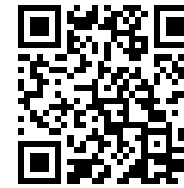
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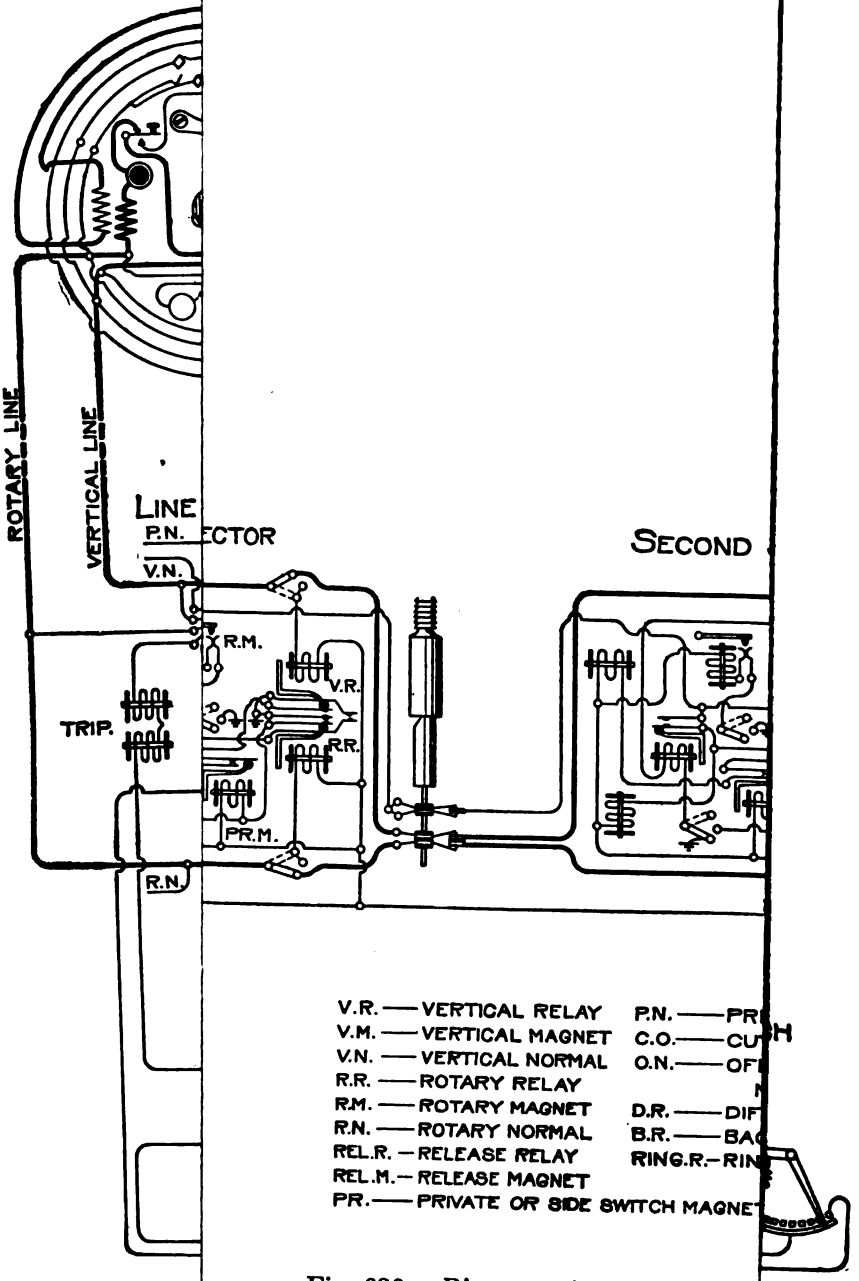


Fig. 636. Diagrammic Circuit of Co

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TELEPHONOLOGY

A DESCRIPTION OF MODERN TELEPHONE APPLIANCES.

A COMMON SENSE TREATISE ON THE ERECTION, EQUIPMENT AND MAINTENANCE OF TELEPHONE EXCHANGES.

LINE, INSTRUMENT AND SWITCHBOARD TROUBLES AND THEIR REMEDIES.

APPARATUS, LINE AND CABLE TESTING.

BY

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SPECIAL ARTICLES BY EMINENT EXPERTS

McGRAW-HILL BOOK COMPANY
Sole Selling Agents
239 West 39th Street, New York
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TO

CHARLES THOMAS MASON

OF SUMTER, SOUTH CAROLINA

WHOSE MANY INVENTIONS HAVE ADVANCE
THE ART OF TELEPHONY

THIS WORK IS DEDICATED

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ACKNOWLEDGMENT

The author desires to express his indebtedness to the manufacturing companies and technical publications for the assistance they have given him, and for cuts, circuit prints and other data, which have made this work possible.

The field of Telephony is so wide that it would be practically impossible for one author to prepare a general work of this nature in any reasonable time, and have it contain much original matter; therefore with a view to presenting a book containing accurate, useful and up-to-date descriptions and data, and one that would not be out of date before it was published, the author has used many articles prepared by specialists, and also much matter from the technical press.

Many of the diagrams and cuts of apparatus were made especially for this work, which represents an effort to present an easily understood treatise on the subject, free from technical terms and phrases, and suited for use by the great mass of practical workers in the telephone field.

THE AUTHOR.

March, 1910.

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TELEPHONOLOGY.

CHAPTER I.

FIRST PRINCIPLES—TALKING EQUIPMENT.

It is not the purpose of this book to give a complete history of the telephone from its first inception, but rather to deal with the different types of equipment together with the methods of installing and caring for same which are now on the market and in general use. For this reason no allusion will be made to the early inventions or types of equipment which preceded those now in use.

To have a proper understanding of the operation of telephone apparatus it is necessary to be somewhat familiar with the principles of sound. It is known that all sounds are caused by vibration. For instance; if a bell is struck, energy is imparted to its body, which is immediately set in motion, and this motion is termed "vibration". The vibrations are transmitted to the air, which conducts them to the ear, where they strike upon several thousand little nerves located within the ear, producing in the mind the sensation of sound.

A simple illustration of this is seen when a pebble is thrown into a pond of water. Numerous small ripples occur at the point where the pebble strikes the water; these become larger and larger as they go further away from the centre point, and finally strike against the edge of the pond.

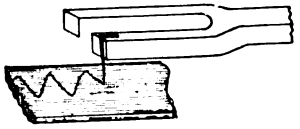


Fig. 1.

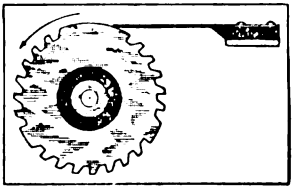


Fig. 2.

It is exactly in this manner that a bell, or diaphragm of a receiver gives forth sound, which is carried through the air to the ear just as the ripples reach the land. Of course sound waves passing through the air are not visible to the sight as ripples of water are, but sound waves can be seen by the use of the necessary equipment, which is very simple, consisting of a tuning fork or other body, with a small needle or pointer attached. If the fork be thrown into motion and then drawn across a sheet of smoked glass, the vibrations of the needle on the end of the fork will scratch a light line or wave through the smoke on the glass. This is shown in Fig. 1.

Sound possesses several characteristics. The principal ones with which we have to deal are pitch and loudness, or, as they are better

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termed, frequency and quality.* As all sound depends upon vibrations, the rate, or number of vibrations per second at which a body moves determines the pitch of the sound. A noise is usually a set of vibrations having no definite time. This confused set of sound waves strikes the ear and produces an unpleasant sensation commonly known as noise. In other words, the different vibrations tend to confuse each other.

A musical sound is almost the reverse of this, as it is a succession of clear, distinct vibrations so close together that they become blended into a harmonious whole. The difference between a noise and a musical sound will be seen by referring to Fig. 2, which shows a toothed wheel with a spring held against the teeth. If the wheel is slowly turned a succession of distinct clicks is heard which may be termed a noise, but if the speed of the wheel is increased so that sixteen teeth per second hit the spring then it is very difficult for the ear to distinguish the different strokes from each other, and a humming noise is the result. If the speed is increased an almost musical sound will be produced.



Fig. 3.

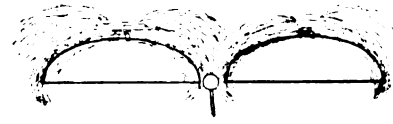


Fig. 4.

Whether the sound produced is musical or not depends largely upon the material used, but the illustrations here given will serve to demonstrate the meaning of the term *Pitch* as applied to sound.

Another common illustration is found in any musical string. When tightened to a certain degree and struck, a note is produced depending upon the number of vibrations or movements per second of the string. If the number of vibrations is sixty-four, the note is called "C" and is the lower "C" of the piano scale.

If the string is stretched so that it vibrates more rapidly then the pitch will be increased. For instance: if the vibrations number two hundred and fifty-six per second, we have middle "C", and so on.

From the foregoing it will be seen that the pitch depends upon the number or, as it is termed, the frequency of vibrations per second. The human ear has the faculty of distinguishing musical sounds ranging from sixteen to thirty six thousand vibrations per second. The range of vibrations to be considered in telephonic transmission is between sixty and two thousand, which is well within the range mentioned.

The velocity, or rate of speed, with which sound travels through the air is about one thousand one hundred feet per second. The rapidity with which sound travels depends to a great extent upon the temperature. This however has nothing to do with the transmission of telephonic sounds.

A great deal of misunderstanding exists as to the operation of the telephone in transmitting sound, and it should be remembered that the sound waves are not transferred along the wire in the shape of sound vibrations, but are changed into electrical waves by the action of the instrument, as described later.

Loudness, or intensity of sound depends upon the distance through which the body causing the sound moves or vibrates. This distance is termed amplitude, and is illustrated by Fig. 3, in which an ordinary pair

*Loudness: number, amplitude and phase of upper partials. See works on Sound.

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of telephone bells are shown; these are supposed to be ringing, and the dotted lines show that the bodies of the bells are vibrating or moving to a certain extent. If the clapper is made to vibrate harder, not faster, the bells will move through a greater distance, and the sound will be correspondingly louder. In other words, the harder a body is struck the greater the volume of sound will be produced, up to the limit of the body to produce sound.

The quality of the note, or that which enables a distinction to be made between the sound given forth by different substances, such as a piece of wood, the head of a drum or a stringed instrument, depends upon the properties of the bodies, the substance of which they are composed, etc. It is very difficult to explain just why "C" on the piano and "C" as emitted by the human throat differ, but as this has very little bearing on the effect that sound produces in the telephone, it will not be discussed here.

The method by which sound waves reach the ear is very simple when you take into consideration that the atmosphere is made up of very fine particles or molecules. We will suppose that the bell, Fig. 4, is rung. Immediately the particles of air nearest the body of the bell will be forced out from it. These will strike the next particles and so on until the ear is reached. Air being an elastic substance, as soon as the first particles strike the second particles the first particles swing back and are again set in motion by the bell, and so on. This action is called wave motion, and takes place in all directions from the sounding body. In the case of the bell, the sound waves completely surround all portions of the gongs, as shown in Fig. 4.

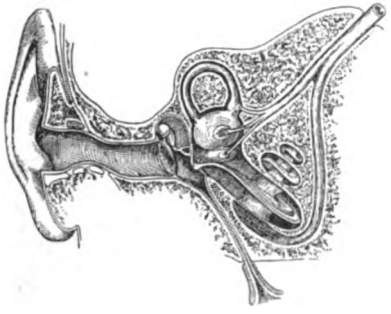


Fig. 5.

The human ear is shown in Fig. 5. A passage extends inwardly, across which is stretched a membrane. Immediately back of this is a small canal containing a fluid and several thousand nerves called the "Rods of Corti" which connect with the brain. If a certain note on the piano is struck, it will cause one of these rods to vibrate, and this vibration will be transmitted to the brain and the sensation of sound will be produced. If a chord, or combination of musical sounds is made, several rods corresponding to the different sounds will vibrate, and this produces a harmonious sound. A noise may cause a great many of the rods to vibrate and this produces a confused sound like that caused by striking a number of keys on the piano at once.

Some people have more of these nerves of hearing than others, and upon the number of these nerves depends a person's capacity for hearing

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a number of sounds. The majority of people have nerves corresponding to the range previously mentioned.

As a rule, solid substances conduct sound better than air. An illustration of this is shown in the ordinary child's telephone, which consists of a couple of tin cans with a piece of paper or bladder stretched across the ends, connected by a string. As long as the string is held tight, the vibrations are carried along it without spreading out in all directions, which would be the case if the string was not used.

From the foregoing it will be seen that a body in a state of vibration gives forth sound, and it is upon this fact that the action of the telephone depends, so far as receiving sound and emitting it at the other end of the line is concerned. The sound waves emanating from the throat of the speaker strike upon the diaphragm of the transmitter. Here they are transformed into electrical currents by the action of the instrument, as will be explained later, and are transmitted along the wire in the form of electrical energy to the receiver at the other end of the line, where in turn they cause the diaphragm of the receiving instrument to vibrate. These vibrations in turn reach the ear, and convey the idea of speech to the mind. It will be noted that the sound waves are transformed from mechanical vibration into electrical energy and then back to mechanical vibration again.

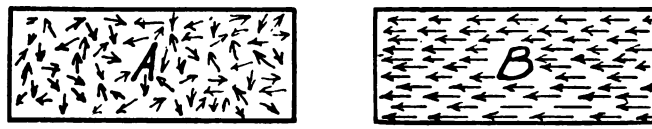


Fig. 6.

Before proceeding to consider the telephone proper it is necessary to review the theory of magnetism, upon which the operation of the telephone depends.

A magnet (so called from the fact that iron ore from Magnesia in Asia Minor was early known to possess this property) is usually a piece of steel having the power of attracting iron.

Natural magnets are an ore of iron generally known as loadstone (Saxon, leaden, to lead) but are seldom met with, and are never used in telephone work.

Commercial magnets are made by subjecting steel bars, either straight or in U shaped form to the magnetizing influence of an electric current. This is usually done by placing them inside a hollow coil, or a piece of steel can be magnetized by simply bringing it in contact with another magnet.

The principal property of a magnet is the ability to attract iron and to retain this power of attraction for an indefinite period.

The operation of the first telephone, or as it is now called the "Receiver" depends upon the fact that if a piece of iron is brought near to a permanent magnet, the invisible magnetic lines of force which exist in the neighborhood of the magnet are varied, and if the piece of iron is moved, a corresponding movement of the lines of magnetic force takes place.

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This will be understood by reference to Fig. 6, where a piece of steel in an *unmagnetized* state is shown at "A." The small arrows represent the molecules or particles of which the steel is composed.

When the steel is magnetized the particles range themselves in a definite direction, as shown at "B." This arrangement is not visible to the naked eye, nor can it be seen, but manifestations that this change has taken place are very evident from the fact that the steel will now attract other pieces of iron, which proves that the magnetic effect is not only present in the steel itself, but exists in the air near the magnet in all directions. It is much stronger at the ends of the bar than in the middle, the absolute centre being neutral, and this is taken advantage of in making telephone receivers and other electrical instruments by bending the bar into a "U" shaped form, so that the attractive power of both ends can be used. This radiation of magnetic lines of force is shown in Fig. 7, which also shows that the greater number of lines, or the greatest strength, is at the ends of the magnet.

If a magnet is suspended so that it is free to turn, it always tends to point north or south. The end which turns to the north is called the north pole, while the other end is called the south pole. The flow of the lines of force is from the north pole to the south pole.

If a small piece of iron be brought near a magnet, it will become magnetized, and immediately changes the position of some of the lines of force near the magnet. This is shown in Fig. 8.

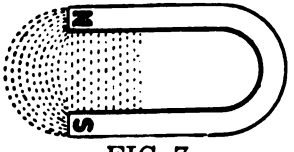
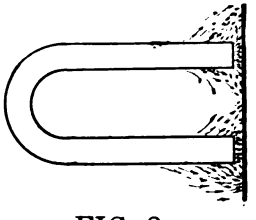


FIG. 7.


FIG. 8.

It will be noted that the lines of force concentrate towards the piece of iron. If the iron be moved near to the magnet or further away from it, a corresponding movement of the lines of force will take place.

If the magnet is arranged as shown in Fig. 8, having in front of it a thin piece of soft iron called in telephone work a diaphragm, and sound waves strike upon the latter, it will vibrate, and this movement will cause a corresponding movement of the magnetic lines of force about the end of a magnet. This is what takes place when an ordinary telephone *receiver* is spoken into.

