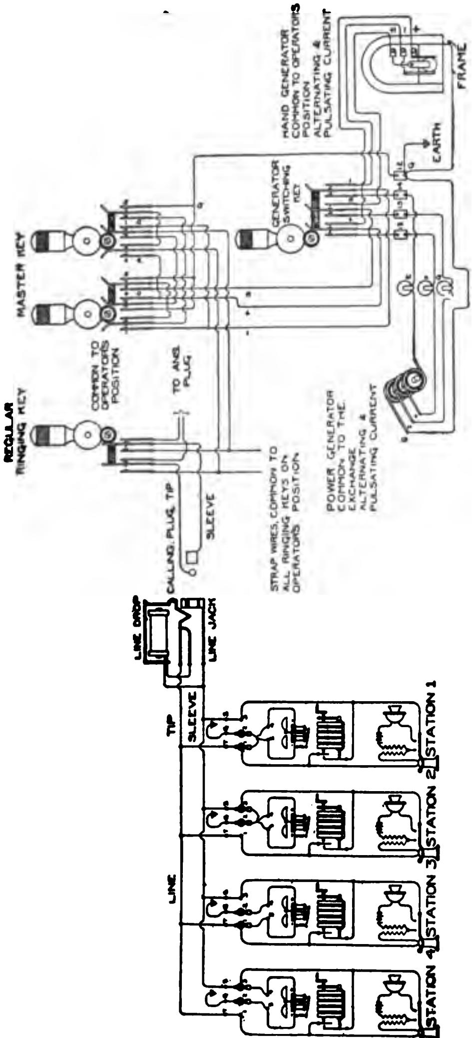


FIG. 78

COMLETE CIRCUIT OF A FOUR PARTY SELECTIVE RINGING MAGNETO SYSTEM ring only the bell with the right polarity of current, the wrong polarity simply tending to attract the armature of the ringer in the same direction as the tension of the biasing spring.

In order to make the telephones interchange-

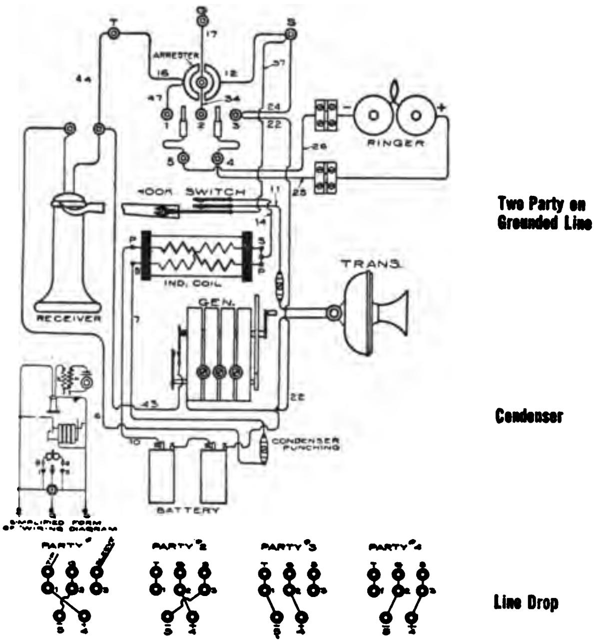


FIG. 79

COMPLETE CIRCUIT OF FOUR PARTY INSTRUMENT

able as regards the station, the ringer is provided with a switching device. This consists of two cords with tips Nos. 4 and 5 attached to the ringer terminals and three binding posts Nos. 1, 2 and 3 arranged to hold these tips. Thus to adapt a telephone to serve for any of the four stations, these cords are connected as per a printed code. Fig. 79 shows the proper connections for each of the four parties as well as the wiring of the set.

Selective telephones should always be connected to the line wiring in the same manner, i. e., by connecting the left hand binding post to the tip side and the right hand binding post to the sleeve side of the line circuit and the middle binding post to "ground," which latter can be a water pipe or regular ground rod of iron driven into a place where it will be in contact with moist earth during the entire year.

These sets have been used to a large extent for two party service on a grounded line. For this work the first and third party are used, connecting the sleeve binding post as well as the middle binding post to ground.

Selective party lines should terminate at the exchange switchboard in low wound line drops arranged to be cut out of circuit when the plug is inserted in the corresponding spring jack.

The function of this low wound drop is to consume enough current from the generator of a party calling the exchange so that the other ringers on the same line will not operate and as far as disturbance from signaling is concerned, each party will have the same advantage as on an individual line.

Besides the low wound drop for each party line it will be necessary to supply the switchboard with generators capable of giving positive (+) and negative (—) pulsating current for selecting purposes in addition to the alternating (+) current for regular ringing and master keys common to each operator's position to switch the different generator currents to the regular ringing keys. Fig. 78 shows the complete wiring of this exchange apparatus.

To call a subscriber on any one of these party lines the operator first sets the master key to correspond to the party desired, and with the plug inserted in the line jack of that circuit, she rings with the regular ringing key in the usual manner. The operation of the master key simply switches the generator current required, to operate the desired station, to the strap wires, which are common to all of the keys in an operator's position, so that any cord circuit can be used in calling. When the levers of the master key are in an upright position, alternating generator current is on these strap wires, so that the switchboard can be operated for regular service.

HARMONIC SELECTION

Since the introduction of the Harmonic System of selective ringing for Common Battery Systems several years ago, there have been many important changes made in the system of supplying ringing current, so that it is now possible at a small expense to install what is called a Frequency Pole Changer which will supply ringing current of different frequencies in the same manner in which original multi-cycle ringing machines were used for large Common Battery installations.

In Fig. 80 a circuit of the connections for a four party system is shown in which the ringing as well as the talking circuit is metallic. A wiring diagram of a four or eight party frequency selective ringing telephone is shown in Fig. 81. This

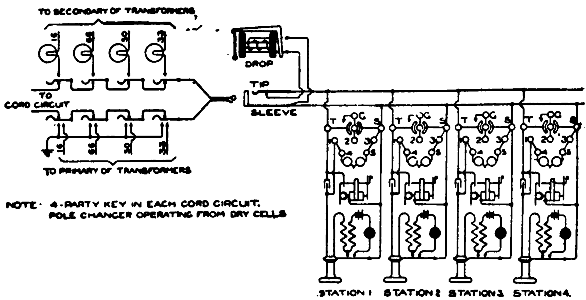


FIG. 80

CIRCUIT OF FOUR PARTY FREQUENCY SELECTIVE SYSTEM

diagram includes the plan of connections for either four or eight party service.

The distinguishing feature in this telephone is the construction of the ringer which is especially designed to respond only on a current of a fixed frequency.

By this system it is now possible to furnish selective eight party service on magneto lines by wiring the ringers of four telephones from each side of a metallic line to ground. In Fig. 82 is illustrated an eight party circuit showing the wiring of the telephones in connection with the line; also the wiring of the ringing circuit at the exchange.

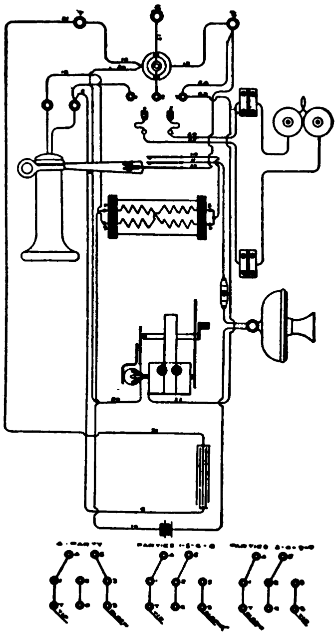


FIG. 81
CIRCUIT OF FOUR OR EIGHT PARTY FREQUENCY SELECTIVE RINGING TELEPHONE

COMMON BATTERY TYPE MAGNETO TELEPHONES.—A type of telephone which has been introduced is called the Common Battery Type, owing to its cabinet being very similar in appearance to the cabinet most commonly used for central energy telephones.

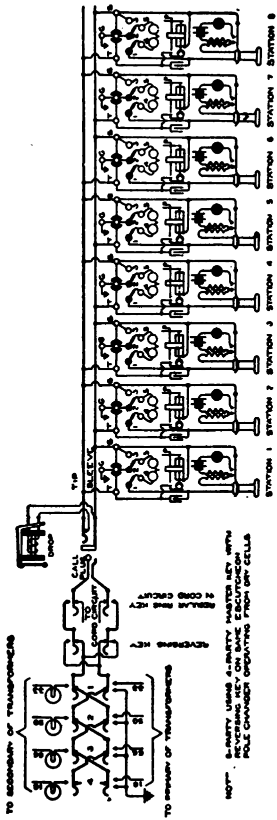


Fig. 82

EIGHT PARTY FREQUENCY SELECTIVE CIRCUIT

This comparatively new cabinet takes up less space than the compact form, and yet there is sufficient room for the convenient mounting of the parts. The writing shelf is hinged to the backboard, so that it can be raised. The front of the generator box can then be lowered, it being hinged at the bottom. This leaves the interior of the cabinet open for the inspection of the parts. A brass arm fastened within the generator box affords a rest for the writing shelf when it is raised, so that a man working on the parts within does not have to hold up the shelf.

A machine screw put through a special bushing and arranged so that it cannot come out when loosened, fastens the writing shelf and the front. This screw is placed under the edge of the shelf where it is out of the way, but readily accessible when wanted.

The ringer is mounted on the front, and as the gongs and striker are located at a point where they might be tampered with, a nickel plated brass guard is placed over the striker ball.

Two cells of dry battery are supplied with this telephone and are placed in the lower part of the cabinet. The cover of the battery box can be removed by loosening the machine screw in the bottom. This machine screw fits into a brass bushing permanently fastened in the wood. A solid fastening is thus secured.

DOUBLE BATTERY BOX TELEPHONES.—A type of telephone, known as the Wide or Double Battery Box instrument, is used for either series or bridging work, with three, four or five-bar generator and ringer of any desired resistance. It is usually equipped with two cells of wet battery, and is so constructed as to permit of the use of all special features, such as condensers, push buttons, etc.

This type of the battery box telephone is shown, open, in Fig. 83. The magneto box contains the generator, induction coil, ringer and hookswitch and is so designed that it can be easily removed

FIG. 83

WIDE OR DOUBLE BATTERY BOX TELEPHONE

from the backboard without unsoldering any connections.

The battery box is also easily removed exposing the batteries for inspection. They rest on a metal shelf fastened to the backboard. Dry cells may be used with this telephone if desired.

SINGLE BATTERY BOX TELEPHONES

The single battery box telephone is identical with the double battery box type just described except that the battery box and the lower part of

Fig. 84
CENTRAL ENERGY TELEPHONE

the backboard are made narrower, to accommodate one wet cell or two cells of dry batteries. These sets are used in either bridging or series. The bridging sets may be used with three or four bar generators and any desired resistance of the ringer. The circuit used in wiring these sets is the same as for the double battery box type.

CENTRAL ENERGY TELEPHONES.—There are numerous types of Central Energy Telephones. Fig.

FIG. 85

MAGNETO RESIDENCE TYPE TELEPHONE OPEN

84 shows a popular type. The arrangement of the parts is very convenient, there being no concealed connections when the front is lowered. The condenser is mounted beneath the writing shelf and parallel to it so that the two terminals are in plain

view when the cabinet is open. The ringer is placed in the box beneath the shelf and the bell tapper which protrudes through the front is protected by a nickel plated brass shield. The hook

FIG 86

MAGNETO RESIDENCE TYPE TELEPHONE

switch is mounted upon a shelf and the induction coil upon the back board. The receiver binding posts are beneath the hook switch shelf, while the line posts are mounted upon it.

The transmitter used on this central energy telephone is different from the local battery instrument only in the construction of the carbon chamber and the use of the carbon granules.

HOTEL AND RESIDENCE TELEPHONES.—In Figs. 85 and 86 are shown two views of a magneto

FIG. 87
MAGNETO RESIDENCE TYPE TELEPHONE WITH LIGHTNING ARRESTER

residence type telephone. This set is equipped with lightning arrester and outside binding posts, while in hotel type telephones the arresters are omitted and the line and receiver cord binding posts are placed within the cabinets. The batteries for both types have to be placed outside as the cabinets are not large enough for their accommodation.

As shown in Fig. 85 the arrangement of the parts is very convenient, as none are concealed

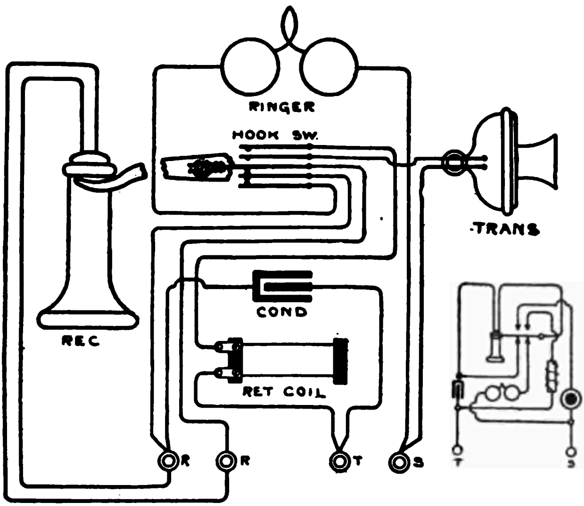


FIG. 88

CIRCUIT OF COMMON BATTERY HOTEL SET

when the door is open. The transmitter is mounted upon a knuckle joint, which allows a considerable vertical adjustment.

Another type of the residence or hotel telephone is shown in Fig. 87, and it may be used with either bridging or series equipment. It is particularly designed to fill the want when a small sized instrument is required.

Telephones of the type shown are made for either series or bridging work. The cabinet used for the five bar residence sets is slightly wider than the

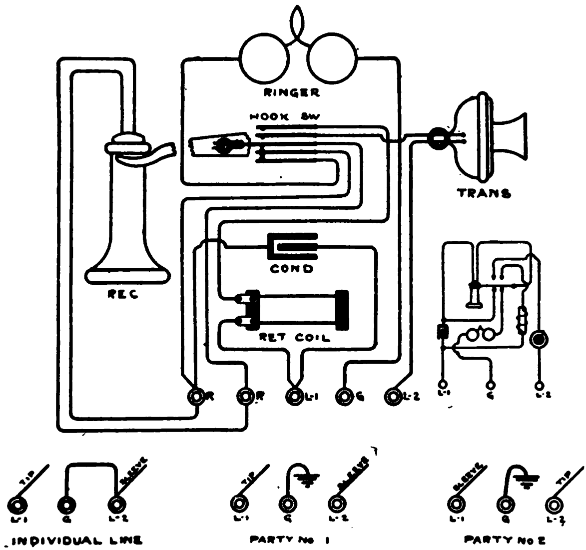


FIG. 89

COMPLETE CIRCUIT OF PARTY LINE TELEPHONE, RESIDENCE TYPE

one shown, but in all other respects it is the same.

Another type of telephone for hotel use is known as the "Kick Coil Hotel Set," as it is equipped with a kick coil instead of a generator. The kick coil operates on the current taken from two cells of dry battery mounted within the cabinet. These batteries are used both for signaling and talking. The removal of the receiver from its hook causes an impulse to be given by the kick coil, which throws the drop at the switchboard. The clearing-

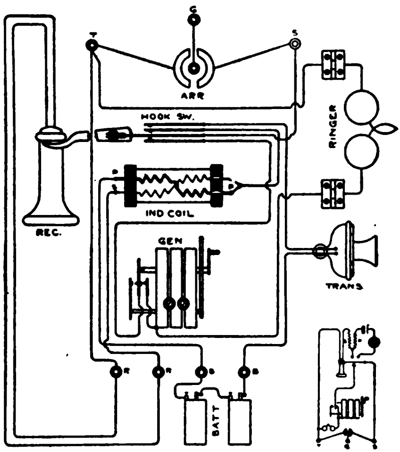


FIG. 90

CIRCUIT OF SERIES TELEPHONE, RESIDENCE TYPE

out signal is given by hanging the receiver upon the hook.

Fig. 88 shows a common battery hotel set circuit and Fig. 89 shows the same circuit two party. The wiring for a series set is shown in Fig. 90, while the bridging wiring is shown in Fig. 91. At the bottom of the backboard two binding posts are provided to give connection with the batteries which are located outside of the telephone cabinet.

in the basement or some nearby closet. These circuits are very similar to those described under double battery box telephone.

Desk Telephones.—Fig. 92 shows a form of desk stand. The desk telephone, which is now an instrument in universal use, is made in a variety of

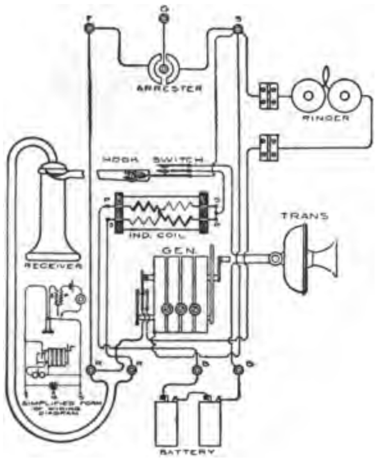


Fig. 91

CIRCUIT OF BRIDGING TELEPHONE

styles, the essential features of all, however, being identical. The switch is mounted in the base, as shown in Fig. 93. The actuating spring engages a rod which extends upwards through the tube to the hook lever. Within the tube is placed a long spiral spring, which gives a quick, positive action to the hook. There are no other parts within the tube so it is never necessary to remove more than the bottom protecting plate of the stand in order to inspect or repair any of the parts.

The supporting block in the base, upon which all of the connections are mounted, is composed of hard rubber and is securely fastened to the cast iron base by three machine screws. This rubber

FIG. 92
DESK SET

block is a unit in itself, as the wiring from the various connections is done on the block with insulated copper wire. The block used in a local battery desk set is slightly different from that used in a common battery desk set, but in order to change from one system to the other, it is only necessary to change the block, as all other parts are standard with the exception of the transmitter. A common battery transmitter, of course, has to be substituted for one of the local battery type.

The transmitter connections are entirely insulated from the stand. They are brought from the transmitter to the mounting block in the base by means of silk insulated cords, which terminate in

Fig. 93

BASE OF DESK TELEPHONE

brass connectors. The four conductor cord which carries the connections from the stand to the ringing apparatus, also terminates on this block in brass connectors. Each connection is marked in the rubber, as can be seen in Fig. 93.

Several different combinations for desk sets are used; one of the most popular being the combination of the desk stand, connecting rack and induction coil, with generator mounted in one box and ringer in another.

Another combination which is fast becoming popular is the desk stand with the cord attached to a connecting rack with induction coil mounted thereon and the generator and ringer mounted in

FIG. 94

MAGNETO DESK SET WITH BOX

one box. A third combination, and one which is almost new in the Independent field, is the desk stand with the four conductor cord extending to a desk set box containing a connecting rack, induction coil, generator and ringer. This box is shown in Fig. 94 and it will be seen that all of the parts, with the exception of the batteries, are included in this one cabinet. This arrangement cuts down the number of pieces of the desk set, and lessens the chances for trouble. The connections on the connecting rack within the box, are marked, and the circuits are easily traced. Batteries are required with any of the above combina-

FIG. 95
PRESSED STEEL DESK STAND

tions, but binding posts are provided on the connecting rack for connecting to the two cells of dry battery belonging to the sets.

Common battery desk sets consist of a desk stand, such as described above, a receiver and common battery transmitter, a four conductor green silk cord, and the desk set box containing a ringer, condenser and induction coil.

Desk sets are made for all classes of service. Bridging sets with four or five bar generators, ringers of any desired resistance and any other

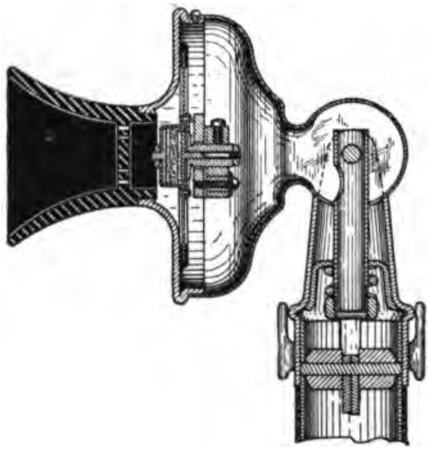


Fig. 96

PRESSED STEEL TRANSMITTED HEAD

special feature the practicability of which has been demonstrated.

An extension desk telephone for talking only consists of a stand with transmitter and receiver, six foot four conductor cord, connecting rack with induction coil and two cells of dry battery. Such instruments are extensively used in offices. They can be connected to either wall or desk sets without difficulty.

Booth sets often consist of desk stands with transmitters, receivers, connecting cords, induction coils and batteries.

Fig. 95 illustrates an excellent desk stand. The construction of the upper part is shown in the

SERIES DESK SET CIRCUIT

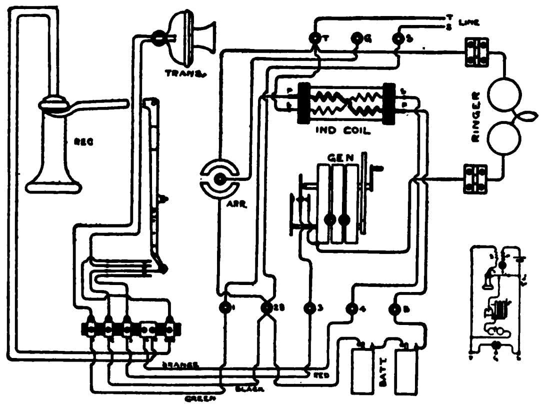


FIG. 97

SERIES TELEPHONE CIRCUIT

sectional view, Fig. 96. Being made of pressed steel, it is very durable.

In Fig. 97 is shown the wiring for a series telephone, while Fig. 98 shows the same for a standard bridging instrument. It will be noticed in both of these circuits that the four conductors leading from the stand to the box are marked Green, Black, Red and Orange. These colors correspond to the colored tracers in the desk stand cord. Green connects with binding post No. 1, Black with No. 2, Red with No. 3, and Orange with No. 4.

This type of telephone is also used to some extent on party lines having different equipments. Fig. 99 shows the wiring of a regular bridging equipment with a condenser in the secondary cir-

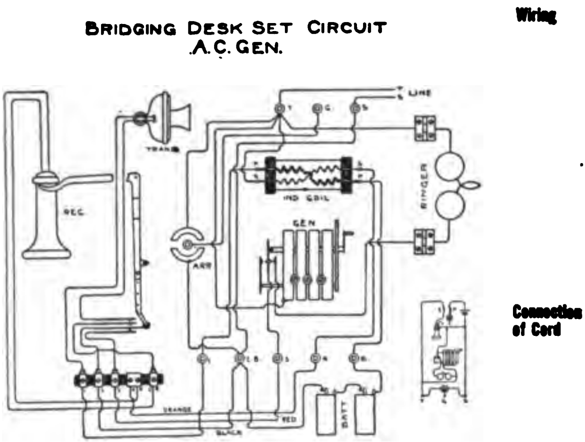


FIG. 98
BRIDGING DESK SET CIRCUIT
A. C. GEN.

cuit, while in Fig. 100 a similar equipment with a grounding key is shown.

In Fig. 101 the wiring is shown for a four party pulsating system.

In the diagram, Fig. 102, is shown the wiring for a four or eight party harmonic equipment of this type. Fig. 103 shows a Kellogg Common Battery Desk Set Circuit.

Battery Box.—In the use of local battery hotel or desk type telephones it has often been a source of perplexity what disposition to make of the batteries. The usual custom is to place them in the

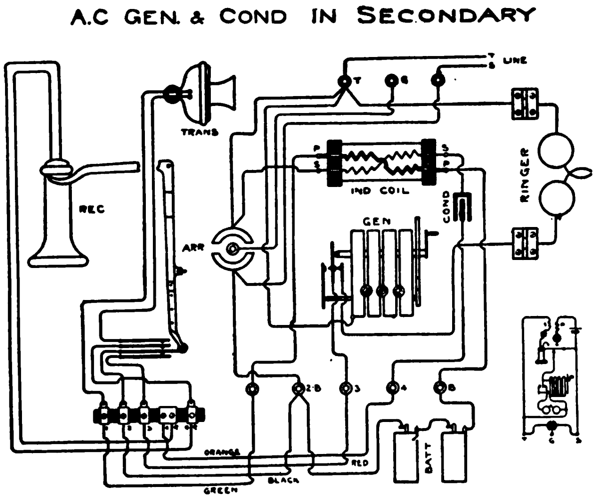


Fig. 99

CIRCUIT OF BRIDGING TELEPHONE WITH A. C. GEN. AND COND. IN SECONDARY

basement or a closet, either of which is undesirable, as it not only requires additional unsightly wiring but the batteries are usually unprotected and apt to be knocked over, and as a natural consequence the telephone is put out of commission by a carbon breaking or a wire being torn loose.

To prevent this trouble a battery box is made, out of pressed steel, lined with fiber.

Holes are provided in the top and bottom for bringing in the wires.

This box is so designed that it can be attached to any desired surface and detached without re-

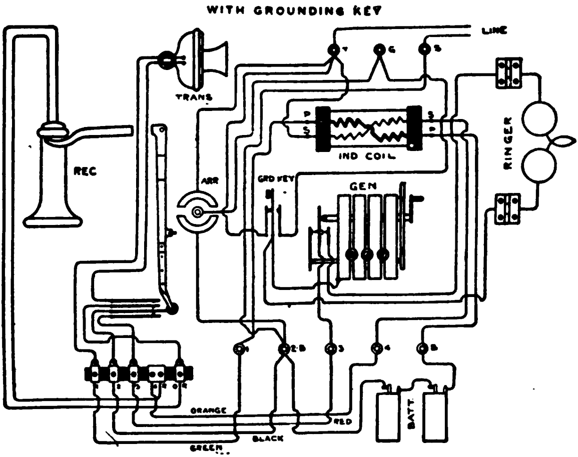


FIG. 100

CIRCUIT OF BRIDGING TELEPHONE WITH GROUNDING KEY

moving screws. For desk use it is convenient as it can be placed beneath or on the end of the same, back of the desk set box.

ADJUSTABLE TELEPHONE. — The instrument shown in Figs. 104 and 105 contains a desk stand and an adjustable desk stand holder combined in one. It may be attached to any vertically or horizontally flat surface, or to any style desk.

The cylindrical box encloses the hook-switch and cord connections and to it the transmitter is adjustably attached. The hook-switch springs are entirely insulated from the metal of the case and re-

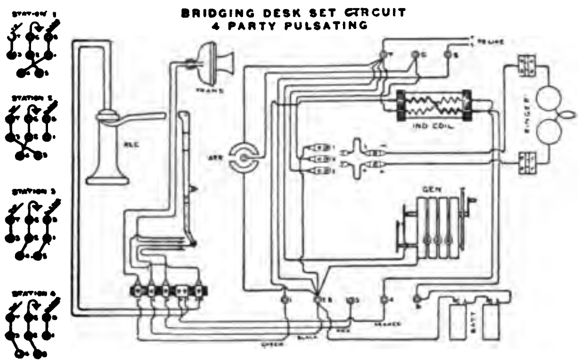


FIG. 101

ceiver hook. The adjustable lever arms and base are made from steel, nickel plated.

The adjustable desk telephone uses the same circuits as the standard portable desk type instruments with slight variations such as the arrangement of the hook-switch springs and binding posts.

SPECIAL BRIDGING TELEPHONES.—A great many improvements have been made in bridging telephones during the past two years; in fact the service on bridging party lines has so advanced that to day the subscribers on such lines can secure almost as perfect service as the subscribers on the individual lines used in towns and cities.

Bridging Telephones with Direct Current Generators.—By the use of a direct current generator in each of the telephones a central checking

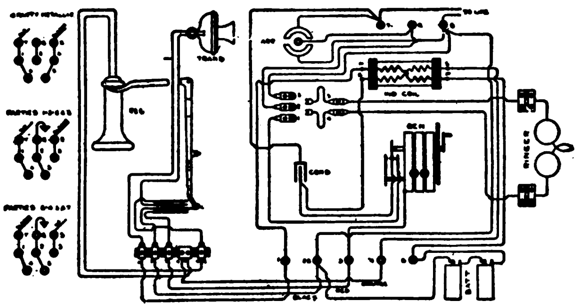


Fig. 102
BRIDGING PARTY LINE TELEPHONE CONDENSER IN SECONDARY

system can be secured in bridging party lines. The subscribers will then have to ring central even though they wish to talk to some other subscriber on the same line. The direct current generator will throw the drop at the switchboard, but will not operate the subscribers' bells, as these bells are arranged to ring on an alternating current. By the use of a system of this kind, the operating company can keep an exact record of each and every call made on the bridging lines, and can find out just which subscribers use the line the most. Several other advantages are derived, which affect not only the operating company, but the subscribers. The bells of the subscribers are not being continually

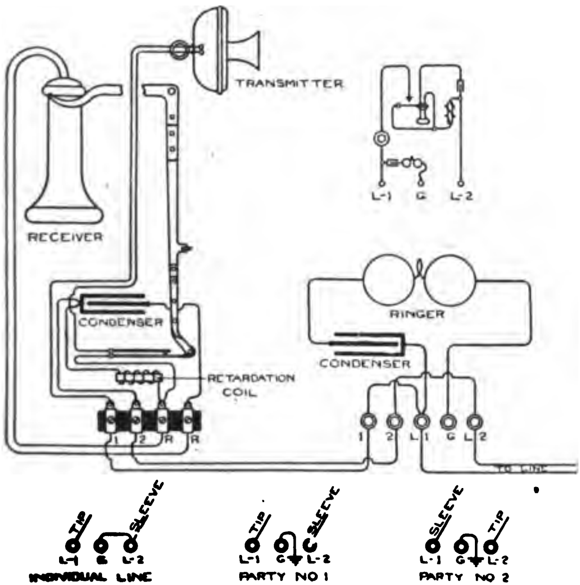


FIG. 103

KELLOGG COMMON BATTERY DESK SET

rung by people calling central. This fact also tends to alleviate the annoyance due to people listening in on the line when they hear central being called.

BRIDGING TELEPHONES WITH DIRECT AND ALTERNATING CURRENT GENERATORS.—By equipping a metallic or grounded party line with direct and alternating current generators, wired to push buttons, very good service may be given to subscribers. By the use of such instruments any subscriber on a bridging line can call any other subscriber on the same line or can call central without ringing any of the telephone bells on that line.

FIG. 104
ADJUSTABLE DESK TELEPHONE

The push button, which is mounted on the side of the cabinet, is wired in the generator circuit, so that an alternating current will be given out by the generator when the button is not pressed, and a direct current will be given when the button is pressed. By turning the generator crank without pushing the button, the alternating current passes out over the line and rings all of the bells and at the same time throws the drop at the switchboard. By the number of rings given the operator knows the signal to be for a subscriber and not for a connection, so she restores the drop without answering the call. By turning the generator crank, and at the same time pressing the button, a direct current

FIG. 105
ADJUSTABLE DESK TELEPHONE

passes out over the line and throws the drop at the switchboard, but does not ring the bells, as they are arranged to be operated on an alternating current. By this means, a subscriber secures secret service to the exchange.

When the operator rings out to call a party on a line equipped with telephones of this description, all of the bells ring as on an ordinary bridging line.

Bridging Telephones Equipped with Condensers.—The most serious disadvantage to the service on a bridging party line is the "listening in" of the subscribers. The fact that the talking circuit of a bridging telephone is of much lower resistance than the ringer, causes a great reduction in the efficiency of a bridging line if one or two receivers are removed from the hooks. In place of the 1,000 ohm, 1,600 ohm or even higher resistance ringer, bridged across the line, is a receiver and the secondary of an induction coil. The combined resistances of the receiver and the induction coil do not, as a usual thing, measure over 275 ohms. This resistance,. as compared to the ringer resistance, is very small, and the path through the talking circuit is therefore of much less resistance than through the ringer. Even one receiver removed will make it almost impossible to ring by that station unless a condenser is installed. By placing a condenser of low capacity in series with the receiver an impedence is offered the ringing current, which fully equals a 1,600 ohm ringer. Therefore it will make no difference whether the receiver is on or off of the hook. The condenser, while offering a high impedence to the ringing or generator current, does not retard the talking current to any appreciable extent. Actual tests made both in laboratories and on country lines show that it is impossible to detect any difference in the talking qualities with a condenser in or out of the circuit. On any bridging line equipped with condensers, all the receivers between the first and last telephones may be removed, and the first subscriber can ring the last without difficulty.

FOR METALLIC LINES ONLY

Bridging Telephones with Push Buttons to Ring Central. Over One Side of Line and Ground.—A metallic line offers greater opportunities for variation of circuits than does a grounded line. A very simple and practical arrangement can be had by wiring the generators of the telephones to push buttons, which, in their normal position, allow the current to pass out over the metallic line, and when operated cut off one side of the line and ground the generator from the other side. The switchboard drop on such a line is grounded so it will not be operated when a subscriber rings while pressing the button. As the ringers of the telephones are bridged across the metallic line, the subscribers can call each other without disturbing central or can call central without ringing any of the bells on that line. This system has all of the advantages of the direct and alternating generator system, and in addition has the advantage that the subscribers can call among themselves without bothering the operator.

Divided Circuit Telephones.—Divided Circuit Telephones are extensively used on metallic bridging lines as they tend to better the service. Each instrument is equipped with a direct current generator bridged across the line, and a high resistance ringer of 1,000, 1,600 or 2,000 ohms, bridged from one side of the line to ground.

One-half of the telephones have their ringers bridged from one side of the line to ground while the other half have their ringers bridged from the other side of the line to ground. Therefore, the metallic line is virtually two grounded lines so far as the ringers are concerned. As stated above, the generators are arranged to give direct current and are bridged across the metallic line. The switchboard drop is also connected across the line and consequently is thrown when any of the generators are operated. The ringers being grounded, this current on the metallic line does not affect them.

The signaling from the switchboard is controlled by a two-way key which grounds one side of the generator according to the position of the cam. In one locking position of the cam the generator is grounded from one side of the line and will ring all of the telephones which have their ringers bridged to ground from that side. In the other locking position, the generator is bridged to ground from the other side of the line and will ring all of the telephones which have their ringers bridged to ground from that side.

BRIDGING TELEPHONES EQUIPPED WITH PUSH BUTTONS FOR CODE SIGNALING.—As the code signals on some bridging lines are necessarily long and complicated, and as the sudden starting of a generator causes a great deal of wear on the parts, it is sometimes desirable to install a push button with which to signal. This button is wired in series with the generator, and is so arranged that in its normal position the circuit is open, but when operated, the circuit is closed. A subscriber, when calling, turns the generator crank continuously and presses the button to give the long and short rings.

OTHER SPECIAL TELEPHONES.—Push buttons can be installed in both series and bridging telephones to cut in or cut out the battery when operated. In the first instance, the transmitter battery circuit is normally open, but by means of the push button, it is closed. A saving of battery can thus be made, as there is no flow unless the button is pressed.

In the second instance, the transmitter battery circuit is normally closed, but when the push button is pressed, it is opened. This arrangement is especially valuable for telephones installed in noisy places, as the subscriber can cut out his own transmitter while listening, and thus eliminate the noise which would ordinarily be taken up from the room about him. While talking he leaves the button in its normal position.

SELECTIVE SIGNALING TELEPHONES

The demand for selective signaling telephones has been increasing very rapidly during the past few years, as a great many exchanges have found them very profitable. Preliminary to a description of one leading four party selective system, a brief outline of the requirements of the switchboard, telephones and line is given below:

A four way locking key or other switch wired in circuit with a pulsating current generator is necessary at the board. The generator must give both positive and negative pulsating current. The telephones must be equipped with biased ringers with terminals arranged so that the polarity can be readily changed and a ground taken from either side of the line. The lines must be metallic with the telephone generators and switchboard drop bridged across. The drop should not be wound to more than 100 ohms resistance.

By referring to Fig. 106 an explanation will be

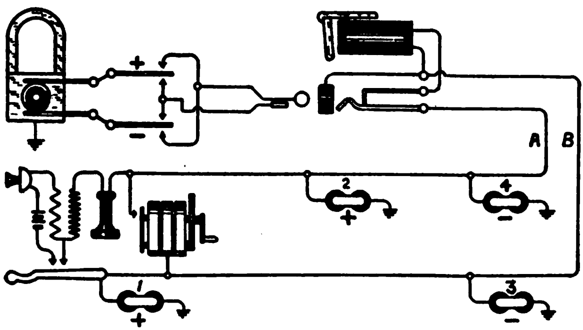


FIG. 106
THEORY OF FOUR PARTY SELECTION WITH PULSATING CURRENT

more readily understood. The circuit used in the telephones is shown in instrument No. 1, which has its ringer grounded from the B side of the line and arranged to ring on a positive (+) pulsating current. Instrument No. 2, has its ringer bridged to ground from the A side of the line and arranged to ring on a positive (+) pulsating current. Instrument No. 3, has its ringer bridged to ground from the same side of the line as No. 1. (B), but arranged to ring on a negative (—) pulsating current, and Instrument No. 4. has its ringer bridged to gróund from the same side of the line as No. 2. (A) but arranged to ring on a negative (—) pulsating current. The four selections are thus secured, the proper party being called by the operator throwing the four way key into the proper position and then ringing with her regular ringing key. Although Fig. 106 shows the generator permanently grounded, the custom is to ground the generator with the key, thus keeping all grounds out of the board except when required.

The subscriber is provided with a weak generator which will throw the drop without ringing the bells.

There is a two party selective system very similar to the four party, but it can be used on either metallic or grounded lines. The ringers are bridged across the metallic line, one being arranged to operate on a positive pulsating current and the other on a negative pulsating current. On grounded lines the ringers are bridged to ground instead of across the line, but otherwise the system is the same.

Fig. 79 illustrates a compact type four party telephone. A three bar generator is strong enough for this service as the only work to be done by it is to throw the drop. Two thousand or twenty-five hundred ohm ringers are the best, although in some cases one thousand and sixteen hundred ohms have proven satisfactory.

A very convenient arrangement for reversing the polarity of the ringer and grounding it from either side of the line is also shown in Fig. 79. It will be seen that the ringer terminals are brought out in flexible cord with clips on the ends. The two sides of the line and the ground connection end in screw terminals. The clips on the cords

FIG. 107
BIASED RINGER

can be slipped under the screw heads and washers and made fast.

A biased ringer is illustrated in Fig. 107. A long spiral spring, fastened to one side of the armature by a hook, holds the armature to one side. An adjustment is provided so the tension can be regulated according to the requirements. Otherwise the ringer is the same as heretofore described.

TELEPHONE TALKING CIRCUIT WITHOUT INDUCTION COIL.—This circuit, devised by the Kellogg Company, is shown in Fig. 108 in which 4 is a polarized bell; 15 is a 1 or 2 microfarad condenser; 17 is a receiver wound to 70 ohms resistance; 6, 7, 8, 9 and 10 are the springs of the switch-hook; 11 is the transmitter and 13 is the retardation coil.

Assuming the receiver to be on the hook, the ringing circuit may be traced from conductor 1 to branch 3, ringer 4, conductor 5, switch-hook points 6 and 7, around the receiver by way of the shunt

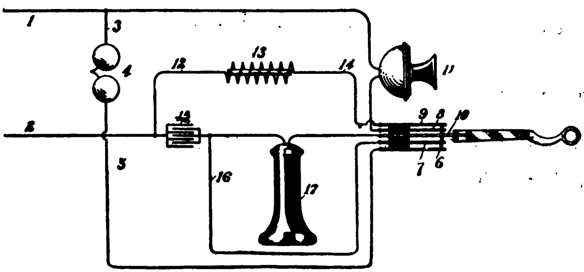


FIG. 108

KELLOGG COMMON BATTERY TELEPHONE CIRCUIT

16, thence through the condenser 15 and back to the central office over conductor 2. With the receiver off the hook, as shown in the figure, two parallel paths are provided, one opposing the passage of alternating or voice currents and the other opposing the passage of direct current but permitting the passage of the voice current. These two parallel paths are shown in Fig. 109.

Referring back to Fig. 108 the first path may be traced from conductor 2, through branch 12, retardation coil 13, branch 14, through the hook springs 8 and 9, transmitter 11 and back through

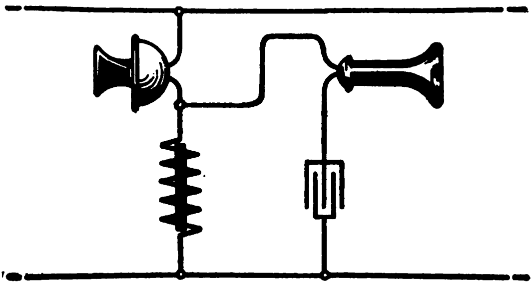


Fig. 109
THEORY OF KELLOGG COMMON BATTERY TELEPHONE

conductor 1. In this path the retardation coil offers a high apparent resistance to the voice cur-

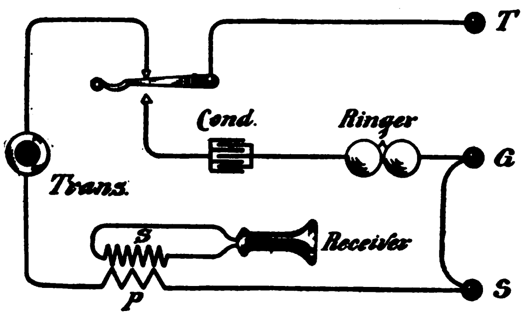


Fig. 110
COMMON BATTERY TELEPHONE, INDUCTION COIL TYPE

rent on account of its high frequency while permitting the passage of the direct battery current.

The second path leads from conductor 2, through condenser 15, receiver 17, through the contacts 10 and 8, back to central by way of the transmitter 11 and conductor 1. In this path the condenser prevents the passage of the direct battery current but offers a low resistance to the voice current.

The circuit shown in Fig. 110 is typical of the circuits employing induction coils and which shows that the current reaching the receiver is an induced one; the incoming voice currents reaching the receiver by being transformed from the primary to the secondary of the induction coil.

CHAPTER X

MAGNETO GENERATORS AND CALL-BELLS

Favorite instruments for calling attention on telephones, and which do not require any batteries, are magneto call-bells. In Fig. 111 the electrical connections are shown. G is a permanent magnet; a b is a soft iron armature magnetized S at both ends by induction. The upper poles of the electro-magnet are both magnetized N when no current is passing, hence both ends of the armature are attracted alike, and will remain against either pole. The electro-magnet poles are oppositely polarized when a current flows, and one end of the armature will be attracted more strongly than the other. The current is reversed at the half revolution of the generator, thus reversing the poles of the electro-magnet, and the hammer is drawn to the other gong. The rapid rotation of the generator armature causes a ringing like that of an ordinary alarm bell.

The generator consists of three or more strongly magnetized horseshoe magnets. The soft iron armature A, usually of the Siemens H pattern, is pivoted between the soft iron pole pieces P P. In the deep grooves on the sides the wire is wound. The pole pieces are cut to fit closely around the curved sides of the armature. In the position shown in the figure most of the lines of force pass from the N to the S pole through the curved sides of the armature. The number of lines of force

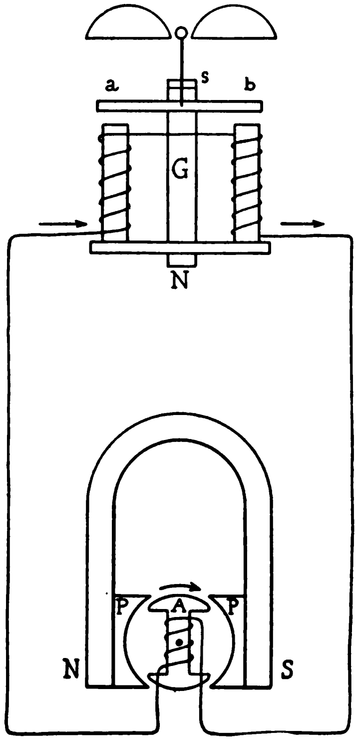


Fig. 111

THEORY OF MAGNETO AND POLARIZED BELL

cutting the coil constantly varies as the armature rotates, and currents are produced in the coil which flow to line, to which the coils are joined. The resistance of the armature is between 100 and 200 ohms. Various devices have been adopted to cut out the coils which should not be in the cir-

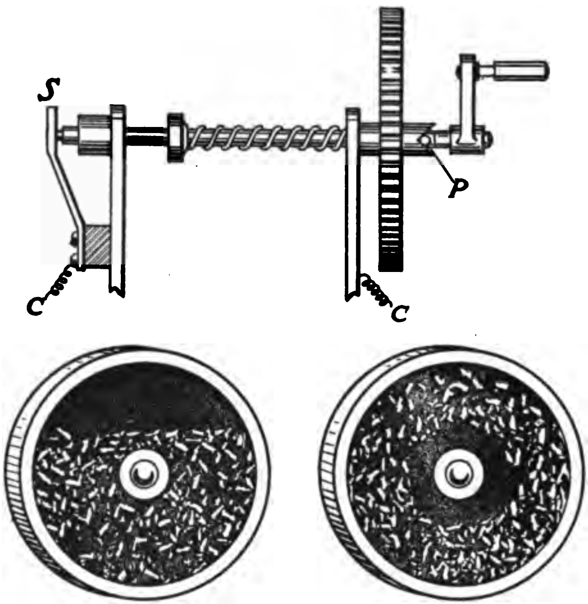


FIG. 112

HAND GENERATOR DETAILS—ARMATURE SHUNTS

cuit of the incoming current, two of which are illustrated. In Fig. 112, cc are the ends of the coils which are short-circuited by the spring S and the axle when the generator is at rest. When the handle is turned the pin p rides up the V recess, drawing the axle away from S, breaking the circuit there and bringing the coil into circuit. In Fig. 112 is shown a centrifugal cut-out. With the

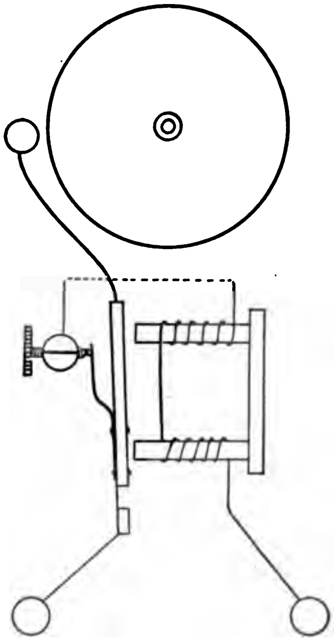


FIG. 113
VIBRATING BELL CIRCUIT

armature at rest the granules of silver-plated copper shunt the coil, and when the handle is turned the granules fly towards the edge of the box, thus breaking connection with the central pin and bringing the armature coil into circuit.

THE VIBRATING BELL

This bell consists of an electro-magnet fixed in a metal frame which is screwed to a wooden back Figs. 114, 115. At one end the armature is fixed to the metal frame by a flat spring, and on the other a small hammer is attached near

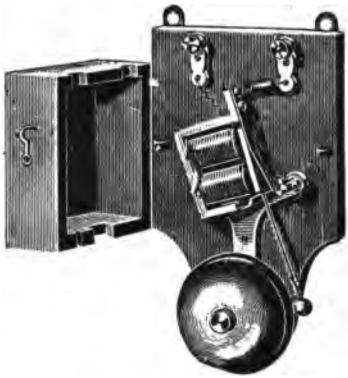


FIG. 114
VIBRATING BELL

the bell dome. See Fig. 113. The spring rests against an insulated stud with which electrical connection with the coil has been established. The current, in passing through the coils, attracts the armature, and the hammer strikes the bell, but in doing so the spring is drawn away from the insulated stud, breaking the path of the current; the electro-magnet no longer attracts the armature, which is drawn back by the spring, when the circuit is again complete, and these same movements occur as long as the battery is joined up.

One form of bell, shown in Fig. 115, has an extra contact spring which keeps the battery circuit closed, and a continual ringing of the bell until it is stopped by pulling a string which is attached to a small lever on the bell.

When a number of bells are connected in a circuit in series, intermittent ringing is caused by the make and break, which is overcome by connecting the coils m m shown in Fig. 116. The armature A is attracted by the current flowing through the coils, a continuation of which makes contact with the spring s and short-circuits the

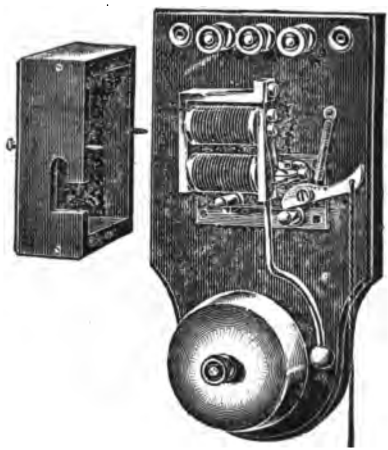


FIG. 115

VIBRATING BELL WITH CONSTANT RINGING ATTACHMENT coils, and causes the armature to fall back. The current flows continuously either through the coils or through the short circuit, which reaching the distant bells is not affected in any way.

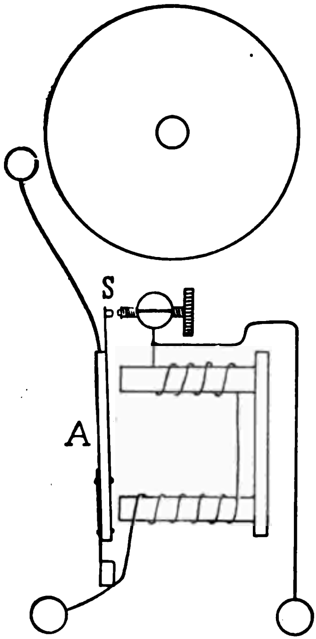


FIG. 116
SERIES SHUNTING BELL

Coils of vibrating battery bells are usually wound to 4 or 5 ohms, though they may be made several hundred ohms for special service.

LIGHTNING PROTECTORS

For the low voltages which are employed in telephony and telegraphy the silk and cotton insulation of the wire used in coils is sufficient, but there is no ordinary covering capable of resisting the enormous electro-motive force of lightning. Therefore lightning protectors or arresters, which are connected between the line and earth, are employed. These protectors or arresters act on the

FIG. 117
MULTI-DISCHARGE LIGHTNING ARRESTER

principle that the impedence of coils to lightning discharges is so great that the discharge sparks across the air-gaps between the carbons, and saves the apparatus from destruction. In locations where lightning storms are very severe the lightning rods and earth wires should be as straight as possible and angles should be avoided as a flash, in preference to turning a right angle in an earth wire, will occasionally leap across a space of 3 feet.

The arrester shown in Fig. 117 is known as the "Multi-Discharge" owing to the numerous discharge points offered for the escape of the lightning. There are several types, the one shown in Fig. 117 being a lightning arrester only, for use on

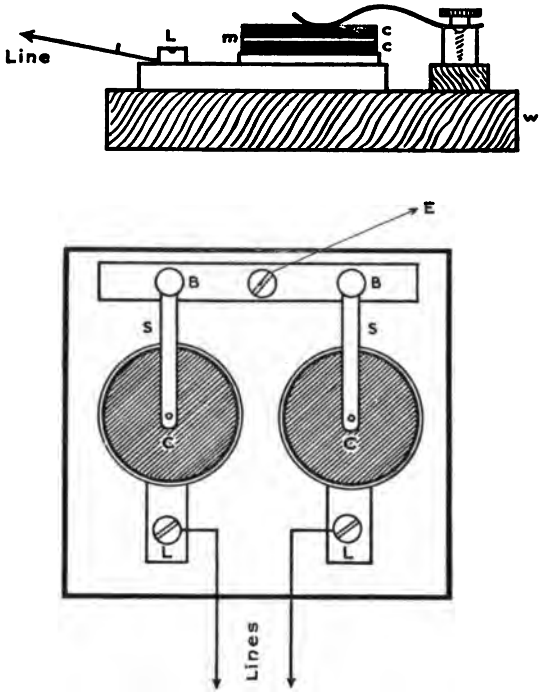


Fig. 118

CARBON PLATE LIGHTNING ARRESTER

lines not exposed to crosses with wires carrying heavy currents. Other types of this device are equipped with fuses of the open or enclosed types.

The saw tooth arrester is an early simple form of lightning protector which consists of two brass plates having sharp saw-teeth clamped close together but without touching. The line connects to the one plate and the earth to the other. (See Fig. 303).

Fig. 118 shows a type of lightning protector used for metallic circuits. It consists of two cir-

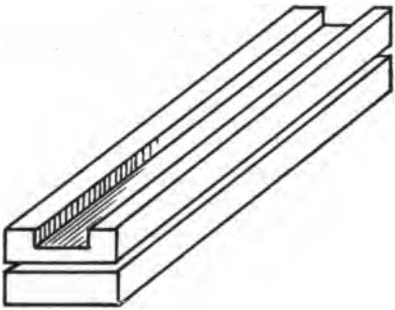


FIG. 119
CARBONS FOR ARRESTER

cular carbon discs cc, separated by a thin sheet of mica m, with three circular perforations. The lower carbon disc rests in a brass cup in metallic connection with the line terminal L, and the system is securely held by means of a spring S, fixed at one end by the clamping screw B, and having at the other end a small projection on its under surface which fits into an indentation in the centre of the upper carbon disc. The whole is mounted on a wooden base W, and the line and earth connections made as shown.

The type of lightning protector shown in Fig. 119 is employed in connection with heat coils, and consists of two rectangular blocks of carbon. The

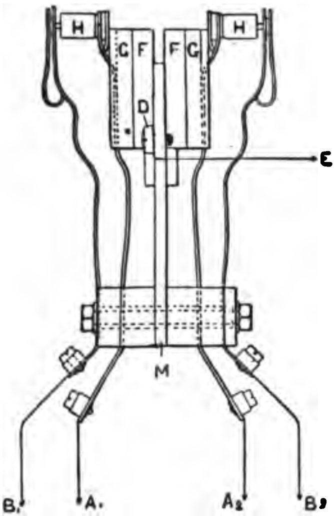


FIG. 120

CENTRAL OFFICE PROTECTOR WITH HEAT COILS

upper block is fluted for the reception of a clamping spring with which both carbons are pressed firmly against an earth connection, the upper block being connected to the line. As carbon is inoxidisable and infusible it is now used instead of brass, which is liable to be fused.

In Figs. 120 and 121 are shown two typical forms of protectors, G F and F G are the carbon protectors, H are the heat coils, and D the earth connection. The lines are joined to A1, A2, B1

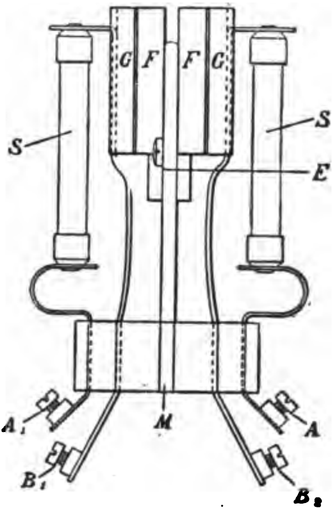


FIG. 121

CENTRAL OFFICE PROTECTOR WITH ENCLOSED FUSES

and B2. In Fig. 121 the heat coil is replaced by a fuse.

A fuse is a safety device which serves to protect the apparatus from the heavy currents used on power circuits. The glass-tube fuse, Fig. 122, one of a great variety of fuses, and an old type, consists of a glass tube two inches long with brass caps cemented to its ends. Passing through the tube is a wire W made of alloy three or five mils in diameter, the ends being soldered to the brass caps in which are a number of small holes to serve as air-vents for expansion when the fuse melts. This occurs when the current reaches a certain value. It is mounted on a porcelain base as a prevention from fire and is called a glass-tube cut-out.

A heat-coil is a small coil wound to a resistance of 25 ohms over a brass bobbin with fibre cheeks,

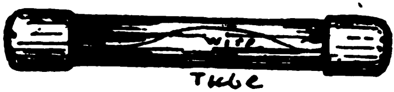


FIG. 122
GLASS TUBE ENCLOSED FUSE

one end of which is soldered to the bobbin and the other is clamped to the metal cover. One end of the bobbin is drilled to receive a pin with a large head which is soldered into position with a special soft solder. The function of the heat-coil is to protect the apparatus from currents which would not blow the fuse but which would probably damage the instrument. A current of 250 milliamperes will operate the pin in 30 seconds but a current of 150 milliamperes will not release it even after several hours. The heat-coil is placed between two German silver springs, see Fig. 120, one of which has an outward tendency. The tension of the spring withdraws the pin and earths or disconnects the line when the current is strong enough to melt the solder and release the pin.

A special coil wound to only 3.8 ohms, and having a striking point of 500 milliamperes, is employed in the common battery system.

CHAPTER XI

BATTERIES

The Primary Battery.—A simple cell, illustrated in Fig. 123, shows the essential principle upon which all chemical batteries operate. A piece of zinc, Z, and a piece of carbon, C, are immersed in the proper solution or *electrolyte* and connected together with a wire which causes a current to flow from one to the other, and the zinc is eaten up by the solution more or less rapidly. Zinc and carbon are the substances in common use; but others can be used.

The current flows through the liquid from the zinc to the carbon and outside of the liquid from the carbon to the zinc. No current will flow unless the carbon and zinc are connected by a wire and when disconnected the zinc is slowly eaten up by the solution. When the connection between the carbon and zinc is not made by a wire, or if the wire is severed between them, the circuit is then said to be *open,* and when the connection is complete, the circuit is said to be *closed.* The zinc and carbon constitute the two poles or *electrodes* of the battery; the zinc carries a *minus terminal* and the carbon a *plus terminal.*

The form of battery which is not designed for continuous work, the circuit being open most of the time, is termed an *open circuit* battery. This battery is used for intermittent work in ordinary telephones, but the *closed circuit* battery is employed for switchboards, as they are in constant use.

The *internal circuit* of a battery is that part which passes through the liquid and the *external circuit* is that part outside of the battery represented by the wire connecting the two poles or

FIG. 123
SIMPLE CELL

electrodes. The resistance which a battery offers to the passage through it of the current is termed the *internal resistance.*

The carbon is said to be the *positive pole,* because it is the first one into which the electricity passes after the electrical condition has been set up by the chemical action of the solution upon the zinc. The zinc itself is *negative,* because its terminal is at a lower potential than that of the carbon. When the carbon is connected by the wire to the zinc in the external circuit, this charge becomes a current, and flows from the positive carbon to the negative zinc, and continues as a current as long as the connection is maintained and the chemical action is kept up.

As already explained, *electricity is not generated.* It exists everywhere, manifesting itself when conditions are favorable to make operative the laws by which it is governed. In verbal intercourse, the phenomena of electricity caused to manifest themselves by chemical or mechanical means, are referred to as "generating" electricity, and this term has the sanction of custom, although it must not be considered in its literal interpretation.

The current given by a battery is equal to its electro-motive force or voltage, divided by the sum of the external and internal resistances.

Batteries are required for two purposes in connection with a telephone system: for ringing up the distant offices, and for speaking in the microphonic circuit. In both cases the time that the battery is actually in use is very short, and the intervals during which the battery is not required may be very long; hence it is desirable to employ cells in which all action ceases when they are not in use.

The Gravity Cell.—A form of cell known as the "Gravity," "Crowfoot" or "Bluestone" battery is shown in Fig. 124. This battery is used to a great extent in telegraph service and also in telephone work where a small but constant current flowing all the time must be had.

Three sheets of copper fastened together at the middle constitute the positive electrode, and to this is attached an insulated wire. The zinc is in the form of a "crow foot," having a lug attached and adapted to hook over the rim and permit the device to hang in the glass jar. This battery is

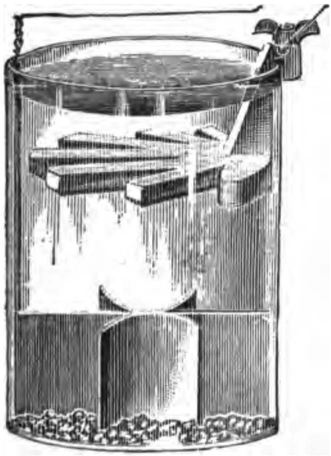


FIG. 124
GRAVITY CELL

set up by first putting the copper in place in the bottom of the jar and filling in around the copper to a height almost sufficient to cover it, with sulphate of copper, called blue vitriol; and then filling the jar with water and setting the zinc in place, as shown in Fig. 124. Sulphuric acid forms in this battery which attacks the zinc and forms zinc sulphate, a fluid which occupies the upper portion of the cell, being lighter than the solution of copper sulphate. The name "gravity cell" is given to this battery because of the fact that the two solutions are kept apart by gravity instead of by means of a porous pot, and the line of separation may easily be distinguished as the zinc sulphate is colorless while the copper sulphate is of a dark blue color. This "blue line," as it is called, should not be allowed to rise high enough to come in contact with the zinc, but should be kept about half-way between it and the copper. The blue line can always be lowered by short-circuiting the battery for a little while or by filling in with zinc sulphate from another battery or by siphoning off some of the blue fluid and filling in with water. Sometimes the reverse may occur and the blue line sinks down. Should it reach the upper parts of the copper, unless the difficulty can be remedied by dropping in more blue stone, some of the zinc sulphate should be siphoned out and clear water supplied in its place. On account of their high internal resistance these batteries are not adapted to telephone work in general, but they give very satisfactory results in closed-circuit work.

THE GORDON CELL.—This cell, as illustrated in Fig. 125, which gives an open view of the cell showing the parts assembled, consists of a perforated tin cylinder, the negative element, which is filled with black oxide of copper—a powerful depolarizing agent. To the lower portion of the cylinder, three porcelain cleats or lugs are attached by iron bolts, and the rolled zinc cylinder, forming the positive element, rests upon these lugs. Electro-sodium—a strong solution of an alkali—constitutes the electrolyte. For a 6x8 inch cell, the size of the zinc is 5½ inches in diameter and 2½ inches wide, containing about 1½ pounds

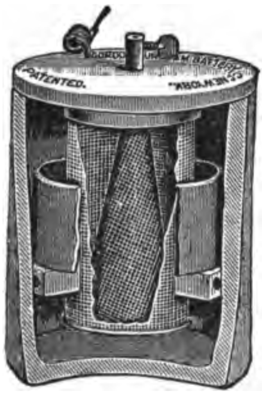


FIG. 125
GORDON CELL

of amalgamated zinc. Fastened to the zinc and extending through a porcelain bushing in the cover and forming the negative pole is a No. 12 B. & S. gauge insulated copper wire.

The positive pole is formed of a metal rod passing through a porcelain bushing in the center of the lid. This rod supports the entire negative element to which it is fastened. A layer of oil is poured over the top of the solution to prevent evaporation after the cell is set up complete.

In comparison with most other cells, the electromotive force of this cell is low, being very close to .66 volt under working conditions. The internal resistance is about .04 ohm. The 6x8 inch cell has a capacity of 300 ampere-hours when discharged at a rate varying from one to six amperes. Larger sizes of cells are made, with capacities said to be as high as 1000 ampere-hours.

This cell is adapted to open or closed-circuit work, particularly the latter, where for a long time a small current is required steadily. It has these advantages: Until entirely exhausted requires no attention. Throughout its life it maintains a constant electromotive force. At all ordinary temperatures it is non-freezing. It is free from local action. In small common battery exchanges, it is frequently used as a reserve battery to supply current, if for any reason the charging current for the storage battery gives out; but it has often been demonstrated, however, that it is not economical to use in such exchanges for the regular source of current supply.

There should be no action between the electrolyte and the zinc when any battery is idle. Were it economical to use perfectly pure zinc this would be the case; but inasmuch as commercial zinc always contains impurities, frequently consisting of other metals, a local galvanic action is set up, the impurities forming with the zinc minute galvanic couples. It is advisable, especially in such cells as the Fuller, to amalgamate the zinc—that is, to coat it with mercury, in order to reduce this action to a minimum. This gives a homogenous surface to the zinc, which prevents local action. The fact that this local action takes place on account of impurities in the zinc shows that the quality of metal used is a matter of much importance.

THE DRY CELL

In telephone work, a type of primary cell, known as the dry cell, is coming into constantly increasing favor. These cells are not strictly dry, for their very action depends on the presence of moisture. If they become really dry chemical action ceases, and with it their capabilities to generate a current.

The dry cell derives its name from the fact that the electrolyte is not in the form of a free liquid, but it is absorbed by some kind of porous material like blotting paper or saw dust, and evaporation is prevented by sealing the cell.

The early forms of dry cells were wholly unreliable and were universally condemned by telephone men, but it is now believed by many that the dry cell when properly made is superior for local battery work than any of the wet forms of zinc-carbon cells using an electrolyte of salammoniac. Electrically and chemically the dry cells have been brought to such a high standard of efficiency that their outputs are as great if not greater than any of the other types of the Leclanché batteries and their recuperative power is better. From the viewpoint of economy and convenience they are superior because of their low cost, and non-spillable and non-breakable features.

Dry batteries may be temporarily renewed by drilling a few holes through the outside case and setting the batteries in a jar filled with a strong solution of salammoniac. This serves very well in an emergency case where it is necessary to get a telephone in working order quickly. In case no salammoniac is at hand, a strong solution of salt and water may be used. The holes should not be punched in such a manner that the zinc case is forced through the paper lining; they should be cut clean with a hand drill and 1/8 inch drill.

Dry batteries being used largely in telephones on rural lines, it is well to caution farmers not to leave their receivers off the hook, and also against unnecessarily long conversations.

On farmers' lines where each subscriber pays for the maintenance of his instrument, the person using the telephone should be shown how to replace the batteries in case some become exhausted, and particularly how to connect the carbon on one cell to the zinc of the other and then connect the two remaining posts to the wires provided for this purpose in the telephone instrument. This is a very simple process, and if the subscribers are shown how to do this, it will very often save the exchange manager much trouble and expense.

In Fig. 126 is shown a recent, improved dry cell. A zinc cup forms the outer casing so that it answers the purpose both of retaining chamber and positive electrode. Shown in detail at the right of Fig. 126 is a carbon rod which forms the negative electrode, and which is held in the center of, but out of contact with, the cup, all the surrounding space being filled with a mixture of peroxide of manganese, powdered carbon and some porous

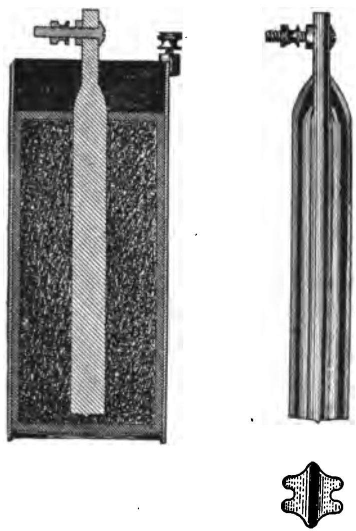


FIG. 126
SECTION OF DRY CELL

substance which will hold moisture. The whole is saturated with a solution of salammoniac.

The exact formulæ used by various manufacturers are not made public. A cylinder of several thicknesses of blotting-paper lining the inside walls of the zinc chamber will prevent the carbon and manganese from coming directly in contact with the zinc.

The zinc chamber is closed, after assembling, with a substance resembling sealing wax poured in while hot, and an outer casing of pasteboard put on. This outer casing has no other function than to insulate the zinc cup from surrounding objects. A binding post serving as the positive end of the cell, is provided at the end of the carbon plate which projects through the sealing material, and a rod extending upward from the casing of zinc carries a binding post which constitutes the negative pole.

The selection by exchanges of batteries having a high degree of electrical efficiency is of paramount importance and low first cost should not be considered as against a basis of practical commercial test. This is particularly significant when considering the fact that among dry cells now used in the United States there is a difference in the ratio of the best and the poorest types of about four to one in their *telephone life.*

In exchanges, therefore, where the poorer types are used the extra expense is very heavy as such exchanges are compelled to pay for the labor and other expenses incident to four renewals, where by using the best types of cells only one renewal would be necessary.

BATTERY TESTS are often made by short-circuiting the cell for a given period, or by permanently closing its circuit through a certain resistance and noting the time taken for a cell to completely discharge or to discharge until its voltage is reduced to a certain amount. These methods lead to erroneous conclusions. These con-

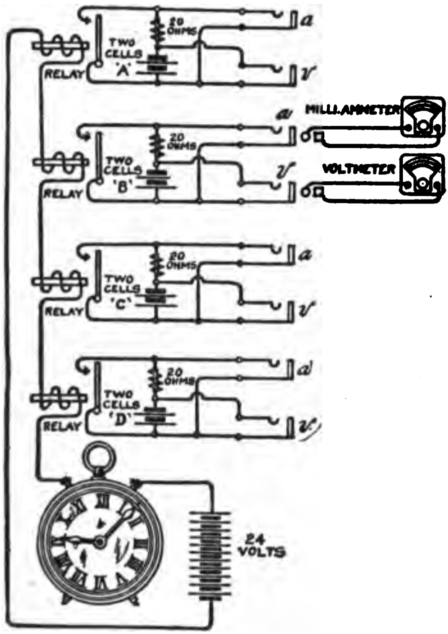


FIG. 127

METHOD OF TESTING PRIMARY BATTERIES

ditions are not those of practical telephony; cells designed for open-circuit work only being thus tested under *the conditions of work that* would be given to a closed-circuit cell.

A method of making comparative battery tests which may be made to closely approximate the actual conditions of service, is shown in the diagram, Fig. 127. Any ordinary clock may be equipped with three contacts on its face, each adapted to be engaged once each hour by a wiping contact carried by the minute hand. Each of these contacts extends over an arc equal to that traversed by the minute hand in the time during which it is desired to have the battery on closed circuit, assuming it to be for five minutes. Thus for a period of five minutes, three times each hour the circuit will be closed, there being between each closure an intermediate open-circuit period of fifteen minutes. The winding of a number of relays, and a battery of 24 volts are placed in series in the circuit with the contacts of the clock. For each battery to be tested a relay is provided and when operated each relay closes its battery circuit through a resistance which equals the average resistance of the transmitter designed to be used in that battery.

In Fig. 127 *a* and *v* represent two double-contact spring jacks connected with the circuit of each battery being tested. This facilitates the daily reading of the current and voltage. The connection of jack *a* includes both the coil and the battery being tested between its terminals, while the connection of jack *v* is across the terminals of the battery only, in order thus to make a direct reading of the voltage when the same kind of a plug in connection with a voltmeter is inserted.

Fig. 128 illustrates in plotted form of curves the result of tests made with apparatus arranged as referred to above. Each battery, in these tests, was closed through its resistance three times an hour for a period of six minutes, all readings were taken for each battery at twenty-four hour intervals and while the batteries were on open-circuit. The voltage readings alone were considered a true indication of the condition of the cell, inasmuch as at all times the current was shown to be substantially in proportion to the voltage. Therefore, for every day during the test these curves show the voltage of each battery. At a height indicating one and one-half volts a line is drawn across the curve sheet, as it was assumed that a battery of two cells was inefficient for service when it dropped below one and a half volts in potential; and the number of days required under the conditions of the test for each battery to drop below this voltage is indicated by the point where the horizontal line is crossed by the curve. These curves show the duration of the several batteries before the drop as follows: A, sixty days; B, forty-four days; C, not quite twelve days; D, about 16 days. While the curve indications for A and B were both first-class, the showing for B is inferior to that of A. Both batteries C and D show poor results, although the showing of battery D is somewhat better than that of battery C.

In making these tests the conditions must be adjusted to meet the requirements of the exchange. Equality of resistance between the coil through which the discharge is made and the average of that of the transmitter and primary winding of the induction coil should be maintained. When desired the clock can be adjusted to close the circuit more frequently and for a smaller period of time. The actual average conditions of telephone service, however, may be more closely

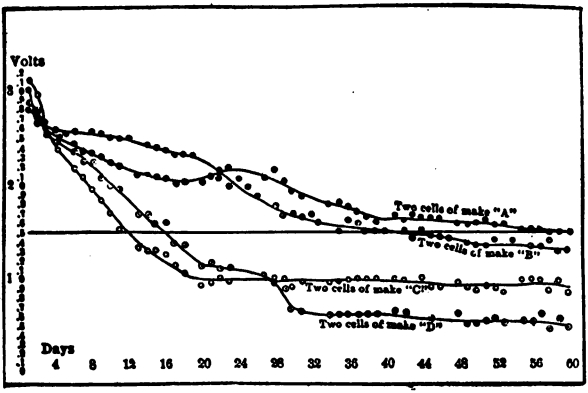


FIG. 128

RECORD OF DRY CELL TEST

approached by opening the circuit of the clock at night, thereby giving a complete rest to all of the batteries, as this is the least busy time for the telephones.

THE STORAGE BATTERY.—This battery is the same in operation as the primary battery with the exception that it can be recharged after being discharged without changing the plates or adding any new material. It only requires a current to be passed through it in the right direction. The plates of a storage battery are composed of lead, the negative plate being of a spongy lead and the positive plate of lead peroxide. Figs. 129 and 130 afford a good idea of the formation of these parts;

FIG. 129
NEGATIVE PLATE OF STORAGE BATTERY

the positive one being made from a solid sheet of lead in which ridges or holes are punched and into which is set the material forming the plate.

Pure sulphuric acid and water is the electrolyte used. The voltage is always the same in a storage battery regardless of the size of the cell and is a little over two volts for each cell. The large types of storage batteries use several positive and negative plates; but the small types have only two plates. There is always one more negative than positive plate where more than two plates are used in one cell and where there are more than two plates, one positive is always placed between two negatives.

In Fig. 131 may be seen four small storage cells

Fig. 130
POSITIVE PLATE OF STORAGE BATTERY

and Fig. 132 shows a cell on wooden base resting on glass or insulation.

These cells require but cursory mention and merely a descriptive outline, as complete directions and explanations are furnished by the manufacturer which will enable any intelligent person to connect the cells, set up the battery and give the initial charge, according to the type of cell.

The electrolyte, which should be procured ready mixed from the manufacturers is added after the cells are set up. When the solution cannot be procured, then a mixture of pure sulphuric acid and water may be used. The specific gravity of this should be 1.200 on the ordinary hydrometer scale.

Fig. 131
TWO-PLATE STORAGE CELLS

A hydrometer is a small glass tube like a thermometer, weighted at one end. The depth to which it sinks when placed in any liquid is shown on a scale and denotes the density of the liquid.

The mixture should be made in a large porcelain crock as it will become hot and a glass vessel is liable to crack. It is best to prepare the electrolyte several hours before use as it must be perfectly cool before using. The vessel should be absolutely free from any dust or metallic substances. Stir the mixture with a stick.

The charging current must be a direct current, and the positive pole of the battery must be connected to the positive pole of the generator. This can be ascertained with a voltmeter of the permanent magnet type, or by dipping the ends of the

FIG. 132
STORAGE CELL IN GLASS JAR

charging wires in a glass of elctrolyte, where, if they are separated about ½ inch, small bubbles of gas will collect around each wire. The negative wire will gas more freely than the positive. The polarity of the charging current must be definitely determined before connecting same to the batteries, for if the charging current is reversed, it will ruin the cells.

After covering the plates about ½ inch with the solution the charging current should be turned on. The amount used, length of charge, etc., vary according to the size of the battery, but the initial charge should be as continuous as possible, i. e., after the charge is once started it should be continued until complete.

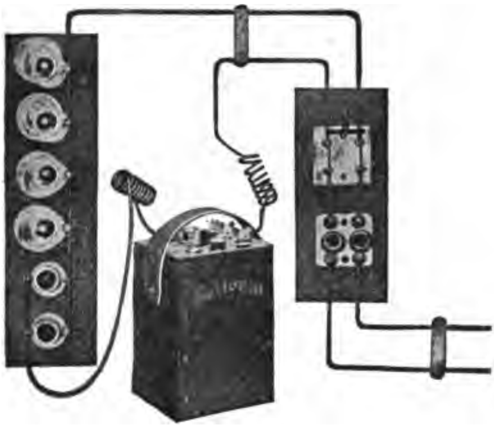


Fig. 133

CHARGING BATTERY FROM DIRECT CURRENT THROUGH A BANK OF LAMPS

By connecting lamps as illustrated in Fig. 133, storage batteries can be charged by any direct current lighting circuit.

The manner of usually mounting cells is shown in Fig. 134.

Storage Battery Charging.—There are three methods of supplying the necessary charging current to a storage batte··.

1st. By a motor generator or dynamotor whereby a suitable charging current is derived from some available power circuit.

2nd. By a rheostat consisting of lamps or other suitable resistance in series with some direct current circuit of higher voltage than that of the battery.

3rd. By a generator belt connected to a suit-

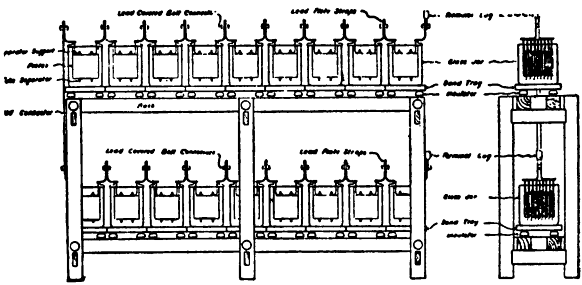


FIG. 134
STORAGE BATTERY RACK

able engine or other available source of mechanical power.

The first method is most common and generally is to be recommended in preference to the second or direct charging method on account of its greater power efficiency.

The third method is also quite satisfactory and is very efficient unless it becomes necessary to run the engine or other machine specially for charging the battery. This method is used to a considerable extent in connection with large exchanges, but seldom in small equipments.

Machine Charging.—The kind of machine that is best adapted to the service required in any instance is always dependent on the nature of the primary power. This may be either alternating or direct in character and may be for any one of a large number of voltages commonly used in electric power distribution. Direct current power circuits are most frequently available and moreover offer certain advantages over alternating current circuits. The chief advantage in favor of the direct current circuit when both kinds are equally accessible is that in case of a breakdown of the machine, the battery may be charged directly through a rheostat. The voltages most commonly met in practice are 110, 220, and 500 volts direct current, and 104 and 115 volts alternating current. The majority of alternating circuits are 60 cycles, single phase, though 50 cycle and 133 cycle circuits are not infrequent. Two phase and three phase circuits are also found.

Where alternating current is used, it is always necessary to use a generator driven by a motor and connected either by a belt or by a flexible coupling.

In the case of a direct current primary power circuit, either a direct connected motor generator set or a dynamotor may be used for charging.

The dynamotor has two windings on one armature. With this latter style of machine a speed regulator must be used.

DIRECT CHARGING.—In any case where a low voltage (110 to 220 volts) power circuit is convenient, and where the power cost is low, or there is a desire to reduce the initial cost of the plant to a minimum, the battery may be charged directly from the power circuit through a bank of lamps or other suitable resistance in series with the battery. By this method a large part of the power taken from the power mains is wasted in the resistance.

CHAPTER XII

COMMON BATTERY SYSTEMS

Methods have been devised in modern practice, where one common source of energy can be employed to supply the entire current required by all of the subscribers working on any one exchange and by which greater efficiency is obtained as well as greater economy in the working of exchange systems. One source of energy only is required, in the systems now being installed, to supply current for all signaling purposes and also for use with the subscribers' transmitters. The principal advantage of these arrangements is that the best results in both speech and signaling are gotten, as the supply, being obtained from the exchange, is uniform and maintained at the necessary standard.

In all common or central battery systems of any consequence, the current is supplied from one or more sets of accumulators specially designed for carrying the load required in the best manner possible. Being placed in the exchange premises they can be constantly inspected by trained men. To guard against any failure of supply it is necessary to employ duplicate sets of accumulators, or to have the dynamos used for charging these so designed that the load of the exchange can be taken direct by the machine without causing disturbance; or where it can be so arranged, means should be provided by which the dynamos can be run either by two or more sources, thus obtaining the current required if the other supply fail.

It is possible that a slightly better speech transmission may be obtained with local battery with first-class primary cells in best condition at each individual instrument, than with a common battery placed at the exchange; but with the common battery the average transmission is better, as the supply is always kept up to the uniform standard.

As indicated, there are two main systems of common-battery working; the first having the current necessary for signaling only, supplied from a common source, and the second, which is rapidly displacing the first as well as other systems, having a common supply, not only for all signaling purposes, but also for energizing all the transmitters of all telephones on the exchange system.

CALL-KEY RING-THROUGH SYSTEM.—This is one pattern of the common-battery system first mentioned. Fig. 135 shows the subscribers' line connections.

This system has been practically forced out of use by the full common battery switchboard.

COMPLETE COMMON-BATTERY SYSTEM.

The entire amount of current required for all purposes in connection with telephones is, in this system, supplied from the exchange. Although many years ago an arrangement of common-battery working was first proposed, it has only been of late years that this system has been used to any great extent. The basis of the modern common-battery system now largely used is that suggested by H. V. Hayes, and was patented in America in 1892. This system has been developed by the Western Electric Company and has been adopted

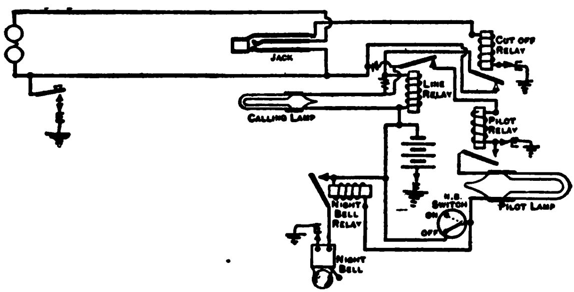


FIG. 135
COMMON BATTERY SUBSCRIBER'S LINE CIRCUIT

by telephone engineers in the equipment of a large number of telephone exchanges. The description of the common-battery system here given deals principally with the methods and apparatus of the Western Electric Company, although there are many other arrangements in use involving modifications of greater or less importance.