Some means must now be devised to transform the magnetic vibrations caused by the movement of the magnetic lines, into electrical vibrations, and to transfer these electrical vibrations along the wire to the other end of the line. This is accomplished by winding a coil of wire upon the end of the permanent magnet, and varying the lines of magnetic force which surround the coil by reason of its nearness to the magnet.

Fig. 9 shows two receivers with the wire coils in place upon the heads of the magnets. The coils are connected together by the lines "L"-"L". If the diaphragm of the receiver "A" is vibrated, the magnetic lines about the end of the magnet are moved. This creates a current of

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electricity in the coil of wire, which travels over the line and into the coil of the instrument "B". Here the process is reversed, and the current in the coil influences the magnet, so that the lines of magnetic force are varied. This produces a coresponding movement of the diaphragm at "B", which in turn gives forth a sound identically similar in every way to that spoken into instrument "A".

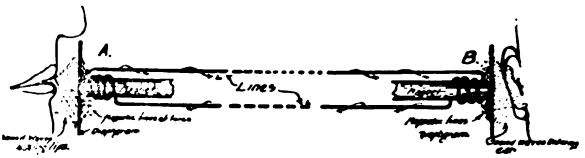


Fig. 9.

The first telephone line consisted of two receivers, as above described, connected together by means of one wire, the earth being used in place of the other wire. At this time there were no other wires carrying sufficient current to cause disturbances, as will be described later, and therefore grounded circuits, as the above arrangement is termed proved very satisfactory. But, owing to the rapid increase in electric light and trolley service, grounded circuits are no longer of value, as the heavy currents from the power wires cause disturbances in the telephone circuit. Two wires, or as it is termed, metallic circuits should therefore always be used.

Another reason for not using grounded circuits is that if the different lines run parallel to each other for any distance, "Cross-talk" will result. This does not occur when metallic lines are used as they can be transposed as described later to remedy the trouble. Grounded lines can not be transposed.

Sometimes, while there are no electric currents traversing the earth at the exact point where a grounded telephone line is located, still, if this grounded line is connected to a line several miles long, the currents in the earth, or as they are termed, "earth currents", will seriously interfere with the operation of the line. In view of the fact that nearly all telephone exchanges are now being equipped for long distance service, it is well to mention here that only metallic circuits should be used.

Two receivers connected together serve very well for a telephone line for a distance of several miles, the speech although weak, being very clear. For business purposes such a line would be practically worthless. It was therefore necessary to devise some means of increasing the power of the instrument. This was accomplished by the invention of the transmitter, which acts as an electrical valve. When the diaphragm is vibrated, the transmitter allows more or less of the electrical current to pass. This will be understood by reference to Fig. 10, where the transmitter is shown at "A". The diaphragm "D" is connected to one side of the Receiver "R". Between the diaphragm and "E", or the back "electrode", as it is termed, is placed a quantity of fine carbon, commonly known as granular carbon, and resembling coal dust. The battery is connected to the other terminal of the receiver, while the other side of the battery is connected to Electrode E.

We will now consider the battery as a tank of water, Fig. 11, and will consider the transmitter as a valve "V", while the receiver will be represented by the wheel "W", supposed to be placed in the pipe in such

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a manner that when the water is flowing through the pipe the wheel will turn. If the valve "V" be almost closed, very little water will flow, and the wheel will turn slowly; but if the valve be open, allowing considerable water to flow, then the wheel will turn faster. This is practically what happens when the transmitter is used in connection with the receiver. When the former is spoken into, the sound waves strike upon the diaphragm. This moves it nearer to or further away from the back electrode. When the pressure is increased, more current from the battery will flow. When the pressure is diminished, which happens when the diaphragm springs back again, after having been pushed inwardly by the sound waves, less current will flow. This movement back and forth of the transmitter diaphragm causes current to flow along the line, and the current passes over the line and through the coils of the receiver, operating same as previously described. This arrangement increases the ability of the telephone to transmit speech, and it was the invention of the transmitter that made the telephone a practical success.

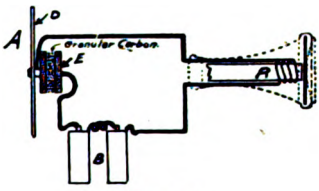


Fig. 10.

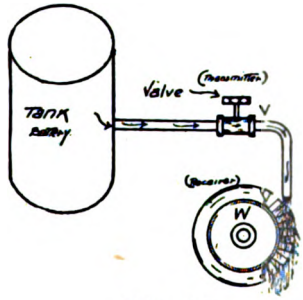


Fig. 11.

There yet remained several difficulties to overcome. One of these, and the greatest, was the fact that any wire opposes the passage of an electric current just as water is impeded in its progress through a pipe by friction. In the case of an electrical current this friction is termed "resistance".

While the pressure of water or steam in a boiler is measured in units of pounds to the square inch, the pressure of electrical currents is measured in units termed "volts.'

While a quantity of water is measured in quarts or gallons, a quantity of electricity is measured in units called "amperes."

The resistance a body offers against being moved is termed friction, and the electrical unit of friction, or resistance, is termed an "ohm."

A VOLT is that pressure of electricity necessary to drive one ampere of current through a resistance of one ohm.

An OHM is that resistance which requires one volt to send a current of one ampere through it.

An AMPERE is the amount of current that will pass through one ohm at a pressure of one volt.

A simple manner of expressing Ohm's law, that will be easily understood by those not familiar with arithmetical expressions, is shown below.

These rules are termed "Ohm's Law" in honor of one of the early investigators of electricity.

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* V = Volts (Pressure)
A = Amperes (Quantity)
R = Ohms (Resistance)

V divided by A x R or $\frac{V}{A\ R}$

To use this method place the thumb over the quantity it is desired to find, for instance, suppose a battery of three volts is used, and is passing a current through 10 ohms, how much *current* (amperes) is flowing?

When thumb is placed over A the formula reads V divided by R, which is: 3 divided by 10 which equals .3 ampere, the amount of current flowing.

Suppose a resistance coil measured 20 ohms and when an ammeter was placed in circuit a reading of 5 amperes was obtained, and the voltage is required. By placing thumb over V the formula reads A times R, or: 20 times 5 equals 100 which is the voltage.

Suppose a 3 volt battery is used, and one-half ampere is flowing, what is the resistance in circuit. By covering up R we have V divided by A, or: 3 divided by .5 equals 6 ohms.

This law will solve any *direct current* problem. Provided *two* of the quantities are known, the third can always be calculated.

It will be seen that if the resistance of a wire is decreased, more current will flow through it. This fact is observed in putting up a telephone line; as the resistance of the line can only be decreased by using a large wire, and owing to the cost, it is impractical to use wire exceeding

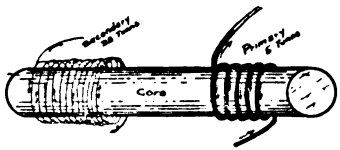


Fig. 12.



Fig. 13.

a certain size. On the other hand, it will be seen that more current will pass through the wire if the voltage or pressure is increased, and this is what actually occurs when the battery and transmitter are used, as previously described.

When the two receivers alone were used a very weak current was created, depending upon the strength of the magnets. Since the transmitter has come into use a greater pressure is obtained by using the battery, and the pressure of the battery is regulated by the action of the transmitter, as shown in Fig. 10.

It would immediately occur to one that the only thing necessary to do in order to gain power sufficient for talking over any distance would be to increase the battery. This, however, cannot be done, owing to the fact that if too much power is used the granular carbon in the transmitter will burn up, as the passage of electricity through the carbon heats it when the voltage is too high.

Some means, therefore, had to be devised to increase the voltage without burning up the transmitter. This was finally accomplished by the use of the piece of apparatus known as the induction coil.

*The standard symbols are: I: amperes; E: volts; R: resistance.

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If a current is passed through a coil wound upon one end of a rod of iron, as shown in Fig. 12, the latter will become a magnet. If another coil of wire is wound over the first, whenever the current in the first coil is increased or decreased a corresponding current will be created in the second coil. This current will be weaker or stronger in proportion to the number of turns the second coil possesses in relation to the first. If the first coil had five turns of wire, and the second coil twenty-five, then the voltage in the second coil would be five times greater than that in the first coil.

This can be better understood if we imagine that when a current is passed through the first coil the iron core becomes magnetized, and the lines of magnetic force spread out from the core, as shown in Fig. 13. As they spread, they encounter the wire composing the second coil, which is usually wound over the first coil. This immediately generates a current in the second coil. If the current is decreased the lines shrink back into the core, and disappear. This back and forth action of the lines of force produce in the second coil of wire a current of electricity identically similar in its character to that in the coil producing it, and, as previously stated, if the number of turns of wire in the second coil are more than those in the first coil, the strength of the current created in the second coil will be greater. This fact is made use of by arranging the transmitter, induction coil and other apparatus as shown in Fig. 14.

Comparatively few turns of coarse wire, known as the primary, are wound directly on the core of the coil. A couple of cells of battery are connected with the transmitter and primary, as shown, while the line wire and receiver are connected to the secondary, which consists of a great number of turns of wire wound directly over the primary.

When the transmitter is spoken into, the current in the primary is increased or diminished, which causes a corresponding increase or diminution of the lines of force created by the iron core. This affects the secondary, causing a current of increased strength, and as an increase of voltage will always carry current through a greater resistance, enough current will pass over the line to operate satisfactorily the receiver, and induction coils are therefore used in all modern instruments.

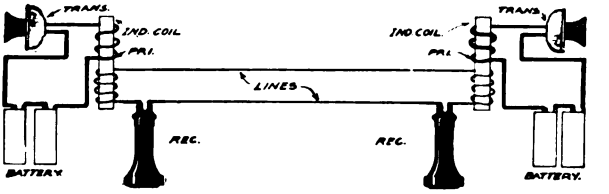


Fig. 14.

The above parts of the telephone constitute all that are used in the transmitting and receiving of speech, and while the form, size, shape and other details of the parts may vary in different makes of instruments, the principles here given concerning their operation hold good for any type. There are many other principles entering into their construction which will be described later.

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CHAPTER II.

SIGNALLING EQUIPMENT.

While we now have the means of talking from one point to another, it yet remains to devise some means of signalling, as the receiver itself is not sufficiently loud to call a person to the instrument, and some form of bell or other device is necessary. It would seem that an ordinary vibrating bell, commonly used for various purposes would also be selected for telephone work. This instrument is illustrated in Fig. 15, but it possesses many disadvantages which render it impractical for telephone use. The main trouble is the fact that the contact point shown at "s" is liable to spark, especially if sufficient battery is applied to ring the bell over a long line.

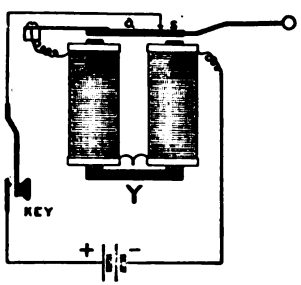


Fig. 15.

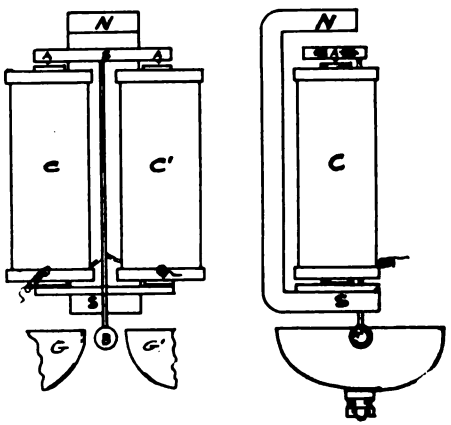


Fig. 16.

When the key is depressed, current flows through the magnet windings N. S. which attract the armature a. This moves toward the magnets breaking contact s, stopping the current flow. The armature springs back, contact s is closed, the current flows, the armature is again attracted. This continues as long as the circuit is closed. A gong, not shown in the figure, is so placed that the clapper rod will strike same at each impulse.

As this instrument requires battery for its operation, it would be inconvenient to have a sufficient number of these at each telephone to ring the bells on the line. Some other form of signalling device is therefore necessary.

A telephone bell, as shown in Fig. 16, consists of two spools of wire wound on soft iron cores. The latter are connected together by means of a piece of soft iron at the bottom, while to this piece the permanent magnet "N. S." is connected, so that the top curves over the armature "A. A." which is a piece of soft iron suspended in the middle so that it is free to

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move. Attached to it by means of a rod is the ball "B", adapted to strike the gongs G and G.

The lines of force from the permanent magnet "N. S." magnetize the soft iron armature so that it becomes a magnet. Instead of opposite magnetic poles being at each end of the armature, the ends of the armature become, we will say, north poles, while the middle portion of the armature directly under the magnet becomes a south pole.

The ends of the iron cores upon which the wire spools are wound also become south poles because they are connected to the south pole of the permanent magnet, and form simply an extension to same.

The current from the generator flows first in one direction and then in another through the two spools of wire, and this magnetizes the iron cores. The left hand core "C", we will suppose, becomes the north pole, while the right hand core "C" becomes the south pole. This being the case, the right hand pole will attract the armature directly above it, because *opposite poles of magnets always attract each other.*

While this is taking place the left hand pole, which is the south pole, will repel the armature directly above it, as *like poles always tend to repel each other.* This causes the ball to move toward and strike one gong. By this time the current from the generator has begun to flow in the opposite direction, and the operation is reversed, the left hand spool of wire causing its core to become a south pole, while the other spool causes its core to become a north pole. This attracts the armature in the other direction, which in turn, causes the ball to strike the other gong.

It will now be seen that with every alternation of the current a movement of the armature to one side or the other is produced.

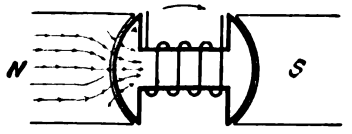


Fig. 17.

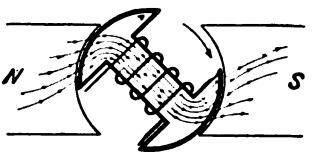


Fig. 17 A.

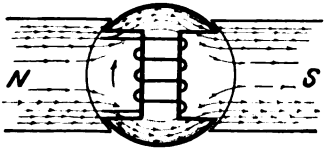


Fig. 17 B.

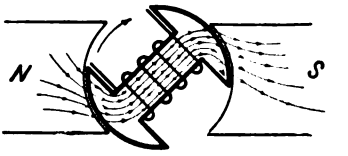


Fig. 17 C.

The machine for ringing telephone bells is called a Magneto Generator, and is shown in theory in Figs. 17, 17a, 17b, 17c. N. S. represent the ends of the permanent magnets. The centre opening is known as the "field." In this is placed the revolving armature upon which is wound many turns of insulated wire. The manner in which the current is generated will be understood from a careful study of the figures.

Magnetic lines of force are flowing across the field, from the N. to

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the S. pole. To generate a current the wire must move across the lines of force, and in Fig. 17, the maximum number of lines are passing through the coil. The number of lines do not change until the armature has passed beyond the position shown in Fig. 17a, and the voltage is 0. A little beyond Fig. 17a the lines begin to decrease and current is generated until Fig. 17b is reached when the remaining lines are shorted out of the coil and the rate of change of the lines is greatest and the voltage is at a maximum. This is the peak or highest point of the wave, shown in Fig. 18.

When the position shown in Fig. 17c is reached the lines of force pass through the coil in the opposite direction, and the voltage drops to 0. This continues as long as the crank is turned.

While the wire is passing from the position in Fig. 17 to that in Fig. 17a, a plus current or as it is termed, a positive current, is generated if the north pole of the magnet is on that side, while from that in Fig. 17b to Fig. 17c a minus or negative current is generated because the wire is there subject to the influence of the south pole.

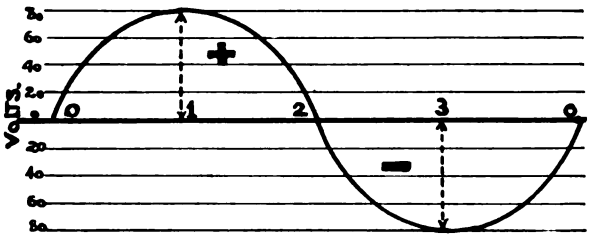


Fig. 18.

Plus current is represented by the sign +, and minus current by the sign —. Current flowing first in one direction and then in another is called alternating current and Fig. 18 illustrates waves of a current of this kind given by a magneto generator. On the left are figures representing the voltage, while the points "0-1-2", etc., along the curved lines represent the different positions of the wire during one revolution, and correspond to those in Fig. 17, a, b, and c. Starting at line "0" where there is no current, we will suppose that the upper curved line represents plus current, and the lower curved line, minus current. From this it will be seen that current from the telephone generator flows first in one direction and then the other, the voltage increasing from "0" to "1", and then decreasing to "2", as the wire at this point (see Fig. 17a) is no longer cutting across the lines of force. The current then increases to "3" in the opposite direction, (see Fig. 17b) and again decreases to "0" (Fig. 17c).