Under "Telephones" are various cuts which show the general appearance of instruments used for subscribers. In Figs. 136 and 137 are shown some diagrams of connections on these instruments. The line circuit through the instrument is disconnected to battery continuous currents by the condenser while the receiver is on the hook and all the other circuits are open; but the bell, being actuated by alternating currents, can be

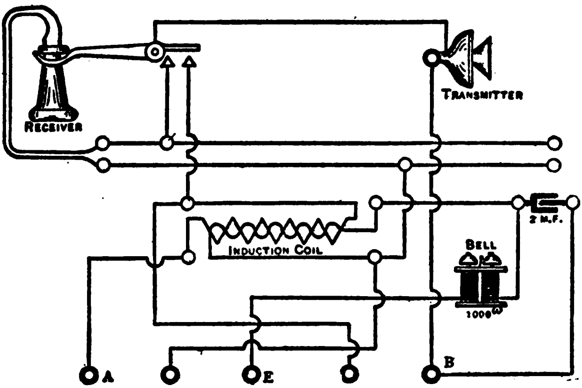
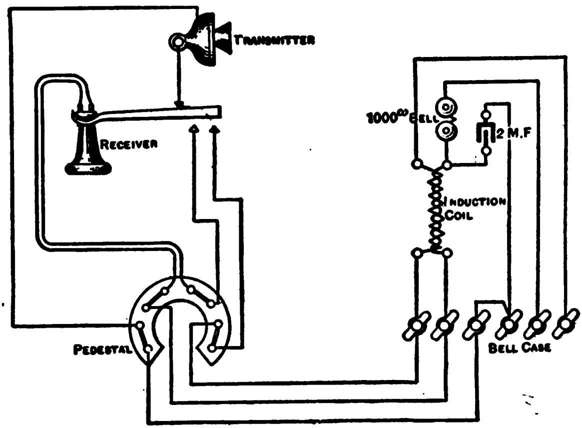


FIG. 136
CONNECTIONS OF WALL INSTRUMENT
(COMMON BATTERY)

freely rung through the condenser. When an extension instrument is not in use the terminals A E are joined together, and the line circuit is then through A to E 1,000-ohm bell, and condenser to B. The other circuits are closed when the receiver is removed from the switch hook, and there is first a connection from A through one side of the induction coil, through the contacts at the switch hook receiver and the second side of the induction coil and condenser to B, with the bell in shunt on this circuit. There is also another circuit through the receiver from A to E through



Connections of Table Instrument

FIG. 137

CONNECTIONS OF TABLE INSTRUMENT

the bell, secondary of the induction coil, receiver switch hook and transmitter to B. Second, there is the circuit from A through the primary of the induction-coil, switch hook and transmitter to B.

The connection is completed on this last circuit as shown on the line diagram, Fig. 138, through battery at the exchange, which energizes

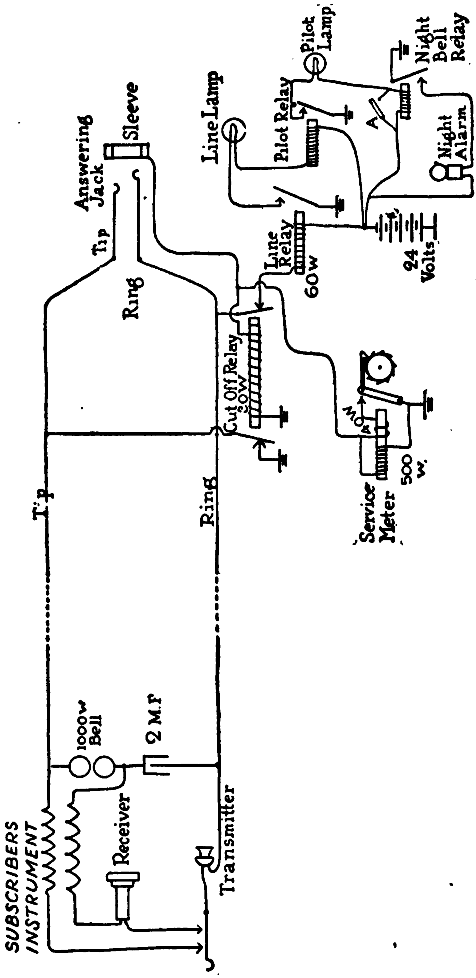
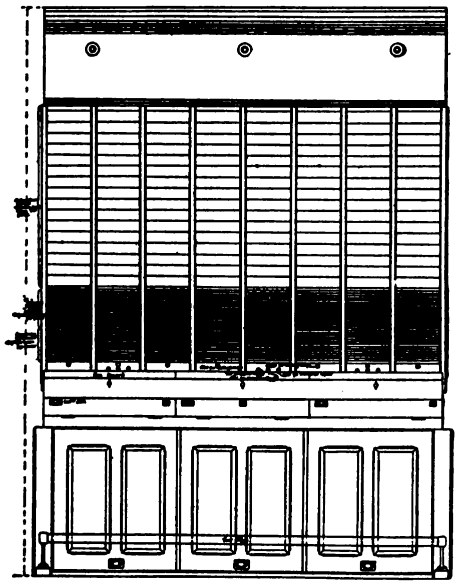


FIG. 138
COMPLETE DIAGRAM OF ONE LINE

the line relay, closing the circuit through the calling-lamp and pilot relay to battery, so that the calling-lamp glows when the subscriber removes



Switch-board Section, Front View

FIG. 139

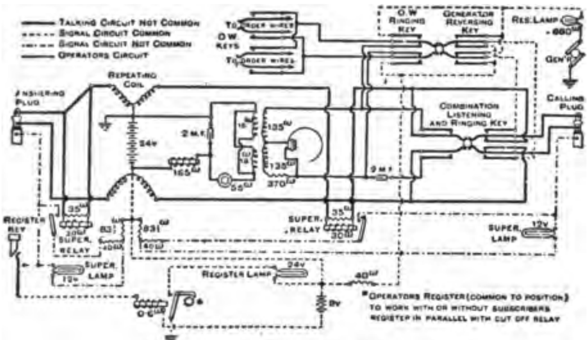
FRONT OF SWITCHBOARD

the receiver from the hook, thus calling the operator's attention.

MANNER OF OPERATING.—The current is completed as described above, when the subscriber lifts the receiver off the hook, and the current passes out from positive battery through the contact and armature of the cut-off relay, over the tip line, and back over the ring line by the second armature and contact of the cut-off relay through the line relay to battery. This gives the signal to the operator, as it closes the circuit of calling-lamp through the pilot relay and the calling-lamp glows, and the pilot relay having been energized, the pilot lamp also lights up. These pilot lamps are common to a group of subscribers' lines, the standard arrangement being one per panel. See illustration showing front of switch-board, Fig. 139. They are larger than the ordinary calling-lamp and serve mainly: 1st, for supervision; and 2nd, to assist in operating by indicating the panel on which a call is being made during the hours of the day and night when there are not many calls and few operators are on duty. A night-bell relay, common to a large group of these, or in small exchanges to all of the operator's positions in the exchange, is also provided in connection with the pilot lamps. When the pilot-lamp glows the circuit of the relay is closed, being in the common wire which connects one side of these lamps to earth. During the day this relay is short-circuited by the switch A, and is brought into circuit only at night; then, being energized, it closes the circuit through the night-bell or buzzer.

When a call is made the operator inserts the answering plug, Fig. 140, in the answering jack corresponding with the lighted lamp, and this energizes the cut-off relay, which opens the circuit through the line relay and automatically puts out the calling-lamp. If only this one lamp has been lighted on the group, current would also be cut off the pilot relay, etc. The operator takes the call from the subscriber after having put the combined speaking and ringing key over the speaking position, and having ascertained if the line wanted is free by tapping the sleeve of the corrospondng jack on the multiple with the tip of the calling plug, the operator inserts this plug into the jack if the line is disengaged. Then the key is allowed to come back to normal position, which completes the connection.

On the cord circuits there are two supervisory relays and they are only energized when both subscribers have the receivers off the hook, so that the supervisory lamp is lighted on the calling cord until the subscriber called answers. When the relays are energized they shunt the supervisory lamps, with a resistance of 40 ohms, and these lamps, which are in series with the third conductors of the cords, cut-off relays and resistance of 83.5 ohms, are consequently robbed of so much current that they do not glow; the resistance of the lamps being 120 ohms when hot. When both subscribers hang up their receivers, the circuit through the relays is opened, the lamps glow, and the operator severs the connection when this double signal is given. The double supervisory signal has various important advantages over other methods of signaling, as it gives to the operator an exact indication of the condition of the connection, and it is not necessary to listen to determine whether the subscribers are talking, as the lamp on the calling cord glows until the called subscriber answers. If only one lamp glows the operator will know that one subscriber has gone to obtain some information necessary while the other awaits his return and reply. The attention of the operator can be attracted, if one subscriber



Connecting Cord Circuit

FIG. 140

has any trouble, by moving the switch hook up and down, causing the supervisory lamp to flicker, while the line is held by the other subscriber. In most conditions these signals are very positive and operating is greatly facilitated.

Each supervisory relay is shunted with a non-inductive resistance to cut down the impedance, which would impair the speech transmission. The supervisory lamps are 12 volt, the potential difference being reduced in the lamp circuit through the 30-ohm coil of the cut-off relay and the resistance of 83.5 ohms being connected in series with the lamp.

The type of repeating coil shown on the diagram is composed of four windings of 42 ohms each, but many other types of repeating coils are used on the cord circuits. A later type has four coils of 22.5 ohms. In both cases, however, the winding is arranged so that the core of the repeating coil is not magnetized when two subscribers are conversing if their lines are of equal resistance, as the windings are equal in resistance and opposite in direction.

A service register is connected up on each subscriber's circuit, Fig. 141, to provide a ready means of keeping a record of the calls made by each subscriber, as the method of charging subscribers, in modern telephone practice, tends to be fixed more on the basis of the actual service rendered, rather than on that of an annual rental for each telephone fitted. This register is actuated by means of a key provided in connection with each pair of connecting cords, Fig. 142. The operator presses the service register key before severing the connection after the clearing signals have been given. This brings in series with the main battery an auxiliary battery of 8 volts, completing the circuit through an "effective" register, which is common to all the cords on one operator's position, to the third conductor of the cord, and so through the subscriber's service register

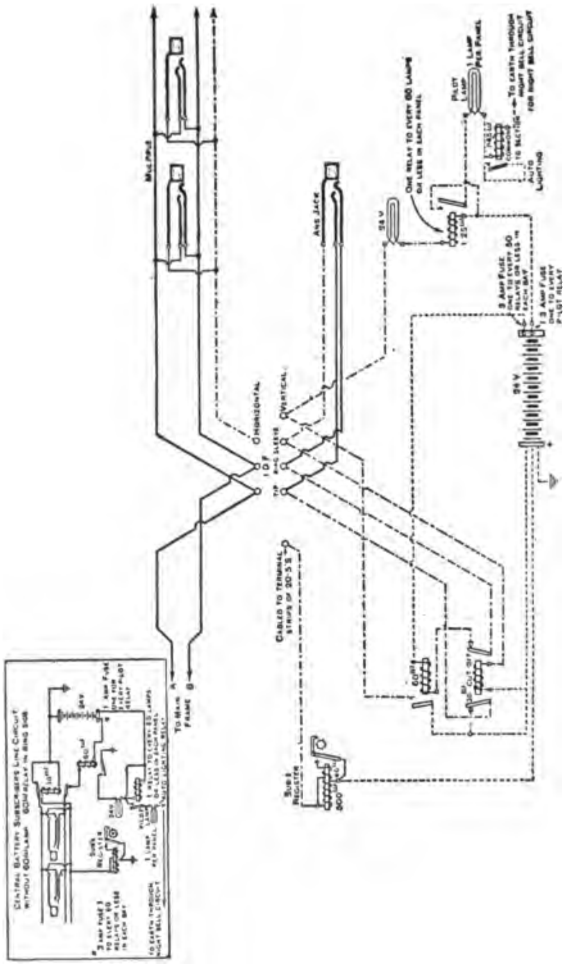


Fig. 141

LINE CIRCUIT WITH METER

back to battery. When the armature is drawn up sufficiently to operate the register, a 24 volt pilot-lamp is brought into circuit as a check on the proper working of the service register, the lighting of the lamp indicating to the operator that this has been done. An "ineffective" register is also provided in order to obtain a complete record on the traffic handled by the operator, and when, for any reason, the call asked for cannot be completed, the key in connection with this register is pressed.

Order-wire keys, besides those above mentioned, are provided for bringing the operator's telephone set into circuit with the order wires to other exchanges over which calls are passed for connections to subscribers on these exchanges. Where the order wire goes to an exchange outside of the area to which calls may be obtained at the normal rate of payment, additional springs are provided, so that when the key is used the circuit is completed through the order-wire lamp, and this lamp lighting up, notifies the operator that an extra charge must be made for this call.

For use with a four party selective system four of the ringing keys provided are shown on the diagram. They are arranged so that positive or negative pulsating currents may be sent over the A or B side of the line, according to the number of the subscriber whose attention is to be called. For ringing the bells of individual-line subscribers the fifth ringing-key gives the ordinary alternating current required. An excessive amount of

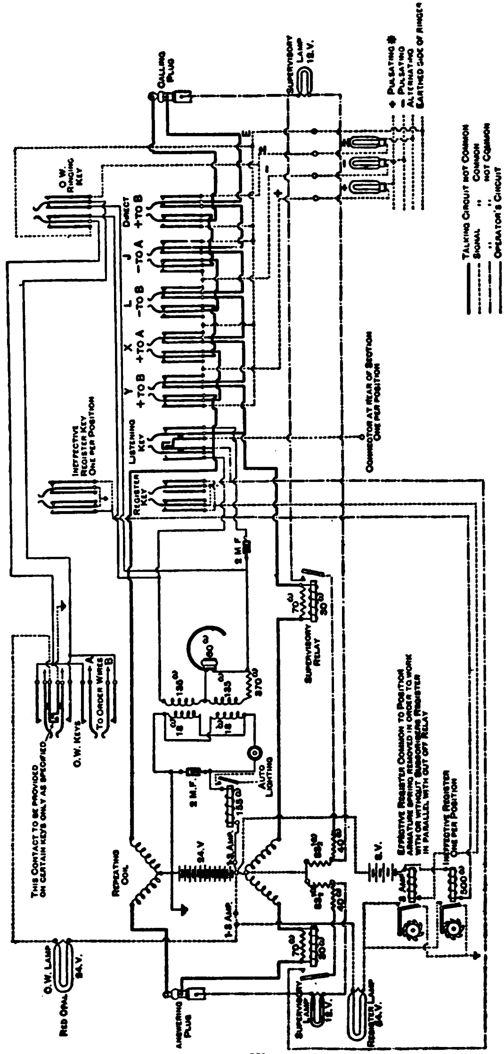


FIG. 142
COMMON BATTERY CORD CIRCUIT

current sent over a faulty line where a short-circuit may have occurred, would not only probably injure the apparatus but might also cause the proper amount of current to be taken from other positions. To prevent this the resistance lamps provided in the ringing circuits are used.

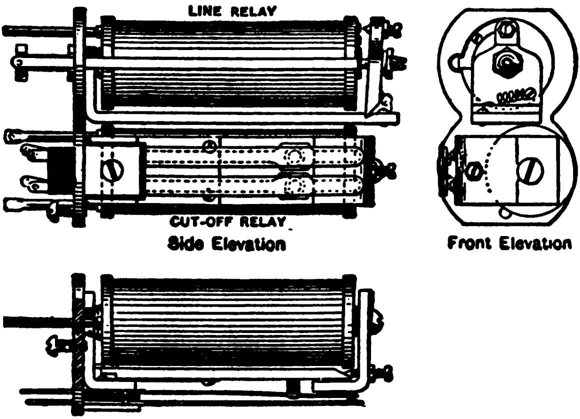


FIG. 143
LINE AND CUT-OFF RELAYS

Fig. 143 shows the line and cut-off relays used. Fig. 144, the line jack and connecting-cord plug, and the register.

PARTY LINES.—The party line is a line on which two or more subscribers are connected. It has been introduced to meet the requirements of small users. It reduces the expenditure required on line and exchange plant per subscriber, and allows a reduction to be made on the installation rate charged. The traffic over these lines is, however, restricted so far as the individual subscriber is concerned, as only one of the subscribers can use the line at any one time. A diagram of the connections on a four-party selective system in connection with common-battery working is given in Fig. 145.

In Fig. 142 is shown the arrangement of the

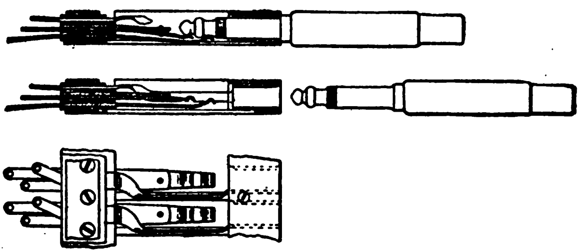


FIG. 144
PLUG AND JACK

ringing keys for the operation of the bells of the telephones connected on this circuit, so that the only bell rung is that of the subscriber wanted. A specially-designed relay is provided, at each station, in addition to the usual common-battery equipment, which is operated either by direct or alternating currents, and the bells are biased so that they are operated only by currents sent in a particular direction. Two of the bells are operated by positive pulsating currents, and the

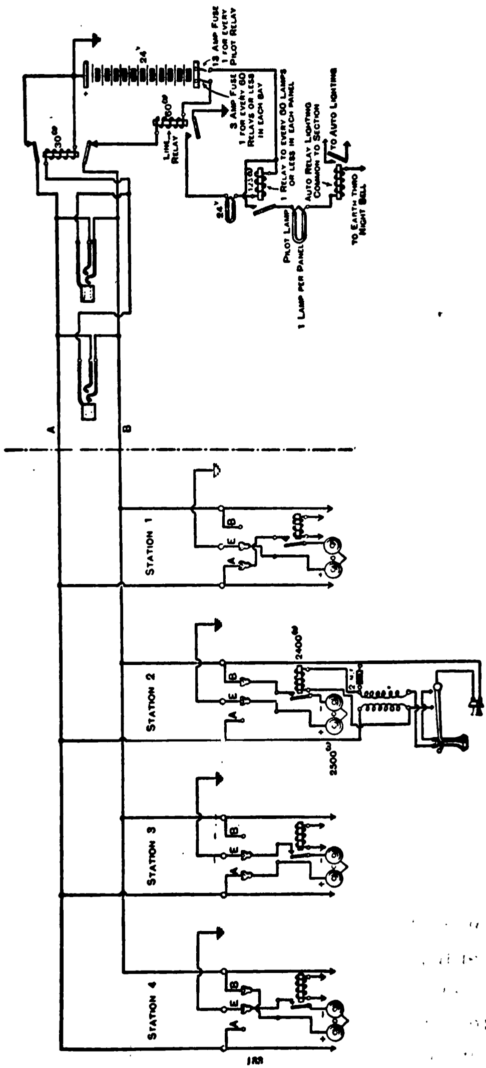


FIG. 145
4-PARTY LINE WITH GROUNDING RELAYS

other two, one on the A and the other on the B side of the line, are operated by negative pulsating currents. The bells are not in circuit until the relay is actuated. This is done by the operator who, to attract the subscriber's attention when station 1 is wanted depresses the ringing key J, Fig. 142, which sends a negative pulsating current over the A side of the line through the relay, and when it is actuated the bell at this station is brought into the circuit, and biased so as to ring with this current; but at station 3, which is on the same side of the line, the bell is not operated, as it is biased to ring only with a positive pulsating current. In the same manner the relay is energized and the bell rung on the telephone of the subscriber wanted for other stations, by the proper key being pressed down by the operator. The apparatus at the exchange end of the line and the manner of operating is the same for both party-line subscribers and individual-line subscribers.

The above system is difficult to keep in good working order and requires very close adjustment of the relays.

Trunk Working.—Connections for an order-wire trunk between exchanges are shown in Fig. 146. In front of all the A operators' positions at the outgoing end, these trunk lines are multipled. The subscriber's or A operator passes the call on the order-wire when a connection is wanted on the distant exchange, and the incoming trunk or B operator gives the line called for, and then, if the line wanted is free, the B operator completes the connection by inserting the plug in the jack of the subscriber wanted. The 83.5-ohm relay is immediately actuated, thus completing the connection of the A line through to the plug, and cutting off from the tip of the plug the 40-ohm winding of the operator's induction coil, which is normally through to that point, to allow the operator to make the busy test on the line of the subscriber wanted. On the other side of the same relay the 83.5-ohm resistance to earth is cut off the contact of the 12,000-ohm relay. This contact is then connected to battery. When the operator at the originating end takes up the trunk assigned and completes connection there, the 12,000-ohm relay is actuated, closing the circuit through relay D, which is also actuated and completes the line circuit on both sides right through to the cord, at the same time shunting out the supervisory lamp. The B operator then depresses one of the five ringing-keys provided to call subscribers, according to the one wanted, which are marked G, X, L, J, for party lines and "direct" for individual lines. These keys having an electro-magnetic clutch, send an interrupted ringing current to line until the subscriber who is called answers. The controlling 200-ohm relay is actuated by the lifting of the receiver off the hook, cutting out the condenser, breaking the circuit through the coils of the electro-magnets of the clutch, and releasing the ringing key. The supervisory relay is also actuated and the 12,000-ohm relay is shunted through

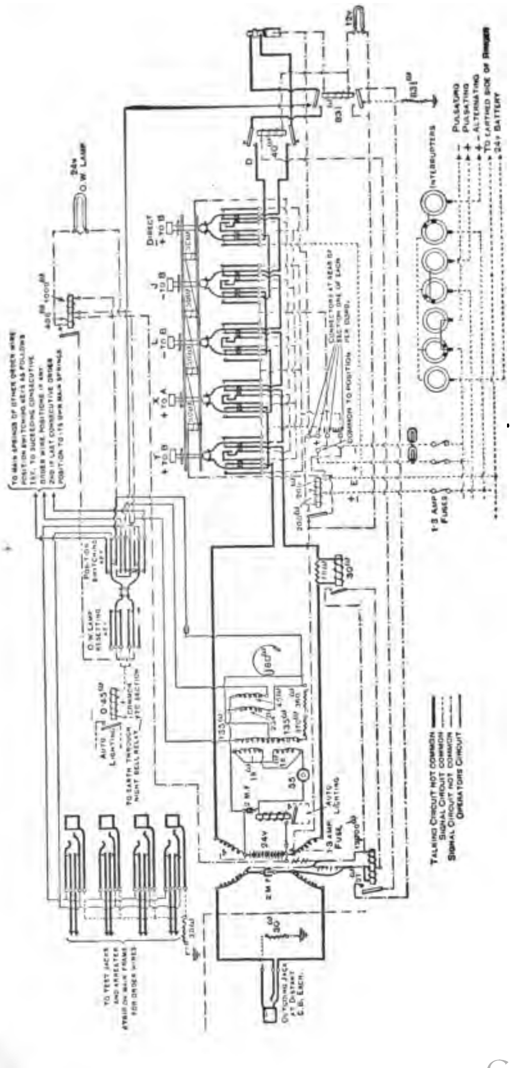


FIG. 146
TRUNK CIRCUIT

its 27-ohm winding. Thus a sufficient amount of current passes through the supervisory relay on the calling cord at the A end of the line to actuate it and shunt out the supervisory lamp there. In this way both operators are advised that the call has been answered by the subscriber wanted.

After the conversation between the subscribers is finished and the receivers have been replaced upon the hooks, the 30-ohm supervisory relay is opened, which in turn opens the circuit through the 27-ohm winding of the 12,000-ohm relay, and releases the supervisory relay on the calling cord, giving the clearing signal to the A operator, who then removes the plug from the jack on the trunk line, which opens the circuit through the 12,000-ohm coil, releasing the armature on that relay and opening the circuit through the 40-ohm relay D, so removing the shunt from the supervisory lamp at the incoming end. The B operator then withdraws the plug from the jack of the subscriber called, and the supervisory lamp goes out.

A relay of 1,000-ohm resistance having a retaining coil of 400 ohms, is connected across the order-wire, so that during the night when the traffic is slight and the B operator is not listening constantly on the order wire, the A operator, by ringing on the order wire through the 1,000-ohm winding actuates the relay, and the armature being drawn up, completes the circuit through the 400-ohm retaining coil and the 24-volt lamp, which lights up and continues to glow as the armature is retained, until the B operator answers the call, and opens the circuit through the retaining coil by means of the order-wire lamp resetting key. As an additional means of calling the attention of the night operator, relays for automatic lighting and night bell are also provided in the common of the lamp circuit. The first mentioned relay completes the circuit of the electric-light lamp for lighting the face of the board at the position where the call is made, and the second relay completes the circuit through the night bell. In order to allow of two adjoining positions being connected together and taken by one operator at slack times during the day, a second key—the position switching key—is provided in connection with the order wire.

For use between smaller exchanges there are many modified forms of trunks in which the total number of lines in a group is too small to warrant the use of an order-wire, and the B operator's attention is called by the lighting of the lamp on the trunk itself. An arrangement of this kind, the working of which is similar to that already described, is shown in Fig. 147.

This circuit is also largely used with order wires the second lamp serving as a check on the "A" operator's using the correct trunk.

General Arrangement of Exchanges.—Figs. 139 and 148, show the front and back of a switchboard section. In the back section the arrangement and fitting of the relays and other apparatus in connection with the cord circuits and the cable

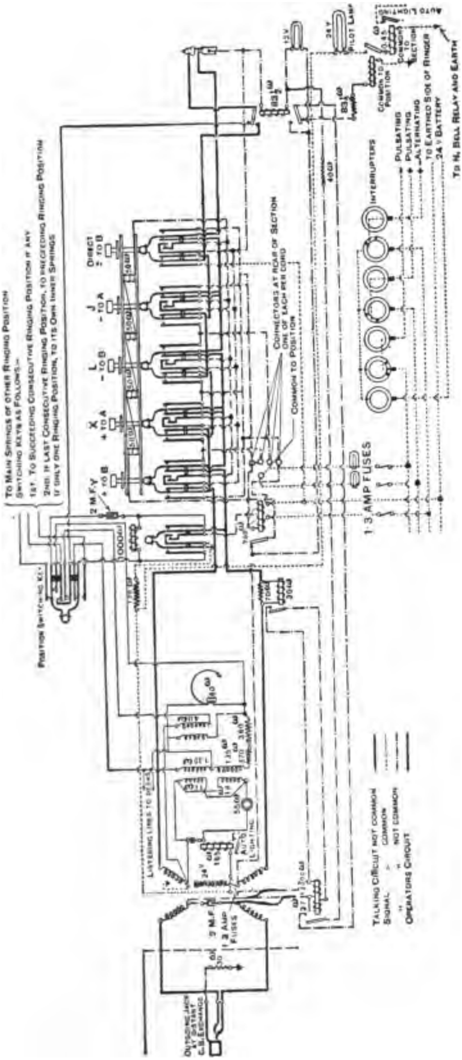


FIG. 147
TRUNK CIRCUIT

shelves for carrying the subscribers' and outgoing multiples are shown. The end view of the switch-

FIG. 148
BACK VIEW OF MULTIPLE SWITCHBOARD

board, Fig. 149 shows the precautions taken to prevent the spread of fire from one part of the frame to another. Between the cord shelf and

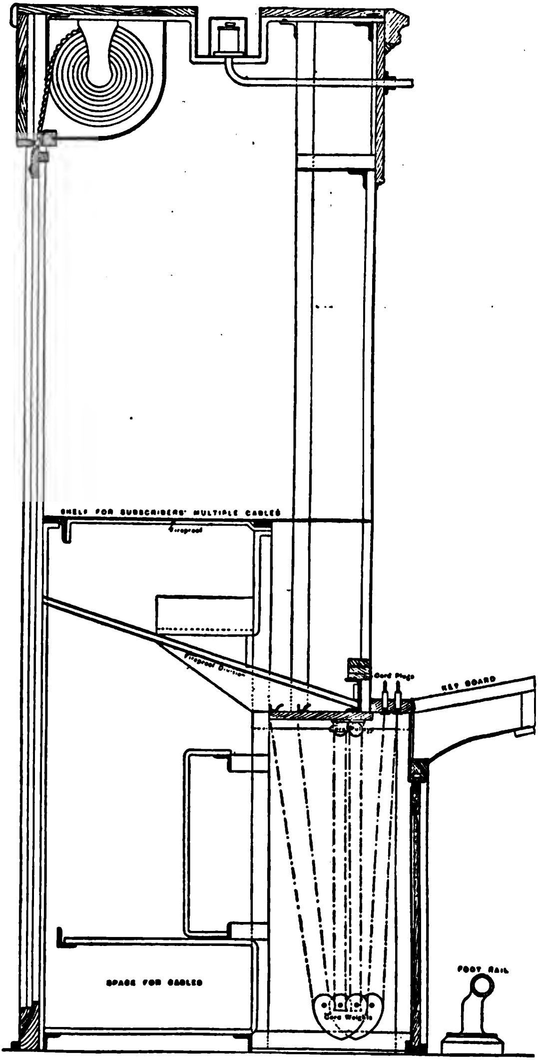


Fig. 149

SECTIONAL ELEVATION OF SWITCHBOARD

the answering equipment, and between the subscribers' multiple and the outgoing trunk multiple fireproof divisions are adjusted; the wooden shutters under the keyboard in front are lined with fireproof material, and at every eighth panel, vertical fireproof divisions are fitted between the multiple jacks. The precautions reduce the danger from fire to a minimum.

CHAPTER XIII

POWER PLANTS FOR COMMON BATTERY SYSTEMS

Formerly, in old magneto exchanges the power plant required for operating was an unimportant part of the equipment. Usually it consisted of a few, or sometimes only one ringing generator operated by a constant source of power, and which being adapted to give alternating currents of the required voltage and necessary frequency, caused the proper ringing of the bells at the subscribers' stations. These machines were often simply magneto generators having very strong fields and were not fitted for operating by hand, but rather by the source of power most readily obtained. Each operator was usually provided with a hand generator so that should the power ringing machines break down, the operators would be somewhat inconvenienced, but the power machines would be only slightly and temporarily disabled. Where hand generators are not provided, as with large switch-boards in modern exchanges and in the general work with the common battery multiple switch-boards, the exchange must depend entirely on the power machines. Therefore the power plant must be absolutely reliable not only for uninterrupted operation of the exchange but because, on the necessary supply of direct current for talking and signaling, the operation of the system depends. On this account exchanges should be provided with duplicate charging machines and ringing machines and two sources of power.

Though power derived from the mains of some private or municipal power plant is most convenient as a source of primary power for a telephone exchange, it is advisable not to place entire dependence upon this source of current supply only, and so most telephone companies have a supply of power from two different power companies, or where that is not possible, current is supplied from the mains of some outside power plant and from a plant operated by a steam or gas engine in the telephone plant; for if only one source of current supply is provided from outside mains, telephone service would be rendered impossible should anything occur, such as a fire or other disaster, which would shut off the power from the mains to the telephone exchange. The source of power which should be used as the regular source depends upon the relative cost of each kind.

Motors used are, as a rule, directly connected to the charging machines for delivering direct current to the storage batteries and to the smaller alternating current dynamos or ringing machines for producing the required current for ringing the subscribers' bells, when electic power is employed, but when a gas or steam engine is used it is usually belted directly to the charging generators and the same charging dynamo may be belted alternately to the gas engine if local power is used, or operated by an electric motor if outside power is used.

With duplicate charging and ringing machines where two sources of primary power are employed, each charging machine should be fitted to be driven from either source of power, and one ringing machine should be operated from the street mains or other source of supply, and the other by a motor whose current is derived from the discharge leads of the storage battery. By this means the telephone plant may still be in operation, should a break-down of all sources of primary power occur, as long as the storage battery, which should be of sufficient strength to run the exchange for twenty-four hours without recharging, is sufficiently charged.

With all of these precautions there is little danger of the complete shut-down of the plant, and the only thing which could cause this would be a serious fire in the switch-board.

Before deciding on the sources of primary power to be used, a careful inspection of the local condition of the city in which the exchange is to be installed should be made, and a difference in practice may exist in this respect due to the unlike condition in different cities, but in regard to the apparatus and circuits used to generate, control and measure the current, a fair standard may be maintained.

Fig. 150 shows an arrangement of the power plant and equipment used in a modern Bell ex-

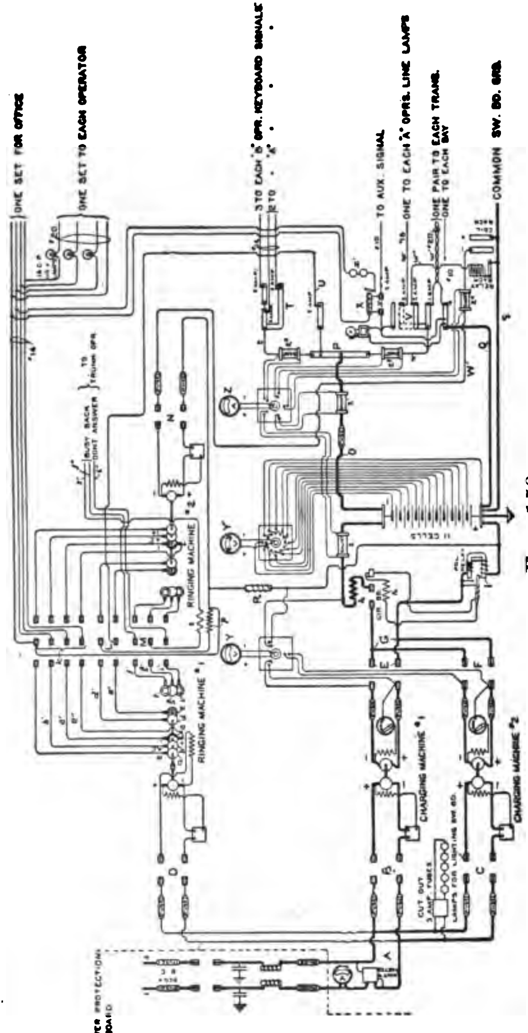


FIG. 150

CIRCUIT OF POWER PLANT

change of the Western Electric Co. On the left of the diagram the power leads from the source of power employed enter the switch-board apparatus and the power obtained is direct current at 500 volts. The mains pass through fuses of adequate carrying power, thence through the main switch by which the entire power back of all apparatus may be cut off, and thence through arresters placed for protecting the power apparatus. These are composed of an air-gap and a choke-coil of low resistance and high impedance placed in each side of the power circuit. Each of the leads then passes through another fuse to the power switchboard proper. For measuring the total current and the total amount of energy delivered to the power board, an ammeter and a wattmeter are provided. The company which supplies the current usually also supplies the wattmeter on the power board which is mounted in some part of the power circuit outside of the power board.

The main circuit branches off into three separate leads at A and two of these pass through two separate fuses to the single-throw, double-pole knife switches, B and C, which control respectively the motors of the charging machines 1 and 2, and the generators of these furnish direct current for charging the storage battery which supplies all direct current to the exchange. The third lead extends to the knife switch D. This controls the motor side of ringing machine 1, used principally to supply alternating and pulsating current for ringing on the subscribers' lines.

Ordinary starting boxes are furnished for the motors of the charging machines and ringing machine No. 1. They, with their respective switches B, C and D, control the motor sides of any of the machines. The generator sides of the charging machines are shunt-wound, and a field rheostat is arranged in the shunt circuit with a number of points sufficient for closely regulating the output of the machines at a great difference in voltage. Ordinarily the charging machines should have a voltage sufficient to furnish the proper charging current to the storage battery as a whole, but when a cell is defective it must often be separately charged, and as a low voltage is required for this, the charging machines should be run without external resistance if possible.

The lamps for lighting the power switch-board are arranged according to the voltage across the power mains and are bridged across the main power leads. In the diagram shown in Fig. 150, 500 volts direct current is used, and five 100-volt lamps are arranged in series across the circuit and controlled by a double-pole cut-out of the snap-switch pattern.

After passing through the fuses the generator leads from each of the charging machines continue on through knife switches E and F, and from these the circuits of the two machines join at G and form the charging circuit of the battery. Of the two sides of this circuit one passes through the switch of an over and under load circuit-breaker to the negative pole of the battery, and the other through a coil of a polarized relay to the positive or grounded pole of the battery. The batteries may be charged to any desired degree without causing damage to the apparatus from excess of current or a reversal of the current in the charging machines, as will be seen from the following description of the functions of the circuit-breaker and relay.

In its passage from either of the charging machines to the negative pole of the battery, the current passes through the heavy wire coil *h* of the circuit-breaker. This heavy wire coil forms a part of the electro-magnet which, should the current rise above a certain point, attracts the armature of the circuit-breaker and releases the circuit-breaker switch, which opens the circuit and prevents any damage which might result from an excess of current. Another winding *h'*, of the circuit-breaker having a resistance comparatively high and a greater number of turns is fitted in the local circuit of a polarized relay I. In the same manner as before, when this relay is closed the charging leads supply current to the coil *h* which operates its armature and releases the circuit-breaker. This polarized relay I, has a heavy winding, placed in series in the side of the charging circuit connecting with the grounded pole of the battery, and the charging current from the machines to the battery continues on through this relay in a direction to keep the local circuit of this relay open. The charging generator would be run as a motor should the voltage of the charging machines become lower than that of the storage battery, by the current backing up from the storage battery through the armature and field of the charging generator. This current, passing through the coil of the polarized relay in a direction opposite to its normal path would, by the action of the coil *h′*, cause it to close the local circuit and open the circuit-breaker.

The three collectors or commutator rings *a, b* and *c* are arranged on the shaft of ringing machine No. 1 which is controlled in the same manner, on its motor side, as either of the charging machines. Rings *a* and *b* are continuous through their entire circumference, but one-half of *c* is of insulating material and the other half is of conducting material. One brush bears against ring *a,* one against ring *b,* and two, 180° apart, against ring *c.* From these to the contacts on one side of the four-lever, double-throw switch, K, four wires, *a′*, *b′*, *c′* and *c″* extend. Alternating current employed in work on single-party lines is carried by the leads *a′* and *b′*, and to supply negative pulsating current or positive pulsating current, as required, the lead *a′* may be used in connection with *c′ or c″*. The distribution of ringing current to each operator's position in the office is made from a four-conductor cable of rubber-covered wire No. 14 connected with the blades of the four-pole switch K.

The other discs *d* and *e,* having brushes bearing against them, connected by wires *d′* and *e′* to the left-hand contacts of the double-pole double-throw knife switch L, are also arranged on the armature shaft of the ringing machine. From one of the blades of this switch L a wire passes through the primary coil *p*, of an induction coil, and continues on through an impedance coil R, to the grounded pole of the storage battery.

In its conductivity, the contact *d′* upon the ringing machine shaft is continuous, and the circumference of the contact wheel *e* is divided into a number of segments by intervening strips of insulating material. The wheel *d*, and the conducting segments on the circumference on the disc *e*, are in electrical connection, and the rotation of the ringing machine alternately makes and breaks the circuit between the leads *d′* and *e′*, once for each segment in the wheel during each revolution. Therefore a periodic electro motive force is induced in the secondary winding *s* of the induction coil, producing a "tone" for different forms of signaling in the exchange, by throwing the switch lever L to the left while ringing machine No. 1 is running and causing a pulsating current to flow from the storage battery through the contact maker on the ringing machine shaft and through the primary *p* of the induction coil.

Another set of contact wheels or discs *f*, *g* and *i*, which revolve with different rates of speed, are also connected with the ringing machine shaft, and their brushes are connected by wires *f′*, *g′* and *i′* to the left-hand contacts of the three-pole, double-throw switch M. Connected between the middle lever of the switch M, and one conductor

s' of the three-wire cable leading to the various incoming trunk operators' positions, is the secondary s, of the induction coil. Disc f on the ringing machine is connected when switch M is thrown to the left and one terminal of the secondary coil is connected to the disc g, the surface of which is a continuous conductor.

When switch M is thrown to the left, the disc f, on the ringing machine is connected with the conductor f'' and i is in like manner connected to the conductor i'', also in the same three-wire cable. The circumference of the disc f is divided into a small number of divisions and revolves slowly, and a slowly interrupted tone, the busy back signal, is heard when the conductors s' and f'' are used together in connection with a talking circuit. The interruptions of this tone are due to the interruptions in the secondary circuit, and the tone, to the interruption of the circuit passing through the primary coil p of the induction coil; inducing current in the secondary winding s of the induction coil. This gives to the connecting trunk operators the use of the busy back signal, and at each trunk operator's position, the wires s' and f'', terminate in the conductors of the busy back jacks. By connecting wires s' and i'' to the "don't answer" jacks on the trunk operators' positions, the "don't answer" signal is also placed at their disposal. The contact wheel i causes greater rapidity of interruptions, and the tone heard in the receiver of the "don't answer" circuits is interrupted more rapidly than that heard in the tone of the busy back circuits.

All of the discs of the shaft of ringing machine No. 2, and the connections from the secondary side of this machine, are made like those of ringing machine No. 1, and all leads of ringing machine No. 2 are led to the right-hand, instead of to the left-hand, contacts of switches K, L and M. The ringing currents from these machines, also the "don't answer" and busy back currents, will be obtained from machine No. 2, instead of from No. 1 machine, by reversing these switches. Ringing machine No. 2 is operated by the current derived from the discharge leads of the storage battery, while ringing machine No. 1 is driven by current from the outside mains. Therefore the motor side of No. 2 is wound for the voltage obtained from the storage battery, and the motor may be connected across the discharge leads of the storage battery, by throwing the switch N, thus operating the machine after the starting box has been properly manipulated. In the circuit, from the storage battery to the motor of ringing machine No. 2, is a retardation coil R, adjusted to prevent fluctuations in the current which is drawn from the storage battery when the machine is running. These fluctuations are due to the commutation on the motor, resulting in "throwing a noise on the battery," which means a periodical variation of the potential at the battery terminals, so that all currents derived from the battery are fluctuating, and produce an audible effect in all receivers deriving current from this source. In order to prevent these fluctuations due to commutation from producing rapid periodic fluctuations in the battery voltage, an impedance coil is placed in the circuit of the motor which drives the ringing machine, but with the charging generators which supply current to the battery, no impedance coils are placed in circuit. As yet no motors have been constructed which will deliver a current free from noisy fluctuations, though charging machines of this sort are in use.

A variation may be made in the distribution of current from the discharge leads of the storage battery to the various parts of the exchange, according to the size of the exchange and the circuits employed in the switch-board, and the extent that the various discharge circuits should be subdivided should be left to the jugment of the engineer.

From the negative side of the battery, the main discharge lead O, terminates in a bus-bar P, from which are led the various supply wires leading to the different parts of the switch-board apparatus. Either to the bus-bars connected to the grounded discharge lead Q, or to the common switch-board ground wire S, the return side of the various discharge circuits are connected. Considering the distribution from the negative or ungrounded side of the battery, the conductor t passes from the bus-bar P to the bus-bar T, and from this No. 14 rubber-covered wires supply current to the keyboard signals of the A and the B operators; two wires in each case leading to each A operator's keyboard and three to each B operator's keyboard. All of these wires from the bus-bar T, are connected to this same bus-bar T by 5-ampere fuses which are mounted on the face of the power board, where they can be easily replaced should they burn out. The leads to the keyboard signals of the A operators, should be separated, in some cases, from those to the keyboard signals of the B operators. This is done by dividing the bus-bar T, as shown in the diagram, the wires to the A operators' positions extending from one section of it, and the wires from the B operators' positions from the other. These two sections are fastened together by a fuse, or a heavy conductor, which carries the current required. To measure separately the current consumed by the A and the B operators' keyboard signals, the two portions of the bus-bar T must be separated.

The lead U which carries current to the local circuit controlled by the contact makers of the ringing machine shafts for producing tone, is tapped off a bus-bar which is connected to the bus-bar P, and is protected by a 5-ampere fuse. The lead *v* connects the E-shaped bus-bar V to the bus-bar P. This lead, *v,* supplies current to the line lamps of the A operators, to the operators' transmitters, and to the relay racks for operating the relays. For supplying current for the operation of the A operators' line lamps, a lead *w* extends from the bus-bar V to each A operator's position, and from this bus-bar a separate No. 16 rubber-coverd wire extends, through a 3-ampere fuse, to each operator's position. Pairs of No. 20

rubber-covered wires *w*, are twisted to prevent cross talk between the operators' sets, have one wire of each pair extending from the bus-bar V, and the other wire of the pair extending to each operator's transmitter, from the bus-bar connected with the discharge lead Q, from the positive pole of the battery.

To each bay of relays on the rack, that is, to the space between any two of the uprights which support the relays, another lead *w″* passes from the bus-bar V through a 3-ampere fuse. Both line and cut-off relays, usually in strips of 20, are mounted together on the relay rack, and there is usually a separate battery lead for each separate bay of relays. In the lower right-hand part of the diagram a bay of the relay rack is shown. Also the repeating coil rack is shown. From the main discharge lead O, from back of the bus-bars, a heavy conductor W, extends to the repeating coil rack, through which all current to the repeating coils is supplied, as well as all current used by subscribers in talking, in the Western Electric system.

The coil of the common night relay X, which can be shunted by the knife-switch *x* when the night alarm bell is not to be used, is adjusted in the lead which extends from the ground discharge lead Q to all of the pilot circuits of the different positions. For the convenience of the chief operator, the night alarm switch *x* is usually placed on one of the panels of the switch-board and not on the power board proper. The night alarm bell

x' is an ordinary magneto bell, and is arranged in the circuit leading from the alternating current leads of the ringing machines, including the local pair of contacts of the relay X, and the operation of this relay causes the bell x' to sound. An ordinary vibrating bell, for use with direct current, and wired between the grounded discharge lead Q, and a contact strip or bus-bar placed close to the bus-bar V, is adjusted at the left of the night alarm relay X. This bell is made to sound by the blowing of one of the line lamp fuses on bus-bar V, which releases a spring and completes contact between this bus-bar V and the one to which the bell is connected.

A double scale voltmeter or usually two voltmeters and one ammeter are placed on the power board for measuring the voltage and current of the various parts of the circuit. In the diagram shown two voltmeters are used. The voltmeter Y is usually employed to measure a potential of about 30 volts at the generator terminals, when eleven cells of battery are used, and the voltmeter Y′ is used to measure low voltages, with great accuracy, the scale reading up to five volts as a rule, although a three-volt scale would be sufficient for the measurements. The scale of the voltmeter Y is higher than is required to indicate the maximum voltage of the secondary sides of the charging machines. A voltmeter switch having three pairs of stationary contacts, is placed just below this voltmeter, and any one of these pairs of stationary contacts may be connected with the voltmeter by the manipulation of the switch. One pair is connected across the discharge circuit of charging machine No. 1; a second pair is connected across the discharge circuit of charging machine No. 2; and a third pair is connected across the bus-bars of the battery. Thus the voltage of the battery may be measured, and the voltage of either charging machine may be taken, when running on either an open or a closed circuit.

Below the voltmeter Y′ is a voltmeter switch having a pair of contacts extending to the terminals of each cell of the battery, and the voltage of any cell may be measured separately by the manipulation of this switch, also the behavior of each individual cell, and of the entire battery, may be watched by the battery attendant. A faulty cell may easily be detected and treated by means of voltmeter and hydrometer readings.

The scale of the ammeter Z, which is really an extremely low-reading voltmeter, should be adapted for recording the maximum current occurring in any one of the charging or discharge leads on the power board. They are employed to measure the drop of potential around the shunts placed in the various leads carrying current to be measured. The voltmeter registers the number of amperes passing through the shunt, by proper calibration of the shunt and the conductors extending from it to the voltmeter. The shunt *z* is fitted directly in the main charging lead passing from the charging generators to the negative pole of the battery, and the total amount of current derived from the charging machines may be measured when this shunt is connected with the ammeter by throwing the ammeter switch. In the main discharge lead O, is another shunt z', by which the ammeter is enabled to measure the total current delivered to the exchange by either the battery alone, or by the battery and machines together. Shunt Z^2 is adjusted in the discharge lead from which the keyboard signals of the A and the B operators are supplied. For measuring separately the keyboard signal current of the A operators, from that of the B operators, the bus-bar T must be divided, as stated before, and a shunt placed in circuit with each of the leads to this bus-bar. The shunt Z^3 is adjusted in the discharge lead *v*, which supplies the bus-bar V, and from this bus-bar, current is supplied to the line lamps, the operators' transmitters, and the line relays. In the lead from the live side of the battery to the repeating coil racks, another shunt Z^4 is adjusted, and this shunt serves for measuring the entire current consumed by the subscribers' lines in talking, as all current for talking passes through the repeating coils. Fig. 150 represents a fair standard of the means provided for measurement of the various branch discharge leads.

A greater subdivision of the current could be effected by placing a shunt in each of the leads *w*, *w′* and *w″*, instead of only one shunt to measure the current consumed by all of these leads, but this is not advisable as it tends to complicate matters, and frequently the current in one set of leads alone would be too small to be measured on the ordinary ammeter provided.

A modern board of average size is shown in Fig. 151. It is of white Italian marble and has all apparatus mounted upon it so that it can be handled from the front of the board, with access to all circuits from the back. Later boards are made of a fine quality of slate, having an oil finish made by applying a heavy coat of oil, which is then burned in. The effect of the burnished copper instruments and switches against the velvety blackness obtained by this treatment of the slate is fully as handsome in appearance as that of the marble board. Much trouble may be caused by marble boards being traversed by metallic streaks sometimes affording conductive paths from one part of the power board to another. This is less liable to occur when slate boards are used. A poor quality of slate is more liable to be defective than marble, but there is little difference in the cost of a fine quality of slate and ordinary Italian marble.

Fig. 152 shows the rear view of a switch-board and the method of wiring and connection employed in large modern telephone plants.

A few points peculiar to the dynamos and motors used for telephone work will be considered, but a full discussion of power machinery (charging and ringing machines) for telephone plants will not be entered into as this would involve

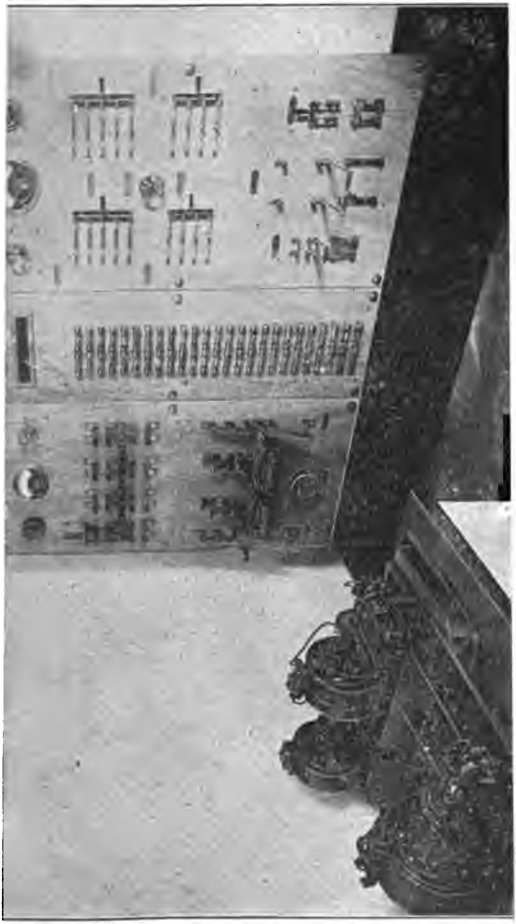


FIG. 151
FRONT VIEW OF POWER BOARD

most of the points in the design and construction of dynamo electrical machinery in general. In telephone work the current derived from the charging generators or consumed by any motor receiving current from the central battery, must be as "smooth" as possible. In any other field of electrical engineering this is not necessary to such an extent as it is in telephone work. If the voltage across the terminals of the storage battery were subject to rapid periodical fluctuations due to the action of the charging machines, or motors actuated from the battery, a noise would be heard in all receivers connected across the lines deriving current from the battery, therefore the fluctuations of electromotive force and current due to commutation at the brushes, or to the entrance of the various armature conductors into the field of force of the machine, or the passage of these conductors therefrom, should be eliminated to the extent necessary to prevent any noise whatever being heard in the talking circuits which derive current from the terminals of the battery, while the machines are in use.

To reduce fluctuations in current and the resulting noise in the talking circuits, it was necessary, with the early types of charging machines, to place a heavy impedance coil in the charging leads, and even then it often became necessary to charge only at night when the exchange was not so busy; but with the machines now in use this is unnecessary, and the impedance coil, which consumes some energy, is not employed, and the ma-

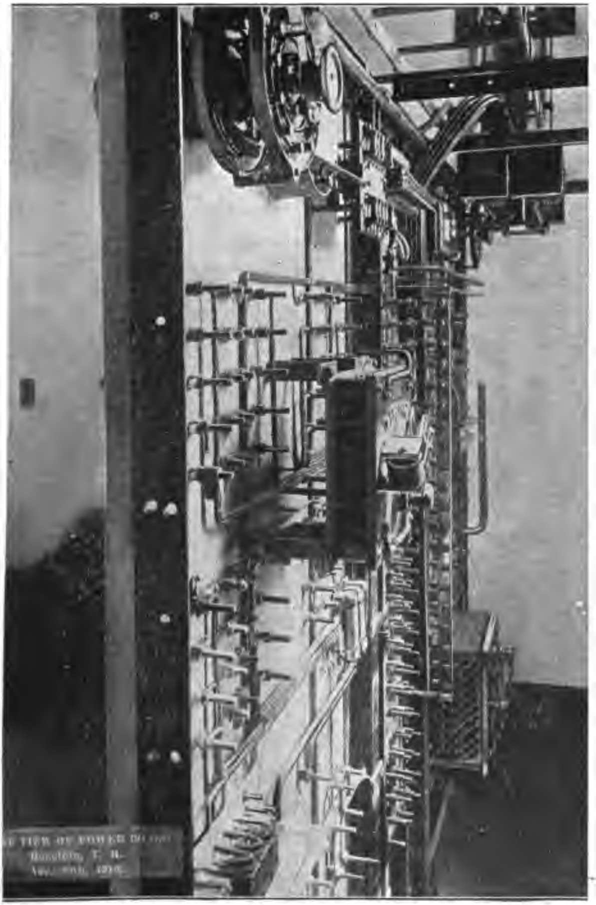


Fig. 152

REAR VIEW OF POWER BOARD

chine may be run at any time, except with machines which are not suitable for giving a sufficiently smooth current, when an impedance coil, Fig. 153, is used.

Two important factors in the design of charging machines are that a much greater number of

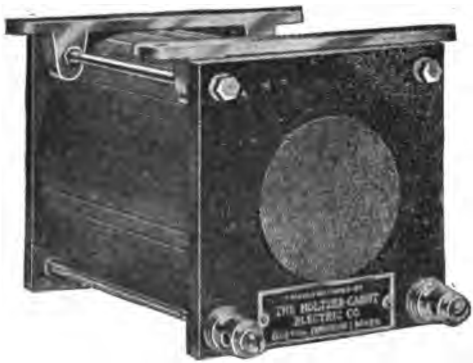


FIG. 153
RETARDATION COIL

commutator bars is used to accomplish the above result than would be required for almost any other type of direct current machine, and that the machine should be as nearly magnetically and electrically balanced as possible, and this can be attained only by most careful attention to its mechanical design and construction.

The brushes and the very narrow commutator bars used on the machines producing the results referred to, cover about three complete segments on the commutator, the armatures are of the smooth core type, and the windings are continuous and employ a larger number of conductors than are ordinarily used. The slotted armature type, having the conductors bunched in groups between the teeth of the armature, cannot produce a sufficiently smooth current.

Sudden fluctuation in the voltage is prevented by the armature conductors gradually entering into and retiring from the magnetic field. This is done by employing diamond-shaped pole faces on the charging machine pole pieces.

The battery ringing machines are, as a rule, used only as a reserve, therefore the motors are not designed with the care necessary to render the machines capable of drawing a sufficiently steady current from the battery, to prevent noise without the use of impedance coils in the discharge lead to the motor.

In Fig. 154 is shown a magneto generator belted to a direct-current motor.

The magneto generator is only used now in the smallest exchanges, and alternating current generators with fields electro magnetically excited are used in larger modern exchanges. Fig. 155 shows a dynamotor of about one-sixth horse-power which is frequently used for ringing purposes where low voltage (not over 220) direct current is available. The motor and the generator windings occupy the same armature core, which revolves in a field common to both windings.

It is not advisable to use dynamotors with only a high potential direct current available for driving it as a breaking down of the insulation between the primary and secondary windings of the machine is liable to occur under the stress of

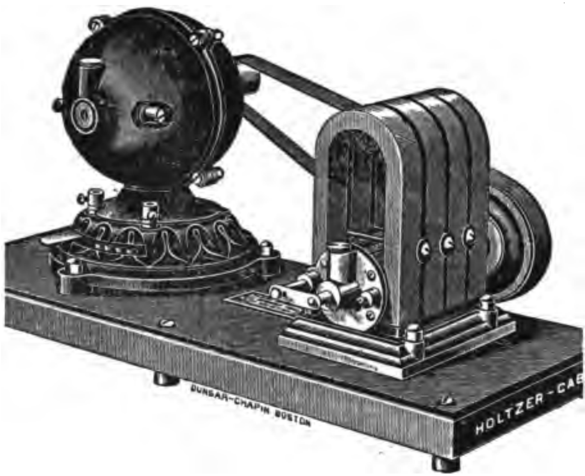


FIG. 154
MAGNETO GENERATOR BELTED TO DIRECT-CURRENT MOTOR

the greater electromotive force, which would impair the action of the machines. This danger does not exist however, where the motor generator is used, as the two armatures are entirely separate. The dynamotor is efficient only for ringing purposes in a telephone exchange. Owing to inefficient regulation, much trouble is caused when used for charging, and as there is but one field for both the generator and the motor sides of the machine it is not possible to regulate the two sides separately.

The ringing machines are employed for driving

FIG. 155
DYNAMOTOR

the busy-back and tone-test attachment as, in modern exchanges, either one or the other of these machines is run for twenty-four hours of each day.

Formerly the frequency of the alternating current generated by all available alternating motors direct-connected to ringing machines, was too great properly to actuate the bells, due to the alternating motors running at such high speed; therefore the direct-connected machines were not used, and the ringing generator was belted to an alternating current motor, so as to reduce speed.

Fig. 156 shows a busy-back outfit, which may be attached to the shaft of almost any ringing ma-

FIG. 156

BUSY-BACK OUTFIT

chine, so that old ringing machines, which were originally without them, may be used.

In Fig. 157 a modern charging machine is shown. This consists of a four-pole direct current motor of standard construction direct-connected to a specially constructed telephone charging generator, both of which are mounted on a common heavy cast-iron sub-base, so that a permanent alignment of the bearings may be maintained. A similar machine is used with an alternating current motor directly connected to the generator, making alternating current mains available for power purposes.

Some companies mount the ringing and charging machines on a table of wood, sometimes with an iron framework, but a better way is to build

FIG. 157
MOTOR-GENERATOR SET

a pier of brick from the floor of the power room, with a heavy slate top on which the machines are mounted. Power machines, including charging and ringing generators and their motors are usually mounted close to the power switch-board, which is provided with all the devices necessary for controlling the action of the various machines.

A very handsome and durable power table, used in most modern exchanges, is built of highly glazed white enamel bricks with a slate top having a burnt-oil finish.

It is necessary at times to regulate the output of charging machines through a very wide range, and to be able to reduce the voltage from that required to charge the entire battery, down to that required to charge a single cell. For ordinary electrical work in commercial practice, in other lines, the range of resistance of the field rheostats is not sufficient, nor is there a sufficient number of steps between its maximum and minimum resistances to effect precise regulation. Therefore more contacts on the rheostat and more steps are necessary, provided that the increased number of steps placed on the rheostat face will not make it of too great a size. To remedy this a rheostat is made having two discs with a certain number of contacts each and each disc is furnished with a rheostat arm or wiper which moves separately and which is adjusted to move all over the contacts on its disc. The resistance coils on the front disc have a resistance sufficient to give the necessary range of action of the machine, and the coils on the rear disc are of such resistance that all of them together equal the resistance of one coil on the front disc. The field resistance may then be roughly adjusted on the front disc and increments added by the manipulation of the lever of the real disc, until the desired resistance is obtained.

Following the rules for the care of dynamo electrical machines in general, even greater attention should be given to the care of the charging and ringing machines in telephone work, particularly to the commutator brushes, which must always be in good order, as neglect of these brushes is one of the greatest causes of noises made by machines in the telephone lines. The brushes will not cause noise in the lines, even without choke coils in the charging leads when they are properly adjusted on a properly designed machine. They should be fitted to the commutator so as to cause the entire surface of the brush to make contact with the commutator surface.

The brushes should be equally spaced around the commutator in multipolar machines. There should be an equal number of commutator bars between each two adjacent sets of brushes. To prevent sparking at the brushes on all loads of the machine, from no load to full load, after properly setting all the brushes, the rocker upon which they are mounted should be moved about until a position is reached in which no sparking occurs, but if after careful adjustment of the brushes, one should spark, it should be carefully resurfaced, and if it still continues to spark, it should be separately moved back and forth without disturbing the other brushes. But this is not liable to occur if the machine is properly designed and the brushes good and uniform.

After the brush-holder is properly placed a brush may be adjusted in the following manner: Place fine sand-paper on the commutator, with the rough side out, and draw it under the brush in the direction that the armature rotates, with the brush pressed against the sandpaper by the brush-holder spring. No harm will be done, during this first rough adjustment of the brush, if the sandpaper is pulled back and forth under the brush. To quickly obtain the approximately proper surface of the brush, greater pressure may be placed on the brush-holder, but the pressure of the spring in the brush-holder only is sufficient for the final touches on the wearing surface of the brush. The motion of the sand-paper should be in the same direction as that of the armature, the sand-paper being all the while closely pressed against the surface of the commutator.

Vaseline thoroughly but sparingly rubbed into a small clean rag, is the best lubricant for the commutator, but care must be taken that no lumps of vaseline come off on the commutator.

The appearance of a properly working commutator is dark and glossy, usually considerably darker than copper freshly cut and seemingly glazed. The cutting of some or all of the brushes is indicated by bright, sometimes rough, streaks.

Usually when telephone central offices are first installed, they are equipped for only a portion of the number of lines that may eventually be called into service, and the switch-board and most of the auxiliary apparatus are equipped only sufficiently to meet present requirements; but they are so arranged that they may be added to as the number of lines called upon to serve increases. The power plant apparatus however, excepting only the storage battery, must be installed in the first place with capacity sufficient for serving the entire number of lines which probably will finally enter the office. The storage battery may be provided with only a sufficient number of plates to serve for present requirements, and room may be left in the tanks for adding subsequent plates, as the demand for extended service increases. It will be seen therefore that in most power plants the full load current output of the charging machines is greater than the normal charging rate of the battery. By running the machines at approximately full load the best results are obtained in the operation of the power machines and charging can be done with greater economy during that period of the day when traffic is greatest, as at this time there is a heavy discharge from the battery, and the current delivered to the battery through the charging leads is probably greatly in excess of the normal charging rate of the battery. The effective charging current absorbed by the battery is the difference between the currents in the main charging leads and the main discharge leads.

Should traffic become so great as to exceed the maximum discharge rate of the battery, due to sudden demands on the service, the charging machines may be employed to assist the battery, and current is delivered to the discharge leads by both the battery and the charging machine.

The traffic determines the length of the daily run which should be continued each time until the batteries are fully charged. The charging rate should be limited by the smaller capacity of either the battery or of the machine, which is usually the battery. The batteries should be fully charged each day, and it is better that the full charge should be reached after the heaviest traffic of the day is over, as this enables the battery to run the entire plant for twenty-four hours without recharging in the event of all of the charging machines becoming completely disabled. The battery should never be allowed to remain discharged, but should be kept fully charged and frequently recharged. The ringing machine deriving current from the battery should be used only as a reserve while the ringing machine whose current is supplied from the main power leads, should be used regularly.

CHAPTER XIV

MAGNETO SWITCHBOARDS

The switchboard is a device by means of which two or more lines may be connected, as the number of telephones which can be operated effectively upon one line is necessarily limited.

A switchboard in its simplest form is a cabinet containing the necessary apparatus to facilitate the switching of telephone lines which terminate in it. There are two principal types of line circuits: first, where only one wire connects the subscriber's telephone to the exchange, the return circuit being a common conductor, and the second, where two line wires are used, making what is called a metallic circuit. The common return of the first may be either the earth, when the system is called "grounded," or it may be a common wire, when the system is known as a "common return." Fig. 158 shows two grounded lines connected through the switching device of the switchboard called a cord circuit. Fig. 159 shows two metallic lines similarly connected. A properly constructed metallic line circuit is the only construction which will assure the most efficient results, and should always be used when possible.

Several classes of circuits enter into the makeup of a switchboard. First, the line circuits, one of which is provided for the line of each subscriber entering the exchange. Second, the night alarm circuit, one only being provided for the entire switchboard. Third, the pilot circuit, one or

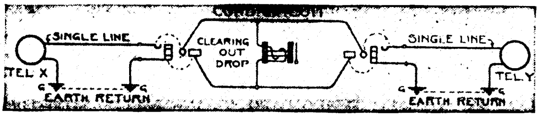


FIG. 158

MAGNETO SWITCHBOARD CONNECTION EARTH RETURN

more being installed for each operator's position. Fourth, the cord circuits, the number of which depends upon the number of line circuits and the greatest number of connections likely to be called for at any one time. Fifth, the operator's circuits,

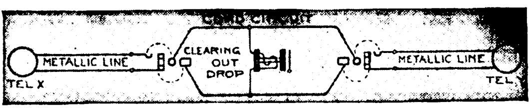


FIG. 159

MAGNETO SWITCHBOARD CONNECTION METALLIC CIRCUIT

one of which must be provided for each operator. Sixth, the generator circuits, one of which is installed for each operator.

In Fig. 160 the circuit of the subscriber's instrument, the line circuit, and the night alarm circuit are shown. The only apparatus in the line circuit proper is a combined drop and jack, to the terminals of which the subscriber's line is led. The path for ringing current may be readily traced through the jack and the winding of the drop. In plugging in to answer a call a contact is broken in the jack which cuts the drop winding out of the talking circuit.

Whenever the operator is not sitting directly

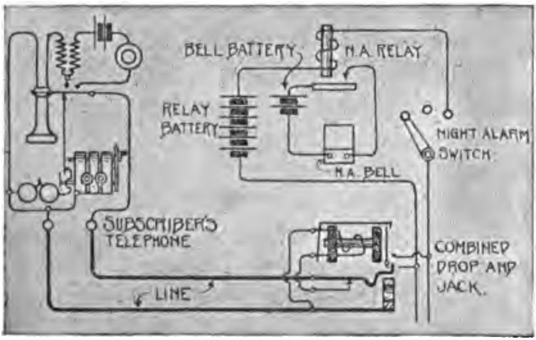


FIG. 160

SIMPLE MAGNETO LINE CIRCUIT

in front of the board, as is usually the case at night, the night alarm switch should be left resting on the right-hand contact. Then when a call comes in which might not otherwise be noticed, the night alarm bell will ring until the shutter is restored. The night alarm circuit operates as follows: In falling, the shutter closes a circuit through the relay battery and the night alarm relay. This relay in turn closes a local circuit containing the night alarm bell and two dry cells, causing the bell to ring. The night alarm contacts closed by the shutter in falling are described under the subject of "Combined Drops and Jacks." The relay in the night alarm circuit is quite sensitive and will operate on a very small amount of current, thus insuring a positive closing of the local circuit containing the bell. This latter circuit, it will be noted, is quite independent of the night alarm contacts of the drop, and throws on the bell a steady current which is essential in order to get a satisfactory ring from any direct current bell. The current necessary to operate the relay is so small that it will not burn the night alarm contacts and leaves them bright and clean at all times. The combination gives a very effective and reliable night alarm.

Cord and Operator's Circuit.—A regular cord circuit and the operator's circuit are shown in Fig. 161. Connected in the cord circuit are a listening key B, a ringing key A, and a ring-back key C. A disconnect signal, known as a clearing-out drop, is bridged across the two sides of the circuit. This drop has a very high impedance and does not shunt the voice currents to any appreciable extent, while it is readily thrown by the generator current in ringing off. In practice it is better to bridge in a clearing-out drop than to insert one in series on either side of the line, as the cord circuit is perfectly balanced and therefore quiet. Both sides of the talking circuit may readily be traced from the answering plug to the calling plug, the platinum contacts of the keys C and A being the only apparatus through which the voice currents pass. By means of the ringing keys C and A the operator may ring out on either cord at will. Each ringing key, when operated, opens the cord circuit so that no generator current passes back to ring the operator in the ear.

The operator's telephone set consists of a head

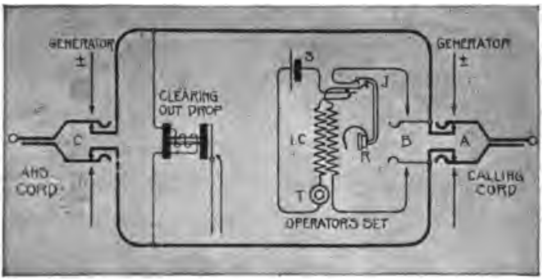


FIG. 161

SIMPLE MAGNETO CORD CIRCUIT

telephone R, a cut-in jack J, an induction coil I C, a transmitter T, and a battery S. The operation of this circuit is similar to that of an ordinary subscriber's telephone set. The induction coil is of a special type designed to meet the exacting needs of the operator. A listening-in key B is wired in connection with each cord circuit in such a manner as to enable the operator to cut her telephone set into the particular cord circuit she happens to be using.

Cord Circuits with Repeating Coils.—In Fig. 162 a repeating coil is shown wired permanently in the cord circuit. In this diagram there

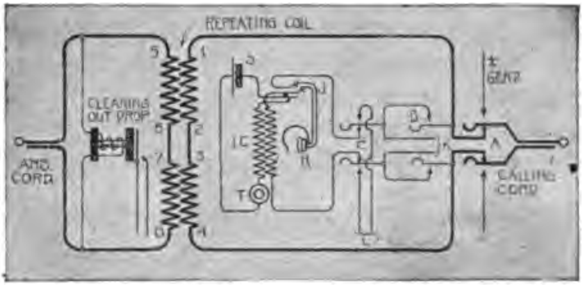


Fig. 162

is also shown an operator's switching key C. By means of this, an operator may throw her listen-

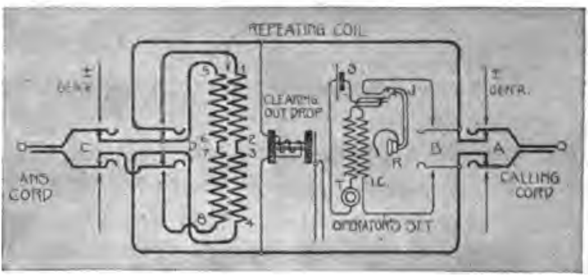


Fig. 163

ing strap wires on to the telephone set of the operator on her right. The operator on the right may then operate both positions, using any of the cord circuits of the two positions, while talking over her own telephone set. This switching key is usually used at night or during other hours of light traffic, when one operator can attend to more lines than appear at her position. The two leads shown at K run to the switching key of the operator on the left.

It is sometimes desired to have a cord circuit available for ordinary use and also for use in connecting dis-similar lines. In such a case the circuit is wired as shown in Fig. 163 in which D is a key designed to throw the repeating coil in or out of circuit. As shown in the diagram, it will be seen that the windings of the repeating coil are not in circuit. Assuming the key D thrown, a circuit may be traced similar to that shown in Fig. 162.

ASSEMBLED SWITCHBOARDS.—When assembled all parts of the switchboard handled by the operator are within easy reach, and are so located that they may be manipulated conveniently and rapidly. The construction is open, facilitating inspection and the removal of parts for repairs.

In Fig. 164 is shown a front view of a 100-line Express type switchboard fully equipped. Fig. 165 is the same board with front and rear panels removed, showing the location of the cords and weights, and with the key shelf open, showing the manner in which the key cable is introduced. Fig. 166 is a rear view with front and rear panels removed, and shows the wiring of the drops and jacks, the location of the generator and the maple rack on which are mounted the distributing bars, to which are connected all leads from outside the switchboard other than the line wires. Fig. 167 gives a closer view of the key

FIG. 164
EXPRESS TYPE SWITCHBOARD

shelf, showing the manner of locating the plugs and keys. This is also shown in a diagrammatic form in Fig. 168.

Figs. 169, 170, 171, 172 show the wiring, as actually installed. All groups of wires which connect to a given piece of apparatus are led out at one point and the whole cable is laced tightly together with lock-stitch twine. The cable is introduced into the cabinet and bound in

Fig. 165

EXPRESS TYPE SWITCHBOARD, KEY SHELF UP

place by means of leather saddles. A color scheme is followed in the insulation of the wires so that circuits may be followed through without the necessity of testing. Each and every talking circuit is wired as a twisted pair throughout its entire length making cross-talk in the switchboard itself impossible.

In Fig. 169 the transmitter circuit may be traced from the positive pole of the gravity bat-

Fig. 166
REAR VIEW OF EXPRESS SWITCHBOARD

tery, through lug 8, the cut-in jack, primary of induction coil, the transmitter, and back through lug 9 to the negative pole of the battery. This wiring is led through the cut-in jack so that the battery circuit may be opened when the plug is withdrawn. The wiring from lug 8 is led considerably out of the way and looped back so that the circuit may be wired as a twisted pair. The receiver circuit may be followed from the upper lead to the strap wires, through lug 5, secondary

FIG. 167
KEY SHELF EXPRESS BOARD

of induction coil, cut-in jack, to the receiver and back through the cord, to lug 4, thence to the lower lead to the listening strap wires.

In a similar manner the other theoretical circuits shown in Figs. 160 and 161 may be traced out in Figs. 170, 171 and 172.

COMBINED DROPS AND JACKS

The line signal and its accompanying jack are, on account of the exacting requirements and duplication, the most important pieces of apparatus in small switchboard construction. The

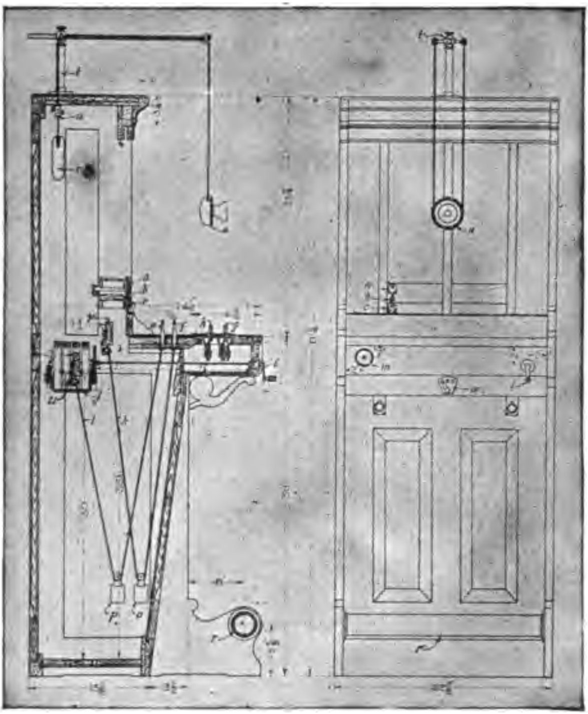


FIG. 168
END AND FRONT ELEVATIONS EXPRESS SWITCHBOARD

combined drop and jack which is used in all Express type switchboards is made up of a sensitive tubular drop mounted together with a spring-jack on the same strip. Fig. 173 illustrates in three views the operation of this piece of apparatus. The first view shows the normal condition with the drop shutter up and ready to re-

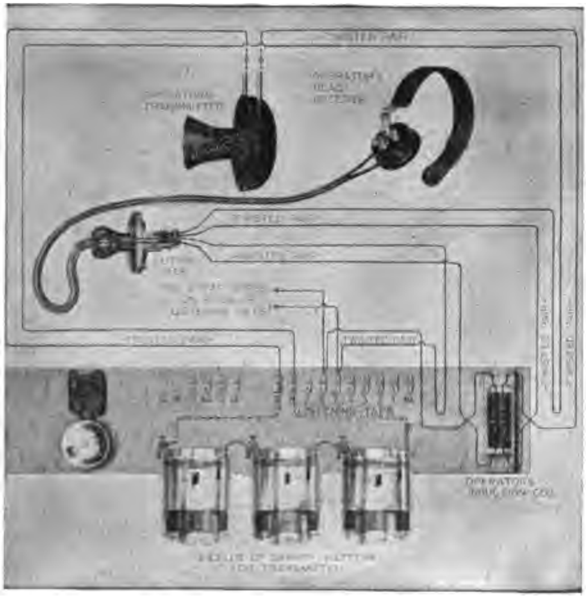


Fig. 169

OPERATOR'S SET, MAGNETO SWITCHBOARD

ceive a call, the second view with the shutter down after a call has been received, and the third view with the shutter restored by the act of plugging into the jack. The restoring mechanism is clearly shown in this last view. The line or tip spring of the jack is elongated sufficiently to project through an opening in the mounting strip and by its rise, due to the insertion of the plug, restores the drop shutter and holds it in this position as long as the connection is up. The up-

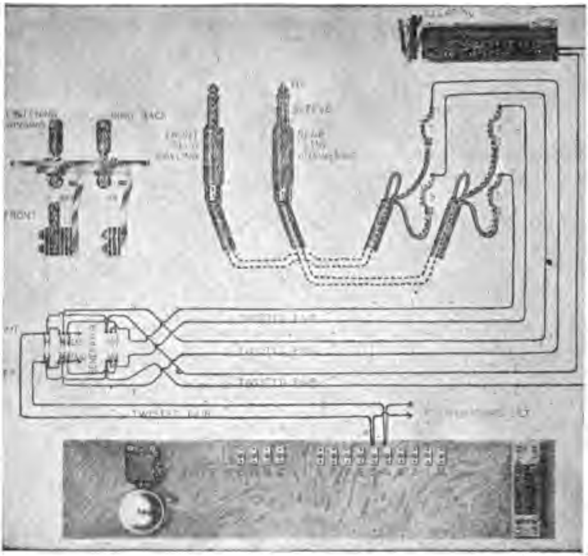


FIG. 170
CORD CIRCUIT MAGNETO SWITCHBOARD

ward movement of the tip spring also opens contact with the short or local jack spring, and thereby cuts the drop winding out of circuit.

The means for mechanically restoring the shutter in this mechanism is very simple. No additional parts are required for accomplishing the complete restoration of the shutter, and for holding it in its locked position during the connection.

THE DROP.—Fig. 174 shows the parts of one complete drop mechanism. It is of the tubular or iron-clad type, the enclosing shell being of soft iron machined out of solid stock and pro-

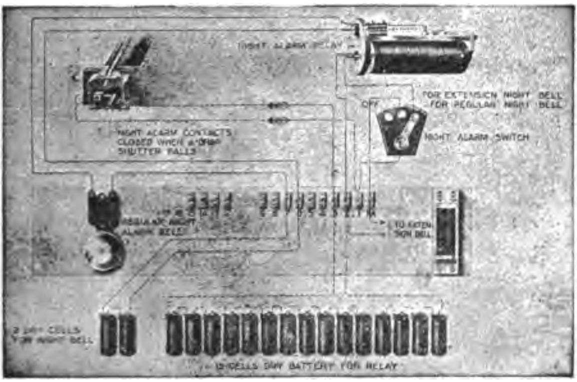


FIG. 171
NIGHT ALARM WITH RELAY

tected from corrosion by copper plating and oxidizing. The armature and core are of the same quality of iron. The winding is of silk-covered copper wire, and is insulated from all metal parts of the drop. The armature is supported on trunnion screws through the agency of a one-piece, formed, metal bridge, thereby insuring extreme sensitiveness. Figs. 173 and 175 show the peculiar shape of the shutter hook and the opening of the shutter itself, through which this hook passes when the same is restored. This construction overcomes any tendency of the armature to freeze to the shell or core, as the drop forces the

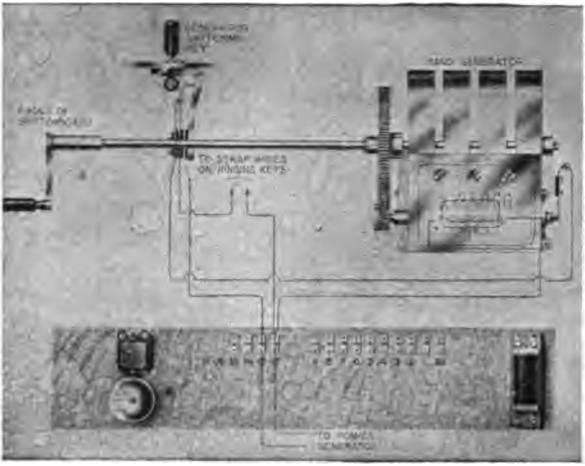


FIG. 172
OPERATOR'S HAND GENERATOR

hook lever down so that its catch will always engage and retain the shutter.

Each complete drop tube is insulated from the mounting strip and from the other tubes by hard rubber. This individual insulation is the most effective way to avoid chances of burning out the drop winding, and to prevent crossing up the lines through the windings.

The tubular part of the drop, including the winding, can be removed from the mounting independently of the jack if so desired without un-

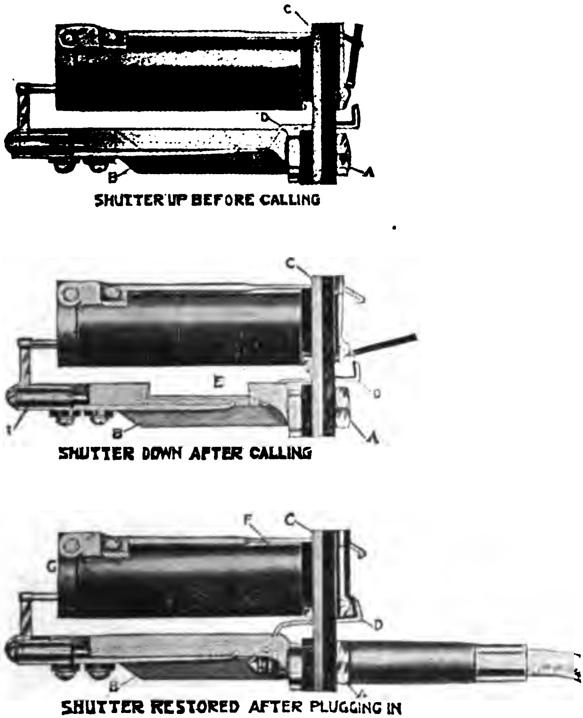


FIG. 173

COMBINED DROP AND JACK,—SELF RESTORING

soldering any connections, the only tool required being a small screwdriver. This is a great convenience if the drop happens to burn out by lightning or other cause, which will sometimes happen, even with the best protection.

FIG. 174
DROP DISASSEMBLED

THE JACK.—Each jack consists of a rigid brass frame on which the German silver tip and local contact springs are fastened, with hard rub-

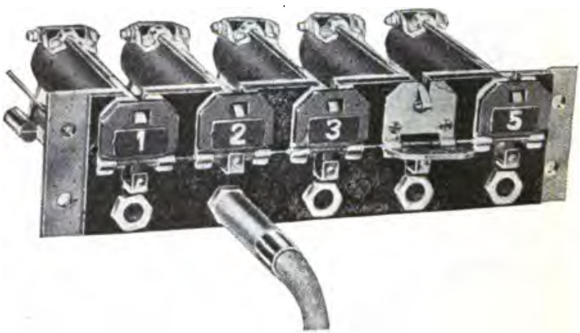


FIG. 175
STRIP OF DROPS

ber separators for insulation. The sleeve connection is in the form of a tubular screw with a hexagonal head. This sleeve passes through the mounting strip, and with the help of two steady pins located in the jack frame, holds the whole firmly in position. Like the drops each jack is thoroughly insulated from the mounting by hard rubber. Fig. 176 shows the method of removing

FIG. 176
REMOVING A JACK

a complete jack without disturbing the drop by simply unscrewing the hexagonal sleeve previously mentioned.