This operation of the current increasing from "0" in one direction, returning to zero and increasing in the other direction, and back to zero again, is called a *CYCLE*.

A telephone generator gives one complete cycle of current for every revolution of the armature and generators are so geared that the armature usually makes 1000 turns per minute, or 5 times the speed at which the crank is turned. When revolutions are spoken of, it should be remembered that it is those of the armature which are referred to.

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A good three bar generator should give from 65 to 90 volts when turned at the regular speed. A four or five bar bridging generator, from 75 to 110 volts. The quantity of current given by the bridging generator is much greater than that given by the series instrument.

The voltage obtained is in proportion to the speed at which the armature is revolved. The faster the speed, the greater number of lines of force the wire on the armature cuts across, and the higher the voltage. This is the reason why turning the crank rapidly on a telephone will sometimes enable one to ring a distant phone which will not ring when the crank is slowly turned.

The FREQUENCY of an alternating current is the number of cycles in one second.

An ALTERNATION is one half of a cycle.

An alternation may be either POSITIVE or NEGATIVE.

A CYCLE consists of one positive and one negative alternation.

As the frequency of an alternating current is the number of cycles passed through in one second, and as a telephone generator gives one complete cycle of current for every revolution of the armature, to find the frequency:

Divide the revolutions per minute by 60. This gives the CYCLES per second.

If you desire to find the alternations per minute:

Multiply the cycles per second by 120, or if the alternations per minute are known, to find the cycles, divide the alternations by 120.

If the coil of wire in the telephone generator were simply revolved in the field, the resulting current would be very weak. The coil is therefore wound on an iron core or "armature", which concentrates the lines of magnetic force in the manner shown in Fig. 19.

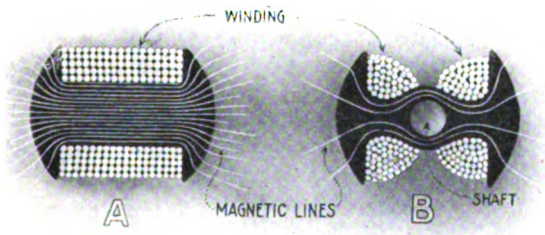


Fig. 19.

This causes more of those lines to pass through the windings, and the strength of the current is thereby increased.

A number of magnets are used, so arranged that all the north poles are on one side of the armature and the south poles on the other.

Series generators usually have three magnets, and are termed three bar generators. The armatures are wound with a great number of turns of wire, and the resulting current has a high voltage but a small amperage.

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Bridging generators have from four to six magnets, and the armatures are wound with coarser wire, thereby producing a considerable quantity of current.

The number of bars is no indication of the strength of the generator, this depending upon the cross section of the magnets. A generator with four magnets ⅞ x ½ in. square is stronger than one with six magnets ¼ x ½ in.

When ringing a telephone bell, during one-half a cycle, or one alternation of the current, the ringer armature is attracted in one direction, and during the other half of the cycle the armature is attracted in the other direction. This process is continued as long as the generator crank is turned.

The alternating current, as above described, can be made sufficiently powerful to ring a "magneto bell" as the telephone ringer is termed, over a considerable length of line, and we are therefore enabled to signal from one end of the line to the other.

It now becomes necessary to devise some means of having the signaling equipment connected with the line in such a manner that after the signal has been given the bells and generator will be automatically disconnected and the talking equipment connected to the line as the line must be free for talking purposes. The batteries must be connected to the transmitter, as they cannot be left on all the time. Various devices for doing this were devised. These consisted of switches, etc., and from them was finally evolved the present type of switch known as the "Hook", or "Receiver Hook".

The hook controls the various circuits connecting or disconnecting them from the line. In early types of hook switches a great deal of trouble was caused by loose connections, in the modern hooks this has been entirely eliminated.

The Sumter Hook Switch shown in Fig. 19a illustrates the modern construction of this part. A steel stamping forms the body upon which all the other parts are mounted. By means of two screws passing through the telephone box, the hook is secured in position and is entirely self-contained, thus eliminating the trouble found in early types where the springs were mounted on one side of the box and the hook on the other. When the wood warped or a screw loosened the parts changed their relative position and no longer operated properly.

All danger of loose contacts has been eliminated in the type of hook shown in Fig. 19a, by using long flexible springs with riveted contact points of platinum.

When the springs are assembled they are given a downward tension which brings them to rest against the rubber rollers as shown. These rollers adjust the relative position of the springs very accurately. From this it will be seen that the position of the springs is not dependent upon the elasticity of the metal but each spring is held under tension.

The rollers act to bring the springs together with a biting motion which puts a pressure of several pounds on the contact points.

One weak point in a great many hooks is the use of some imitation of rubber for insulation between the springs. Nothing but pure hard rubber should be used and this should be as thick as possible to guard against lightning punctures.

In some hooks the tension of the contact springs is relied upon to raise

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the hook lever. This sometimes causes the contact spring to weaken and fail to operate properly. In the Sumter hook a separate raising spring is used, made of round steel. This is placed on the rear side of the hook base and is locked on two pins from which it can be instantly removed if necessary. This spring is enameled to prevent rust.

The escutcheon plate is held in position on the telephone instrument by two machine screws which also hold the hook in the telephone box, as shown. The hook which is a heavy stamping from sheet brass, nickle-plated, is inserted through the escutcheon plate and clamped to the hook by means of a heavy steel set screw. The escutcheon plate does not limit either the upward or downward motion of the hook lever, this being taken care of by a permanent adjustment forming part of the hook base itself. It is therefore unnecessary to pay any attention to the adjustment of the travel of the hook lever, this adjustment being taken care of in the assembling of the hook parts and cannot be changed by any wear in the hook itself.

For shipment or in case of breakage, the hook lever can be withdrawn from the hook by simply loosening the cap screw and pulling the lever out.

In some types of hooks the lever is made instantly removable by unlatching same, a catch or other means readily operated by the finger being provided.

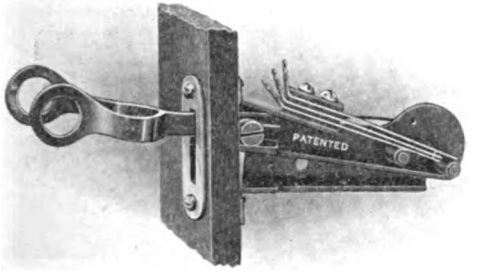
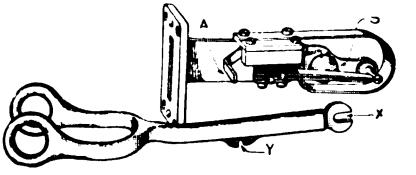


FIG. 19a.



Dean Hook Switch.

Fig. 19a shows a hook for bridging telephones. The three springs close when receiver is off the hook lever. For series work another spring is required, so placed that when the receiver is on the hook, two of the springs will be in contact, this contact being broken when receiver is off and the three springs closing together same as in the bridging, leaving the extra spring not in contact with anything.

All modern hook switches are so arranged that the hook lever and metal parts of the hook body are insulated from the contact springs carrying the circuit of the instrument. This prevents the user at the phone receiving a shock from touching the hook.

A simple diagram of the telephone with the hook and necessary signalling and talking equipment is shown in Fig. 20.

The instruments are in the signalling position when the receivers are on the hooks, and the bells and generators are so connected that if the crank on one of the generators is turned, a current will pass over the line through the bells and back again.

After the signal has been given, if the receivers are removed from the

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hooks, the hook lever moves upward and closes the top contacts, so that the transmitter batteries are placed in circuit, the receivers and induction coils are connected with the line, and the generator and bells in each instrument are cut off, leaving the line entirely free for talking purposes, as the bottom contacts shown dotted, are broken as soon as the receivers are removed from the hooks.

We have considered the apparatus necessary to transmit speech and signals over the line. There are two ways in which telephones may be connected: in series, and in multiple or "bridging". A series circuit consisting of three telephones is shown in Fig. 20.

If a telephone on one end desires to call the telephone on the other, upon turning the generator crank, the bells in all three instruments will ring. By having a different ring for each phone, any of the three can be called at will.

If the two end phones remove their receivers from the hooks they can talk together, the voice currents passing over the bottom line and returning over the top line in the figure and passing through the ringer coils at the middle 'phone. If there were other telephones on the line the current would also have to pass through the ringer coils of each one.

The series method is perfectly satisfactory when there are only two telephones on the line, as the ringers are not in circuit when the receivers are off the hook, but when there are more than two instruments on the line it is necessary for the voice currents to overcome the resistance of the fine wire wound on the ringer coils in all the instruments on the line except the two in use. For instance: when the end instruments in Fig. 20 are speaking together, the voice currents must pass through all the fine wire on the ringer at the middle 'phone.

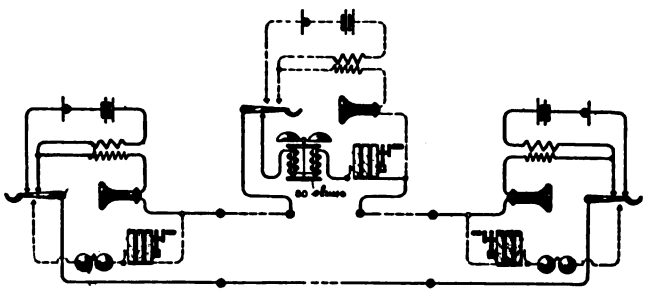


Fig. 20.

Another serious objection to the operation of series circuits is what is termed "self-induction" or impedance, which is illustrated in Fig. 21. Here a soft iron core is shown upon which is wound a number of turns of wire. When a current is sent through the wire, it passes around the core, and at every one of the turns it induces or creates in the turn of wire next to it a current which moves in the direction opposite to that of the first. This reacts upon the main current, and tends to check or impede its progress. In this way a current will react upon itself, and its progress through the coil will be hindered. This reaction is called self-induction.

The self-induction of a coil depends directly upon the number of turns of wire and upon the strength of the passing current together with the amount of iron in the core. As a ringer coil possesses a great many

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turns, the self-induction is very high, and the voice currents are hindered much more in their passage by an 80 ohm ringer than they would be by 80 ohms of straight wire, which possesses no self-induction.

Just as the unit of pressure of electricity is termed a volt, the unit of self-induction is termed a "Henry."

The phenomenon of self-induction is principally exhibited in connection with alternating currents. The effect of self-induction upon the transmission of voice currents is similar to resistance. The "inductance" of a coil is measured in Henrys by the number of volts of Counter Electro Motive Force generated when the current changes at the rate of one ampere per second.

The ringer coils of telephones have an inductance varying from one to seven Henrys, while generators vary from two to ten Henrys. Telephone receivers vary from fifty to one hundred and twenty-five milli-Henrys, a milli-Henry being the one-thousandth part of a Henry.

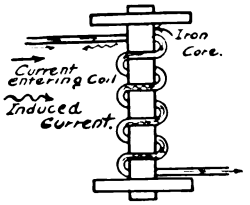


Fig. 21.

The resistance due to self-inductance equals 6.2832 multiplied by the frequency of the current times the Henrys.

To illustrate this we will suppose that a coil has an inductance of 5 Henrys. The frequency of the current is 60 cycles per second. Multiply 6.2832 by 60 and the result equals 365.1920 times 5, equals 1884.961 ohms.

From this it will be seen that a ringer possessing an inductance of 5 Henrys will offer a resistance* of over 1800 ohms to the passage of an alternating current at a frequency of 60 cycles per second, and as voice currents have a frequency ranging into the thousands, the opposition of the coil to the passage of such currents is very great.

To obtain the impedance of a coil, square the resistance, square the reactance, add these two quantities, and extract the square root of the sum.

From the above it will be seen that it is impractical to put many telephones in series, as the result of the self-induction of the ringer coils is to render the speech very indistinct and unsatisfactory.

Another serious objection to the series circuit is the fact that the voice and ringing currents must pass through all the bottom hook contacts of the different telephones on the line. This is shown in Fig. 20. In case the hook fails to make proper connection the entire line is out of service, and it is sometimes very difficult to locate just where the trouble is, a visit to every telephone on the line often being necessary, and it is generally the case that the trouble is found to exist in the very last instrument visited. This trouble was eliminated to a certain extent by wiring

*This is really "Reactance," but is spoken of here as simple resistance so as not to confuse the reader, as it really acts as resistance to an alternating current.

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the instrument as shown in Fig. 22. When this is done the instrument will ring in case the bottom contact is bad, for the ringing current will pass through the receiver and secondary of the coil and then through the ringer in the ordinary manner. The trouble due to self-induction and resistance of the ringers still remains, however, and for this reason series lines are rapidly going out of use.

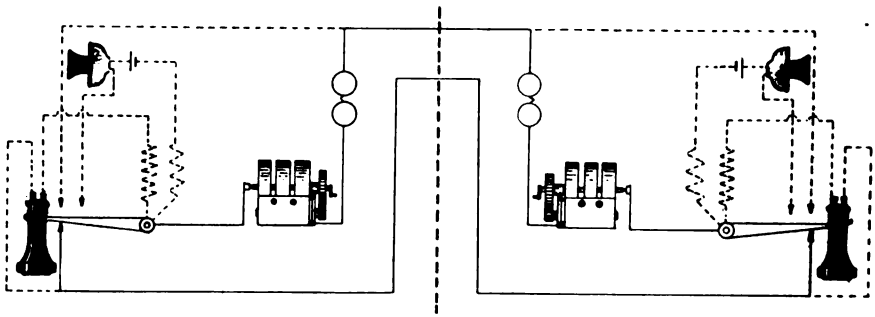


Fig. 22.

Series telephones may be used one on a line for ordinary exchange use, and when used in this manner give as perfect service as any.

Three telephones connected on a bridging circuit are shown in Fig. 23. The principal difference between this and the series circuit already noted is the fact that the different bells and generators are bridged across the line like the steps of a ladder, instead of being in series with the lines.

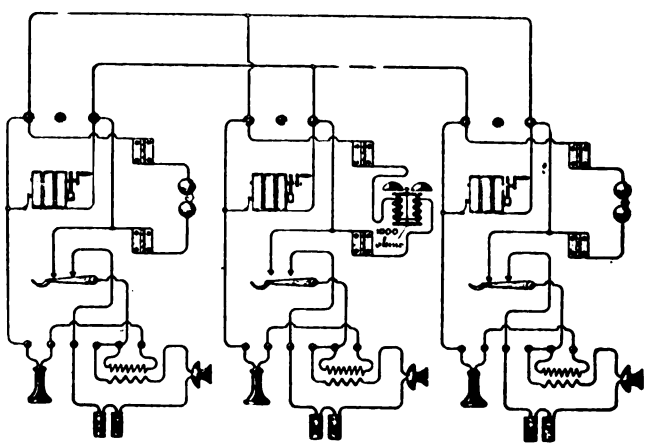


Fig. 23.

The generator in a series instrument is equipped with a set of shunt springs, so that except when the crank is turned the winding of the armature is short circuited, and offers no resistance to the passage of the current. This is necessary to remove the resistance of the armature from the circuit.

In bridging instruments the reverse of this is done. The generator armature, instead of being short circuited is open all the time except

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when the crank is turned, in which case the axle moves inwardly and connects the generator to the line.

In bridging instruments advantage is taken of the impedance of the ringer coils, which are wound with a great number of turns of wire and are of high resistance. They therefore offer an enormous resistance to the passage of the high frequency voice currents. When either of the end telephones calls the other, (Fig. 23) the voice currents will pass over the line from telephone to telephone, and will not pass through the ringer coils of the middle phone at all on account of its high ohmic resistance and impedance.

Another desirable feature in bridging instruments is the fact that there need be no bottom hook contact and the bells can be left always connected to the line wires which reduces the number of springs in the hook to those necessary for connecting the receiver and transmitter circuits.

From the above it will be seen that self-induction which is a hindrance in series work, is of great advantage in bridging service. Bridging ringers are therefore wound so as to possess as high self-induction and resistance as possible. 1600 ohms is generally accepted as the standard winding for bridging ringers. As the number of turns of wire determines the impedance, it will be apparent that simple ohmic resistance is not all that is necessary, and when extremely fine wire, such as is used in 2000 and 2500 ohm ringers is used, the actual number of

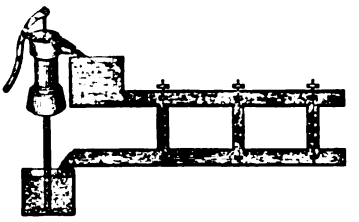


Fig. 24.