Small connecting clips are soldered to the switchboard cable and attached to the terminals at the rear of the jack by machine screws, constituting a drop and jack which can be removed from the switchboard without the use of a soldering iron.

These drops and jacks are assembled on a laminate mounting made up of a rigid piece of sheet brass, faced and backed with thick strips of hard rubber for insulating purposes. The standard mounting is for five drops and jacks per strip, as shown in Fig. 175.

The drop shutters are attached to the front of this mounting, and are provided with removable metallic number plates, allowing the drop numbers to be readily changed.

NIGHT ALARM CONTACTS.—Each drop is so constructed as to operate a positive night alarm contact when the shutter is down and in its calling position. This contact is made by a lip on the lower portion of the shutter, forcing a gold-plated spring into metallic connection with a gold-plated rod. These springs are fastened to the metal frame of the mounting strip, while the rod extends across the face of the mounting, and is held in the rubber and normally insulated from all metallic parts. This obviates establishing the night alarm connection through the hinge of the drop, a method which has not proven entirely satisfactory.

COMBINED RINGERS AND JACKS

The various parties on a bridging line usually employ a code of known signals, consisting of either short or long rings, for calling each other. When these lines are connected to the ordinary switchboard drop, the operator depends on the noise made by the vibration of the drop and armature to determine whether the exchange is desired. This proves very satisfactory when the switchboard operator is always in attendance, but for a small switching station it is often desirable to terminate these bridging lines in a signal which will not only visually indicate the line, but will give a distinct audible signal, loud enough to be heard throughout the room.

A combined ringer, drop and jack, is designed especially for this service. It consists of a long core ringer with double gongs and a latch drop indicator, the latter designed to indicate the line signaling. This drop is provided with night alarm contacts which can be wired to the regular night bell circuit. The jack mounted in connection with each ringer is of the same construction as that used on a combined drop and jack, but is not provided with the self-restoring feature. The local contact spring in the jack is opened when a plug is inserted, thus cutting the ringer coils out of the line circuit.

Two combined ringers, drops and jacks, mount side by side on a mounting strip and occupy the space of two strips of the combined drops and jacks.

CORD CIRCUIT APPARATUS

CLEARING-OUT DROPS.—These are of the same design as line drops (see Fig. 177) and are fitted with the same sort of night alarm contacts, but are not associated with jacks. The standard drops are wound to 500 ohms resistance and present a high impedance to voice currents and have no appreciable effect in cutting them down.

A combined ringing and listening key is used and also a ring-back key, all mounted on one escutcheon, which permits the key to be mounted directly on the wood of the key shelf.

The cams are provided with rollers which cut

FIG. 177
CLEARING-OUT DROPS

down friction and wear, and eliminate sticking. All springs are of German silver, with platinum contacts. They are mounted on a heavy brass frame, and are insulated from each other and from the frame by hard rubber blocks.

A form of single listening key is used on a cab-

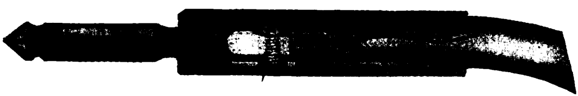


FIG. 178
PLUG AND CORD

inet, the key shelf of which is not wide enough to permit the mounting of a ring-back key. The listening key is self-locking in the listening position and both the listening and ring-back keys are automatically restored from the ringing position when released.

PLUGS.—Fig. 178 shows in principle a design of plug used in some types of magneto switchboards.

The tip contact of the plug is of brass, reinforced by a steel rod running back through the sleeve contact which is also of brass. The two are insulated by a bushing of hard rubber. The heel of the plug is threaded to receive the cord. The tip terminal of the cord is fastened by means of a machine screw to the butt end of the

FIG. 179
CORD CONSTRUCTION

steel reinforcing rod. A tough red fiber sleeve incloses the cord connections.

CORDS.—A switchboard cord would seem to be a very simple bit of apparatus, but experience has shown that a satisfactory cord is one of the most difficult parts of a switchboard to manufacture. Because of their constant use and the rough and careless manner in which they are usually handled by operators, cords are generally a source of trouble. By recent improvement in the manufacture of cords much of the trouble heretofore attending the handling of cords has been materially modified. Fig. 179 illustrates a cord in which the use of tinsel in the main body of the cord has been abandoned and a steel conductor cord has been produced to supplant the earlier method of manufacture. Beginning at the right, the different elements are, in the order named, a strand of Boston lock-stitch twine, a linen braiding mixed with three tinsel strands, the inner conductor of round spiral steel, a braiding of Tussah silk, a linen braiding, a loose tinsel braiding, the outer conductor of round spiral steel, a cotton braid, and a linen braid. The cord is reinforced at the plug end for a length of fourteen inches by another braiding of linen. The tinsel used is for the purpose of cutting down the resistance of the main steel conductors.

Fig. 180 shows the manner in which the plug end is finished off; also the tip terminal. Fig. 181 shows the tail end and the method of connecting to the córd rack. A loop which puts the strain on the braiding, rather than on the conductors, is provided to slip over the cord hook. This cord hook is curled so that the cord cannot bounce off. From the point where the loop is secured and the cord butted the two conductors are brought out separately, the sleeve conductor having a blue thread in the braiding to distinguish it from the tip conductor. Each of these ends is provided with a terminal c, which is fastened under a washer and screw cord fastener b. The terminal clip is also shown in Fig. 182.

Cord Weights.—Figs. 183 and 184 illustrate standard types of cord weights. A boxwood pulley large enough not to cut the cord is held between two brass supports. The weight is supplied by a casting of lead.

OPERATOR'S CIRCUIT APPARATUS

Transmitter.—The transmitter does not differ in any of its vital parts from regular telephone transmitters.

Transmitter Arm.—The transmitter is suspended from the arm as shown in Fig. 185 by two silk cords, each of which is led over a brass pulley on the arm, through the pulley of the weight and fastened to a binding post in the top of the cabinet.

Fig. 180
FINISHING OFF PLUG END OF CORD

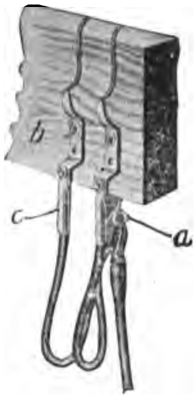


Fig. 181
CORD TAIL AND SUPPORT

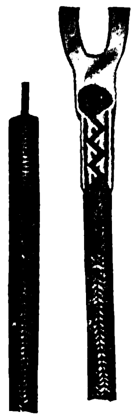


Fig. 182
CORD TERMINAL CLIP

Binding Posts.—Fig. 186 shows a binding post for operator's transmitter cords. It is provided with two milled binding screws, one to hold the cord tip which should be inserted in the bottom hole, and the other to hold the lead from

Fig. 183
CORD WEIGHT

Fig. 184
CORD WEIGHT

the local switchboard wiring. These posts permit the removing or replacing cords without the use of a soldering iron.

Induction Coil.—Fig. 187 shows an induction coil suitable for both local and long distance work.

The core is composed of a bundle of annealed iron wires. The maple base is six inches long by two inches wide, and has two terminals at either end for the windings, one primary and one secondary lead appearing at each end. The primary winding, which is next to the core, has a resistance of .32 ohms; the secondary 103 ohms. This high wound secondary makes the coil very power-

FIG. 185
TRANSMITTER ARM

ful for long distance work, and also enables the operators to talk in a low tone of voice in handling local calls.

HEAD RECEIVER.—Figs. 188 and 189 illustrate a head receiver of the watch-case type assembled and disassembled respectively. The shell is of hard rubber with a removable earpiece. The spring steel head band is covered with leather so as not to catch in the operator's hair and is pro-

FIG. 186
BINDING POST FOR OPERATOR'S TRANSMITTER CORD

vided with a hinge so that it may be swung back, allowing the receiver to be used as a hand tele-

FIG. 187
INDUCTION COIL

phone. The band and hinged piece may be removed by loosening a thumb screw. It is impossible for an operator to receive a shock from this receiver as there are no metal parts whatever which will make contact with the head.

The arrangement of the cord terminals, as shown in Fig. 190, is such as to permit standard

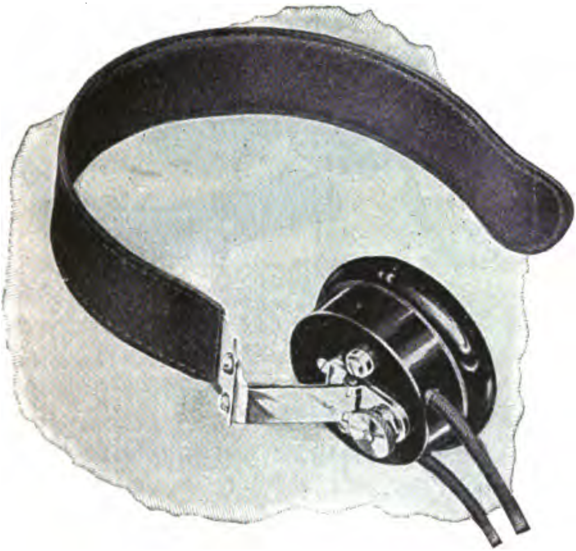


FIG. 188
HEAD RECEIVER

cord tips to be used on the receiver cord, and at the same time be practically concealed and entirely free from any liability of a short circuit which frequently "cuts out" the receiver when the tips project as they ordinarily do. It is possible to attach or remove a cord without opening the case. Fig. 190 also shows the permanent magnets, six in number, semi-circular in form, and arranged so as to be supported by the case

Fig. 189

HEAD RECEIVER DISASSEMBLED

from the back and sides. The magnet coils are wound to 60 ohms resistance.

Cut-in Jack.—An operator's individual cut-in jack is made with a frame in one piece and

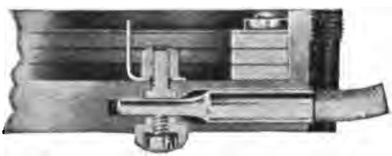


Fig. 190

arranged to be fastened in position on the switch-board shelf by machine screws. The springs are of German silver, platinum pointed, and by reason of their U-shape, are of good length themselves without making the jack long. The face of the jack is one and seven-eighths inches in diameter. The operator's transmitter battery is wired to two points of this jack, and the arrangement of the springs is such that the battery circuit is closed when the plug is inserted and opened when the plug is removed.

Hand Generator.—This is identical with that used in other magneto telephones, such as is shown in Fig. 60, with the exception that the automatic shunt feature is omitted and an extension shaft is provided so that the generator may be mounted in the rear of the cabinet out of the way of the operator's knees. Four-bar generators are usually used, but extra powerful five-bar generators or generators especially equipped to give positive and negative pulsating current may be employed for four-party selective service.

In construction this generator, is electrically and mechanically, very efficient. It has a shuttle type armature, and the usual continuous, one-piece shaft, has been supplanted by steel shaft projections attached to either end of the armature core by heavy brass discs. This design affords a greater cross section of iron in the core proper, and a larger winding space free from irregularities. The winding is of silk-covered copper wire. The two iron pole pieces forming the frame and field are separated and securely fastened by four heavy brass posts. The end plates, unlike the usual method of construction, serve primarily as bearings for the running gear and are made with large contact surfaces, where the crank and armature shafts revolve, with a view to longer life and smooth running. The gear wheels are made of hard brass. The faces of the gears are extra wide, and are cut with special shaped teeth.

NIGHT ALARM RELAY

RELAY FOR NIGHT ALARM CIRCUIT.—The relay has a single winding of 500 ohms, and in operating makes one contact. The contact springs are of German silver, platinum pointed. A closed magnetic circuit, which includes the core, armature and the L-shaped iron piece on which the springs are mounted, serves, when current flows through the winding, to concentrate on the armature the full effect of the magnetic lines of force.

This relay is designed to operate through 1,000 ohms resistance on twenty volts, which may be taken as a fair average of the voltage given by the fifteen dry cells during their life.

SWITCHBOARD CABINETS

There are a great variety of switchboard cabinets in general use and designed to meet the requirements of the smallest to the largest exchanges using magneto apparatus. The standard woodwork is generally solid quarter-sawed oak for the entire exterior of the cabinet.

The most approved cabinets are made with the front panels below the key shelves removable; the bottom of the panels being secured by a tongue fitted to a groove in the cabinet which insures a more substantial fastening than dowel pins or other methods of fastening.

KEY SHELVES.—These shelves are built in layers of wood with grain crossing to add strength and prevent warping and they are hinged and

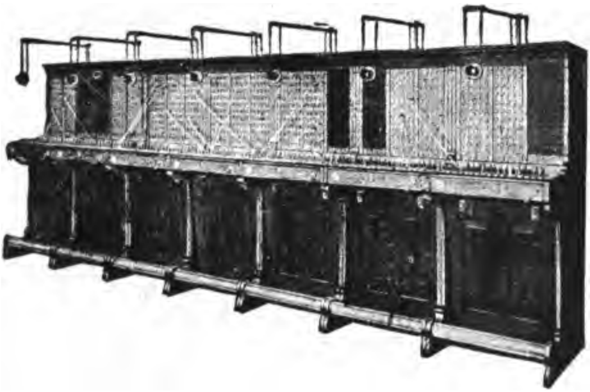


FIG. 191
UNIT TYPE CABINETS

held in place by spring locks of standard design.

METAL JACK FRAME.—An iron frame is securely fastened into the face of each cabinet upon which all drops and jacks or other line circuit apparatus are fastened.

UNIT TYPE CABINETS.—This is a type of cabinet which is uniform in style and is so designed that it can be placed side by side with other cabinets of the same pattern, giving the effect of a continuous switchboard and thereby allowing expanding with the growing needs of an exchange. (See Fig. 191.) This is not unlike the sectional book-case idea, additions being made with the same facility. With this type of cabinet the extension of a switchboard necessitates no change in the original installation excepting the addition of connecting circuits between the various operators, provisions for the latter being made in such types.

TRANSFER CIRCUITS

When there are more than two operators' positions equipped in some switchboards, whether in

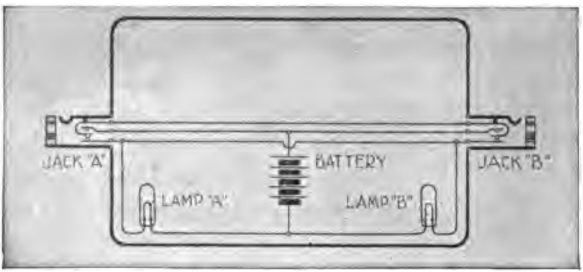


FIG. 192
TRANSFER CIRCUIT

the same cabinet or not, certain lines will be out of reach of each operator so that the connections to these lines cannot be made direct without a two-way transfer circuit, such as is shown in diagram, Fig. 192. Each end of this circuit terminates in a lamp and associated jack. These lamps and jacks are made in strips of five, and are mounted in the regular iron jack frame just below the line drops and jacks.

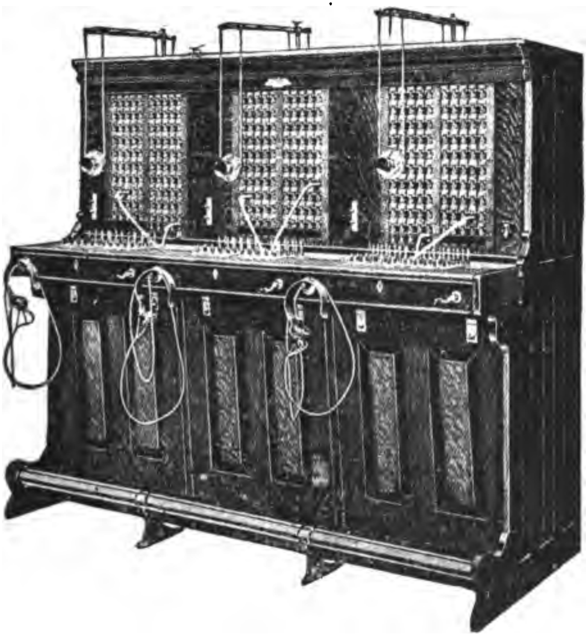


Fig. 193

TRANSFER SWITCHBOARD

The transfer circuits are located in the cabinets so as to extend from each operator's position to every other non-adjacent position, thereby allowing all necessary connections to be made with ease.

This trancfer circuit is also used to good advantage as a trunk between local and toll boards, in which case order wire circuits are installed for communication between operators in ordering up connections, the toll operator having a circuit leading to each local operator.

The operation of these transfer circuits is illustrated in Fig. 193, which is a three-position type cabinet with the two end positions equipped with five lamp transfers. No transfer circuits are necessary in the middle position as this operator can readily reach all of the lines in the switchboard. If a subscriber whose drop and jack is in the right hand operator's position calls for a party in the other end of the cabinet, or vice versa, it will be necessary to use the transfers. The operator receiving call answers in the regular way and after ascertaining the party wanted, immediately plugs into transfer leading to the position in which the jack of the called subscriber appears. This act lights a lamp at both ends of the transfer circuit, the one in the remote position serving as a signal for the second operator, who answers and completes the connection between the two subscribers. When the second operator answers, both transfer lamps are extinguished. The subscribers ring off in the regular way, operating clearing-out drops in both positions. When either operator pulls down the connecting cords, both signal lamps of the transfer circuit illuminate and remain in this condition until the other operator disconnects when both lamps will be extinguished. Thus the lamps serve as a check on each operator's action and prevent any possible "tying up" of the connected subscribers on the transfer circuit.

Seven cells of Fuller battery are required to operate the lamps. These cells require very little attention and are comparatively inexpensive to maintain and renew.

CUT-IN STATION APPARATUS

It is very desirable when a toll line passes through an intermediate station to have some means of completing through connections which will obviate the necessity of talking through switchboard cords and the contacts between plugs and jack springs. The switchboard cords may be worn and defective and introduce troublesome cutouts. The contacts between plugs and jack springs may be imperfect, cutting down the transmission and introducing unbalancing resistances which will make the line noisy in spite of careful line construction. To overcome this, telephone men have in many cases resorted to some such device as an extension bell and a knife switch, but the most modern and approved method to remedy these irregularities is by the employment of a cut-in-set, the circuit of which is shown in Fig. 194.

It will be seen that the only apparatus through which the toll line has to pass are the platinum contacts of two jacks. Normally a high impedance drop is bridged across the line by means of which the operator can distinguish the various rings from the clatter of the armature. Upon receiving her own signal she plugs into jack No. 2 to determine whether it is a distant station at the left or at the right which desires a local connection. Should a station on the left be signaling, the operator removes the plug from jack No. 2 and inserts it in jack No. 1, learns the name or number of the local subscriber wanted and completes the connection. Plugging into jack No. 1 leaves the right-hand end of the line free for another conversation. The

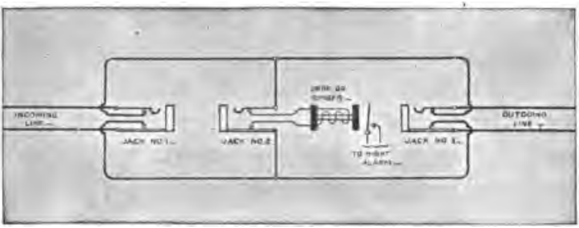


FIG. 194
TOLL CUT-IN CIRCUIT

operator may still be signaled from both directions; from the left by means of the clearing-out drop of the cord circuit in use; from the right by means of the drop associated with jack No. 2.

If the circumstances are such that an audible signal is desired, the jacks may be mounted on a maple strip in connection with a ringer as shown in Fig. 195.

TWO-PARTY SELECTIVE SYSTEM SIGNALING

A very convenient and satisfactory method of operating several telephones on the same metallic line, is to connect the ringers of one-half of the telephones from one side of line to ground, and the remainder from the other side of line to ground. By this divided circuit arrangement only one-half of the subscribers will be disturbed when one is signaled, which, for a heavily loaded line, is a great advantage. Also, as far as operators' ringing is concerned, this division will allow twice

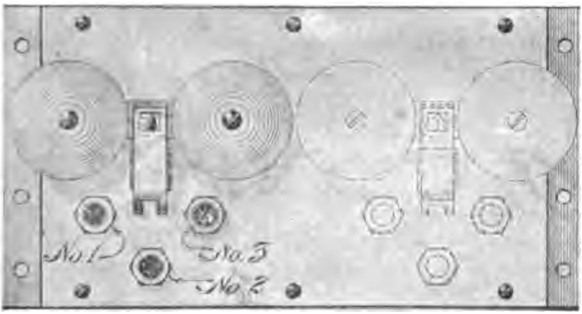


FIG. 195

TOLL CUT-IN JACKS WITH BELL

as many subscribers on the same line. When only two subscribers are connected to the divided line circuit, each can be signaled without disturbing the other, thus making a two-party selective system.

Fig. 196 shows in diagram the signaling circuit of this system. A master key common to each operator's position is provided for switching the generator to the tip or sleeve side of the regular ringing keys, thereby allowing any cord circuit to be used for divided circuit signaling. With the master key lever in its normal position, generator current is available at the point A, so that when a regular ringing key is pressed, this current has a circuit established through the tip side of the connected line, through station No. 1 to ground, and thence back to the generator. Thus the bell at station No. 1 will be rung without disturbing station No. 2. The latter station, however, can be signaled without disturbing the former by throw-

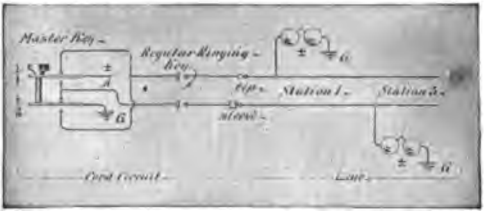


Fig. 196
2-PARTY SELECTIVE SYSTEM (THEORY)

ing the master key lever to position No. 2, before operating the regular ringing key. A circuit for generator current will then be established through the sleeve side of line, station No. 2, to ground and back to generator. With the lever of the master key in its normal or upright position, generator current is available for ringing in the ordinary manner.

Fig. 197 shows the actual wiring of this system. The distributing bars in the rear of the switchboard cabinet, are for connecting the power generator, or a battery pole changer, to the generator switching key. When this latter key is in its normal position, H, Fig. 197, the generator circuit is connected for service through the master key, while with its lever locked in position, P, the power generator is cut out of the circuit and the hand generator substituted. The resistance, L, is a standard 110 volt, 16 candle power, incandescent lamp, ordinarily used for lighting purposes, but in

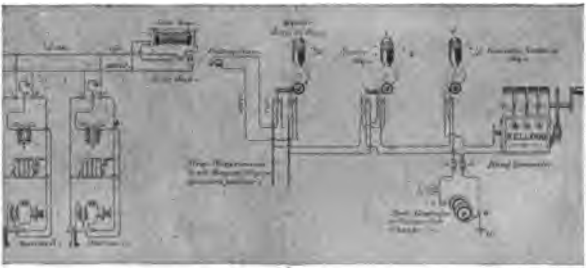


FIG. 197

WIRING OF 2-PARTY SELECTIVE SYSTEM

this case it serves as a safety resistance to prevent damage to the power generator by any accidental crossing or short circuiting of the ringing circuit. The master key and generator switching key are mounted on escutcheons (see Fig. 198). These keys are self-locking when the lever is thrown. The generator switching key is supplied with all standard equipments of this type of switchboard, therefore it only remains to add one master key to each operator's position in order to equip the switchboard for two party or divided circuit ringing.

All subscribers whose bells are connected to the tip side of the line are called in exactly the same manner as subscribers having individual lines. To signal a subscriber whose bell is connected to the sleeve side of the line, the operator first throws the master key to position No. 2 (see Fig. 197),

FIG. 198
MASTER KEY

then plugs into the line jack and rings with the regular ringing key in the usual manner.

Under ordinary conditions the terminating of divided circuit lines in low wound or series type drops, will allow the subscribers to signal the exchange without disturbing the other parties on the same line. This is made possible by the low winding of the drop, which allows most of the current from the subscriber's generator to pass through it in preference to the other path through the bells of the other telephones. Combined drops and jacks, which are wound to 100 ohms resistance, should be used on all divided circuit lines in order to enable one party to signal central without disturbing other subscribers.

FOUR-PARTY SELECTIVE SYSTEM SIGNALING

This system is adapted for calling any one of four parties bridged across a metallic line with-

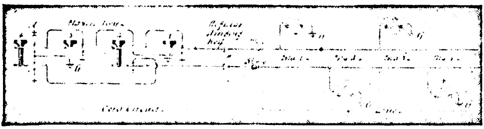


FIG. 199
4-PARTY SELECTIVE WITH PULSATING CURRENT (THEORY)

out ringing the bells of the other three. It employs positive and negative pulsating currents to actuate ringers of similar and opposite polarity; hence, by using each side of a metallic line and a ground return with proper selecting keys at the exchange, four stations can be arranged, each to respond to its proper signal.

The signaling part of this system is shown in Fig. 199, the operation being as follows: When the key No. 1 is pressed, positive pulsating current will be connected to the regular ringing key, which when operated will allow this current to pass over the tip side of the line through stations No. 1 and No. 3 to earth, and thence back to the generator. This will ring the bell at station No. 1, which is polarized to respond to positive pulsating currents, while the bell at station No. 3 will remain silent as it is arranged for negative and pulsating currents. Station No. 3 will, however, be operated by pressing key No. 3, which allows negative currents to pass out over the same side of the line. Operating keys No. 2 and No. 4 produce similar results on the sleeve side of the line and ring the bells of stations No. 2 and No. 4 respectively. It will be noticed that when any one of the four keys is pressed, a ground connection will be left on the other side of the line to the one receiving the generator current, the object being to establish a shunt circuit around the instruments on that side of the line, and thereby prevent stray ringing currents from operating their bells. Alternating current is connected at the point A, key No. 4, so that when the four key levers are in their normal positions it will be available for ringing subscribers in the ordinary manner.

Fig. 200 shows the actual wiring of the circuit just described; also the wiring of the subscribers' station apparatus. In practice the master key is made up of two keys mounted on an escutcheon. Each of the two levers of this master key can be thrown forward and backward and will remain locked in these positions until restored. Positions of the levers for ringing the four parties are shown in Fig. 200. A subscriber is signaled by the operator first setting the lever of the master key to correspond to the station desired, after which the calling plug is inserted in the line jack of the circuit and the regular ringing key operated in the usual manner. The movement of the master key simply switches the generator current required to signal the de-

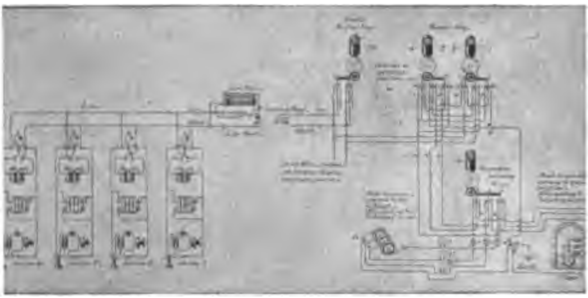


FIG. 200
WIRING OF 4-PARTY SYSTEM USING PULSATING CURRENT

sired station to the strap wires which are common to all of the regular ringing keys in an operator's position, so that any cord circuit can be used in calling. When the levers of the master key are in an upright or normal position, alternating generator current is on these strap wires so that the switchboard can be operated for regular service.

Positive and negative pulsating and alternating currents necessary to operate the exchange when fitted with this system are supplied from special generators, which only differ from the regular type in the addition of a commutating device. If a power generator or pole changer is to be used, it should be constructed to give similar currents. The lugs for connecting the power generator to the switchboard are located in the rear of the switchboard cabinet. The wiring from these lugs passes through the generator switching key, which latter is used for throwing from the power generator to the operator's hand generator and vice versa. The resistance lamps, located in the power generator leads, are for the same purpose as the lamp L, used in connection with the two-party line system already described.

A ground return necessary to complete the ringing circuit through the subscribers' station ringers, should be provided at the exchange by connecting the distributing bar No. 12 shown in Fig. 200 to a metal plate buried in damp earth which will remain moist during all the year. The wire used in making this connection should be of copper and about No. 12 B. and S. gauge in size.

The use of combined drops and jacks for terminating the selective party lines will, under ordinary conditions, allow the subscribers to signal the exchange without disturbing the other parties on the same line. The drop has a winding of 100 ohms resistance, and therefore consumes enough current from the generator of the party calling the exchange so that the other ringers connected to the same line will not be operated.

The positive and negative pulsating current system of selective signaling is not adapted for all conditions of service.

The Four Party System Signaling Selective Operated on the Harmonic Principle.

—This system employs alternating currents of four different frequencies, and rings the parties bridged across a metallic circuit without any ground connections. This feature renders the signaling non-interfering and positive in action, while the construction of the ringers is such that they will operate with as little attention as the latest type bridging bell. The harmonic system is in successful operation in a number of common battery exchanges, and since the perfection of the harmonic converter for producing 4-frequency current this system has become very common.

CHAPTER XV

SWITCHBOARD INSTALLATION

The specific method of installing the great number and variety of switchboards would constitute a treatise in itself too voluminous to be undertaken within the space of a single volume; but as the underlying principle of construction is identical in all standard switchboards, a concise yet comprehensive description, will convey an adequate idea of the *modus operandi* in general, and from which sufficient theoretical knowledge may be deduced to equip the operator with the necessary working skill to proceed intelligently in any system with which he may be confronted; especially as it is customary for manufacturers to furnish their patrons complete printed instructions and blue prints with each switchboard.

First. Place the switchboard cabinet in the position it is to occupy permanently. Remove the back and front panels and take away the packing material from the cords and weights so as to leave them free.

Second. Fasten the transmitter arm in place and run the transmitter cords over the pulleys and through the cord weights connecting the ends into the binding post provided for the same in the roof of the cabinet.

Third. Set up the batteries furnished with the switchboard and place in their permanent location, preferably in a cabinet or in a box with a lid. The brass distributing bars with the binding screws for connecting the outside power wires to the switchboard will be found on a terminal board located in the rear of the switchboard cabinet. These bars are numbered as shown in Fig. 201. Distributing bars No. 8 and No. 9 are to be respectively wired to the positive pole of the first and the negative pole of the last of three cells of gravity battery connected together in series. This battery furnishes talking current for the operator's transmitter.

Distributing bars No. 6 and No. 7 are to be wired to two cells of dry battery connected together in series. Current from this battery will ring the night bell whenever the night alarm relay is energized. As previously described, this relay is used in the night alarm circuit for the reason that it is more sensitive and positive in operation than having the night alarm bell connected directly to the battery and drop contacts.

Distributing bars No. 2 and No. 3 are to be wired to fifteen cells of dry battery connected together in series. Current from these cells operates the night alarm relay located in the roof of the section whenever a line or clearing-out drop falls, provided the lever of the three-point night alarm switch is at its right-hand position.

Batteries are connected together in series when the negative pole of the first is connected to the positive pole of the second and the negative pole of the second to the positive pole of the third, etc. Carbon or copper poles are positive and zinc negative.

The night bell or buzzer is located on the con-

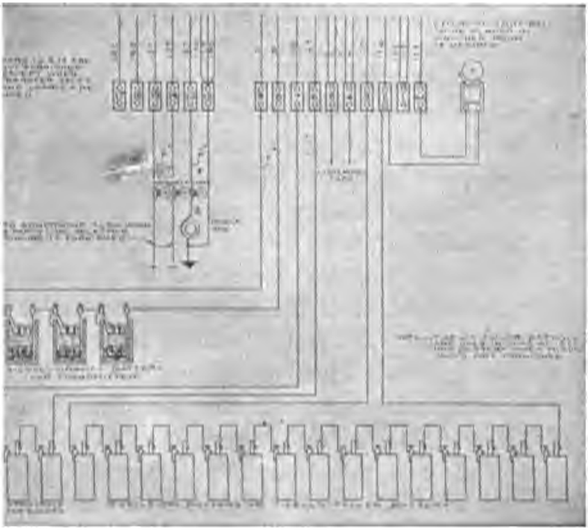


FIG. 201

BATTERY CONNECTIONS MAGNETO SWITCHBOARD

necting rack in the rear of the cabinet. If it is desired to locate a night alarm at a distance from the switchboard it can be connected to distributing bars "N. A." and No. 2, then if the lever of the three-point switch is thrown to the center position, the falling of a line or clearing-out drop will cause the distant night alarm to ring, but in such a case the alarm in the switchboard will not ring. This night alarm switch is a rubber base "Keystone" switch, and is located on the front of the switchboard cabinet immediately under the key shelf box.

Fourth. Distributing bars No. 12 and No. 13 are for connecting a power generator or battery pole-changer if outside ringing current is to be used. Bar No. 12 should be connected to the frame or ground side of the machine, and also to a good earth connection. But if no party lines are used it is good practice to leave the generator insulated from ground. The earth connection can be a metal plate buried in damp earth which will remain moist during all the year. A generator key is provided for switching from hand to power generator. This key is located on the key shelf and so wired that when its lever is in a normal position the ringing can be done by the power generator, and when the same lever is pulled toward the operator the power generator will be disconnected and the hand generator will be connected. Bus bars Nos. 14 and 15 are used only when pulsating current is to be furnished for four-party line selective ringing.

Fifth. Distributing bars No. 4 and No. 5 are to have no outside connection unless it is desired to connect the operator's telephone set of this cabinet to the telephone set of another operator at some other switchboard cabinet. In case this is to be done, wires should be led from these distributing bars to a two-lever switch which is connected to the two corresponding bars in the second cabinet, so that whenever the switch lever is thrown the bars on the two boards, and hence the two telephone sets, will be connected together.

Sixth. The switchboard is now in operating condition, and it only remains to connect the combined drops and jacks to the line circuits. The drops and jacks are wired for ten feet from the base of the cabinet in switchboard cable, the end of which should be formed out and connected to the terminals of the distributing frame or arrester strips.

If metallic circuits are used throughout the system, the switchboard cable should be connected by pairs straight through the distributing frame to meet the open line wires of the subscribers' circuits at the pole terminal box.

If the system is grounded or common return there will be of necessity some cross-talk. But in order to reduce the cross-talk as much as possible, all lines should be carried metallic through the twisted pairs of the cable to the terminal box where the open line wire construction commences. At this point connect all of the sleeve or colored wires to a common conductor not less than a No. 8 B. and S. Gauge, as shown in Fig. 202, and run to a good ground or to the common return wire of the system. This will give a metallic twisted pair circuit for each line to the open wire construction.

If the wires are connected to the common conductor at the distributing frame or arrester strip, and each conductor of the outside cable used as a line wire, as shown in Fig. 203, the cross-talk would be greatly increased. This is due to the fact that the cable conductors would then be in the condition of parallel line wires without transposition and the electrical induction from any one of them carrying voice currents would affect the remainder in the same cable, and thus bad cross-

FIG. 202
CARRYING LINES METALLIC THROUGH CABLE

talk would result. This induction cannot exist between lines made up of twisted pair circuits.

Care must be exercised in connecting sleeve wires to the ground or common return as any reversal of these conductors will produce trouble when a circuit thus transposed is connected through the switchboard cord circuit to a properly grounded line. A short circuit will be established from the tip side of the wrongly grounded line, through the common return to the sleeve of the connected line, as shown in Fig. 204. On account of this low resistance path across the line no conversation can take place between the connected subscribers, neither can they ring down the clearing-out drop for disconnection. The lines will of course remain tied up until the operator discovers the trouble.

Fig. 205 shows the correct way to bring the out-

FIG. 203
COMMON OR EARTH RETURN LINES THROUGH CABLE

side cable into the exchange. In the majority of cases other simpler methods are used, but are open to serious objections on account of the many chances for trouble.

Seventh. When a switchboard cabinet contains

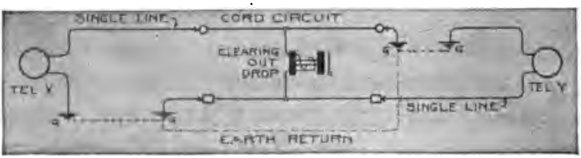


FIG. 204
EFFECT OF REVERSED LINE

more than one operator's position equipment, the power wiring or connections to the battery and power generator should be made as shown in Fig. 206. The lug N. A. appears only in the first cabinet. Lug 1 appears in each cabinet and all should be connected together. The fifteen cells of dry battery or seven cells of Fuller battery being common to the exchange, a wire should be run from each of the lugs 2 and 3 to the corresponding lugs in each of the other cabinets. Lugs 6 and 7,

FIG. 205

ENTRANCE TO TYPICAL SMALL OFFICE

to which two cells of dry battery are connected for the night alarm bell, appear at the first position only. A separate battery of three gravity cells is furnished for each operator and must be connected to lugs 8 and 9 at each position. The power generator apparatus being common to the exchange, wires should be led from lugs 12, 13, 14 and 15 to the corresponding lugs at every position. Battery for the transfer lamps should be brought to lugs 16 and 17 by running wires from lugs 2 and 3 respectively, and the lugs 16 and 17 should be connected to the corresponding lugs at every position. All of these wires which are led from one position to another, are wired by the

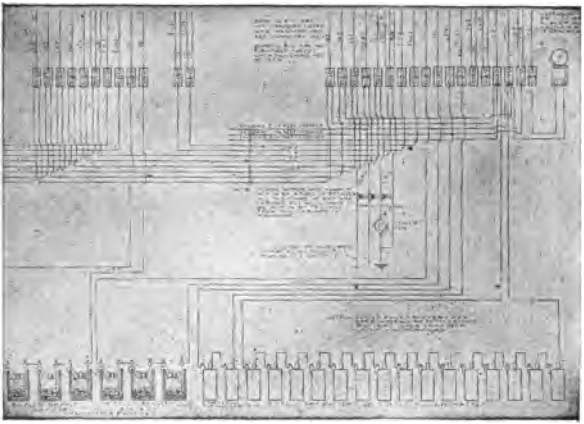


FIG. 206
GENERAL WIRING, SMALL BOARD

manufacturer between all positions in any one cabinet, but will have to be put in by the telephone company from one cabinet to another.

Lugs 4 and 5 appear at each position and are connected to the operator's listening strap wires. Listening taps may be wired to these lugs and run to the manager's desk so that he may listen-in on any operator at any time, without the operator knowing it.

Lugs 10 and 11 appear at each position and are wired to a telephone switching key which is mounted in front of the regular generator switching key and upon the same escutcheon. When lugs 10 and 11 at one position are wired to lugs 4 and 5 at another, the operator at the first position may connect her listening keys to the telephone set of the operator at the second position by throwing her telephone switching key. In a two-position cabinet, if the lever of this key in either operator's position is pulled toward the operator, that operator's listening keys will be connected to the telephone set of the other operator. In a three-position cabinet, if the lever of these keys in both the right and left hand operators' positions are pulled forward, the listening keys belonging to these two positions will be connected to the telephone set of the middle operator. If the lever of this key in the middle position is pulled toward the operator, the listening keys belonging to this position will be connected to the telephone set of the operator at the right. When there are more than four positions, each telephone switching key throws the position to the operator next on the right.

POWER RINGING

Even in a small exchange it is always desirable to install a power-ringing machine of some description. It relieves the operator of a great deal of manual work, and enables her to answer calls more promptly and therefore to handle a greater number of lines than she possibly could using a hand generator; in case code signals are used for party lines, they may be given evenly and distinctly.

There are several classes of power-ringing machines in use; battery pole-changers, belt-connected motor-magneto-generator sets, dynamotors, and direct-connected motor-generator sets. Any of these may be equipped with an attachment to give positive and negative pulsating current.

Among battery pole-changers the Warner is perhaps the most widely and most favorably known. This outfit consists of a battery of sixty dry cells, one type R. R. Edison Lalande battery, one special condenser, and one Warner pole-changer, all contained in an oak cabinet.

The belt-connected motor-magneto-generator sets consist of a small motor similar to a fan motor and a four or five bar magneto-generator mounted on one base. Motors may be had for either alternating or direct current.

A ringing dynamotor consists of a single field and armature core, the latter having two separate windings brought out to the commutator and collector rings on either end. They should be used only when the electric power is direct current of less than 250 volts pressure.

Motor-generator sets consist of two complete machines mounted on a rigid iron or slate base, and connected with a coupling. The motor end may be either direct or alternating current.

For use in exchanges of less than 600 lines, either a battery pole-changer, a dynamotor for direct current power, or a belt-connected motor-magneto-generator set for alternating current power may be used. Hand generators may be used as auxiliaries. For exchanges of 600 to 2,000 lines, a dynamotor for direct current power or a motor-generator set for alternating current power with a battery pole-changer auxiliary will give the best results.

WALL TYPE SWITCHBOARD

The illustration, Fig. 207, shows a combination telephone and switchboard, designed for use as a switching or connecting station for farmers' and toll lines. It has a capacity for twenty lines and five complete cord circuits. These lines terminate in combined drops and jacks, while the cord circuits are provided with high-wound bridged clearing-out drops and listening-in jacks. Instead of the twenty drops and jacks four combined ringers, drops and jacks, may be used as they occupy the same space in the jack cabinet.

Connections between the lines are made with the cord circuits without the use of keys; the ringing, listening and talking being done through the bridging long distance telephone equipment which is mounted on the backboard. The circuits of this telephone terminate in a cord and plug which can be inserted in any of the jacks.

Two carbon-block lightning arresters are provided for each of the line circuits, and are mounted at the top of the cabinet. A night bell is also provided, and may be mounted in any convenient location. The battery box contains two shelves for the four cells of dry battery furnished

FIG. 207
COMBINATION TELEPHONE AND SWITCHBOARD

with the switchboard, two for the telephone and two for the night alarm circuit.

BELL TYPE SWITCHBOARD

What is known as the Bell type switchboard differs from the boards described on the preceding pages in one feature only—the line drops are *manual restoring* instead of *self-restoring*. This, of course, slows down the speed of operation, but the board can be used with

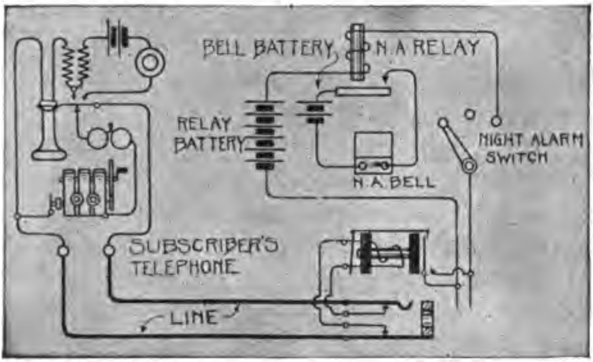


FIG. 208

LINE CIRCUIT, SMALL MAGNETO SWITCHBOARD

satisfaction where extreme rapidity is not required. The operator's circuit, the cord, night alarm and generator circuits and the pieces of apparatus entering into them, are all exactly the same as those used in the Express boards. The line circuit is shown in Fig. 208.

JACKS.—The line jacks are located in one bank directly under the drops.

LAMP SIGNAL MAGNETO SWITCHBOARD

This switchboard is intended for use with magneto telephones and the operation of the line and supervisory signals is almost identical with the present-day common battery practice. It is intended for exchanges where it is desirable to employ the latest methods of operation in his switchboard without discarding magneto telephones already in use and without incurring the expense of bringing the line construction up to the standard required for common battery service.

When the growth of the exchange makes it necessary to change the system to full common battery, the switchboard may be adapted to this purpose without throwing away a single piece of apparatus. An addition to the battery and a simple change in the wiring of the board, is all that is necessary.

Operation.—The method of operation can best be understood by taking a pair of subscribers through a complete conversation. To signal central, the calling subscriber turns the crank of his generator in the usual manner. This operates to illuminate his line lamp and the operator answers the call and extinguishes the lamp by plugging into the jack located immediately above it. Having ascertained the number of the subscriber desired, she plugs into the jack of that line and rings. When the conversation is finshed each subscriber rings off. Associated with each cord on the key shelf is a small incandescent lamp, called a supervisory signal. Each subscriber is ringing off lights the supervisory lamp of the cord plugged into his jack, and when both light up the operator knows that the conversation is finished and pulls down the cords, which act extinguishes both lamps. With this method of lamp line and supervisory signaling an operator can handle many more lines than she can at a switchboard employing magneto drops. In this system a double supervisory signal, one for each subscriber, is obtained instead of the single signal given by the usual clearing-out drop.

Farmers' and toll lines do not terminate in lamp signals, but in combined drops and jacks, so that the operator can, by the clatter of the drop armature, distinguish her signal from the various rings. The cords are fitted with plugs which fit the jacks associated with the lamps and also those associated with the drops. The cord circuits may be used indiscriminately for connecting a lamp line to a lamp line, a lamp line to a drop line, or a drop line to a drop line, and in all of these connections the double lamp supervisory signals are obtained in the regular way.

The switchboard is of the unit type, and when several are installed as one switchboard, they are equipped with transfer circuits.

The wide keys are used for communication between operators in connection with transfer circuits.

Lamp Jacks.—The operator's equipment, the keys, cords and plugs are all similar to the apparatus used in the express boards.

The lamp caps and lamps may be removed from the jack strips by means of extractors. The terminals of the lamps consist of two strips of brass cemented to the globe and extending backward, being insulated from each other by a small block of wood. When the lamp is slipped into place these two strips engage with the jack springs. The lamps which are one-third candle power, 24

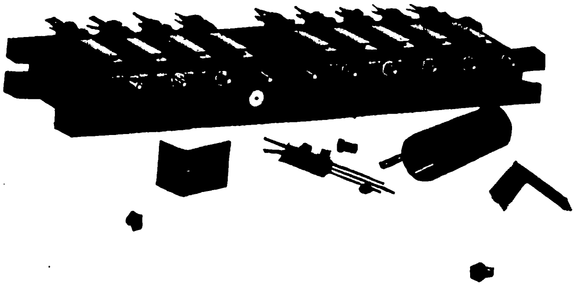


FIG. 209
STRIP OF RELAYS (MINOR TYPE)

volts, are very efficient and give off but a small amount of heat.

Each lamp is protected by means of a cap which is inserted over it in a drilling in the key shelf. An openwork metal guard is placed over the cap to protect its opal from the impact of the plugs.

LAMP CAPS.—One lamp cap is placed over each lamp in the jack strip for a double purpose: first, as a protection for the lamp; and second, as a sort of number plate. The shoulder is screwed down over the tubular portion to hold three discs in place—a mica disc, which is nearest the lamp, a paper disc on which is printed the number of the line, and a glass disc to protect the paper and mica discs. When the lamp is burning, the number of the line on the paper punching shows up clearly. Ordinarily the operator is not concerned with the number of the line she is answering. She simply sees the signal and plugs into the jack immediately above it. But at times, such as when linemen are testing, it is convenient for her to be able to know at a glance the number of the line on which a call comes in. Should an operator carelessly punch a plug through the discs, it is evident from the construction of the cap that it may readily be repaired by unscrewing the shoulder and inserting new discs.

Line Jacks.—The line jacks are rigidly mounted on a piece of polished hard rubber, and are equal in construction and design to the spring jacks used in the largest common battery multiple boards.

Relays.—In Fig. 209 is shown a strip of ten relays of the type used in these switchboards. A single iron casting is drilled out for the reception of the relay coils, sufficient space being left between the drillings to prevent any suspicion of cross-talk. The contact springs are thoroughly insulated both from the armature and the iron block containing the relays, and are made of German silver, platinum pointed. In the cut one of the relays is shown dis-assembled, and the armature of another is removed to show the construction.

Power Plant.—Where a source of electric power is available the use of a battery of Chloride Accumulator storage cells is preferable. If the primary power is direct current, the cells may be charged through a lamp rheostat; if alternating, a suitable motor-generator charging set should be obtained. When storage cells are used there should be installed from the beginning jars having sufficient capacity to furnish talking and signaling current for the ultimate number of lines when changed to full common battery. And in the jars installed there should be enough plates to provide signaling current for the number of lines originally installed. The increased amount of current demanded by the growth of the exchange or a change to common batery is taken care of by the simple addition of plates to the jars already installed. When no electric power is to be had a suitable battery of Fuller or Gordon cells may be used.

REPEATING COILS

The use of repeating coils in connection with telephony is mainly for the purpose of providing a quiet connection between dissimilar telephone lines.

In the majority of cases in magneto work the dissimilar lines to be connected are grounded or common return lines and full metallic lines, it being taken for granted that all practical working lines are uniform as regards size of wire in the same circuit, and that the wires of a metallic circuit subjected to disturbances are properly transposed.

In Fig. 210 is shown a simple ground return line with any kind of an electrical circuit as a disturbing source. The two sides of this telephone line being unequal in capacity and resistance, renders the circuit unbalanced with respect to the disturbing source, as the line wire does not present the same receptive or resisting effect as the earth or common return. Current will be induced in the line wire, and in attempting to come to an equilibrium, will pass through one of the connected

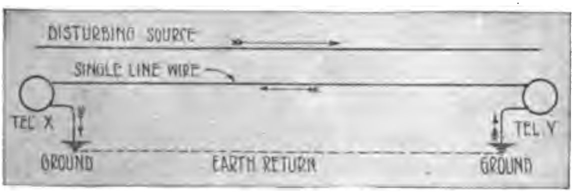


FIG. 210

EARTH RETURN TELEPHONE LINE AND DISTURBING WIRE

telephones to earth and back through the other telephone. This passage of electricity through the telephones produces a noise in the receivers which makes conversation difficult. However, in localities where the disturbing elements are slight, a common return or grounded line is sufficiently quiet to give good service. The only remedy for noisy lines of this character is to make the circuit metallic and transpose the two wires in respect to the disturbing source, as shown in Fig. 211. It will be seen from this drawing that the transposition of the wires causes each side of the line to take turns in passing close to the disturbing source, thereby preserving the equilibrium, and as a result, no induced current passes through the telephones at X and Y.

Fig. 212 shows a balanced metallic line con-

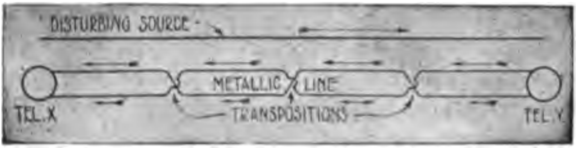


FIG. 211
METALLIC CIRCUIT AND DISTURBING WIRE

nected to a grounded or common return line through the cord circuit of the switchboard. Now, if the disturbing source is the line A B, we can

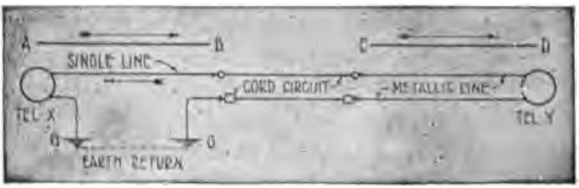


FIG. 212
INDUCTION ON CONNECTED LINES

easily see that the single wire of the grounded line will be affected as it is a simlar case to that shown in Fig. 210. Both of the telephones X and Y will receive the induced disturbing current, as it will have to pass through the entire circuit in its efforts to come to equilibrum. Furthermore, if the disturbing source is the line C D, in close proximity to the normally balanced metallic line, it will be rendered unbalanced as soon as connection is made through the cord circuit to the grounded line. This is due to the fact that the connected circuit presents unequal dimensions on either side of the completed line. Both of these lines may be normally quiet before being connected, but as soon as the ground of the single

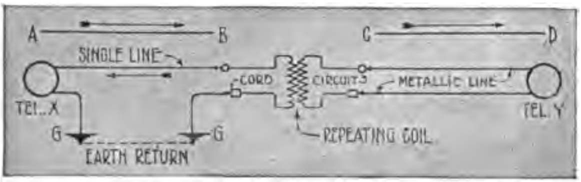


FIG. 213

USE OF REPEATING COIL TO KEEP CONNECTION QUIET

wire circuit is metallically connected through the cord circuit of the switchboard to the metallic line, an unbalancing exists, as the disturbing element which is tending to induce charges on both sides of the line will then find a path to earth in coming to a balance. Therefore, when a long, quiet toll line is connected to a short and normally quiet grounded or common return line, the completed circuit often becomes too noisy to give service. The detrimental results of the latter conditions can be partly or entirely eliminated by the use of a repeating coil for metallically separating the two lines, as shown in Fig. 213. Both the common return or grounded line and the metallic line are now in their normal and quiet condition, as no metallic circuit exists from one to the other and no flow of induced current is possible. While the repeating coil separates the two lines from metallic connection, it serves as a means of accurately repeating the voice currents through this separating gap with only a small loss of energy.

The repeating coil may either be placed per-

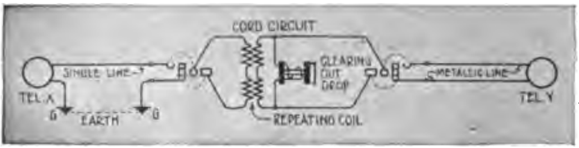


FIG. 214

SIMPLIFIED CORD CIRCUIT WITH REPEATING COIL

manently in the exchange end of the line circuit or in one or more of the connecting cords, so as to be available for use in joining any two unbalanced lines. When the repeating coil is located in a cord circuit, the operator can easily determine the condition of the connected lines when listening in, and only inserts the coil when necessary.

When only a few of the lines are ground or common return and the remainder metallic, it might be advisable to place repeating coils in the line circuits giving the trouble from unbalancing rather than bother with repeating coils in the cord circuits. This would also apply when a few of the lines are metallic and the remainder of a mixed nature.

Fig. 214 shows the location of a repeating coil in the cord circuit, connecting two dis-similar lines, while Fig. 215 shows a repeating coil located permanently in a subscriber's line. The actual talking circuits of these two connections are the same, but in the second case it will be necessary to ring through a repeating coil in signaling the subscriber on that line, while in both cases the

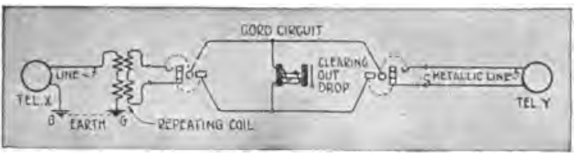


FIG. 215

REPEATING COIL IN GROUND RETURN LINE

ringing-off current from the subscriber's station will have to be repeated by the coil in order to operate the clearing-out drop. This drop is usually made with a large margin of sensitiveness so that any loss of energy in the repeating coil will not affect the operating of the clearing-out signal. This loss of energy in the repeating coil would, however, be of a serious nature in ringing the less sensitive bells on the long line, thus the method of placing the repeating coil in the cord circuit, as shown in Fig. 214, is preferable from a signaling standpoint.

Repeating Coil Efficiency.—Telephone repeating coils must be adapted to two kinds of service, one for talking through only, and the other a combination of talk through and ringing through.

Ringing current from a hand or power generator, has a rate of change of about 1,000 complete times per minute. This current is also of considerable magnitude, and in order to repeat it with little loss of enegry, the coil would have to contain a large amount of iron in a closed magnetic circuit and a great number of turns in the windings. In fact, the highest efficiency coil for ringing purposes only, would take on the form and size of the small commercial electric light or power transformer.

On the other hand, the most efficient repeating coil for talking purposes only, would have a very different construction, not unlike the standard telephone induction coil. Voice currents are of small magnitude, and have a high rate of change, an average of about 50,000 times per minute, which is fifty times that of the ringing current. This high rate of change requires a small amount of iron and a small winding in order to prevent waste of energy in the core and to give a responsiveness with low retardation effect, so that the voice currents will retain their original character. A talk-through repeating coil is shown in cross section in Fig. 216. This coil is designed for the transmission of voice currents without regard to signaling. This coil has not enough winding and core iron in its construction for ringing through to operate drops or ringers; but is especially adapted for toll work when talking efficiency is vital. It is seldom used on magneto switchboards on account of its inability to repeat ringing currents for signaling.

A repeating coil adapted for ringing througn as well as talking through, must necessarily be a

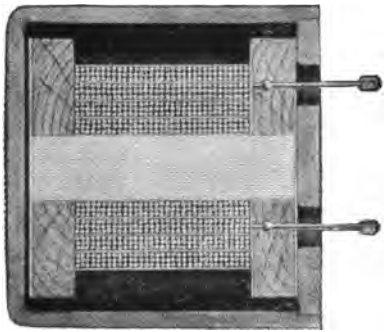


FIG. 216

SECTION OF TALK-THROUGH REPEATING COIL

compromise or average between the two extremes just described. The type of repeating coil, shown in cross section in Fig. 217 is designed to give the highest efficiency in a combination coil for both talking and ringing through. It has been found to give the best results for all kinds of local exchange work and will give satisfaction wherever used.

Both types of coils shown in Figs. 216 and 217 have four windings brought out to eight terminals, so that the middle points of the coils are available for various purposes. For regular service where only two windings are required, the middle terminals can be strapped together, thus combining two windings in each half of the repeating coil. Figs. 218 and 219 show how these middle windings may be used in common battery work. These repeating coils are inclosed in iron shells, copper-plated and oxidized, to prevent cross-talk due to magnetic induction, to or from other coils

FIG. 217
SECTION OF RING-THROUGH REPEATING COIL

and telephone apparatus. The windings are of silk-covered copper wire, insulated from each other and from the core and shells.

CORD CIRCUIT PRACTICE FOR MAGNETO SWITCH BOARDS

Although many are inclined to consider the telephone a comparatively recent invention, it must be remembered that its beginning dates back to a time when the entire science of applied electricity was new and in an extremely crude condition.

The modern principle of multiple or bridging connections of several pieces of apparatus on a single circuit, having not yet been discovered and the connection of electrical instruments up to that time having been confined to the old "series" scheme, it is but natural that the latter was the one attempted for the operation of the first systems of telephones.

The series arrangement for party line telephones proved a failure and was in time supplanted by the

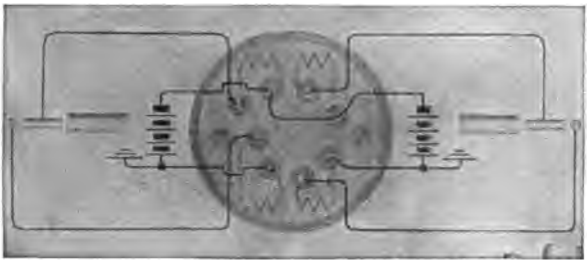


FIG. 218
TALK-THROUGH REPEATING COIL CONNECTIONS FOR COMMON BATTERY CORD CIRCUIT

modern bridging system, on which principle not only our telephones, but also our electric lights, street cars, motors and numerous other electrical devices of the present day are operated.

The fact that many exchanges are failing to give first-class service at the present time on account of this difficulty, makes it advisable to go to the bottom of the matter, explaining exactly what the trouble is and the simple method by which it may be overcome without discarding present equipment.

The first switchboards designed, being for use with lines equipped with the series telephones of early days, were very properly provided with series "ring-off" drops. These earlier boards were all of the single conductor type for use with the grounded or common return lines of that time.

The crude apparatus of the earlier days, operat-

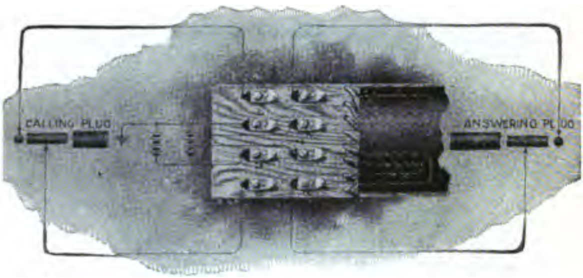


FIG. 219

REPEATING COIL CONNECTED IN COMMON BATTERY CORD CIRCUIT

ing under a straight series system throughout, aside from its poor talking, gave a more reliable service so far as disconnect signals were concerned, than do the majority of the mixed series and bridging systems so frequently found in service at the present day.

In their practical operation the bridging system of modern times and the series system of the earlier days are exactly opposite and but very little apparatus planned for use with one will operate properly with apparatus designed for the other. Thus it is a matter of common knowledge that series and bridging telephones will not operate successfully on the same line. But a principle almost as important, is the fact that series telephones should not be used in the same exchange with bridging telephones, and the ordinary type of

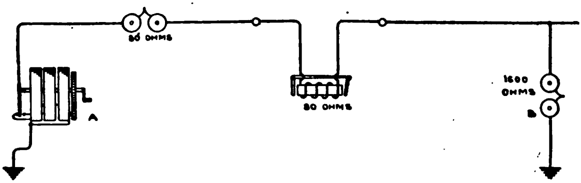


FIG. 220

SERIES TELEPHONE CONNECTED TO BRIDGING TELEPHONE

switchboard employing a single bridging ring-off drop to each cord circuit.

With the series arrangement both parties had to talk through the ring-off drop in order to get through the board. This is now known to be very bad practice and renders long distance service almost impossible.

The reliable ring-off feature of the earlier series boards was not lacking in case of the connection of two series party lines with each other, or in the case of the connection of a series party line to a private line having but one series telephone. In either of these cases, on the operation of the generator at any telephone on either of the two connected lines, *all* current produced passed through the central office ring-off drop, and under any circumstances one was almost assured of "getting central" with the first ring.

But the series arrangement of any great number of telephones on one line having proved a failure, on account of poor talking, necessity proved as usual, "the mother of invention," and soon, for party line service, the bridging telephone with its high wound ringer, was introduced in substantially the same form as it exists today.

The very first thing discovered in connection with the new 1,000 ohm and 1,600 ohm bridging telephones was that they could not be used one on a line with the series ring-off drop boards of that time. The condition prevailing when this was attempted is shown in Fig. 220.

It is to be noticed that when party "A" tried to "ring off," the high wound bell of party "B" would not allow enough current to pass to operate the ring-off at the board and in his efforts to "get loose" and get central's attention, party "A" would only ring through the board without throwing the drop and annoy party "B."

It was found that if two or more bridging telephones were added to "B's" line as indicated in Fig. 221 this trouble disappeared, since with four bells bridged from "B's" line practically four times as much current passed through the ring-off drop, enabling the same to operate. Parties on "B's" line (Figs. 220 and 221) had no trouble ringing off, because no matter what number of bridging telephones were on "B's" line, a large part of the current generated would pass through the ring-off drop on its easiest path back to ground through "A's" 80 ohm bell.

Thus it came about that while bridging telephones became the standard for toll and party line equipment, series telephones continued to be used for local city work, because with the series board

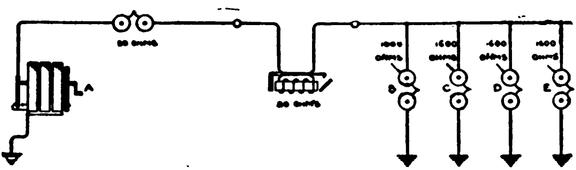


FIG. 221

SERIES TELEPHONE CONNECTED TO LINE OF BRIDGING TELEPHONES

the use of single bridging telephones was not practicable.

About this time the development of the long distance business proved the desirability of full metallic or two wire circuits, and the single wire grounded line for long talks was gradually abandoned. It was then found impossible to connect two metallic lines with a cord circuit having one ring-off in series, as shown in Fig. 222.

Such an arrangement cuts resistance into one side of the line, while the other side remains clear and, as a result, the metallic line becomes "unbalanced" and "noisy."

To overcome this difficulty it became necessary to use a bridging ring-off drop, as shown in Fig. 223.

This drop is high wound like the bells in the bridging telephones and, the line being connected

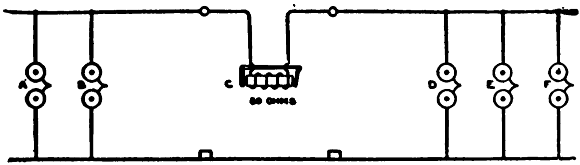


FIG. 222
SERIES RING-OFF DROP BETWEEN BRIDGING LINES

through the switchboard direct, it is as easy to talk through the switchboard as to talk past one of the bridging telephone stations out on the line.

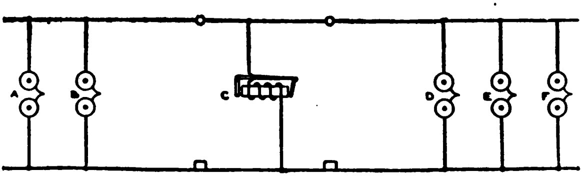


FIG. 223
BRIDGING RING-OFF DROP BETWEEN BRIDGING LINES

From the above it will be readily understood why good results were not had when a series telephone, or drop, was connected in circuit with a bridging set. However, many thousand series lines and boards are in use today, and the object is to show how good results can be secured, both talking and ringing, even though a bridging and series line are connected together.

This difficulty has been overcome by placing a condenser in the cord circuit between the two lines. The practice has proven a success and has made possible improvement in farm line service. The condenser lets the "thin voice currents" through

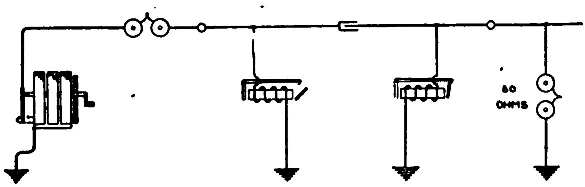


FIG. 224

NEW CORD CIRCUIT CONNECTING SERIES TELEPHONES

as readily as water passes through a sieve, while the "coarser ringing current" is held back and forced to go through the drops.

Fig. 224 shows the simplest condition for the connecting of two series city telephones. The lines are connected with each other through a special condenser.

This condenser passes talking current perfectly, although it will not permit of the passage of ringing current. The two subscribers are, therefore, connected for talking purposes only, which is the proper condition.

When either of the two connected subscribers attempts to ring-off or call central again, all ringing current produced by his generator goes through his own ring-off drop at the central office, none of it escaping to the connected party's bell or drop. The calling party's ring-off drop, therefore, operates in a reliable manner; the operator knows immediately which of the connected parties is ringing, and the second party's bell is not disturbed.

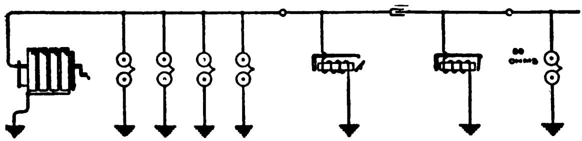


FIG. 225

NEW CORD CIRCUIT CONNECTING FARM LINE AND SERIES CITY 'PHONES

The high impedance ring-off drops will not permit voice currents to escape to earth at the board and they are, therefore, compelled to go on through the condenser out to the second party, who gets the talk practically undiminished in strength.

By installing the proper type of board, having two ring-off drops in each cord circuit, separated by condensers, the old 80 ohm telephones can be retained in city service with results, so far as supervision is concerned, as reliable as would be secured with new city telephones of the biased bridging type.

Taking up next in order the connection of heavily loaded 1,600 ohm rural lines with 80 ohm city lines, it has been found that the new type of split cord circuit with double ring-off drops gives the proper conditions, as shown in Fig. 225.

For the sake of clearness, all diagrams previously given have shown ground line conditions. All equipment of this type is arranged for use

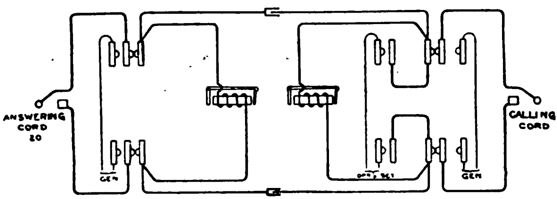


FIG. 226

DETAIL OF CORD CIRCUIT WITH DOUBLE DROPS AND CONDENSER

on either full metallic or ground line circuits. The cords, plugs and other parts are built for metallic service and it is only necessary to ground one side of the line circuits if single wire grounded or common return lines are to be used. The actual apparatus in each cord circuit with the double clearing-out drops, is shown in Fig. 226.

REPEATING COILS, CONNECTIONS, ETC.

It has long been known that the proper connection of a grounded local line to a metallic toll line requires the use of a repeating coil, which is placed in the switchboard cord circuit at the most convenient point, and rarely will a board be found in service that does not have repeating coils in

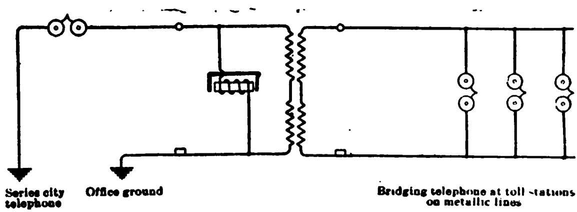


Fig. 227

OLD STYLE REPEATING COIL CORD CIRCUIT, DROP ON LOCAL LINE

one or more pairs of cords for the connection of ground and metallic lines. These repeating coils have been used for the most part in connection

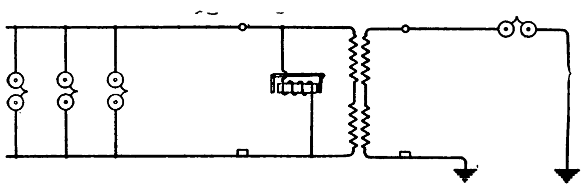


Fig. 228

OLD STYLE REPEATING COIL CORD CIRCUIT, DROP ON TOLL LINE

with cord circuits having but one ring-off drop, the actual condition with a grounded local line connected with a metallic toll line being as indicated in Figs. 227 and 228.

In Fig. 227 the toll line has called the local subscriber and the plugs have been so inserted that the ring-off drop is on the local subscriber's side of the repeating coil. In Fig. 228 the conditions are reversed and the ring-off drop is on the toll line side of the coil. In the first instance the toll line cannot operate the ring-off drop without ringing through the repeating coil, while in Fig. 228 the local subscriber cannot ring off without ringing through the repeating coil.

These conditions have led to the endeavor to

FIG. 229

REPEATING COIL FOR RINGING AND TALKING

produce a so-called "ring through and talk through repeating coil," a standard type of which is shown in Fig. 229.

This coil is of large size and has a large number of turns of wire with a comparatively low resistance and performs repeating of both ringing and talking currents. Nevertheless, when used in connection with series telephones in cord circuits having but one ring-off drop, as in Figs. 227 and 228 great difficulty in ringing off is encountered, especially by the line on the opposite side of the coil from the ring-off drop. Furthermore, the design of the coil, so as to pass ringing currents, has, to a certain extent, interfered with its efficiency as a talking coil and for talking purposes only, a smaller type of coil will be found more efficient.

Such a coil is shown in Fig. 230, while Fig. 231

FIG. 230
REPEATING COIL FOR TALKING ONLY

shows the proper conditions for perfect ringing and talking and also reliable ring-off drops. It will be observed that separate ring-off drops have been provided for each of the connected lines. Condensers placed at the middle points of the repeating coil's windings prevent the escape of ringing current and compel all ringing current entering the exchange from either line to go through the proper ring-off drops and operate the same in a reliable manner.

It might at first appear that the presence of the extra ring-off drop and of the two condensers would noticeably cut down the talking efficiency, but such is not the case. The small repeating coil is much more efficient for talking purposes than the large high impedance coil that must be used for ring through work. For this reason the circuit shown in Fig. 231, using the small repeating coil, shown in Fig. 230, is not only perfect in regard to re-

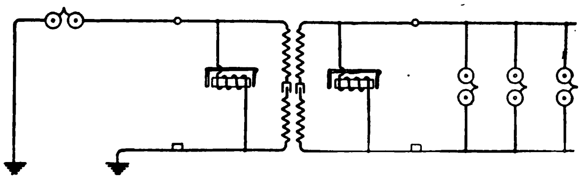


FIG. 231

NEW REPEATING COIL CORD CIRCUIT WITH DOUBLE RING-OFF DROPS AND CONDENSERS

liable operation or ring-off drops, but is even more efficient as a talking circuit than that of Fig. 227, using the large coil without condensers and with only one ring-off drop.

Reliable ring-off conditions being even more important in connection with toll lines than in ordinary exchange work, the circuit shown in Fig. 231 is the one that should be used whenever any grounded line, either toll or rural, is connected with any toll or rural metallic line. Repeating coils need not be used in connecting ground lines to short metallic local exchange lines, unless the local lines are subject to electric light induction or other disturbances. When such disturbances are present, repeating coils should be used the same as in connections between ground and long distance metallic lines.

It will be seen that in Fig. 231 either of the two connected lines can throw their ring-off drop with the same degree of reliability as they can throw the line drop itself. Furthermore, when either of the two connected lines rings in, only one of the two ring-off drops will be operated and no bells will be disturbed on the other line. This enables the operator to tell immediately which of the two connected lines is calling, which is impossible with the ordinary cord circuit having the single ring-off drop.

SWITCHBOARD PROTECTORS

All switchboard and telephone apparatus should be protected when the lines are exposed to lightning, high potential currents, leakage or sneak currents. Even if it were possible to construct switchboard apparatus so as to be proof against these various currents, there would still be liability of injury to the operators if sufficient protection were not provided.

Arresters.—With small installations it is customary to provide a combination protector consisting of a carbon block arrester combined with a low-carrying capacity fuse. The former provides a ready path to ground for the high potential lightning charges which collect on the line circuit, while the latter serves as protection by fusing, when sufficient current to do damage to the apparatus passes through it. Fig. 232 and Fig. 233 show a combined protector and distributing board. In this combined protector and distributing board postal type mica base fuses with copper ends are used, and are fastened securely to the terminals by clamping screws. These terminals have a slanting surface arranged so that the fuse can easily

FIG. 232
VIEW OF PROTECTOR AND DISTRIBUTING BOARD

be removed without interfering with adjacent fuses. The line cable terminal clips, located on the bottom of the strip, are connected to the right-hand fuse terminal by a copper wire soldered in place, as shown in the dotted lines, Fig. 233 Thus a reliable circuit is provided from the line cable to the switchboard, which is not affected in any way by shrinking or swelling of the woodwork. The ground plate has spring clip projections which serve to hold the two carbon blocks and interposed mica separator of each line. This construction allows the carbons to be easily removed and replaced for cleaning after lightning storms, as it is necessary to remove all dust caused by electrical discharges from between the carbons.

The carbon blocks serve as a lightning protection while the heat coil serves as a protection from sneak or low potential currents, which are usually not of enough magnitude to blow a regular fuse, but in time would heat up the small wires in the

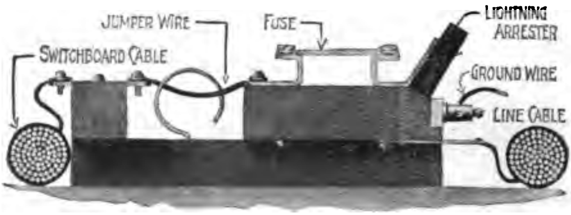


FIG. 233

SECTION OF PROTECTOR AND DISTRIBUTING BOARD

apparatus windings and thus cause damage. The action of the heat coil depends on the melting of a low-fusing solder through the heating effect of the sneak current. Fig. 234 shows a diagrammatic view of the circuit of one metallic line from the line cable to the switchboard cable including the protector. The operating of a heat coil opens the circuit to the switchboard, grounds the line, and closes a local contact which will ring an alarm bell if desired. The alarm bell circuit is shown in light tint in Fig. 234.

Fig. 235 shows a strip of 100 pairs of this protector for 100 metallic lines. The base of the strip is made from steel and the protector is otherwise constructed so as to be fire proof. These arrester strips are usually mounted on a metal framework together with the switchboard terminal clips and jumper rings, thus constituting what is

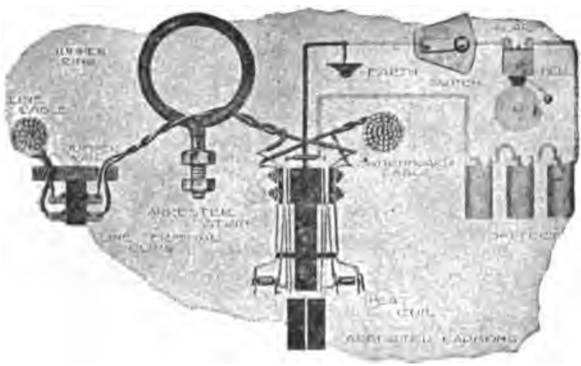


FIG. 234

HEAT COIL PROTECTOR AND ALARM

known as a main distributing frame with protective apparatus. Another type of arrester strip can, however, be separately mounted on metal brackets without the terminal clips and jumper rings.

A testing plug is made to slip under the springs of the metallic circuit protector for making the regular line and switchboard tests.

SWITCHBOARD CABLE FORMING

Where drops and jacks are wired out with

FIG. 235
PROTECTORS—100 PAIR STRIP

lengths of switchboard cable the only work necessary to connect up the lines is to attach this cable to the distributing frame or arrester clips. In order to prevent confusion, the ends of these cables must be brought out and attached to the terminal clips so that the drop numbers will correspond to the terminal clip numbers.

After the cables are laid in their permanent

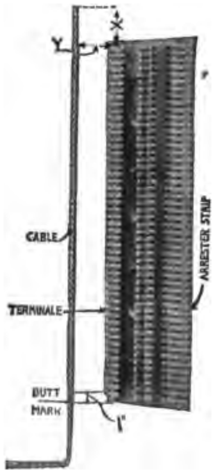


Fig. 236

LINING UP CABLE AT PROTECTORS

positions, the free ends should be lined up parallel to the arrester strips to which they are to be attached, as shown in diagram, Fig. 236. The end of each cable should extend a distance X beyond the top clip of the strip to which it is to be attached, this distance being about one inch longer than the space Y between the cable and strip.

The diagram also shows the location of the buttmark, which should be made about one inch below the lowermost clips included by the cable.

Stripping.—The outer covering from the buttmark to the end of the cable is first removed so as to expose the twisted pairs of wires. This operation can easily be accomplished by using a sharp pocket-knife, as shown in Figs. 237 and 238, being

Fig. 237
SLITTING SWITCHBOARD CABLE

careful not to cut through the paper binding and injure the insulated wires. Fig. 237 shows the knife blade held on a slant, tangent to the circular cross-section of the cable in the operation of cutting from the buttmark to the end of the cable, while Fig. 238 shows cutting around the cable at the buttmark so as to leave a clean edge to the braiding. The paper binding strips which are under the braiding should also be removed and cut away at the buttmark.

Butting.—A strip of linen tape, one-quarter inch in width, should next be bound tightly around the exposed edge of the cable covering. The various operations of doing this binding, which is called a cable butt, are shown in Fig. 239. First, the forming of the loop; second, the winding of the long end b of the tape around the cable four or more complete turns and threading same through the loop first formed; third, the drawing of the end b under the turns by pulling the end a,

FIG. 238

CUTTING COVERING OFF SWITCHBOARD CABLE

which act closes the loop; fourth, the cutting away of the loose ends a and b close up to the turns. It is a good plan to shellac the completed butt, as it will prevent the turns from loosening or becoming disarranged.

WAXING.—The exposed twisted pairs of wires should now be boiled in beeswax or paraffin up to the butt and including it, until all bubbles in the liquid disappear. The wax serves the double purpose of a moisture repellent and a means of preventing the insulation of the wires from loosening up while performing the succeeding operations.

All surplus wax should be removed from the wires by lightly whipping the cable end against a board immediately upon taking it from the boiling liquid.

FORMING.—A soft wood board should now be

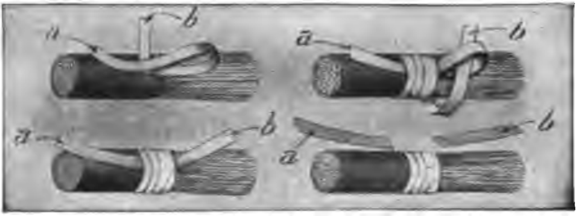


FIG. 239

BUTTING SWITCHBOARD CABLE

marked off similar to Fig. 240. The lines E F and S L should have a separation equal to the distance the cable is to be located from the clips when strapped in place, and the lines S L and G H a

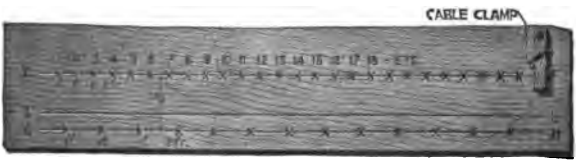


FIG. 240

FORMING BOARD LAYOUT

separation of about one inch. The points c c c, etc., located on the line E F, are spaced to conform to every other terminal clip, so that when a pair of wires is brought out at each of these points they will be exactly opposite a pair of clips on the distributing frame or arrester strip. Wire nails are driven in at these points and at the points d d d, etc., on the line G H. The board thus arranged is called a temporary form over which the prepared end of the cable is to be fanned out. The cable is now clamped at the butt to the forming

FIG. 241

FANNING OUT CABLE ON FORMING BOARD

board, as shown in Fig. 241, then each pair of wires is selected in numerical order according to the color code dyed in the insulation of the conductors, and drawn into place around each successive nail, c c c, etc., and fastened to nails d d d, etc. The spare pair of wires is left projecting at the end of the cable, as it is only intended for use in case one of the regular pairs becomes defective. The formed part of the cable is sewed up with a stout, waxed, linen twine, preferably "six-ply, Boston lock-stitch," by the aid of a four-inch packer's needle which facilitates passing the twine under the bunch of wires. Fig. 242 shows a secure way to thread this needle and prevent the twine from pulling out of the eye. Before commencing

Fig. 242
ATTACHING THREAD TO NEEDLE

sewing, two turns of the twine should be taken next to the butt, drawn up tight and tied with a knot similar to that shown in Fig. 243, in which a

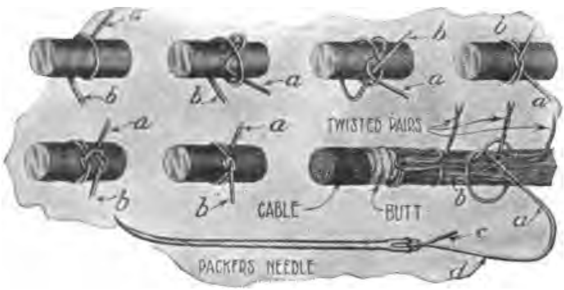


Fig. 243
STARTING THE LACE-UP

is the needle end of the twine and b the short end. The loose wires are bound together from this point to the end of the form with what is called a lock-stitch, shown in the last operation, Fig. 243. A stitch is taken at each nail, and if the space between is over one inch an extra stitch should be taken. In making this stitch the needle is passed under the wires and through the loop, as in Fig. 241, being careful not to include the nails in the loop or stitch. If it is properly done, as shown in the illustrations, the loop will hold without loosening after the strain is removed from the

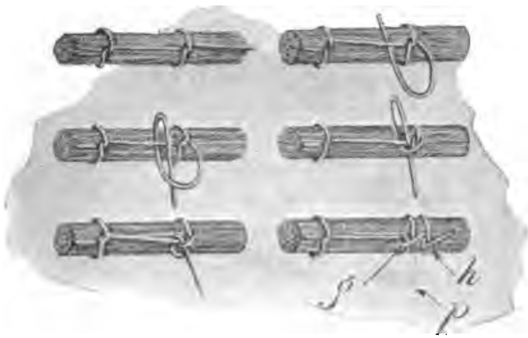


Fig. 244

METHOD OF MAKING LOCK STITCH

needle end of the cord. The last regular lock-stitch, taken where the last pair of wires leads off, is reinforced by the knot g, Fig. 244, after which it is preferable to take another stitch and knot h around the spare wires and on the other side of the last regular pair p.

Skinning.—Before taking the cable from the forming board, the ends of the wires should be cut off even with the line of nails d d d, etc., Fig. 241, and the insulation removed from the ends of each with the line S L as a guide. This latter operation can be performed with a sharp knife, as shown in Fig. 245, by drawing it from the skinning line S L toward the ends of the wire, at the same time pulling on the covering which will slip

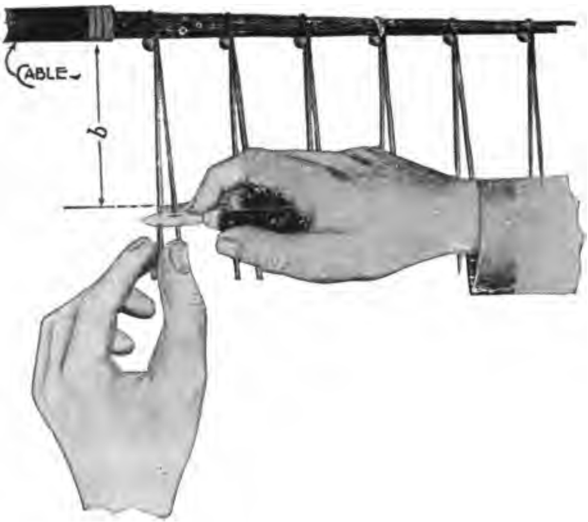


FIG. 245
SKINNING WIRE ENDS

off as soon as the insulating threads are severed. Great care must be taken not to nick the wire, as it will be liable to break at the weakened point upon being moved or handled.

SOLDERING.—If the terminal clips are provided with connectors, no soldering will be necessary, as the bare ends of the wires can be readily clamped to the clips. The wire with the white insulation should always be connected to the uppermost clip of the pair, as it comes from the top spring of the line jack and goes to the tip side of the line wire. The colored mate should be connected to the next clip, as shown in Fig. 246.

If the wires are to be soldered to the terminal clips, their bare ends should first be threaded through the holes in the clips up to their insulated covering and bent back, or, if no holes are provided, they should be wound once around the

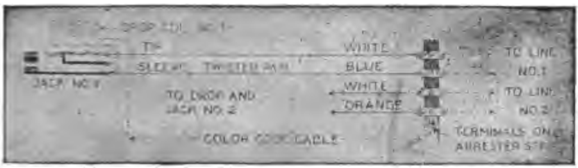


FIG. 246

USE OF COLOR CODE

notched portion of the clip. Care should be taken not to have any of the insulation in the hole or notch of the clip, as in that case it will be impossible to make a clean job of soldering. *Acid must not be used under any conditions,* as it forms a good conductor for the voice and generator currents, and cross-talk or generator noise will result from the leakage from one line to another. Resin core solder is the safest and quickest for all switchboard use, as the flux is fed in the right quantity to do good work. After soldering, the free end of the wire should be cut off close to the clip and each joint tested to detect any imperfect work.

The cable can now be strapped in place with leather saddles, or bound to the distributing frame with lock-stitch twine or tape. After the exposed wires are smoothed up, they can be given a coat of white shellac for a finish. This is not necessary, but is preferable for a good job, as it keeps dust and dirt from sticking to the wax or paraffin in which the wires have been boiled.

LEAD-COVERED CABLE

The importance of lead-covered cables in outside construction is a subject which should engage the special attention of telephone cable men and repair men.

Telephone cables rely upon both paper and air for insulation between the conductors, and as the least moisture will spoil the insulating qualities, it is necessary to keep the lead sheath or covering sealed at all times. It will be noticed that cable is received from the manufacturers with the ends hermetically sealed for this same reason; therefore, when a cable sheath is opened for any purpose it should be sealed up as soon as possible, for, in the meantime, an opportunity is afforded for the entrance of moisture from the surrounding atmosphere. When the time can be chosen for making splices or doing other work on cable, dry days only should be used, and each job completed before leaving. The mere description of the making of a cable splice or pot head is not sufficient for actual work, as a great deal of practice is required to produce reliable results. In case of an emergency, however, or when an expert or experienced cable man cannot be had, the following simple instructions may be of great help to the telephone repair man.

Cable Splicing.—When preparing to splice a cable, always plan to finish the job without delay

Fig. 247
SLITTING LEAD SHEATH

and to keep the open cable dry, and remember that in new work wires can be joined without regard to the numbering of pairs, but that wires of the same color must be joined together in splicing each pair.

When ordering new cable, three feet should be allowed at each end to be used for splicing or for terminal or pot head connections, in addition to the waste ends which are thrown away in any case.

For a simple example of splicing, two cables of the same size will be taken:

1. Cut back the lead sheath of the cable so as to give from eighteen to twenty-four inches of good insulated conductors. The size of the cable determines this length, the cable with the greater number of pairs requiring a greater length of free conductors to make a splice which will not be too large in diameter to give a neat and compact job. Figs. 247 and 248 show the operations of

FIG. 248
CUTTING OFF LEAD SHEATH

cutting the sheath. A simple knife held on a slant, tangent to the circular cross section of the cable can be readily driven through the lead in cutting back the sheath, without fear of injuring the conductors. In cutting around the sheath the knife is driven nearly through the lead, which is sufficient to cause the sheath to break off. The sharp edge of the lead left after the end of the sheath is removed should be smoothed off and the paper packing unwrapped so as to expose the conductors, leaving about one-quarter of an inch standing to prevent the sheath from cutting the insulation of the wires. (See Fig. 249.) A few turns of cotton wicking or twine is sometimes

FIG. 249
SHEATH CUT OFF

bound around the wires next to the lead sheath for the same purpose.

2. The ends of the cable, up to the lead sheath and including it, should now be immersed in boiling paraffin until the bubbles cease rising. These

FIG. 250
SPLICING PAPER INSULATED CABLE

bubbles are due to air and moisture which must be removed in order to protect the exposed ends of the cables.

3. The lead sleeve which is to cover the splice after it is finished is slipped over the end of one

of the cables far enough back to be out of the way while working on the splice. These sleeves can be obtained from the cable manufacturers and should be between one and one-quarter and one and three-quarters of an inch larger in diameter than the cable to be spliced, and long enough, allowing for a small diameter splice, to overlap one inch and a half or more at each end for the wiped joints. The length of sleeves for various sized cables increases proportionately from eighteen inches for a ten-pair cable to twenty-six inches for a two-hundred-pair cable, depending upon the gauge of the cable conductor and the experience of the cable splicer, less experienced men requiring longer sleeves to cover their joints.

4. The two cables are securely supported so that the ends of their lead coverings will be from three to four inches nearer together than the length of the lead sleeve which is to cover the completed joint. Preparatory to splicing the wires, the conductors are turned back out of the way without disturbing the twists in the pairs, as shown in Fig. 250.

5. Commence splicing one pair at a time by cutting one conductor of the pair of one cable about four inches and the other conductor of the same pair about two inches from the lead sheath. Untwist this pair and the one to be spliced to it a sufficient amount so that two paper tubes, from two to three inches long, can be slipped over a different colored conductor of each pair, as shown in Fig. 250. Then clean or scrape off the paper

covering of each conductor for about an inch back and bend the bare ends of the same colored insulation at right angles to the length of the cable and twist these ends tightly together. The soldering of this joint is not necessary for good contact. Clip off any surplus on the ends of the twisted joints and bend down parallel to the two wires of the pair, drawing the paper tubes over the joints to cover them evenly and to clear each other, as

FIG. 251

SPLICING PAPER INSULATED CABLE, PAPER SLEEVES IN PLACE

shown in Fig. 251. Proceed to splice the remaining pairs in the same way, being careful to offset the joints so as to avoid bunches by distributing the work evenly between the ends of the cables. The pairs are sometimes spliced in groups with an offset of about three inches between each group, the whole being calculated to fill the space. Some engineers favor splicing inside pairs of one cable to outside pairs of the other cable, and in that way distributing the electro-static capacity.

6. After the joints are completed, boiling paraffin is ladled over the splice, as shown in Fig. 252, until all bubbling in the liquid paraffin has ceased. A strip of muslin about one inch in width should be bound around the splice to keep the joints in place, as shown in Fig. 253. This wrap-

Fig. 252
BOILING OUT SPLICE WITH PARAFFINE

ping should be done as soon as possible after the preceding operation and before the paraffin in the splice cools. The splice should now be subjected to a second application of the boiling paraffin.

7. The lead sleeve is now drawn into place over the splice so as to overlap both ends equally from one and one-half to two inches or more at each end, depending upon the size of the cables. (See Fig. 254.)

The succeeding operations of wiping the joints should, in the absence of a cable splicer, be done by a plumber.

The ends of the lead sleeve are hammered down with a plumber's maul until they tightly grasp

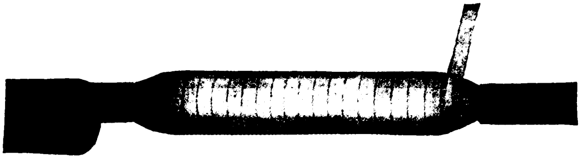


FIG. 253
SERVING SPLICE WITH MUSLIN TAPE

the lead sheath of the cables. The ends of the sleeve and the cable sheaths next to the joints should be scraped clean with a plumber's scraper, care being taken not to touch the brightened surface during the process of wiping. Paper ribbons

FIG. 254
LEAD SLEEVE IN PLACE

are now pasted around the cables one inch from the sleeve itself, as shown in Fig. 255. These rings prevent the solder from sticking to the lead outside of the space alloted to the joints, and upon removal after the wiping is completed, gives a finished appearance to the job. A special, quickdrying paint is sometimes used instead of the paper strips. The brightened lead surface is now covered with tallow by thoroughly rubbing it with a pure tallow candle before pouring on the solder.

FIG. 255
LEAD SLEEVE BEATEN DOWN AND PAPER STRIPS APPLIED

The hot solder is now carefully poured from a spoon, held in the right hand, over the prepared joint, the overflow of solder being caught in a

FIG. 256
WIPING THE JOINT

tallow-covered wiping rag held in the left hand. (See Fig. 256.) Hot solder should be ladled back and forth over the cable and sleeve so as to get it hot enough to wipe without melting through the sheath. The wiping rag should retain only enough hot solder to furnish the heat necessary for wiping the lower side of the joint. As soon as the solder and lead mix together, the pouring should cease and the wiping of the joint begin. While finishing the latter process, to make a perfectly tight joint the utmost care must be exercised to prevent cracks and blow-holes.

The composition of wiping solder varies with different users, but the most common is known as "half-and-half solder," made from equal quantities of tin and lead. Some splicers prefer a small quantity of sulphur added to the solder before using, taking care to skim off the slag after the sulphur is consumed.

The wiping operation completes the splice, which should of course be thoroughly tested out.

POT HEADS.—The paper-covered conductors of a lead-covered cable are usually brought out by splicing regular insulated wires to them and protecting the joints by a lead-covered sleeve filled with a sealing compound. This joint, which is practically a cable splice with one end open, is known as a pot head.

In making a pot head, the paper cable is prepared as for a regular splice, and the twisted-pair conductors are immersed in boiling paraffin to keep the paper from untwisting and exposing the wire. The cables should not, however, be boiled out as in the case of the splice. The paper insulated wires are bound tightly together as they leave the sheath with several layers of twine, to prevent the sealing compound from entering the cable.

If rubber-covered wires are to be spliced to the cable for weather-proof work, No. 19 B. and S. gauge, twisted pair conductors, are usually taken as a standard, the rubber covering of one wire of the pair being black and the other red. The black wire is usually taken as the tip conductor and should always be joined to the white paper-covered conductor, while the remaining two wires of the two pairs should be joined together. All the other pairs should be connected in the same manner.

Before commencing to splice the conductors, a lead sleeve, used for covering the joints, should be slipped over the end of the lead-covered cable and out of the way of the workman. These sleeves vary from one inch to two inches larger in diameter than the cable, and from eighteen inches in length for a ten-pair cable to twenty-six inches in length for a two-hundred-pair cable. An experienced splicer usually depends upon his judgment for the proper size of sleeve to cover the joint.

After the paper cable is prepared for splicing, operations enumerated under No. 5, on page 404, are followed, and in addition to these instructions it is usually considered advisable to solder the twisted wire joints. If the outside wires, however, are well tinned and can be thoroughly cleaned so as to make a reliable joint, it will not be necessary to use solder. The spliced wires should now be opened up as much as possible, so as to leave free spaces between for the compound, and then bound or sewed together with twine, after which the lead sleeve should be slipped into place and joined to the lead cable with a wiped-joint connection. The operation of wiping this joint is the same as for a regular cable splice.

Some engineers recommend that the rubber-covered wires be bound together with rubber tape for about three inches, where they are to emerge from the sleeve, so that one-half of the taped wire will be below the surface of the compound when the pot head is finished.

A thin brass tube, about one-half of an inch in diameter and two and one-half inches shorter than the lead sleeve, is sometimes bound alongside the wires of the splice with the lower end even with the end of the cable sheath. The object of this tube is to serve as a vent for the escape of air or gases while filling the sleeve with the compound.

The open end of the sleeve is now sealed by an insulating compound, consisting of pitch, asphalt and resin, boiled together until it runs freely. Another preparation often used is known as D.D., or Chatterton compound. The sealing compound is poured into the pot head while boiling, and is continued until no more bubbles appear, the joint being left nearly full (about one-half inch from top of sleeve). In order to prevent melting or unduly softening the rubber insulation of the outside wires, it is advisable to test the compound just before pouring, by immersing in it a small piece of the wire. If the insulation is not softened so as to be readily removed, the compound is not too hot.

Paraffin should never be used in pot heads nor in any filling where rubber-covered wires are used,

FIG. 257
STRUCTURE OF POT HEAD

on account of its detrimental effect on rubber insulation. Furthermore, cracks are liable to develop in this kind of filling which will admit moisture into the pot head.

Fig. 257 shows component parts of cable pot head.

COMMON BATTERY MULTIPLE SWITCHBOARDS

To obtain a thorough understanding of the multiple switchboard it is essential to study the more important circuits, as these convey to the reader in the most concise and direct manner a clear idea of what may be expected in the way of operation.

Fig. 258 shows the circuits of a connection between two regular subscribers in the Kellogg common battery switchboard. The operation succintly stated, is as follows:—

To call central, the subscriber removes his receiver from the hook thus lighting the line lamp at the central office. The operator answers by inserting the answering (back) plug of any pair of cords into the jack corresponding to the line lamp, thereby extinguishing the same. She then throws her listening key which connects her talking circuit to the subscriber's line.

After obtaining the number of the subscriber desired, the operator tests the multiple jack of the line called, and if the same is idle, inserts the connecting (front) plug into it and rings. This action causes the supervisory lamp associated with this plug to light and remain lighted until the called-for subscriber removes his receiver from the hook, when it will be extinguished.

When either subscriber hangs up his receiver, the lamp associated with the cord with which his

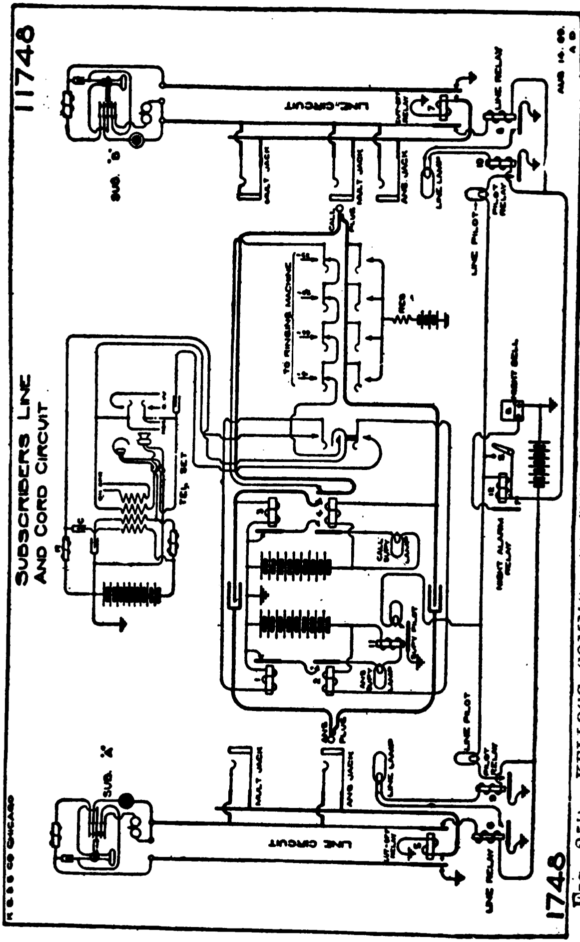


FIG. 258 KELLOGG COMMON BATTERY MULTIPLE SWITCH-BOARD CIRCUITS

line is connected will light up. When both subscribers have hung up, lighting both line lamps, the operator knows that the conversation is finished and takes down the connection without listening in.

Should either subscriber desire to attract the operator's attention he can do so by working the receiver hook up and down, thereby flashing the supervisory lamp. By this system of supervision the operator knows at all times the exact condition of each connection without listening in.

From the foregoing brief statement of operation it might be difficult for those not familiar with common battery equipments to follow the changes in the circuit, so that here a fuller description will be given referring to the notations on the accompanying diagram, Fig. 258, in order that the various steps may be easily followed.

Subscriber A desiring a connection removes the receiver from the hook, which closes the line circuit, causing the line relay 6 to attract its armature, which in turn completes a circuit through the line lamp and pilot relay. The pilot relay, upon being energized, closes the circuit through the pilot lamp. The operator, upon seeing the line signal, inserts the back plug into the answering jack associated with the lighted lamp. This action completes a circuit which may be traced from battery through relay 2 and the cut-off relay 5 to ground. Also through the line conductors, the telephone instrument and relay 1 to ground side of battery. This flow of current energizes all three relays. The operation of the cut-off relay extinguishes the line lamp. The other two relays have no action at the present time except to feed battery to the line circuit.

The operator now ascertains the number of the party desired and then tests the called-for line by touching the sleeve of the multiple jack with the tip of the calling plug, and if the line is not in use she inserts the same and rings. Until subscriber B answers, no current flows through relay 3, but relays 4 and 7 are operated as soon as the plug is inserted into the multiple jack. The operation of relay 4 closes the tip conductor of the cord circuit and also completes a battery circuit through the back contact of relay 3 and the calling supervisory lamp. This lamp remains lighted until the subscriber answers by removing his receiver from the hook. This action completes the circuit through relay 3, thereby causing it to draw up its armature, breaking the lamp circuit.

When the conversation is over and the receivers are returned to the hooks, the trip relay associated with each cord is de-energized, thereby allowing their armatures to fall back, lighting up the supervisory lamps.

Should the line desired be busy when the operator touches the sleeve of the multiple jack with the tip of the plug, she will get a click in the ear, due to the fact that as a plug is already in one of the other jacks of this line there is live battery on the sleeve of each jack connected to the line. The condenser C is normally charged by virtue of being connected directly in the battery circuit between one winding of the induction coil and the retardation coil R. When the listening key is thrown and the tip of the plug brought in contact with the sleeve of the jack of a busy line, the condenser is discharged, as the potential on one side is made equal to that on the other. This arrangement gives a positive test and at the same time the click given is not sharp and unpleasant as in the so-called direct test.

It will be seen that in the four-party ringing key, shown in the cord circuit, there are no series talking contacts whatever. The tip conductor of the cord runs directly to the armature of the tip supervisory relay. This arrangement simplifies the construction of the ringing key to some extent as all other four-party systems have from one to eight series contacts in the talking conductors of the four-party key alone. This arrangement is an advantage, as the fewer contacts in any conductor, and especially the talking conductor, the better. The cord circuit has only the one relay contact in one of the talking conductors, thereby reducing the chances of trouble from poor contacts to a minimum.

"TRUNKING"

In large cities, covering a great many square miles, it is advisable to use several exchanges instead of bringing all the lines into one large central office. The reason for this is the great saving in the cost of excessive line equipment and construction work, as well as the additional cost of maintenance. The method in use in this country is to divide the large cities into exchange districts, each district having its own telephone exchange with connecting lines to all the other exchanges, thus permitting the subscriber to be readily connected to any other subscriber in the city.

The number of these connecting lines or trunks, as they are called, must be determined by local conditions. For instance, two exchanges located in congested business districts should have more interconnecting trunk lines than between smaller exchanges and an exchange located in a residence district. In determining the probable number of trunks needed, one must take into consideration the occupation and number of subscribers in each individual exchange district. This very often becomes a complicated problem, especially if there are many exchanges.

Naturally the operation is more complicated where trunk lines are used in completing the connection than for connections between subscribers of the same exchange. The handling of such connections requires the aid of two operators—a subscriber's operator at the board where the call originates, and the incoming trunk operator at the board where the called for party's line terminates. The trunk line terminates at the calling subscriber's board in jacks multipled in each section, which are called out-going trunk lines, and at the trunk board in cords and plugs, designated in-coming trunks. The out-going trunk multiple jacks are placed in a space between the answering jacks and the regular subscriber's multiple jacks in each subscriber's section, while the incoming trunk cords are placed in the plug shelf in front of the in-coming trunk operator, as shown in Fig.

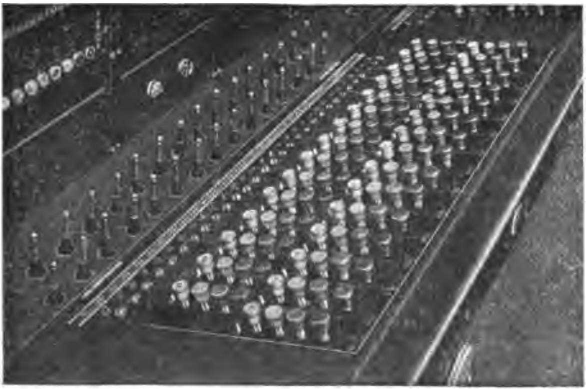


FIG. 259

TRUNK POSITION KEYBOARD

259. Each in-coming trunk operator is usually expected to handle about thirty in-coming trunks.

When a local subscriber desires a connection with a subscriber located at another exchange, he calls up in the usual manner, and the operator upon learning the number of the desired party, speaks over an order circuit to an in-coming trunk operator at the exchange in which the called for party's line terminates, and gives the number of the called party.

The in-coming trunk operator in turn gives the subscriber's operator the number of the trunk line to use. The subscriber's operator then inserts the calling plug of the cord circuit into the multiple

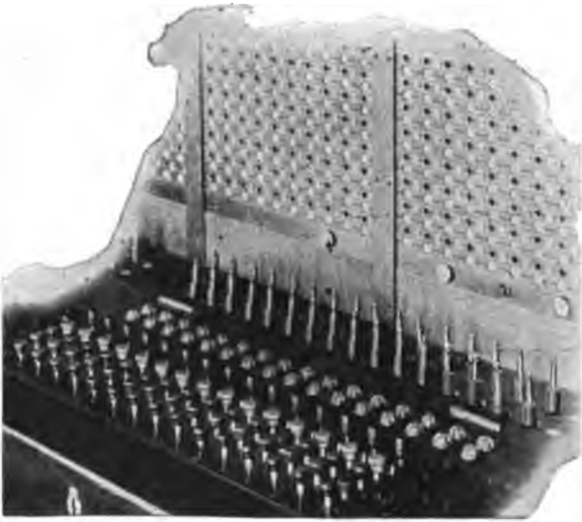


FIG. 260
"A" OPERATOR'S POSITION

jack of the trunk assigned. The incoming trunk operator then tests the line called for, and if found busy, inserts the trunk plug into the busy-back jack. This act flashes the supervisory lamp at the local board, Fig. 260, and at the same time gives the calling party an audible busy signal. If the line is not in use, the trunk operator inserts the plug into the jack and rings. Should the subscriber's operator plug into the designated out-going trunk multiple jack before the trunk operator has inserted the trunk plug into the multiple jack of the called for line, the disconnect lamp associated with this trunk at the in-coming trunk operator's position will light. But as soon as the trunk plug has been inserted into the multiple jack, the disconnect lamp will be extinguished, in case it has been lighted, and the ringing lamp will light and remain lighted until the subscriber removes his receiver from the hook.

When the called party hangs up his receiver, the disconnect lamp associated with the subscriber's cord, which is connected to his line through the trunk circuit, lights up, and the operator removes the connection providing the calling party has given the disconnect signal. The act of withdrawing the plug from the trunk jack causes the disconnect lamp at the incoming trunk operator's position to light up, and the operator immediately removes the connection.

In the foregoing has been given, in a general way, the operation of a trunk connection; but as it might not be clear just how some of the actions were brought about, the operation from the time the subscriber's operator inserts the calling plug into the out-going trunk multiple jack is given below in more detail.

Assuming that the trunk plug has not been inserted into the line jack; the sleeve relay 4 in the cord circuit, as well as the high resistance relay

14 in the trunk circuit are energized, Fig. 261. The tip relay 3 does not receive sufficient current, due to the high resistance of relay 14, to pull up its armature, consequently the calling supervisory lamp in the cord circuit remains lighted. As soon as the trunk plug is inserted into the line jack, relay 18 will be operated, opening the circuit through the disconnect lamp, at the same time completing a circuit through the ringing lamp. When the called-for party answers, relay 16 will be energized by the completion of a circuit through the line and telephone instrument. The operation of this relay brings about several actions. First, the placing of the shunt around relay 14, thereby de-energizing the same, and at the same time furnishing a low resistance path for battery through relay 3 in the cord circuit, which, upon being energized, extinguishes the calling supervisory lamp. Second, it completes a circuit from battery through relay 17 to ground. The operation of relay 17 extinguishes the ringing lamp, which is prevented from relighting during the conversation by the locking of this relay on itself, which can be released only by the withdrawal of the trunk plug from the jack.

When the party connected with the trunk cord returns the receiver to the hook thereby opening the circuit, relay 16 will be deenergized, allowing its armatures to fall back; one armature will open the shunt around relay 14. This act will cause relay 3 in the cord circuit at the subscriber's board to release its armature, which will light up the

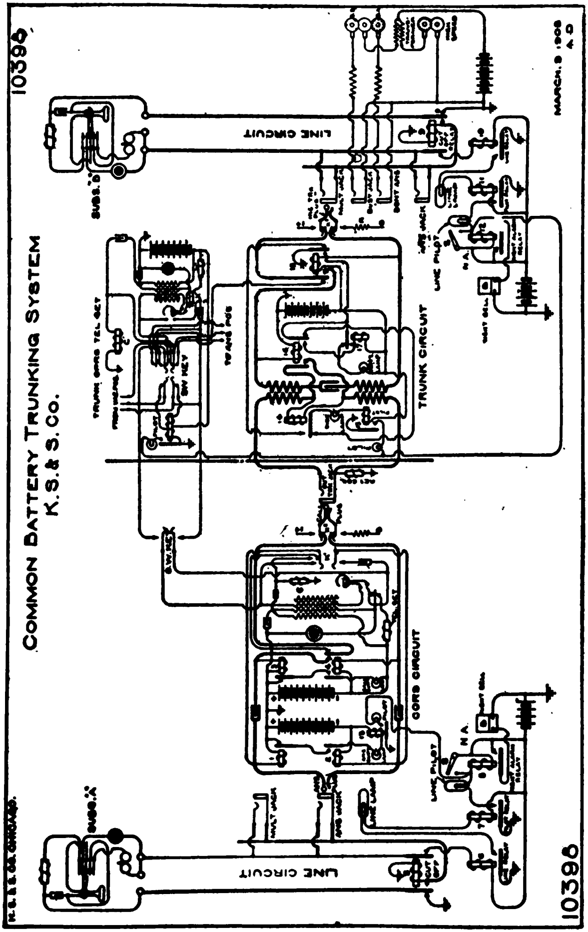


FIG. 261

KELLOGG COMMON BATTERY TRUNK CIRCUIT

disconnect lamp associated with the plug inserted in the out-going trunk multiple jack.

When the subscriber's operator takes down the connection, relay 14 in the trunk circuit will return to normal, thereby completing a circuit through the disconnect lamp, which may be traced from negative back through the pilot relay and disconnect lamp, the battery contacts of relays 14 and 16 and the armature of relay 18 to ground. The trunk operator now removes the connection, thereby releasing relay 18 which, in turn, opens the circuit through relay 17 allowing all apparatus to return to normal.

CHAPTER XVI

STANDARD MULTIPLE SWITCHBOARDS

Multiple switchboards are built of all sizes. Standard size sections are built for an ultimate of 3000, 5400, 10400, and 18000 lines. The two smaller sizes are of the six-panel type. The 10400 line section has eight panels, and the 18000 line section has ten panels. Fig. 262 shows a modern exchange of 18,000 lines capacity and Fig. 263 shows the rear view of a switchboard and the practical arrangement of every part of a standard multiple. Fig. 264 is a model floor plan.

For all exchanges with an ultimate capacity of less than 3000 lines, the standard 3000 line section is the most suitable. It is provided with a space for 200 answering jacks and lamps for each of the three operator's positions.

The number of lines that should be handled by an operator depends to a very large extent upon local conditions. If the lines are principally located in a business district, sixty lines keep an operator busy, but when they are mostly from a residence section, she is often able to handle as many as 160, or in some cases as high as 200. In cities having but one exchange for all lines, the average number of lines to the position usually ranges between 120 and 160.

FIG. 262
VIEW OF MODERN OPERATING ROOM

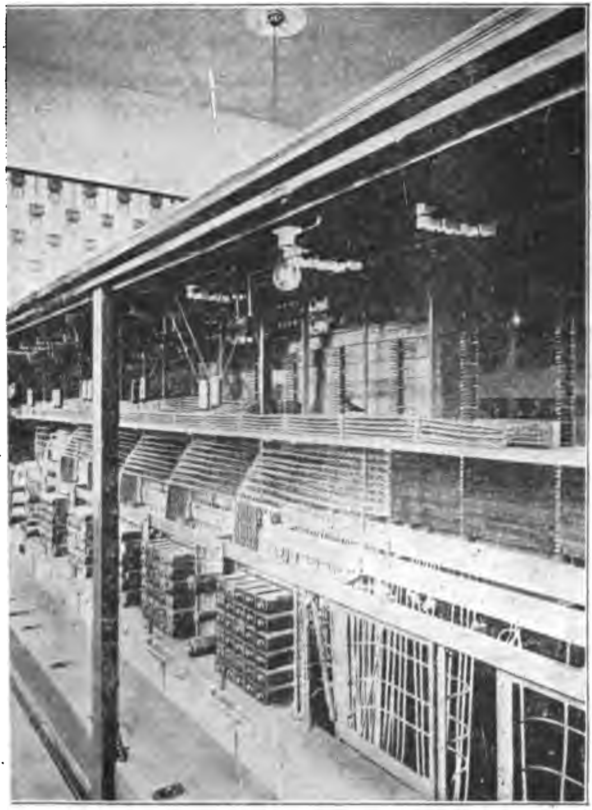


FIG. 263
REAR OF SWITCHBOARD

It is often convenient to have the rural lines come in on the local board. When this is done the best plan is to bring them to the second position. The first position should not be used as a regular operator's position, as an operator at this

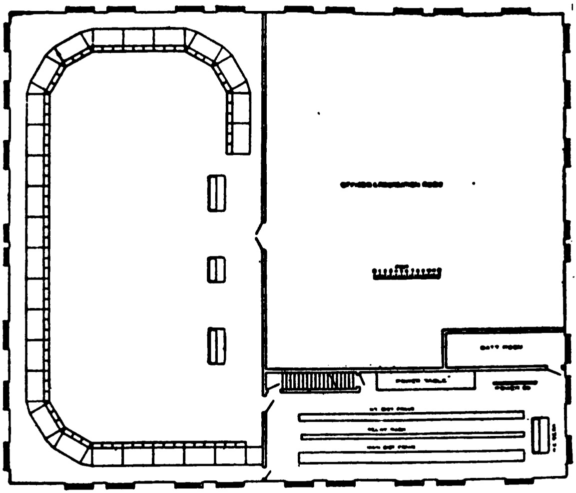


FIG. 264

FLOOR PLAN OF TYPICAL CENTRAL OFFICE

position is not able to reach all the multiple jacks. In equipping a rural position, means must be provided for making connections between rural subscribers, as well as between rural and common battery subscribers. To accomplish this two general plans are used. One is to furnish two types of cord circuits; one for the connection between rural subscribers only, and the other for connections between rural and common battery subscribers and vice versa. The second plan is to use only one type of cord circuit, and have it so arranged as to be suitable for making all kinds of connections. This method is the most convenient from an operating standpoint, as the operator does no need to select the cord to be used for any particular connection, thereby saving time. Also, she does not require as many cord equipments as where two kinds are necessary.

The number of cord equipments for a regular subscriber's position has been practically fixed at fifteen by most engineers.

LINE SIGNALS.—The line signals consist of 24 volt 1/3 candle power incandescent lamps mounted in lamp jacks arranged ten per strip. The insulating material used in the construction of this jack consists of lava and mica, neither of which is affected by heat as is hard rubber.

SUPERVISORY SIGNALS.—The supervisory signals consist of a pair of lamps located in the front of each pair of cords as shown in Fig. 260. The lamp jacks are of the individual open construction type. They are mounted on the under side of the key shelf over openings into which the lamps project, and are covered by thoroughly protected opalescent lamp caps.

PILOT SIGNALS.—A 1/3 candle power, 24 volt lamp is placed in the lower left hand panel of each operator's position to be used as a calling pilot signal. This lamp is connected so that it will light whenever any line lamp in the position is illuminated, and so that it can be extinguished when the plug is inserted into the jack. A white opalescent lamp cap protects this lamp.

There is also a 1/3 candle power, 24 volt lamp placed in the lower right panel of each operator's position to be used as a supervisory pilot signal. This lamp is connected so that it will light whenever a supervisory lamp of the answering cord is lighted. A red opalescent cap is mounted in front of the lamp.

ANSWERING JACKS.—The answering jacks are made in strips of ten. The springs are made of German silver, and the insulation of rubber. The strips are provided with removable metal number plates. These plates are for the line numbers and correspond to the numbers on the multiple jacks.

MULTIPLE JACKS.—The multiple jacks are similar in construction to the answering jacks but are mounted twenty per strip, and are not provided with removable number plates. These jacks are arranged and numbered in groups of one hundred, from 0 to 99, from left to right, and from top to bottom. The one hundred numbers being designated by an ivory number plate located on the stile strips at the left of each group of one hundred spring jacks. To further aid in the location of any particular jack, each strip has two white spots between the fifth and sixth, tenth and eleventh, and the fifteenth and sixteenth; and the groups of one hundred jacks are separated by narrow strips of white holly. This scheme divides the multiple into groups of five in each direction.

KEYS.—The equipment shown in Fig. 260 is for a board equipped with four-party line ringing keys. A four-party line indicating ringing and

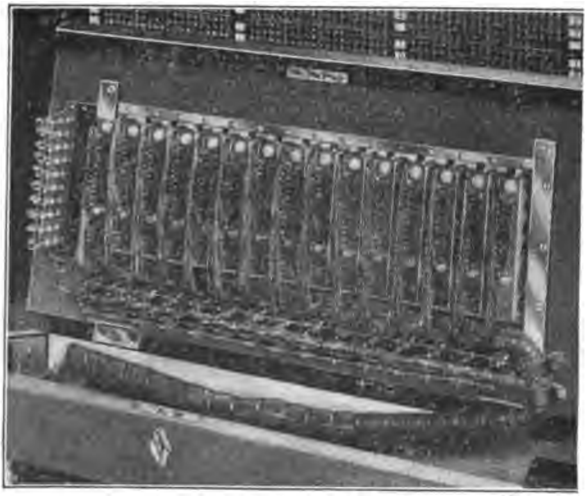


FIG. 265

UNDER SIDE OF OPERATOR'S KEYBOARD

listening key is used for each local cord equipment, which consists of four buttons for ringing, and one cam for listening. The front button is used for ringing on individual lines, as well as the first party on party lines. The keys are so designed that the last button operated will remain partly depressed, thus indicating which party was rung, Fig. 265, and they are so constructed and wired that it is impossible to throw two generators together by depressing two or more buttons on the same key, thereby making the use of a protection relay unnecessary which simplifies the equipment.

The cam key in the rear is so arranged and wired that by pushing the key forward the operator's set is bridged across the cord circuit. The

Fig. 266

LINE AND CUT-OFF RELAYS

key maintains its position when placed either in the normal or listening-in position.

Cords.—The cords are of the two-conductor type, 72 inches in length, and are provided with connecting clips and arranged to be fastened so that the strain of the cord weights is taken by the braid.

Plugs.—The plugs are of the two-conductor type, the contact part being made of brass, insulated with hard rubber. That portion of the plug which is not used for contact purposes is covered

FIG. 267
STRIP OF LINE AND CUT-OFF RELAYS

with a red fiber shell which can be removed, to allow easy access to the cord terminals.

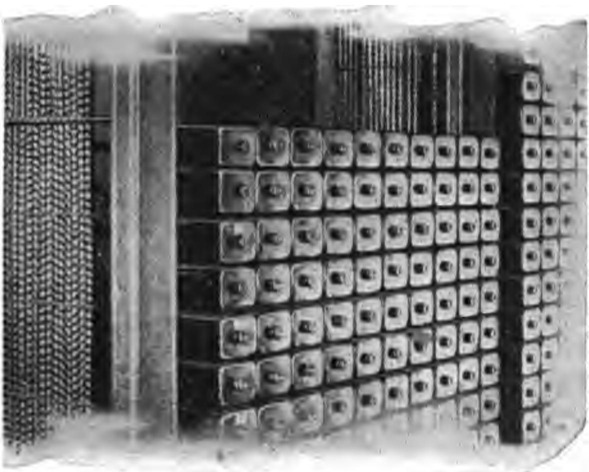


FIG. 268
RELAY RACK AND CABLES

CORD WEIGHTS.—All cord weights for switchboard cords are made of lead and antimony, with hard wood rollers for the cords to act upon, and of such design and arrangement as not to entangle adjacent cords.

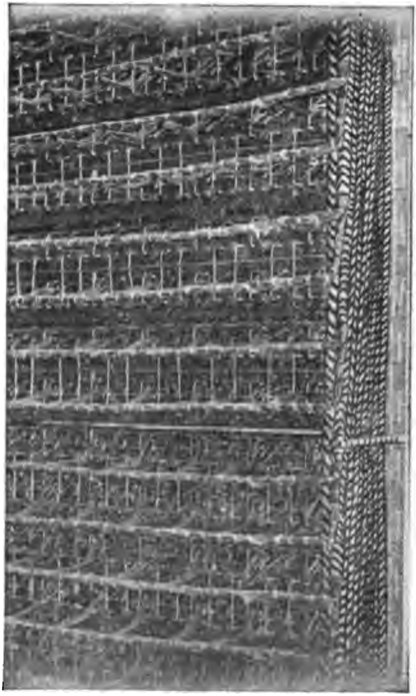


FIG. 269
REAR OF RELAY RACK

RELAYS.—In Fig. 266 is shown a standard Kellogg relay mounted in strips of twenty, Fig. 267. The relays mounted on the relay rack in actual working condition are shown in Fig. 268, in which illustration is also shown the method of running the switchboard cable. In Fig. 269 is shown the terminal side of a bank of line and cut-off relays with the connecting cable in detail.

The supervisory relays are of the same construc-

FIG. 270
CORD RELAYS

tion as the line and cut-off relays, but with a slightly different spring arrangement, and are mounted ten per strip, as indicated in Fig. 270, which shows the complete relay equipment for one subscriber's operator's position and also the method of arranging the relays in the rear of the switchboard section with the swinging rack in normal position. Fig. 271 shows the same equipment with the rack swung back exposing the wiring of the relays, as well as providing an easy means of getting at the cords for repair or replacement. The cabling and terminals are

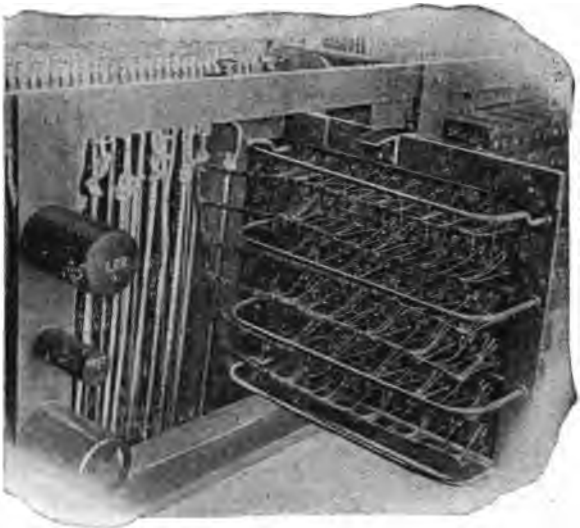


FIG. 271

CORD RELAYS MOUNTED ON SWINGING FRAME

protected from the cord weights by suitable guards.

This type of relay rack has the advantage over the earlier type of permitting the cords to be replaced without interfering with the front of the board.

OPERATOR'S EQUIPMENT.—The standard operator's equipments are of two general types. One with a transmitter suspended from an arm, and the other using a breast-plate type transmitter. The latter type seems to be the favorite, as it leaves the operator entirely free to move about, and yet have the transmitter in the correct position for talking. The head band should be covered with leather, which forms a cushion preventing the metallic parts from coming in contact with the operator's head.

Duplicate operator's jacks are used in each position for teaching new operators.

MAIN DISTRIBUTING FRAME.—The main distributing frame is made of structural iron of open construction. It is equipped with a set of terminals on the line side for the outside lines, and a set of lightning arresters and heat coils on the switchboard side.

The arresters are so connected that when a coil is open, a lamp signal associated with the side of the upright, upon which the burnt coil is located, lights up indicating its location to the attendant.

INTERMEDIATE DISTRIBUTING FRAME.—The intermediate distributing frame is of the same construction as the main distributing frame, and is so arranged that any line may be connected to any operator's position without changing the number of the outside line or the multiple jack.

For exchanges in small cities it is often advisable to omit this frame in order to reduce the first cost.

Fig. 272 shows distributing frames, wire chief's desk, etc.

WIRES AND CABLES.—All circuits are arranged to prevent cross talk. The switchboard cables are made of No. 22 or No. 24 B. & S. gauge tinned copper wire, 97 per cent pure. Each wire has an inner insulating wrapping of silk and an outside wrapping of cotton, and are twisted into pairs

FIG. 272

VIEW OF TERMINAL ROOM AND WIRE CHIEF'S DESK

and formed into a cable with a substantial covering. The wiring of the power circuit is of rubber covered wire and should be of a size conforming to the underwriter's specifications. All magnet wire used throughout should be of silk covered wire.

The cables are laced to the frame work and when they are fanned out to attach to the terminals of the apparatus, they should be carefully laced up, and the exposed wires boiled in beeswax to keep out any moisture. After being soldered to the apparatus they are treated with a coat of

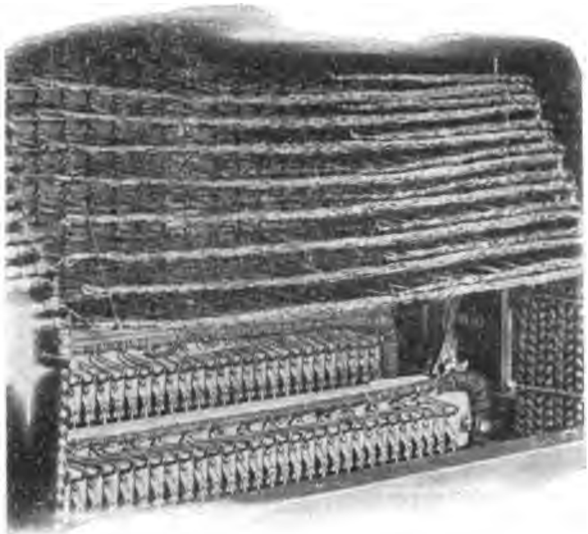


FIG. 273

REAR OF SWITCHBOARD—ANSWERING JACK CABLES AND CORD TERMINALS

white shellac as an additional precaution against moisture. Fig. 273 shows the method of bringing in the cable and fanning out the wires at the answering jacks and line lamps. By this method the jack terminals may be readily inspected. In

Fig. 274 is shown the manner in which the cables are carried to the intermediate distributing frame.

In COMMON BATTERY installations it is a short-

FIG. 274
CABLE RUNWAY—TURNING A CORNER

sighted policy and poor economy not to provide power equipment that will amply care for the ultimate capacity of the board.

POWER PLANT.—Fig. 275 illustrates a standard equipment.

The meaning of a "Central Energy" plant is that all the power necessary for operating the

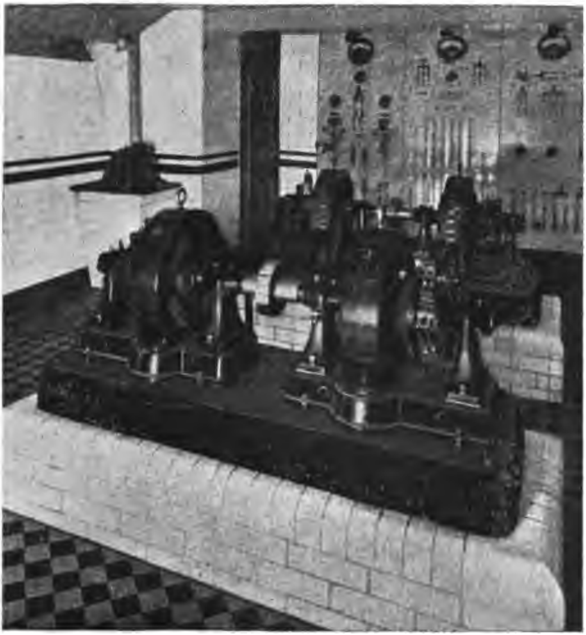


FIG. 275

MOTOR-GENERATOR SETS AND POWER BOARD

board, as well as the telephones, is located in one centralized plant. The source of power must be steady, not fluctuating in nature as is the electric light circuit, so that no noises will be produced in the various telephones. A storage battery seems to be the only reliable and satisfactory source of power available, as primary batteries are practically prohibitive on account of the expense.

Storage batteries may be charged direct from the power leads through a suitable lamp rheostat, by a motor generator set, a mercury arc rectifier charging set, or a charging generator run from a gas or gasoline engine. Except where the primary power is extremely cheap the first method should never be used for a multiple board, as the expense is excessive.

The method whereby a motor generator charging set is allowable, should always be restored to if possible. Where alternating current only is obtainable, either a motor generator charging set or a mercury arc rectifier can be used, Figs. 276 and 277. The last mentioned device has met with much favor in the past. The mercury arc rectifier is self contained, easy of operation and highly efficient. The initial cost as well as cost of maintenance is less than for a motor generator set of equal output. It is always advisable to have two battery charging machines, and where possible, these machines should be operated from two different primary sources; thus tending to insure continuous operating power.

The means of providing suitable ringing current is another feature that requires considerable thought. There are two available methods of producing current for ringing telephone bells; one by a dynamotor or motor generator and the other by a pole changer. Where current is required for ringing single party phones, the dynamotor is the most reliable source of power.

At the present time most of the exchanges in-

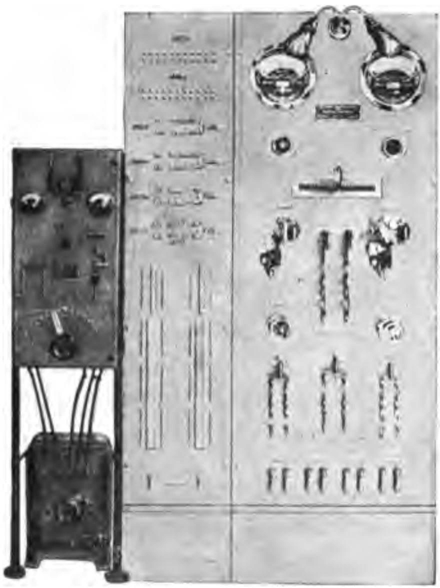


FIG. 276

MERCURY ARC RECTIFIER AND POWER BOARD

stalled are equipped with four-party selective ringing, and the four frequencies necessary for this service are produced by a vibrating pole changer or the motor generator set. The motor generator set consists of a motor operated from some primary source and four generators of different frequencies. This method is seldom used except for very large exchanges, the ringing current be-

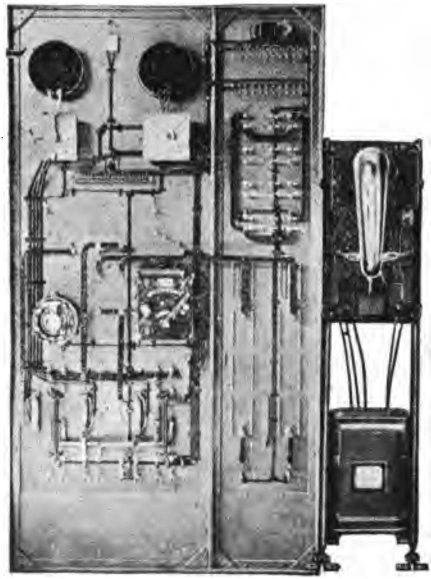


FIG. 277
REAR OF MERCURY ARC RECTIFIER AND POWER BOARD

ing furnished in nearly all cases by pole changers operated from the storage batteries.

No one should attempt to operate an exchange from but one source of ringing current, as any machine, no matter how well constructed, is apt to break down at some time. Where dynamotors, or motor generator sets are used it is advisable to have one machine operate from some primary source while the other should be designed to operate from storage battery. Where pole changers are used a complete duplicate set should be provided to be on the safe side in case of an emergency.

POWER BOARD.—Proper means of distributing the battery and ringing current must be provided and this is the function of the power board.

The illustrations clearly indicate the character, construction and type of apparatus used. In Fig. 277 is shown the rear view of a board illustrating the manner in which the wiring and bus bar work is accomplished.

CHAPTER XVII

COMMON BATTERY NON-MULTIPLE EXCHANGES WITHOUT CENTRAL OFFICE CONNECTIONS

With the modern facilities for manufacturing, and the development of the storage battery to a very high degree of efficiency, has come the development of the Common Battery Telephone Exchange. It would be superfluous at this stage of the common battery development to enter into all the details and points of superiority the Common Battery System has over the local battery or the magneto systems as they are called.

For certain classes of service such as long toll lines, and farmers' lines, the magneto or local battery method still holds its own, both as regards efficiency, and cheapness of installation. On the other hand the small Common Battery System is by far the most efficient and economical where a fairly large number of subscribers are expected to be served, and this especially where the subscribers are all located within a short radius of the exchange.

Small Common Battery Exchange Systems may be divided into two classes according to the principle uses to which they are to be put. To the first class belong Common Battery Non-Multiple Exchanges without central office connections. To the second class belong Common Battery Non-Multiple Exchanges with central office connections or, as they are commonly called, Private Branch Exchanges.

In the first class there is what are known as Lamp Signal and also Mechanical or Magnetic Signal equipments. The circuits of the lamp signal system are shown in Fig. 278. On the left and right hand sides of the drawing are shown subscribers' lines. The subscriber's station circuits are shown at the upper corners, and the operator's cord circuit is shown in the middle. All the circuits are shown in their normal conditions. The heavy line shows the "talking circuit." The operation of this system is as follows: Suppose subscriber "A" wishes to call subscriber "B." He removes his receiver from the switch hook, this operation automatically causing the line relay of his line to be operated. This line relay in turn, by the closing of a contact, causes the line lamp corresponding to this line to light. This lamp is located under a line jack in front of the operator, and the operator upon seeing the lamp light up, immediately inserts one of her answering plugs which is not in use into the line jack corresponding to the line lamp previously mentioned. The operation of inserting the answering plug into the line jack, mechanically opens the circuit of the line relay, thereby causing the line relay to drop back into its normal position, thus causing the line lamp to be extinguished. The operator then throws the listening key in that particular cord

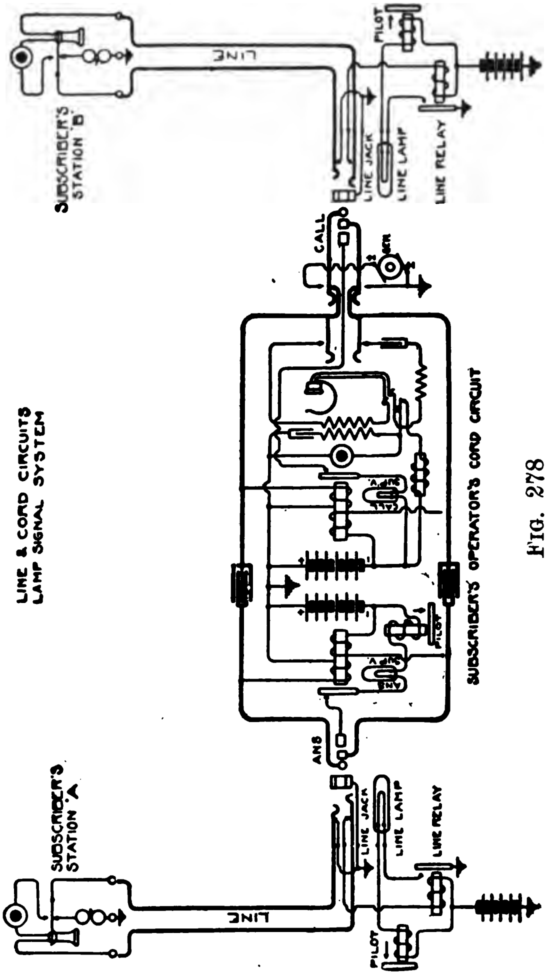


FIG. 278

LINE AND CORD CIRCUITS, SMALL COMMON BATTERY SWITCHBOARD circuit, which bridges her telephone set across the line, thereby enabling her to speak with the calling subscriber. In this manner she ascertains the number that the calling subscriber wishes.

In this case it is subscriber "B" that is wanted. Then the operator, upon learning the number of the party desired, picks up the calling plug corresponding to the answering plug of this same cord circuit, and inserts it into the line jack corresponding to subscriber "B." This act automatically cuts out the line relay and line signal apparatus of line "B," making it impossible for the line lamp to light up while the plug is in the jack. This act of plugging into the line jack allows current to flow through the third conductor of the plug and through the calling supervisory lamp to the battery, which lights the calling supervisory lamp, this lamp staying lighted until the called for subscriber answers.

The operator now throws her ringing key, which puts alternating current out onto the line of the subscriber which she is calling. This alternating current passes out over the line and through the bell of the called subscriber's station, thereby signaling the subscriber wanted. As soon as the called for subscriber answers, he does so by simply removing his receiver from the switch-hook. The act of removing the receiver from the switch-hook operates a switching device, thereby short-circuiting that line, which operation causes the calling supervisory relay in the cord circuit to pull up, thereby extinguishing the calling supervisory lamp and giving the operator a signal that the called subscriber has answered.

Conversation between the two subscribers is now possible. When the two subscribers are through talking, they simply replace their receivers upon their respective switch-hooks. This operation causes the armatures of the supervisory relays, both calling and answering, to fall back into their normal positions, allowing both supervisory lamps to become lighted. The operator, upon seeing both lamps lighted, now knows that the conversation is finished and immediately removes both calling and

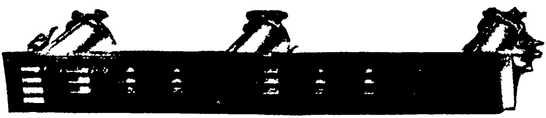


FIG. 279
MECHANICAL SIGNAL

answering plugs from the line jacks, whereupon the cord circuit is in condition to be immediately used again for another connection.

The operation of a Mechanical or Magnetic Signal System is very similar, except that instead of lamp signals the mechanical or magnetic signal is used. These mechanical signals are illustrated in Fig. 279. They are operated on the principle of the relay, with the addition that the operation of the armature displays a visual signal in the manner shown in the figure and they are commonly known as "gridiron signals,"

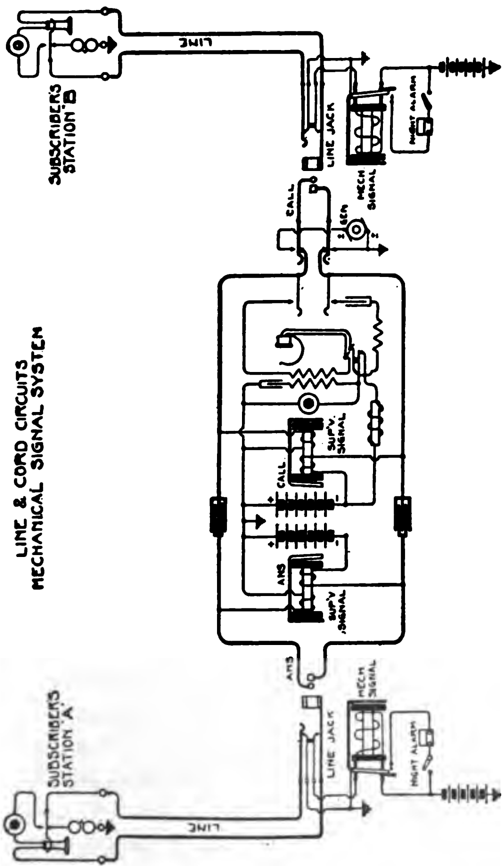


FIG. 280

LINE AND CORD CIRCUITS, MECHANICAL SIGNAL SYSTEM due to the peculiarity in the construction of the plate in front of the signal. The mechanical signal line and cord circuits are illustrated in Fig. 280. The operation is nearly identical with that of Fig. 278, illustrating the lamp signal system, except that when a subscriber wishes to call another subscriber, instead of operating a line relay, the act of short-circuiting the line through his instrument causes the mechanical signal to operate, and this immediately attracts the attention of the operator without the use of a lamp signal.

The operator answers a call in the same way as in the Lamp Signal System, and the mechanical signal is made inoperative. The operator ascertains the desired number in a manner similar to that described before, and plugs into the jack corresponding to the line of the subscriber called for. The subscriber answers the call in the same manner as with the Lamp Signal System, but the operation of the supervisory signals is somewhat different than that in use in the Lamp Signal System.

The supervision is what may be termed negative supervision inasmuch as the signals are not displayed when the operator plugs into the jack, but are displayed as soon as the subscriber answers; in other words, as soon as the operator answers a call, the calling subscriber already being on the line, causes the answering supervisory mechanical signal to be immediately displayed.

When the operator plugs into the line of the called for subscriber, the supervisory signal is not displayed, but remains normal until the called for subscriber answers.

Besides these two systems there is what is known as the Magneto-Lamp-Signal System. The principle is this: The line and cord circuits are so designed that regular magneto instruments and lines are brought into the exchange. A subscriber wishing to call another, simply operates his hand generator in a manner similar to that of calling the regular magneto exchange, but instead of this causing a drop to be operated in the exchange, generator current from the subscriber's instrument comes in through the line and operates a line relay. This relay in turn operates a line lamp in practically the same manner as that described under the lamp signal system.

The operator now makes the connection in a manner described under lamp signal systems, with this difference of operation, that instead of the supervisory lamps in the cord circuit becoming operative during the conversation, they are only operated when the subscribers ring off, in a manner usually the case with the magneto system. When the subscribers ring off, this causes the supervisory relays to operate, thereby causing both of the supervisory lamps to become lighted. In this way the operator has double supervision, whereas in the ordinary magneto system the clearing out drop is the only means whereby the operator can know of the termination of the conversation.

With this system when a telephone company wishes to change over to common battery instruments, all that is necessary is the changing of a few strap wires on the terminal or connecting rack at the rear of the switchboard, and, of course, the installation of common battery instruments at the subscriber's stations. This system enables the telephone company to utilize its magneto instruments to the fullest extent before finally changing to the COMMON BATTERY SYSTEM.

There has also been recently introduced a type of switchboard which contains both common battery and magneto lines. This board is especially valuable where it is desirable to have farmers' or toll lines as well as local common battery lines terminate in the same exchange. The operator of a switchboard of this kind is supplied with two kinds of cord circuits, namely: cord circuits for making connections between two toll lines or farmers' lines, and also cord circuits for making connections between local or common battery lines. If it is desired, the operator can also use what is known as a combination cord circuit, which enables her to answer a toll call with one of the plugs of this combination cord circuit, and with the other plug to call a local subscriber.

Another system meeting with favorable recognition is a simplified Lamp Signal System which is considerably cheaper to install.

The operation of this system is as follows: The subscriber signals the operator in the manner described before, by simply removing the receiver from the switch-hook, which operation causes the line relay to operate and light the line lamp. This calls the attention of the operator who immediately answers the call by plugging into the line jack with one of her answering cords which is not in use. This operation mechanically cuts out the line lamp. The operator now ascertains the number of the party to be called and in the usual manner picks up a calling plug and inserts it into the jack of the line corresponding with the subscriber wanted. This plugging into the line jack immediately causes the line lamp to light, and this lamp remains lighted until the subscriber answers the call. When the subscriber answers the call by removing his receiver from the hook-switch, this act automatically closes the line circuit and operates the line relay, thereby cutting out the line lamp and giving the operator a signal showing that the subscriber has answered.

The line lamp really is used for both line and supervisory signal. When a subscriber calls into the exchange this lamp acts as the line signal, and, as has been already described, is extinguished when the operator answers the call, but in the case of calling a subscriber this lamp lights upon plugging up and is extinguished when the subscriber answers the call. At the termination of the conversation, both subscribers replace their receivers on their respective switch-hooks, thereby opening both line circuits. This operation now causes the respective lamps of the lines to be again lighted. In this manner the operator receives a disconnect signal from both parties in the same way as though she had two supervisory lamps located in the cord circuit.

COMMON BATTERY NON-MULTIPLE EXCHANGES WITH CENTRAL OFFICE CONNECTIONS OR PRIVATE BRANCHES

Telephone companies in devloping their service, and trying to meet the requirements of a large and busy community, are confronted from time to time with many difficult problems.. Many new features have been introduced to overcome these obstacles, and the Private Branch Exchange is without doubt the most successful and remunerative scheme ever adopted in connection with large exchange service.

The Private Branch Exchange is practically an extension of the exchange principle to the subscriber's station. The subscriber has on his own premises a telephone switchboard equipment connected by one or more trunk lines to the main exchange or central office, and by local lines to telephones in different offices or departments of the building to be served. These telephones may be of the desk type, wall or cabinet sets, according to the various wishes of the local subscribers.

One of the great advantages of this system is its flexibility. Once the system is established it may be enlarged or diminished as necessity demands. If the business grows, as is usually the case now-a-days, more lines or more stations may be added with a very little expense, and without disturbing the telephone service.

It also saves time, and increases the efficiency of the lines terminating in the central office. The local operator acts as a distributer of all traffic, all incoming and outgoing calls going first to her. There is no time lost in "holding the wire," for the operator will tell the party calling up when the line is busy, call the party wanted and when gotten to the phone will notify the calling party and put both in communication. Thus the user gets good and quick service from his telephone lines.

Another advantage of the private branch system is that it sets going the inward traffic which so frequently becomes blocked by a heavily loaded single line. To all users of the telephone, the incoming calls are the most important, yet they unconsciously delay it and turn it away by using their lines most continuously for outgoing calls, and consequently are very frequently reported busy. The Private Branch Exchange reduces the "busy" trouble to a minimum, and in many cases abolishes it altogether.

In large establishments of all sorts a Private Branch Exchange System has an additional value, for besides furnishing exchange service direct to every department, or apartment where it is required, it also provides intercommunication between the different parts of the establishment. The users of this system embrace almost every line of business; architects, bankers, hospitals, colleges, engineers, railroad offices, department stores, importers, wholesale dealers, printers, publishers, newspapers, hotels, apartments, etc.

In addition to the regular subscriber's line and cord circuits which are required in any of the small common battery exchanges, it is necessary in a Private Branch to have some means of trunking with the main or central office. Several systems have been adopted to take care of these trunk connections. Two kinds of trunks in the Private Branch System which are standard and embody all essential modern features are the plug-ended and jack-ended trunks.

The plug-ended trunk under certain conditions is most efficient on account of the speed with which the connections can be put up. On the other hand the jack-ended trunks, while not quite as speedy in making the connections, are nevertheless equally as efficient as regards transmission. In Fig. 281 is shown a standard Lamp Signal Private Branch Exchange with a plug-ended trunk connecting with the central office. In order to understand more clearly the method of operating the trunk, a particular instance cited will afford a clear idea. Assuming that a subscriber at the Main Exchange wishes to call a subscriber at a certain private branch exchange. The main exchange subscriber calls into the Exchange in the usual manner and gives his number to the Main Exchange operator. This operator has out-going trunk lines going to different private branch exchanges. By an examination of Fig. 281 it will be seen that the trunk which goes to the private branch is an extension of one of the regular lines of the Main Exchange, i. e., the trunk ending in the plug at

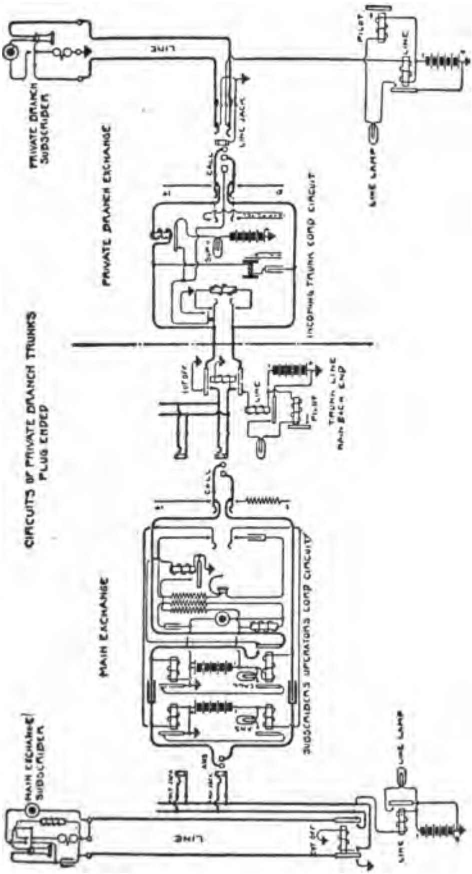


FIG. 281

CIRCUITS OF PRIVATE BRANCH TRUNKS, PLUG ENDED

the private branch terminates in a regular subscriber's line at central office.

The operation of this trunk circuit is as follows: After the operator at Main Exchange has ascertained the private branch and the number of the party desired, she takes her calling plug and inserts it into one of the out-going trunk jacks which terminates in the desired private branch exchange. The operator throws the ringing key in the same manner as though she were calling a regular subscriber; this act, however, causes the drop at the private branch exchange to fall, thereby signaling the private branch operator, whereupon the operator at the private branch throws her listening key and ascertains from the calling subscriber the number of the line in the private branch which is desired. Of course, it is necessary for the private branch operator to restore this drop to its normal position, and immediately after this is done she plugs into the private branch line and rings the subscriber called for. This subscriber answers in the usual manner by removing his receiver from the switch-hook. This operation short-circuits the line and causes the relay in the tip side of the trunk circuit to operate.

Previous to this the lamp in this trunk circuit has been lighted, as current is fed through this lamp immediately upon plugging into any jack. Therefore, when the private branch subscriber answers the call, thus operating the tip relay, this causes the lamp in the trunk circuit to be extinguished, thus giving the operator a signal that the subscriber has answered. At the same time this closing of the line circuit by the called subscriber operates the tip relay in the cord circuit at the Main Exchange, which gives that operator a signal that the called subscriber has answered. Conversation can now take place over the trunk line.

When the conversation is finished the subscribers replace their receivers upon their respective switch-hooks and this operation at the calling subscriber's station causes the answering supervisory lamp in the cord circuit at the Main Exchange to become lighted. When the called subscriber replaces his receiver on the switch-hook, this opens the circuit of the line and causes the armature of the tip relay in the trunk circuit to drop back into its normal position, thereby allowing the lamp to become lighted and giving the private branch operator a disconnect signal, upon receiving which she immediately pulls down the connection.

At the same time the armature of the calling tip relay in the cord circuit at the Main Exchange drops back into its normal position, and allows the calling supervisory lamp at the Main Exchange to become lighted. Thereupon the operator seeing both lamps lighted at the same time, immediately takes down the connection. This, in brief, shows the method of a Main Office subscriber calling a Private Branch subscriber.

When a Private Branch subscriber calls the Private Branch Exchange, the operator at that station answers the call with one of her regular cord circuits and if the called party is in the Private Branch Exchange she can make this connection with this same cord circuit. But if the party called for is in the Main Exchange it is necessary for her to remove the answering cord from the line jack and insert in its place one of her trunk plugs. The subscriber being already on the line, causes the line relay on the Main Exchange end of the Private Branch trunk to operate as soon as the Private Branch operator inserts the trunk plug into the calling party's Private Branch line jack. The operation of this line relay at the Main Exchange causes the line lamp corresponding to that trunk to light up. The operator in front of this line lamp at the Main Exchange answers the call in the same manner as though it were a regular subscriber calling and completes the connection with one of her calling plugs in the same manner as is the case with a regular call between two subscribers at the Main Exchange.

It often happens that the private branch operator wishes, for some reason or other, to call the Main Exchange, and this is made possible by the key which is placed in the private branch trunk for this purpose. This key, as will be seen by reference to Fig. 281, throws an impedance coil across the line which causes the signal to be displayed at the Main Exchange. In this way the Private Branch operator can get the Main Exchange line and hold it for one of the Private Branch subscribers until the Private Branch subscriber is ready to be connected. This signal key makes it possible for the

Private Branch operator to get the Main Exchange subscriber desired, and after obtaining this subscriber she can then call the Private Branch subscriber to his telephone.

It often happens in certain private branch systems that there are some private branch subscribers to whom it is desirable to the operating company to give main office connections, whereas it is undesirable to give others there main office connections. Consequently a scheme was devised whereby it is impossible even with the aid of an operator, for the private branch subscriber who is not supposed to have main office connections, to get these connections. The method adopted is as follows: The private branch lines are led into the board and may be wired to one of two sets of connectors. These two sets of connectors are wired to two sets of jacks. One set of jacks has a large aperture while the other set has a small aperture; consequently only one size of plug would fit a certain jack. If it is desirable to give a certain subscriber the privilege of obtaining main office connections his line would be connected to the larger set of jacks, and it would be manifestly impossible for a subscriber whose lines are brought in on the small jacks, to get a trunk connection because it would be impossible for an operator, even though she desired, to insert one of the large trunk plugs into a small line jack.

A system of the jack-ended trunk type is illustrated at A in Fig. 282.

The operation is as follows: The Main Office subscriber calls the operator at the Main Exchange in the usual manner. This operator, upon ascertaining the number of the Private Branch, plugs into a jack terminating in a jack-ended trunk at the Private Branch desired. She then operates her ringing key in the manner as described before, which operation throws the shutter of a line drop at the Private Branch Exchange. The operator at the Private Branch Exchange, upon seeing the shutter of the line drop fall, immediately inserts one of her answering plugs into the trunk jack corresponding to the line drop. This operation mechanically cuts out the drop from the line.

These drops and jacks may be either of the Bell type or of the self-restoring type. The Private Branch operator, upon ascertaining the Private Branch subscriber desired, inserts her calling plug into the line jack, and rings the desired party. The Private Branch operator then has supervision in a similar manner to that described in connection with plug-ended trunks.

When the conversation is finished the Private Branch operator gets her disconnect signal from the calling supervisory lamp, whereupon she immediately takes down the connection. As soon as the connection is taken down, the operator at the Main Exchange receives the disconnect signal on her calling supervisory lamp, and upon receiving the answering disconnect signal the Main Office operator takes down her connection.

At B in Fig. 282 is shown the cord and line circuits at the Private Branch Exchange equipped with mechanical signals.

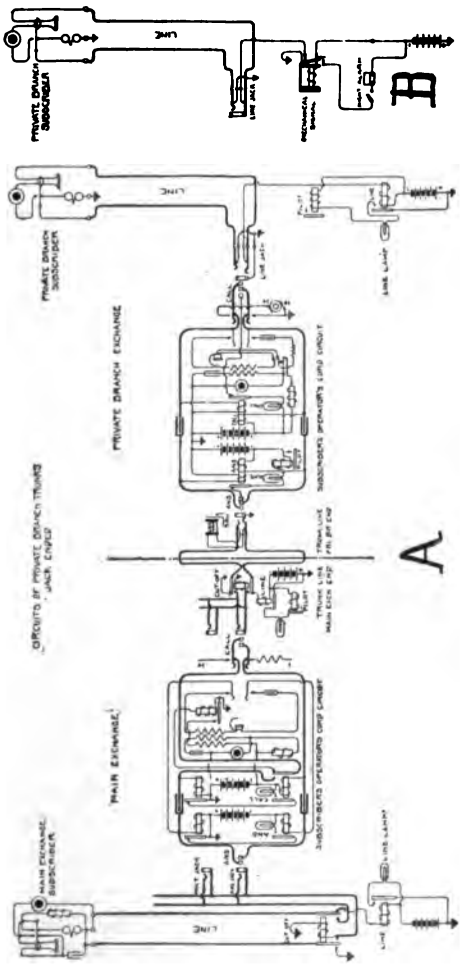


FIG. 282

CIRCUITS OF PRIVATE BRANCH TRUNKS, JACK ENDED

LINE CIRCUIT APPARATUS

SWITCHBOARD LAMPS.—Under the heading of Line Circuit Apparatus comes all that miscellaneous material which goes to make up the complete line equipment. The principal materials and devices used in two of the modern systems of non-multiple common battery exchanges—first the lamp signal, and second the mechanical or magnetic signal—are enumerated, illustrated and described in the following pages:

In the lamp system it is necessary to have small incandescent lamps which will serve as the line signals. These lamps are made in different voltages, but the standard throughout the country for common battery use is approximately 24 volts. The lamps furnish 1-3 candle power and consume 1-10 of an ampere.

RELAYS.—Two leading types of relays used in lamp signal relay systems are the major relay, and the minor relay. The only difference between these relays is that the major type of relay consists of individual relays with separate shells mounted on a flat mounting plate, while the minor type of relay consists of a cast iron strip drilled out to contain the number of coils necessary for the total number of relays to be mounted on that strip.

LINE JACKS.—A type of line jack for the lamp signal system is constructed in the same general manner as the spring jacks which are used with large common battery switchboards.

Pilot Lamp.—In connection with non-multiple common battery switchboards what is known as a line pilot lamp is much employed. This lamp is usually located at the top of the jack panel, and its function is to light up whenever any line lamp in that panel is lighted. In this way it is not necessary for the operator to watch the whole panel, for the pilot lamp is sufficient to attract her attention, and when this is done she can readily locate the line lamp which is lighted.

Fig. 283 shows one of these lamps set into the pilot lamp jack.

Pilot Relay.—The line pilot lamp is lighted

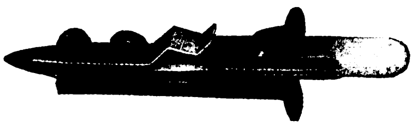


Fig. 283
LAMP AND JACK

by the operation of the pilot relay. The relay is wired in the line circuit, as shown in Fig. 278, and is usually of low resistance for the reason that the line lamps receive their supply of current through the winding of the pilot relay.

Mechanical Signals.—This signal serves as a line signal in place of a line lamp, thereby doing away with the line relay. These signals are known as "grid-iron signals," due to the construction of the mounting plate which is in front of all the signals. The shutter of each individual signal is so arranged that a very slight movement of the same will show a white signal through the openings of the mounting strip. The armature at the rear end of the signals is provided with a set of platinum contacts, which can be used for a night alarm or a pilot circuit.

In mechanical signal systems, a line pilot lamp is preferable to a single mechanical signal, for the reason that the pilot lamp more easily attracts the attention of the operator.

CORD CIRCUIT APPARATUS

PLUGS.—Several types of plugs are used in the operation of cord circuits. What is called a three conductor plug, for the reason that three separate circuits are carried through the contacts between the plug and the jack. This plug is used almost exclusively for common battery use.

CONDENSERS.—The condenser shown in Fig. 284 is a standard one microfarad condenser and is used in the magneto light system. It is of the same general construction as those of the same type of greater capacity and is used where if a two microfarad condenser were used, a subscriber in ringing off for the disconnect would ring the other subscriber as well as operate the other supervisory signal. This is not possible with a condenser of a lower capacity.

In all common battery telephone sets either one or two condensers are necessary. The part these condensers play is different in the two cases. When the condenser is used in the primary circuit of the operator's set, its function is as follows: By consulting the operator's circuit drawing shown in Fig. 278, it is seen that the battery current starting from the tip or grounded side of the battery, passes through the transmitter, thence through the operator's cut-in jack, thence through

FIG. 284
CONDENSER

the retardation coil, back to the negative or sleeve side of the battery. The primary winding of the induction coil in series with the condenser is bridged around the transmitter. When the transmitter is spoken into, the resistance of the transmitter varies; at the same time the condenser is charged, and consequently these variations cause the charge and discharge of the condenser, which exactly follows the fluctuation of the current produced by the transmitter. This charge and discharge through the primary of the induction coil, of course, induces a corresponding effect in the secondary. The rest of the operation is generally understood.

MECHANICAL SIGNALS.—In a switchboard which has a line equipment made up with mechanical signals, it is the usual practice to supply the cord circuits with the same kind of signals. In some cabinets it is desirable and in others a necessity to place the supervisory mechanical signals at the lower end of the jack panel. When this is done the answering supervisory signal is usually placed below the calling supervisory signal when there are enough cords to require two strips. If the number of cords is so small as to only require one strip of signals, the answering signals are placed to the left of the calling signal.

These signals have two coils wound in tandem for supplying the battery current for talking.

The object of a mechanical signal is to display as large a white surface as possible with a minimum movement of the armature of the signal. In the normal position of the signal the black stripes of the signal are behind the openings of the mounting plate. Thus it will be seen that a very slight movement of the armature end of the signal will cause a much larger motion of the striped plate at the front end, thereby giving the effect of a large white surface appearing when the signal is operated.

CHAPTER XVIII

TEST-BOARDS, DISTRIBUTING BOARDS, TESTING APPARATUS

A protector of efficient pattern is used for the best modern practice and carries also the testing feature, which consists of a sneak-coil and lightning-arrester combined. In Fig. 285 is shown a section of one of these strips, which are made up to take a 104-wire cable, there being fifty-one pairs of tabs, leaving two wires in the cable spare.

A central iron plate H carries the strip and the springs are placed on either side, the inner pair (those nearest the plate) taking the cable leads and the outer pair the cross connections to the test-jacks, and the outside pair of springs C and D being used for one side of an alarm-bell circuit. Two blocks of carbon, having a thin sheet of mica which is shaped ⊔ between them, separate each of the line springs from the iron plate.

A small amount of fusible metal composed of an alloy of lead and bismuth is sunk in the centre of the carbon block which is nearest to the iron strip. A small heat-coil is inserted between the line springs and the cross-connection springs, and is made to slip easily in or out, being gripped by the springs on either side. It consists of a coil of platinoid or German-silver wire wound on a small metal tube, containing a small quantity of fusible metal into which the contact pin P is embedded. The circuit to the test-jack, is from the line, through the line spring, thence through the heat-coil and contact-pin of same on to the cross-

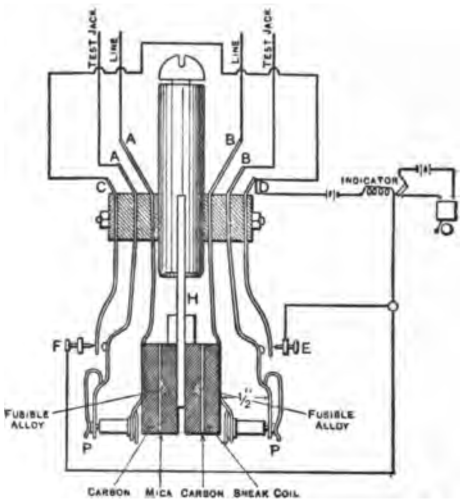


FIG. 285

PROTECTOR WITH HEAT COILS

connection spring. If all excess of current is sent over the line the heat-coil becomes heated, the fusible metal melts, and the cross-connection spring flies out, releasing the pin. This forces back the spring C or D, which makes on the contact E or F and closes the local circuit of the alarm.

In the event of the line coming in contact with a high-voltage electric-light wire, or trolley line lead, not only will the heat-coil break the circuit towards the exchange, which saves the internal apparatus from destruction, but the current will leap across the space between the carbon blocks, heating them in its passage and melting the fusible alloy embedden in them, thus short-circuiting the blocks and putting the dead line to earth. Some heat-coils are adjusted to act with a current of over 1-3 ampere, and at a pressure of 400 or more volts, a current will leap across the space between the carbon blocks.

Figs. 286, 287, 288 and 291 show the general construction of main distributing frames. On one side of these the cables from outside are terminated, and the multiple cables are brought from the switch-room to the other side, after passing through the intermediate distributing frame. Flat iron bars at right angles and projecting on both sides of the angle irons, are fitted to strong vertical supports of angle iron attached to floor and ceiling. On one side these flat bars, to which the switchboard cables are brought, and which are arranged in vertical rows of from 200 to 300 pairs in each row, carry the arresters, with heat-coils and fuses; and on the other side the bars carry the connectors to which the outside cables are attached, and these connectors are fitted in horizontal rows, Fig. 288, made up in strips of twenty pairs. In Fig. 289 is shown the latest form of arrester with heat coils. They are mounted on broad flat iron bars, which are set vertically. The arresters are made of two carbon

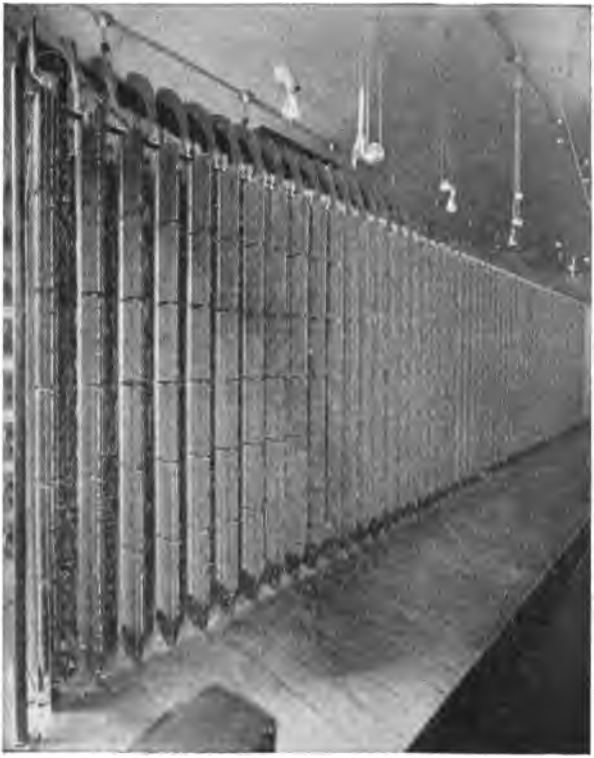
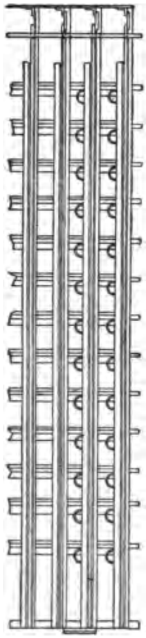


Fig. 286

MAIN DISTRIBUTING FRAME

blocks separated with mica, are similar to those shown in Fig. 285. The heat coils are arranged in such a manner that when an excessive current, i. e., over 3 amperes, passes through the coil it softens the fusible metal and unfastens a thin spring which opens the line.