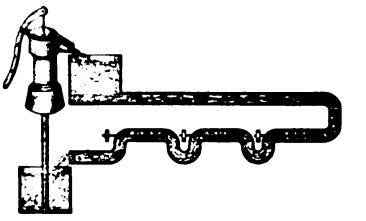


Fig. 25.

turns is somewhat reduced, as it has been found that a 1600 ohm ringer possesses a maximum of self-induction together with ohmic resistance.

The generators used in series and bridging work differ, as generators used in series work must be designed to deliver current of high voltage to force the current through all of the bells on the line, whereas generators designed for bridging work need not possess very high voltage, but must give a quantity of current sufficient to move all the ringers, as the current divides, a little bit passing through each ringer on the line.

The difference between series and bridging circuits, both as to talking and ringing is well illustrated by Figs. 24 and 25. By reference to Fig 24 which represents a bridging circuit, it will be seen that the water in the upper pipe subdivides, one third of the water flowing through each of the wheels, the return pipe taking it to the receiver tank. The pump in this illustration representing the hand generator, while the water acts in exactly the same manner as the current given forth. In Fig. 25 a series arrangement of the wheels is shown, and the water must flow through all of the wheels to get back to the receiving tank. It will be seen that a sufficient quantity of water to move all three of the wheels is necessary in the bridging arrangement, while a smaller quantity of water having a high pressure, will do the work in the series arrangement.

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It will also be seen that in the series arrangement, if one of the wheels becomes inoperative, the water could not flow through any of the wheels, while in the bridging arrangement if one of the wheels should cease to move, it would in no way affect the other two.

The actual resistance of an 80 ohm ringer to voice currents is approximately equal to 50,000 ohms. It will thus be seen that the two end subscribers on a series line of three instruments are obliged to talk through 50,000 ohms resistance in addition to the line resistance.

In the bridging arrangement a bell of 1000 ohms resistance possesses an impedance of much more than 25,000 ohms. It will thus be seen that any loss due to leakage through the ringer between the two end parties on a bridging line of three instruments is infinitesimal.

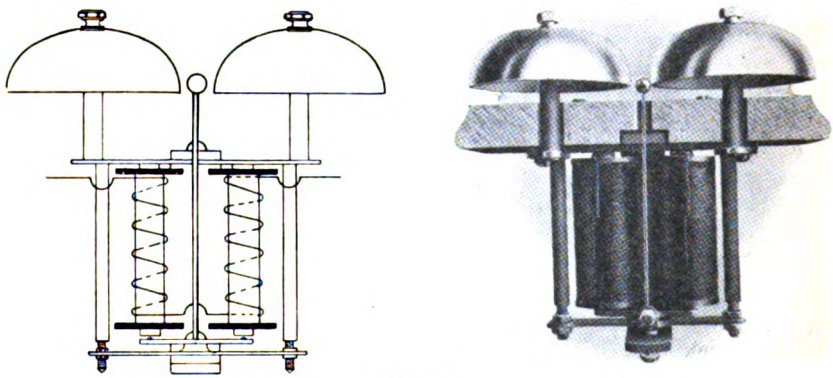


Fig. 26.

A standard telephone ringer is shown in Fig. 26. The side rods support a yoke in which is pivoted the armature, to which is connected the striker rod and ball. The permanent magnet is securely fastened to the cross piece to which the coils are fastened, and curves upward over the armature which it magnetizes.

The distance of the armature from the pole pieces is readily adjusted by turning the nuts on the side rods up or down. In the type of ringer shown in the figure as additional adjustment is provided by tapping the end of the magnet and inserting a screw, which can be turned while the bell is ringing, this springs the cross yoke carrying the armature, and the proper distance of the armature from the pole pieces can be accurately obtained. On long and heavily loaded lines the armature may be brought very near the pole pieces. This shortens the stroke of the clapper, and the gongs must be brought near together, or the clapper ball will not strike them.

The accurate adjustment of the distance between the gongs is important. The method of obtaining this varies in different ringers, but the common method is to fasten lugs to each bell post with slots cut in them, in which screws are fastened in such a manner that the posts can be clamped in various positions. The clapper should hit each gong and spring back. At rest on each side, it should be about 1-64th inch away from the gong.

The use of telephones in which the ringer gongs are mounted upon the wooden door of the instrument should be avoided. If the wood

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shrinks it will change the adjustment of the bells, and thereby render the instrument inoperative.

The length of the clapper rod plays a considerable part in the sensitiveness of the bell. A short rod will produce a weak but sensitive stroke which insures the instrument ringing, but the ring will not be very loud, while a long rod will secure a powerful stroke, but the bell will not be as sensitive.

The only difference between series and bridging ringers is the length of the wire coils. The exact dimensions as used by one manufacturer for a series ringer coil are shown at "A", Fig. 27, while a bridging coil is shown at "B". The heads are 1 1-16 inch dia. A series winding may be of 80 ohms resistance, which gives very satisfactory results when a number of series telephones are used on one line. This is no longer done, the principal use to which series instruments are now put being local exchange service, in which case the ringers should be wound to 250 or 500 ohms resistance. If ringers of low resistance are used, when two

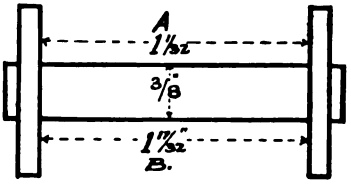


Fig. 27.

telephones are connected through the switchboard by means of an ordinary cord circuit in which the clear-out drop is bridged, the clear-out drop will be short-circuited by the low resistance ringers, and the drop will not operate perfectly when the ring off signal is given. If the ringers are wound to a resistance of 250 ohms no trouble from this source will be experienced.

Standard series and bridging windings on the size cores shown in Fig. 27, are given in the accompanying table.

One coil for	Turns	B. & S. Gauge Single silk Ins.	Layers.	Resistance, ohms.
250 ohm ringer	3360	33	32	125
1000 ohm ringer	8640	35	34	500
1200 ohm ringer	8096	36	32	600
1500 ohm ringer	9108	36	36	750
1600 ohm ringer	10160	36	40	800
2000 ohm ringer	11520	36	48	1000
2500 ohm ringer	13440	36	54	1250

*"To the average electrician who wishes to find the proper size of wire to use in the windings of electromagnets, the use of winding formulæ is often confusing. The graphic system, however, not only eliminates the necessity of formulæ, but makes the whole operation clear and simple."

In describing each of the accompanying charts actual cases will be cited to facilitate following the methods employed. No reference will be

*Chas. R. Underhill in Am. Electrician.

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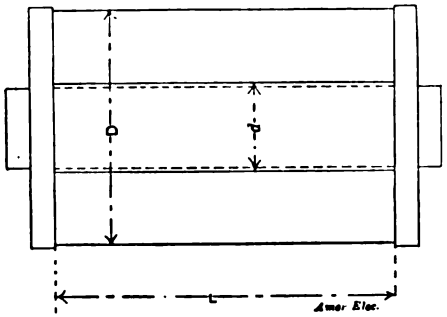


Fig. 28.

made to the theory of the electrical constants or how the charts are made.

In order to find the proper size of insulated copper wire to fill a given winding space, and have a given resistance, it is necessary to know the cubical contents of the bobbin, or the actual volume of the winding space in cubic inches, and the ohms per cubic inch for the various sizes of copper wire with various increase in diameters due to the insulation.

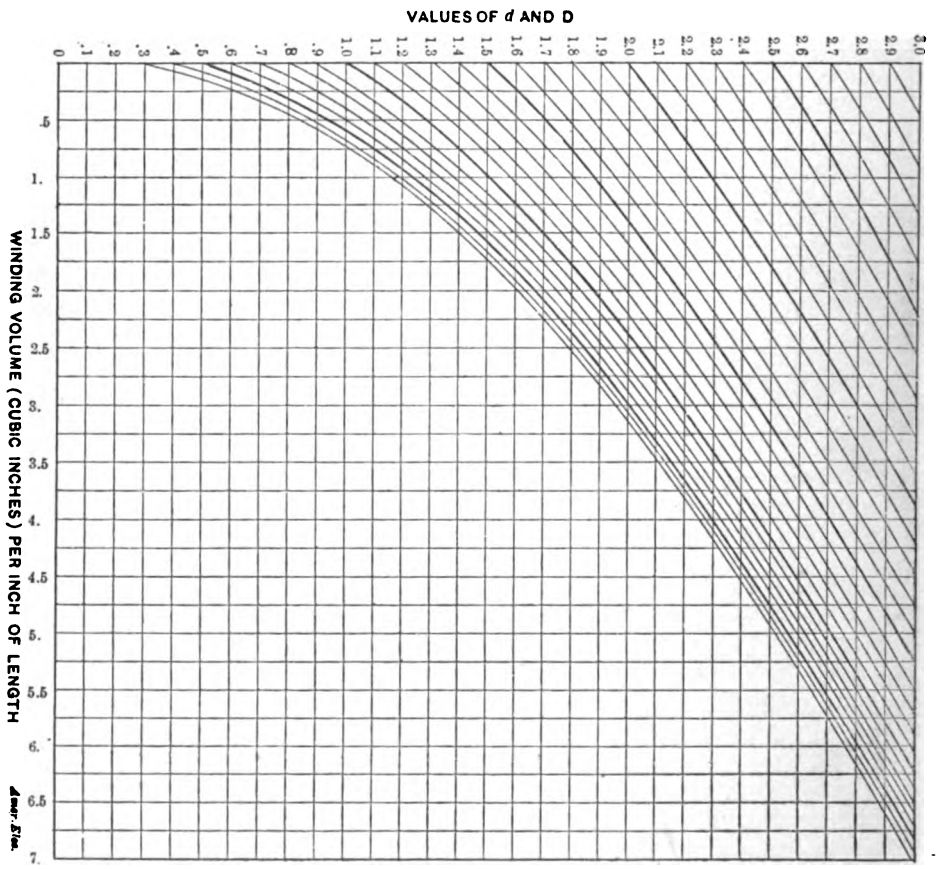


Fig. 29.

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Therefore, if the winding volume of a bobbin be 2 cubic inches, and the ohms per cubic inch 250, the resistance of the winding would be 500 ohms. It is very important that the actual available winding space should be taken; that is, the space which is left after the bobbin is properly insulated.

As most windings for electromagnets are wound upon a round core or tube, the round type of bobbin will be assumed throughout this article. This bobbin is illustrated in Fig. 28.

Referring to Fig. 29 the winding volume (in cubic inches) per inch of length of winding is found by following the curved line, which starts from the value of *d*, the inside diameter, to where it intersects the horizontal line corresponding to the value of *D*, the outside diameter, and then tracing vertically downward.

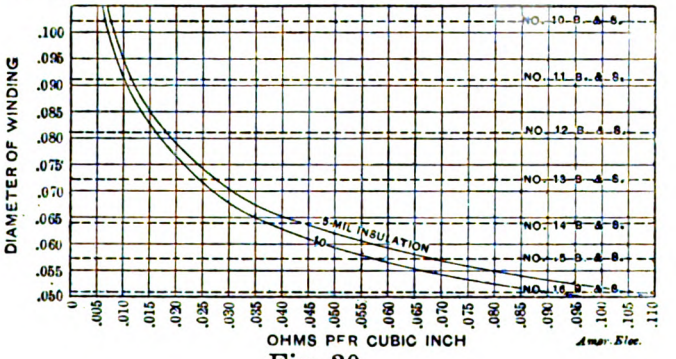


Fig. 30.

As an example, the outside diameter of a winding is 2 inches and the diameter of the insulted core, *d*, is .9 inches. Following the curve which starts at .9 it will be found that it intersects the horizontal line corresponding to 2 at the vertical line corresponding to 2.5 cubic inches per inch of length of winding. If the length, *L*, be 3 inches the volume of the winding will then be $2.5 \times 3 = 7.5$ cubic inches.

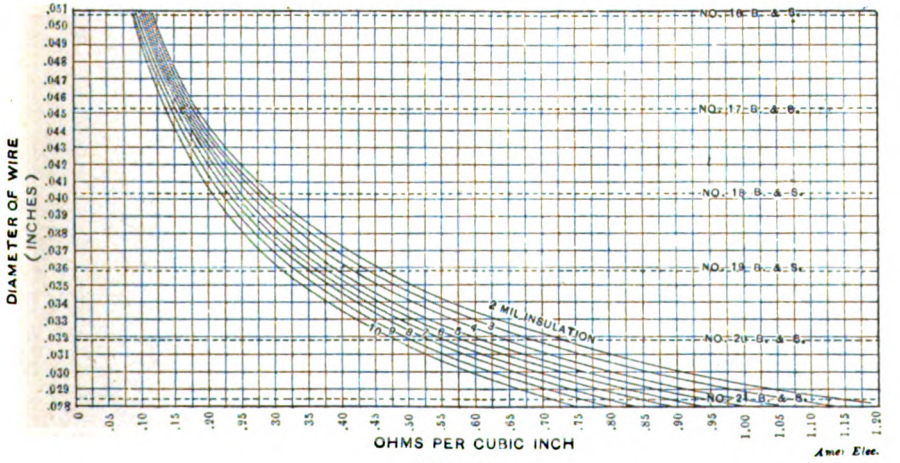


Fig. 31.

The charts, Figs. 30 to 35, show the ohms per cubic inch for various diameters of copper wire irrespective of the gauge number, with various

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increase in diameter due to insulation. A 4-mil increase means that the diameter of the insulated wire measured over the insulation, is 4 mils greater than the diameter of the bare copper wire. For convenience, the different sizes of wire of B. & S. gauge are shown in dotted lines, in positions corresponding to their diameters.

Although the increase in diameter due to insulation on the wire may vary with different manufacturers, the increase in diameter due to single silk insulation varies from 1.5 mils to 2.5 mils, and from 3 mils to 5 mils for double silk insulation. For cotton-covered wire the increase in diameter varies from 4 to 5 mils for single cotton, and from 8 to 10 mils for double cotton insulation. In any event it is well to caliper the insulated wire with a rachet stop micrometer, to ascertain the increase in diameter due to the insulation.

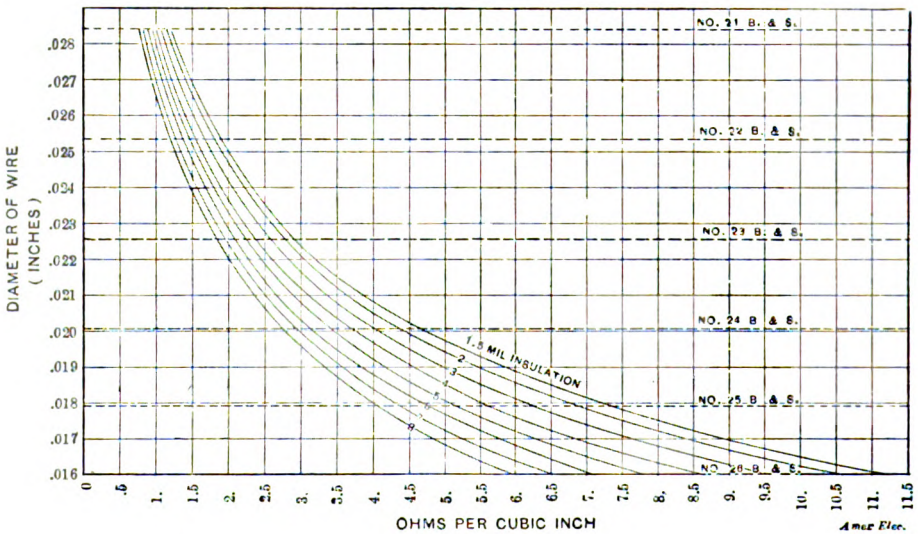


Fig. 32.

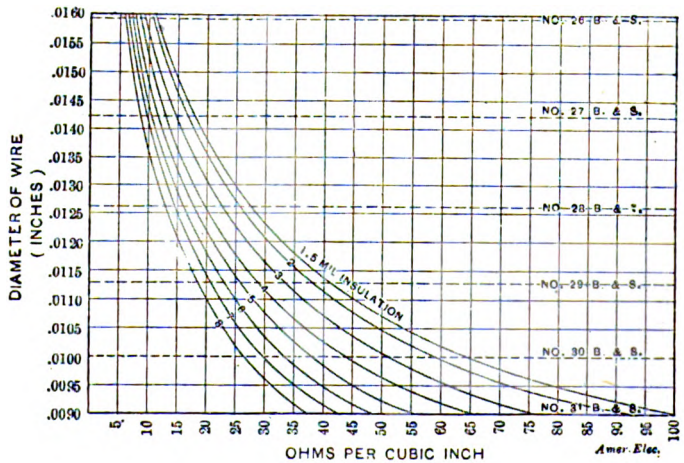


Fig. 33.

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As an example of the use of these charts, refer to Fig. 32 and assume that an insulated copper wire is desired which shall have a resistance of 4 ohms per cubic inch when wound on a bobbin. Tracing vertically upward from 4 it will be found that this result is obtained with a wire .018 inch in diameter, with 8 mil insulation, or with a wire .0184 inch in diameter with 7 mil insulation, etc., the largest diameter of copper being obtained with 1.5 mil insulation, the diameter of the wire being .0208 inch.

Therefore, if the 8-mil insulation be used a No. 25 B. & S wire would be used, while with even 3-mil insulation a No. 24 B. & S. wire would suffice, this latter wire being desirable.†

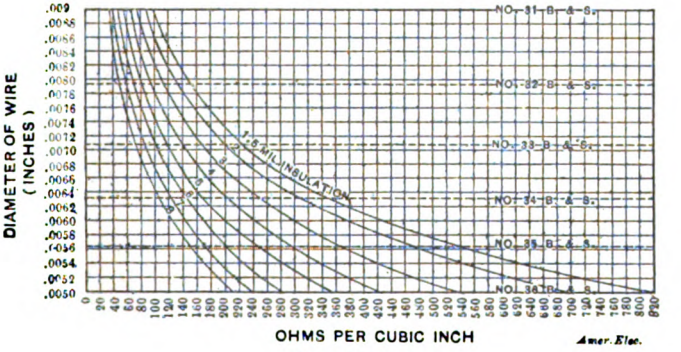


Fig. 34.

Likewise, if the bobbin will contain 1.24 cubic inches of wire, and a resistance of 500 ohms is required, it is evident that an insulated wire with 4050 ohms per cubic inch would satisfy this condition, and by referring to Fig. 35 it is found that No. 40 B. & S. wire with 1.5-mil silk insulation will meet this requirement.

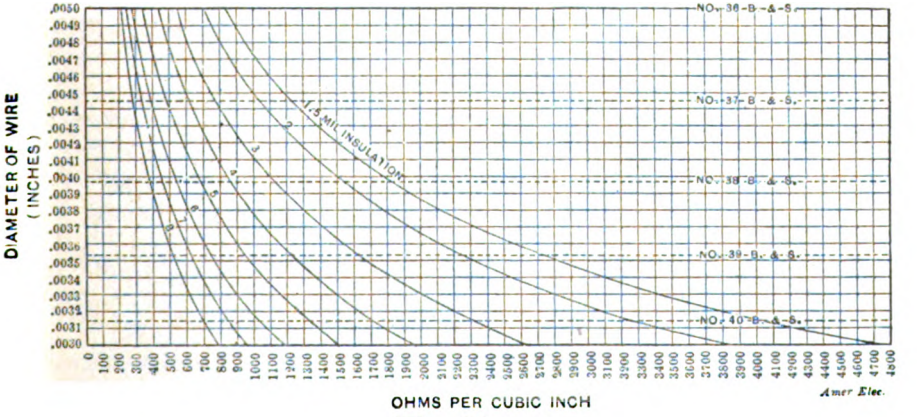


Fig. 35.

† See "Comparison of Common Methods of Coil Windings," American Electrician, May, 1905.

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The following cases will aid in approximating coils:

Case 1.—Given a bobbin with dimensions D = 3, d = 1.5, L = 3.25 resistance 500 ohms, to find proper size of wire with 4-mil single cotton insulation.

Referring to Fig. 29 it will be found that there will be 5.25 cubic inches per inch of length of winding which makes the volume of the winding 5.25 × 3.25 = 17.06 cubic inches. The ohms per cubic inch will then be 500 ÷ 17.06 = 29.3. Reference to the charts will show that the nearest copper wire with 4-mil insulation will be No. 29.

Case 2.—If No 30 B. & S. 4-mil insulated wire were used in the above will then be 500 ÷ 17.06 = 29.3. Reference to the charts will show that side diameter of the winding, all other dimensions remaining the same?

Referring to Fig. 33, it will be found that the ohms per cubic inch are approximately 44 for No. 30 B. & S. wire with 4-mil insulation. Therefore, the volume of the winding must be 500 ÷ 44 = 11.4 cubic inches, since the length of the winding is 3.25 inches the winding volume per inch of length will be 11.4 ÷ 3.25 = 3.5. Referring now to Fig. 29, and tracing vertically upward from 3.5 to the point where this line intersects the curve which starts from 1.5 the outside diameter, D, is found to be 2.58 inches. Therefore, wind to a diameter of 2.58 inches, with No. 30 B. & S. wire with 4-mil cotton insulation, and the resistance will be approximately 500 ohms.

While other cases may be worked out for any given diameter of wire and any increase due to insulation, the two cases above given are the most used, and after a little practice these problems may be very easily worked out."

With the majority of ringers, some tool is necessary to adjust the position of the armature in relation to pole pieces. For instance, with the type of ringer shown in figure 26, long used by the Bell and many independent companies, the cross yoke holding the armature in front of the pole pieces is mounted on two side rods, the yoke being clamped between two nuts on each rod. To adjust the armature, it is necessary to move these nuts up and down, and thereby increase or diminish the distance between the armature and the pole pieces. In the majority of ringers now sold the adjustment of the armature is accomplished in this manner.

There are a number of ringers on the market in which the position of the armature is permanent, while the pole pieces have threaded extensions which can be turned up or down, thus increasing or diminishing the space between the pole pieces and the armature. When proper adjustment is secured, these extensions are clamped by means of thin flat nuts.

With a view to securing a ringer that could be adjusted without the use of any tools, the type shown in figure 36 was developed, which may be taken as typical of modern ringer equipment.

The various parts are assembled in the standard manner, the gongs being mounted on posts which are adjustable by means of machine screws. After the gongs are once set, and this is usually done in the factory, they seldom require adjustment, and in this particular ringer, owing to the shape of the gongs and the adjustment of the various parts, all necessary readjustments when the ringer is in service can be accomplished by moving the armature up and down.

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The armature is mounted upon a cross yoke of spring brass, which has an initial upward trend holding the armature away from the pole pieces. A stem passes through this cross yoke down to the supporting

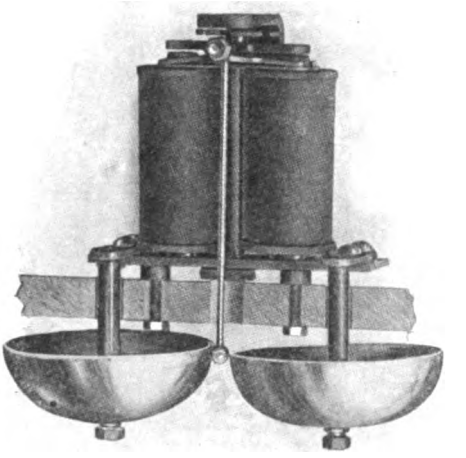


Fig. 36.

plate of the ringer frame. At the upper end of this stem is the adjusting wheel.

By turning this wheel, the cross yoke holding the armature is brought nearer to or further away from the pole pieces.

The adjusting wheel can be turned with the fingers alone as shown in Fig. 37, thereby adjusting the ringer while in actual operation.

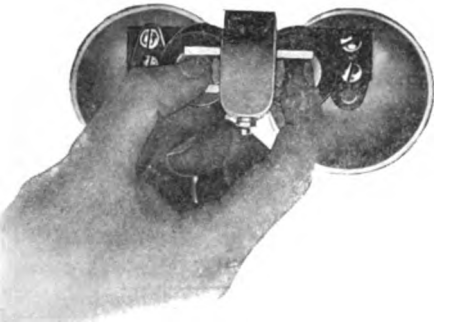


Fig. 37.

On long and heavily loaded lines where a very careful adjustment is required, and when the wheel should only be turned a very minute distance, any object such as an ordinary nail or key can be inserted in the slots of the adjusting wheel, and the wheel turned very slightly. This fine adjustment is shown in Fig. 38.

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Fig. 38.

After making the adjustment in the manner above described it is not necessary to lock the wheel in any manner as it is so placed in relation to the other parts that it is held firmly under tension, and cannot itself turn, or get out of adjustment. The operation of the ringer has no tendency to change the adjustment, and therefore same is entirely permanent.

By turning the adjusting wheel all the way up and removing the screws from the magnet and coils, the various parts of the ringer may be disassembled as shown in Fig. 39.

The coils can then be easily removed, as there are no stamped punchings forced around the ends of the pole pieces, nor are the coils used to support any of the other parts, as they are simply attached to the ringer frame by means of screws.

It would seem that this method of construction possesses some mechanical superiority over many older types, and it may be said that a

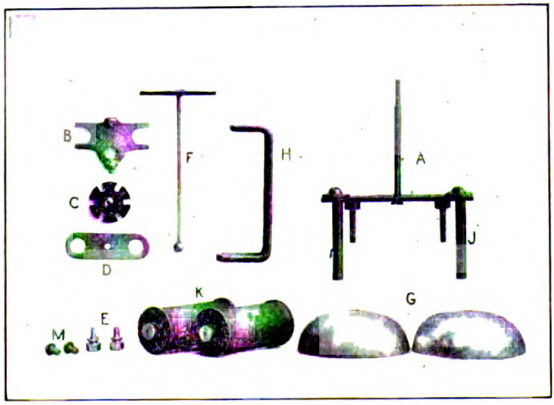


Fig. 39.

distinct gain in electrical efficiency is secured, inasmuch as the iron parts of any ringer are subject to a magnetic reversal which takes place during each revolution of the generator armature, and the more iron parts, the less sensibility the ringer will possesss. In this ringer all side rods, iron posts and other parts are eliminated, with the exception of the small adjusting wheel which is purposely made of soft iron, and this is placed directly between the end of the magnet and the armature itself, and serves

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to conduct the magnetic lines of force directly from the magnet to the armature, thus magnetizing same to a greater degree than has heretofore been possible. This secures a maximum of efficiency and a distinct gain in sensibility and strength of stroke has been noted, due to this method of construction.

A very unique method of assembling a ringer is used by the Sweedish American Tel. Co. This ringer is shown in Fig. 40. The magnet is mounted between the coils and it is claimed, a more uniform distribution of the magnetic lines results from this method of assembly. A screw is put in each end of the armature, adapted to strike upon the cores of the coils. These screws are iron with small brass tips and really form an extension of the armature. By turning them up or down, the armature adjustment is accomplished.

This method of assembly makes a ringer of compact and efficient design.

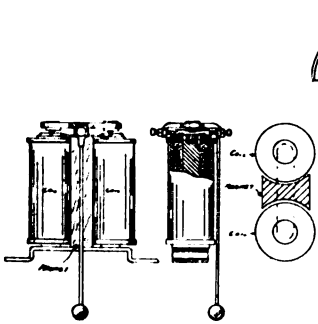


Fig. 40.

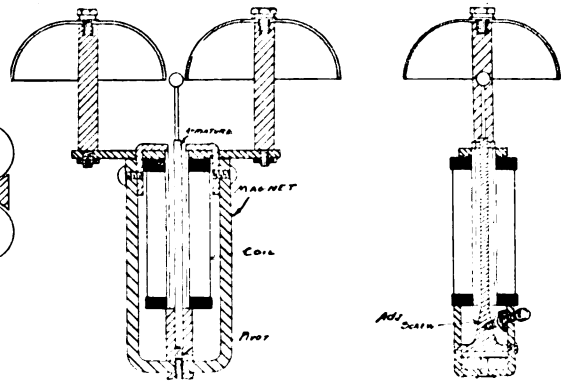


Fig. 41.

The majority of ringers in use are of the double coil type. Several types of ringers having only one coil have been developed. Typical of these is the ringer shown in Fig. 41.

The armature is pivoted at the bottom end while the top forms the striker rod. The coil is hollow and the armature passes through the center of the coil. A magnet is used, shaped as shown. When current flows through the coil the armature, which really forms the core, is magnetized, first in one direction and then in the other. This causes it to be attracted by first one and then the other of the magnet poles. This back and forth motion rings the bells in the usual manner.

For ordinary exchange service, one phone or a line, this type of ringer would seem to be entirely satisfactory, but for bridging line service, it would seem to possess the objection of not having sufficient impedance, owing to the absence of a core in the coil, the armature not being nearly as large in cross section as a proper core. Another objection is the fact that to get a high resistance winding on one coil, the wire must be very fine, and therefore more liable to break downs and other troubles.

To adjust the armature, adjusting screws are placed as shown in the figure. These however only limit the stroke of the armature, and do not bring it nearer to the magnet. The gongs are rigidly mounted on the cross yoke and no means of adjusting them are provided.

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Another single coil ringer in which the objection of no core is obviated, is shown in Fig. 42.

Here the coil is provided with a core, a U shaped magnet is used, and the armature is mounted over the core and magnet as shown. When current passes through the coil the armature is attracted alternately by the poles of the magnet as previously described.

Another type is shown in Fig. 43. The core of the coil forms the armature. The entire core and coil are pivoted at the bottom as shown and swing freely between the two pole pieces. By means of nuts on each pole piece, extension ends are adjusted so as to limit the swing of the moving parts.

By making this ringer with a larger core and long winding, sufficient impedance is secured. The wires leading into the coil are coiled in small spirals thus making them flexible.

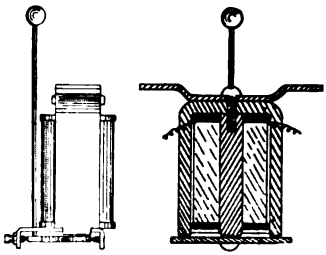


Fig. 42.



Fig. 43.

Compared with the double coil type, none of these types have ever come into extended use, although they possess advantages as to size and simplicity in construction. These types are of comparatively recent design and may prove of value to the trade when more fully developed.

In winding ringers it is customary to solder a comparatively coarse wire to the wire with which the ringer is to be wound. Then wrap tissue paper on the splice and begin winding. Before the first layer is put on, cover the core with paper.

It is very bad practice to wind the ringer spool in any old fashion, as it renders it more liable to short-circuit and the efficiency of the instrument is reduced. The wire should be wound in smooth layers.

Ringer coils intended for instruments to be used in mines and other damp places should be covered with shellac or paraffine. It is also advisable to shellac the generator armature. Instruments of this class require careful winding and treatment along this line.

In theory the coils of ringers and receivers should be wound in opposite directions. That is: if one coil is wound from left to right, the other coil is wound from right to left. This would be impractical from a manufacturing standpoint, as it would require "right and left" coils and cause confusion. In actual practice the inside ends of the coils which are both wound in the same direction are connected together, which accomplishes the same results. Particular attention should be paid to this fact. It does not matter which direction a pair of coils are wound in as long as they are both wound the same way, and both inside or outside ends are joined together. Do not join one inside and one outside end. It is better to connect the inside ends together and leave the outside ends to be connected to the wires in the telephone: for, in connecting the ringers,

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in case the outside ends should become broken, a few turns can be wound off and the coils can again be connected, whereas if the inside end was broken, it would be necessary to re-wind the entire coil before it could be used.

In removing the coil from the ringer frame, or when replacing same, make the screw connection between the ringer core and frame as tight as possible. This is necessary not only to have it tight, but also from the standpoint of securing greater electrical efficiency.

It is well to sand paper the end of the core and yoke to which it is connected.



Fig. 44.

It should be remembered that all ringers on the same line must be of the same resistance. This applies particularly to bridging circuits, and when re-winding ringer coils be sure that you use the same gauge wire as that which is taken off. The insulation should be the same. The gauge can be decided by securing a wire gauge, as shown in Fig. 44 and gauging the old wire. The kind of wire used for winding ringers comes on small spools which can be secured from the manufacturers, and by procuring one of the winding machines shown in Fig. 45, the exchange manager is well equipped for re-winding ringer and other coils.

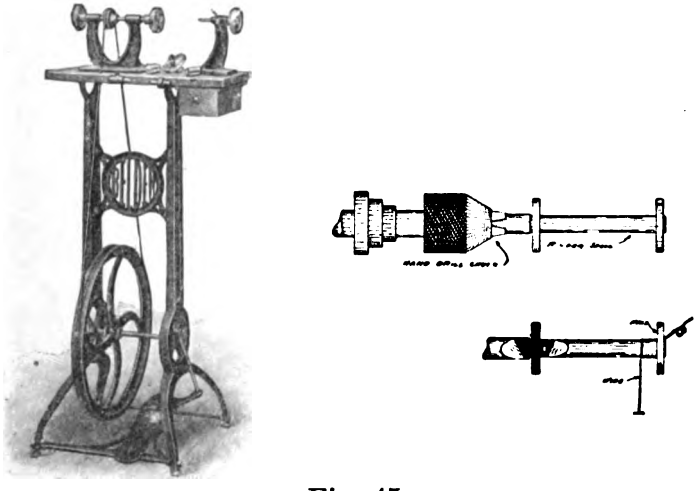


Fig. 45.