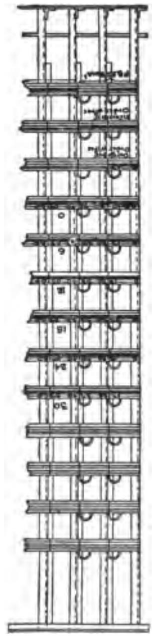


Fig. 287 Fig. 288

MAIN DISTRIBUTING FRAME

Fig. 290 shows the way in which the connectors for the outside wires are made up.

The cross-connecting wires, of twin No. 20 B. & S. wires, are insulated with rubber and cotton and, to render it flameproof, the outer covering over the pair is coated with asbestos. These wires are carried through rings and pass across from one side of the frame to the other, as indicated by the dotted lines shown in Fig. 291.

INTERMEDIATE DISTRIBUTING BOARDS.—These

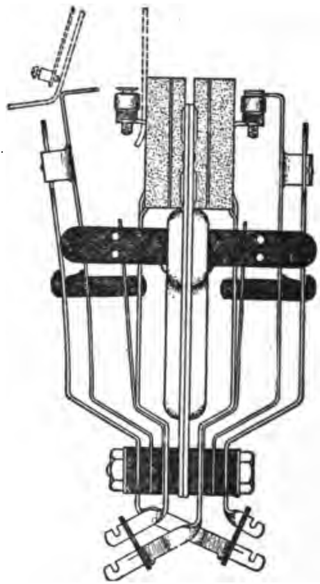


FIG. 289
PROTECTOR FOR MAIN DISTRIBUTING FRAME

are used for the distribution of work among the operators, and to supply a simple disconnecting point to test and localize faults.

All of these boards consist of two sets of soldering tabs with cross-connections between them. To one set is attached the wires from the multiple jacks, and to the other set the wires from the local jacks and from the indicators or relays, according to the type of switchboard used.

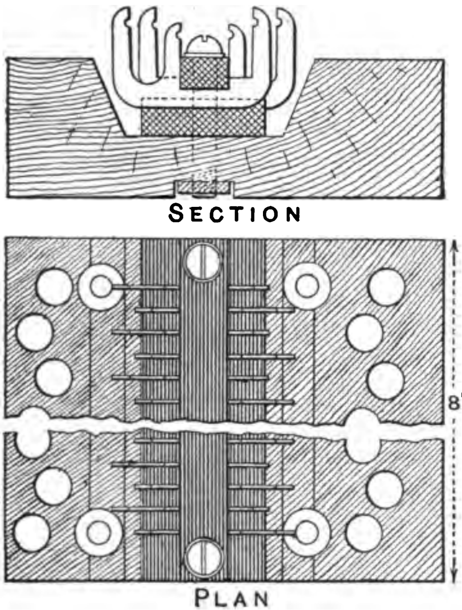


FIG. 290

DETAILS OF CONNECTING BLOCK

This enables any subscriber's line to be joined to any indicator and local jack in the exchange, by arranging the cross-connections properly.

Fig. 292 shows a pattern of distributing board with an iron frame, of a kind largely used in connection with central-battery systems. The multiple cables are brought in from opposite ends on the horizontal side H, and are secured by tape to the under side of the iron bars B supporting

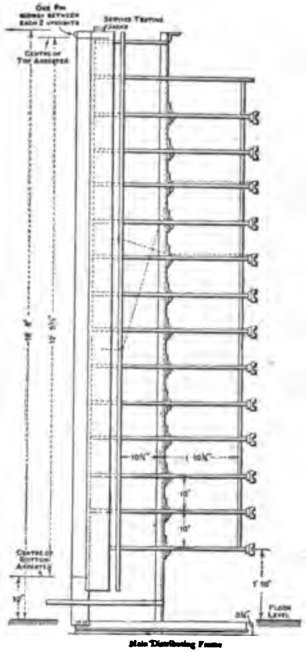


FIG. 291
END VIEW MAIN DISTRIBUTING FRAME

the horizontal rows of tabs. Fig. 293, shows the vertical rows of tabs in detail.

The cables from the local jacks and indicators, in Fig. 292, or relays, are brought in on the vertical side V, either from the top or bottom, or both, and are taped against the iron frame-work behind the strips so as to be out of the way of the cross connection, or jumper wires, as they are some-

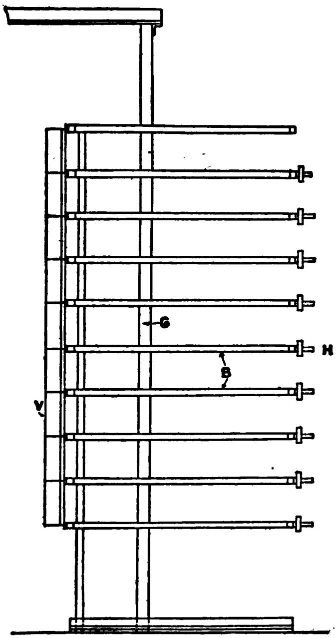


FIG. 292
DISTRIBUTING BOARD

times called. To protect them from chafing on the iron-work, these wires should have an extra covering, asbestos preferred, which encompasses the three wires. Those on the horizontal side are run on top of the iron cross-bars B, and are taken along the frame to a ring fastened to G, opposite the vertical strip to which they are to be connected.

The relay racks are placed, in modern practice, alongside the intermediate distributing frame and opposite the vertical side of that frame. On these are arranged the line and cut-off relays on subscriber's circuits, also the relays on the

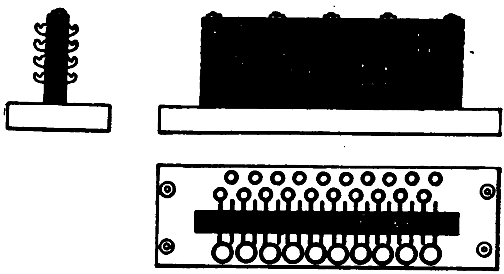


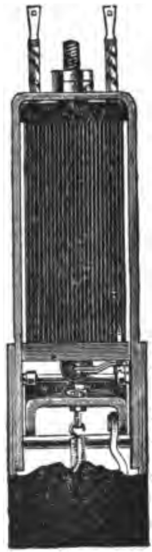
FIG. 293

DETAILS OF CONNECTING BLOCK

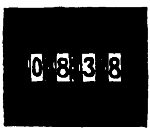
trunk lines. The supervisory relays on the cord circuits are fitted on the frames of the switchboard, under the cable shelves, and behind the cords at each position. The line and cut-off relays are mounted in pairs, in strips of ten pairs, on metal plates, each strip fitted with a sheet-iron cover, which protects the relays from dust, or disturbance from anyone brushing against the rack in passing. The other relays are also mounted on metal strips, in the numbers required, but each relay has a separate metal cover, which is necessary where the relays are in the talking circuit to prevent disturbance induced from currents in adjoining relays. The relays on the rack are wired from the back, the tabs to which the connecting wires are soldered passing through the plate, and the cables are formed out and attached to light supports, so that they stand out 3 inches clear of the plate, making examination at any time, easy. The register rack is also placed in the apparatus room say near to the intermediate distributing frame, and on this the registers are fitted for recording calls. Fig. 294 shows one of these registers which are mounted on plates in strips of twenty. The principle of their mechanism is much the same as some cyclometers, but the ratchet is operated in this case by an electro-magnet.

The rack for repeater coils, should always be as near the battery room as possible. The fuse-boards carrying the fuses, which are mounted on a slate panel fitted in an iron frame, for protecting the apparatus against heavy current in case of short-circuits, are placed at the end of this rack to the right hand. To the left the ends of the channel irons are on a similar panel. This form of iron makes a suitable run for the wires to the fuses. The upper portion of the repeater rack takes the condensers fitted in connection with the cord and junction circuits. The essential parts of the power plant, which will not be given in detail, are the motor-generators used for charging the battery and the ringing dynamos which

Back View



Plan



Front View

FIG. 294

VIEWS OF SERVICE METER

supply the necessary alternating and pulsating currents for calling the subscribers. The interrupters, which give the varying currents required for tone tests, busy back, etc., are also fitted in connection with the latter. The main battery for supplying current for all transmitters and signaling, consists of as many storage cells joined in series as are necessary to give the voltage normal to the switchboard. Iron racks carry all the cabling between the various frames and the switchboards.

TEST-ROOM APPARATUS.—To determine quickly whether any line, both inside and outside the exchange, is in working order, a set of testing apparatus is employed in all test-rooms. The set in general use consists of a telephone instrument, several switches, a voltmeter, and a battery of dry cells. The set is simply used for qualitative tests, as to indicate whether a line is grounded, but it cannot be used for delicate quantitative tests, as are required to localize a ground fault in a wire. With such a test set the following tests can be made: First, to indicate a disconnection of a metallic circuit at any point. Second, to indicate whether any of the lines comprising a metallic circuit is grounding. Third, to indicate short-circuited lines.

Fig. 295 shows how the voltmeter is connected up to test for first and third, *i. e.* to show whether a metallic circuit is disconnected at any point, and to show whether the lines are short-circuited.

A deflection will be obtained when the voltmeter is connected up and tapped on a grounded line A, as shown in Fig. 296 and the resistance of the ground fault can be estimated by the extent of the deflection. If the ground fault is a low-resistance one a slight deflection would be obtained on the B wire.

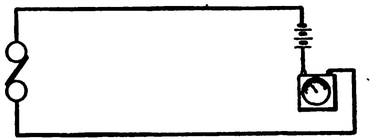


Fig. 295

VOLTMETER TEST FOR CONTINUITY

More elaborate arrangements for testing are made in the larger central battery exchanges. With the voltmeter a set of tables is provided which give the equivalents in megohms or in ohms of the various deflections obtained when batteries of different voltages are used, so that, at any time, a sufficiently accurate test may be had of the insulation of any line. The voltmeter has two scales, one is

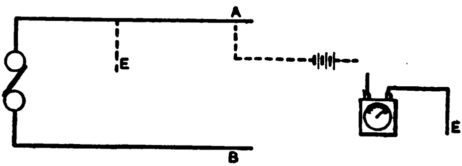


Fig. 296

VOLTMETER TEST FOR LEAK TO EARTH

a 4-volt used for low-resistance tests, and the other 40 volts for high resistances. Fig. 297 shows an arrangement for a testing circuit with a group of key switches, with which various rapid tests can be made for ascertaining the condition of any circuit and localizing any fault. The use of the keys is indicated on the diagram. Lines are carried from the testing desk to the switchboard, main

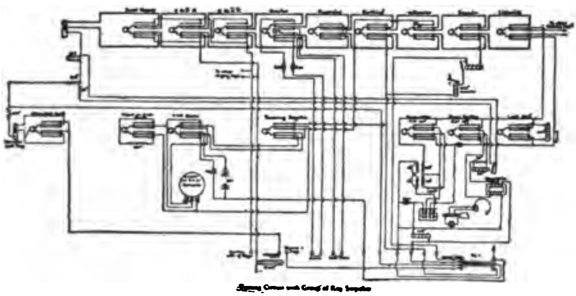


FIG. 297
VOLTMETER TESTING CIRCUIT

frame, etc., and the circuits to be tested are connected to these lines, which terminate on jacks at the desk. Figs. 298 and 299 show the arrangement of two such lines. In the first diagram the line circuit is from the jacks on the desk to a specially-designed plug, shown in at the main frame. To make a test either to the line outside or the switchboard inside, the plug inserted in the protector, but usually all lines are tested right through the switchboard without breaking into the circuit at the main frame. An arrangement of the circuit for this manner of testing is shown in Fig. 299, by which the entire apparatus on that line, including the line and cut-off relays and calling lamp, can be tested by inserting the plug into the multiple jack of any line which

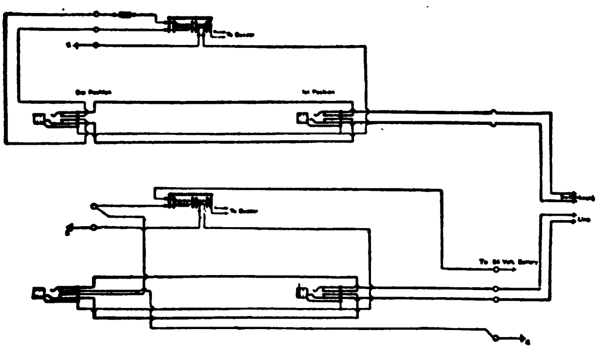


FIG. 298
LINE TO TEST-CLERK'S DESK FROM MAIN FRAME

it may be desired to test, as when the plunger key is fitted in the third conductor, the cut-off relay can either be actuated or released, causing the line relay and calling-lamp to be cut out or into circuit as desired.

GENERAL ARRANGEMENT OF APPARATUS ROOM.—Fig. 300 shows the general arrangement of an apparatus room. On one side is shown the main frame, to which the cables from the outside, which are attached to the strips on the horizontal side, are brought up through the floor in a shaft provided for this purpose. Switchboard cables are carried in iron racks overhead from the vertical side of this frame across to the horizontal side of the intermediate distributing frame on the opposite side of the room, and cables are also run from the multiple jacks on the switchboards to the same side of the intermediate frame. One set of cables is run from the vertical side of this frame to the

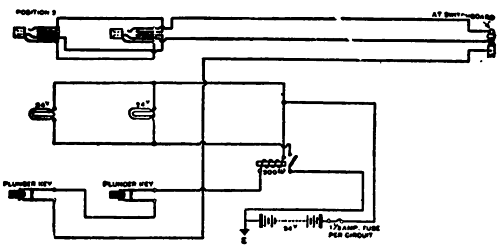


FIG. 299

LINE TO TEST-CLERK'S DESK FROM MAIN FRAME

answering and lamp jacks on the switchboard, a second set is run to the line and cut-off relays on the relay rack, and a third set to the subscribers' register rack. Between the horizontal and vertical sides of each of these frames the individual lines are cross-connected by "jumper" wires, being each line from the arrester to its own multiple jack at the main distributing frame, and to its own answering and lamp jack, etc., at the intermediate distributing frame in parallel with the multiple jack, a twin "jumper" is used at the main and a three-way "jumper" at the intermediate frame.

The power plant, motor-generators, ringing dynamotors, power switchboard, and accumulators, with the fuse panels and repeating-coil racks are placed at one end of the room. To prevent overhearing between the circuits the repeating coils

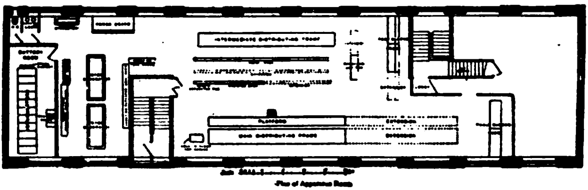


FIG. 300
FLOOR PLAN OF TYPICAL TERMINAL ROOM

are always placed in close proximity to the accumulators and the length of the commons from the battery to the talking circuits is as short as possible.

CHAPTER XIX

PROTECTIVE DEVICES

"Arresters," being a contraction by usage of the term "lightning arresters," is now the common term generally applied to devices used for the purpose of protection. The fuse and the spark-gap form the basis of most protectors. In Figs. 301 and 302 are shcwn some of the earlier

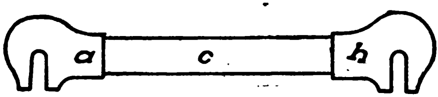


FIG. 301

FLAT LINK FUSE

types of fuses. Fig. 301 shows the style of fuses used on the charging and discharging mains. It consists of a strap of fuse metal c attached at either end to two copper lugs a and b. These copper lugs are slotted to fit over studs, and are held in place by nuts. The fuse metal is made of the requisite size to carry the current required. The type of fuse used on the leads to the transmitter bus-bars is shown in Fig. 302, and consists of a hollow cylindrical fiber tube a, fastened to two German-silver slips d and e, by two brass screws b and c. Through the center of the tube runs the fuse which is soldered at each end to the brass collars m n. The lugs are fastened to the power board by means of the screws s s′.

In the early days of telephone practice the old "saw tooth" arrester was considered ample protection for telephone apparatus; but more complex conditions have arisen with the advanced development of street railway operation, electric lighting and other allied systems in the field of electrical engineering.

Briefly stated there are, at the present stage of evolution in electric engineering, three elements threatening damage to apparatus which must be guarded against, viz: lightning, high tension cur-

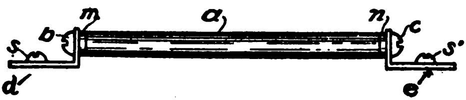


FIG. 302
ENCLOSED FUSE

rents and sneak currents. The action and effects of lightning are well known and self-explanatory. High tension currents are such as result from the crossing of a telephone line with power lines such as an electric railway or electric light line. Lightning and high tension currents are both elements of great danger to human life. Sneak currents are not violent and instantaneous in their effects. When, however, they are not discovered and the flow is permitted to continue they may cause damage by the accumulation of heat.

Fig. 303 shows a type of saw tooth lightning arrester generally employed on telephone instruments a few years ago and was an adaptation of telegraph line arresters employed on single telegraph lines at intermediate stations where two wires looped into the office terminating respectively in the binding posts on the plates, A and B, the local instruments being also looped between these posts. The plate C being directly connected with earth, the local instrument was short-cir-

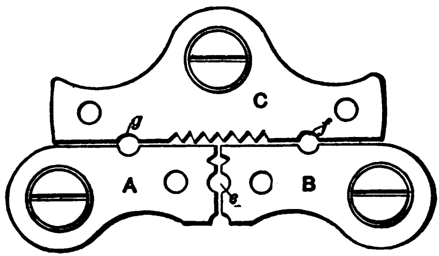


FIG. 303
SAWTOOTH LIGHTNING ARRESTER

cuited and the line left connected through by inserting a conducting plug in the pole e. The end of the line terminating in plate A was grounded when the plug was inserted in plug g, if the local instrument were connected in circuit with that end of the line terminating in plate B. In like manner the end of the line connected with plate B would be grounded if the plug were inserted in the hole, f, thus leaving the instruments connected with the end of the line terminating in the plate A in operative relation. The common practice in the early days was to connect telephone instruments in series in a party line, so that either end of the line could be cut off and grounded, and in the same manner as described in relation to the telegraph line, the instrument was left in operative relation with the other end.

When communication was desired with the other end, this supplied an efficient means of cutting out a defective end of the line; thus this device served on a telegraph or on a series telephone line the double purpose of a switch and a lightning arrester. When serving as a lightning arrester, if the line became subjected to a high potential charge of electricity, the charge would seek a path across the air gap between the ground plate and plates A or B, as this would be a more available path to earth than through the high impedance coils inside of the telephone. Usually the current is of an oscillatory nature of immeasurably high frequency in lightning and other high tension discharges across an air gap, and the air gap, even though it be one of considerable distance presents a more available path than the impedance of a coil consisting of only a few turns. The action of air gap arresters are all based upon this principle. Sometimes it occurs that there is a shorter air gap than that provided for by the arrester and which exists between the core and a wire of a coil and from the core to ground. Hence telephone apparatus is generally defective when it has grounded cores, therefore when such is the case it is preferable that the line wire be connected with the outside layer of winding and not the inside one.

Besides its inefficiency the old saw tooth arrester had other serious faults. When the instrument was short-circuited on the approach of a thunder storm by inserting a plug in hole, e, or connecting it directly to earth by plugging in f or g or in both, the instrument was often left out of service by subscribers forgetting to remove the plug after the storm. Furthermore the insertion of the plug in hole, e, on a line using bridging instruments would leave other instruments on the line out of service and the insertion of the plug in one of the ground plates on a series party line would break the connection between the two ends of the line.

In Fig. 304 is shown a much more efficient arrester, but designed on the same general principles. It consists of two carbon blocks separated by a thin disc of mica. The line wire to be protected is connected to one block of each pair; the other block of each pair resting on a ground plate of metal. The mica strip between the blocks is perforated so as to allow a small air gap between the blocks, over which the high potential charge may jump with much greater ease than between the comparatively widely separated plates of the old saw-tooth arrester. The length of the air gap as determined by the thickness of the separating mica strip usually varies from .005 inches to .007 inches. Carbon block arresters of this general type are now almost universally used for protection against lightning, and against all currents such as might produce potentials of 300 volts or over between the line and ground. With a distance of .005 of an inch between the carbon blocks a pressure of 300 volts across the blocks will break down the insulation of the air gap between them.

This kind of an arrester operates by grounding the line either temporarily or permanently; and

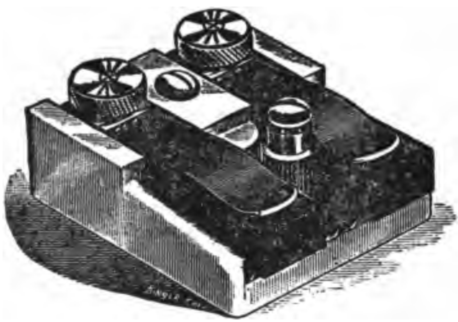


Fig. 304
CARBON BLOCK LIGHTNING ARRESTER

in the case of a lightning discharge, which persists for only a minute period of time, no other protection is required; but for a high potential current resulting from a cross with a high tension wire and which is liable to persist, some other means for opening the circuit after it has been grounded must be provided; for if the current allowed to flow by the grounding is of sufficient strength the danger of damage is great. In this instance the means of safety provided is a fuse wire of limited carrying capacity. A low fusing metal such as lead is generally the material of which such a wire is composed.

The diagram of fuse and carbon arrester, as illustrated in Fig. 305, shows the manner in which they are connected together on telephone lines. This arrangement is calculated to protect

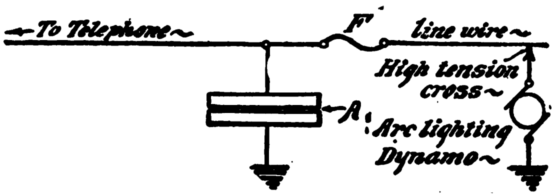


FIG. 305

CORRECT RELATIONS BETWEEN FUSE AND CARBON BLOCKS

A—CARBON ARRESTER

F—FUSE

the instrument from current resulting from a high tension cross and then again to protect the line from the current flowing after the line is grounded at the carbon arrester.

Sneak currents may be caused by induction from some wire carrying high potential alternating current, or by a low potential cross at some point on the line; or by a high potential cross through a very high resistance; or in common battery work, by the grounding of one of the telephone wires or the crossing of two wires. In the latter cases, although the lines may not be subjected to any external electromotive force, the common battery current flow, may persist in some systems to the point of eventually damaging the apparatus.

A fuse wire of very small capacity is a simple means of protection against these small currents. Wires in use for this purpose are made to fuse under a current of 1-8 ampere. In Fig. 306 is shown a fuse of this type mounted on a strip of mica, and to the ends of the strip are adjusted a

FIG. 306
MICA FUSE—WESTERN UNION TYPE

suitable terminal for making the necessary connections. These fuses, however, have been very generally superseded by a sneak current arrester of a very different type, usually termed a heat coil, because of the fact that, together with other objections it has frequently been found that a fuse of the small capacity type, has carried safely a current four times stronger than it was intended to carry.

The construction of one of Cook's heat coils, now widely known and used, is shown in Fig. 307. It consists of a metal shell lined with insulating material except under the head. A circular plate with a threaded stud closes the opposite end, but is insulated from the shell, which is filled with graphite composition to serve as resistance.

The heat coil is screwed into a stationary spring as in Fig. 308 and attached with soft solder to the bent spring, which tends to pull away. If the heat generated by the current is sufficiently great, the solder melts and allows the bent spring to escape as shown at the left in the figure. This

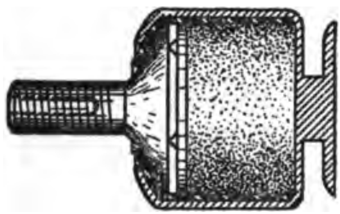


FIG. 307
SECTION OF HEAT COIL—COOK TYPE

breaks the line while an auxiliary spring grounds the line and closes an alarm circuit. The dotted lines show the ends of the spring of the re-setting device, which with 6 to 8 dry cells resolders the heat coil.

What is at present regarded the proper degree of protection for telephone apparatus may be considered in relation to the diagram shown in Fig. 309. There is a line shown in this figure extending from the central office to the instrument of a subscriber. This line passes from the office through a section of underground cable, onward to a section of overhead cable and thence to the premises of subscriber through bare wires on poles. The underground cable, running directly into central office terminates in potheads or their

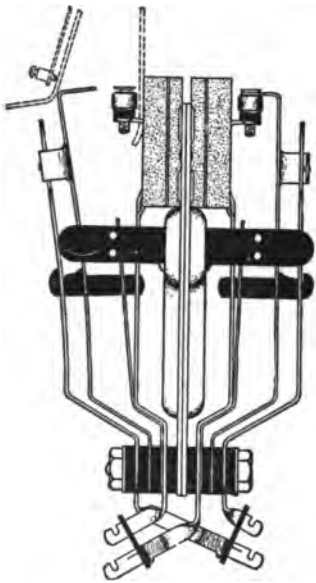


Fig. 308
COOK PROTECTOR

equivalents or directly on the line side of distributing frame. Practically this precludes the danger of a cross between telephone and power wires at any point between the outer end of the underground cable and central office.

A combined carbon and sneak current arrester is provided at the point in the office where the conductor emerges from the cable. In the diagram, Fig. 309, the carbon arrester is shown at A and the heat coil of the sneak current arrester is shown at B. When the sneak coil is released it allows the line spring, b, to come in contact with the ground connection, which grounds the line and opens the circuit to the switchboard or grounds it while leaving it closed as the case may

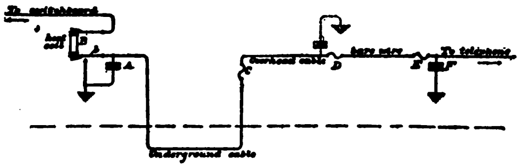


Fig. 309

DIAGRAM OF COMPLETE PROTECTION FOR TELEPHONE LINE

be. A fuse should be placed at the outer end of the underground cable at C where connection is made with the overhead cable; and a fuse should be placed at D and another at E—the first point being the junction of the overhead cable and the bare wire and the second point being where the line wire enters the subscriber's premises. The dotted lines show where a carbon lightning arrester is sometimes introduced at D. At F, a carbon arrester, which should form a part of the telephone equipment, is placed inside of subscriber's premises. A heat coil is also sometimes used at D.

Most engineers prefer to place a fuse between the underground and overhead cable, as at the point, C. It is undoubtedly an additional protection and might prevent serious loss where a heavy cross existed between the sheath of the overhead cable and a high tension wire. Such a cross might easily cause the current to arc to the sheath, and, melting a hole in this, to the conductors within the overhead cable, in which case the fuse at C would probably save the conductor in the underground cable. If a cross with a potential of over 300 volts occurs on any of the conductors, a flow of current will probably take place through the carbon arrester at A, or F, or both, and the consequent flow due to the low resistance path thus established would cause sufficient current to flow to blow one or more fuses at C, D, or E. If, on the other hand, a comparatively low potential cross existed not of high enough potential to cause the carbon arrester at A or F to act, and not causing a current of sufficient strength to flow to blow the fuses at C, D, or E, the heat coil, B, would receive the current and would operate, throwing a dead ground on the line, and thus effectually prevent any current entering the exchange apparatus. The low resistance path thus leading to the ground would, if the current were of sufficient strength to affect the conductors in the cable, cause the blowing of one or more of the fuses.

The placing of combined heat coils and carbon arresters at the exchange of the line fuse at C or D and E, and of the carbon arrester at F, represents well established practice. The sensibility of the various protective devices and also the questions as to whether a fuse, or carbon arrester or both should be placed at C, whether at D a carbon arrester should be added to the fuse and whether at a subscriber's station a heat coil should also be added to the protective devices are as yet all debatable questions, and it is still a subject of contention among exchange engineers whether or not it is always necessary or desirable to secure absolute protection, as a too perfect system of protec-

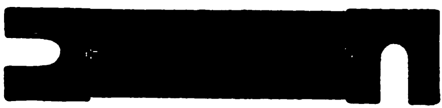


FIG. 310

MICA FUSE—POSTAL TYPE

tion increases the cost of maintenance and is the cause of frequent interruptions of service. For this reason the aim in general practice is to follow a middle course affording thereby sufficient protection while minimizing the cost of maintenance and interruption to service.

In actual practice at the present time the leading devices and apparatus generally used in protecting telephone lines and equipments are shown in the following illustrations:

In addition to the usual form of sneak current fuse, known as the Western Union type, and previously referred to and shown in Fig. 306, is another fuse, Fig. 310, which differs only in the style of its terminals. The difference between these two types is that the former is designed to be inserted between spring clips, whereas in the latter cross screws extending through the slot ends

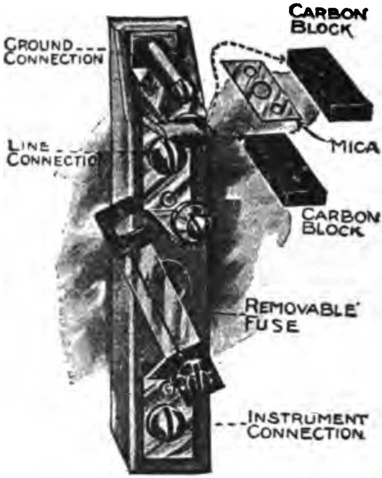


FIG. 311
COMBINED FUSE AND CARBON ARRESTER SINGLE CONDUCTOR

are used to secure it in place on its clips. When used in outside construction these fuses should be inclosed in weather-proof boxes. In order to afford protection against both low and high potential currents these fuses are frequently mounted in association with carbon arresters. Fig. 311 illustrates a combination of this character adapted to a single line wire. For a metallic circuit such a device, as shown in Fig. 312, is employed adapted to Postal fuses, and in Fig. 313 the same

FIG. 312
OLD STYLE DOUBLE POLE ARRESTER WITH POSTAL FUSES

combination is shown adapted to Western Union type fuses. For a line circuit entering an ordi-

FIG. 313
OLD STYLE DOUBLE POLE ARRESTER WITH WESTERN UNION FUSES

nary magneto-telephone the construction of a combined carbon and fuse arrester is shown in Fig. 314.

A tubular line fuse, shown in both perspective and sectional view in Fig. 315, has come into very general use in such sections of a line in outside construction as may be observed at C, D, and E in Fig. 309. This tube is of either wood or fibre

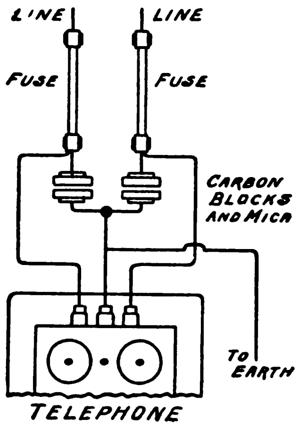


FIG. 314
PROTECTOR INSTALLED AT TELEPHONE

and encloses a long fuse wire. Heavy brass terminals arranged with convenient means for attaching to line wires, serve to close the ends of the tube. The fuse wire extends entirely through the terminal at each end and within the tube is secured to the terminal at each end by solder. This fuse is made by the American Electric Fuse Company, and is especially adapted to clamping directly on the line wire outside of subscriber's premises (see point E, Fig. 309), the parallel jaws at the right end of the cut serving to grip the line wire while at the other end of the cut the

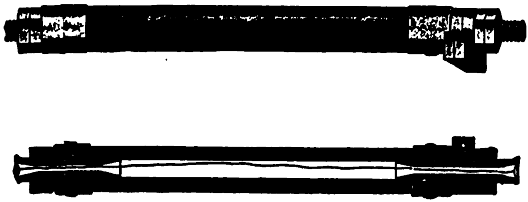


FIG. 315
TUBULAR OR ENCLOSED FUSE

nuts shown serve to clamp the wire leading to the subscriber's premises. Fig. 316 shows these fuses placed in boxes and mounted in banks to

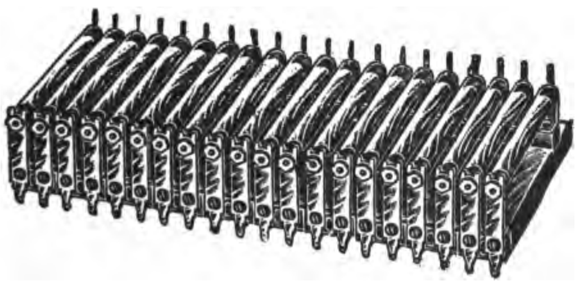


FIG. 316
BANK OF TUBULAR FUSES

economize room when used on a cable pole as, for example, at D in Fig. 309.

There is a similar arrangement to that which is shown in Fig. 316 with the exception that in this arrangement each fuse is supplemented with a carbon arrester for protection against high tension currents.

A device, for complete protection at subscriber's premises is shown in Fig. 317. It consists of tubular fuses, heat coils and carbons all mounted on a single porcelain block.

A most efficient carbon block arrester, used in

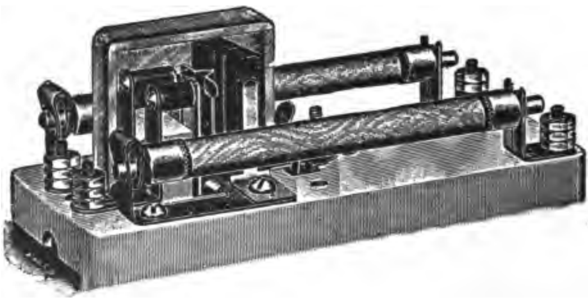


Fig. 317
SUBSTATION PROTECTOR

manufacture of the most modern telephone sets is that designed by the Kellogg Switchboard and Supply Company, and is illustrated in Fig. 318. Fig. 319 shows the method of introducing this arrester into the line circuit and into the circuit of the instruments which terminates in the binding posts.

This arrester consists merely of two brass discs of approximately semi-circular form, one being permanently connected to each of the line binding posts of the instrument. Over these fits a perforated mica washer of circular form, and over this is clamped, by means of a centrally disposed screw set, a carbon plate, covering both the semi-circular brass plates. The screw holding this carbon in place is permanently connected to the

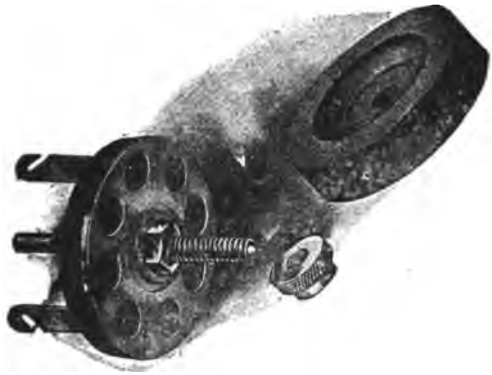


FIG. 318

KELLOGG CARBON ARRESTER FOR TELEPHONE SETS

ground binding post, these connections being shown in Fig. 319.

The lightning arrester usually furnished by the Stromberg-Carlson Company on their telephone sets is shown in Fig. 320, in which the binding posts shown are those of the telephone instrument.

As two heat coils and two carbon arresters are used in connection with each line circuit in a modern central office, economy of space and in the amount of wiring between them, has brought about the association of the carbon arrester with

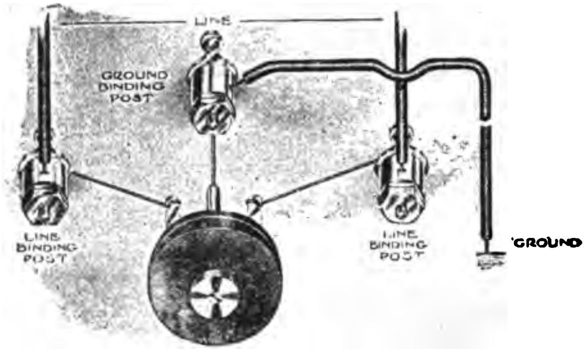


FIG. 319
CIRCULAR BLOCK ARRESTER WIRED TO TELEPHONE

the heat coil device in such manner as to form virtually one piece of apparatus.

FIG. 320
STROMBERG-CARLSON CARBON ARRESTER FOR TELEPHONE

To make electrical tests as to the outside condition of the line or the condition in the office, a

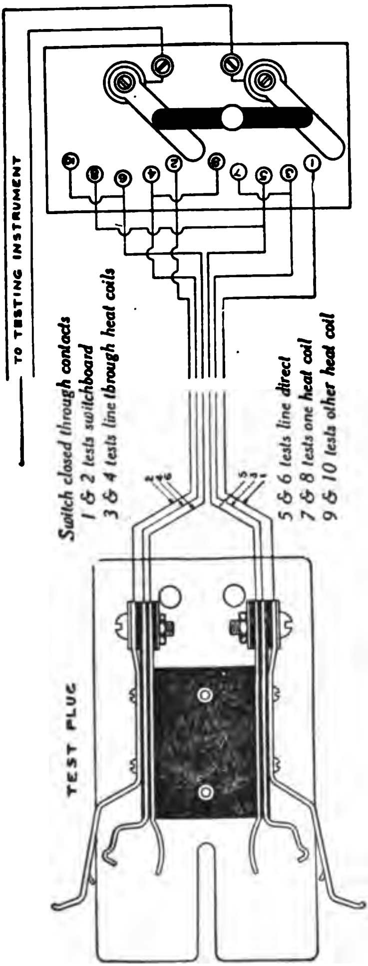
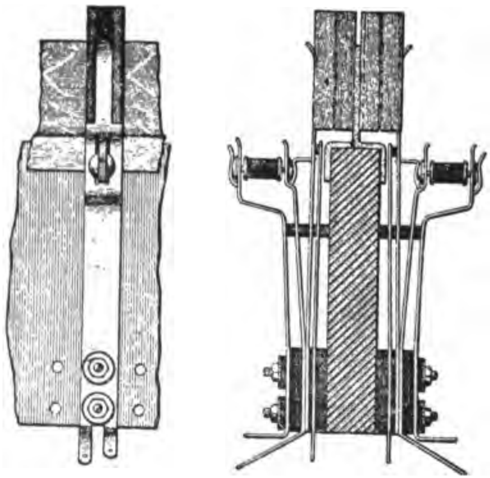


FIG. 321
TEST PLUG OR SHOE FOR COOK PROTECTOR

test plug is inserted in the arrester. See Fig. 321. In making such tests the heat coils of the pair of arresters belonging to the line to be tested, are not disturbed but the 6-spring plug pushed into position. This plug makes contact



SIDE VIEW CROSS SECTION VIEW

FIG. 322
KELLOGG PROTECTOR

with the two line springs and also with the two springs connected with the switchboard circuits.

An arrester in general use, the general plan and operation of which is shown in Fig. 322, has been devised by the Kellogg Switchboard and Supply Company. The heat coil of this arrester is somewhat novel. A small cylindrical block or carbon is used instead of German silver wire as a heat-producing medium (see Fig. 323). The heat generated by the passage of a current through a carbon of suitable resistance operates this device by melting the solder by which the brass terminals are soldered to the block.

The Rolfe coil, shown in Fig. 324, manufactured by the American Electric Fuse Company, is recognized as an improvement on those in general use because of the fact that it obviates the necessity of discarding a coil or incurring expense to restore it to usefulness when it has once been used. In this device, when the solder melts the movable part is not separated from the body of the coil, but moves from one position to another and in doing so releases the spring which grounds the line. The circuit through the coil is broken as soon as the spring is released and the cooling of the parts begins at once, thus, as soon as it is sufficiently cooled, automatically resoldering the movable part into its new position, where, by its other end it can hold the spring as before.

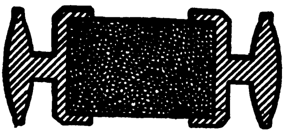


FIG. 323
CARBON HEAT COIL

As shown in Fig. 324, the only movable part of this device is a small lever shown at the right-hand end of the coil. When it is in the position shown in the upper left-hand view of this cut, the spring of the arrester holder is adapted to be caught under the lower leg of this lever and thus retained in place. When the solder holding this lever in this position is softened, the spring forces the lever into the position shown in the upper

FIG. 324
RESETTING HEAT COIL

right-hand view of this cut, and the spring is thus released. After the coil is cooled it is only necessary to turn it around in the holder in order to bring the other end of the lever in connection with the spring, as that end is now in such position as to retain the spring. This device may be operated many hundreds of times without showing any appreciable deterioration, and as a result the only expense caused by the blowing of the heat coil is that of the time necessary for the attendant to again set the springs which it released by this operation.

Another type of thermal arrester or heat coil which deserves passing mention, is that also designed by Rolfe and shown in Fig. 325. In this the heat coil assumes the form shown in the upper portion of this figure, it consisting of a little metallic capsule having embodied within it a coil of German silver wire held in place and insulated by

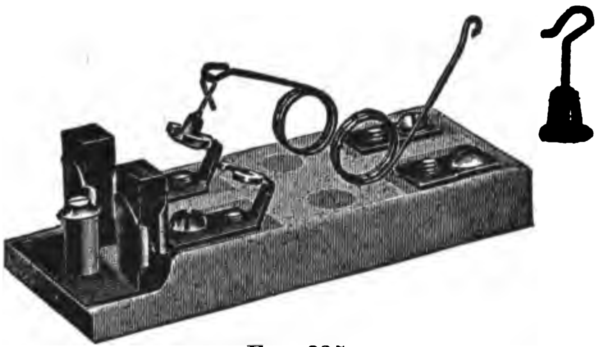


FIG. 325

ROLFE HEAT COIL—OLD TYPE

a plastic material resembling sealing-wax. A hook projects from the small end of this capsule, thus forming one end of the coil, the capsule itself forming the other terminal. This device is held between a coiled spring and a forked clip, as clearly shown in Fig, 325, the heat coil being thus subjected to tension and also forming a link in the circuit to be protected. When traversed by too heavy a current the hook pulls out of the capsule, due to the softening of the plastic material, and the circuit is broken by the retraction of the coiled spring.

These arresters have also been so made as to adapt them to service in place of the ordinary Western Union fuse, the working parts of the arrester being mounted on a fibre strip provided with clips adapted to slide into the fuse holder in place of the ordinary fuse. This arrangement is quite clearly shown in Fig. 326 as applied to the Western Union style of fuse holder.

In Fig. 327 is shown a type of arrester used by the Monarch Telephone Manufacturing Company.

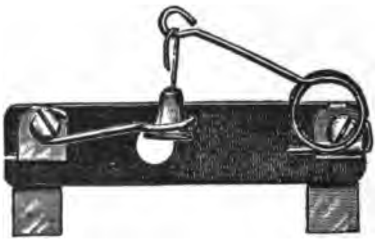


FIG. 326
ROLFE HEAT COIL

It is known as a disc arrester, owing to the shape of the carbon ground plate.

Its construction is very simple, A heavy fiber mounting plate supports the two line binding posts which extend through the back board and there form a part of the cabinet wiring. Attached to these binding posts and resting against the fiber plate, are the broad, flat line plates. Between these two plates, and in no way connected to them, is the ground post which passes through the back board, and is there connected to the top binding post by a brass strip. The carbon disc is held between the nut at the top of the ground

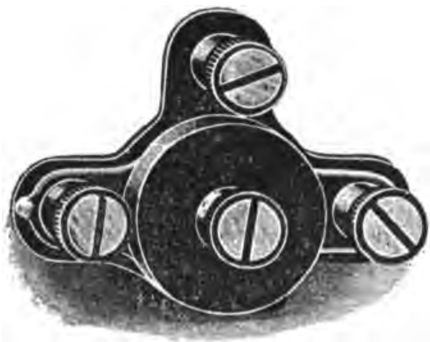


FIG. 327

CIRCULAR BLOCK ARRESTER WITH BINDING POSTS

post and the line plates, but is insulated from these plates by a perforated mica separator.

FIG. 328

LIGHTNING ARRESTER—PENCIL TYPE

Lightning coming in over one side of the line finds a ready path to ground from the line plate through the perforated mica separator to the carbon block, and thence to the ground binding post.

Another type of arrester manufactured by the same company is shown in Fig. 328. It consists of three metallic posts fitted with carbon pencils. The outside posts are connected with the line wires, while to the center post is fastened the ground connection. The carbon pencils are placed close together but do not touch. Lightning coming in over one side of the line finds a path to ground through the small air gap between the line and ground carbons. The arrester is wired to three binding posts at top of telephone.

CHAPTER XX

MEASURING INSTRUMENTS

The Wheatstone Bridge

For testing purposes some form of the Wheatstone bridge is now used almost entirely. *Resistance coils* must be double wound, and those most frequently used are made of German silver, platinoid, or platinum silver, because of their durability and high specific resistance, and partic-

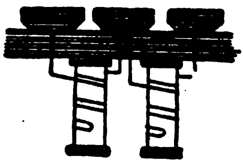


FIG. 329
NON-INDUCTIVE RESISTANCE WINDING

ularly because, owing to change of temperature, a small error only is due to their variation of resistance. A double length of wire is required for the double winding of the coils, and both lengths are wound side by side on the bobbin as shown in Fig. 329, or two wires may be bound together on the bobbin with their ends carefully soldered.

Continuously wound coils would set up a magnetic field and affect galvanometers near, causing serious errors in the testing results. When doubly wound the magnetic effect due to the current in one wire exactly neutralizes the effect in the other wire. A separate core or bobbin, usually of brass or copper, is required for each coil. To prevent induction currents it is split longitudinally, and is

FIG. 330
VIEW OF SIMPLE RESISTANCE BOX

covered with thin rubber or varnished paper for insulation. Each layer of the coil, after being wound, is dipped in melted paraffin which protects the wire from damp and ensures good insulation. The bobbins are adjusted under the ebonite top of a box similar to that shown in Fig. 330. The two ends of the wire are fastened to two adjacent brass blocks, and the coils are thus connected in series. The current flows through the coil when the plug is removed, and the coil is short-circuited when the plug is inserted. In order that the plugs may be interchangeable they should be of uniform size.

In Fig. 331 the well-known figure used for illustrating the principle of the instrument is shown, A and B being the proportional arms, R

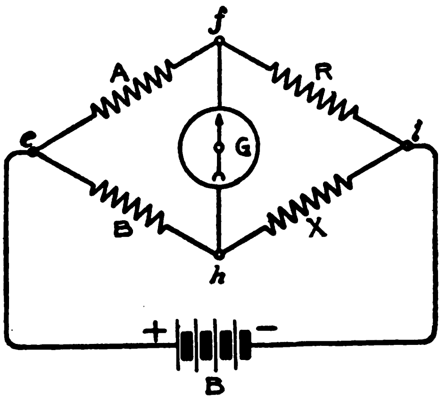


FIG. 331
THEORY OF WHEATSTONE BRIDGE

the resistance coils, and x the unknown resistance. the resistance R is adjusted until the needle remains undeflected, which shows that the potentials at the points f and h are alike, and that no current flows through that arm in which the galvanometer is connected. The unknown resistance x is then calculated from the formula, $X = \frac{B}{A} R$. If A is made equal to B, then x = R.

A form of Wheatstone bridge instrument is shown in Fig. 332, and Fig. 333 shows the elec-

FIG. 332
DIAL WHEATSTONE BRIDGE

trical connections. The proportional coils consist of six coils, giving 10, 100 and 1000 ohms on either side. In the right-hand dial, the resistance of each coil is one-tenth ohm; in the next dial the resistance of each coil is one ohm; in the third dial, 10 ohms each; in the fourth dial, 100 ohms each, and in the fifth dial 1000 ohms each. The

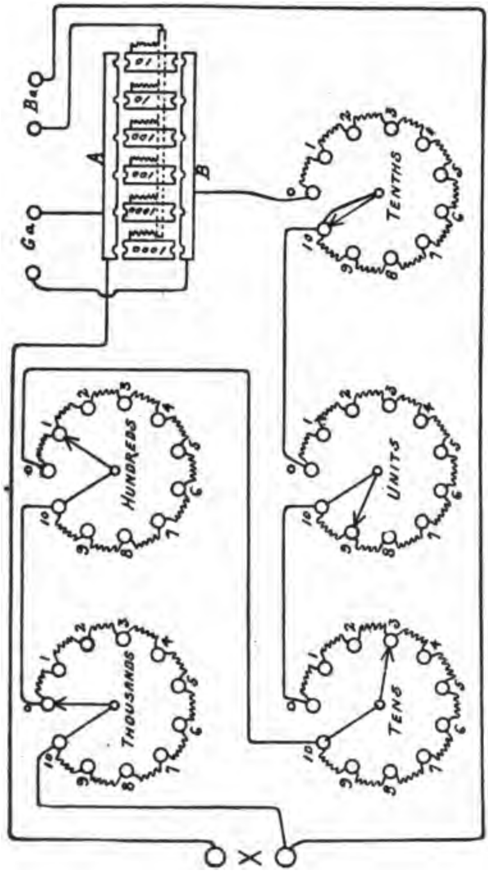


FIG. 333

WHEATSTONE BRIDGE—ELECTRICAL CONNECTIONS

two outside dials are connected to the terminals as shown, and the dials are connected to each other from the centre to the zero of the next dial. When the brushes are turned to 9 in each dial the resistance in circuit is 9999.9. By adjusting the proportional arms, any resistance between

$$.1 \times \frac{10}{1000} = .001 \text{ ohm and}$$

$$11{,}111 \times \frac{1000}{10} = 1{,}111{,}100$$

can be measured by this instrument, but great battery power would be required for such high resistance as the latter, so as to obtain a considerable fall of potential, and thus produce a sufficient effect on the galvanometer.

In another form of the Wheatstone bridge the resistance coils are arranged in a box with their ends connected to the brass blocks on the ebonite top. Double terminals are provided to ensure good electrical contact where two are externally connected to any particular point, and terminals are also provided for each key. Two infinity plug-holes are made as shown in Fig. 334. The first, between B and the resistance coils, are useful for purposes as follows: First, by the removal of the plug in an insulation test, the insulation of the line is infinite, that is, perfectly insulated; second, if the resistance of the instrument is too small a second rheostat can be connected at this point; third, to test batteries by the shunt method, the proportional coils being used as a shunt. The other infinity plug-hole is between the 10 and 20-ohm coils. At the side of the instrument is the reversing switch for reversing the direction of the current. As the switch is not provided with plugs, two of the proportional coil plugs must be used, which necessitates the re-

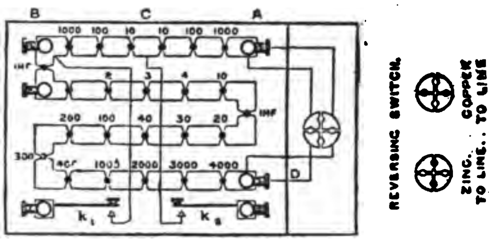


FIG. 334

WIRING OF WHEATSTONE BRIDGE

moval of the plugs from those coils, thus preventing the instrument from being short-circuited. A two-position reversing switch is provided in later instruments.

Fig. 335 shows a good method of connecting the Wheatstone bridge. To the table near the instrument seven terminals are fastened. The connections to the terminals being permanent, imperfect connections are less liable to be made. The straps are connected for conductivity and insulation tests. If a and b are valves of proportional arms, D that of the rheostat and L the insulation of the line, then $L = D\frac{a}{b}$. To make a loop test for the distance of a ground fault the straps should be connected to 2 and 5, and 3

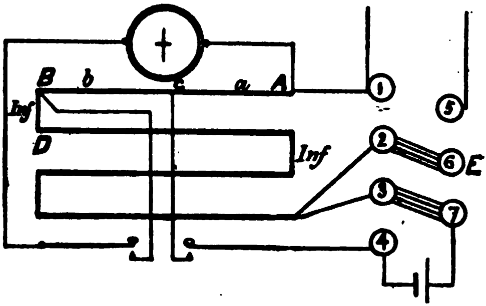


FIG. 335

CONNECTING WHEATSTONE BRIDGE TO BATTERY AND LINE

and 7 for the first test, and to 2 and 5, and 6 and 7 for the second test. If a and b are equal and X is the distance to the leak, then $X = \frac{L - D}{2}$ if L = loop resistance of lines.

To find the distance of a contact between two wires when the contact point is on the near side of the centre of resistance, connect 2 and 5 by the strap, and 1 and 6 by a wire, removing the strap from 7. Connect one line to the terminal 5, the other end being grounded, and connect the other line direct to the copper pole of the battery at the

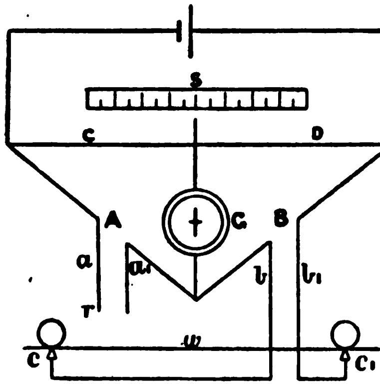


FIG. 336

METER BRIDGE

battery box, with the other end disconnected.

Then $X = \dfrac{L - D}{2}$ if $a = b$. $L =$ loop resistance.

Connect terminals 2 and 6 by the strap, and 5 and 7 by a wire, if the point of contact is beyond the centre of resistance. One line is connected to terminal 1, with the distant end grounded, and the other line is connected direct to the copper pole of the battery, with the distant end disconnected.

$$\text{Then } X = \frac{L + D}{2}.$$

STEARNS' METRE BALANCE

Fig. 336 shows a metre balance for testing the resistance of wires in the factory. A, B, C and D are the arms, and G is a galvanometer with one side connected to a vernier, which slides along the graduated scale S, and carries a knife-edge to make contact with the arms C and D. A standard resistance equal to the resistance of a definite length of wire, say 1 ohm, is at r. The size, length, quality, and resistance of the leading wires a, a_1 and b, b_1 must be the same as the wire under test, so that all may be equally affected by changes of temperature. When the standard resistance is .1 ohm, a length of wire to be tested of the same resistance must be passed over the points c, c_1. If the wire is, say, 450 lbs. iron wire, its maximum resistance must not exceed 12 ohms per mile; thus a length of 44 feet will be .1 ohm exactly; therefore the points c, c_1, must be 44 feet apart. The resistance of the wire drawn over the points c, c_1, is correct as long as the needle remains at zero. The resistance of the wire is below the standard if the vernier has to be moved two divisions to the right over a scale divided into 600 equal parts. The exact resistance per mile is found thus—

$$302 : 298 :: .1 : x$$
$$\text{whence } x = .09867$$

Multiplying this by 120 the resistance of the wire under test is found to be 11.8404 ohms per mile. If the vernier had to be moved two points to the left of the zero the resistance would be

$$298 : 302 :: .1 : x$$
$$\text{whence } x = .10134$$

and $.10134 \times 10 \times 12 = 12.1608$ ohms per mile.

To show definite degrees of increase or decrease in the resistance of the wire—each division representing, say, .01 ohm—the scale S may be divided. The variation in resistance can then be read direct.

In the galvanometer circuit a sensitive relay can be connected to enable a current passing through the circuit to close a local circuit containing a bell, or to release a detent which stops the machinery. Constant personal attention to the instrument is then not required.

THE BRIDGE GALVANOMETER

A separate galvanometer is furnished with both forms of bridge. Fig. 337 shows a form with window to illuminate the scale. It is wound to a resistance of about 800 ohms as a rule, but some forms offer a resistance of 1,000 ohms. The galvanometer is very sensitive owing to the many turns of wire, the proximity of the wire to the needle, and the delicacy of the pivoting of the needle. A small mirror is fitted in the dial, and the reflected image of the indicator is made to coincide with the indicator, and thus parallax error is avoided. When connected to a standard cell of 1.07 volts through a resistance of 52,000 ohms, a deflection of 10 divisions is obtained, representing a current of about .0206 milliamperes.

A later form of this instrument, wound to a resistance of 100 ohms, gives a deflection of 1 degree with .008 milliamperes, and a current of .002 milliamperes will produce a similar deflection, when wound to 1,000 ohms.

FIG. 337
GALVANOMETER

In Fig. 338 a plan of a portable testing set is shown. This is a very useful instrument and the complete set is contained in two boxes, one holding the batteries and the other the galvanometer, resistance coils, and the bridge coils. The galvanometer consists of a coil of fine wire wound on a brass bobbin, with a small magnetic needle pivoted in the centre. The needle is provided with an aluminum indicator projecting through the opening in the end of the coil, and the excursions of the pointer are limited by the size of the opening to about 45° on each side of the zero in the centre. The scale used is approximately a scale of tangents. When the indicator is at zero the north end of the

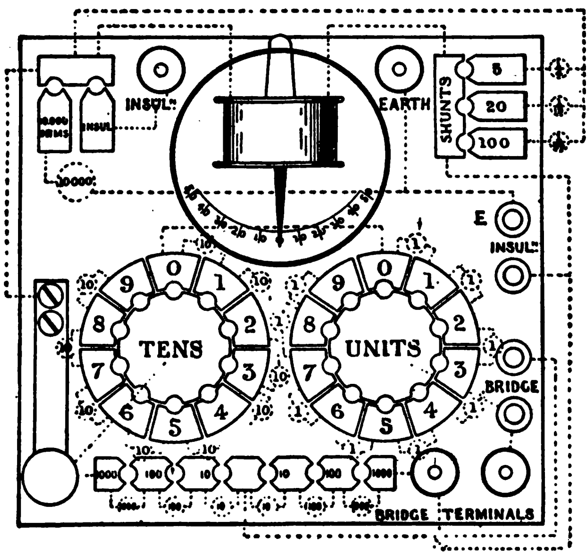


FIG. 338

DIAL BRIDGE

needle points to the left hand side of the box, and on this same side of the box the controlling magnet is placed. The galvanometer is most sensitive when its north pole is uppermost, and the deflection of the needle due to any given current will be reduced by about 40 per cent, when its south pole is uppermost. By turning it to one side or the other, the magnet also adjusts the needle to zero in its position of rest. The pointer will be at zero when the box is placed with its left side to-

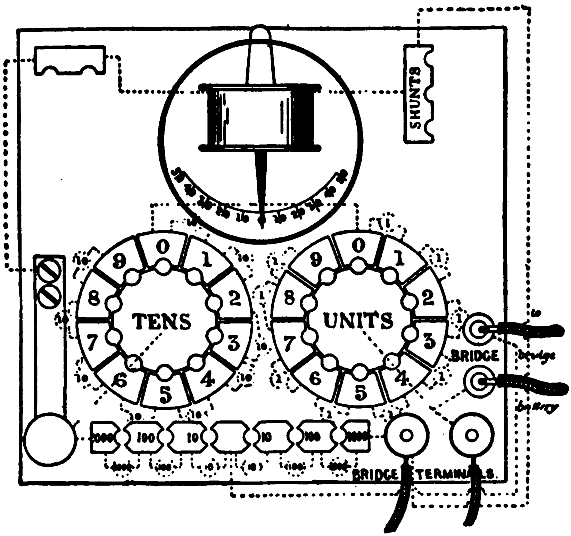


FIG. 339

BRIDGE CONNECTED FOR MEASURING RESISTANCE

wards the north, as it should be placed for testing.

The bridge method is used for measuring conductor resistance. The parts of the instrument used in making this test are shown in Fig. 339, The proportional resistances are composed of two coils of 10 ohms each, two of 100 ohms each, and two of 1,000 ohms each, as in the form of instrument described. The adjustable resistance is composed of two sets of nine coils each connected to circular dials. One of these sets of coils has nine resistances of 10 ohms each, in all 90 ohms, and the other set has nine resistances of 1 ohm each, making 9 ohms in all. The dials are connected in the manner shown. The total resistance is 99 ohms when the plugs are inserted at 9 in each dial. For testing from .01 to 9,900 ohms the proportional coils can be varied in the usual way. Depressing the key on the left-hand side connects the galvanometer terminals to the two ends of the bridge. One pole of the battery is connected to the middle of the bridge as usual, and the other pole to that point where the end of the adjustable coils is connected to one of the terminals marked "bridge terminals," and the ends of the conductors, or of the conductor and ground, are also connected to the terminals marked "bridge terminals."

The parts of the instruments required for insulation tests are shown in Fig. 340. The method is that of direct deflections. The poles of the battery composed of 30 cells are connected to the terminals marked "insulation" on the right-hand side of the instrument. First the *constant* is fixed, that is, the resistance through which the testing battery produces a deflection of 1 division, which is ascertained in the following manner:

Connect the battery as stated above, and insert the plugs in the bridge coils to cut out these coils. Insert a plug in the 10,000-ohm coil and in the

100-shunt coil, thus making the deflection through the galvanometer equivalent to a deflection through 1,000,000 ohms, or 1 megohm. It will be seen that as the deflection is inversely as the resistance,

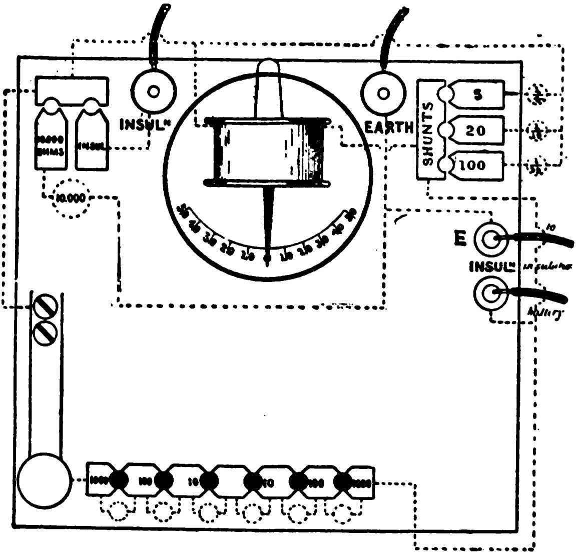


FIG. 340

BRIDGE CONNECTED FOR INSULATION TEST

if the deflection is 20 divisions, by increasing the resistance to 20 megohms a deflection of 1 divison only will be obtained, which, in this particular case, would be the constant. The plug is then removed from the 10,000-ohm coil and adjusted in the adjoining plug-hole, and the line which is disconnected at the distant end, is connected to the terminal marked "insulation" at the tops of the box.

A suitable shunt can be employed if it should be necessary to reduce the deflection when the line is being tested, and this deflection will bear the same relation to the deflection when the constant was fixed at 1 division, as the constant resistance of 20 megohms bears to the insulation of the line, or the total insulation $= \dfrac{1 \times 20 \text{ megohms}}{\text{deflection}}$, or simply divide the deflection into 20 millions. If, say, the 1/5 shunt has been used, and the deflection received was 20 divisions, the insulation resistance of the line will be $\dfrac{20{,}000{,}000}{20 \times 5} = 200{,}000$ ohms, or .2 megohms. The total insulation is multiplied by the mileage of the line to obtain the insulation per mile. The explanation of *multiplying* instead of *dividing,* as is done to find the conductor resistance per mile in conductivity tests, for which an explanation was unnecessary, is that taking the insulation test is really testing the resistance of the insulators, the wire serving to connect all the poles in the parallel. If the poles are represented by a, b, c, d, etc., their joint conductivity $\dfrac{I}{R}$ will be equal to the sum of their separate conductivities, or $\dfrac{I}{R} = \dfrac{I}{a} + \dfrac{I}{b} + \dfrac{I}{c} + \dfrac{I}{d} + \ldots$

If the resistance of each pole is 20 megohms, $\frac{I}{R} = \frac{4}{20}$ is obtained, and their joint resistance R, which is that obtained in the test, is $R = \frac{20}{4}$ or $4 \times R = 20$ megohms, whence $R = 5$ megohms. It is sufficient to know the insulation per mile, therefore in the example the word "mile" can be substituted for the word "pole." After having obtained the insulation per mile by multiplying the result of the test by the mileage, the resistance of each insulator can be obtained if necessary by a further multiplication by the number of poles per mile.

The needle may be prevented from swinging, and brought quickly to rest, by depressing the key on the left, practically cutting out the galvanometer by opening a short circuit to the battery.

The complete instrument opened is shown in Fig. 341.

Sometimes it may be necessary to ascertain the insulation resistance of a distanct portion of the line. The insulation resistance of two or more lines is the same, in fine weather, either connected in series or bunched together. Their joint insulation resistance is then equal to the reciprocal of the sum of the reciprocals of their separate resistances.

A metre bridge, shown in Fig. 342, is used for measuring very small resistances where fractions of an ohm are involved. A metre length of manganin wire (39.37 inches) ww is connected to

FIG. 341
VIEW OF DIAL BRIDGE

the brass frame, and forms the ratio arms of the bridge.

The standard resistance is connected to the gap S, and the unknown resistance in the gap x. One terminal of the galvanometer is connected to a knife-edge which moves along ww until the balance is obtained. The value of x is then read off the scale ab, which is divided into 1,000 millimetres. Two resistance coils, each equal to the resistance of the metre wire, can be connected in the gaps n_1, n_2, if still greater accuracy is required which

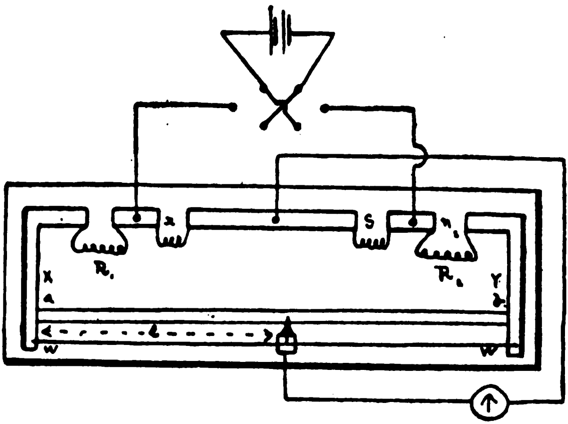


FIG. 342

METER BRIDGE FOR SMALL RESISTANCES

is obtained when the knife-edge is near the centre of the metre wire. If the gaps n_1, n_2, are closed and the knife-edge slider has to be moved one to the left to obtain a balance, then a is 499 and b is 501. If S is a standard ohm, then

$$x = 1 \times \frac{499}{501} = .996008 \text{ ohm nearly.}$$

If resistance coils are then introduced in n_1, n_2 equal to that of the metre wire

$$x = 1 \times \frac{1499}{1501} = .998667 \text{ ohm}$$

is obtained, which is still more accurate.

The metre bridge should be carefully set up so that the metre wire will not be stretched unduly and that it will be uniform in thickness and resistance. At the joints of the metre wire and at the various connections there should be no resistance. The slider knife-edge and the pointer must coincide exactly, and so that the various resistances will not become heated the battery power must be moderate.

A method of using the bridge independent of the resistances which may be introduced at the points and connections, making unnecessary the precautions above mentioned, has been devised, in which the standard coil has been removed and it is connected with a thick wire without appreciable resistance, and the slider was then moved towards a, until a balance was obtained. Call the result a. The unknown resistance was then placed in the gap S and the gap X closed, and the slider was moved towards b until a balance was obtained, say, b. Then $x = \frac{b - a}{n}$ ohms.

Where n is the number of millimetres per ohm.

Resistance coils are frequently adjusted by this method.

Fig. 343 shows a double bridge for measuring accurately the resistances of short pieces of wire. The arms A B are fixed, and the standard resistance is placed in the arm B, and the resistance to be measured in the arm A. So that no resistance may be introduced at the contact points, the con-

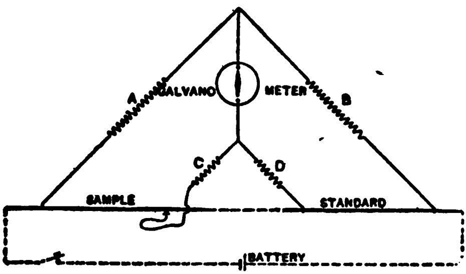


FIG. 343

DOUBLE BRIDGE FOR WIRE TESTING

tacts from A, B and from the two coils connected to the galvanometer are made by knife-edge sliders.

Fig. 344 shows the principle of a double-bridge system of nine wires connected at six points. a, b, are the ratio coils, A B are the small resistances to be compared, d the connecting resistance between A and B, and 1 and 2 are the auxiliary ratio coils. "a" and "b" can be replaced by a slide wire for measuring small resistances, and for measuring large resistances it can be replaced by coils in the form of a dial rheostat, and another rheostat for the auxiliary coils 1 and 2. The latter usually contains 100 coils of 20 ohms each, and the former 101 coils of 1,000 ohms each. Therefore 10,000 ratios are available, and each one differs from the next by 10 ohms. If the auxiliary ratio coils 1 and 2 are in exactly the

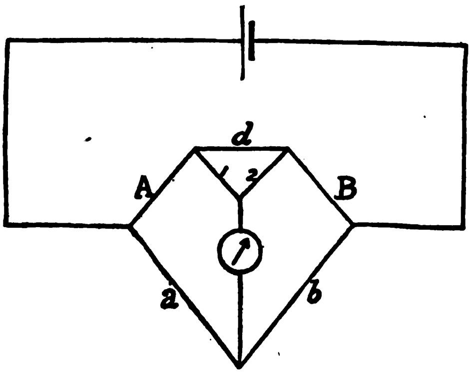


FIG. 344
THEORY OF DOUBLE BRIDGE

same proportion as the main ratio coils a and A, the formula for the Wheatstone bridge:

$$A : a :: B : b$$

applies; but if not exactly in this proportion a correction is necessary. Some resistance must always be in d, and in most instruments the handle connects 2,000 ohms in d. Because of its almost negligible temperature coefficient and high specific resistance, all the resistances are made of manganium.

Fig. 345 shows a plan of a horizontal moving coil galvanometer used with the Wheatstone bridge, pattern A. It consists of a horseshoe magnet of the highest quality which has been thoroughly aged before using, and has its pole-pieces shaped to admit the soft iron core, which consists of two

FIG. 345
MOVING COIL GALVANOMETER

hemispheres. The circular coil is wound on a metallic frame fitted with a radial spindle, with a pivot on the end which turns on a jewel in the centre of the spherical core. The moving system is carefully adjusted so that its centre of gravity is at the centre of the coil where the pivot is placed. The relieving of the pivot of the weight of the coil in transit, the reduced friction, and the very small clearance necessary to reduce the air gap to a minimum, are the special advantages of the centre mounting. 1.07 volts will produce a deflection of ten divisions through a resistance of 52,000 ohms, the current being .0206 milliamperes, in the ordinary horizontal galvanometer, but with the new galvanometer wound to a resistance of only 60 ohms, a deflection of six degrees is produced through a resistance of 100,000 ohms from one volt. Some of the advantages of this instrument are that it does not require setting in the magnetic meridian, has no needle to become demagnetized, is not affected by neighboring magnets, is perfectly dead-beat, has great sensibility, low resistance, no frictional error, and the calibration being constant, it can be used as a direct-reading milliamperemeter, millivoltmeter, or megohmmeter.

GALVANOMETERS

THE DIFFERENTIAL GALVANOMETER.—The differential galvanometer is one of the earliest forms of measuring instruments. It consists of a magnetic needle with an indicator attached which is pivoted horizontally, and surrounded by two coils of wire of equal resistance wound in different directions. As it is rather difficult to obtain two coils equal in length, resistance, and magnetic effect, this difficulty is overcome by unwinding a part of the wire which has the greater magnetic effect on the needle, and winding it back in the opposite direction; or the length of wire so unwound may be coiled up double on a separate bobbin and placed in the base of the instrument. The current in each coil is of equal strength when the current flows through the coils without deflecting the needle,

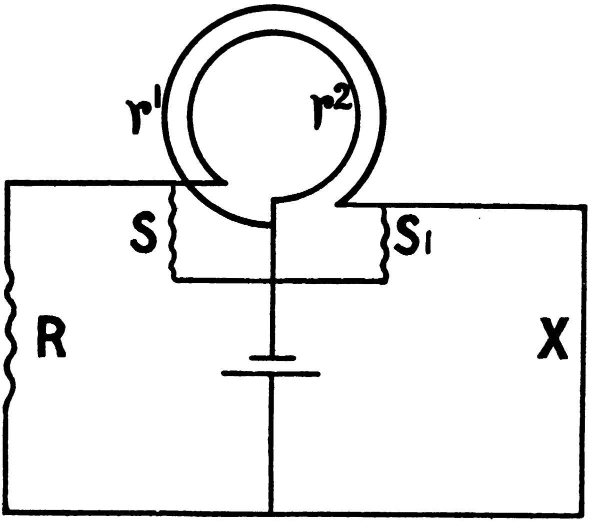


FIG. 346

DIFFERENTIAL GALVANOMETER AND SHUNTS

and conversely, the resistance of each circuit is equal when the current in each coil is equal.

One will be able to understand clearly the principle of the shunts from Fig. 346, in which r^1, r^2 are the coils of the galvanometer, R the resistance coils, X the resistance to be measured, and S and S_1, are shunts to the two coils. In making a measurement with the 1/10 shunt in S,

$X = R \times 10$, and so on with the other shunts. For measuring a resistance under 1 ohm, a set of shunts, S_1, can be joined across the coil r_1, in connection with X. If 1/10 shunt is so connected $X = \frac{R}{10}$, and if $R = 1$, then $X = .1$ ohm. If the shunt is $\frac{1}{100}$, X will be .01 ohm, and with the $\frac{1}{1000}$ shunt X will be .001 ohm.

The resistance to be measured, whether galvanometer, relay or resistance of any kind, is connected

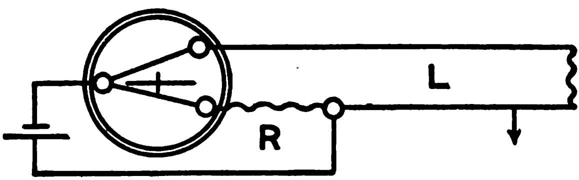


FIG. 347
DIFFERENTIAL GALVANOMETER MEASURING LOOP RESISTANCE

in the arm marked X and resistance inserted in R, until a balance has been obtained, when the resistance is read direct.

The branch X is divided to measure the conductor resistance of a line, one end being connected to ground and the other to the line, which must be grounded at the distant end. For measuring the insulation resistance of a line the same connections are used, but in the test the distant end of the wire is disconnected. The line is looped at the distant end and the resistance of the loop measured to measure the resistance of a ground fault. A second test is taken with the copper pole of the battery connected to ground. The current then

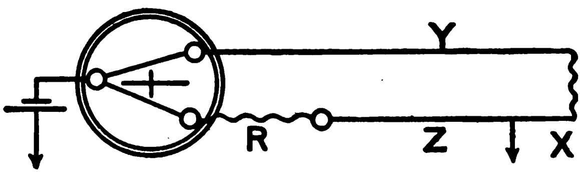


FIG. 348
DIFFERENTIAL GALVANOMETER LOCATING FAULT

flows by ground to the fault where it divides, and resistance is inserted until a balance is obtained.

Figs. 347 and 348 will enable one to better understand these two tests. Resistance is inserted in R until the needle is undisturbed, in Fig. 347, whence $R = L$, where L is the whole loop. Resistance is inserted in R, in the second test, until $R + Z = X + Y$; but $X + Y = L - Z$, hence is shown $R + Z = L - Z$, or $2Z = L - R$, and

$$Z = \frac{L - R}{2}.$$

One line is connected to the good line terminal and grounded at the distant end, to test for the distance of a contact between two wires, and the other line is connected direct to the copper pole of the battery, with the distant end disconnected, and the resistance coils are connected to ground, as shown in Fig. 349. When R has been adjusted

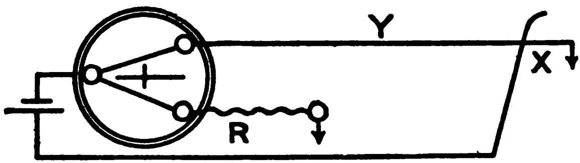


FIG. 349
DIFFERENTIAL GALVANOMETER LOCATING CROSS (FIRST TEST)

then $X + R = Y$, but $Y = L - X$. (L is known from the records)

$$\therefore X + R = L - X, \text{ and } X = \frac{L - R}{2},$$

which gives the distance from the testing office, and $X + R = Y$, but $X = L - Y$.

$$\therefore Y = L - Y + R, \text{ and } Y = \frac{L + R}{2},$$

which gives the distance from the testing office, when the point of contact is beyond the centre of resistance. If the deflection indicates too much resistance in R + X, when R is nil, then X is greater than Y, that is, the point of contact is on the near side of the centre of resistance. Fig. 350 shows the rheostat which is now connected between the line and the good line terminal, and the coil to which the rheostat was connected is joined to ground. When R has been adjusted X = R + Y, or $X = R + L - X$, or $X = \frac{L + R}{2}$ from the distant office and $Y = \frac{L - R}{2}$ from the testing office.

The distance in miles in all the tests is obtained by dividing the result by the resistance per mile.

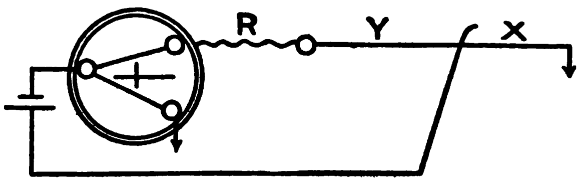


FIG. 350

DIFFERENTIAL GALVANOMETER LOCATING CROSS (SECOND TEST)

The above tests are subject to error on account of earth resistance and earth potentials. Care must be taken not to let them influence the result. The latter can be compensated by reversing the battery and taking the average of the two results. Use a fairly high testing voltage.

D'ARSONVAL GALVANOMETER

Another form of galvanometer, the D'Arsonval galvanometer, is shown in Fig. 351. On a light

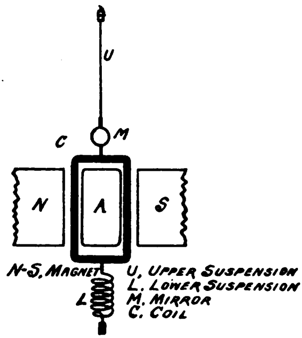


FIG. 351
PRINCIPLE OF D'ARSONVAL GALVANOMETER

rectangular frame of copper a coil of fine wire is wound which is suspended between the poles of a powerful compound horseshoe magnet, by means of fine hard-drawn silver, bronze, or steel wires. A cylinder of soft iron which acts as an armature concentrating the magnetic field and which is supported from behind, nearly fills the open space in the rectangular frame. In the intense magnetic field which exists in the narrow spaces between the poles of the magnet and the soft iron cylinder, the coil is free to move. The suspending wires act as the connections to the coil, and when a current passes the coil tends to turn under a force proportional to the strength of the magnetic field, the strength of the current, and to the number of turns in the coil. The deflection of

FIG. 352
PORTABLE D'ARSONVAL GALVANOMETER
NEEDLE FORM

the coil is controlled by the elasticity of the wires, which, when the current ceases, causes the coil to return to the zero position. Usually the deflections are read by a mirror, with light and scale as in Thomson's galvanometer, but a pointer is used instead of a mirror, in some forms. The telescope and scale are very popular for the best work. Fig.

352 shows a portable needle form, used chiefly on Wheatstone bridges.

The coil of wire, which is the moving part of the galvanometer, is non-magnetic, and the field in which it moves is so intense that the galvanometer readings are not affected to any appreciable extent by the earth's field and even strong magnetic fields

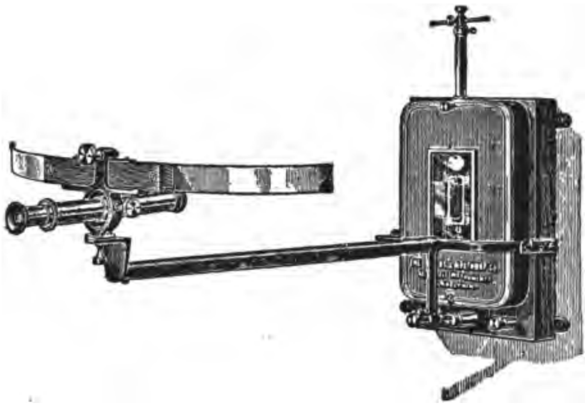


FIG. 353

in its neighborhood. It is also remarkably dead-beat in its action, as the coil in turning cuts through the lines of force of the magnetic field, and produces currents in the coil and frame tending to oppose the motion. These currents though decreasing in strength as the needle comes to rest, do not diminish the final reading. The coil moves slowly round under the influence of a current, and takes up its final position without any oscillation.

The D'Arsonval galvanometer is used for testing the insulation resistance of underground telephone and telegraph circuits. An excellent type is shown in Fig. 353. This galvonometer has an advantage over other forms as it is not affected by any external magnetic field, and

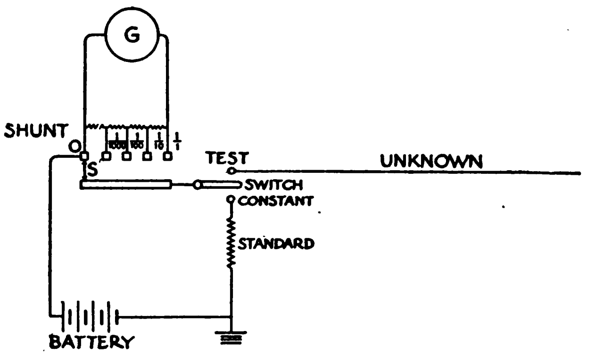


FIG. 354

INSULATION MEASUREMENT WITH GALVANOMETER

it is almost dead-beat. One minute is allowed for the needle to come to rest before reading the deflection, as the swing of the coil is very slow. Their figure of merit is about 150 times higher than that of the tangent galvanometer. The coil being suspended in the field of a powerful magnet, this instrument belongs to the suspended coil class of galvanometers.

Connections are shown in Fig. 354. The battery, ground, and line are connected. First, set the shunt slider "S" on zero. Then the switch is turned to the stud marked "constant" to obtain the constant, and the shunt slider is moved to the 1/1000 and 1/100 studs, and pause for a second on each until the proper shunt value is found for obtaining a readable deflection. After obtaining and recording the data for the constant, restore the slider "S" to zero. Turn the switch to the "test" stud to take the insulation test, and in five seconds turn the shunt slider successively to the studs 1/1000, 1/100, 1/10 or 1, in order to give sufficient time for the needle to assume its final readable position at the end of *one minute.* Note the reading obtained at the end of the first minute, as this is the figure from which the insulation resistance of the line should be calculated. Then the constant deflection × multiplying power of the shunt × standard resistance ÷ shunt in use when the line is tested × deflection observed, gives the insulation resistance of the circuit in ohms. That is $X = \frac{d_1 S_1 R}{d_2 S_2}$ in which d_1 and d_2 are the deflections, S_1 and S_2 the powers of the shunt and R the standard resistance. A reading should be taken after another minute if the electrification value is desired. The percentage difference between the first and second readings is the value of the electrification. The fall in the value of the deflections should be uniform and gradual, and should not increase. Unsteadiness points to a fault in the wire.