It is almost needless to say that a duplicate set of ringers of various resistances corresponding to those in the telephones in use should always

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be kept on hand, so that in case of an accident to a ringer in use, the trouble can be remedied by taking out the damaged ringer and substituting the duplicate. By observing this method, the subscriber will be pleased that his instrument is not out of service as long as it would be if the duplicate ringer had not been at hand. The damaged coil can be repaired at leisure.

It will be noticed that spools for 250 ohm ringers are marked "125 Ohms". The 250 ohms is the total resistance of the entire instrument.

A bridging ringer of 1600 ohms consists of two spools of 800 ohms each. Ringers for bridging work should possess great self-induction, which is obtained by making the cores long and shallow, and winding them with comparatively coarse wire. Resistance in itself is not desirable, but when the number of turns is increased the resistance is also increased. A ready means of distinguishing bridging and series ringers is by the length of the spools, the bridging spools always being longer.

Series ringers are usually tested by ringing them through a resistance of 10,000 ohms or more. A series ringer with an ordinary 3 bar generator in good order that will ring through a resistance of 10,000 ohms is in a satisfactory condition. An excellent test for a 1000 ohm ringer would be to connect the ringer, generator and a shunt coil, as shown in Fig. 46. Suppose the ringer to have a resistance of 1000 ohms and the generator to be a good 4 bar instrument, then the shunt coil "S" would be 40 ohms. When the generator is turned at the usual speed, the current which passes through the ringer may be considered equal to the amount of current which would pass if this ringer and 25 others of the same resistance were connected on one line.

It will be seen that this affords a rough method of adjusting ringers in the exchange before they are taken out and put on the line, while the operative efficiency of different makes of ringers can also be tested.

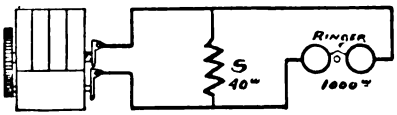


Fig. 46.

If ringers of make "A" will ring perfectly with a 40 ohm shunt, while ringers of make "B" fail to operate, it will be seen that "A" is the best instrument, and by making the shunt "S" variable, it may be stated that the best ringer is the one that will ring with the lowest possible resistance in the shunt "S".

This method of shunting bridging ringers is to be preferred to testing them to ring *through* a given resistance, as the high resistance is not always at hand, while the 40 ohm resistance can easily be made from some wire from an old ringer or induction coil.

These tests are very rough and serve only to approximate the efficiency. All tests of this nature are comparative: there is no standard.

It will be seen from Fig. 20 and 23, Pages 16 and 18 that quite a difference exists in the calculation of the resistance of series and bridging circuits. In Fig. 20 a series circuit of three telephones is shown. Suppose these instruments to have ringers of 80 ohms resistance, the total

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resistance of the circuit through which the ringing current would pass is 80 multiplied by 3, which equals 240 ohms.

In Fig. 23 a bridging circuit of three telephones is shown. We will suppose the ringers in this case to possess a resistance of 1000 ohms each. Here, instead of a total resistance of 3000 ohms, which would be the case in the series arrangement, it is one third of the resistance of one ringer, or 333 ohms.

From this it will be seen that to calculate resistance from one side of the line to the other in a bridging circuit, when all the ringers are the same it is simply necessary to *divide the resistance of one bell by the number of bells on the line,* while in the case of series circuits, with all bells alike, *multiply the resistance of one bell by the number of bells on the line.*

The foregoing measurements do not take into consideration the resistance of line wires.

If a line with 3 series telephones on it was 10 miles long and the wire of which same was composed measured 50 ohms per mile, there would be an additional resistance of 500 ohms which would be added to the resistance of the ringers which equals 750 ohms, which would make a total of 1250 ohms.

*"In calculating the combined resistance of a line of bridged ringers a different condition exists. This then becomes a problem in resistance in which several resistances are in parallel, combined with some in series. If the line wires do not have a resistance, then the three instruments located at B, C and D, Fig. 47, would be considered as ordinary resistances in parallel, and consequently their magnitude would be determined by the equation:

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

where R is the resulting resistance, and the others are the resistances of the respective instruments. In this particular case this formula reduces to the following:

$$R = \frac{R_1 \; R_2 \; R_3}{R_1 \; R_2 + R_1 \; R^3 + R_2 \; R_3}$$

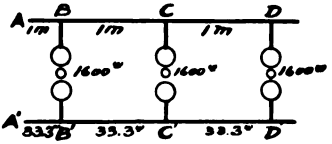


Fig. 47.

in which, if we substitute the value of the resistances as 1600 ohms each, we get a resultant R 533.33 ohms.

The line wires, however, are in series with the resistances, and these circuits must be taken into account. The current sent out on the A side

*Sound Waves.

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of the line from the central office, divides at B, part of it going through the resistance of the instrument at that place, and part of it continuing on through the rest of the circuit. At C the current again divides, going through the remaining two branches of the circuit. In order to compute the resistance of this circuit, we begin at CC'. The resistance as measured between these two points consists of the two coils located at C and D, together with the two miles of iron wire connecting these two places. The resistance of C to C', as measured around through DD' is equal to 1666.6 ohms, it being the resistance of the coil at DD' plus the resistance of the two iron wires, each having a length of one mile, and a resistance of 33.3 ohms. The resistance from C to C', through the instrument, is 1600 ohms. Combining these two resistances in parallel as given by the first formula above, we get the following:

$$\frac{1}{R} = \frac{1}{1600} + \frac{1}{1666.66} \qquad R = 816.6$$

Now the resistance as computed from B to B' consists of this resistance just computed above, considered as being in parallel with the resistance of the first instrument. The resistance of B to B' by the way of CC' is equal to the resistance between CC' or 1600 ohms combined with resistance just computed added to the resistance of two miles of wire, or 1600 ohms combined with 816.6 + 66.6 ohms.

Considering this latter resistance in parallel with the instrument BB', we again use the formula above, and compute the resistance of BB' as follows:

$$\frac{1}{R} = \frac{1}{1600} + \frac{1}{883.2} \qquad R = 569 \text{ ohms}$$

We have now computed the resistance of the circuit as measured across the point BB'. Add to this the resistance of the two iron wires, each one mile in length, from A to B, and from A' to B', or the total of 66.6 ohms, and we have

$$569 + 66.6 = 635.6$$

This is the true resistance of the circuit as measured from the point AA' to the central exchange.

The usual difficulty with problems of this kind is that one forgets to consider the line resistance, and is tempted to deal with the instruments as though they were in parallel, the circuit having no resistance. When twenty or thirty of such instruments as given in the above example are bridged across the line, the calculation of the total resistance becomes an extended problem, tedious, although not difficult.

It will be found, however, that in such a problem on account of the great difference in resistance between the instruments and the line wires, the resulting resistance of the circuit will not be widely different from that calculated upon the assumption that all of the instruments are in parallel with wires having no resistance. However, for accurate computation, the line wires must be taken into account. In the above example the

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difference is that of 635.6 ohms and 816.6 ohms or 181 ohms. This is an error of about 30 per cent."

In some cases after ringers have been in service for some length of time the magnets become weak.

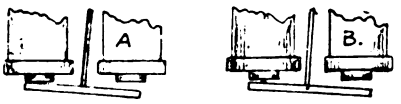


Fig. 48.

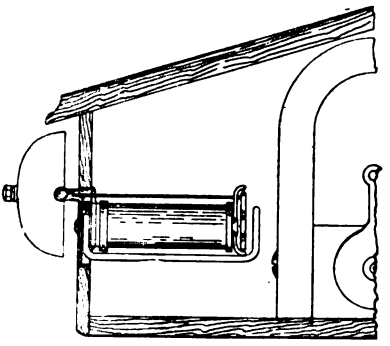


Fig. 49.

An ordinary ringer magnet should lift a weight of about 13 ounces, if not it should be re-magnetized.

Another trouble which sometimes occurs is that the armature will stick to the core of one or the other coil. This is caused by the armature coming in contact with the core, as shown at "A", Fig. 48. The manufacturers usually drive a small brass pin into the armature or end of the pole piece, as shown at "B". This prevents direct contact between the two, and sticking is thereby prevented. If the pin is all right and the sticking causes trouble, then the iron in the core has become magnetized and is not soft. There is no remedy for this trouble except to unwind the wire, and take the heads off the core, then heat it to red heat, cooling it slowly in the ashes of the fire, after which it can be rewound. This trouble is due to poor material, and ringers that have this defect should be returned to the factory and claim made against the manufacturers. Sometimes this trouble will develop in ringers of the best manufacturers, as it is very hard for a plant turning out hundreds of ringers per day to carefully inspect each one for a trouble as hard to locate as this.

Another trouble which has happened in connection with ringers used in telephones where the ringer is brought in close proximity to the generator, as in the type of instrument shown in Fig. 49, is that the ringer is sluggish, or strikes first one gong, sticking there a few strikes, and then striking the other and sticking. It has been found that the end of the ringer magnet nearest the generator, must be of the same polarity as the generator magnets. If the generator magnets are of an opposite polarity they will so affect the ringer as to neutralize the action of the ringer magnets, thereby causing the instrument to act in the manner above described. This should be remembered when placing ringers in this type phone, and the ringer magnets made accordingly.

There has been a tendency of late years to use bare wire windings for the coils of telephone ringers. It is true that a slight gain in theoretical efficiency is effected by this method, as the turns of wire are brought closer to the core, and their action on same is thereby increased. In

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actual practice this gain is very slight, and is not noticeable, while it is entirely offset by the fact that if the ringer coil is damaged in any way, a new coil is necessary, as the bare wire is wound on the coil by automatic machinery and cannot be unwound and rewound by the hand, which is not the case when ordinary silk insulated wire is used.

The bare wire windings are somewhat cheaper, and therefore among a certain class of manufacturers, have gained precedence. The use of ringers with bare wire windings should be avoided by managers who desire to rewind their own coils, and nothing but the best silk covered windings should be used. Recently wire with flexible enamel covering instead of silk, has been placed on the market. This appears to give satisfactory results.

The thickness of insulation is approximately half that of single cotton and two-thirds that of silk-covered magnet wire. This allows a larger number of turns on the same spool or same number of turns with a less weight of wire. The percentage of advantage of enameled wire becomes less in the coarser size and increases in the finer size. Enameled wire may be bent around a mandrel four times its own diameter without injury. Owing to the thinness of the insulation and its good heat conductivity, spools wound with enameled wire run at a lower maximum temperature and a lower average temperature than spools of cotton-covered wire under the same conditions. Enameled wire will stand a temperature of 212° F. without injury.

The diameter of enameled wire is as follows:

Size B. & S. Gauge.	Diameter.	Size B. & S. Gauge.	Diameter.
24	.022	32	.0092
25	.020	34	.0073
26	.0175	36	.0062
28	.0140	38	.0052
30	.0113	40	.0042

The most common trouble with ringers is an open coil. Before testing the coils on series telephones, disconnect the telephone from the line wire, then short-circuit the line posts and turn the crank. The bells should ring in the usual manner. If not, place an ordinary receiver across the terminals of the bell, and leave the line posts short-circuited. The generator should then turn quite hard, and the generator current should be heard in the receiver. If not, the trouble may be somewhere else in the circuit, but if the current can be clearly heard in the receiver, it is a pretty sure indication that one of the ringer coils is open.

In case of bridging instruments, disconnect the line wires and turn the crank, but do not short-circuit the line posts. If the bell does not ring, place the receiver across the terminals of the ringer as in the case of the series instrument. The generator should turn hard: if not, look somewhere else in the circuit for the trouble.

If the circuit is O. K., but the bells do not ring, connect one receiver terminal to the left hand side of the circuit where it enters the ringer, then connect the other receiver terminal to the splice between the spools. If a sound is heard, then the trouble is in the coil between the receiver terminals. If no current or a very weak sound is heard, put the receiver terminal on the outside of the other spool, still keeping one side of the receiver connected to the middle point. Then if the sound of the generator is heard, the trouble is in the other coil. If no sound is heard

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in either case put the receiver terminals across the ringer and if sound is heard then both of the ringer spools are open.

Biassed and "Harmonic" ringers and other special types are described elsewhere in connection with the special equipment with which they are used.

Another type of ringer sometimes used in telephone work is the Schwarze bell, which requires less current than the usual battery bell. Two ordinary dry cells will operate the smaller bells, shown in Fig. 50, over one mile of No. 18 Copper Wire.

When applied on High Tension Current,—for instance, on 110 volts —all that is necessary is a 110 volt lamp in series with the bell, or a resistance unit equal to a 110 volt lamp, to bring the amperage down to the rating which is noted on the back casting of every bell. This enables operation from one Central Station to large buildings without using heavy wire

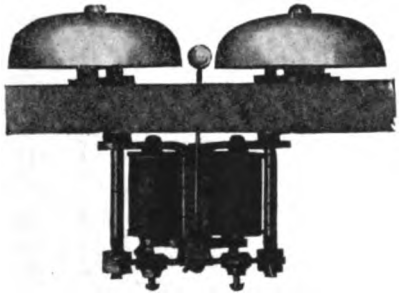


Fig. 50.

To rewind Schwarze bell coils, always when unwinding them, count the layers and the turns of both the primary and secondary carefully, and rewind them in exactly the same manner with the same size wire. The secondary or retarding winding is always to be short circuited. This arrangement is shown in Fig. 51.

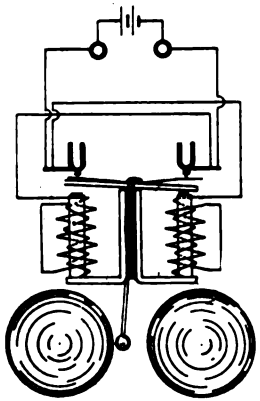
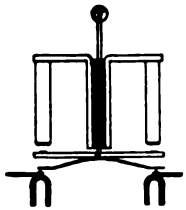


Fig. 51



a

The contact springs should strike the contact points equally on each side, and when the armature stands neutral both points are slightly open, as shown in Fig. 51 at a. Adjust the gongs to the bell hammer in such a

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manner that the hammer will strike both gongs with an equal blow, and so that the bell hammer will have a sufficient whip. When applying bell in circuit watch the rating for operation, see that the armature swings free, and that the small coil which makes connections between the armature and bracket is intact, and see that the brass points in the armature hold the armature from direct contact with the iron cores. This bell is made with gongs from 2½ to 28 inches in diameter.

GENERATORS.—The theory of the creation of current by the magneto generator was discussed in the first part of this chapter and the design of the telephone generator at the present day is almost solely a question of good mechanics. The pole pieces should be made of the best soft iron. The center opening, or field, is accurately milled to shape, and the permanent magnets, which should be made of the very highest quality of steel are placed with their north poles in connection with one pole piece, and their south poles in connection with the other.

The armature, a detailed drawing of which is shown in Fig. 52, is made from many punchings of soft iron, or is a special soft casting, and is accurately ground to fit the opening between the pole pieces as closely as possible. In some makes this is within one one-hundredth of an inch. If possible, the steel axle upon which the armature is mounted should be ground to an exact fit in the brass bearings, which should be sufficiently long to afford a firm support for the axle.

The gear wheels should be made from heavy cast brass with cut teeth, and should be so designed that they will turn smoothly and noiselessly without wear.

The magnets are bent by various processes. Some bend the magnets cold, while some heat the magnets in the middle and make the bend, tempering the magnet afterwards.

In bridging generators the greatest attention should be paid to securing magnet steel of very best quality. Everything else being equal, the strength of the generator is proportional to the cross-section of its magnets. An excellent size magnet is made from ⅞ x ½ or ⅜ inch bar.

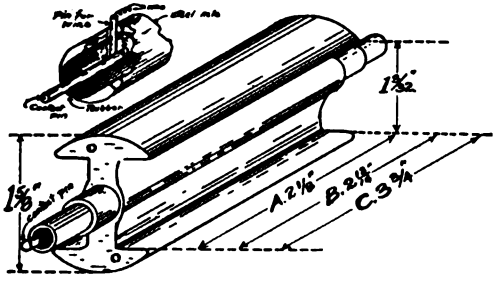


Fig. 52.

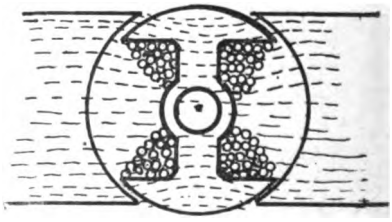


Fig. 52a.

As the strength of the machine is proportional to the cross-section of the magnets, it will readily be seen that a 4 bar generator, each bar ⅞ x ½ inch is more powerful than a 5 bar magnet with bars ½ x ½ inch. It is not a question of the number of bars, but the size, which determines the strength of the machine.

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*The general trade offers permanent magnet generators equipped with from three to eighteen bars of horse shoe type.

These magnets vary in length, and greatly in cross-section. Therefore we find that many of the four bar magnetos are more powerful than some others of five bars.

An illustration of this is shown in two types most popular to the telephone trade for bridging and toll line use:

Five bars: Cross section $\frac{3}{8}'' \times \frac{5}{8}'' \times 5$ bars $= {}^{75}/_{64} = 1^{11}/_{64}$ sq. in.

Four bars: Cross section ${}^{4}/_{8}'' \times {}^{6}/_{8}'' \times 4$ bars $= {}^{96}/_{64} = 1\frac{1}{2}$ sq. in.

In the above case the four bar magnet field contains 28 per cent greater cross-section than the five bar field.

We must bear in mind that our magnets are very effective, if subdivided for the purpose of covering the whole length of the field—where we are limited in length and cross-section by the economy of present practice—and the processes applied in magnetizing them: so it is clear that one cannot depend on the number of bars, nor, always upon the cross-section of them, in selecting the best generators. One can get poor results from five or more small bars well magnetized, or the same number of large bars poorly magnetized.

Of course, it is understood that the analysis of metals, processes of heating, tempering and handling of these permanent magnets during their manufacture enter largely into the question of good production and long life. In order to secure the greatest output, the permanent magnets should be as strong as possible, as the greater the number of lines of force flowing across the field, the greater will be the current. The shape of the poles, and the distance between them has a great deal to do with this. If pieces of soft iron be placed between the poles of the magnet they concentrate the lines of force and cause them to pass across the field better than if they were not used, and therefore soft iron is used for the pole pieces.

As the object sought is to get as many of the lines of force as possible to pass through the windings, the armature core is also made from softest iron. This causes the lines of force to pass through the wire windings in the manner shown in Fig. 52a.

The importance of a small air gap, or space between the armature and pole pieces is at once apparent from this figure, as it will be seen that the greater the air gap, the more lines of force will be lost, and the greater the loss of power will be. Generators should therefore be selected in which the air gap is made as small as possible.

The wire used in winding an armature should be of the largest size that will give the desired number of turns, as the voltage given depends directly on the number of turns of wire used.

In series generators the amount of current required is not great, while the current should possess a very high voltage.

The dimensions of an armature for a 3 bar machine are shown at "A", Fig. 52, Page 38. This is wound to a resistance of 650 ohms with 3120

*Am. Tel. Journal.

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turns of No. 36, B. & S. G. single silk covered wire. One end of the winding is soldered to a pin driven in the steel axle, while the other end is soldered to an insulated brass pin which extends through the end of the armature, as shown in upper corner of Fig. 52, and is intended to make connection on the contact spring which is mounted on the end of the generator.

A 4 bar generator armature, dimensions of which are given at "B", Fig. 52, is wound to a resistance of 330 ohms, with 2640 turns of No. 33 B. & S. G. silk covered wire, while the armature of a five bar machine, the dimensions of which are shown at "C", Fig. 52, is wound to a resistance of 200 ohms, with 1760 turns of No. 31 B. & S. G. silk covered wire.

In winding generator armatures it is absolutely necessary to secure some form of revolution counter. The simple counter described on Page 57 can be used for this purpose. One half the number of turns should be wound on one side for the armature, taking care to wind the wire evenly and smoothly. The wire can then be crossed over and wound on the other side with exactly the same number of turns.

In some types of armatures the winding space is constructed as shown in Fig. 53, and the wire can be evenly wound, thus saving time and obviat-

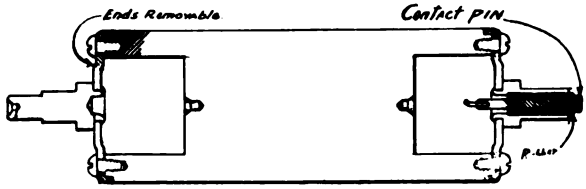


Fig. 53.

ing the necessity of counting the turns on each side. An increase in efficiency is said to be secured, as a larger amount of wire can be wound on the armature.

Before winding, the space on the armature should be carefully insulated with paper or cloth and shellac. Before the winding is put on a

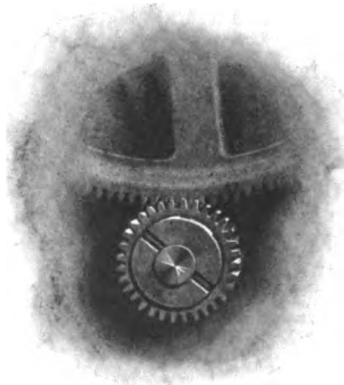


Fig. 54.

string should be placed crosswise in the armature slot, the wire is wound over the string, and the string securely tied down to prevent the wire from

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coming loose. The entire armature should then be heavily coated with shellac and allowed to dry before using.

Shellac is not absolutely the best substance that can be used for this purpose, but it is one of the most readily obtainable. The shellac should be of the best grade, and should be dissolved in 95 per cent. alcohol. Wood alcohol, or alcohol containing water, should not be used, as it will seriously impair the instrument.

The small gear wheel on the generator armature is usually attached by means of a Cotter Pin or other device, which allows some lost motion. The object of this is to enable the user to start the machine without a sudden jerk, which would happen if the gear was rigidly connected to the armature. This also insures smooth, noiseless running, and resulting uniformity in the current waves generated. The Driving Gear used by the Holtzer Cabot Electric Co., is shown in Fig. 54, and in detail at U. L. M. and R. Fig. 55. The two springs R. are placed inside piece J. and held in place by cap M. which is held by piece L. to armature shaft. The small gear wheel J, is loose on the shaft, and can only turn as far as the elasticity of the springs will permit, owing to the small projection inside of M. which engages the springs. Fig. 55 shows the generator disassembled.

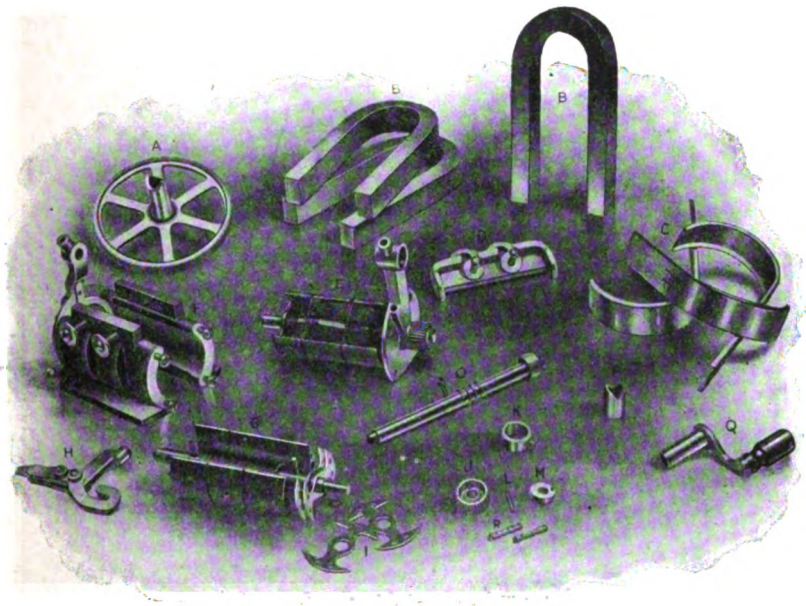


Fig. 55.

The shunt springs H. Fig. 55, and method of operating same are the parts of the instrument which usually cause trouble. Several arrangements for series work are in common use. Two of these are shown at "A" and "B", Fig. 56. At "A" it will be seen that the axle on the large wheel is normally in connection with the spring, "X", which connects to the insulated pin of the generator winding; the winding is thereby short circuited, which will be noted by tracing the circuit from "P" to "F". When the crank is turned, the axle moves outwardly, and opens conection

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at "X". This connects the generator winding shown by the spiral dotted line, in circuit.

The other type of series shunt is shown at "B" in the figure. Here it will be seen that the armature winding is short circuited by the long spring "X" coming in contact with the inner spring "Y" thus short circuiting terminals A and B. When the crank is turned, the axle moves inwardly, and in this case forces the spring "X" out of connection with the spring "Y", thereby connecting the armature winding to the terminals "A" and "B". It would seem that the method shown at "A" is to be preferred, as the axle always forms a rubbing connection on the spring, whereas in the method shown at "B" the connecting points simply touch and do not rub, and a possible cause for trouble exists.

Several methods of arranging the springs in bridging instruments exist. Referring to the method as shown at "C" Fig. 56, it will be seen that normally the axle of the large gear wheel is out of connection with spring "X", and when the crank is turned, the axle moves inwardly, thus connecting the generator winding to terminals "A" and "B".

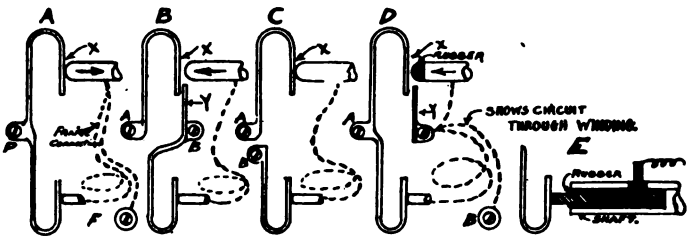


Fig. 56.

The type of shunt shown at "D" can be used for series or bridging generators. For series lines connect to A and B and winding is short circuited until crank is turned. For Bridging, wires shown by dotted lines are disconnected from Y, lines are connected to Y and B and crank is arranged to move outwardly, *away* from X, thus making A contact on Y and completing the circuit.

The armature contact as shown at "E", Fig. 56, is often a source of trouble. The pin projecting from the shaft should be as large as possible, and the spring bearing on the pin should be long and flexible, so that it will not lose its tension, in which case it would fail to make connection.

It is customary in the best types of generators to bend the spring in a "U" shape form, as shown. If the generator fails, it is best to examine the spring which should be held against the end of the pin while the crank is turned. If it is found that the spring does not make good connection, the trouble can sometimes be remedied by bending the spring so that it will properly press upon the pin.

The usual method of rating the output of generators is to state the ohms resistance through which they will ring. It is about as absurd a method as could be imagined, as it is seldom if ever stated what the resistance of the bell is that the generator is supposed to ring. For instance: in connection with a 10,000 ohm series generator, it is not stated what resistance bell the generator will ring through the said 10,000 ohms. It must be supposed on the part of the purchaser that the manu-

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facturer means the generator will ring its own bell through 10,000 ohms. This is the usual acceptance of the statement. For ordinary exchange use a generator that will ring the bell on its instrument through a resistance of 10,000 ohms will prove satisfactory.

For bridging work, the requirements are almost the reverse, and it is not the matter of resistance through which the generator will ring its own bell, but the number of bells the generator will ring.

Some bridging generators are stated to ring through 100,000, 200,000 or more ohms. This is of little consequence, and in purchasing bridging generators the fact to be considered is, how many bells will the generator ring on a given line. An ordinary 4 bar generator, "G", Fig. 57, should ring the bell "R" of 1000 ohms resistance, with the shunt "S" of 40 ohms resistance, through a resistance of 2000 ohms; while a 5 bar generator should ring the same bell through a resistance of 3000 ohms.

Generators complying with these requirements will be found to give satisfaction. The bell, of course, should be carefully adjusted, and in testing heavy duty 5 bar instruments, it is well to decrease shunt "S" to 36 ohms. This may be considered equal to ringing fifty 1600 ohm bells through 2000 ohms resitance.

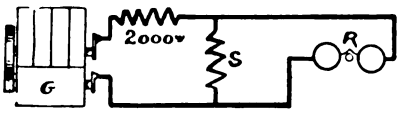


Fig. 57.

It is necessary in some types of generators to remove the magnets when repairing the instrument. When replacing the magnets they should be carefully placed so that the north poles are on one side and the south poles on the other. This is readily determined by taking the magnets and so arranging them that they do not stick together. If they stick together when the ends are touched on each other, then they are in the wrong position. They should be replaced in the machine with like poles all on one side.

In testing generators it should be remembered that the speed at which the crank is turned has a great deal to do with the output.

For testing purposes it is well to adopt a speed of 150 turns of crank per minute, which is about the speed the average man turns when making a call.

The result from different size generators at this speed should be as follows or better, these measurements counting for little, however, unless special instruments are used; ordinary voltmeters will not answer:

3 bar generators 65-90 volts 150-200 milliamperes.
4 bar generators 70-90 volts 250-300 milliamperes.
5 bar generators 75-110 volts 325-400 milliamperes.
A complete generator is shown in Fig. 58.

*Permanent magnets of telephone generators and polarized ringers actually do, from various causes, lose a portion of their magnetism or in some cases a complete demagnetization is effected. It is needless to say

*American Telephone Journal.

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that manufacturers of this type of equipment have made most careful studies of this subject, and while it is possible to use special magnet steel and to "age" the magnets so that under average conditions they will hold their magnetism practically indefinitely there is still a chance for a further loss of magnetism. For example, a generator when new will give a certain output due to its strong magnets. If this generator is operated on a short circuit for any length of time the armature reaction will establish lines of force opposing those of the permanent magnets and of sufficient magnitude to greatly weaken them. It is easy to see that on heavily loaded bridging telephone lines a similar action might in time greatly weaken the generators.

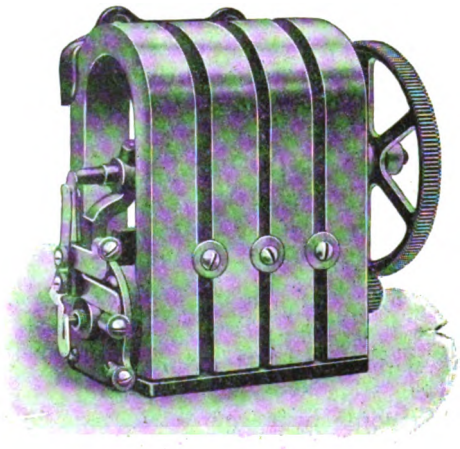


Fig. 58.

Another and not uncommon way in which generator magnets are demagnetized is through a discharge or leakage of direct current through the generator armature winding. This is only possible when the generators are not provided with a shunt. The permanent magnet of a polarized ringer is not usually affected by the passage of current through the windings, as when correctly designed it occupies a neutral position in respect to the magnetic circuit of the coils. In addition to the losses resulting from the action of electric currents a partial de-magnetization of any magnet can result from mechanical shocks, so that even with the best construction it must be assumed that, when a big factor of safety in operation is not provided, there will be in time a necessity for re-magnetizing.

Polarized ringers for regular exchange work have a sufficiently large factor of safety, but on bridging lines where the circuits are generally loaded until the limit of signalling is reached there is no margin left and a very slight weakening of the permanent magnets of the generators will immediately become known. As previously mentioned, the reaction in a generator under such conditions has a tendency to cause this weakening, so that from this point of view the practical or limiting load on a bridging line is reached long before the signal becomes questionable.

The act of removing or replacing generator magnets, such as taking them from one generator and placing them in another, will greatly

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weaken them. In every case, they should be strongly magnetized before being replaced, thereby giving the generator its original large output.

The magnetizing of new magnets or the re-magnetizing of old ones must be thoroughly done as there is considerable loss of magnetism during the process of assembling the apparatus. To prevent too great a loss, when the magnets are not immediately used as soon as magnetized, a "keeper" or armature of Norway iron is placed across the magnet poles until used.

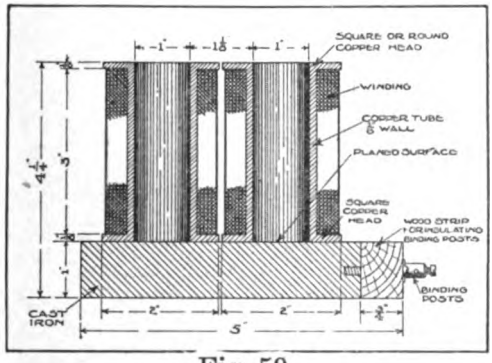


Fig. 59.