BATTERY RESISTANCE

The battery is joined to a galvanometer and resistance coil in the *Half Deflection* method. A resistance R_1, at least three times the estimated resistance of the battery should be introduced to prevent polarization, and the deflection noted. Then increase the resistance to R_2 until the deflection is halved. The resistances in circuit at first are the battery resistance r, galvanometer G, and the resistance coil R_1, and in the second case r, G and R_2. The resistance must have been doubled as the deflection has been halved. Therefore:

$$2\,(r + R_1 + G) = r + R_2 + G$$
$$\therefore r = R_2 - 2\,R_1 - G \text{ or } R_2 - (2\,R_1 + G).$$

If $G = 320$, $R_1 = 450$, and $R_2 = 1370$, then $r = 1370 - (900 + 320) = 150$ ohms.

As it takes a little time to produce the half deflection exactly, the *Diminished Deflection Direct* method can be employed, by which the second deflection is only reduced and not halved. In that case

$$r = \frac{d\,R - D\,R_1}{D - d}\,G,$$

where D and d are the first and second deflections respectively.

The battery is connected to a galvanometer and a high resistance R_1, and the battery is then shunted with a resistance equal to that of the galvanometer and R_1, and the deflection noted. The shunt is then disconnected, and the resistance increased to R_2 until the first deflection is reproduced. Then $r = R_2 - R_1$.

CHAPTER XXI

TELEPHONE TROUBLES AND HOW TO FIND AND REMEDY THEM

In looking for telephone troubles, it should be borne in mind always, that no trouble can ever be remedied by separating the permanent magnets. If for any reason they have been taken off they should be restored to their proper places with the same poles together. Opposite poles attract each other and similar poles do not; therefore the ends of the magnets which do not attract each other must be put in place so that these ends, or similar poles, touch, otherwise one magnet will neutralize the other and the armature coil will not be affected. The opposite poles may very easily be ascertained by touching the ends of the permanent magnets together, as they will attract each other.

1.—When two magneto bells or two drops ring together, look for a cross of office or line wires. If on common return wire, the return wire may be broken or the drop ground is broken.

To test for the trouble one line at central should be opened and the other rung upon and the line will be found crossed if both bells ring; but the common return will be found broken if neither of the bells ring.

To test for the trouble in drops, the line at the subscriber's station should be opened and the other one rung. The line will be found crossed if both fall; but if neither fall the drop ground will be found broken.

2.—Frequent ringing of magneto bell from no apparent cause indicates a swinging cross with telegraph or other lines.

3.—When bell cannot ring or receive a ring, wire is severed in line or office—protector open, grounded if bridged to ground, short-circuited if bridged metallic line.

If the line is open or protector open, by tapping the transmitter and listening on the line little or no sound will be heard. The transmitter will give loud sound if short-circuited or grounded.

4.—Bell can ring but no response can be had.

Line grounded; line open, or protector burned out if bridged.

The line is grounded in the protector, or elsewhere.

5.—When a magneto bell receives a ring but cannot ring its own bells.

This would indicate a broken wire or connection in the generator or a conducting wire from it; or armature does not make contact with spring if bridging, or current cannot get to the line because shunt will not open, or coils are short-circuited.

6.—When magneto bell receives and transmits the rings but talking cannot be done, it indicates a broken receiver cord, bad connections, the hook does not go up to place, or weak battery.

When the receiver is taken down the hook should go up, switching the line into talking apparatus.

The hook will not go up if its spring is weak or if it does not move freely and in that case the talking instruments are not connected with the line.

7.—When magneto bell receives a strong ring itself but rings other bells feebly, it indicates that the trouble is with the generator. It is usually due to bad connections but may result from weakness of the permanent magnets of the generator.

Friction bearings are used in making the connections to the revolving generator coils: one through the trunion or axle and the box or bearing in which it turns, and the other through a flat spring which bears upon the end or side of the axle. If the first connection is too freely oiled, or if the latter one is oiled at all, the current is very materially weakened by the resistance opposed to its flow by the oil which is a poor conductor of electricity.

Now, when the generator is not revolving it is cut out of circuit by the shunt wires which permit the bells to be rung loudly by some other bell. But when the generator is not turning the shunt wires cut the generator out of the circuit, and hence one's own bells can be loudly rung by another bell.

8.—When the magneto bell rings other bells vigorously and its own bells will not ring or are weak, the trouble is weakness of the ringer magnet or poor adjustment of armature. The armature (or vibrating bar to which the hammer lever is attached) is polarized, or magnetized by a bent steel magnet. The adjustment of this armature should be such as to hold it exactly the same distance from both poles of the electromagnets, while sufficiently loose in its pivots to permit of perfectly free movement. When properly adjusted the armature is rarely the cause of trouble; but it may be generally sought and found in the permanent steel magnet, which has lost its strength and does not magnetize the armature sufficiently to make it act vigorously. Ringer coils are burned out if bell does not ring.

9.—When the magneto bell will not ring at all, look for protector burned out, broken wire in box or line or ground wire—if bridging metallic, short circuit—if bridged grounded line, grounded.

If series bell, and protector not burned out, connect the two main binding posts together.

A wire is broken in the box, if now it will not ring. If careful search fails to find it, the break is in the ringer coils, or generator open or short circuited. The same applies to bridging bells, only the main bridging posts are disconnected from line and not connected together.

When the hook goes up, in some of the later make of bells, it closes the generator circuit through the ringer coils so that the bell rings with the hook up for the purpose of testing the ringer coils.

In order to locate the break after it is known that the circuit is open in the bell box, the trouble may be located with the receiver by disconnecting the receiver and the local battery from everything and hanging something on the receiver hook to keep it down.

A wire is then connected from one binding post at the top of the bell to one pole of the battery and the other pole of the battery is connected to one post of the receiver and another wire is connected to the other post of the receiver.

The bell box is then opened and the wire that runs from the binding post to which the battery is attached should be traced. When this wire is touched with the loose wire from the receiver a click will be heard, and until the break is passed this click will be repeated each time that this wire is touched at points where it makes contact with the spring, hinge, generator, ringer, coils, magnets, etc. When the click is no longer heard upon touching the wire, the break will be found between such point and the point where it was last heard. A battery current will follow the circuit and actuate the receiver just so far as the wire is perfect; but will stop at the break. As the generator circuit is open when at rest with bridging bell, only the ringing coils can be tested by this method.

The generator circuit can also be tested from one side of the line to the spring and from the other side to spring contact through generator.

In making this test, it is necessary to disconnect the line and ground wires from binding posts on the top of the bell box. The coils and other apparatus may be tested by this test.

A very simple test may also be made by disconnecting the wires from the bell binding posts on top of the bell, removing the receiver cord tips from their binding posts, and connecting the receiver cord tips to the line wire binding posts. After the hook is securely fastened down by a weight, the crank should be turned and the receiver listened into, and if the vibration of the bell ringing apparatus is heard, this will indicate that the circuit is normal.

A satisfactory test may also be made to determine the condition of the talking circuit, by securing another receiver and cord and connecting up the same in its proper place, leaving the other connected on top of bell to the line binding posts.

Talk into the transmitter, at the same time holding the receiver (the hook being up) to the ear. If the tester can hear the talking in the receiver connected to the line binding posts, the testing party's telephone is in order and the trouble is outside of the instrument and should be looked for in the inside wiring or outside line wire. The cause of the trouble may be a poor ground connection if such connection is used; or the ground rod may be too short to reach moist earth. If the trouble is not located after the inside wire, ground connection and line wire have been examined, the trouble is not in the station where test is made.

10.—When the magneto bell receives and transmits a feeble ring and talking can be done clearly over the wire, in all probability the trouble is due to a poor connection inside of the box: The connections through the hinges of the box should be closely examined. The springs on them should be bright and free from any foreign substance, such as oil. When the box is closed the springs should press firmly on the opposite side of the hinge, so that the contact will be perfect. If the trouble is not found to be with the connections through the hinges, a bad ground wire should be looked for. A poor ground wire connection may answer for talking and yet be inadequate for ringing. If bridging metallic, look for resistance cross; if bridging grounded line, look for escape or poor ground.

Weak ringing and talking may be produced by an imperfect shunt around the generator coils in one of the magneto bell boxes on lines with more than one set of telephones in series. This leaves the coil constantly in circuit. If bridging line—escape resistance cross, or some hook on the line may not cut out the instrument.

11.—When the call is made on toll or party line and no response can be gotten, the trouble may be tested for as directed under Number 3.

12.—When toll or party line bell rings and talking cannot be done, trouble to be treated as explained in Number 6.

13.—When on a Four Party Selective System a ring is received, but talking cannot be done, test for open line should be made. (See Numbers 3 and 6.)

14.—When a Four Party Selective System bell rings unaccountably, the trouble is due to receiver being off the hook at some station on the line, or an armature spring is loose, or the line is crossed. To locate the trouble one station on the line should be rung up from central. Should the other station of same polarity on the line ring, the telephone has been left off of the hook at some station. Should the trouble be due to a loose spring, the bell will ring when the other station on the same side of circuit is called. The circuit will be noisy if the trouble is due to line crossed with foreign wire.

15.—When (1) a Four Party Selective bell calls but can get no answer, or when (2) the bell rings feebly or will not ring at all:

See for (1) explanation under Numbers 3 and 4.

See for (2) Number 8.

This trouble may be due to poor ground or frost below ground rod, if in winter.

16.—When connections are loose connect cord tips firmly in the binding posts.

17.—When the receiver is weak the trouble may be due to any one of several causes: (1) There may be a bad connection; (2) bent or dirty diaphragm; (3) coil partially short circuited; (4) weakness of permanent magnet. *The position of the diaphragm should be .015 inch from the magnet and the magnet, to be of sufficient strength, should be able to hold the diaphragm up on edge or support the weight of an eight ounce iron bar.*

The case cover should be examined to see that it is not screwed on so tight as to prevent free vibration of the diaphragm. If the magnet has dropped down it should be restored to the correct position by means of the regulation screw at the end of the receiver. If it is of the permanently adjusted type, an error of this nature must be corrected at the factory.

High tension currents and atmospheric electricity have been known to burn out the receiver coil and when it occurs, the coils must be rewound.

RECEIVER CORD.—A receiver cord is made up of two separate conductors, each one being composed of strips of copper tinsel or fine wires which are spirally wound around a string so as to render it flexible. The two conductors are run along together in one sheath and are insulated from each other, as each one is covered with cotton or silk braiding. The sheath or covering for the two conductors consists of one or more layers of braided cotton or silk. A metal tip forms the terminal of each conductor. One end of each of the two conductors is fastened to the binding posts of the bell box and the other two ends are fastened to the receiver, forming a loop by which the current reaches and leaves the receiver respectively by the two conductors

18.—When the bells ring, but speech cannot be transmitted and no inductive noises can be heard, it is almost certain that the cord will be found broken. In most cases the troubles occurring with cords are due to the breaking of the conducting wires at the tip or terminal junctions.

It is possible, however, that the trouble may be in the receiver or transmitter, if not in the cord, as the switch connects the line to these instruments when the receiver is off the hook.

The cord should be disconnected from the box in order to ascertain definitely where the trouble is,

FIG. 355
HOW TO USE A TELEPHONE

and a weight should be hung on the hook to keep the switch in the right position. The line and ground wires should then be removed from the top posts in the bell box and two tips of one end of the cord inserted in these binding posts. If upon ringing the bell the sound is heard in the receiver, the cord is not broken and vice versa.

It may occur that the wires in a cord are broken and yet a scraping sound will be heard in the receiver, or even speech may be audible in an interrupted form. This is because the conducting wires, although broken, make contact when the cord is held in a certain position.

BATTERIES.—The various forms of batteries are described in Chapter 10.

When transmission of speech is feeble, but is received normally, the cause is due to a weak battery unless the speaker is not talking properly into the transmitter.

In Fig. 355 is shown the right and the wrong way to use the telephone.

If the battery is weak the test is to listen in the receiver, tapping at the same time on the transmitter or mouth piece with the finger. The diaphragm of the transmitter should never be struck in testing lest it be bent or injured and thus rendered useless. The sound will be very loud if the battery is in good order; but if the battery is weak there will be little or no sound.

When a singing or sputtering sound is heard in a telephone it may sometimes be remedied by a few taps on the transmitter or mouth piece; but a scratching sound is generally the effect of a broken wire in the flexible cord making an imperfect and intermittent contact.

In order that a perfect contact may be at all times maintained, the wires at the connections on the battery should be often examined for oxidization or other foreign matter which may accumulate at these points.

In Fig. 356 is shown a diagram of a solid back transmitter with the detailed construction, of which it is important to be thoroughly familiar.

A metal case called the back electrode, W, is insulated on the inside and secured to the supporting bracket, P, by an adjusting screw. A small

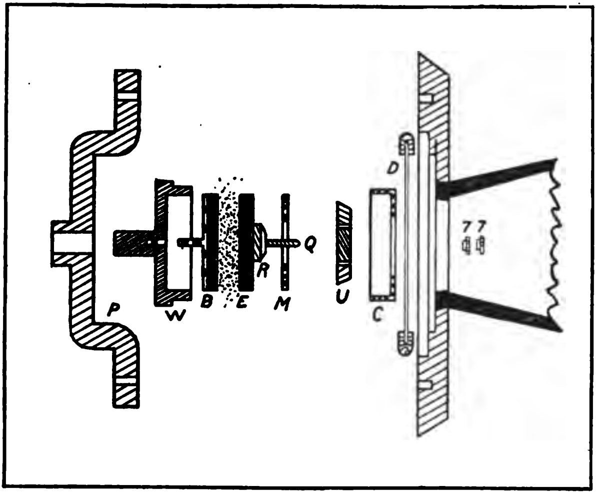


Fig. 356

SECTION OF TRANSMITTER

brass disc, B, is adjusted against the back wall. This disc is attached to the support by a pin set on its center and on its face is a button or plate of carbon. A quantity of granules is in front of and around this carbon disc and these granules rest on the other side against another carbon disc, mounted on the brass butt on E, from the center of which the screw-threaded bars, R and Q, project. The mica washer, M, the nut, U, fit over R and Q and all are covered by the cap C, and screwed in position. Through the center of the vibrating diaphragm, D, the bar, Q, projects and is held in position by the nuts, T T.

19.—When speech is received strong in the solid back transmitter, but the transmission is weak, the trouble is due to weak batteries, corroded diaphragm or packed carbon, or the speaker is not talking properly into the transmitter. When the carbon is packed, dampening is the effect on the diaphragm.

Exchange Drops.—This apparatus consists of an electro-magnet, as armature on a movable lever, and a target, which drops and exposes a number when the armature is moved by the current acting upon the electro-magnet.

20.—When the action of annunciator or drop is feeble, imperfect adjustment of armature should be looked for. The pivot screws may be loose or worn, or on the other hand so tight as to interfere with free action of the armature lever.

21.—When there is an irregular action of the drop, the cause is generally due to a loose connection.

22.—When the drop will not work the trouble is due to a bad connection, a broken wire, bad adjustment or short circuit. To test for bad connection or broken wire the connections should be examined, and wires run between the two connecting clips of the annunciator and the two line posts of a series magneto bell. The receiver should then be hung up and an attempt made to ring. If the ring fails the wire of the coils in the drop will be found broken.

23.—When the drop or shutter of annunciator will not remain up the trouble may be due to a bent latch but is generally caused by earth currents or by a current from a battery line crossed with the annunciator's line. When these foreign currents are present the coils become magnetized and the armature is drawn away preventing the latch from engaging the shutter.

24.—When the action of the annunciator is feeble the trouble may be due to coils weakened by the effects of lightning. This would occur when the damage to the coils is only partial, such, for instance, as the burning out of one coil. Then again the cause may be short circuiting of the coils by both coils sparking across to the cores.

The remedy is to rewind the defective coils after a battery test of each coil has located the trouble. The line wires should always lead to the outside layer of fine wire covering the core of the coil and not directly to the core itself, i. e., the line wire should lead into the spool from the outside layers. In rewinding both annunciator and bell coils, the ends of the fine wire should be brightened and protected with a winding of silk or covering of tissue paper.

THE COMMON BATTERY OR CENTRAL ENERGY SYSTEM

This system (elsewhere treated—See index) briefly summarized, is one which dispenses with the local battery and magneto generator at the subscriber's station. A bell box containing a set of bridging ringers, a hook switch condenser and induction coil, compose the equipment of subscriber's station. Fig. 357 shows the circuit of a common battery telephone. When the receiver is

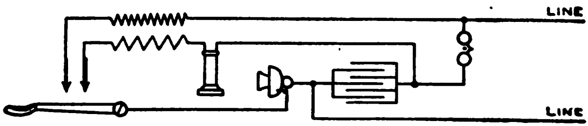


FIG. 357
COMMON BATTERY TELEPHONE

removed from the hook a relay at the central office is actuated and this causes a lamp signal to glow or an annunciator drop to fall.

All troubles due to local battery are avoided by this system. Efficient operation in this system depends principally upon thorough insulation in the installation of plants.

25.—When speech is not distinct and is accompanied by a grating or scratching sound, the trouble is due to loose connections in the transmitter circuit, and it should be sought for at transmitter terminals, in the fine wire connecting button to cord terminal, or at induction coil.

26.—When a call is made and no answer can be had, the trouble may be ascribed to any one of several causes.

The circuit of each subscriber is equipped either with relays at central office, which operate a local signal, or with electro-magnetic signals, the latter being directly actuated by the removal of the subscriber's receiver from the hook, which closes the circuit.

When a mechanical signal does not operate the trouble will occur. It will also be caused when relays are used, by the line circuit of relay being open or short circuited on terminals or in coil, or poor contacts may exist in the local circuit because of mal-adjustment of relay line circuit. The cause may also be a burned out lamp.

The trouble may occur where electro-magnetic signals are used from the coil being open or short circuited in terminals in coil, or there may be imperfect adjustment of the armature, or it may be stuck. An open circuit, a ground or a short circuit in protectors, on the line, or in the subscriber's condensers, are also causes of this trouble. A permanent signal showing at central office will indicate a short circuit or ground.

27.—When the bell receives a ring, but talking is arrested, the trouble is probably in the repeating coil circuit at central office, which will be found open. The springs of ringing keys do not make connection with back contact (See Number 6); or wire may be broken, fuse blown out, or the coil burned out. Also the subscriber's receiver may be open, or the transmitter or the winding of the induction coil.

28.—When a ring cannot be received there is an open, short circuit, or ground in instrument, or line, or in office wire. An armature out of adjustment, or a weak ringer magnet, will also cause the trouble.

If the circuit is open, ringer coils may be burned out, or line wire, or condenser circuit may be broken. A permanent signal will show in central office when there is a short circuit on ground or line.

29.—When on different lines, two bells or two signals act at the same time, there is a cross of office or line wires. The signals at central office will operate together if office or line wires are crossed.

30.—When a bell rings frequently and unaccountably the permanent calling current on the line is intermittently interrupted by a swinging short circuit which causes a vibration of the armature of subscriber's bell. The bell will also ring if there is a swinging cross with telegraph or other lines. (Refer to Number 2.)

31.—When the receiver is weak the receiver cord may be reversed. (For other causes refer to Number 17.)

32.—When a selective signal party line bell (1) rings unaccountably, or, (2) if the ring is feeble, or bell will not ring at all, the trouble for (1) may be looked for as explained in Number 14.

(For explanation of (2) see (2) Number 15.)

33.—When in a central energy or common battery transmitter the speech is transmitted feebly, but received strong, the causes may be traced to (1) defective induction coil, (2) carbon packed, (3) corroded diaphragm, (4) resistance in line circuit too great. High tension currents or lightning impair the efficiency of induction coils, in which event they must be replaced, as also should be corroded diaphragms. Packed carbon can be loosened by rapping on the back or side of the transmitter; but the diaphragm should never be tapped. Modern transmitters of reputable make seldom pack.

34.—When speech can be heard, but talking cannot be effected, the trouble may be caused by a broken wire between transmitter and induction coil, or the transmitter may be short-circuited. It may be a broken transmitter cord or a short circuited secondary induction coil winding.

35.—When central office signal is weak the cause may be assigned to the following conditions: Bad contact in relay causing high resistance in local circuit; insufficiency of main batteries or power leads not large enough.

If the signals weaken as the load increases on switchboard it indicates insufficiency of main battery, or too small power leads.

36.—When signal will not act it is due to some one of the following causes: Line open, local circuit broken, relay adjustment wrong, or, insufficiency of battery. (See Number 32.)

37.—When speech is indistinct and accompanied by a grating or sputtering noise, the line is crossed, or there is a loose connection in the line circuit. Signals showing in central office indicate cross in line. Loose connections in this trouble may be classified as follows: Poor contact in protectors, in hook switch in bell, in spring jacks; or a defective hand telephone cord or switchboard cord used; or defects in office or line wire connections.

38.—When the signal at central becomes permanent the condenser is short circuited, and the condensers should be connected through a 25 ampere fuse immediately across a circuit carrying not over 110 volts. Any voltage will do if a storage battery is used for this purpose, provided there is sufficient current. The current will fuse any segment of tin foil that has pierced the insulation if the condenser is not too badly damaged. Sometimes a 16 candle power lamp is used instead of the fuse.

If when plug is inserted the lamp does not go out the induction coil should be tested.

DIRECTIONS FOR INSPECTORS

SOLID BACK TRANSMITTER.—This part of the telephone has little or no adjustment. Should the carbon become packed the trouble can be remedied by tapping gently upon the side or top of the case.

The battery should be kept at all times in perfect condition and also all connections in the primary circuit.

RECEIVER.—Broken wood discs, or magnets that are too weak to support an eight ounce should be condemned.

The adjustment of .015 inch of the magnet to the diaphragm should be verified by a suitable gauge.

Replace with new ones all corroded or bent diaphragms.

Bells.—All screws should be kept tight and firm and corrosion or dust in hook connections should be removed. The wire connections of bells should be securely fastened and contact points well soldered.

Cords.—Frequent examination and tests of cords should be made to discover breaks.

Dry Batteries.—Exhausted dry batteries may be restored and used for a time by perforating the bottom and standing them in a salammoniac solution, but it is not advisable. It is best to replace them.

Ground Wire.—The connections must not be permitted to corrode; and in testing to establish condition no result should be taken for granted as being satisfactory until the full talking efficiency of the instrument has been obtained.

Inside Wire.—In the interior all unworkmanlike wiring should be brought to standard in repairing; such, for example, as two wires under an ordinary staple, sagging wires, soldered connections to line wire, etc.

The method of inspection for Magneto System and Common Battery or Central Energy System is the same excepting as to batteries.

INSPECTION OF POLE LINES

Pole lines, exchange or toll, should be systematically inspected in order to keep in touch constantly with the condition of every pole and fixture and their wires and cables.

To determine the condition on pole lines of poles that were set new within eight years, each pole should be examined six inches below the surface of the ground, by removing the earth and cutting away the decayed part on one side of the pole until sound wood is reached, and making note of how many inches the decay has penetrated. A small spud or any convenient tool may be used for this purpose.

A pole will last from five to seven years longer on exchange pole lines where the earth surrounding the butts of the poles is free from vegetation, than it will on toll lines.

Poles that are set in flag or cement sidewalks are not subject to the same destructive elements as those set in earth and surrounded by vegetable growth, and the only attention they require is to see that they are properly guyed and kept in line.

All crossarms badly decayed under an external painted surface apparently sound, should be replaced as soon as discovered. If testing for decayed crossarms any suitable tool, such as a screw driver, may be driven into the decayed wood by a sharp blow; and the ends particularly should be subjected to this test.

For the inspection and repairs of these small pole lines one lineman, a groundman and a horse and wagon will serve as a crew sufficient for the purpose. In testing for the condition of a pole a ten-foot pike pole should be used, by means of which the telephone pole may be pushed against in a lateral direction, and if it is found to be badly decayed it should be replaced at once; but if the decay is not of sufficient extent to require immediate replacing, the pole should be reset and a note made of its probable future life, in order that it may be renewed later on.

To cope successfully with troubles arising from defective inside wiring a practical knowledge of what constitutes efficiently executed inside wiring should be possessed by inspector and repairer—that is, the proper way to run all wires leading from the entrance of a building to the telephone, should be thoroughly understood.

The line wire (outside wire) should be run as near as possible to the location of the telephone, thereby making the inside wire lead as short as practicable. The hole in a window or door frame through which the wires are passed should be bored slightly downward, if bored from the inside, or upward, if from the outside, so that water will not enter.

All leading-in wires should be soldered to the ends of the line wires, and all wires entering the building should pass through separate holes 2½ inches apart, and they should be well taped or enveloped in some suitable tubing at those points.

A twisted pair of No. 19 braided rubber covered wires should be used for inside wiring from the telephone to the arrester and secured in place by insulated staples.

When looking for the cause of a trouble which cannot be located outside of the building, a test set or series bell should be employed to test the inside wires; as these wires, being covered with insulation, are deceptive when broken.

Crosses.—It is generally out of doors, where the wires are unprotected by insulation, that crosses or contacts between two wires occur; but trouble will occasionally arise from a cross of inside wires caused by contact with staples or water, after lightning has burned off the insulation.

An important feature in wiring is the proper use of staples. They should be of the insulated or saddle-back style. When these are not available the plain staple may be used, providing no two wires are fastened by one staple; because, in that case, sooner or later, a cross will occur, as the straining or movement of the wires against the staple will cause the insulation to wear off and a contact between wires and staple will result.

Crosses Between Two or More Circuits. To locate such crosses let it be assumed: First.—That circuit a, as shown in Fig. 358, is crossed with circuit b. Then a should be short circuited about the center while some one rings or talks on b. If the inspector's end is quiet while the cross talk is heard on the other end of a, the lines are crossed between that end and the short circuit. Continuing the same tests on the faulty section will locate the trouble near one end or the other.

Second.—Both sides of both circuits should be opened at arresters or test board at both ends of the line, and when the crossed wires are found the strength of the ring or pull of the generator will indicate how near the trouble is to inspector.

GROUND WIRES.—Defective ground wires are a continual source of trouble on rural lines. The ground wire derives its name from the fact that

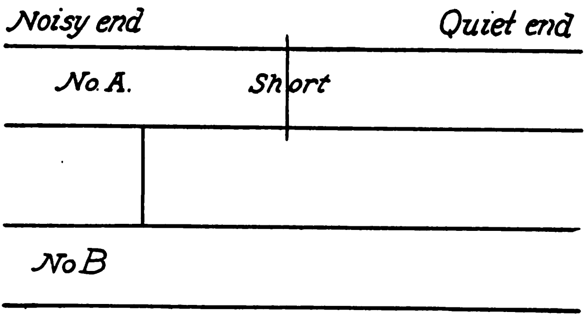


FIG. 358

PRACTICAL TEST FOR CROSSED CIRCUITS

the wire is run to ground at each end and the earth completes the circuit by taking the place of a return wire. This obviates the necessity of using two wires for each circuit. In order to make a good circuit contact must be made with damp earth, as dry earth, gravel, sand, etc., are non-conductors. To get the proper contact the wires should extend down into the earth below the point where the earth becomes dry in summer, or freezes in winter. *A ground wire is totally useless in* *frozen earth, as the dry ice is itself a material of high insulating qualities.*

A ground wire, where it is possible to do so, should be terminated in a stream of water, or next in preference, in a well, securing its stability by means of a weight attached to the end of the wire. The body of water into which the ground wire is immersed, must be one in which the water has connection with the surrounding earth and unlike a cistern or any kind of tight vessel.

A perfect ground connection may be made, when ground rods are used, by scraping the top of the rod, wrapping the ground wire around it and securing it with solder. Wherever available gas pipes or, better still, water pipes should be utilized to make contact, and for water pipes ground clamps should be employed and the ground wire secured to the clamp by soldering.

The ground wire should always be connected to the house pipe outside of the meter to avoid an open line, should that apparatus be removed for any cause.

COMMON RETURN WIRE.—To avoid the noisy effects of induction caused by electric railway and electric light currents, small exchanges generally use a common return wire, i. e., the grounded lines on certain routes are carried back and grounded at central by a common return wire to which they are all connected. A separate return wire to central—preferably of copper because of its high conductivity—must be provided for each route. The insulation and connections of the return wire should be perfect. The gauge of the wire and its carrying capacity should be sufficient to dispose of the business of subscribers' lines and avoid cross-talk.

PROTECTORS.—(See Chapter 19 in which protective devices are treated at length.)

Briefly described, the combination device which is employed at subscribers' stations to protect instruments from high tension currents, consists of carbon plates separated by a layer of mica and two three-inch fuses incased in asbestos tubes and mounted on a base of porcelain.

During a thunder storm the lightning arrester fuse may burn out, or a wire burn off in annunciator, or in the ringing coils of magneto bell. Any of these occurrences will leave the line "open."

Should small particles of carbon lodge between the carbons it will cause a grounded line. Carbons should be kept free of all foreign substances.

DIRECTIONS FOR TESTING AND LOCATING TROUBLES ON TOLL LINES

SHORT CIRCUITS.—To locate this trouble some one should get on the line and try to ring the party testing, and if the latter receives the ring on his line drop, ring-off drop or bell, the trouble is between the party ringing and the other end. He will not be able to ring the testing party if the trouble is on the other side of him and within a few miles. The testing party should have the other stay on the line while a connection can be had around him so that he can be talked to from the other end, and if he cannot now be talked to the short circuit is between him and the other end. See Fig. 359.

GROUND.—To locate and clear a ground:

1st—The line should be short circuited as near the center as possible, and the party testing should then listen at either end, and on the grounded section of the line the noise will be heard. The short

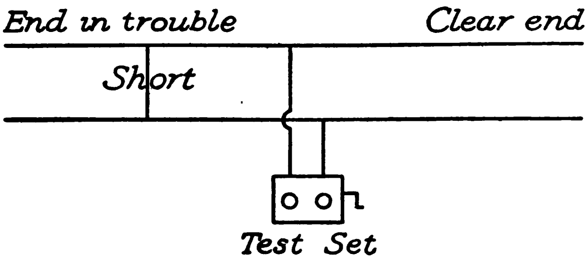


FIG. 359

TESTING A SHORT CIRCUIT WITH MAGNETS

circuit should then be removed and the line short circuited successively at other points until the ground is located in proximity to one end or the other.

2nd—Both sides of the line, at the arresters or test board at further end, should be opened, and each side of the line should be listened on by the inspector on his end, with a ground on his instrument. Less noise will be heard on the grounded side of the line if the ground is near the inspector. This test may then be verified by the inspector leaving his end open while the same test is made by the station at the other end.

3d—If the noise is cut off from the inspector after the line has been short circuited at the further end, the ground will be found at the other end. (See Fig. 360.)

Loose Connections on Open Line.—To locate this trouble:

1st—The line should be short circuited at about

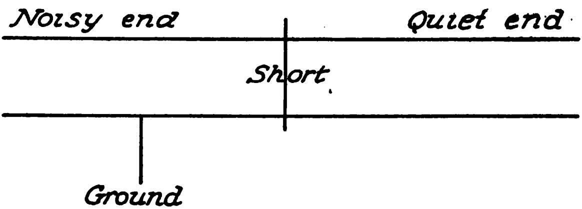


Fig. 360

PRACTICAL TEST FOR A LEAK.

the center and listened in on either end for the noise, which will indicate the end upon which the open circuit is located. The short circuit should then be removed and the line short circuited successively at other points until the ground is located in proximity to one end or the other.

2nd—Both sides of the line should be opened at the further end and listened into on each side at the inspector's end, with a ground on his instrument, and if the open or loose connection is close by there will be less noise on the faulty wire, if it is an open line. Unless the loose connection amounts to an open it cannot, by this means, be so readily detected.

If he has an 80-ohm bell the ring will be strong; but if the test is made with bridging set of 1,000 ohms, the bell will not ring on 100 ohms or under.

If the cross is between the inspector and the center of the line there will be less noise when listening metallic in the two wires of the two

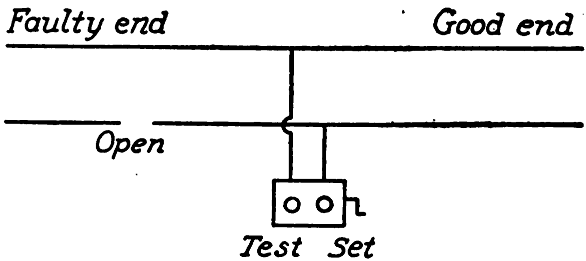


FIG. 361

TESTING FOR OPEN CIRCUIT WITH MAGNETS

crossed circuits than on either circuit that is crossed. (See Fig. 358.)

OPEN CIRCUIT.—To locate this trouble:

1st—Both sides of the line should be opened at test board or fuses, at the other end, while the inspector listens at his end, with a ground on one side of his instrument. The noise noticed on the open side will be, up to the break, proportionate to that on the good side.

2nd—If a ring is made near the center of the line, the line will be open between that point and the end which receives no ring. (See Fig. 361.)

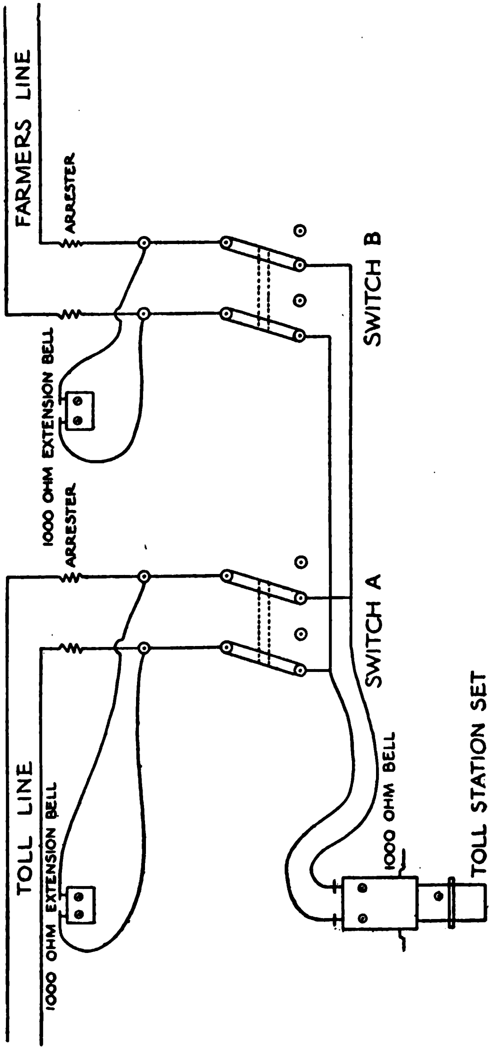


Fig. 362
SIMPLE SWITCHING STATION

DIRECTIONS FOR CONNECTING UP A RURAL METALLIC CIRCUIT WITH METALLIC TOLL LINE

To connect the toll station set with the toll line and cut off the rural line ending it on the extension bell, the lever of switch A, Fig. 362, should

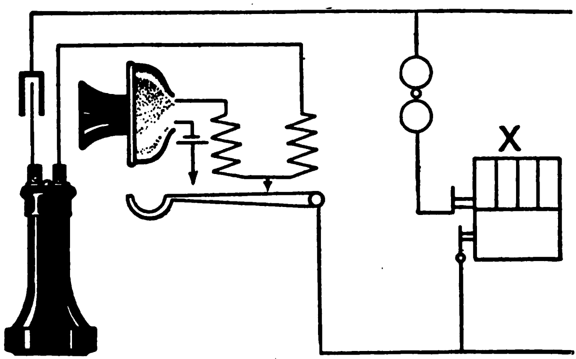


FIG. 363

USE OF CONDENSER IN TELEPHONE

be thrown to the left, and that of switch B to the right. To connect together the toll line, toll instrument and Farmer's line, the levers of both switches should be thrown to the left. To cut off the toll line in order that toll station can ring and talk with Farmer's line without interfering with the toll line, the lever of switch A should be thrown to the right, and that of switch B to the left.

No messages will be lost in this method, as the extension bell is permanently bridged on to the toll line.

CONDENSERS FOR RURAL TELEPHONE LINES

The function of a condenser, which is shown at x in Fig. 363, is to enable "Centıal" to ring

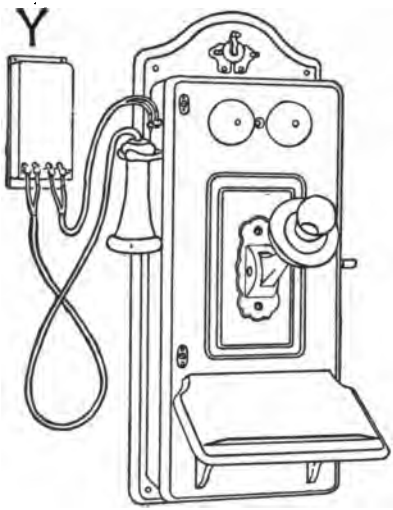


FIG. 364
CONDENSER ATTACHED EXTERNALLY

up subscribers when receivers have been left off the hook or when parties are "listening in." The condenser should be connected up in series with the receiver, and it is a very simple matter to install condensers, as they are made in a variety of styles calculated to fit any case.

The condenser offers high resistance to ringing currents and low resistance to talking currents, which makes it possible to ring any telephone on the line regardless of the number of receivers left off the hook. This attachment in no way affects the talking qualities of the instrument. Sometimes the condenser is mounted in a small box and connected to the telephone as shown at Y in Fig. 364. This enables the condenser to be attached to the telephone without changing the internal connections of the instrument in any manner, as the condenser is put in series with the receiver by means of the extra cord, as shown.

Several manufacturers of this device claim that on a line of twenty instruments eighteen of them may have the receivers off the hook, while the two remaining instruments can ring each other without trouble.

QUESTIONS

Why should the ends of the permanent magnets which do not attract each other be put in place so that they touch each other?

What would be the effect if the permanent magnets were put in place with their opposite poles touching each other?

How may the opposite poles of magnets be known?

State the cause, the method for locating the trouble, and the remedy for the following irregular occurrences:

1. When two magneto bells or annunciators ring together?

2. Frequent ringing of bell from no apparent cause?

3. When bell cannot ring or receive a ring?

4. When bell can ring but no response can be had?

5. When a magneto bell receives a ring, but cannot ring its own bells?

6. When magneto bell receives and transmits the rings, but talking cannot be done?

7. When magneto bell receives a strong ring itself, but rings other bells feebly?

8. When magneto bell rings other bells vigorously and its own bells will not ring, or are weak?

9. When the magneto bell will not ring at all?

10. When the magneto bell receives and transmits a feeble ring and talking can be done clearly over the line?

11. When call is made on toll or party line and no response can be gotten?

12. When toll or party line bell rings and talking cannot be done?

13. When on a Four Party Selective System a ring is received, but talking cannot be done?

14. When a Four Party Selective System bell rings unaccountably?

15. When a Four Party Selective bell calls but can get no answer; or, when the bell rings feebly or not at all?

16. When connections are loose?

17. When the receiver is weak?

18. When the bells ring, but no speech can be transmitted, and no inductive wires can be heard?

19. When speech is received strong in a solid back transmitter, but the transmission is weak?

20. When the action of annunciator or drop is feeble?

21. When there is an irregular action of annunciator or drop?

22. When the annunciator drop will not work?

23. When the drop or shutter of annunciator will not remain up?

24. When the action of the annunciator is feeble?

IN THE COMMON BATTERY OR CENTRAL ENERGY SYSTEM

25. When speech is not distinct and is accompanied by a grating or scratching sound?

26. When a call is made and no answer can be had?

27. When the bell receives a ring but talking is arrested?

28. When a ring cannot be received?

29. When on different lines two bells or two signals act at the same time?

30. When a bell rings frequently and unaccountably?

31. When the receiver is weak?

32. When a selective signal party line bell rings unaccountably, or feebly, or not at all?

33. When in a Central energy or common bat-

tery transmitter the speech is transmitted feebly but received strong?

34. When speech can be heard but talking cannot be effected?

35. When central office signal is weak?

36. When signal will not act?

37. When speech is indistinct and accompanied by a grating or sputtering noise?

38. When the signal at central becomes permanent?

39. Describe a receiver cord?

40. Describe the right and the wrong way to use a telephone?

41. Describe the various forms of batteries? (See Chapter XII.)

42. Describe the solid back transmitter?

43. What composes the equipment of a subscriber's station in the Common Battery or Central Energy System?

44. Should the carbon become packed in a solid back transmitter?

45. What is the weight that magnets should support as a test of strength efficiency?

46. What is the proper adjustment of the magnet to the diaphragm?

47. What is necessary for the proper care of bells, of cords, of batteries, of ground wires and inside wires?

48. What is the difference in the method of inspection for the Magneto System and the Common Battery or Central Energy System?

49. How is the condition of poles on pole lines determined?

50. How is the condition of crossarms or brackets determined?

51. What is the proper way to run the wires leading from the entrance of a building to the telephone?

52. How should holes be bored in window and door frames through which to pass wires?

53. What size wire should be used for inside wiring from telephone to arrester and what size from the arrester to the outside line wires?

54. Where are crosses most likely to occur?

55. What causes crosses of inside wires?

56. What is the proper use of staples in wiring?

57. How are crosses between two or more circuits located?

58. How may the troubles arising from defective ground wires on rural lines be minimized?

59. Where are the best places to terminate ground wires?

60. Describe a common return wire and its uses?

61. Why do small exchanges generally use a common return wire?

62. Describe the combination device used at subscribers' stations to protect instrument from high tension currents?

63. How are the following troubles located on toll lines: Short circuits, grounds, loose connection or open line, open circuits?

64. Describe the method of connecting up a rural metallic circuit with metallic toll line?

65. What is the function of a condenser?

CHAPTER XXII

CONSTRUCTION OF RURAL TELEPHONE LINES

The methods and material used in construction as given in the following pages are based on standard práctice, approved by the leading engineers in the telephone business and adopted by the most successful operating companies.

While it is not always practicable to follow out the method to the letter, on account of the local conditions, it is advisable to conform to it wherever possible. For instance, in many localities chestnut pole timber is more cheaply and easily obtained than cedar. In this event it would be unwise to expend money and time to obtain cedar when chestnut will answer equally as well. In all cases it is intended that the prospective purchaser shall use his best judgment regarding material available.

In the construction of country telephone lines there is nothing complicated or difficult; the main thing being to build the lines substantially and of sufficient capacity to accommodate the maximum number of subscribers that can be obtained.

Generally speaking, the construction of farm lines is divided into two classes; bracket and cross-arm. The former should never be employed where there is a possibility of more than two wires ever being placed on the poles. With bracket construction, the load of wires being less, a lighter pole can be used and less guying is required.

Where cross-arms are used the poles should always have at least 6-inch tops, and the line throughout should be substantially anchored and guyed by the methods shown in the following specification. It is also advisable that the poles be "gained" for the maximum number of cross-arms they are supposed to carry.

CONSTRUCTION SPECIFICATIONS

LOCATING LINE.—Starting from the initial point, measure off the distance at which poles are to be set and locate stakes as near to these measurements as possible.

Each stake should have plainly marked upon it the size of the pole to be set.

Follow a straight line as much as possible.

GRADING.—The length of poles set shall be such that abrupt changes in level of the line will be avoided.

CROSSINGS.—At all railroad crossings use poles of a length sufficient to insure a distance of at least 22 feet between the top of the rails and the lowest point to which the lowest wire to be used may sag.

At the crossing of all streets and roads use poles that will insure a distance of at least 20 feet between the ground or road and the lowest point to which the lowest wire to be used may sag.

In crossing the lines of telegraph or other electric companies use poles that will insure a distance, in the clear, of at least four feet between the tops of the poles in the line crossed and the bottom of the lowest gain in the pole used.

HAULING AND SELECTING POLES.—Poles must be loaded at the yards on wagons in such order that in distributing, the proper length pole can be unloaded at each location in regular sequence.

The heaviest poles shall be placed on corners and curves and the straightest and best-looking poles shall be placed in cities and towns and in front of residences.

The dimensions of each pole must conform to the dimensions of the marking stake.

FRAMING POLES.—The roof of the pole shall be formed by sawing the top in a plane at an angle of 45 degrees from the squared top of the pole, and so that the ridge will be in the center and stand at right angles with the cross-arms.

Each gain shall be cut to the depth of ¾ of an inch, or so as to make a flat surface of 4½ inches, and shall be square and true with the axis of the pole and with all other gains, and shall be cut so that the cross-arm will fit snugly. The center of the top gain shall be 10 inches from the ridge of the pole, and the distance between the centers of the succeeding gains shall be 20 inches. Poles are to be so framed that when set bends will show least when viewed in the direction of the line. A 5/8 of an inch hole shall be bored through the center of each gain to which a cross-arm is to be attached at the time the pole is set. (See Fig. 365.)

All roofs and gains are to be painted with one thick coat of Prince's metallic paint, mixed in

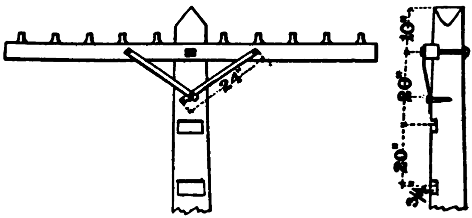


Fig. 365

the ratio of seven pounds dry paint to one gallon of pure linseed oil.

Cross-Arming.—All cross-arms and braces shall, whenever possible, be attached to poles before the poles are set.

The cross-arms shall be fitted with pins and braces before being distributed. Each cross-arm shall have its full complement of pins, each pin being driven snugly into place and fastened in position by driving a six-penny galvanized iron wire nail straight through the shank of the pin.

Each brace shall be attached to the cross-arm by a galvanized iron carriage bolt, the head of the bolt and a washer to be on the back of the cross-arm, and the nut on the face of the cross-arm.

The cross-arm shall be attached to the pole by a 5/8-inch machine bolt, which shall be driven through the pole from the back, so that the thread and nut shall be on the face of the cross-arm; a square washer shall be placed under the head of the bolt and under the nut. When the cross-arm is firmly attached in position the free ends of the braces shall be made to overlap on the pole and attached thereto by a 4-inch fetter drive screw firmly driven into position. (See Fig. 365.)

Stepping.—Junction poles and poles which are painted shall be stepped with galvanized iron pole steps, driven alternately on each side of the pole in line with the cross-arm and staggered 30 inches on centers on each side of the pole, extending downward from the cross-arm to within 10 feet of the ground.

Lightning Rods.—Every tenth pole shall be equipped with a lightning rod made of No. 9 B.B. galvanized iron wire, which shall be attached to the pole every two feet by a 1½-inch galvanized iron staple. The rod shall extend to the top of the pole and have two hand turns under the bottom.

Setting Poles.—Poles shall be set to depths specified below, except in solid rock, where the depths shall be one foot less, and on curves, where the depth shall be six inches more in each case.

25 foot pole, 4½ feet.	40 foot pole, 5½ feet.
30 foot pole, 5 feet.	45 foot pole, 6 feet.
35 foot pole, 5½ feet.	50 foot pole, 6½ feet.

All holes shall be large enough to admit the pole without hewing or cutting and to permit the free use of the tamping bar around the bottom.

All poles shall be set perpendicularly, with cross-arms at right angles with the direction of the line.

The refilled earth shall be thoroughly tamped, three tampers being used for each shoveler. Soil shall be firmly packed around the pole to a height of at least 12 inches above the surface of the ground.

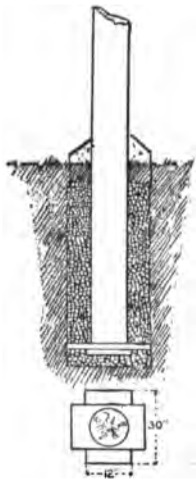
All blasting shall be in charge of men experienced in the use of explosives, and, if possible, shall be let to a contractor who shall be responsible for and assume all risk of damages to persons or property.

Where soft ground is encountered a packing of concrete, consisting of one part cement, two parts sand and five parts stone, shall be used for refilling. The holes shall be dug from 6 to 12 inches deeper than holes would be dug on curves for poles of corresponding length, and the poles shall rest on a foundation formed of two planks one inch in thickness, 12 inches wide, and from 24 to 30 inches long. (See Fig. 366.)

Where quicksand is encountered a barrel shall be driven down, the pole placed within the barrel, and the barrel then broken and withdrawn.

Small rocks and stones shall then be driven down by tampers in the sand surrounding the pole until no more can be forced downward; rocks shall then be piled about the pole if possible.

All guy stubs shall be set in the ground to a



POLE SET IN CONCRETE

Fig. 366

depth of six feet, and shall be set so as to lean away from the pole which is guyed to them.

All anchor logs shall be at least ten inches in diameter and five feet long and set to a depth of not less than six feet.

Facing Cross-Arms.—On straight lines, where the distances between the poles are equal, the cross-arms shall be placed on alternate sides of the pole, as shown in Fig. 367.

On long spans the cross-arms shall be placed on the side of the pole opposite the long section.

At terminals the cross-arms or the last two poles shall be placed on the side facing the terminal.

On curves the cross-arms shall be placed on

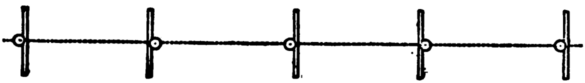


FIG. 367

the poles so that the strain of the wires will pull the cross-arms against the poles.

At road crossings the cross-arms shall be placed on the side of the pole facing the road.

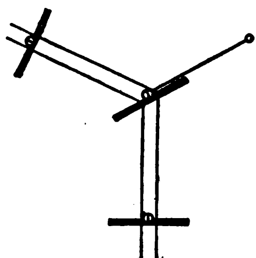


FIG. 368

GUYING.—Poles shall be guyed at every angle in the line greater than ten degrees.

The guy strand shall be 5-16 of an inch galvanized iron guy strand, and shall be wrapped twice around the pole or guy stub and the free end fastened to the long section with a three-bolt clamp. A thimble shall be placed in the eye

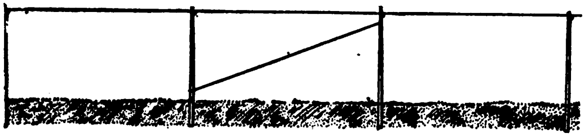


FIG. 369

of the anchor rod and the lower end of the strand passed through it, drawn up tight, and the free end fastened to the long section with a three-bolt clamp.

Where the pole to be guyed carries but one

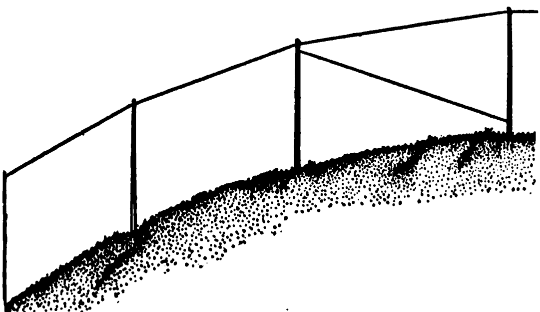


FIG. 370

cross-arm, attach the guy strand above the arm; where the pole carries two and not more than four cross-arms, attach the guy strand between the top and second cross-arms.

Single guys to anchors shall be used whenever possible, and they shall be set in the line of the resultant strain from the line wires, as shown in Fig. 368.

On lines carrying more than two cross-arms

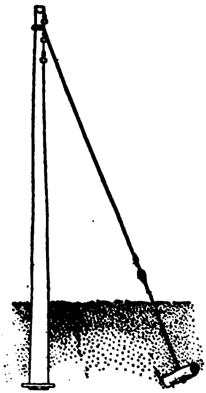


FIG. 371.

head-guys (as shown in Fig. 369) shall be used on every twentieth pole.

In a hilly country head-guys (as shown in Fig. 370) shall be used.

Poles, at the ends of long spans for river crossings and ravines shall be head-guyed and side-guyed in both directions, if possible.

Where possible, the anchor shall be placed 20 or 25 feet from the base of the pole as shown in Fig. 372. When it is necessary to set the anchor 10 feet or less from the base of the pole, the pole shall have a foundation formed of two planks, 1 inch thick by 12 inches wide and 30 inches long, set at right angles, as shown in Fig. 371.

Guy stubs shall be used only where necessary to raise the guy strand to a sufficient height to

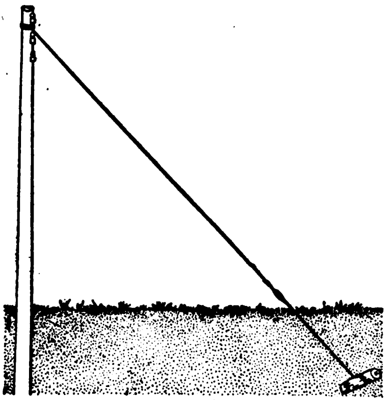


FIG. 372

clear obstacles or traffic, and shall be set as shown in Fig. 373.

No guys shall be attached to buildings or trees without special instructions from the Superintendent of Construction.

At slight curves in the line pole braces may be used, as shown in Fig. 374. The brace shall be beveled off to fit a flattened surface on the pole, and attached to it with two 6-inch lag screws. The brace shall be set to a depth of at least 2 feet, and shall have a foundation of two planks 30 inches long, set at right angles.

Road crossings may be guyed as shown in Figs. 375 and 376.

Corners may be guyed as shown in Figs. 368, 377 and 378.

STRINGING WIRE.—All wire shall be strung

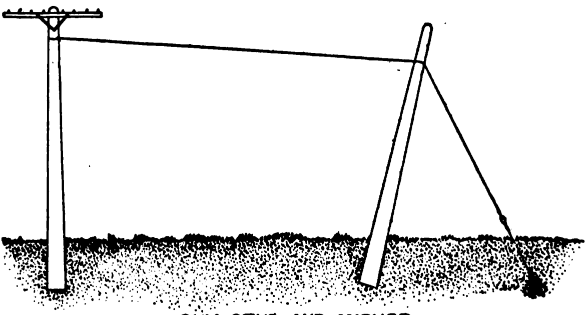


FIG. 373

from pay-out reels in such a manner that it shall be free from twists and kinks. The grip used in pulling up copper wire shall be of the parallel type (as shown in Fig. 379), and no other kind shall be used.

Iron wire may be pulled up with an eccentric clamp, as shown in Fig. 380.

In stringing wire the spans shall be drawn up to give a sag, as shown in the following table. Due consideration must be given to the prevailing degree of temperature:

SPANS IN FEET

	100	130	150	165	200
Temp.	Sag	Sag	Sag	Sag	Sag
30° F.	3 in.	5 in.	7 in.	9 in.	13 in.
40° .F	3 in.	6 in.	8 in.	10 in.	14 in.
50° F.	4 in.	7 in.	9 in.	11 in.	15 in.
60° F.	5 in.	8 in.	10 in.	12 in.	16 in.
70° F.	6 in.	9 in.	11 in.	13 in.	18 in.
80° F.	6 in.	10 in.	12 in.	14 in.	20 in.
90° F.	7 in.	11 in.	13 in.	15 in.	21 in.
100° F.	8 in.	12 in.	14 in.	16 in.	23 in.

Long spans, river crossings, etc., when from 400 to 600 feet in length, shall have a sag equal

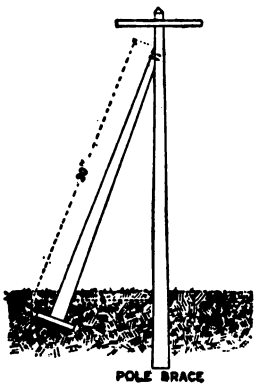


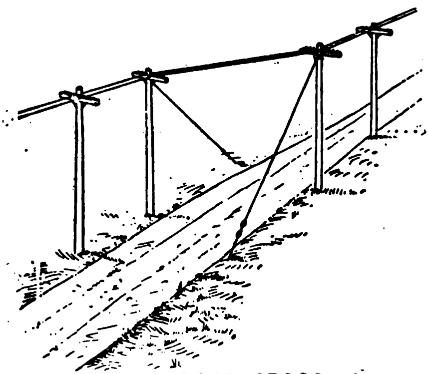
FIG. 374

to 1-40 of the span; when from 600 to 1,000 feet, the sag shall be equal to 1-30 of the span.

On straight lines the wire shall be tied to the insulators in the position as shown in Fig. 381.

On curves and corners the wire shall be tied to the side of the insulators away from the strain, as shown in Fig. 382.

Tying Wires.—Copper line wires shall be tied to the insulators in the manner shown in Fig. 383. One end of the tie wire shall pass over the line wire and make five complete turns, and the



ROAD CROSSING

Fig. 375

other end shall pass under the line wire and make five complete turns.

All ties upon iron wire shall be the Western Union tie, as shown in Fig. 384. Both ends of the tie wire shall pass under the line wire and make two and one-half complete turns.

Joints.—All copper wire shall be joined with the standard McIntyre sleeve, as shown in Fig. 385. In joining No. 10 B. & S. copper wire, each sleeve shall have three complete turns.

All iron wire shall be joined by the Western Union joint, as shown in Fig. 386.

DEAD ENDING.—In terminating a line or any insulator, it shall be given two complete wraps around the insulator and then wrapped five times around the line, as shown in Fig. 387.

TRANSPOSITIONS.—Transposition poles shall be located as follows:

Measure a distance of 1,300 feet from the

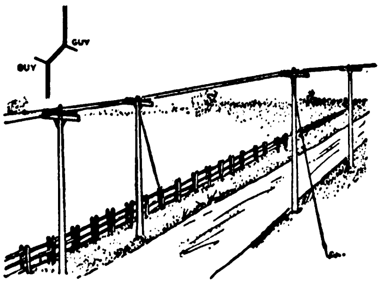
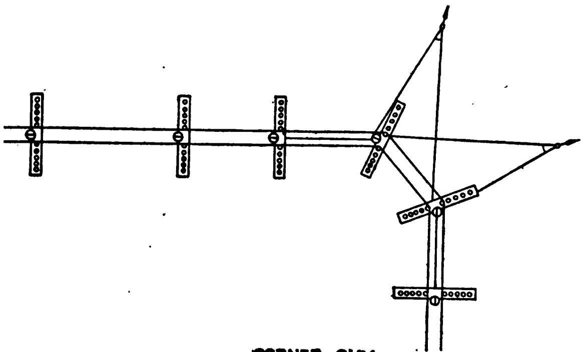


FIG. 376

first pole of the line and mark the pole nearest to the point so measured "A." Measure successive distances of 1,300 feet each, and letter the nearest poles, "B," "C," "B," "A," "B," "C," "B," "A," "B," "C," etc., successively.

The circuits shall be transposed upon the poles so lettered, as shown in Fig. 388.

All transpositions in copper circuits shall be made by cutting the wires on the pole side about 20 inches from the cross-arm, and slipping on each a half McIntyre sleeve with which the wires on the cross-arm side are dead-ended, one in the lower groove and one in the upper groove of the transposition insulator, leaving the ends projecting. About 6 feet of slack is then joined to the wires on the cross-arm side by using a whole McIntyre sleeve, half sleeves are slipped

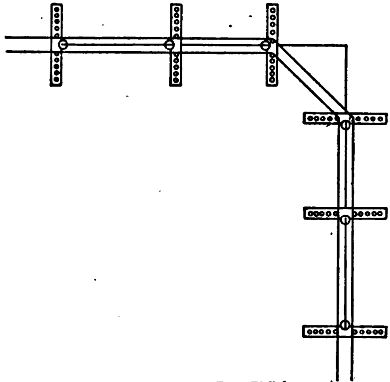


CORNER GUY

FIG. 377

on and the wires dead-ended in the vacant grooves of the transposition insulators. The free ends are now crossed and connected by half sleeves. In dead-ending hold the stationary connectors next to the insulator, so that the twists will be made in the long section. All whole sleeves shall be given three complete turns, and half-sleeves one and one-half turns. Regular and pole pin transpositions are shown in Figs. 389 and 390 respectively.

Iron wire shall be transposed by dead-ending the line upon a transposition insulator and leav-

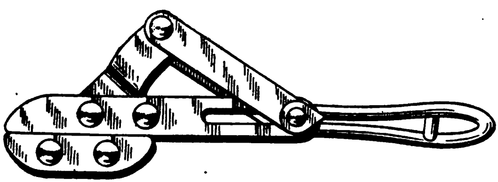


CORNER GUY

FIG. 378

ing one end long enough to reach the opposite wire and make a half connection thereon.

All cross-arms will be fitted up with stand-



COPPER WIRE CLAMP

FIG. 379

ard pins. For transpositions cut off the shoulder of the pin and drive it through the cross-arm, then drive in the transposition pin and secure it with a nail.

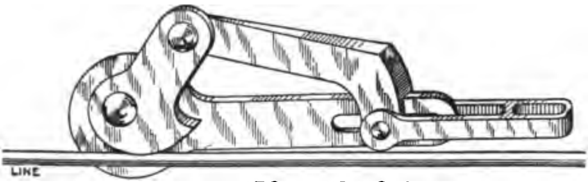


FIG. 380

TEST CONNECTORS.—In order to facilitate testing for and locating trouble, test connectors

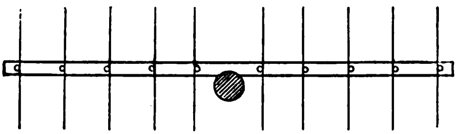


FIG. 381

(see Fig. 391) shall be cut in on all circuits where they pass through towns or railroad stations

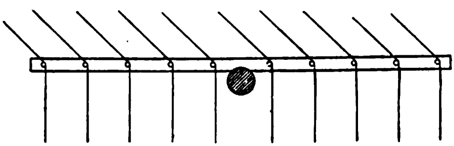


FIG. 382

(provided such towns or railroad stations are at least five miles apart), and at distances approximating five miles throughout the length of the line.

All test connectors shall be located on transposition poles, preferably transposition pole "C."

Fig. 392 shows the method of cutting in test connectors in circuits which are transposed.

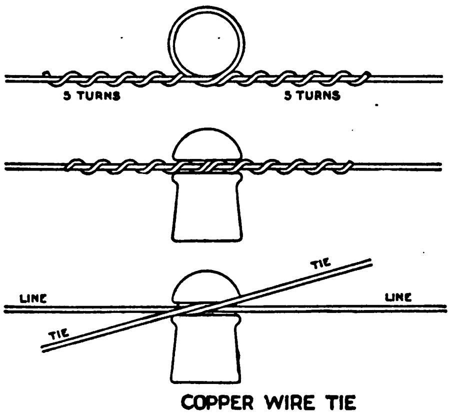


FIG. 383

Other circuits shall have the test connectors cut in as shown at Fig. 393.

All test connectors must be securely fastened in such a manner that they will in no way cut or injure the line wire.

CUTTING IN STATIONS.—All toll stations' telephones shall be bridged on to the line; this may be accomplished in two ways; by bridging direct, as shown in Fig, 394, or by looping, as shown in Fig. 395. The chief advantage of the latter is that it offers additional facilities for testing.

Open line wire shall be run as close as pos-

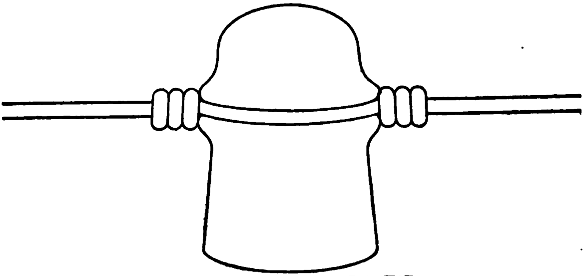


FIG. 384

sible to the toll station telephone, usually to brackets or cross-arm fixture attached to the building in which the toll station is located. No. 14 braided rubber insulated copper wires

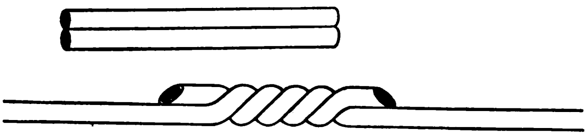


FIG. 385

twisted in pairs shall be used from the line wire to the telephone.

The insulated wire must be soldered to the line wire.

In looping in stations, care must be taken not to place a transposition in the line.

TREE TRIMMING.—All trees shall be trimmed

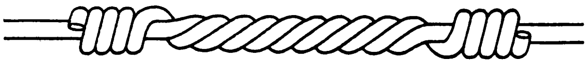
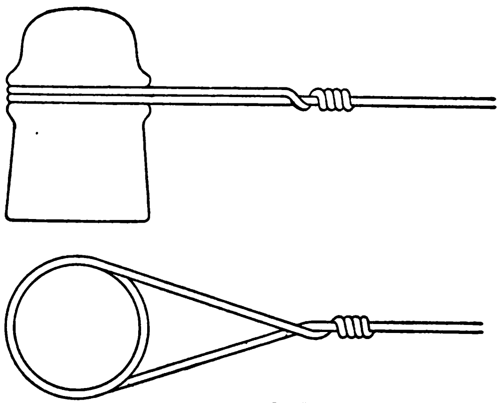


FIG. 386

WESTERN UNION JOINT

so as to clear the circuits at least 18 inches on all sides, and in such a manner as to cause the least possible injury to the tree or its appearance.



DEAD END

FIG. 387

Remove all brush, tree trimming and debris of every character within twenty-four hours after cutting same.

FARMERS' CIRCUITS

General.—The growing demand for telephone service among those who live in suburban

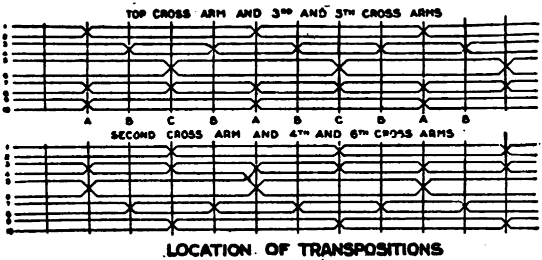


Fig. 388

and rural districts necessitates a method of constructing telephone lines somewhat cheaper than that above described, but which, neverthe-

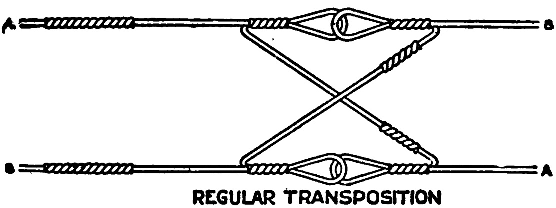
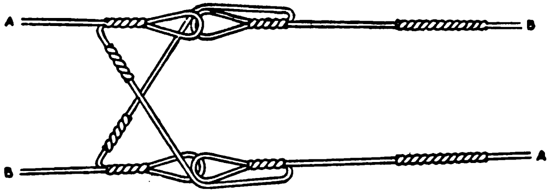


Fig. 389

less, will accomplish all that is desired of it, viz.: give good and reliable short-line service. The instructions here given are simply methods of modifying and cheapening the standard construction to meet these requirements.

POLES.—Poles shall be of cedar or good native timber, 25 feet long and not less than 4



POLE TRANSPOSITION

FIG. 390

inches in diameter at the top. Where more than one circuit is to be erected the poles shall be at least 5 inches in diameter at the top, preferable 5½ or 6 inches.

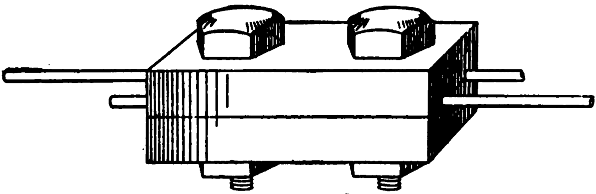

TEST CONNECTOR

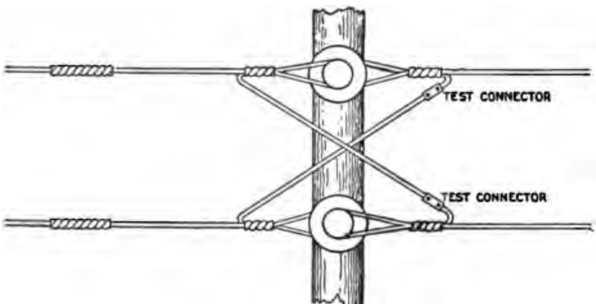
FIG. 391

Poles shall be set in a straight line, not more than 200 feet apart (26 poles to the mile). For cross-arm lines 30 or 32 poles to the mile shall be used. It is very important that they be set to the depths as specified, and that the refilled earth be well tamped.

A lightning rod shall be attached to every tenth pole.

GUYING.—All poles upon which curves or corners are made shall be securely guyed with No. 6 galvanized iron wire. Where the strain is great, two pieces of No. 6 wire shall be twisted into a strand and used for guying.

Galvanized iron anchor rods, one-half of an



TRANSPOSITION TEST CONNECTION.

FIG. 392

inch in diameter and 6 feet long, shall be used.

CROSS-ARMS AND BRACKETS.—Where but one circuit is required, brackets shall be used, two of which shall be attached to each pole. The upper bracket shall be placed 8 inches from the top of the pole and the other one 20 inches below it on the opposite side. Each bracket shall be nailed to the pole with one fifty-penny and one twenty-penny cut nail.

Where more than one circuit is to be erected six-pin cross-arms shall be used. They shall be of yellow pine, 2¾ inches by 3¾ inches and 6 feet long, bored for 1¼-inch pins. They shall be attached to the pole by two ½-inch by 7-inch lag screws.

Six-pin cross-arms shall not be braced except

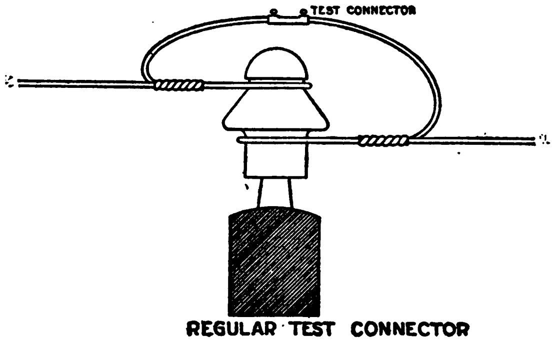


FIG. 393

on corners, but the gains in which they are placed shall be 1¼ inches deep.

The pins on a six-pin cross-arm correspond to pins 3 to 8, inclusive, on a ten-pin cross-arm.

Braces, where required, shall be of galvanized iron 3-16 of an inch thick, 1¼ inches wide, and 20 inches long. They shall be attached to the cross-arm by carriage bolts, which need not be galvanized, and to the pole with a 4-inch fetter drive screw.

INSULATORS.—Pony glass insulators shall be used.

WIRE.—No. 10 E.B.B. iron wire shall be used. It shall conform to the general requirements as specified.

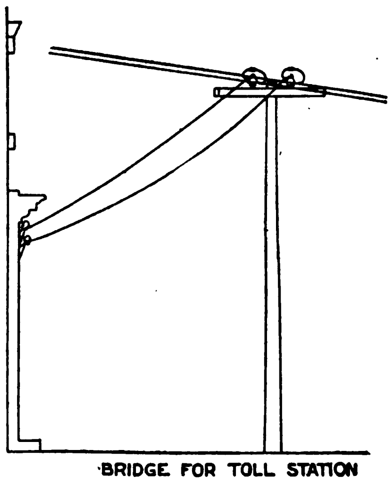


FIG. 394

All iron wire joints shall be of the Western Union pattern.

Transpositions are unnecessary where there is but one circuit on a pole line, but where there are two or more circuits they shall be transposed as directed.

A single metallic circuit, 15 or 20 miles long, constructed as above, will give excellent service to as many as twenty subscribers, when connected with bridging telephones.

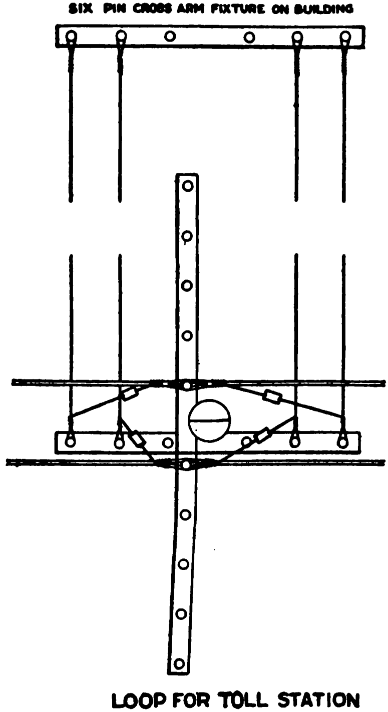


FIG. 395

Full metallic construction differs from grounded construction in that two wires are used instead of one for each talking circuit.

Below we give estimated cost for this style of construction.

FULL METALLIC CROSS-ARM CONSTRUCTION

26	poles, 25 ft. x 6 in. tops, @ $1.50 ...	$39.00
4	poles, 30 ft. x 6 in. tops, @ $2.10 ...	8.40
30	6-pin cross-arms, @ 17c	5.10
180	1¼-in. pins, @ 70c	1.26
60	No. 9 pony glass insulators, @ $15.75 M.	.95
330	lbs. No. 12 BB galv. iron wire, @ 3¼c lb	10.72
60	20-in. braces	1.44
60	½x7-in. lag screws	1.20
30	½x6-in. lag screws	.49
60	3½x⅜-in. carriage bolts	.51
120	washers for above	.25
	Labor setting poles and stringing wire...	27.75
	Total	$97.07
	Each additional pair of wires, including insulators, wire and labor, per mile	$25.88

FULL METALLIC BRACKET CONSTRUCTION

26	poles, 25 ft. x 6 in. tops, @ $1.50 ...	$39.00
4	poles, 30 ft. x 6 in. tops, @ $2.10 ...	8.40
60	12-in. oak brackets, @ $12.00 M.....	.72
60	No. 9 pony glass insulators, @ $15.75 M	.95
330	lbs. No. 12 BB galv. iron wire, @ 3¼c lb.	10.72
10	lbs. nails, @ 3c per lb	.30
	Labor setting poles and stringing wires..	28.90
	Total	88.99

One additional pair of wires, including brackets, insulators, wire and labor, per mile $26.88

From the estimates furnished it will be an easy matter for parties contemplating the building of telephone lines to estimate the amount of material necessary with which to build their lines, and should govern their order accordingly.

We give herewith the estimated cost for constructing common return telephone line, both of the bracket and cross-arm construction.

SINGLE LINE, BRACKET CONSTRUCTION

26 poles, 25 ft. x 6 in. tops, @ $1.50 ...	$39.00
4 poles, 30 ft. x 6 in. tops, @ $2.10 ...	8.40
30 12-in. oak brackets, @ $12.00 M	.36
30 No. 9 pony glass insulators, @ $15.75 M	.48
165 lbs. No. 12 BB galv. iron wire, @ 3¼c per lb	5.36
5 lbs. nails @ 3c per lb...............	.15
Labor setting poles and stringing wire, per mile	19.00
Total	$72.75

One additional circuit, including brackets, insulators, wire and labor, per mile $15.44

SINGLE LINE, CROSS-ARM CONSTRUCTION

26 poles, 25 ft. x 6 in. tops, @ $1.50 ...	$39.00
4 poles, 30 ft. x 6 in. tops, @ $2.10 ...	8.40

30	6-pin cross-arms, @ 17c each	5.10
180	1¼-in. oak pins, @ $7.00 M	1.26
30	No. 9 pony glass insulators, @ $15.75 M	.48
165	lbs. No. 12 BB galv. iron wire, @ 3¼c per lb.	.36
60	20-in. cross-arm braces	1.44
60	½x7-in. lag screws	1.20
30	½x4-in. lag screws	.49
60	3½x⅜-in. carriage bolts	.51
120	washers for above	.25
	Labor setting poles and stringing wire, per mile	19.00
	Total	$83.49
	Each additional circuit, including insulators, wire and labor	$14.25

CHAPTER XXIII

LINE CONSTRUCTION

In modern telephone line construction every possible improvement in method and quality of equipment must be considered and utilized in most minute detail, as the telephone is most sensitive to invasion by foreign currents, either by induction or leakage into the line. The telephone current is at best a feeble one as compared to currents employed in other electrical systems, and therefore efficient operation becomes impossible in the presence of undue loss by leakage or in overcoming resistance.

The proper conductor for a telephone line is one of low resistance and thoroughly insulated and so located as to obviate as far as possible its exposure to all sources of induction.

In long distance work copper wire is now universally used as conductors, however, for short distance work the relative high resistance of iron is not considered a serious objection, and modern practice sanctions the use of galvanized iron or steel wire; but the conductivity of copper is six times higher than that of iron and consequently an iron wire, for the same resistance as a copper wire, will have six times the weight of the copper wire. The speed of transmission is also greater over copper than iron, as the effect of *electro-magnetic inertia* is less in copper than in iron. Electro-magnetic inertia is that quality of a conductor which tends to check the speed of a current passing through it.

The size of hard drawn copper wire generally used for telephone lines in this country is No. 12, standard gauge, having a diameter of 104 mils, a weight of 166 pounds per mile and a resistance of 5.2 ohms per mile. For short lines No. 14, diameter 80 mils, weight 102 pounds, and resistance 8.7 ohms per mile, is a sufficiently heavy wire, and amply strong enough if carefully put up, with not too long spans. The practice of calling different sizes of wire either by their weight per mile or their diameter in mils (thousandths of an inch) is fortunately increasing, as either way is much less confusing than the use of any one of the numerous gauges now in existence. Two handy rules to remember in connection with the diameter, weight and resistance of copper wires are these: The weight in pounds per mile can be found by dividing the square of the diameter in mils by the constant 62.57; and, conversely, the diameter can be found from the weight by multiplying the weight by 62.57 and extracting the square root of the number obtained. The resistance in ohms per mile is found by dividing the constant 890 by the weight per mile.

The tensile strength and ductility for which wire bought in large quantities is tested should be not less than 500 pounds breaking weight for the 104 mils wire for tensile strength, and 24 twists in three inches without breaking, for ductility.

Among the best tests for the ductility of hard drawn copper wire is to wrap and unwrap it around itself in the same direction, say,

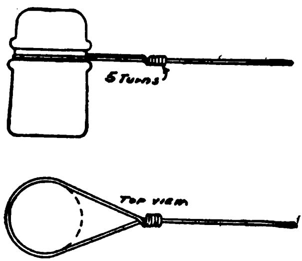


FIG. 396

once six times and then again six times. If the wire does not break it may be considered efficient. For overhead work the resistance of wire is measured at a temperature of 60° F. If the temperature of copper wire changes 1° F. its resistance will change about one fifth of one per cent.

The resistance increases as the temperature increases and vice versa; hence a wire showing 100 ohms resistance at 60° will show 102 ohms at 70° and 98 ohms at 50°.

A clear glass insulator of the form shown in

Fig. 396, top cut, is used in modern practice and is superior to green glass, as it permits the free penetration of light thereby preventing insects from collecting under the insulators. A locust pin 1 inch in diameter fitted into a hole in the center of the cross-arm and held in place by a nail driven through cross-arm and pin, supports the glass insulator which is threaded to fit the pin.

When the wire is drawn, first it should be observed that the head pole, or the end of the line is properly guyed to prevent it from being pulled over. The glass insulators should be screwed on the pins, and the ends of the wires thoroughly tied by winding them twice around the glass knob and twisting the end around the body of the wire. The line man should then go to the other end of the line, draw one of the centre wires and fasten it to the body of the next pole near the ground and then take the next centre wire in the same manner, continuing until all the wires have been drawn and fastened to the body of the pole, observing to draw each wire with an equal tension, and tie the same as above described, except that instead of bracing the head pole, he should unfasten four of the wires from the body of the pole (leaving two wires for the time as a temporary guy), and splice them upon the new lead, and then proceed as before.

In terminating a line the wire is generally "dead ended" on either a shackle or an ordinary insulator; the wire is given a round turn on the insulator, and the free end is brought back and twisted round the taut wire or bound to it by a piece of tie wire. A piece of the end

BRITANNIA JOINT

FIG. 397

is generally left projecting beyond the joint for attaching the leading in wire; with the twisted sleeves the leading in wire can be joined directly to the line.

Particular care is necessary in making the joints in a telephone wire, as a loose joint is

MC INTYRE SLEEVE JOINT.

FIG. 398

apt to constitute a sort of microphonic contact in itself and to produce noises in the line. The ordinary telegraph joint is not reliable enough for telephone work and should not be used. When it is used the joint should be carefully covered over with tin foil and taped with ordinary jointing tape. This will tend to keep out moisture and prevent corrosion. No American linemen can be induced to solder joints, and the tin foil and tape covering has been introduced as a substitute, but it is a poor makeshift.

The Britannia joint, Fig. 397, made by overlapping the ends of the wires and binding them with a fine tie wire is very much safer, but requires to be soldered to make a good job. The quickest and safest way of jointing is by the use of the well-known McIntyre sleeves, Fig. 398. The ends of the wires are slipped into a double sleeve of the proper size, and the sleeve is then twisted with a special tool. These joints have given excellent results, both electrically and mechanically, and they are very quickly made.

The construction of an overhead line must always be governed by the local conditions, the number of wires to be erected, their weight and so on.

In all aerial lines the various items of construction are: Poles, cross-arms, anchors, stubs and anchor guys, push pole braces and wire stringing.

Poles.—The various poles in use are those for: Street and alley lines; farm lines; toll lines; self-sustaining poles with ground brace or set in concrete. The following table, A, shows the standard poles used in the different kinds of line construction, also the size and spacing for same; and table B shows the depth at which the poles, according to length, should be set in rock or earth.

TABLE A.

25 feet or less	3 feet	5 feet
30 feet or less	3½ feet	5½ feet
35 feet or less	4 feet	6 feet
40 feet or less	4 feet	6 feet
45 feet or less	4½ feet	6½ feet
50 feet or less	4½ feet	7 feet
55 feet or less	5 feet	7½ feet
60 feet or less	5 feet	8 feet
65 feet or less	5 feet	8½ feet
70 feet or less	5½ feet	9 feet

Before setting the pole in the ground the top should be roofed. The first gain should be cut five or six inches from the peak of the roof.

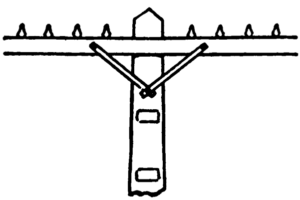


FIG. 399

The standard gain is one inch deep by 4¼ inches wide, but gains may be proper size to admit the cross-arm. Other gains should be cut 18 inches below, eighteen inches apart, in order to admit more cross-arms should more wires be required than can be carried on one cross-arm. See top of pole, Fig. 399. All roofs, gains and holes should be painted. All holes should be bored 21-32 inch.

All pole holes should be dug large enough to admit the pole without stabbing or hewing, and should be full size at the bottom so as to admit of the use of iron tampers.

In crossing railroads, wires should be carried

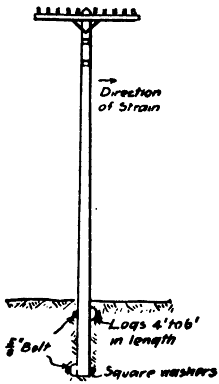


Fig. 400

at least twenty-seven feet above the tracks and firmly secured to double cross arms with iron pins and large glass insulators. It is well to observe the same rule in crossing large streams.

In Fig. 400 is shown the method of setting self-sustaining poles with ground brace.

Cross Arms.—In Fig. 401, at *a*, is shown the standard construction of cross-arm for street lines in city; at *b*, for alley lines; at *c*, for farmer lines; at *d*, for suburban toll and street lines; at *e*, for long heavy route terminal poles. Cross-

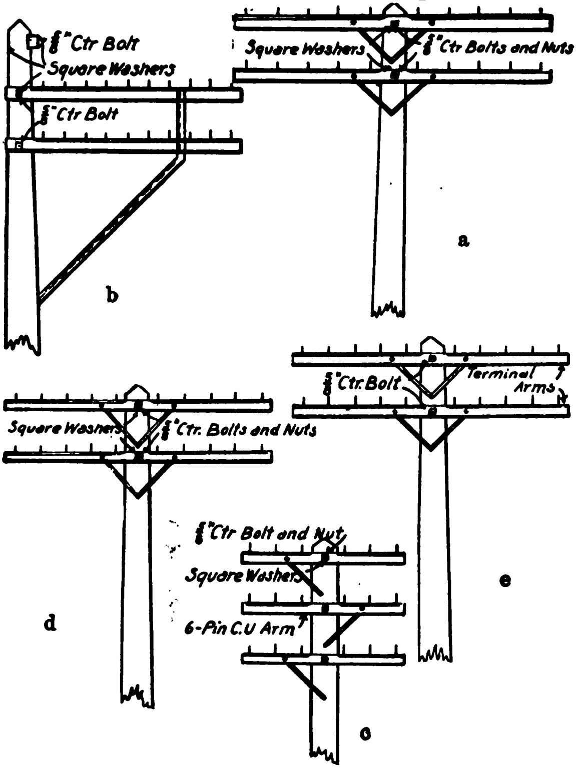


FIG. 401

arms are classified as: six-pin, ten-pin, ten-pin alley and six-pin terminal.

ANCHORS, STUBS, AND ANCHOR GUYS.—Anchors and stubs are classified as: Log anchors, rock anchors, Miller anchors, anchored stubs, self-sustaining stubs with ground braces and self-sustaining stubs in concrete.

In Fig. 402 at A is shown a log anchor; at B, a self-sustaining stub with ground braces; at C, an anchored stub. Anchor guys, lugs and pole protectors are included with stub and anchor.

In Fig. 402 is shown the manner in which anchor guys should be attached. No excavation for anchor logs should be less than four feet deep and should always be six feet deep when the nature of the soil will permit. The strain upon an anchor log should determine its size and the depth of the excavation as shown in Table C following:

TABLE C.

6 ft.	5 ft.	10 ins.
5 ft.	5 ft.	16 ins.
5 ft.	8 ft.	16 ins.
4 ft.	5 ft.	23 ins.
4 ft.	8 ft.	14 ins.
4 ft.	10 ft.	12 ins.

At *a* in Fig. 402 is shown how the log should be firmly anchored by covering with logs, rocks or planks. Guy stubs should be set at least six feet in the ground and anchored or set in concrete as shown at *b* and *c* Fig. 402.

Push Pole Brace.—The butt of this brace

should be set 3½ feet in the ground a reasonable distance from the base of the pole, and be supported on something solid, such as a large stone

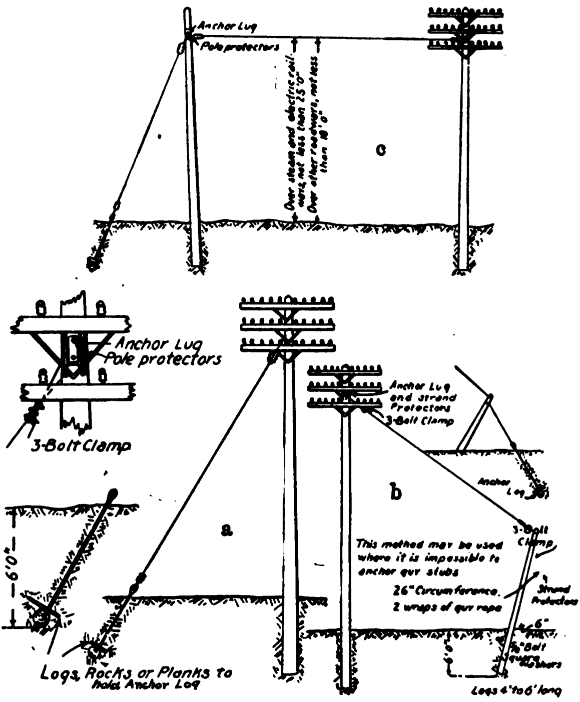


FIG. 402

or a heavy plank. The upper end of the brace should strike the pole at a point about 2-3 the length of the pole from the ground and should be fastened to the pole with a cross-arm bolt, without cutting the pole.

Wire Stringing.—The following kinds of line-work are classified under wire stringing: No. 12 galvanized steel for farm line, No. 12 galvanized steel for toll circuits, .104 bare copper for toll circuits, .104 bare copper for street and alley lines, line orders for city and village lines, line orders for farm line, and running drops. Included in wire stringing is tieing-in

Fig. 403

and equipping. Running drops is included in line orders and also recorded separately. The methods of stringing wire and tieing-in are: The wires should be run out from reels. See Fig. 403. They should be attached to a running board, or boards, to the end or ends of which should be attached a running rope or wire. Where there are only two wires to be run, the running board may be dispensed with. Where a running board is used the reels of wire should be placed at one end of the section. The wires, when the pole is reached, should be carried up and placed inside the pins of the proper arm. Wires should be fastened to insulators.

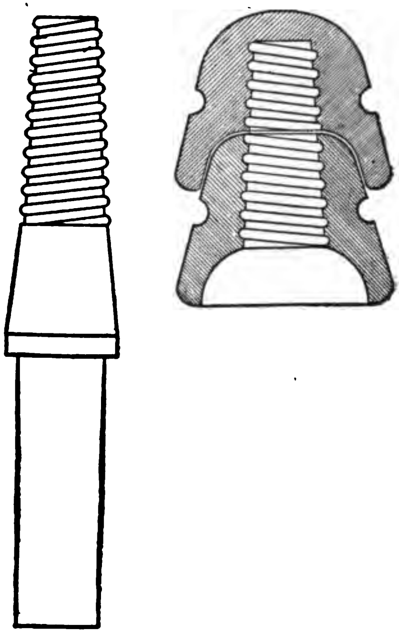
METALLIC CIRCUITS

A noisy line will invariably result on a metallic circuit if the two sides of the circuit are not properly balanced with respect to their electrical conditions and qualities.

Each wire of the circuit should have as nearly as possible the same resistance, insulation and electrostatic capacity.

The capacity of a single wire is measured against the ground; but that of a loop or metallic circuit disconnected from the ground, is less than one of its wires against the ground—practically demonstrated, the capacity of an overhead metallic circuit has been fixed at about 60 per cent. of the capacity of one of its wires against the ground. Aside from establishing harmony of electrical conditions of each wire in the circuit, the relative exposure of each side of the circuit to sources of induction must be made equal—as for instance, where other lines (telephonic or telegraphic) run on the same set of poles. If the adjustment is not perfect cross talk, from strong induction, will result. To prevent this the most practical method is to cross or transpose the two wires of a circuit at given poles on the line and by this means each wire is made to do duty for the other along certain stretches. These transpositions are made according to the number of circuits on the line.

The system of transposition must be adapted to the number of circuits on a particular line. In Fig. 404 is shown the insulator employed for



TRANSPOSITION INSULATOR AND PIN

FIG. 404

making transpositions. The transposition insulators make a break in each wire, the two ends of each side of the metallic circuit being dead-ended on the upper and lower cups of each insulator. By cross connecting the two wires on the upper insulators and the two on the lower the transposition is made and in the next span the relative position of the wires is reversed, the left hand becoming the right. The effect of the transposition is to cause any induced currents to be set up equally in each wire; they thus neutralize each other, and no disturbance is produced in the telephones at the terminal station. In comparatively short lines (of twenty or thirty miles) very few transpositions are needed to secure silence, but the number requisite must generally be determined by experiment.

CHAPTER XXIV

ELECTRICAL CONDUIT CONSTRUCTION

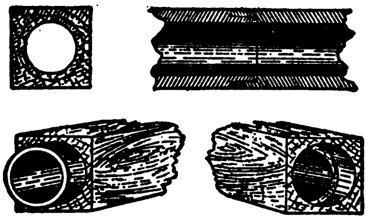
In recent years it has become the practice in the business districts of cities to run all telephone wires underground. The preliminary work consists of the planning of the conduit system which includes the street location of ducts and manholes; determining the style and number of ducts to be used and the methods of laying, locating manholes and service boxes, making the drawings and estimates of cost.

The essential requirements of a standard conduit should be:

Durable material, i. e., absolutely proof against decay, corrosion from dampness, gases, dry rot and other agencies of disintegration.

Tensile, shearing and crushing strength are principal requirements of good conduits, and their greatest strength should be in a vertical direction because of the severe vertical strains to which they are subjected due to the settling of the ground and other causes. Fractures of the structure or undue settling caused by the stress imposed upon it, impair or destroy the alignment of the ducts, interfere with the drawing in or out of the cables and prevent proper drainage. Ducts should be straight between manholes, but where curves are unavoidable they should not be so sharp as to cause abrasion of cable sheaths when drawing in.

It is always better, where the nature of the conduit permits it, to form all bends of curved sections instead of joining together short straight sections as is frequently done in making slight turns. The structure should be composed of in-



"PUMP LOG" CONDUIT.

Fig. 405

sulating material and be moisture-proof. No dependence, however, for insulation of the conductors themselves must be placed on the conduits, as the cables must in all cases provide the means for keeping the conductors thoroughly insulated and free from moisture. No conduit system has yet been constructed which has been kept dry.

Conduits should contain no chemical agents capable of exerting a deleterious effect on the cable sheath. An important item in the selection of conduit to be used is economy of space, and under crowded conditions that conduit which will place a given number of ducts within the smallest space is the most desirable, other things being equal.

Several views of a tube shown in Fig. 405 illustrate the simplest and cheapest form of conduit which consists of creosoted wooden tubes commonly known as pump logs and which are made in eight-foot lengths with a three-inch bore. They are $4\frac{1}{2}$x$4\frac{1}{2}$ inches square and have a tenon joint one and one-half inches long to maintain alignment. These tubes are seasoned and creosoted by a process which insures long life.

These conduits are laid in a trench, the bottom of which is graded to a gradual slope towards both manholes from an intermediate point, or a continuous slope from one manhole to the others. A creosoted plank two inches thick serves a foundation upon which the ducts are laid side by side in different layers to the number required, and in such manner that separate ducts break joints in order to add strength to the entire structure. When the ducts are all laid the top layer is covered with another creosoted plank two inches thick and the trench is filled in with earth.

This forms a comparatively cheap conduit as no concrete is used in the foundation.

Conduits of clay or terra-cotta, burned hard and with vitrified surfaces are largely used and are made in a number of forms and are classified as multiple duct conduits and single duct conduits. For telephone conduits some ducts have a round opening $3\frac{1}{2}$x4 inches in diameter and others a square opening with round corners and of the same dimensions both ways.

The early forms of clay ducts had in view

Fig. 406

the economy of duct space; but this was obtained at the expense of safety as in drawing out sheaths were damaged. Later the single-duct and the multiple-duct types of tile were introduced and are favorably considered in modern practice. (See Fig. 406.)

Some advantages are claimed for the single duct tile among which are greater flexibility and greater facility of handling.

The form shown in Fig. 407 has come into very wide use and has proven its adaptibility to meet almost any conditions that may arise. These tiles are $4\frac{5}{8}$ inches square by 18 inches long, and have a $3\frac{1}{4}$-inch bore. By it curves are easily made, short curved lengths being provided, or curves of long radius may be made

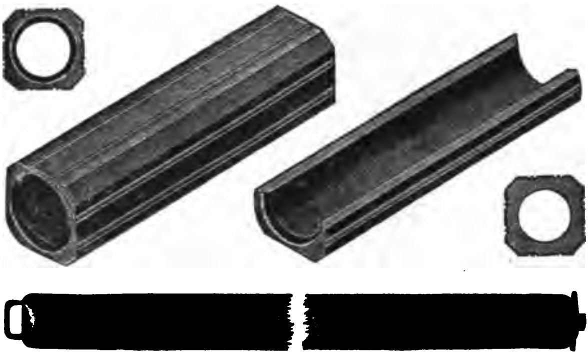


Fig. 407

with the regular tiles, the lengths being so short as to form a practically smooth interior surface. This conduit is laid in much the same way as ordinary brick, and in order to insure proper alignment a mandrel (shown in lower portion of Fig. 407), three inches in diameter and about thirty inches long, is laid in the duct and pulled along through it by the workmen as each additional section is laid on. The rear end of this mandrel is provided with a rubber gasket a little larger than the diameter of the conduit, which effectually smooths the inner surface and prevents the formation of lips which might prove injurious to the cable sheaths in drawing in. On the front end of the mandrel is provided an eye which may be engaged by a hook carried by the workmen in order to move it forward. Fig. 408

Fig. 408

shows a single-duct subway in process of construction.

In laying vitrified clay tile the process used is as follows: The trench is dug to such a depth as to allow at least two feet of earth above the top of the entire structure. Some specifications call for as great depth as three feet, but this is necessary only where there is a probability that new ducts may be added to the conduit in the future. The width of the trench should be about six inches in excess of the actual width of the number of ducts which are to be laid side by side. In the bottom of the trench is laid a concrete foundation from three to six inches deep as circumstances may require, and the tiles are then laid in the cement and the sides of the trench filled up with the cement level with each layer of tile as it is completed. All spaces and interstices in each layer are well grouted with thin cement, and when all layers are completed the top is covered with four inches of concrete composed of: Hydraulic cement, 1 part, clean sharp sand, 2 parts, broken stone or brick or screened gravel, 5 parts. *Ducts must never be moved while concrete is settling.*

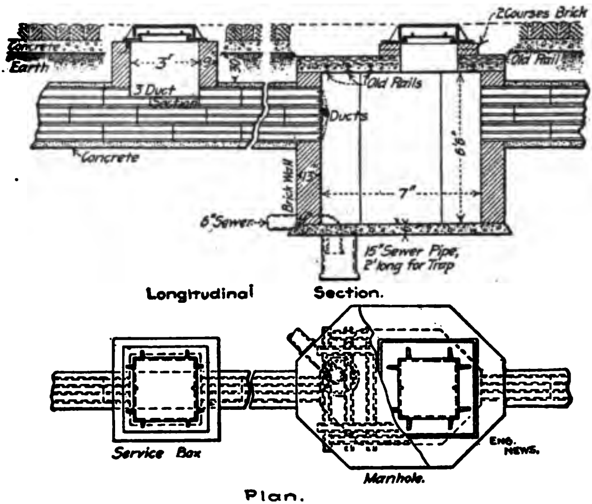
When an entire subway is laid from manhole to manhole a scraper is drawn through to smooth the inside walls and the ducts are then thoroughly washed out with a hose. Another style of conduit consists of cement lined pipe laid in concrete practically in the same manner as the clay tube; but this style of conduit is falling into disuse.

Many obstructions are met with in laying conduits in city streets and in each case the difficulty must be overcome as conditions best permit. Sometimes the support from heavy pipe lines have to be removed for a considerable distance as, for instance, when such a pipe line lies diagonally across the trench. In all cases suitable supports for these pipes or other structures should be provided until such time as the trench is again filled. The usual means adopted is to place a beam of sufficient strength across the top of the trench and support the pipe therefrom by chains or heavy rope. It is frequently necessary in passing an obstruction to fan out

Fig. 409

the pipes in one layer so that they occupy the same level as those of another layer. Such a construction, and also a rather crooked piece of conduit work, is shown in Fig. 409, where, on account of obstructions in the street, the two layers of two pipes were formed into one layer of four until the obstructions were passed. This particular obstruction was a sub-cellar extending out under the street.

The manholes (see Fig. 410 showing a standard manhole and service box) may be built of



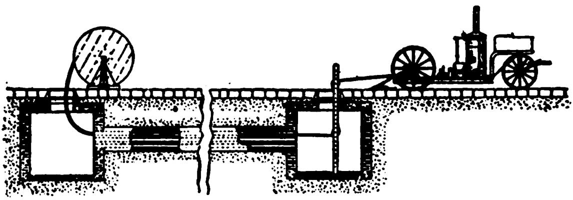
Standard Manhole and Service Box.

FIG. 410

various forms and dimensions to meet existing requirements. In the best construction the foundation consists of a layer of concrete six inches deep, the concrete being mixed as specified for laying of tiles, with the exception that the crushed stone may be considerably coarser. The walls of the manhole are then built of good brick-work of suitable thickness and well plastered on the outside with cement mortar in order to exclude dampness. An eight inch wall is the usual thickness for an ordinary manhole; but for large vaults twice and sometimes three times this thickness becomes necessary and when these very thick walls are used an air space of about one inch should be left between the outer and inner course of brick to keep the interior dry. Where a great number of ducts enter a manhole the size of it should be made adequate to requirements; but in every instance a manhole should provide enough room for two men to work in conveniently.

When the conduits are laid and the manholes finished the cables are drawn in. This in accomplished by stretching a rope through the duct from manhole to manhole. The rope is put through duct by a process called "rodding," i. e., a number of wooden rods about four feet long and equipped with joint devices, are first run through the duct and they serve to draw the rope through to which in turn the cable is attached and started through the duct. Sometimes physical conditions being favorable a steel wire is of sufficient rigidity is first put through the duct instead of the jointed rods. The cable in passing through the duct is paid out from the top of the reel which stands near one of the manholes. (See Fig. 411.) This illustration shows the method of drawing in a large amount of cable by means of a three and one-half horse power horizontal engine and capstan instead of a hand-operated winch and windlass used for less extensive construction. In feeding in cable a funnel-shaped shield is used at the mouth of the duct to protect the cable from abrasion and sometimes in addition to the shield one or two men are employed to guide the cable into the duct.

In conduit work the leakage of gas mains through the earth and its accumulation in man-



DRAWING IN BY STEAM POWER.

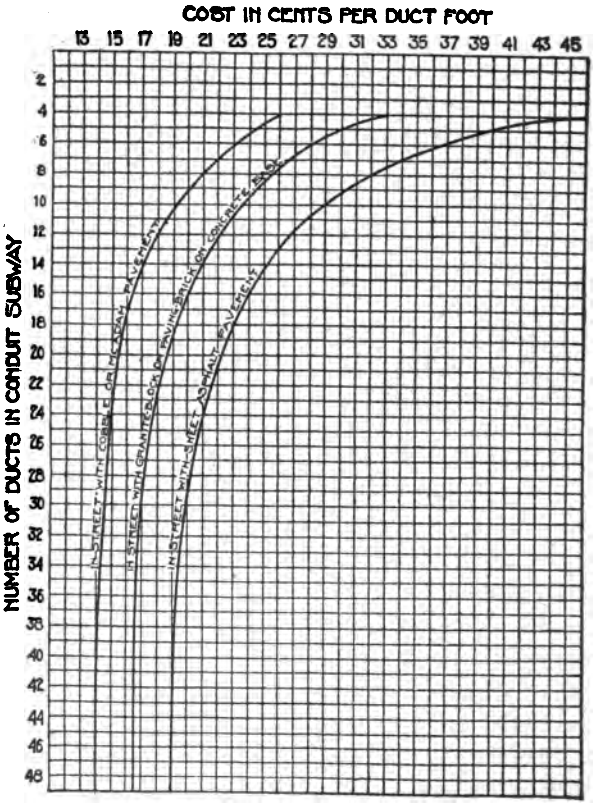
FIG. 411

holes is a source of danger to be constantly borne in mind and before striking a match or taking a torch into a manhole the gas should be pumped out by the inverted umbrella made for the purpose or by the use of a screen of cloth placed above the manhole and on the side opposite to that from which the wind is blowing.

All of the cable sheaths entering a manhole should be bonded together, the usual method of doing this being to brighten the surface of the lead sheaths and to bend a No. 10 B. & S. copper wire around each sheath, afterwards soldering the connection. This assures the fact that all of the cable sheaths will be at an equal potential and that whatever bonds are run for the protection of one sheath will afford protection for all. The method of bonding to a gas pipe usually adopted is as follows: The surface of the pipe is brightened for a space of about three by eight inches with a coarse file. This surface is then heated by a torch and tinned with ordinary solder. A copper plate about three by seven inches previously tinned is then soldered to the gas pipe, after which the bond wire leading from the cable is wound into a flat coil and soldered to a copper plate. In bonding to a water pipe it is impossible to heat the pipe sufficiently to make it take solder, and instead of solder a heavy U-shaped band of wrought iron is made to fit around the pipe. The ends of the band are screw-threaded and pass through a yoke piece, which is shaped to fit the upper part of the pipe, and the yoke is screwed in position by nuts. To the yoke piece the bond wire is then soldered and the whole arrangement painted with asphalt paint.

There are other forms of duct material; but those above mentioned are most in common use.

The cost of material and labor for the different parts of an underground system of telephone wire distribution vary so widely that the matter of estimating cost to apply to construction generally cannot be reduced to any reliable degree af accuracy except by one method and

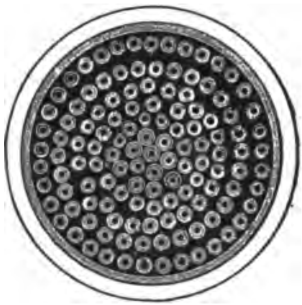


CURVE OF CONDUIT COSTS.

FIG. 412

that is to lay out the routes, figure the cost of each and strike a total. A compilation of data, by Mr. C. J. Field, to whom engineers are indebted for a useful table of approximate costs, is shown in Fig. 412, the curve in which gives such costs based on a duct material price of five cents per foot.

In compiling an estimate the curve is used as



STANDARD TYPE OF UNDERGROUND TELEPHONE CABLE.

FIG. 413

follows: The runs of conduit are tabulated under their several sizes and character of pavement, and the cost per duct foot for each is located in the curve. The cost thus found is multiplied by the number of ducts in that trench, and by its length. The same is then done for all the trenches and the result added. The cost of the system will be represented by the sum. The curve should be modified accordingly should the cost of duct material on the ground be less or more than five cents; but it will not be necessary to redraw the curve.

The standard type of underground telephone cable contains 100 wires. These are twisted in pairs with a lay of about three inches, and the pairs are cabled in reverse layers, forming a cable about 1⅝ inches in diameter. This cable is enclosed in a lead pipe having an internal diameter of 1¾ inches. The pipe Fig. 413 is one-eighth inch thick, and is alloyed with three per cent. of tin to prevent chemical action tending to eat away the lead.

The standard cable of to-day contains conductors of No. 19 B. & S. (35.9 mils), having a resistance of about 45 ohms per mile. The average electrostatic capacity allowed is .085 microfarad per mile.

MODEL RULES AND REGULATIONS ADOPTED BY THE CHICAGO TELEPHONE COMPANY FOR THE GUIDANCE AND GOVERNMENT OF THE EMPLOYEES OF THAT SYSTEM.

COURTESY

(1) A courteous bearing towards all the patrons of the Company is insisted upon. The same courtesy in your intercourse with your fellow employes and others will save you work and enhance your value.

ENTERING A SUBSCRIBER'S PREMISES

(2) When entering a subscriber's place, give

those in charge some idea of your intention of working on the wires, instruments or terminal box.

(3) When attempting to gain admission to a residence, you should go to the back door; also see that your shoes are clean.

(4) If entrance to a subscriber's premises cannot be gained on account of subscriber having moved, do not force the doors or windows, but report same to Wire Chief. Do not enter and remove telephone from an occupied apartment without your presence being made known to the party in charge.

(5) If refused admittance when sent on a case, report the facts to the Wire Chief and be guided by his decision. Do not start an argument on this account.

BEHAVIOR ON SUBSCRIBER'S PREMISES

(6) Make yourself as inconspicuous as possible around a subscriber's premises.

(7) Do not use his desk as a work bench and do not monopolize his office chair.

(8) Employes must not smoke while working on a subscriber's premises.

(9) Do not make statements and do not give information concerning the Company's business and methods. Many trifling things are said by inspectors that at the time seem to be of no consequence, but are construed by the subscriber as flat statements, thereby creating a misunderstanding.

(10) A request for information can generally be answered by referring the subscriber to the Contract Department, as these inquiries are usually regarding moves or changes of contract.

(11) Do not, in the presence of a subscriber, criticise the service, a co-workman or any department; it only reflects upon yourself and your department.

REPORTING FOR DUTY

(12) Call the Wire Chief's office as soon as possible after any unusual lightning, rain, wind or sleet storm, and see if your services are needed. Do not wait for him to send a messenger for you, as messengers are scarce, and a Wire Chief's time precious in emergencies of this nature.

(13) In case of sickness or other causes detaining you from reporting for duty at the usual time, call your Wire Chief and give reason for being detained; if you are unable to do this, have some one report for you.

AVOIDING OF RISKS

(14) As a safeguard against accidents, rubber gloves are furnished, and repairmen are cautioned to have them with them at all times and to wear them whenever exposed lines are encountered. Gloves that are defective must be replaced as soon as defect appears.

(15) Do not work in an elevator shaft while the car or counterweights are running. Work

should only be done when the car makes special trips, so that the elevator man can give his entire attention to you.

(16) Be careful to inspect all step-ladders before using same.

(17) The use of many high tension currents in the city for lighting and power purposes makes it absolutely necessary that employes should always be vigilant and cautious and should not take chances with dangers, which are known or can be ascertained with due care. Men have lost their lives or severely injured themselves by dragging wires across leads of so-called insulated bare wires in contact with others of a like character and apparently harmless. Such risks can be avoided by the exercise of proper care.

THINGS TO BE REPORTED

(18) Report all cases of careless or defective construction work to the Wire Chief's office.

(19) Where both drop wires are bare and causing trouble, or likely to cause trouble, recommendation should be made to change to one insulated.

(20) All lines at cable poles and also at subscriber's premises are to be protected with line fuses. Repair if otherwise.

(21) Be very careful to close cable box doors when leaving them. A cable box noticed open should be closed, or if impracticable at the time, report same.

(22) Bare iron rings for jumper supports in cable boxes are not to be used. Report all instances. Care should be taken not to break the enamel of insulated rings.

(23) Cable boxes located in such a position as to be impracticable to work on, or dangerous on account of having to stand on the messenger, thus grounding yourself while at work, must be recommended moved; if not moved within a reasonable time, to be reported again.

(24) Report all cases of missing or broken cable hangers.

(25) Report all situations where cables or aerial lines are in close proximity to the feed wires or high tension circuits.

(26) In places where a cable is dangerously low at trolley crossing and likely to be struck by a trolley pole, if it should slip from the trolley, it should be protected by heavy rubber insulation. Refer all such cases to the Wire Chief. Report all lines, drop wires or cables which do not clear street or steam railway crossings by twenty-five feet above the tops of the rails.

(27) Cables supported from the messenger wire by Marline hangers should not come in contact with the strand. Report all instances.

(28) Messenger wires fastened to an elevated railway structure are to be insulated from the same. Report if otherwise.

(29) Bills or posters should not be posted on the Company's poles. Report all instances. On discovering a person posting bills on the

Company's poles, the repairman will, if possible, follow him until he encounters a policeman, whose attention should be called to the fact that the man is posting bills on poles, while he is in the act of doing so, if possible. The matter should then be taken up with the Tester, who will notify the Claim Agent, and advise what further action is to be taken.

(30) Insulation cut from covered wire for the purpose of testing or joining must be covered with okonite tape. Joints formed of copper and iron must *always* be thoroughly taped with okonite.

(31) Do not attach test clamps to iron wire. Cut in a short piece of copper wire, using sleeves to join same. Tape these sleeves two inches from each end, leaving about six inches of bare copper to attach to test clamp. Use okonite tape on this work, and cover with a protecting layer of friction tape.

(32) Trespassing on roofs should be avoided. Subscriber's lines should be put in service without using roofs wherever possible. Climbers should be removed before going on a roof. Report all insecure fixtures to your office for attention. Do not leave any old wire or rubbish on the roof when you are through with your work.

THINGS TO BE OBSERVED AND CARED FOR

(33) Only one mica to be used between carbon arresters. Remove all excess.

(34) On wall and cabinet sets, the receiver cords are to be fastened through screw eyes. Enough slack should be taken up so that the receiver will not hit the floor if it falls.

(35) Requests for moving or changing type of instruments should be referred to the Contract Department.

(36) An extra charge is made for (desk set) instrument cords over eight feet in length. Refer requests for same to Contract Department.

(37) When you find an old telephone directory at a subscriber's station, see that it is removed. If a subscriber is found who has not received the latest directory, a request should be made to the Wire Chief to furnish him with one.

(38) When abandoned instruments are found, report same. If in danger of being stolen, they should be brought into the exchange.

(39) Where money boxes have been robbed, instruments or other property of the Company's stolen, obtain full particulars and report to Wire Chief.

(40) In case of fire, discover as far as possible the origin of same and damage caused to our wires and instruments, and report to the Wire Chief.

(41) On the new style No. 7 nickel automatic boxes, tin slides should be placed in the chute, so as to prevent the piling of coins against same. These tin slides are not designed however, to be used on No. 5 or No. 8 nickel automatic boxes.

CAUTIONS

(42) In dime automatics, see that the platinum points on both contact springs are on a line with each other.

(43) When necessary to change automatic boxes, the old box containing the money should be left in charge of the subscriber. Upon notification from the Collection Department that it has been collected, it should be brought into the office. Boxes put on with bolts through the cash box should be changed in conjunction with a collector.

(44) Metallic circuits out of service which cannot be cleared by the inspector should, when possible, be temporarily worked grounded or on a split pair of conductors until same is cleared or the line reversed, at the dictation of the Tester.

(45) When clearing instrument trouble, the inside wire should also be inspected and any defects repaired or referred; see that instrument and signal cases are securely fastened; also keep continually on the lookout for bogus attachments of all kinds. Report any gas fixtures in use near the telephone that are liable to set fire to the cords or a person's wearing apparel when using the telephone.

(46) If an instrument is out of service due to inside line trouble, put back in service by rerunning the wire as far as defective. If a very long run that will take several hours to complete,

it may be left in temporary shape and referred to the Installation Division to be cared for. This will be left to the judgment of the Wire Chief's office, as they know how much work they have on hand awaiting you.

(47) Connections on inside wiring must always be soldered and taped. If it is impracticable to solder, owing to the escape of inflammable gases, the joints should be thoroughly cleaned for two inches, twisted firmly together, and wrapped with tinfoil before taping. Look well after your insulation and appearance of wires. Use okonite tape only, on all inside wire splices and repairs.

(48) When a re-run order is recommended by you on account of alterations, find out who is responsible for the same, and explain to him that he will be billed for necessary changes.

(49) Any accident to persons or property caused by or connected with our service, should be promptly reported.

(50) Avoid as much as possible calling the Tester and Operator for tests; learn to test instrument and inside wire trouble with your head and head telephone. All ordinary trouble, such as shorts, grounds, crosses and opens, can readily be detected by using a head telephone; the work of an additional test, in the majority of cases, is only time lost.

(51) Avoid attempting to solder connections with an iron too cold to properly melt the solder. Such a joint not only looks unworkmanlike, but is likely to cause trouble.

(52) Under no circumstances is a repairman to handle or touch the money in an automatic telephone. In case the box is unlocked and the money falls on the floor when the cover is removed, the subscriber should be requested to witness the return of the money.

(53) All coins found in the slot are to be deposited by moving the armature so that the money will fall into the coin box, excepting in such cases where it becomes necessary to remove the side of the slot to remove the slugs or defective coins. Any coins removed in this manner must be deposited and not used to test with.

(54) Do not act as collector or mediator between the Chief Operator and the subscriber. They must arrange their own settlement.

(55) Do not break seals on coin boxes; if accidentally broken, report same.

(56) C. T. Co. slugs are to be used for testing purposes only, and should be confined to your own district, except in such cases as where you are sent into another district on trouble, and are not to be used on systems where the subscribers do their own collecting.

(57) When recommending a change of desk set instrument, you should verify the length of the cord, so that the subscriber will not be given a 6-foot cord in place of an 8-foot or 10-foot cord.

(58) When measuring the size of glass broken in booths, be careful to give the proper dimensions of same.

(59) The transmitter cord on desk sets

should be brought up at the back of the transmitter support and not to the front; to avoid the cord being cut by the transmitter being moved up and down.

(60) Do not leave a switchboard unlocked unless lock is defective; then recommend new one.

(61) Do not change parts of apparatus on suspicion; make sure of your trouble and then remedy it.

(62) Keep relays and cord fasteners clear of dirt and candle drippings.

(63) Candles should only be used where no electric light is available.

(64) Do not forget the storage battery; a little water added when you are there will sometimes prevent a case of trouble.

(65) When rebutting cords, be thorough; do not cut the insulation so far that the tinsel or wires will cross each other as soon as cord is used.

(66) If you find a case of trouble on a switchboard other than the one you are working on, or wornout plugs and ragged cords that need attention, report them to the Wire Chief's office at the time you clear the trouble. They will tell you whether to repair them at the time, or whether they will send you back later, depending on the amount of work in hand.

(67) Do not be led into telling a subscriber that his switchboard is not up to date. All the boards in use will give good service if properly

cared for. If he desires a change of contract, do not make any explanation regarding rates of service. The subscriber's agent in your district will attend to this.

(68) A neat grip or case of sufficient size to hold all necessary material must be carried, except on special permission from the Wire Chief when detailed for special work.

(69) No loose material or parts of instruments should be left around a subscriber's premises. Please give this particular attention and see that all material not in use is promptly returned to the office.

INSTRUCTIONS TO BE OBSERVED IN ADJUSTING RINGERS

Ringers may be divided into two classes, biased and unbiased. By biasing is meant such an adjustment of the armature that at no time is it at right angles to the coils, and is held against the biasing screw "X" by a slight tension on the biasing spring "J" (See Fig. 1.) This biased adjustment is required only on ringers intended for 4-party line selective ringing. All other ringers should have the unbiased adjustment, which consists of placing the armature at right angles to the coils, slacking off all tension on spring "J" and resetting biasing screw so that it clears the armature in all positions that the armature may take.

ADJUSTMENT OF UNBIASED RINGER

(1) Take all tension off of biasing spring "J."

(2) Swing gongs as far apart as possible.

(3) Loosen locking nuts on armature pivot bar and push armature up against the cores of coils.

(4) Note now whether or not the bell hammer is in center of space between gongs. If not, place it so by bending rod of hammer.

(5) Adjusting armature so that when one end is resting against one core, the other end of armature clears opposite core by about 1-32 inch.

(6) Secure armature in place by tightening nuts on pivot bar.

(7) Place gongs in such a position that hammer when resting normally on either side will clear either gong by 1-64 inch. This is in order that gongs will give a clear sound when struck by rapidly vibrating hammer.

ADJUSTMENT OF BIASED RINGER

(1) Reset armature pivot bar by moving same a slight distance away from coils.

(2) Set biasing screw "X" up to bear on armature, continuing until armature is about 1-32 inch from core. The opposite end should be twice this distance from opposite core.

(3) Adjust tension spring to hold armature against bias screw.

(4) Adjust gongs as in unbiased adjustment.

CHAPTER XXV

WIRELESS TELEPHONY—HISTORY AND SYSTEMS

Ever since the discovery of electrical waves and their application to wireless telegraphy, numerous wireless stations have been erected in various parts of the world. Many systems have been devised, all of which are, however, one and the same, based as they are on the application of electric waves of the same nature, the difference being only in the construction of the apparatus. Those who were engaged in the science of wireless telegraphy soon found out that they were limited to certain conditions as the waves were of a certain nature, i. e. intermittent electrical discharges. These were influenced by electrical discharges in the atmosphere as well as waves sent from outside stations. The conclusion to which they all came was, that if it were possible to produce continuous waves for wireless telegraphy, the tuning would be much more selective, a much larger number of stations could operate, and by this means only is it possible to produce practical wireless telephony. These waves travel over mountainous regions much farther and easier than intermittent discharges.

Wireless telegraphy and telephony involve the use of electro magnetic waves invisible to the eye emitted from the sending station radiated through air space over the earth in all directions and received in the very minutest part by a suitable receiving detector at the station. An electro magnetic wave is a disturbance in the ether which moves with enormous speed and is capable of being produced by electrical disturbances and may be compared to a mechanical disturbance on the surface of a pond produced by the fall of a stone therein and which produces a mechanical splash in the water. In the case of the mechanical splash you can readily observe the disturbance on the water, which is in the form of a circular wave, which takes the form of an expanding ring from the splash point traveling outwards in all directions at a speed small enough to be readily followed by the eye, diminishing as it travels until it becomes unobserved. In the same way (although invisibly) the electrical splash produced by the discharge of the mast wire emits an elctro-magnetic wave, taking the form of an inverted ball with the edge touching the conducting surface of the ground expanding in all directions with the velocity of light, but always clinging to the ground surface. This wave contains an electric force such as may be capable of affecting and displacing a delicately suspended electrified particle.

Parallel to the ground another wave is set up which contains magnetic force such as may be capable of acting upon and displacing a delicate compass needle.

These two disturbances, viz: the electric and magnetic, always remain mutually perpendicular and vary alike in intensity as the wave expands from its origin. Owing to its dual nature,

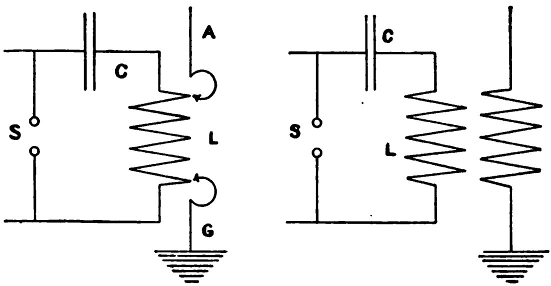


FIG. 414

CONDUCTIVELY COUPLED OSCILLATION CIRCUITS   INDUCTIVELY COUPLED OSCILLATION CIRCUITS

the wave is described as an electro-magnetic wave. Just as the water wave emitted from the stone splash in the pond is capable of producing a minute secondary disturbance such as the bank of the pond, so this expanding electro-magnetic wave is capable of producing a feeble secondary disturbance when it strikes a vertical condenser or receiving mast at any point in its path and so by suitable instruments, these electrical disturbances may be caused to produce audible signals.

For wireless telegraphy, groups of these waves are emitted to represent a code of signals such as the Morse or Continental. The circuits for producing these waves is shown in Fig. 414, in which "s" represents a spark gap, "c" the condenser that is charged and discharged

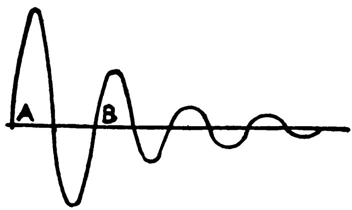


FIG. 415
DAMPED OSCILLATIONS

and "L" the inductance. In series with said condenser is a gap used for the production of oscillations. Connected with said "L" either inductively or conductively as shown are the aerial or sending mast and ground, constituting another oscillating circuit which set up these electro-magnetic waves.

High frequency currents or electric oscillations are currents which alternate in direction hundred of thousands or even millions of times per second. There are only two commercial devices for producing electric oscillations and these are (1) by the spark, or disruptive discharge, of an induction coil or condenser of a transformer, and (2) the arc lamp around which are shunted an inductance and a capacity. The former produces damped or periodic oscillations as shown in Fig. 415, and the latter sets up undamped or sustained oscillations as illustrated in Fig. 416.

A complete oscillation or cycle is made up of two alternations as shown in Fig. 415 from A to

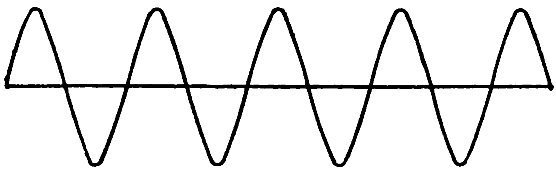


FIG. 416
UNDAMPED OSCILLATIONS

B. The highest point reached during an oscillation is called the amplitude and the difference between the amplitudes of any two successive oscillations is called the damping factor and indicates the extent of the dissipation of energy due to high frequency resistance and to radiation. The interval in time between two successive oscillations is termed the time period. The damping factor is due to the resistance, while the period of the oscillations are governed by the inductance and the capacity of the circuit, the ohmic resistance being considered as negligible.

When the maximum value of each successive oscillation gradually decreases, so that each oscillation is more feeble than the one preceding it we have collectively a group or train of decadent alternating currents. These are called damped oscillations.

When a disruptive discharge is produced by an induction coil or by a condenser charged by a transformer, oscillations are set up in the circuits shown in Fig. 414. The time required for the current to surge forth and back through the circuit depends upon its electrical dimensions.

If the circuit is an open one the oscillations will be damped out in two or three swings.

If the circuit is a closed one the oscillations will be more persistant and the energy may not be damped out until twenty or more swings have taken place.

The open circuit is a good radiator of energy but a poor conductor, or oscillator as it is called, and conversely a closed circuit is a poor radiator but a good oscillator while a compromise is made in a combined open and closed circuit system, the large capacity, poor radiating closed circuit being coupled with the small capacity, good radiating open circuit. It is this compound system which is so extensively used at the present time.

It is difficult to tune with the strongly damped oscillations which are set up in the open circuit, while the feeble damped oscillations of a closed circuit making tuning easy, but the latter are limited in their radiating powers. Hence in order to transmit to effective distances and at the same time to be able to tune the sending and the receiving instruments, the open and closed circuits are coupled together as shown in the diagrams. Where a large radiating distance is required the circuits are directly or conductively coupled, but where sharp tuning is of importance the circuits are connected indirectly or inductively.

Undamped or sustained oscillations are high frequency alternating currents and are similar in every respect to alternating currents used for commercial lighting and power purposes, the only difference between these two forms of current is that the frequency of the former is from 1,000 to 100,000 times as great as that of the latter.

These arrangements have been utilized for the production of sustained oscillations, namely (1) the alternating current generator; (2) the mercury vapor lamp and (3) the oscillation arc lamp.

Many different forms of alternators have been constructed during recent years with the idea of producing electric oscillations mechanically. The most successful form consists of a fixed magnetic field formed of a ring with inner polar projections and a revolving element called an armature. The field magnet is toothshaped and has 400 poles which are energized north and south alternately. The armature also has 400 poles and when run at a speed of 3,000 revolutions per minute delivers an alternating current having a frequency of 10,000 cycles per second.

The most recent alternators built for wireless telephony are run at a speed of 10,000 revolu-

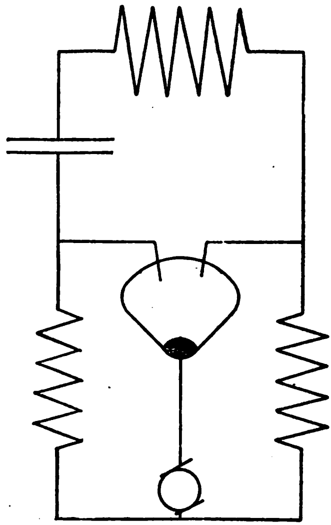


Fig. 417

MERCURY VAPOR OSCILLATION GENERATOR

tions per minute by means of a steam turbine, and gives a frequency of 50,000 cycles per second. The high frequency alternator is objectionable as a generator of oscillations in a number of ways and among these may be cited that (1) the energy obtained is so small that its practical use is quickly limited; (2) that it is very dangerous to operate at high speeds, especially on shipboard; (3) high losses due to friction and churning; (4) low efficiency and (5) small output.

The mercury vapor arc for producing sustained oscillations is shown in Fig. 417. The arrangement includes a mercury vapor lamp having three electrodes, two being metal anodes and the third a mercury cathode. The resistance of one of the anode circuits is different from the other anode circuit and hence a small difference of potential obtains when a direct current is supplied the lamp in virtue of the variations of the arc. This varying potential difference charges the condenser which discharging through the closed circuit produces sustained oscillations.

When an arc lamp having an inductance and a capacity shunted around it is energized by a direct current the variations of the arc causes some of the current to charge the condenser and since the source of current energizing the arc is constant any decrease in the current will increase, proportionally, the voltage across the arc and this tends further to charge the condenser.

The condenser when fully charged discharges through the closed oscillation circuit which includes the inductance and the arc lamp. This increases the current through the arc when the condenser is charged in the opposite direction. This cycle of operations is kept up constantly and so persistant or sustained oscillations are set up in the closed circuit. The arc lamp and closed circuit are shown diagramatically in Fig. 418. With this means of producing sustained oscillations wireless telephony becomes an accomplished fact. Moreover sustained oscillations by

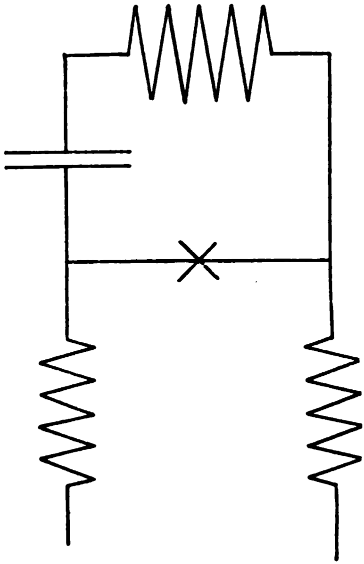


FIG. 418
OSCILLATION ARC GENERATOR.

an oscillation arc provides a method for absolute tuning and at the same time avoids the use of high tension circuits at the sending station which is not possible with the spark method. There is also less interference by static electricity and their persistance offers great advantages when transmitting overland.

In the early experiments with the arc lamp a very small percentage of the initial direct current was converted into sustained oscillations. Later it was ascertained that when the arc was burned in hydrogen compounds, the oscillations were intensified; this type of oscillation arc is known as a hydrogenic arc.

APPARATUS FOR WIRELESS TELEPHONY

Note:—See London Electrician December 30th, page 462. The Cosmos Revue des Sciences et le leurs Applications No. 1365, 25 Mars, 1911. Paris Rue Bayard 5.

WIRELESS TELEPHONE SYSTEMS—DUBILIER SYSTEM

Although the wireless telegraph has been in practical use for over a dozen years, yet nobody has succeeded in a successful practical application of the wireless telephone. Installations have been made, but at present no instance is known in which a commercial instrument is successfully operating for ten miles or more.

It was with this point in view that the machine herein described was constructed by its inventor, William Dubilier, and so made that the simplicity of operation and the elimination of many drawbacks, connected with the production of undamped oscillations might induce its ready installation.

In the apparatus in question there is one adjustment to be made, and that is at the oscillator

—all other factors, such as the inductance and capacity being fixed; and at the oscillator it is only necessary to press a button and the machine is ready for operation.

In the test already made the record for distance was broken in talking between Seattle and Tacoma, but in course of time and with a better installation, it is probable that two or three times this distance will be reached.

The first series of tests was made with the chief electrician Mr. J. B. Annis (U. S. Signal Corps), between the Bremerton Navy Yard wireless station and Mr. Dubilier's laboratory at Seattle, Washington, over mountainous land, which would be equivalent to about 50 or 60 miles over water. After the test, the following report was sent back: "A great deal plainer and louder than the Bell Telephone we use here. My name is not Bannis. I shall make an official report at once.—J. B. Annis, Bremerton, Navy Yard."

The great advantage of using the telephone will be its great simplicity, its cheapness, the possibility of accurate tuning and its great freedom from interference with statics. It is not necessary that the operator should have a high degree of training. The apparatus is noiseless in operation. In cost there is hardly any comparison with the telegraph, for, instead of the large transformer, the oscillator can be built for one-tenth the price and the inductances and capacity for less than that. The machine described here does not cost more than $75.00 in all, and can be made to operate up to 100 miles under favorable conditions, and at the same time it can also be used for telegraphic purposes.

The transmitter and oscillator is supplied with constant current at 220 volts, and is so made that it can be used with or without oils and gases. An oscillating circuit is shunted across the electrodes, the inductance of which acts as a primary to Mr. Dubilier's newly designed high-potential transformer; this latter has a much higher efficiency than those heretofore constructed, utilizing the electro-magnetic strains on both sides of the primary and still maintaining resonance. The oscillator consists of a porcelain tube, through the ends of which the electrodes are held by means of collars, and the whole thing mounted on a base of 3/4 inch marble 5 in. in diameter. The electrodes consist of the hardest phosphor bronze obtainable and are 1 1/2 inches in diameter.

In the experiments tried with the metals varying in diameter from 2 mm. to 3 cm. the irregularities common in the Duddell arc are greatly eliminated by supplying the arc chamber with a gas containing a large amount of hydro-carbon, such as ordinary house gas. As the electrodes burn away the gas decomposes and the carbon particles deposit themselves on the cathode and so the length of the arc seems to adjust itself by collecting the carbon particles from the gas, but this arrangement is not as convenient as when two metal electrodes are used. Copper, iron, zinc, lead, silver and aluminum have been tried, but the best combination has been found to be when hard phosphor bronze and silver are used. Fig. 1 shows the oscillator complete with radiating flanges to rob the anode of the heat. The large handle on top is for adjusting the distance.

When the oscillations were established between the phosphor bronze, the silver in air and a current of about 2 amperes was supplied, the discharge was in the form of a glow of a deep blue color. The ammeter in the oscillator circuit showed a current of 14 amperes, and in the aerial circuit of about 4 amperes. The oscillating circuit, which is shunted across the discharge gap, is of fixed units, as tuning is accomplished by means of varying the resistance of the oscillator only; it is frequently variable, depending upon a large number of factors such as the nature and form of electrodes, means of disposing of heat, distance between electrodes, the resistance of the oscillating circuit, the E. M. F. supplied and the nature of the surrounding gases. By considering these factors an apparatus was made to generate oscillations having a frequency of about 300,000 cycles.

Great care should be taken to have the electrodes free from oxides and the ends as parallel as possible. Many experiments have been tried with the electrodes immersed in oil, and although paraffin oil seems greatly to increase the radiating energy, it gave much trouble.

With this oscillator it was found that the degree of coupling can be varied with wide limits without causing any alteration in the radiating energy.

Another great advantage was that no attention was required, and in many instances the operation was kept up for 8 hours continuously without a falling efficiency; also that it is noiseless, which is an important factor on board ship and in high powered stations. Each oscillator can be loaded up to 3 K.W. or 4 K.W. and connected with a condenser having a capacity of 0.01 M.F., the energy radiated is then absolutely constant, the waves being undamped and of an equal amplitude. The oscillator transformer is so fixed that the condenser is inserted in the center of it and the whole thing moulded in a solid form with an equal mixture of beeswax and resin. The transmitter, which is shunted across a few turns of the primary of the oscillation transformer, is of a double diaphragm type, and so fixed that the diaphragms vibrate against each other. The transmitting apparatus is then assembled in a box 12 in. by 12 in. by 8 in. as shown in Fig. 419.

In conclusion the following advantages may be further claimed: Simplicity, reliability of the spark length, compactness, a 2 K.W. station occupying a space not more than 4 cubic ft. The regularity of the oscillator (no high potentials being used) and the high efficiency which has been found to run up to 75 per cent. It requires little regulation, can be tuned to 2 per cent, is

noiseless and does away with interference from statics.

FIG. 419

WIRELESS TELEPHONE, TRANSMITTING APPARATUS

The reciving apparatus consists of a loose coupled tuning coil, variable condenser, fixed condenser, two combination crystal detectors and a switch enabling either of the latter to be used separately. There is one pair of 2,000 ohm head telephone receivers and a variable potentiometer for use with a battery. All this apparatus is fixed in a box 11 in. square and 5 in. deep. The

FIG. 420

WIRELESS TELEPHONE, RECEIVING APPARATUS

tuning coil is so made that all sliding contacts are eliminated, in this way overcoming troubles due to short-circuiting turns, imperfect contact and other troubles arising from the use of this device. This is accomplished in the following manner:—

The primary consists of a hard rubber tube of comparatively small diameter, that is, 4½ in. This allows for a finer regulation of the inductance and wave-length. The ring is wound with

110 turns of No. 22 double silk covered wire and is divided into 11 sections, the ends of which are brought to switch points, the 10th turn to the first point, the 20th turn to the second point, etc., making ten sections so that by turning the switch handle more or less sections of the tuning coil can be cut in or out. This would, however, not be sensitive enough for the primary, as in telephoning it is sometimes necessary to cut out or add a single turn to tune as closely as 2 per cent. In order to get this finer regulation, each turn of the first section is tapped and brought to the switch point at A, so that by turning the switch handle A, single turns can be cut in or out. By using these two switches, therefore, any number of turns can be obtained, making the regulation between each turn simple and easy. It is thus possible to tune very sharply and to eliminate the sliding contact so common on all tuning coils. Fig. 420 indicates the arrangement.

The secondary is wound on a hard rubber tube of 3 and 3/8 in. in diameter and 1/4 in. thick. It consists of 200 turns of 28 D. S. C. wire. Taps are made at every 20th turn and brought to the switch, which is mounted on the front of the coil, shown at C on the diagram, as it is found in all practical work no finer regulation is necessary. By means of a flat sliding gear the secondary can be moved in and out, making a very close coupling as may be necessary. This is accomplished by turning the handle at the side as shown clearly in Fig. 420 herewith. The variable condenser consists of 15 semi-circular aluminum plates 2 in. in diameter, mounted on a revolving shaft to which the handle and pointer are screwed, and these swing between another set of stationary plates. The aerial is connected to one end of the primary and the other end, which is in series with the variable condensor, to the earth. It is thus possible to vary the electrical length of the aerial wire system to any degree. A pair of ½ in. brass strips are also connected across the aerial and the earth, the ends of which are placed about 1/100 in. apart. This helps greatly to eliminate static charges. Another way to eliminate static charges is to connect a large paper condenser of about 1 M.F. capacity across the aerial and the earth. The condenser robs the aerial of the static charge as it accumulates, but does not reduce to any degree the strength of the received waves. The secondary is connected in series with a small paper condenser, consisting of about 6 sheets of tin foil 2 in. by 3 in., and the detector. This latter is of the quantitative crystal type. Many different crystals have been tried, but all have had their defects; some have been found to be very sensitive for long distances, such as the perikon. But these do not stay in this condition long. The silicon detector also requires much manipulation. For telephone tests a good piece of iron pyrites and a hard steel spring made of piano wire will be found very sensitive and will keep its adjustment for a long time. A switch is so

FIG. 421
WIRELESS TOWER, DUBILIER SYSTEM

fixed that two detectors can be used. The receivers which are of high resistance, are shunted across the condensers. In using many crystals, such as carborundum, a battery has been found necessary, together with a potentiometer of 1,000 ohms divided into 12 sections leading to the switch points shown at "D" so that the current can be varied.

One of the highest wireless towers in the world is employed by William Dubilier for his wireless telephone experiments, and is shown in Fig. 421. The tower has a total height of 320 feet and the inventor is confident of sending 3,000 miles.

DEFOREST'S SYSTEM OF WIRELESS TELEPHONY

DeForest employs the Elihu Thomson method of producing continuous oscillation, but has added many improvements. One of the main features of the DeForest system is the Audion detector which has proven to be especially adaptable for wireless telephony. A view of the complete DeForest set as installed on the flagship Connecticut (United States Navy) is shown in Fig. 422. To the right is shown the complete receiving set consisting of the Audion detector, storage battery for operating Audion, rheostat, etc., and on top of the case, the unique "pan cake" tuner previously described.

To the left is shown the transmitting set consisting of the case containing the transformer, the transmitter, and overhead, the hot wire ammeter and necessary switches. The wiring dia-

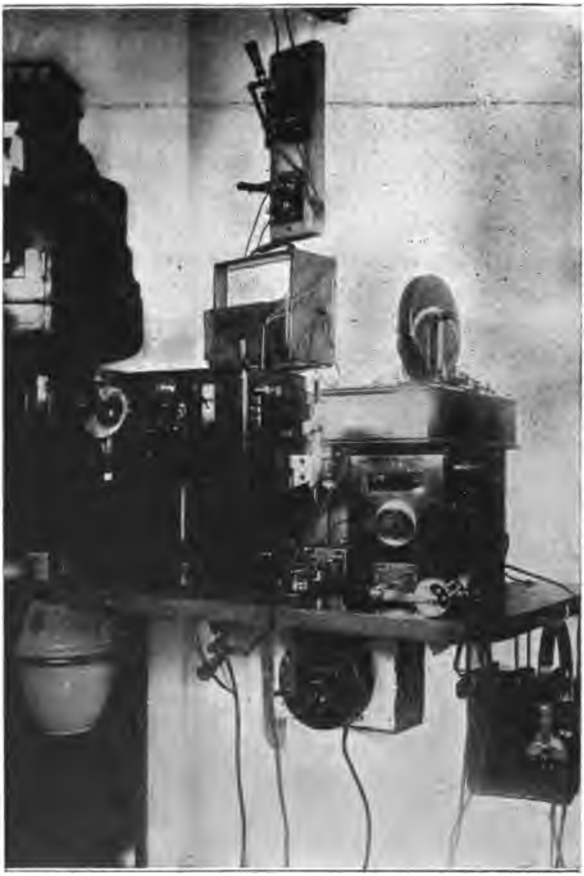


Fig. 422

VIEW SHOWING INSTALLATION OF DE FOREST WIRELESS TELEPHONE SET ON SHIPBOARD gram of the complete set is shown in Fig. 423. The 250-volt generator supplies the current which burns the arc. The arc in this instance consists of one electrode of carbon and one of copper. The electrodes are burnt in the vapor from the flame of an alcohol lamp. As shown the inductance coil B is shunted around the two electrodes with the condenser in series. The upper terminal of the secondary of the inductance coil leads to the aerial wire, and the lower to the hot wire ammeter, switch and transmitter.

In operation the current from the dynamo flows through the choke coils, the choke coils being inserted in order to prevent the alternations from flowing back on the line circuit. The arc due to the peculiar conditions under which it is burning, sets up alternations of about 100,000 per second. The alternations charge the condensers, which discharge through the turns of the inductance coil B. This induces a like current of enormous potential in the secondary turns of the coil, the current flowing through the aerial wire, and to the ground through the hot wire ammeter and transmitter.

The current surging through the aerial and ground owing to the high number of alternations is noiseless, and no indication would be made on a distant receiver, but if some slight variation was made in the aerial circuit so that the wave would be changed in a like manner, the indication would be heard. It is the purpose of the transmitter to make such variations.

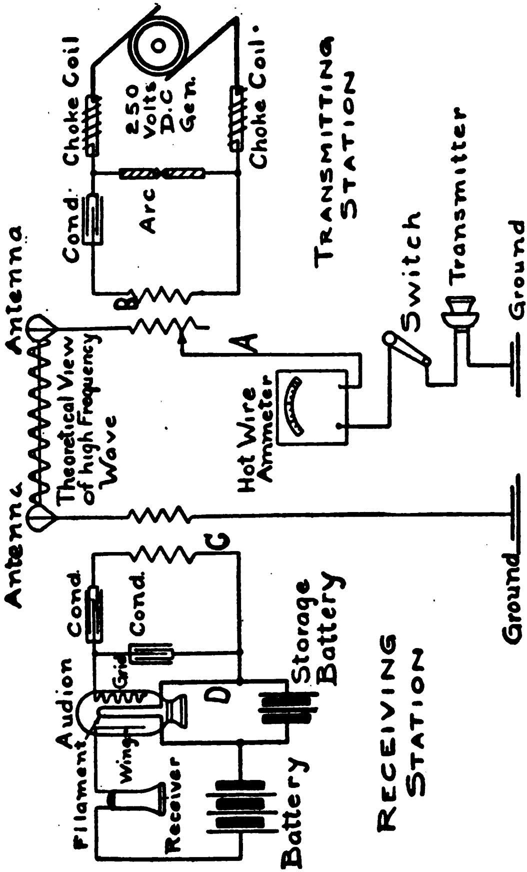


FIG. 423

DE FOREST WIRELESS TELEPHONE SENDING AND RECEIVING CIRCUIT

A complete set in actual use on shipboard is shown in Fig. 424. The tower as erected on the Terminal Building, New York is shown in Fig. 425. The tower is 110 feet high and rests 310 feet above the street level. The cross arm is supported by means of a rope run through a pulley and will allow the whole to be lowered for inspection of the aerial wires. The aerial consists of eight, stranded phosphor bronze wires which drop from the cross arm to the roof of the building and here are connected to the lead-in that runs down to the room in which the instruments are located. The distance covered from this station has an average range of 75 miles, but this will soon be increased indefinitely as the new and more powerful instruments are installed.

THE FESSENDEN SYSTEM

No other investigator has devoted more time to the study of wireless communication than Prof. Fessenden, and the various instruments and improvements which he has brought out in the last few years speak for themselves.

His experiments in wireless telephony cover a broad range as he has used the majority of methods, but has finally adopted the high frequency alternator as producer of the continuous oscillation and has, with it, been able to hold communication over a distance of 100 miles.

Prof. Fessenden's first experiments were with a very simple set. The circuit consisted of an

Fig. 424
DE FOREST WIRELESS TELEPHONE SET IN USE

induction coil, with the primary terminal connected to a battery source and mechanical "make and break" that gave 10,000 sparks per second. The secondary terminal was connected to the aerial and ground with transmitter included. With this arrangement communication was held over a distance of 1 mile, although the articulation, it is understood, was by no means good owing to the irregularity of the spark.

Experiments were conducted with other types of generators which gave up to 20,000 sparks per second, but results were poor with all these types, as the received speech was accompanied with a harsh, grating noise, due to the slow speed of alternation.

The alternator which is used at the present day runs at a frequency of 80,000 to 100,000 per second, and the disagreeable noise at the receiving end has been entirely eliminated. Such an alternator when run at a frequency of 81,700 per second, gives a voltage of 150 volts open circuit and a field current of 5 amperes.

The interior view of a station is shown in Fig. 426. The high frequency alternator is shown to the right; the receiving equipment, telephone transmitter, and measuring instruments to the left.

A number of different plans can be utilized for modifying the emitted wave to the voice inflections. Three different plans are shown in Fig. 427. The plan to the left consists of a primary and secondary winding wound on an

Fig. 425

TOWER ON TERMINAL BUILDING, NEW YORK

iron core. The primary terminals are connected to the aerial lead and the secondary terminal to a transmitter and set of batteries. If the transmitter be spoken against the resistance of the secondary will be changed and in a like manner the iron field, varying the inductance of the primary winding to the same proportion, and the wave flowing through. No receiving circuits are shown as the same cycle of transformation, as explained in this DeForest system above, takes place in all receiving circuits, whether the audion detector is employed or not.

In the middle plan what is known as the condenser transmitter is employed. This transmitter is very simple and unique in operation. It consists of a fixed metal plate with a thin plate, free to vibrate in front of it.

If the thin plate is spoken against it will vibrate and increase and decrease the air dielectric separating the plates, to the same proportion as the spoken words, impressing on the wave current flowing through the variations of the voice. Prof. Fessenden regarding this transmitter says the following: "As a practical illustration with a diaphragm, 2 centimeters in diameter, a movement of 1/100 of an inch inwards with the arrangement used for telephoning to Plymouth reduced the current from 3.1 amperes to 2.5 amperes. This is without a resonant circuit between the movable terminals of the condensor transmitter and ground. With this and other modifications, which I cannot

FIG. 426
INTERIOR VIEW OF A FESSENDEN WIRELESS TELEPHONE STATION

publish at the present, much greater effects are obtained.'' The writer in experiments has found that this transmitter gives wonderfully clear and articulate tones, but seemingly the current is reduced to such an extent that it would not be adaptable for long distance use.

To the right hand side is shown the carbon transmitter. This type was fully described in the preceding DeForest system. Numerous plans can be used and it has not yet been determined which method is the best. From the methods which have been shown, the reader can understand that the question of providing a suitable transmitter is a very important one. The objection to the ordinary transmitter is that it will not carry over one-half ampere, and the current to be utilized ranges up to five amperes. A transmitter that has been utilized to a certain extent is made by arranging several transmitters in a circle, so that the voice will accuate the whole, the current dividing up among the various transmitters. This type however has never proven practical.

Prof. Fessenden employs a certain type of receiver, known as the Heterodyne receiver, which he says is far more sensitive than the ordinary telephone receiver, and is employed direct in the aerial circuit. Prof. Fessenden gives a description of the receiver as follows in the Electrical Review:

"All forms of voltage operated receivers, and most forms of current operated receivers, with

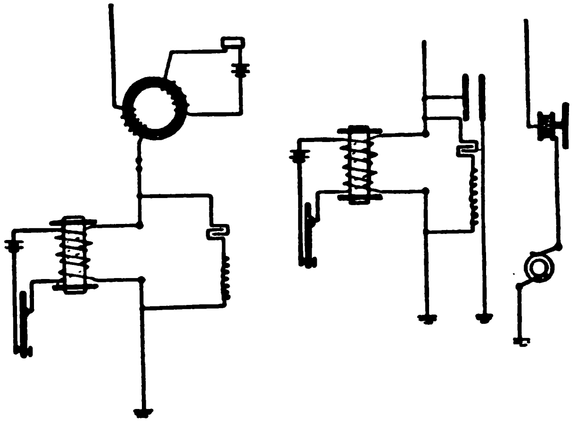


FIG. 427

TRANSMITTING CIRCUITS EMPLOYED BY PROF. FESSENDEN

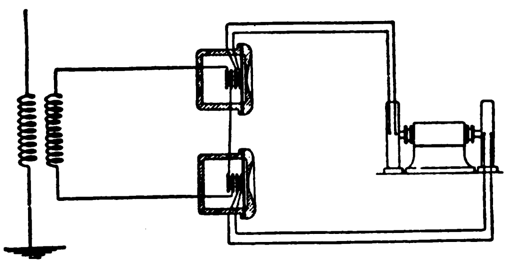


FIG. 428

HETERODYNE RECEIVER

the exception of two or three of the writer's invention, are very inefficient. Even the liquid barreter, which is as sensitive as any of those in common use, has an efficiency of only about one-tenth of one per cent for weak signals. This might, of course, be expected from the fact that the liquid barreter forms a thermo-dynamic engine."

"In the writer's experiments the magnetic receiver is rather less efficient; in any case, the efficiency, or rather the unefficiency, is of the same order of magnitude.

"A liquid barreter or a magnetic receiver will gives an audible indication between 1/100th and 1/1000th of an erg. An ordinary telephone receiver requires to produce an indication less than a millionth of an erg.

"It is evident that if any method could be devised for using the telephone receiver direct the efficiency would be increased about a thousand times."

"This the writer has succeeded in doing with his Heterodyne receiver. This is a combination of the "beats" method of United States patent 706,740 and the method of operating by continuously generated waves of United States patent 706,737."

A telephone is constructed having a fixed magnetic core formed of iron wires 1/1000 of an inch thick, and excited from a source of high frequency such as a frequency or condenser dynamo.

Fig. 429
INTERIOR VIEW OF FESSENDEN STATION

A small coil with or without a core is cemented to a thin mica diaphragm, and this coil is arranged to be excited by the oscillations produced by the received magnetic waves.

It is of course, impossible to make the frequency of the wave generated at the sending station exactly equal to the high frequency oscillations, generated at the receiving station. In fact this is not desirable for most work. Advantage is, however, taken of the fact that if the frequencies are slightly different, beats will be produced and the telephone will emit a musical note. This is undoubtedly the most efficient form of receiver in existence, and it is doubtful if the method will be improved upon so far as most classes of work are concerned. No difficulty is found in practice in maintaining the frequency of wave generators, or wave mills as they are called, to within one-quarter of one per cent by automatic means.

One advantage of the Heterodyne receiver is, that it is obviously unaffected by atmospheric disturbances or by disturbances from nearby stations, and that it lends itself very nicely to multiplex working, it being unnecessary to point out that there is no difficulty with this receiver in receiving a message on the same aerial which is being used to transmit a message to another station. This places for the first time wireless telegraphy on an absolutely commercial basis and renders it capable of entering into competition with both land lines and cables.

With the Heterodyne system, practically any number of messages can be simultaneously transmitted and received on the same aerial without interference from each other, or from neighboring stations.

The diagram of the Heterodyne receiver circuits is shown in Fig. 428. A second interior view of the Fessenden station is shown in Fig. 429.

CHAPTER XXVI

THE AUTOMATIC SYSTEM OF SWITCHING

Reasons for Automatic Switching

When the telephone came into existence its first commercial use was for conversations between two points, connected by a single circuit. This is called a private line. This limited use was soon broadened by the addition of several stations to the same circuit, making a private party line. Still wider range of communication being needed, the stations were connected to a common center where they could be interconnected in any desired manner. Thus the first public exchange was born.

Owing to the necessity of some means for switching, the methods of the telegraph were adopted and later adapted to the service of the telephone. Thus the earliest telephone switchboards comprised spring-like line terminals, plugs on flexible cords, and a human attendant.

The conditions of telegraph and telephone switching are very different. The former consists of relatively few connections, and each exists for a fairly long time. The latter consists of a large number of connections, each of which must be promptly disconnected after a very short time. Telegraph switching is naturally adapted to use manual methods. Telephone switching, on the contrary, because of its multiplicity of connections and disconnections, does best with machine methods. Wherever an act must be repeated a large enough number of times, a machine can do it more cheaply, better, and more quickly. Hence it is not strange that telephone service soon felt the handicap of manual operation.

The chief disadvantages felt in manual telephone switching were slowness in connecting and disconnecting, wrong numbers, discourtesy and irregular attention to the wants of subscribers, eavesdropping on conversations, and increasing cost of operation. Though the modern operator is as well drilled as a human being of her capacity can be, much of the above trouble still exists, for it is inherent in humanity. Hence the automatic had its origin in the desire for secrecy, speed, accuracy and uniformity in telephone service and increased profits to the investor.

VARIOUS AUTOMATIC SYSTEMS

The earliest inventors of automatic systems rarely had more than one hundred or less telephones in mind. Their devices were usually based on some step-by-step ratchet action driven by electro-magnetic means, and limited to one device per line or in the exchange.

Modern automatic systems approach the problem from three general standpoints, which are well illustrated by three typical systems which will be briefly characterized at this point.

THE LORIMER SYSTEM

Though this system grew out of the old Callender system, it was the invention of George William Lorimer and J. Hoyt Lorimer. It was intended to follow the sectional book-case idea, being made in 100 line sections. It was intended to build an exchange of any size by the simple addition of sections, but the impossibility of this soon became apparent.

The chief characteristics are power drive from a constantly running motor, one line relay for 100 lines, the cylinder switch, and the positively controlled calling device at the subscriber's telephone. It was intended to work on a percentage basis, reducing to a minimum all the apparatus individual to each line.

Each section, serving 100 lines, has two general classes of apparatus, general and divisional. See Fig. 440. The general apparatus consists of a decimal indicator DI, a decimal register controller, DRC, and a division starter, DS. This apparatus is common to the 100 lines and may be used by any subscriber but only one at a time. It is concerned only with initiating a call and placing the proper selecting apparatus at the service of a calling line. The divisional apparatus is the selecting and connecting agency. Each division is like the cord circuit of a manual board and performs the same function. There are about ten divisions in a section, it being assumed that not more than ten subscribers out of one hundred will be talking to others at any one time.

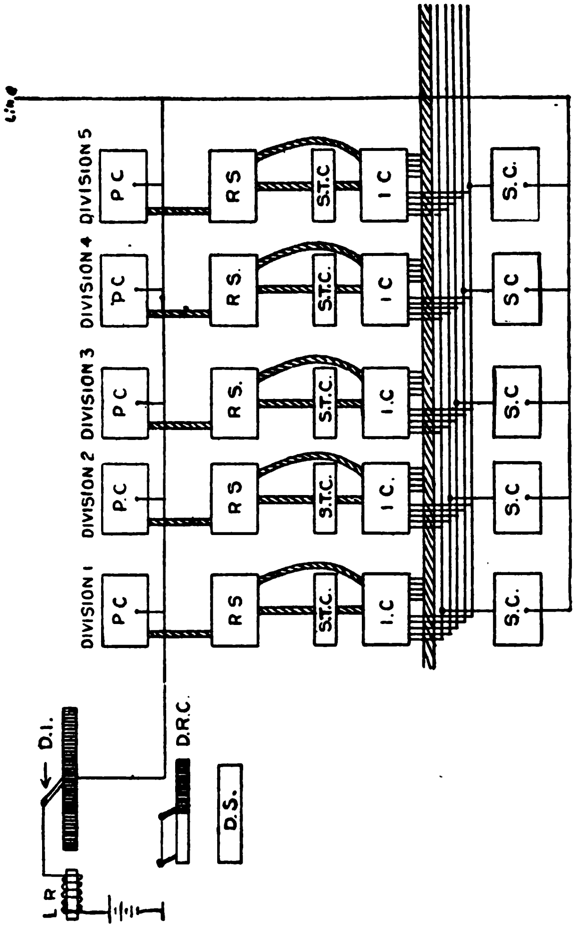


FIG. 440

SECTION OF LORIMER SWITCHBOARD

The names of the different pieces of apparatus in a division together with their duties, are given below. The primary connector PC is a line finder. It hunts for and connects the division to the calling line. In this it is guided by the common sectional apparatus mentioned above. The rotary switch RS is the circuit changer for the division. From time to time it switches the circuits which control the rest of the apparatus. The signal transmitter controller, STC, acting over the line wires, regulates the movements of the calling device in the telephone. At the same time it gives impulses to the exchange apparatus for setting it to connect with the desired line. The thousands register, on the rotary switch, controlled by the joint action of the signal transmitter controller and the signal transmitter (calling device), picks out the desired thousand group of sections. The interconnector IC under the same guidance, picks out the desired hundred in that thousand and automatically selects an idle trunk line to that section. This trunk line ends in a secondary connector SC, which guided as above connects the trunk to the desired line.

The sectional apparatus common to all lines and divisions in that section is as follows: There is a stationary commutator which has one hundred segments DI. To each segment is connected one subscriber's line. A brush is made to revolve continuously over the commutator touching each segment in turn. Connected to this brush is the line relay, LR, which is thus regularly testing the lines, one after another. When a subscriber initiates a call, he first sets up the desired number on a set of disks and then pulls a lever. This grounds his line.

The next time the rotating brush (of the decimal indicator) in the central office strikes the segment attached to that line, the line relay will be energized. This will stop the brush and start the division starter. The latter will cause an idle division to seek for the calling line. The decimal register controller assists the primary connector of the seized division to find the calling line. When this has been completed and the division has begun to receive the call, the decimal indicator and the other common apparatus revert to common use.

The circuits by means of which the above actions are accomplished are very complicated and since the system is in very limited use will not be reproduced here. Those interested further should procure a copy of the Wise patent issued in England, No. 8648, AD. 1901.

One peculiarity of the Lorimer system lies in the cylinder switch. It consists of a hollow cylinder of plaster of paris with rows of contacts extending completely around. Heavy brushes or wipers are mounted on a shaft in the center. These brushes always rest on some contacts and move when a magnetically operated clutch attaches them to the constantly revolving power shaft. This cylinder switch is the basis of the primary and secondary connectors, rotary switch, interconnector, and the signal transmitter controller.

Mounted on several of the cylinder switches is another switch known as a register. It comprises a plaster of paris bank occupying about 90 degrees of a circle, a set of brushes moving under the power of a spring, and an electro-magnetically operated escapement. Impulses of current through the magnet allow the brushes to advance step by step over the contacts. The brushes are forced back to normal by the power of the driving shaft. The brushes of any cylinder switch are brought to normal by being rotated on around the rest of the circle.

THE AMERICAN AUTOMATIC SYSTEM

This system of automatic switching was the work of Lattig and Goodrum, though later others contributed to its development. Its characteristic points are the flat type switch (rotary motion, no vertical) the line finder, and the 50 point dial or calling device.

The basic switch consists of a bank having 50 sets of contacts. There are, therefore, three or four horizontal rows of 50 contacts each. The bank occupies nearly a half circle. The motor magnet drives the wipers through a steel spring ratchet. The release magnet is mounted so as momentarily to press the ratchet and the detent away from the ratchet wheel, allowing the wipers to be rotated back to normal by a coiled spring.

The subscribers' lines are in groups of fifty each, because that is the capacity of a single bank.

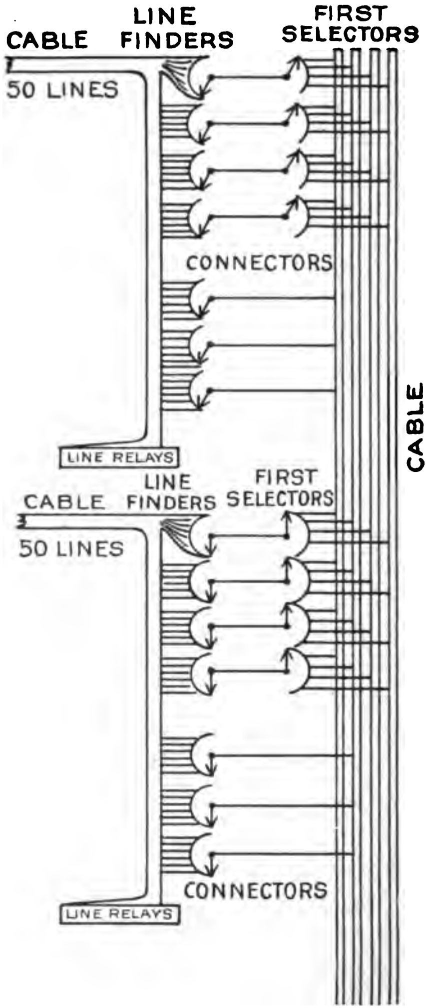


Fig. 441

SCHEME OF AMERICAN AUTOMATIC TELEPHONE CO. SYSTEM

Each line has a line and a cut off relay, differing from manual relays only in the number and arrangement of the springs. The lines are also multipled to the banks of flat switches known as line finders. See Fig. 441.

When a subscriber removes his receiver from the hook, his line relay is energized. This causes an idle finder switch to rotate till it strikes the bank contacts belonging to the calling line. There it stops and pulls up the cut off relay, thus disconnecting the line relay.

The first selector has its bank divided into ten groups of five sets of contacts each. To each group are wired five trunk lines leading to some group of fifty subscribers' lines. Thus the first selector can reach five hundred. When the calling subscriber rotates his dial from the number corresponding to the desired "50," impulses are sent to the selector, causing it to rotate its wipers to the first trunk of the group. Then it automatically selects an idle trunk from the five. The second pull of the dial operates the wipers of a connector, which makes connection with the desired line. The ringing is done by another turn of the dial. Release is accomplished by simply hanging up the receiver, as in all automatic systems. Each switch is returned to normal by a spring which moves the wipers back over the contacts to the starting point.

SYSTEM OF THE AUTOMATIC ELECTRIC COMPANY

This system of automatic switching was originated over twenty years ago by Almon B. Strowger, and for a number of years bore his name. The modern automatic is, however, the joint result of the work of several men, among whom we may mention John Erickson, Charles Erickson, A. E. Keith, T. G. Martin, W. Lee Campbell and E. A. Mellinger. A large number of others have contributed more or less to the art.

The characteristic features are the switch with a vertical and rotary motion of the wipers, the side switch, the Keith line switch, and a standard system of local and inter-office trunking. Since this system is the most widely used in the world, it will be the basis of the later discussion of methods and apparatus, so that a detailed description is not necessary at this point.

THE PLAN OF AN AUTOMATIC EXCHANGE

We will first examine the design of a single-office exchange, whose ultimate capacity is 10,000 lines. The basis is a switchboard or unit which serves one hundred subscribers' lines. These 100 line boards are numbered from one to ten and arranged in groups of ten boards or 1,000 lines each. Ten of these thousand groups make up a 10,000 line exchange, a theoretical floor plan of which is shown in Fig. 442. Each rectangle represents a switchboard for 100 subscribers' lines.

The left row of boards constitutes the first thousand, the next row the second thousand, etc. The first board in any thousand is its "0" board or hundred, the next its "1" hundred, the next its

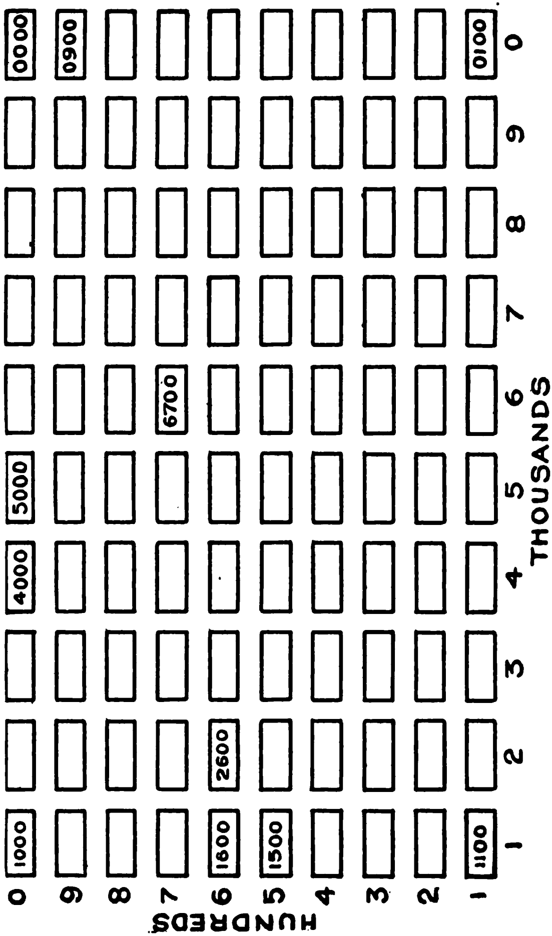


FIG. 442

ARRANGEMENT OF THOUSANDS AND HUNDREDS

"2" hundred and so on. Thus the arrangment is according to the decimal system. The floor plan of a modern exchange does not present the appearance of Fig. 442 owing to the use of line switching apparatus.

The automatic apparatus in the office may be classified as follows, selecting switches, line switches, and accessory apparatus.

The selecting switches have the duty of picking out the thousand and hundred desired, and also of actually connecting with the called line. In a 10,000 line exchange these are called first selectors, second selectors, and connectors. The first selectors pick out the thousand, the sècond selectors the hundred in that thousand, and the connectors select the tens and units, completing the connection.

The line switches have the duty of securing for the calling line an idle selecting switch or first selector. They act as introductory to the switches which do the work. Small offices have primary line switches only, which trunk the calls directly to first selectors. There is one primary line switch for each line. Usually one hundred primary line switches trunk into ten first selectors, so that any one of the hundred lines may secure the services of any idle one of the ten first selectors. Large offices have secondary line switches also. From 1,000 to 2,000 primary line switches trunk into about 300 to 400 secondary line switches, which in turn trunk into one hundred first selectors.

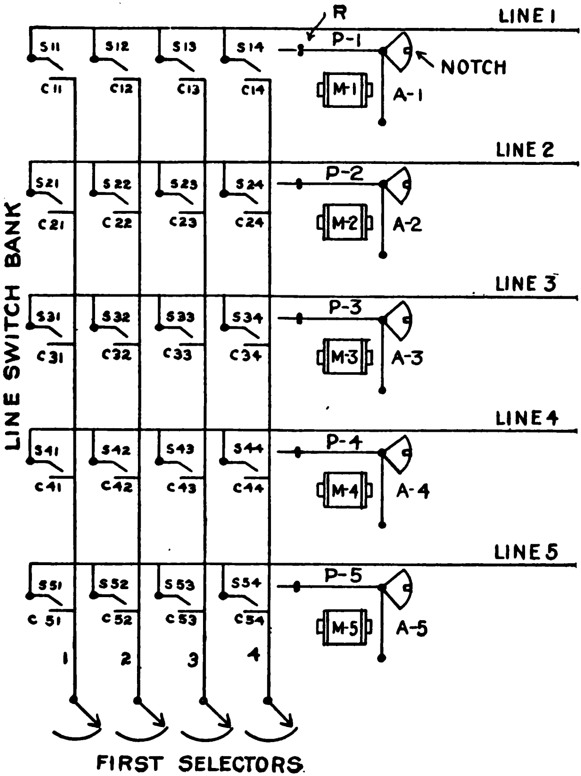


FIG. 443

PRINCIPLE OF KEITH LINE SWITCH

THE KEITH LINE SWITCH

The purpose of this apparatus is to permit any one of a number of lines to connect itself to an idle one of a smaller number of trunk lines. Its principles may be understood from Fig. 443. Let several subscribers' lines come into the exchange from the right. A smaller number of first selectors are shown at the bottom. Each subscriber's line is attached to several springs, S-11, S-12, S-13, etc., as many springs as there are first selectors. Each spring is adapted to make contact with a fixed piece, C-11, C-12, C-13, etc., each spring having its own fixed contact. These pairs are arranged in horizontal rows, each over the other as indicated in the figure.

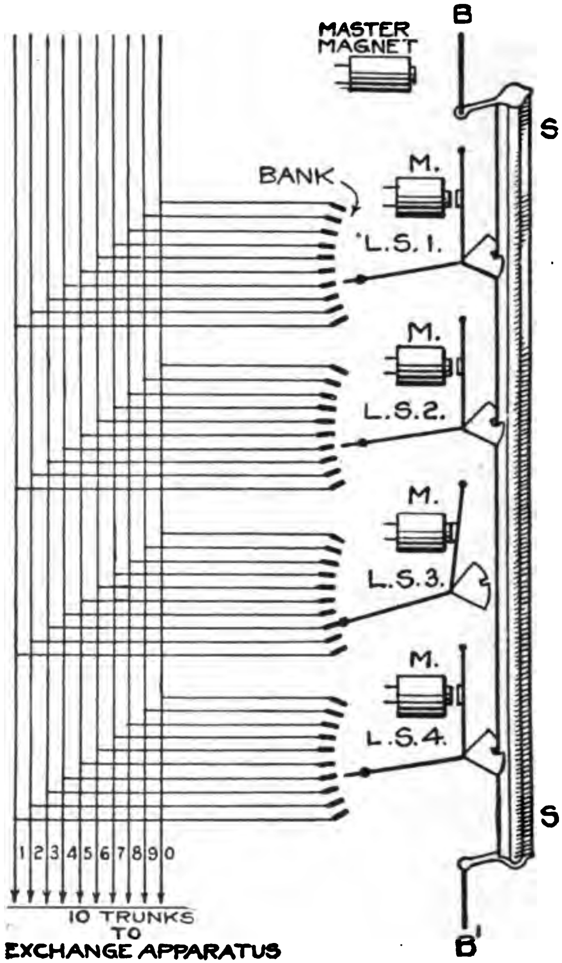
The contacts are wired to the first selectors. All the first contacts, as C-11, C-21, C-31, etc., are wired together and to first selector No. 1. All second contacts, as C-12, C-22, C-32, etc., are wired to first selector No. 2. If any subscriber desires to use the exchange apparatus he can do so by causing one of his springs to be pressed into contact with its corresponding contact, which will extend his line to a first selector.

The means for causing the above connection are found in the plunger and line switch magnet. The plunger, P-1, P-2, P-3, etc., consists of a light steel arrow carrying a pair of insulated rollers, R, on one end and a fan-shaped tail on the other end. The plunger is pivoted on the end of the magnet armature, A-1, A-2, etc. The magnet, M-1, M-2, etc., is controlled by the subscriber's line. The bank springs and contacts are arranged on the arc of a circle, whose center is at the pivot, of the plunger. When the magnet is energized, the plunger is drawn forward into the bank so that one of the insulated rollers presses a spring into contact with its contact plate.

The selection of an idle first selector and the prevention of interference between subscribers are performed by the master switch, not shown in the figure. A guide shaft is arranged to keep all the plungers in line. This is done by having the notch in each fan tail engage a feather cam on the guide shaft. The master switch, by means described later, keeps all the plungers pointing toward the same trunk line, which is idle. When any subscriber removes his receiver from the hook, his line switch magnet, M, at once pulls his plunger into the bank, connecting his line to the idle first selector. The fan tail of the plunger is thereby removed from engagement with the guide shaft. Instantly the master switch moves the guide shaft, carrying all the remaining plungers, so that they will now point toward some other trunk which is still idle.

The relation of the plungers and guide shaft is shown in Fig. 444. It will be noted that the shaft is pivoted above and below. Between the pivots it jogs away from the center line. This is to permit it to rotate about the tails of the plungers and have the pivots of the plungers in line with the pivots of the guide shaft.

An individual line switch, plunger and bank are



MASTER MAGNET
B
S
BANK
M.
L.S.1.
M.
L.S.2.
M.
L.S.3.
M.
L.S.4.
S
1 2 3 4 5 6 7 8 9 0
10 TRUNKS TO EXCHANGE APPARATUS
B'

Fig. 444

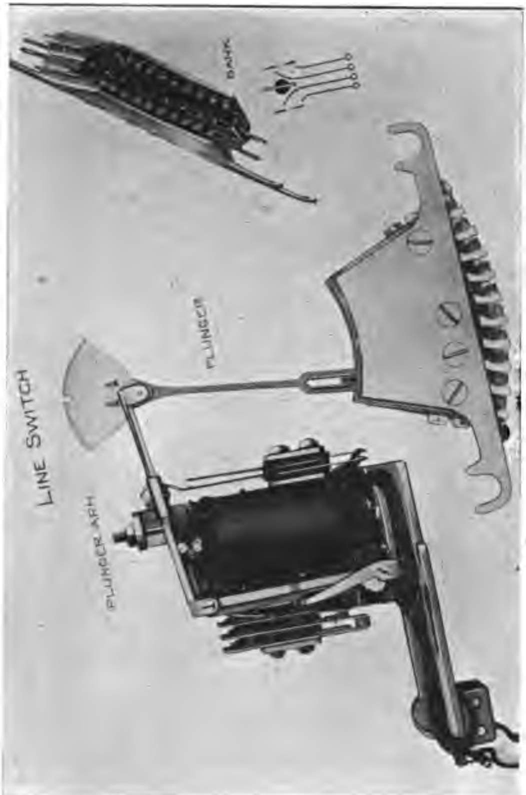


FIG. 445
LINE SWITCH AND BANK

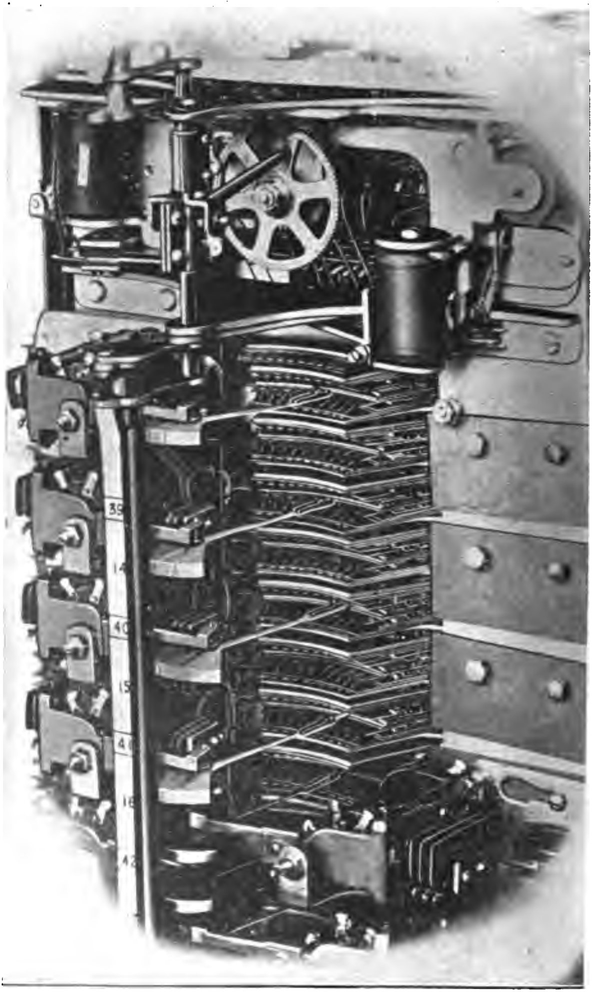


Fig. 446

KEITH LINE SWITCH SHOWING PLUNGERS AND BANK

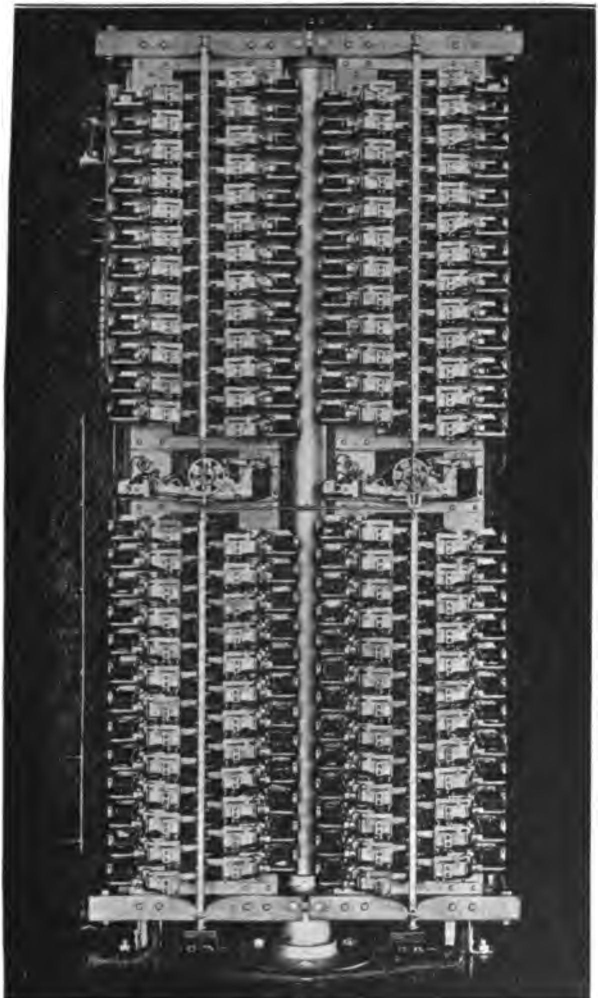


FIG. 447
KEITH UNIT (LINE SWITCH) FRONT VIEW

shown in Fig. 445. There are four springs and four contacts in each set. This is because it requires two springs for the line circuit (metallic) and two other circuits for operating purposes.

A view of part of a Keith unit is shown in Fig. 446. Some of the individual line switches have been removed, in order to show the plungers and bank more clearly. The master switch may be seen at the top.

A complete Keith unit is shown in Fig. 447. This cares for one hundred lines. The line switches are mounted on two "shelves", fifty on each shelf. The latter consist of vertical iron frameworks, pivoted so as to be swung outward like doors. This gives easy access to the rear to get at the wiring. If the traffic be light, one master switch controls the position of all the plungers on both shelves, one hundred in all. If the traffic be too heavy to be handled by ten trunks, each shelf is equipped with a master switch, so that each fifty lines are given the use of their own ten trunks. This makes twenty trunks to the hundred lines. If necessary, on account of extremely heavy traffic, each shelf may be divided so as to have twenty-five line switches to each master switch. This means also that each half shelf (25 line switches) has its own ten trunks, making a total of forty trunks to the hundred. The most common arrangement is to operate each shelf with a master switch. It is often possible to get along with six, seven or eight trunks instead of ten.

Fig. 448 is a rear view of a Keith unit, showing

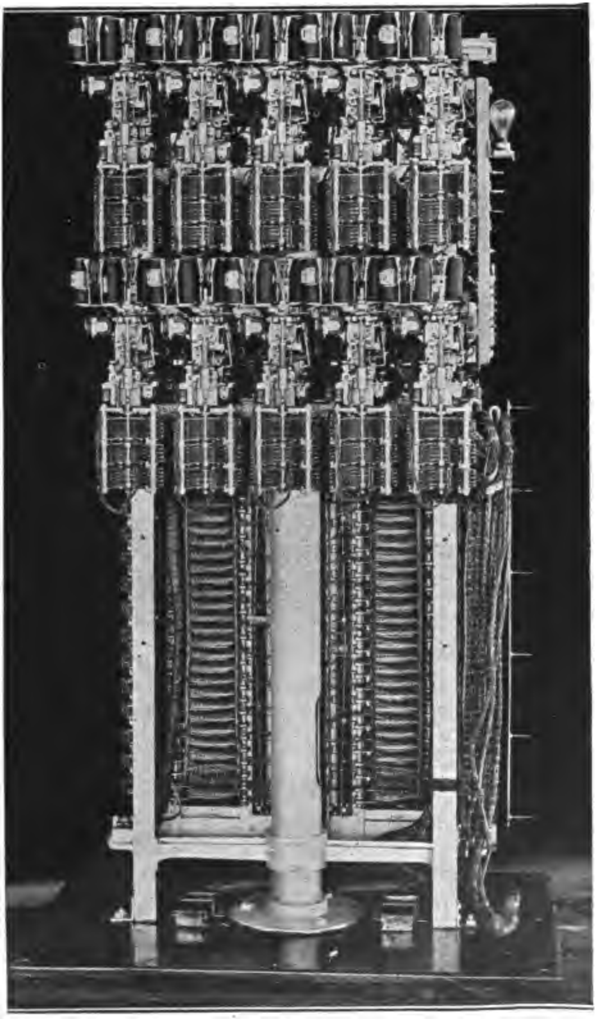


Fig. 448.

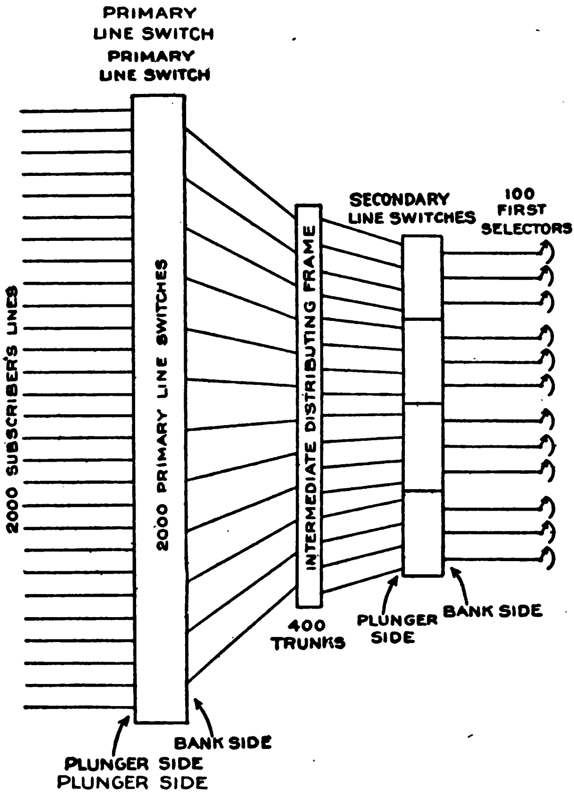


FIG. 449

PRIMARY AND SECONDARY LINE SWITCH

the connector switches used in making calls out to the hundred lines. A detailed description of the connector will be given later. The connector switches are mounted on the line switch uprights in order to save cabling, since each subscriber's line must be attached both to a line switch (for calling into the exchange) and to the banks of a number of connector switches (to receive calls from other lines).

The relation of the primary and secondary line switches is given in Fig. 449. The trunks from the banks of the primary shelves run to secondary line switches. The banks of the secondary shelves are wired to first selectors directly. In this way any subscriber in the group can secure the services of any of the first selectors connected to it. It is customary to have 2,000 subscribers' lines in one group, trunking into one hundred first selectors. In a 10,000 line exchange there are five groups. They are designated by the numbers of the thousands of which they are comprised. The 3-4 group is composed of the third and fourth thousands.

In the 10,000 line single office system, each group has its own distinct set of first selectors, as indicated by Fig. 450. At the left are the secondary line switches in five groups, each serving 2,000 lines. The primary line switches are not shown, on account of space. There are ten shelves in each group of secondary line switches. Each shelf has ten trunks leading to as many first selectors at the right. The hundred first selectors for each group are mounted on shelves con-

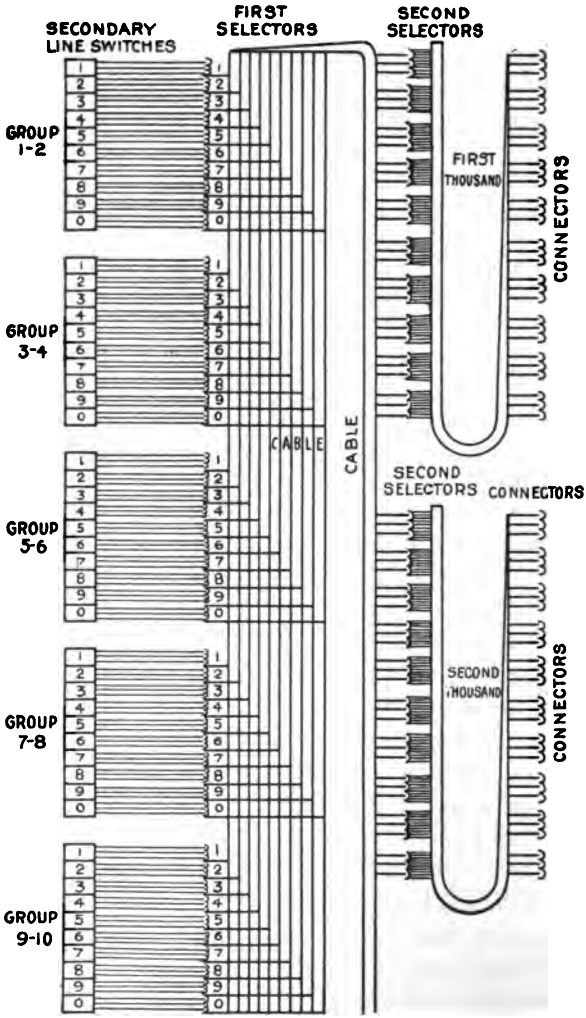


FIG. 450

ARRANGEMENT OF FIRST AND SECOND SELECTORS taining ten switches each, so that there are ten shelves for each group.

The duty of each first selector is two-fold, first, under the control of the calling device and at the will of the subscriber to pick out the thousand in which lies the desired line, and second, automatically and without the knowledge of the subscriber to select an idle trunk line to that thousand. Accordingly, its bank of contacts is made up of ten rows, having ten sets of contacts in each row or level. See Fig. 451. The bottom or first level of contacts is wired to ten trunks all leading to second selectors in the first thousand. The second level is wired to trunks to the second thousand, and so on to the top, tenth, or "0" level, which handles the trunks to the tenth thousand. In Fig. 451 the lower bank consists of one hundred *pairs* of contacts, since the talking circuits are metallic. Only one hundred single contacts are necessary in the upper or private bank, one for each trunk circuit. They are to protect the trunks from interference when busy and are also used in connection with releasing the switches.

The second selectors are arranged by thousands, as shown in Fig. 450. The banks of the first selectors are connected to them as follows: All first selector shelves numbered "1" in all five groups are multipled together and run to the second selectors according to thousands. That is, the first level is wired to the first thousand, the second level to the second thousand, etc. These

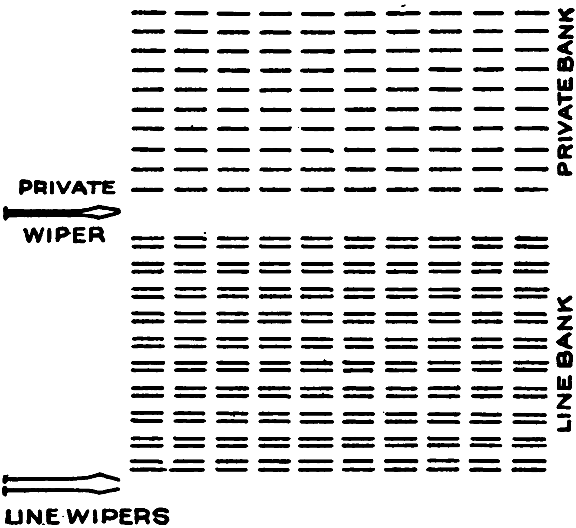


FIG. 451
BANK OF SELECTOR

trunks terminate in each case in second selectors on shelf No. 1 of each thousand. In a similar way all first selectors of shelves numbered "2" in all five groups are multipled together and wired to the proper thousands, terminating in second selectors on shelf No. 2 in each case. This orderly arrangement not only permits any group to call any thousand, but allows calls to be traced with ease. Further details of interest concerning this trunking may be obtained by reading United States patent No. 831,876, to A. E. Keith.

The trunking from the banks of the second selectors to the connectors is entirely local to the thousand concerned. The ten shelves of second selectors (100 switches) have their banks all multipled together. The lowest or first level is then wired to ten trunks leading to ten connector switches in the first hundred of that thousand. They are mounted on the same upright which carries the primary line switches belonging to that particular hundred. The second level is wired to the connectors of the second hundred, the third level to the third hundred, and so on.

MULTI-OFFICE TRUNKING.

In a 100,000 line system, the lines are served from several offices. It is convenient to figure on 10,000 lines in an office. The first selectors, therefore, have the duty of picking out the desired office and of selecting an idle trunk line. The second selectors, for this reason, take up the duties which have been described for the first selectors in

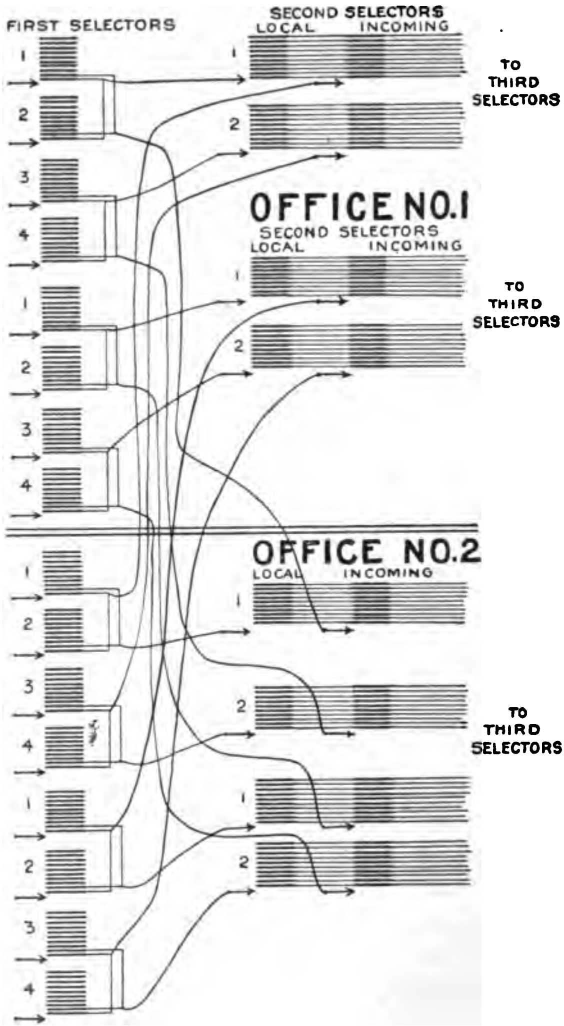


Fig. 452

INTER-OFFICE TRUNKING (100,000 LINE SYSTEM) the 10,000 line system, namely, the selection of the thousand in the office. The third selectors do the work of picking out the right hundred, while the connectors have the same duties as in the 10,000 system.

The scheme of inter-office trunking is shown in Fig. 452. All the switches above the double horizontal line are in office No. 1, while those below in office No. 2. Each rectangle of ten horizontal lines represents a selector bank, the arrow at the left indicating the wipers for the same. Each line means a level of ten sets of contacts. Each bank is taken as representative of all ten selectors on a shelf.

In office No. 1, the trunks from the first level of the first selector banks run to second selectors in the same office. The second level trunks run to second selectors in office No. 2. In the same way the trunks from the other levels are carried to second selectors in all the other offices in the exchange. In office No. 2 the trunks from the first level of first selector banks go to second selectors in office No. 1. The second level is wired to local second selectors in office No. 2. The third and other levels run to the respective offices indicated by the number of the level. Two or more shelves of first selectors are often multipled together and run to one shelf of second selectors. This depends upon the amount of traffic to be handled.

In each office the local and incoming second selectors have their banks multipled together for

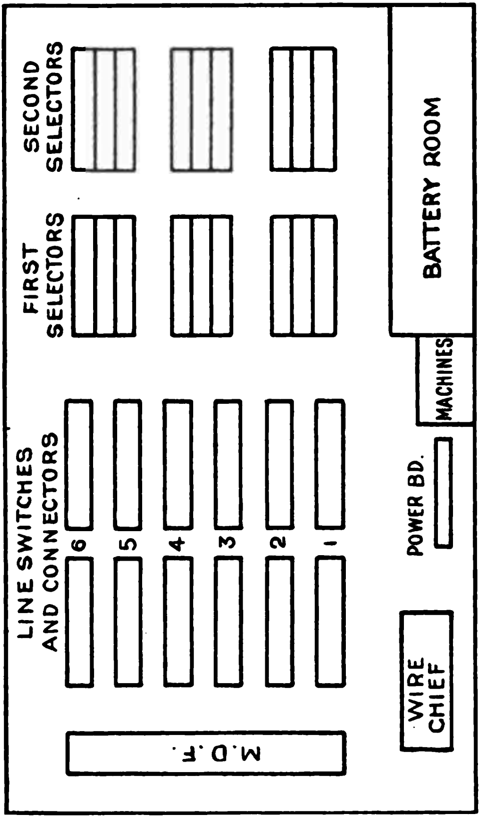


FIG. 453

FLOOR PLAN. 6,000 LINE SINGLE OFFICE EXCHANGE (10,000 LINE SYSTEM) trunking to the third selectors. This is indicated in Fig. 452.

FLOOR PLANS OF AUTOMATIC EXCHANGES

Fig. 453 gives a fairly representative floor plan of an office having no secondary line switches. The subscriber's lines come in through a main distributing frame, M.D.F., which is identical with those used in any manual office. From the protector or switchboard side of the main frame the lines are cabled to the line switchboards. Here each line is attached to its own line switch and also multipled to the banks of that group of connectors which serve that particular hundred.

The wires from the bank side of the line switches run to the first selectors, which are grouped ten on a shelf. The banks of the first selectors are wired by levels to the different second selectors, the latter being arranged by thousands. From the banks of the second selectors the trunks run to the connectors, which are located, as mentioned before, on the same uprights with the line switches whose lines they serve.

Fig. 454 is a typical floor plan of an office in a 100,000 line system. The subscriber's lines come in as usual through a main distributing frame to the primary line switches and the connectors. From the primary line switch banks the trunks are run through an intermediate distributing frame, I.D.F., to the local secondary line switches, from which the trunks are distributed to the first

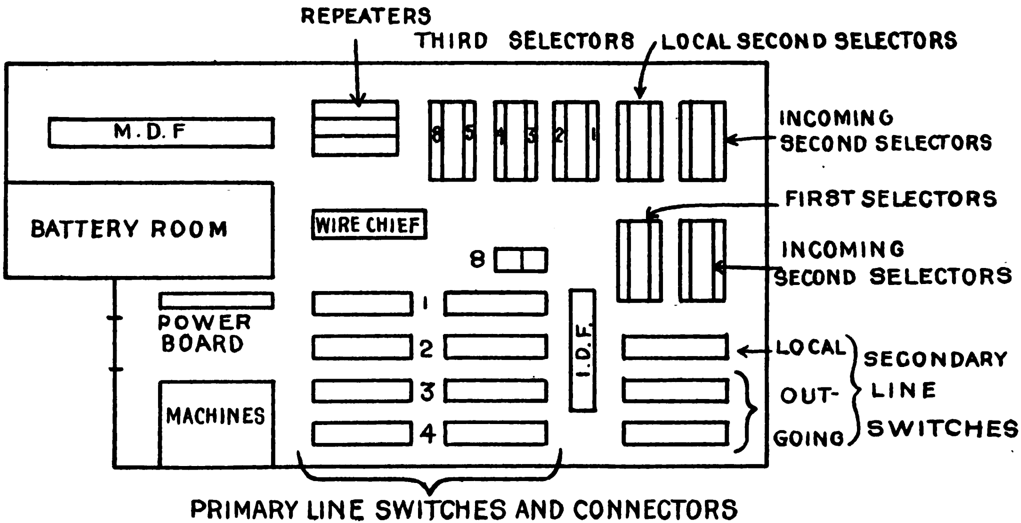


FIG. 454

FLOOR PLAN. 4,000 LINE OFFICE (IN A 100,000 LINE SYSTEM)

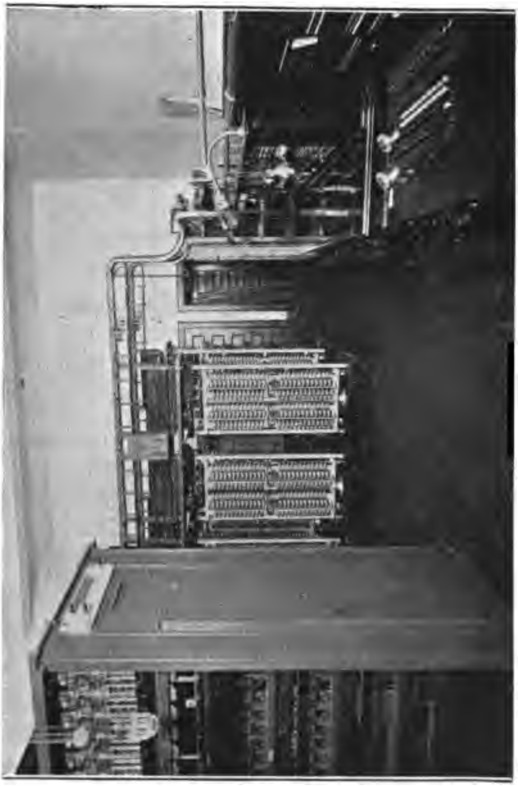


FIG. 455
SWITCHROOM AT MISSOULA, MONT.

selectors as described above and illustrated in Fig. 449.

All the levels of the first selectors (Fig. 454) except the one serving this office, are wired through the intermediate distributing frame to outgoing secondary line switches. From the banks of these the trunks pass through repeaters to the main distributing frame and thence to the other offices in the exchange.

The first selector bank level corresponding to this office is wired to local second selectors. The banks of these local second selectors are multipled to the banks of incoming second selectors (from other offices) and carried to the third selectors by thousands. From the banks of these third selectors the cables run to the connectors.

Fig. 455 shows a view of the switch room at Missoula, Montana. At the right and rear is the main distributing frame, with the cables going overhead to the line switchboards at the center. At the left is one end of a selector board. At the extreme right front are the wire chief and information desks.

ESSENTIALS OF THE LINE SWITCH

In Fig. 456 is shown the arrangement and electrical connections of a 3-wire line switch with its master switch. The plunger, P, is pivoted to the end of the plunger arm, P. A., which is carried by a fixed pivot on the base plate. A spring, S, riveted to the plunger arm, has its free end held by a stirrup which is in turn held by the adjusting

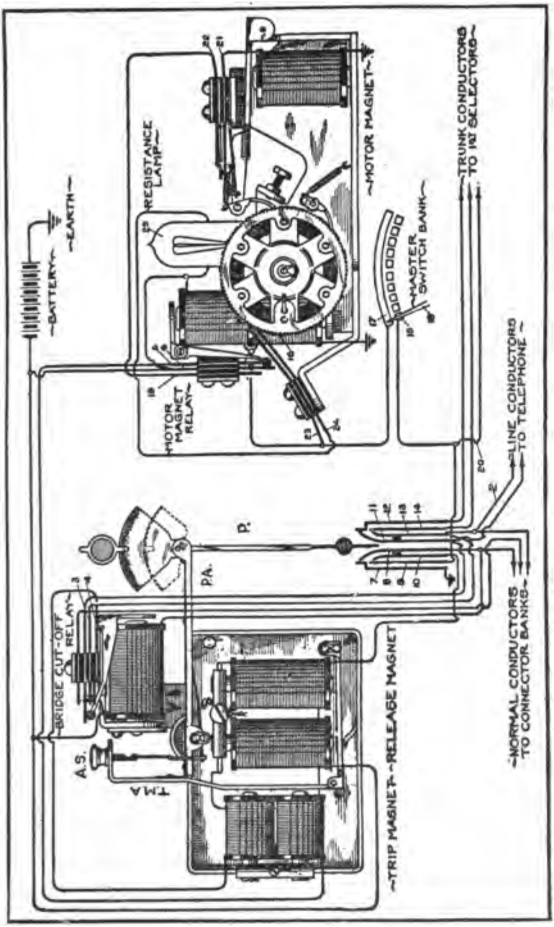


Fig. 456

LINE AND MASTER SWITCH

screw, A.S., which is in the end of the trip magnet armature, T.M.A. The left end of the plunger arm is held by a catch on the trip magnet armature so that the force of the spring tends to hold the plunger out of the bank. When the trip magnet is energized the catch is released, upon which the spring forces the plunger into the bank. Although space forbids treatment of it here, this neat device by means of which one spring is made to do the work of no fewer than four springs, two of which would act in opposite directions, is well worth the careful study of any person interested in mechanical movements.

The trip magnet armature is pivoted to the end of the release magnet armature. The latter is held by a fixed pivot in the base plate. When the release magnet is energized, the trip magnet armature is pulled up so that its catch slips over the end of the plunger arm. When the release magnet lets go, the force of the flat spring, S, pulls the plunger out of the bank.

The master switch consists of a toothed wheel, which by means of a radial lever (see top of Fig. 446) moves the plunger guide shaft back and forth. The toothed wheel is caused to rotate by a motor magnet and ratchet. Fig. 456. The motor magnet is self vibrating, with a make-and-break contact on the armature, the same in principle as that on a door bell.

The master switch bank is composed of a segment and ten contacts. The segment is wired to the motor relay or starting relay. Each contact is wired to a trunk circuit, so as to act as a guard to prevent the master switch from allowing the idle plungers to rest opposite a busy trunk. The master switch wiper consists of two springs which form an electrical and mechanical unit and establish a connection between the segment and any contact of the master bank.

The 2-wire line switch, Fig. 445, is much simpler, consisting of a line relay and a magnet to pull the plunger into the bank. A high resistance coil retains the plunger there during conversation so that the simple de-energization of the coil allows the plunger to be released. The other details are the same.

The bank springs and contacts, Fig. 456, are so constructed as to give a good sliding contact, which effectually rubs off any oxide or dirt. The line wires come to the springs 11 and 13, which make contact with 12 and 14 respectively. The latter are wired to the first selectors. Spring 8 engages contact 7 to put a ground on the bridge cut off relay and the private normal. The former relay cuts off the trip magnet from the line. The private normal is a wire which leads to the connector banks and by being grounded prevents other people from interfering with this busy line. The two talking wires (normal conductors) from the connector banks are also shown. One is attached directly to a line wire while the other is carried through a contact on the bridge cut off relay before reaching its line wire. Spring 10 in the bank makes connec-

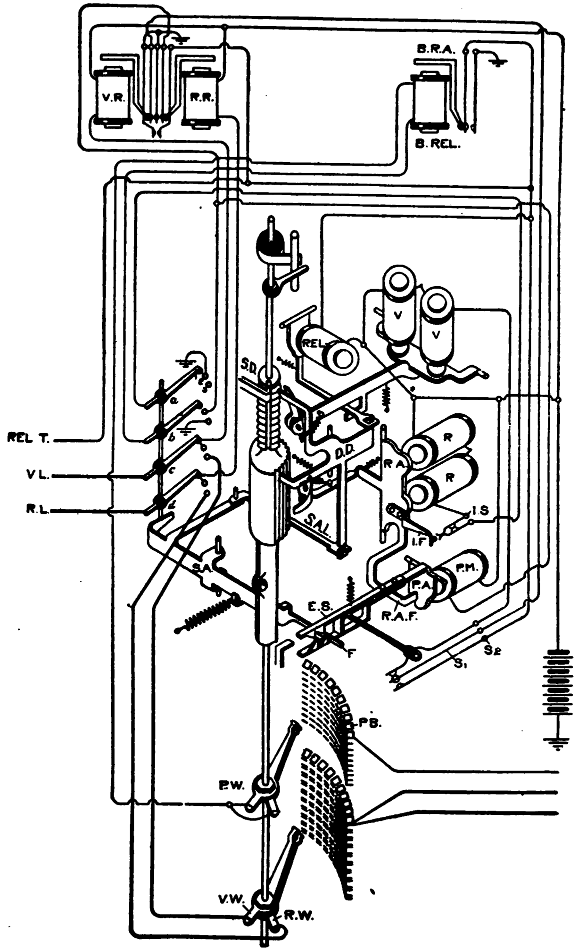


FIG. 457

SKELETON OF FIRST SELECTOR

tion with contact 9 to close the circuit for the release magnet to the release trunk circuit.

ESSENTIALS OF THE SELECTOR

Fig. 457 shows the essential mechanical features of a selector. At the bottom, the two groups of contacts arranged as if on a cylindrical surface are the bank contacts. The upper group is the private bank, the lower the line bank. P.W. is the private wiper and engages the private bank. V.W. and R.W. are the vertical and rotary wipers, respectively, and engage the line bank. These three wipers are carried by the switch shaft. At the upper end of the shaft is a spring which rotates it back to normal after use. Gravity restores it vertically. V.V. is the vertical magnet which operates a lever whose free end carries a pawl. This pawl engages teeth on the vertical ratchet cylinder and lifts the shaft upward, step by step. The shaft is retained at each step by a detent called the double dog, D.D.

The rotary magnet, R.R., actuates the rotary armature, R.A., which, by means of a pawl acting on the rotary ratchet cylinder, turns the shaft to any desired degree. A detent on the double dog retains the shaft in its rotated position. A stationary dog, S.D., takes the weight of the shaft from the double dog as soon as rotation has begun. Since the figure illustrates a selector, the rotary armature, R.A., is equipped with an interrupter finger, I.F., and a pair of interrupter springs, I.S., which cause the rotary magnet to vibrate automatically like a door bell. This is used in rotating the wipers to find a non-busy trunk. The vertical motion is, however, under the control of the subscriber.

The side switch is an interesting feature of the selector. It consists of several wipers, *a*, *b*, *c*, and *d*, each sliding over three contacts. All wipers are mounted on one set of pivots and move as a unit. The spider arm, S.A., is attached to the side switch wiper and moves it. A spring tends to pull the spider arm forward and hence to move the wipers from contacts 1 to contacts 3. Normally the wipers are held on contacts 1 by the escapement springs, E.S., which hold the spider arm finger, F.

The private magnet, P.M., controls the movements of the side switch. The private armature, P.A., carries the escapement springs above mentioned. When the private magnet is energized and its armature, P.A., pulled against its core, the escapement springs, E.S., move downward. This causes the spider arm finger, F, to slip off the first lower tooth and be caught by the first upper tooth. The latter is a trifle forward, so that the spider arm is allowed to move a little, but not enough to change the contacts of the side switch wiper. When the private magnet is de-energized and the escapement springs therefore caused to rise, the spider arm finger slips off the first upper tooth and is caught by the second lower tooth. This makes the side switch wipers move from position 1 to position 2. Thus the private magnet and the side switch act as a relay of peculiar performance. The ordinary relay makes certain circuit changes when energized and switches them back to normal when de-energized. But this side switch combination makes no circuit changes until after the private magnet has been energized and then de-energized. Further, the restoration of the circuits to normal must be done by some outside force.

The rotary armature finger, R.F.A., extends from the rotary armature to a point in front of the private armature, P.A. Whenever the rotary magnet, R.R., is energized and pulls up, it thus mechanically operates the escapement springs and the electrical contacts, S_1 S_2, just as if the private magnet had been energized. This relation is used in seeking an idle trunk.

The release of the selector involves two elements, the withdrawal of the double dog to release the shaft, and the resetting of the side switch. The release magnet, R.E.L., has attached to its armature, at the left, a link (under release magnet) which has a hole in the end. Normally this holds the double dog, D.D., away from the shaft. The first movement of the vertical armature lifts the release link off the double dog, and allows the latter to engage the ratchet cylinder. When the switch is to be released the release magnet is energized and de-energized. When the release magnet pulls up, the hole in the release link slips over a lug on the double dog. When the release armature falls back, it pulls the double dog away from the shaft. At the same time it exerts a pressure on the side switch, through the spider arm link, S.A.L., so that the side switch wipers are forced back to position 1, against the force of the spider arm spring.

The latest type of release magnet has the armature on the right side of the switch. It acts directly upon the double dog. In this case the release link is stationary and retains the double dog until the vertical magnet acts again.

One important part, not shown in Fig. 457 is the off normal switch. This is located at the top of the shaft and consists of two or more springs which are operated by a finger attached to the shaft. One step of the shaft upward suffices to operate the contacts.

Fig. 458 is a photograph of a connector switch, which in the most important details is identical with the selector. At the top are the relays which govern the action of the various magnets. The latter are hidden within the frame, but occupy the relative positions shown in the open sketch of Fig. 457. In Fig. 458 the shaft and wipers are seen at the center and lower part of the illustration.

A better view of the shaft and wipers is obtained in Fig. 459. At the bottom are the two line wipers, mounted on a single hub. Above is the private wiper on another hub. These hubs are attached to the shaft by set screws and can be adjusted as to height and angular position to cause the wipers to engage the bank contacts correctly. Above the private wiper is the cam, a long featherlike projection whose purpose is to prevent the side switch from being moved to its third position until the shaft has rotated at least one step.

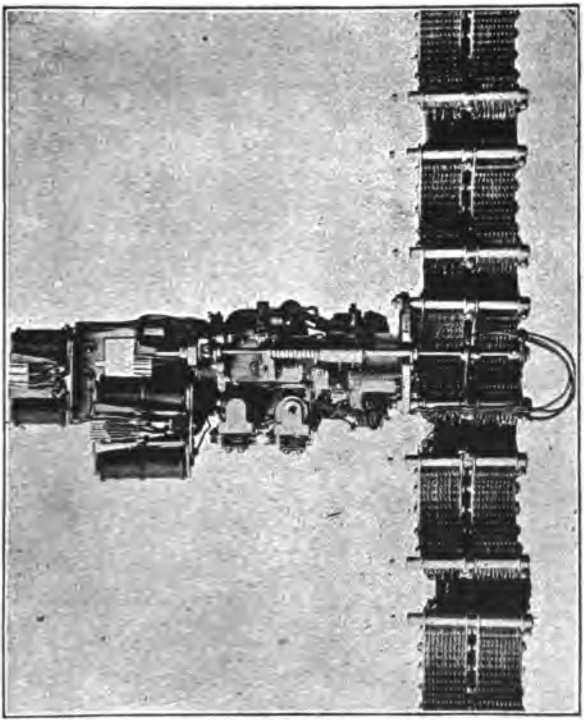


Fig. 458

CONNECTOR SWITCH AND BANKS

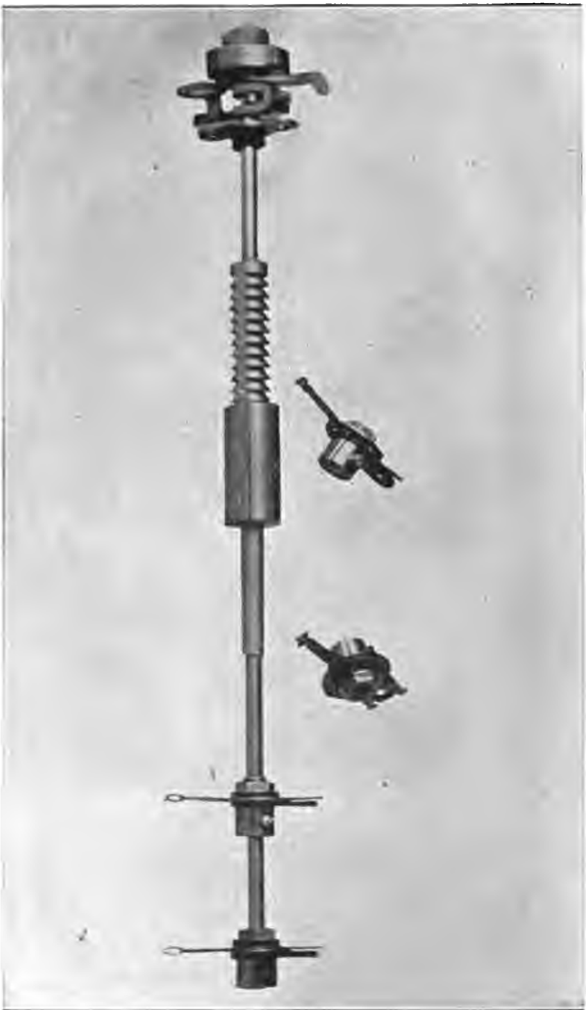


FIG. 459
SWITCH AND WIPERS SHAFT

Above the cam is the rotary ratchet cylinder, with longitudinal teeth. Then comes the vertical ratchet cylinder, with circular teeth and a longitudinal groove cut for the stationary dog. Both cylinders are milled from one piece of metal and are often termed the "hub" of the shaft. At the top of the shaft is the cup containing the coiled clock spring. This is to rotate the shaft back to normal.

THE AUTOMATIC TELEPHONE

The duty of the automatic telephone is twofold, first to talk the same as any telephone, second to operate the switches. The talking part, Fig. 460, consists of a transmitter in series with the primary of an induction coil and connected across the line to receive current from the common battery at the central office. Its circuit is controlled by the hook switch as usual. Attached to the secondary of the induction coil is the receiver. The bell and condenser are wired through the hook as usual.

The work of controlling the switches is divided into three parts, selecting, ringing, and release. To operate a 3-wire switch requires the grounding of each wire a certain number of times. To send the digit "4" we must ground the vertical line wire, V.L., four times and then ground the rotary line, R.L., once. This must be repeated for each digit of the call number, sending over the vertical line as many impulses as there are units in the digit, and following by one impulse over the rotary line.

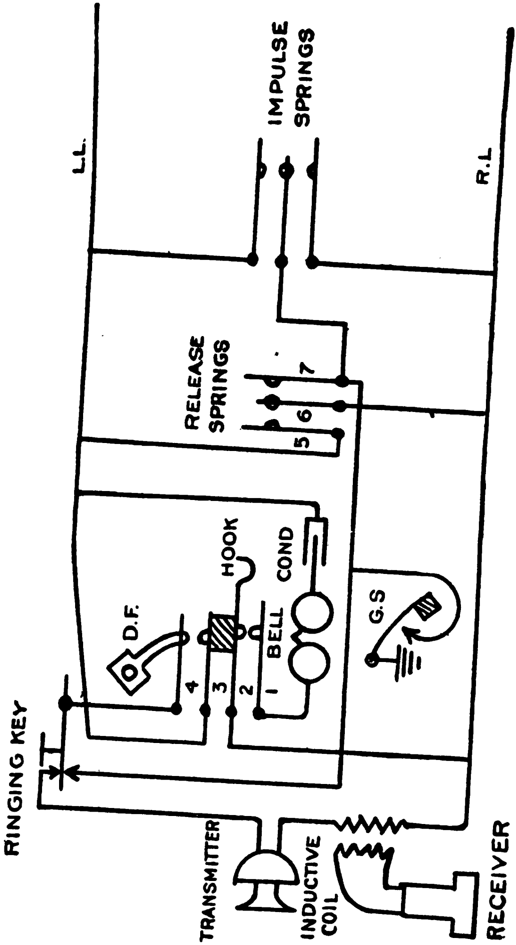


FIG. 460
TELEPHONE CIRCUIT

FIG. 461
WALL TELEPHONE (AUTOMATIC)

This is done by the impulse springs, actuated by the dial and associated mechanism.

During the sending of the impulses it is necessary that each line shall be insulated from the other. Accordingly a finger, D.F., is arranged to cause the springs, 3 and 4, to separate when the dial is turned in calling. When the receiver is on the hook, the ground connection should be cut off from the telephone wiring. This is to enable line and instrument troubles to be more readily separated from each other. This is done by the ground spring, G.S., which is let down on its contact at the first pull of the dial and lifted off when the receiver is placed on the hook.

Ringing is accomplished by grounding the vertical line, V.L. The ringing key is wired in series with the talking set and arranged to open the circuit and ground the vertical line when depressed.

Release is made by simultaneously connecting both line wires to earth and then clearing them. When the hook lever descends, a lug presses springs 5 and 6 together and then into contact with spring 7. When the lever is completely down, the lug slips off spring 5, allowing all three springs to clear each other. When the hook lever rises, as in initiating a call, the release springs are not operated, because the lug on the lever passes to the right of spring 5, thereby pressing the latter away from the other springs, instead of against them.

Fig. 461 illustrates a wall telephone of the latest type. The calling device is set into the wooden door and the connections made inside the telephone.

Fig. 462

DESK TELEPHONE (AUTOMATIC)

At the right is seen the finger stop. When the finger is inserted into any hole and the dial rotated to the right (clockwise) the motion will be limited by the stationary finger stop.

The desk set, Fig. 462, has the calling device set into an opening in the base, where it is out of the way and yet easily handled.

LINE SWITCH CIRCUITS

A very much simplified circuit drawing for the line and master switches is given in Fig. 463. Above is the line switch circuit, there being one such circuit for each subscriber's line. VL and RL are the vertical and rotary lines which run to the subscriber's telephone. VN, RN, and PN are the normal lines which come from the banks of the connectors. The last of the three is called the private normal because it protects the line from intrusion. The four contacts at the right are closed when the plunger is tripped into the bank.

There is one master switch circuit to one shelf, so that the open main wire is common to at least fifty line switches. Each trunk leaving the line switch bank has its own tap running to the master switch bank, so as to reveal its condition to the master switch.

When a subscriber initiates a call, a preliminary impulse is sent in over the rotary line. This operates the trip magnet, which allows the plunger to be forced into the bank as described in connection with Fig. 456. This closes the four bank contacts, Fig. 463. Two of them extend the vertical

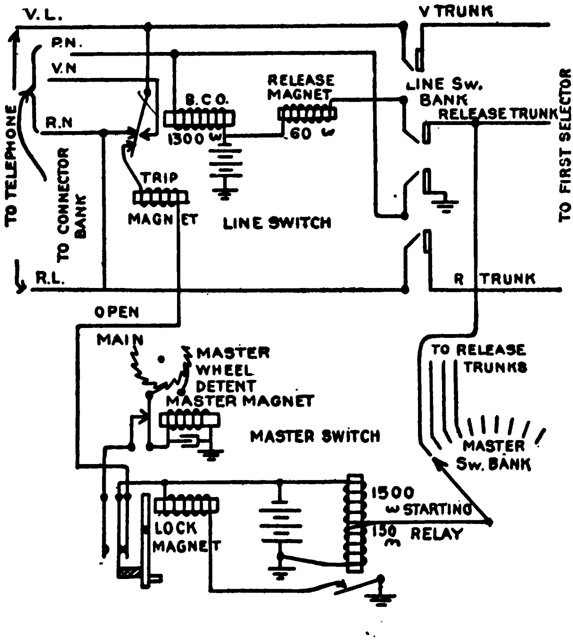


Fig. 463

LINE AND MASTER SWITCH CIRCUITS

and rotary lines to an idle first selector. Another grounds the private normal and operates the bridge cut off relay, so as to cut off the trip magnet and connect up the vertical normal, V.N. The fourth bank contact closes the release trunk from the release magnet to the first selector. The circuit is now ready for use by the subscriber.

When the release magnet became connected to the release trunk it energized the starting relay of the master switch. The starting relay has two 1500 ohm windings which are in series and normally carry current, but oppose each other with respect to magnetizing the core. When the 60 ohm release magnet of the line relay is connected to the release trunk, it is really connected in parallel with one of the 1500 ohm windings of the starting relay. This short circuits that winding and allows the armature to pull up. This energizes the lock magnet, which at once cuts off negative battery from all the trip magnets of the line switches, so that no one can plunge in during the time that the master switch is seeking an idle trunk. This wire which the lock magnet opens is called the "open main."

The same movement connects negative battery to the master magnet, which starts to vibrating like a door bell, driving the notched wheel by a ratchet action. This carries the idle plungers away from the occupied trunk. When the master switch wiper finds an idle trunk, the starting relay falls back and allows the trip magnet to cut the current from the master magnet when the latter has gotten the plungers aligned exactly opposite the idle trunk.

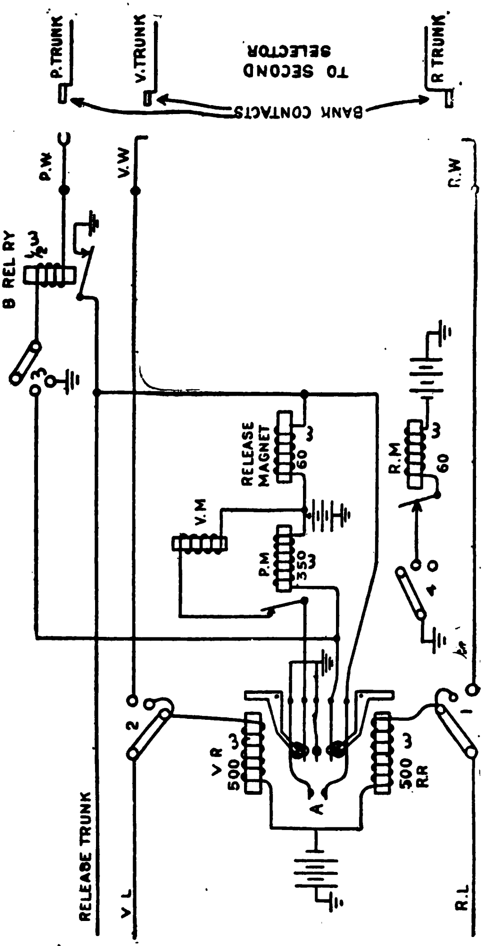


FIG. 464
FIRST SELECTOR CIRCUIT

This restores the negative battery to the open main, so that other subscribers can now call.

THE FIRST SELECTOR

The simplified circuit of a first selector is shown in Fig. 464. The four members of the side switch, 1, 2, 3, and 4, are arranged at various locations so that their work will be more easily seen. They are all at normal or first position and move simultaneously under the control of the private magnet as previously described.

When the subscriber pulls the dial for a certain digit, the vertical line is grounded a certain number of times, followed by one ground on the rotary line. The vertical impulses operate the vertical relay, V.R., which repeats the impulses to the vertical magnet, V.M., operating it on a local circuit. This lifts the wipers to the desired level. The front release contact, A, is not closed during this operation.

The single ground on the rotary line energizes the rotary relay, R.R., which causes the private magnet, P.M., to be pulled up on a local circuit. When the rotary impulse ceases, the rotary relay and the private magnet fall back. The latter, by its escapement, described before, lets the side switch move to position 2. Here two circuits are connected, first, a testing circuit from negative battery through the private magnet, P.M., side switch 3, back release relay, to the private wiper, P.W., and second, from negative battery through the rotary magnet, R.M., its contacts, side switch 4, to ground. The latter causes the rotary magnet automatically to pull up and fall back, rotating the shaft and carrying the wipers over the busy trunk lines. At its first motion the rotary magnet presses the rotary arm finger against the private armature, so that the escapement springs are forced down. Thus the side switch is ready to be snapped into its third position if the pressure be removed. But as long as the private wiper, P.W., finds a ground on the private contacts over which it is wiping, a current will flow through the private magnet, holding the escapement locked. The half ohm back release relay is marginal and is not affected by this current. When, however, the wipers reach an idle trunk, the private wiper will find no ground, the private magnet will let go and all members of the side switch will be allowed to slip to position 3.

At position 3 current is cut off from the rotary magnet and the private wiper is grounded through the half ohm back release relay, so as to protect the trunk line from being seized by another selector. The vertical and rotary lines, V.L. and R.L., are now cut through to the second selector.

Release is accomplished by a current sent back by the second selector over the release trunk and private wiper to the back release relay. This grounds the release magnet and so releases the first selector. At the same time it grounds the release trunk which extends to the line switch, thereby energizing the release magnet of that apparatus and securing its release.

If the subscriber, having merely occupied the first selector, desires to release without making a call, he can do so by hanging up his receiver as usual. This pulls up both vertical and rotary relays at the same time. This closes the front release contact, A, putting a ground on the release magnet of the first selector and through the release trunk on the release magnet of the line switch as well.

THE CONNECTOR

The connector has somewhat more complicated duties to perform, because in addition to selecting the number it must make a busy test, ring the called station, and furnish talking current to both telephones. The circuit is shown in Fig. 465.

The vertical line, V.L., is carried through the vertical relay, V.R., and one winding of the differential relay, D.R., to negative battery. The rotary line, R.L., is wired through the rotary relay, R.R., and the other winding of the differential relay to the main spring of the back bridge relay, B.B.R., which is normally connected to negative battery. The vertical and rotary relays and the differential relay feed battery current to the calling line for operating the switch and for talking purposes. The back bridge relay supplies talking current to the called line. It will be noticed that during selection the rotary as well as the vertical lines must be attached to negative battery, in order that the ground impulses sent in by the calling device shall be effective. However, in order to send current through the transmitter of the calling telephone (which is attached across the two line wires)

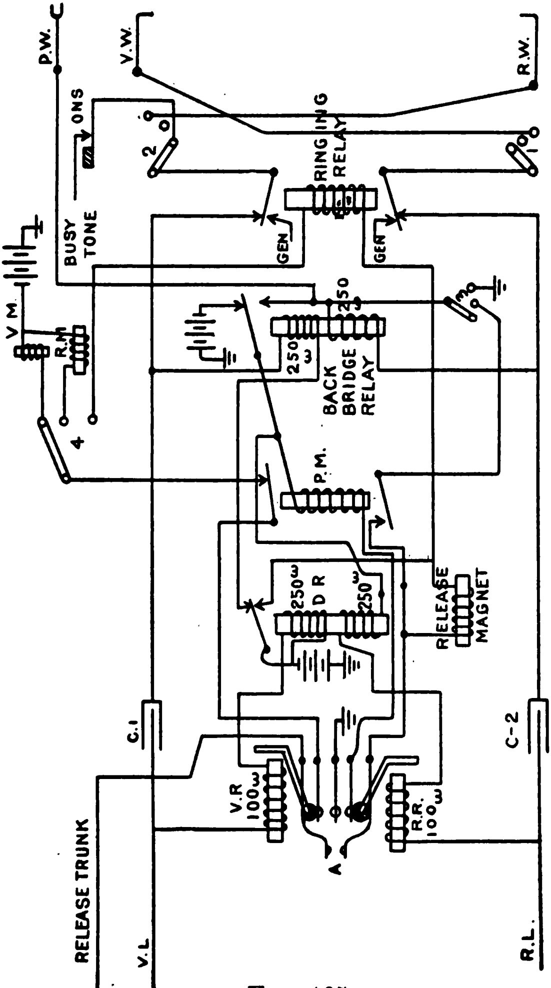


FIG. 465

CONNECTOR CIRCUIT

it is necessary that the rotary line be grounded in the connector. This change is performed by the back bridge relay.

The impulse spring of the vertical relay, V.R., is carried through a contact on the private magnet, P.M., to the wiper of side switch 4. Here it is connected normally to the vertical magnet, but may be switched successively to the rotary magnet, R.M., and the ringing relay, Ri.Ry. The private magnet is controlled by the rotary relay and governs the side switch by an escapement as previously described for the selector.

The release magnet restores the double dog and the side switch by a direct action, forcing them to place when energized, not when de-energized. The ringing relay performs exactly the same work as is done by a manual ringing key.

When the subscriber has operated his dial for the selectors and has secured the services of a connector, his line circuit runs as a clear pair of wires to the vertical and rotary relays of Fig. 465. On pulling the tens digit the vertical line is grounded as many times as there are units in the digit, followed by one ground impulse on the rotary line. The vertical impulses actuate the vertical and differential relays at the same time. The latter cuts off the winding of the back bridge relay so as not to affect the operation of the vertical relay. The vertical relay repeats the signals to the vertical magnet and so steps the line wipers up to the desired level. The one ground impulse on the rotary line energizes the rotary and the differential relays.

The latter does nothing which is of importance in this connection. The rotary relay pulls up the private magnet, which prepares the escapement of the side switch to act. When the rotary relay falls back, it lets the private magnet fall back, which allows the side switch slip into the second position. At side switch member No. 3, a busy test circuit is prepared from the private wiper, P.W., through side switch 3 to a contact on the private magnet. At 4 the impulse spring of the vertical relay is switched from the vertical magnet to the rotary magnet.

The units impulses on the vertical line are now sent in by the calling device. These operate the vertical relay as before, but the latter now repeats them to the rotary magnet, which rotates the line wipers to the desired set of contacts in that level. The single impulse on the rotary line energizes the rotary relay, which in turn pulls up the private magnet. At this point the switch tests the called line to determine whether or not it is busy. If busy, there will be a ground on the private contact upon which the private magnet is resting. If free, there will negative battery on the private contact.

At the instant when the private magnet pulls up, it closes a contact which extends the testing circuit above mentioned to the release magnet. This makes the complete testing circuit consist of the following path: negative battery, release magnet, contact on the private magnet, side switch 3, to private wiper. If the called line be free, the private wiper is resting on a contact which leads to negative battery, so that no current can flow. Hence the release magnet can not be energized. When the rotary line impulse ceases and both rotary relay and private magnet fall back, the side switch escapes to its third position.

At position 3 the side switch makes the following connections: at 1 and 2 it cuts the lines through to the line wipers so that the back bridge relay is connected to the called line; at 3 the private wiper is grounded, protecting the called line from being seized by another connector and operating the bridge cut off relay of the line switch of the called line (See Fig. 456). This clears the called line and makes it ready for ringing and talking. Side switch 3 (Fig. 465) also furnishes ground for the back bridge relay. At 4 the impulse spring of the vertical relay is switched from the rotary magnet to the ringing relay.

The subscriber now presses his ringing key, which opens the talking set and grounds the vertical line. In response to this, the vertical relay and differential relay both energize. The former supplies ground to the ringing relay and the latter furnishes a connection to negative battery. When the ringing relay pulls up it cuts off the line wipers from the rest of the circuit and connects them to a generator which delivers the ringing current.

When the called subscriber answers and takes his receiver from the hook, (See Fig. 460) the bell and condenser are removed and the talking set put in their place. At once the battery current begins to flow through the back bridge relay of the connector (Fig. 465) over the line and through the transmitter and primary winding of the induction coil. The back bridge relay then pulls up, switching the rotary line from negative battery to positive battery or ground. Current now begins to flow from ground through the lower winding of the differential relay, the rotary relay, calling telephone, vertical relay, and the upper winding of the differential relay to negative battery. The differential relay is not energized, because the current in the two coils is now in opposition. The vertical and rotary relays may pull up without doing any harm. Conversation may now proceed, the condensers, C-1 and C-2, forming the connecting link between the two circuits.

When the subscribers are through talking, they hang up their receivers. The hook switch of the called station does nothing, because the release springs have no ground connection, the dial not having been rotated. But the back bridge relay is allowed to fall back, switching the rotary line back to negative battery. As the hook lever of the calling station descends, it grounds both line wires. This causes the vertical and rotary relays and the differential relay to pull up simultaneously. The differential relay connects negative battery to the release magnet. The mutual action of the vertical and rotary relays closes the front release contact, A. The effect of this will be seen more clearly by referring to Fig. 466, which gives the release circuits through all the switches, stripped of all other connections. The first release circuit may be

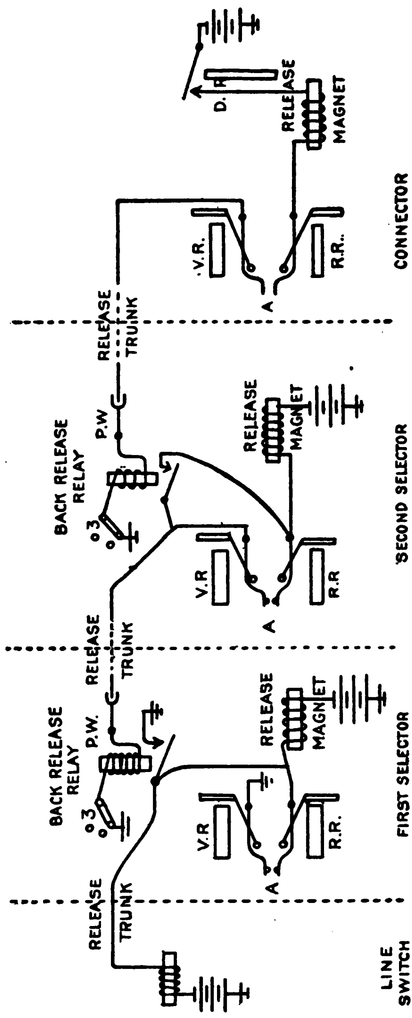


FIG. 466

SCHEME OF RELEASE CIRCUIT

traced from negative battery through a contact on the differential relay, release magnet winding, contact A, release trunk, back to the bank and private wiper of the second selector, through its back release relay and side switch 3 to ground. This pulls up the release magnet of the connector and releases that switch at once.

The above current is strong enough to energize the back release relay of the second selector, which closes the release magnet circuit of that switch as follows: negative battery, release magnet, contact of back release relay, release trunk to first selector, private wiper, back release relay, side switch 3, to ground. This releases the second selector and passes the action back to the first selector and line switch in a very obvious manner.

In case the called line is busy (Fig. 465) the private wiper of the connector will be resting on a ground at the moment of making the busy test. The side switch is in position 2 and the rotary line is being grounded, so that the rotary relay and private magnet are energized. Hence, when the private magnet closes the test circuit from the private wiper to the release magnet, the latter will be energized and instantly release the switch. This restores the side switch to position 1. The calling subscriber, not knowing what has happened, presses the ringing key as usual. Since the switch is released, and the wiper shaft is at normal, this has the effect of stepping the wipers up one or more notches, thereby closing the off normal switch, O.N.S. The busy tone is therefore connected to the vertical line and heard by the calling subscriber while he waits for the other party to answer. Realizing that the line is busy, he hangs up his receiver. This releases all the switches in the same manner as described above.

TWO-WIRE SYSTEM.

The two-wire system of automatic telephony employs no ground at the subscriber's station for operating purposes. A ground may be installed if needed for protective purposes, but it is not used for transmitting signals. All impulses are sent by merely opening and closing the line circuit, without reference to the ground. The advantages secured are a much simpler construction of telephone and the absence of inductive effects between the circuits during the sending of impulses. The line work is also much simplified, because the reversal of a pair of wires will not interfere with the proper selection of a number.

It is an easy matter to arrange a two-wire circuit which will cause a relay at the central office to operate a magnet to do whatever we wish. But the problem is more difficult. There are several digits to be selected, each of which required a series of impulses. Without some separating or circuit changing device, these impulses would all be added up on the same apparatus. If we desire to send in the number 2415, we have four sets of impulses to transmit. The first has two impulses, the second four, the third one and the fourth has five impulses. Each series must affect a different apparatus.

Thus, the first must operate a first selector, the second a second selector, the third the vertical motion of the connector and the last the rotary motion of the same.

The above considerations make it necessary to provide a circuit changing device, which, during the pause between two series of impulses shall shift the connections so that the next series shall act on the next switch or apparatus. For many years slow acting relays have been known and used in the art of telephony and it is natural that these should have been pressed into service in this new work.

A slow acting relay is one which will pull up almost as quickly as a quick acting relay, but which will not allow its armature to fall away for an appreciable time after the current has been cut off. A short circuited winding or a copper washer will secure this effect. During the flow of current in the working coil, the core of the relay is magnetized, the flux passing through the short circuited winding or copper washer. When the current in the working coil vanishes, the magnetism begins to decrease. But, by the laws of induction, this decreasing magnetism induces a voltage in the short circuited winding. This causes a current to flow in the closed winding or washer in such a direction as to prolong the magnetism, which thus disappears much less rapidly than it does in the ordinary magnet. Hence the armature is attracted for some time after the current in the working coil has ceased.

Fig. 467 shows the general idea employed in the

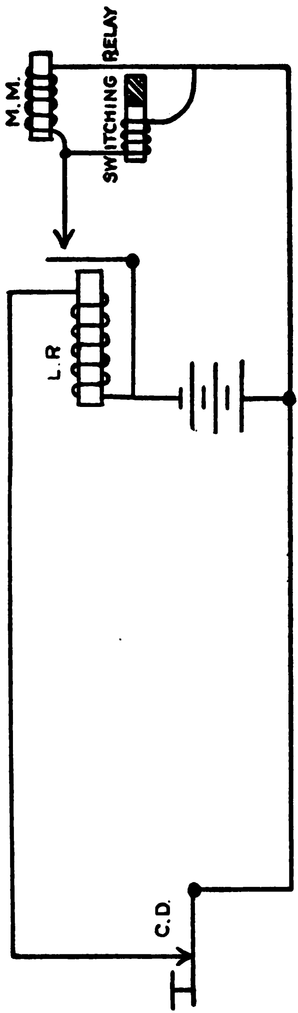


FIG. 467
THEORY OF 2-WIRE OPERATION

two-wire automatic system as made by some manufacturers. L.R. is a relay in series with battery, the line, and a circuit breaker, C.D., the latter being under the control of the subscriber. The relay is quick acting and will follow the rapid impulses of the key, C.D. The motor magnet, M.M., is used to operate the switching apparatus, such as the line wipers. It also is quick acting and follows the impulses given to it by the relay, L.R.

The switching relay controls whatever mechanism is necessary for changing the circuits so that the next series of impulses shall be effective on the next switch or device. It is slow acting and will remain energized during a series of impulses.

When the key, C.D., is rapidly opened and closed, the relay, L.R., will vibrate, giving one impulse to the magnet, M.M., for every break of the key. The switching relay remains pulled up to the end of the series, when it falls back and changes the circuits to the next switch. Detailed circuits showing the exact arrangement of apparatus are not available for publication at this time.

The two-wire automatic telephone is very simple in construction and wiring. It is made up of two circuits, Fig. 468, the bell and condenser for ringing and the talking apparatus and calling device. The latter is a simple series circuit made up of the transmitter, primary winding of the induction coil, and the contact of the calling device, C.D. The latter consists of a cam operated spring contact. By suitable clockwork the finger dial is connected with the cam so that the subscriber can

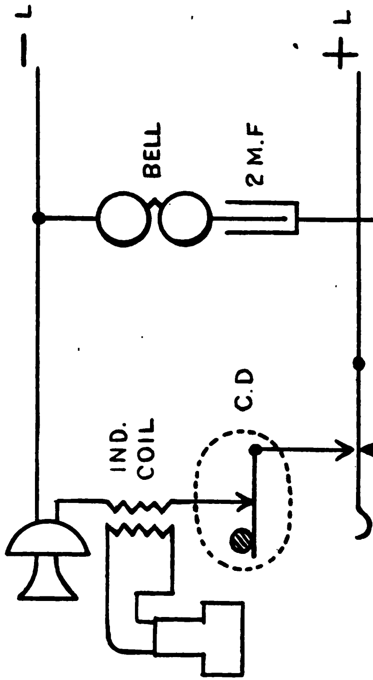


FIG. 468
DIAGRAM OF 2-WIRE AUTOMATIC TELEPHONE

cause the contact to be opened and closed any number of times. A compact governor prevents the cam from operating too fast for the switches to follow.

MEASURED SERVICE.

Two classes of measured service, credit and prepayment, are both handled successfully by the automatic system. The former needs merely to record the number of calls, as a basis for periodic collections. The latter must make the collection in advance before the service is rendered and therefore calls for a coin box at the substation.

An essential condition is that no charge must be made if the called station fails to answer. That is, only completed calls are to be charged. Also, certain classes of telephones should receive calls without requiring the calling party to pay. Such telephones are the police and the fire departments of the city, the information and complaint clerks and certain officials of the telephone company. Although this is apparently a discrimination which calls for human intelligence, the conditions have been given a physical significance and an arrangement made which fulfills the conditions.

The credit meter is attached to the line switch and is of the polarized type. It has a low resistance coil in series with one line, so that when the receiver is taken from the hook, current is drawn through the meter coil. The direction of the current is such as not to operate the meter. The coil is shunted by a condenser.

When the connection has been established and the called subscriber answers, a relay in the connector reverses the flow of battery current to the calling station. The current now flows through the meter coil in the other direction and operates it, recording one number. It automatically locks itself in this position, so that if the called subscriber should hang up his receiver or work his hook lever up and down, no more calls can be registered until the calling subscriber has released the connection and called again. At the same time that the meter pulls up and locks, the meter coil is shunted by a pair of springs, so that its impedance is completely removed from the circuit.

If the subscriber makes a call to any free telephone, no reversal of current takes place, so that the call is not recorded. This is done by grouping all such lines on one or more boards or hundreds and using for them connectors which do not reverse the battery when the called station answers. Thus the meter is not operated and conversation will take place through the series coil and the condenser which shunts it. Such a combination is never used for long distance conversation.

The automatic pay station or coin box attachment for prepayment service allows the call to be made as usual, but will not permit conversation until a coin has been deposited. A polarized relay in the box governs three short circuiting springs. These are normally open. During the operation of the dial selecting the number, the current flows through the polarized relay in such a direction as not to operate the springs. When the called subscriber answers, the reversal of battery current caused by the connector switch energizes the polarized relay in the coin box. As a result the springs are operated, putting a dead short circuit on the transmitter and a low resistance shunt in parallel with the receiver. Though the subscriber can not talk, he can faintly though distinctly hear the voice of the called subscriber. On dropping the coin in the chute, the springs are tripped clear of each other, both shunts are removed, and conversation can proceed as usual. It should be noted that the shunt which is placed around the receiver is low enough to prevent conversation if the subscriber should attempt to use the receiver as a transmitter.

TOLL LINE CONNECTIONS.

Every telephone exchange must provide means for giving long distance service to other cities. Toll lines are worked upon the magneto principle, which is so radically different from automatic switching methods and apparatus as to require special arrangements to connect the two systems.

There are two classes of toll circuits which will be dealt with here, "recording" and "service." The first is used merely to record the desires of the subscriber upon a ticket. This passed on to a toll line operator, who rings up the distant city and secures the desired person. The line operator then uses a "service" trunk to call the subscriber who originated the call, after which conversation takes place.

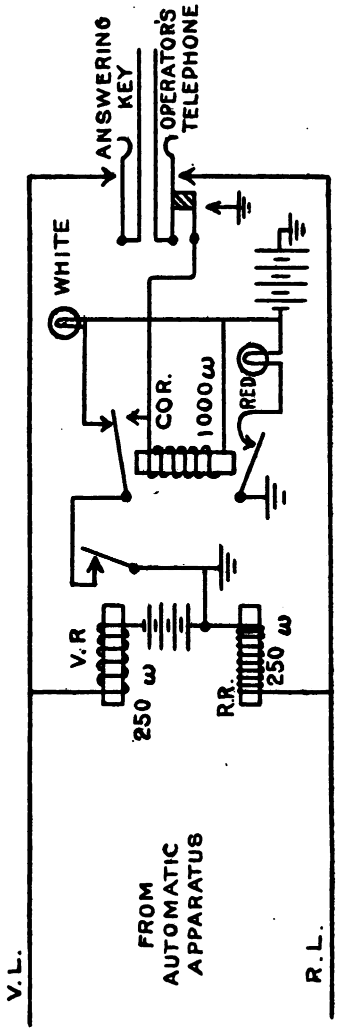


FIG. 469
RECORDING TOLL TRUNK

A form of recording toll trunk is shown in Fig. 469. When the subscriber desires to make a long distance call, he pulls a special number on his dial. This connects his line through one or more selectors to the apparatus of the figure. The vertical line is wired through a relay, V.R., to negative battery, while the rotary line gets positive battery through a retardation coil, R.R. This supplies talking current to the subscriber. As soon as he occupies the trunk, the relay, V.R., pulls up, lighting a white lamp. The recording operator, seeing the light, presses the answering key associated with this trunk, which connects her telephone set to the trunk and permits conversation. At the same time, a contact on the answering key energizes the cut off relay, C.O.R., which extinguishes the white lamp and lights a red guard lamp. If for any reason the recording operator is obliged to leave the call, releasing the answering key, the red lamp remains lighted as a warning that the call is unfinished. When the subscriber releases, the relay V.R., falls back, puts out the red lamp, and unlocks the cut off relay, C.O.R.

The service toll trunk is shown in Fig. 470, together with the cord circuit and the toll line circuit. The two line wires, V.L. and R. L., at the left, run to a first selector which is special to the service toll work. The trunk is mutipled to several positions on the toll board and is provided with visual busy signals or targets. It is so arranged that when the operator removes the plug from the jack, the switches will be automatically released.

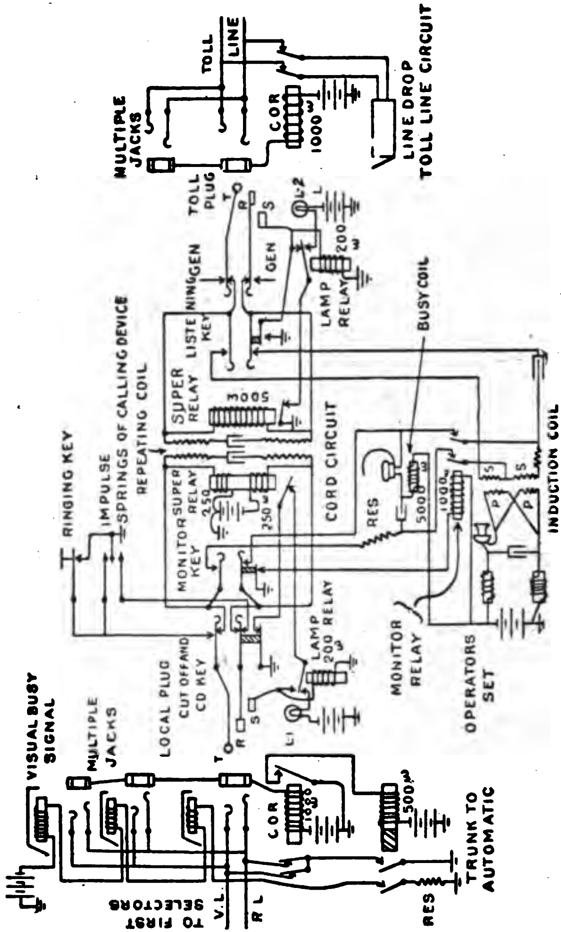


FIG. 470

TOLL TO AUTOMATIC CIRCUITS

The toll line circuit is composed of the usual line drop and cut off relay, C.O.R., and conforms to standard manual practice, except that the cut off relay is wired to negative battery.

The cord circuit is divided into two parts by the repeating coil. A 500 ohm supervisory relay is bridged across the toll end to give notice when the distant toll operator rings. The local or automatic end is provided with a two-winding supervisory relay, which furnishes battery current to the automatic line as well as giving supervision.

The operator's set is of the anti-side tone type. The primary circuit has two retardation coils. The busy test is made by a 5000 ohm retardation coil wired to negative battery. A special monitor circuit is arranged so as to cut off the transmitter and induction coil and allow the operator to listen on the toll connection without sensibly impairing the transmission efficiency.

The toll line operator makes a call to the distant toll office by plugging into the line jack and ringing. The cut off relay, C.O.R., disconnects the drop and gives a clear line. It is pulled up over the following circuit: positive battery, contact of 500 ohm supervisory relay, sleeve strand of plug, sleeve of jack, cut off relay, 1000 ohms, to negative battery. This energizes only the cut off relay, the lamp relay being short circuited.

When the line is ready, the operator inserts the local plug into a service trunk and calls the subscriber who originated the call. On plugging into the jack, the cut off relay, C.O.R., is pulled up by current flowing through the sleeve of the plug, but the lamp relay is short circuited by the contacts on the calling device key and the supervisory relay. The cut off relay removes a short circuit from the lines, V.L. and R.L., and also energizes the 500 ohm slow acting relay. The latter prepares the release ground and pulls up all the visual busy signals.

The operator now selects the automatic subscriber by throwing her cut off and calling device key, and working her dial. The impulse springs ground the vertical and rotary lines as usual. After the last pull of the dial she presses the ringing key, grounding the vertical line and causing the connector to ring the automatic telephone as was described before. When the calling device key was thrown, it will be noted that it took the short circuit from the lamp relay, allowing it to pull up and lock. When the calling device key is released, the lamp, L-1, will light. As soon as the subscriber answers, the supervisory relay pulls up, cutting off the lamp, which gives notice to the operator that the subscriber has responded.

If at any time the distant toll operator rings, the 500 ohm supervisory relay on the toll end of the cord will become energized by the alternating ringing current. On pulling up it takes the shunt off the lamp relay. The latter attracts its armature, cuts off its own shunt, and connects the circuit to the supervisory lamp, L-2. When the ringing current ceases and the supervisory relay falls back, the lamp lights and remains lighted. If the distant operator rings intermittently, the lamp will flash.

When the toll operator in this office answers, her listening key throws a shunt on the lamp relay. The latter now falls back, puts out the lamp, and remains shunted out until another ring is received.

If during the conversation between the local automatic subscriber and the person at the other end of the toll line the toll operator wishes to see if all is going well, she can listen by means of her monitor key. This connects her receiver across the cord in series with a resistance and a condenser, so that it will not appreciably cut down the voice transmission on the line. A relay automatically cuts off the talking set from the receiver, so that local noises will not become a disturbing factor.

When the toll operator withdraws the local plug from the jack at the end of conversation, the cut off relay, C.O.R., is the first to fall back, since it is quick acting. This grounds both line wires, energizing the vertical and rotary line relays in the connector. A moment later the 500 ohm slow acting relay falls back, taking the ground off both wires. The line relays in the connector then fall back and the release is complete.

THE END.

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