A simple and efficient magnetizing device, one which can be readily constructed without the use of special tools, is illustrated in the accompanying drawings. Fig. 59 shows a cross section with dimensions, while Fig. 60 shows a perspective view of the magnetizer with a generator magnet inserted. It consists of a base of magnetic metal such as annealed Norway iron (cast iron or steel will do) with a finished or plain upper surface. Upon this base are mounted two solenoids, made exactly alike

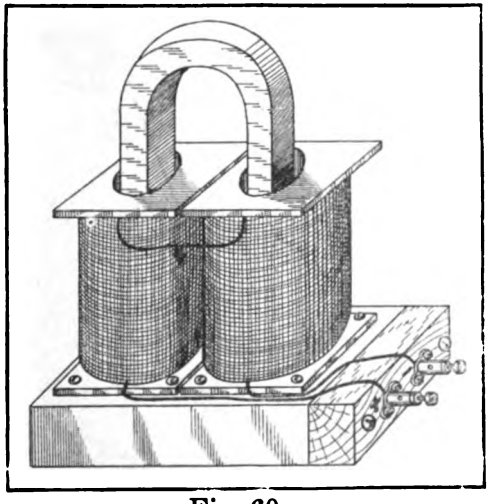


Fig. 60.

and with openings large enough to admit a generator magnet loosely, so that its ends will rest squarely on the surface of the base plate. In this

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way the coils act directly on the magnet, and the only air gaps in the magnetic circuit are those between the ends of the magnet and the base plate, the latter serving as a yoke. This not only simplifies the construction of the magnetizer, but gives a most efficient electrical arrangement.

The spools can be made from any metal or thin wood, but it is preferable to use seamless copper tubes with sheet copper heads so as to give a quicker action to the coils.

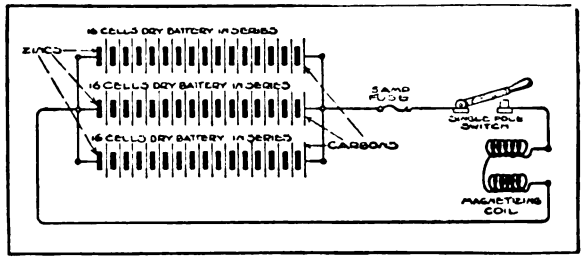


Fig. 61.

When a direct current lighting circuit of 110 or 220 volts is available the magnetizer should have each spool carefully filled with a winding of No. 32 B. & S. gauge single silk covered copper magnet wire. This winding should be done in layers and the completed coils covered with book binders' cloth for mechanical protection. Before winding the spools should be carefully insulated with heavy paper and then shellacked. A good paste containing no acid or other harmful ingredient should be used for fastening the paper insulation. (The paste known as "Photo" or "Photo-Library" paste will do).

It will probably be found necessary to insert layers of paper at intervals during the winding so as to cover rough layers of wire and allow the remainder of the winding to be laid on smooth. It is not advisable to put more than five or six layers of paper on each spool as valuable winding space will then be sacrificed. However, the presence of several papers between the layers will add to the insulation of the winding and for that reason is an additional advantage. The inside ends of the two windings should be connected together, while the outside ends are to be attached to the insulated binding posts provided on the base plate. The two windings will then be in series so as to act together. If the connections are reversed the inserted magnet can be easily withdrawn when the current is flowing.

If no lighting circuit is available for furnishing current for the magnetizers, very good results can be accomplished by using dry cells or other primary battery connected so as to give approximately 24 volts. As each dry cell when new gives one and one half volts, there should be at least sixteen connected in series, or if the cells are small, two or more sets of sixteen in series should be connected in multiple as shown in Fig. 61. For this low voltage the magnetizer should have a winding of No. 26 B. & S. gauge single silk covered copper magnet wire.

In remagnetizing old magnets it is advisible to insert them in the solenoids in such a position as to increase the magnetism rather than to demagnetize them. The proper direction is readily ascertained by means of a small pocket compass or by suspending the magnet above the solenoid while the current is flowing as shown in Fig. 62. In the latter method

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the magnet will revolve so that its north pole will come over the south pole of the solenoid. It should be especially noted that it is necessary to insert the magnet in this position, so that its south pole will be in the north pole of the solenoid.

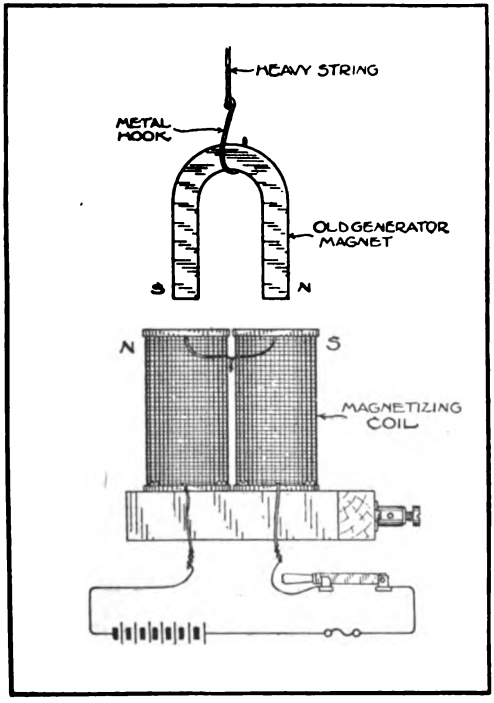


Fig. 62.

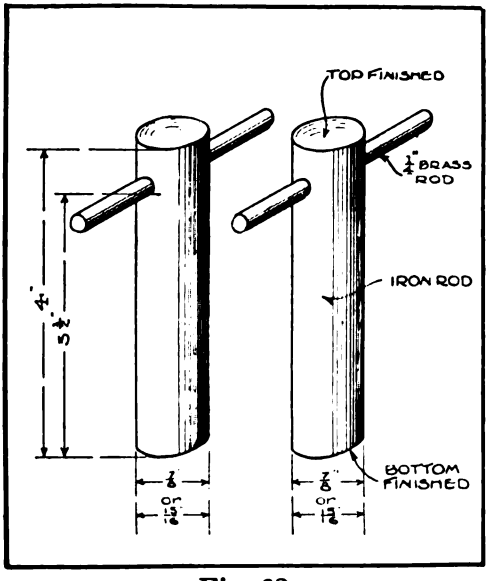


Fig. 63.

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When using the magnetizer the magnet should be inserted in the solenoid before the current is connected and removed after the switch is open. A few seconds is sufficient time to give a good magnetization, the upper or projecting portion of the magnet being rocked during this time so as to settle its poles into better contact with the base plate. These magnetizing coils can be used for re-charging ringer or receiver magnets by providing iron cores as shown in Fig. 63 for the solenoids.

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CHAPTER III.

COMMERCIAL TALKING EQUIPMENT.

As the receiver was the first piece of telephone apparatus constructed and yet remains one of the most important, it is advisable to consider its construction and repair first. Every receiver must possess three qualities. It must faithfully reproduce sound without distortion, and with as little diminution as possible, and must be so designed and constructed as to retain under all conditions of temperature its receiving qualities in spite of the rough handling to which this instrument is subjected, without need of re-adjustment or repairs. It should be practically indestructible.

The first of these qualities can be called "Electrical Efficiency", the second, "Permanency of Construction" and the third "Mechanical Strength".

In regard to electrical efficiency, it is a fact that all first class receivers on the market talk about the same when each one is new and properly adjusted. It takes an expert with delicate testing apparatus to distinguish between receivers of a half dozen of the leading manufacturers. In other words: they are all electrically efficient to a marked degree.

Early models of the receiver were of the single pole variety, in which a straight magnet was used with a coil mounted upon one end. In the very early models the containing case was of wood. Now hard rubber or what is known as "Composition" shell are used. These are unaffected by temperature and of much higher insulating quality than wood.

It was soon found that an increase in the efficiency of the instrument would be obtained by making the magnet "U" shaped, and using two coils. This is what is known as the Bi-polar construction, and is now universally adopted.

One of the principal defects in many of the existing types is the fact that the adjustment of the distance between the pole pieces and the diaphragm varies, due to atmospheric changes, as the metal and the containing case expand or contract differently, thereby throwing the magnets nearer to or further away from the diaphragm.

In the early types of Bi-polar instruments an attempt was made to remedy the unequal expansion of the metal and rubber parts of the instrument by attaching the metal parts to the rubber shell near the diaphragm by means of a threaded portion which screws into the shell. This object was defeated, however, on account of the use of a screw which was used to hold the block upon which the binding posts were mounted, in place at the rear end of the case; this screw going into the metal part of the receiver. This and other defects in construction caused the threads holding

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the metal parts to loosen from expansion and contraction, which made frequent re-adjustment necessary.

The electrical action of the receiver is very simple, and any receiver when properly adjusted will give good results from the standpoint of speech transmission. About half the trouble met with in receivers is due to rough handling, for the receiver is tampered with more than any other part of the telephone. It is generally the first part attacked when the instrument fails to give satisfaction, and therefore in some models, this trouble is obviated by securely locking the case in such a manner that the receiver cannot be opened except by the use of a special wrench or other device.

The diaphragm plays an important part in the operation of the receiver, and the structure supporting it in front of the pole pieces should be carefully constructed. There is a growing tendency to use a metal cup for this purpose upon which the diaphragm is placed and held by a metal cap, which secures it in position irrespective of the outer receiver case.

The diaphragm should be carefully cut so that it is absolutely flat and so that the edge is not turned up or dished.

Diaphragms in commercial use are made from two materials: ferrotype sheet, which is common sheet iron coated with Japan, or sheet tin, which is sheet iron coated with tin. The ferrotype diaphragm gives very good results in connection with receivers adjusted to work with it, while in other cases the tin diaphragms give the best results.

When a receiver is purchased with a ferrotype diaphragm it is bad practice to substitute a tin diaphragm, and, of course, when the instrument is adjusted for use with a tin diaphragm do not substitute a ferrotype.

For the pole pieces the softest iron should be used, and the pole pieces should be permanently attached to the magnets, the greatest possible surface being secured. This is accomplished in most makes by carefully milling the ends of the magnets and pole pieces and then forcing them together under pressure, finally binding the entire structure together by means of a heavy bolt. If the receiver is ever taken apart, always make sure when putting it together to get this bolt tight.

Most receiver coils are wound directly on the soft iron pole pieces, the spool heads being usually made of brass. The wire is prevented from coming in contact with the heads by means of fiber washers, while the space between the heads is covered with paper. In one modern type of receiver, the wire is wound on spools made from small stampings, which are slipped over the heads of the pole pieces and held in place by screws. This affords an easy means of removing and rewinding the spools when necessary.

The magnets should be constructed from steel that will permanently retain its magnetism for an indifinite period.

The claim made by some of the smaller manufacturers regarding the weights their receiver magnets will lift are amusing, as the lifting power of a receiver magnet has very little to do with the efficiency of the instrument. In fact, a very strong magnet is not advisable. In proof of this it is a well known fact that the old single pole receiver has seldom, if ever, been excelled for clearness of articulation, the modern double pole instrument with its stronger magnet, being louder but not clearer.

The thickness of the diaphragm has a great deal to do with the various qualities of the transmitted speech, such as clearness and volume.

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Probably the accoustic properties of the diaphragm have received less attention than any of the other properties of the receiver. When the receiver diaphragm is acted on by the magnetic force, its tendency is to vibrate as a whole, emitting a certain note called its "fundamental" and others called "over tones." These mingle, and the resultant sound is an exact duplicate of the original one, the different shades and tones being faithfully reproduced.

With a thin diaphragm, clearness is gained at the expense of volume, while with a thick diaphragm louder transmission is obtained, and the distinctive over-tones and sharpness is sacrificed. A thin diaphragm makes the voice appear to be shrill and high pitched, while thick diaphragms give the voice a heavy, growling tone.

The adjustment of the diaphragm and pole pieces is an important detail. This is accomplished in various ways, the usual one being that after the instrument is assembled, the face of the cup and upper ends of the pole pieces are ground, the pole pieces being ground slightly lower than the rim of the cup. The difference is the "adjustment" of the instrument. In modern types, no attention is paid to means for re-adjusting the instrument, as in properly constructed receivers there is no need of re-adjustment.

Modern receivers are so constructed that an ordinary cord with tips on both ends can be used, and receivers requiring special cords should be avoided, for, if it becomes necessary to buy cords for re-equipment, they must be purchased from the same factory, who having a monopoly of the business, can maintain any price they please.

The concealed cord receiver is now in general use, and the instrument with binding posts on the outside while in general use, does not seem to meet with as much favor as the concealed type, the latter model not requiring as frequent cord renewals.

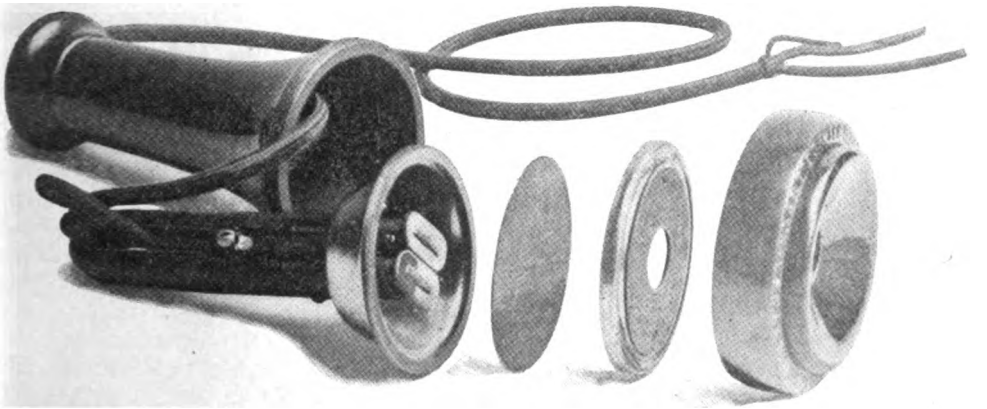


Fig. 64.

There are three points of importance to be considered in a receiver where low cost of maintainance is desired.

First: The shell should not support the working parts, but should simply serve to insulate the metal parts, and act as a casing only.

Second: The receiver parts should be held in position in such a manner that if the outer case becomes broken the instrument will still be operative.

Third: Every part should be easily accessible and readily interchange-

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able in case of damage, and should be manufactured of such material as will stand mechanical shocks so that a relative change of position is impossible.

One type of instrument fulfilling these requirements, which can be taken as representing the present state of receiver development is shown in Fig. 64. The coils and pole pieces are inclosed in a case of heavy metal. Upon the top of this metal cup threads are cut, and when the diaphragm is in place the metal ear piece corresponding to the ordinary receiver cap is securely screwed in place upon the metal cup. This incloses every working part of the receiver, including the diaphragm, in a metal case, which prevents the diaphragm from being injured in case of a broken shell. In fact the instrument will operate just as well without the outer shell.

The metal cap can if necessary be locked in place by a Spanner wrench which prevents the curious from tampering with the instrument, as it is impossible to remove the metal cap without the wrench. As the inner metal cup completely incloses the diaphragm except at the centre opening, the receiver can be placed firmly against the ear in case the outer cap is missing without affecting the vibrations of the diaphragm.



Fig. 65.

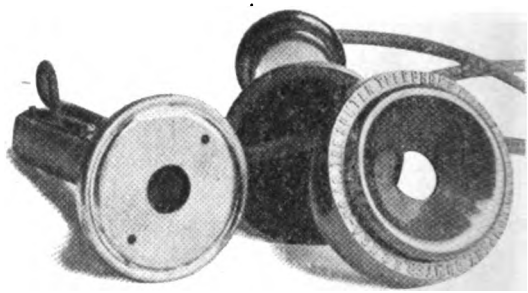


Fig. 66.

The coils of the instrument are wound in such a manner that the adjustment and assembly of the receiver is complete before the coils are put in place. In the first model of this instrument the coils are wound on spools which are slipped on the head of the pole pieces and are held in place by means of screws, as shown in Fig. 65. If it should become necessary to replace the coils, it is only necessary to take out the screw and slip the coil off the pole piece. In some receivers the coils may be replaced by taking out the bolt holding the pole pieces and magnet in place. This allows the pole pieces to be taken out and the coils rewound, and this method is used in the last model of the above instrument.

Cord terminals in receivers are usually located between the sides of the magnet, and should be made of brass or some other metal. The screws for holding the cord tips should go into brass sockets or terminals.

The terminals should be so constructed that either loop or tip cords can be used, and should be connected to the receiver coils by means of heavy strips of brass or other metal insulated by hard rubber. The fine wires from the coils should not run the cord terminals, as the wire is easily broken.

In some instruments the receiver diaphragm is held in place by a ring exactly the same as the brass cap heretofore mentioned, except that it does not extend over and completely cover the diaphragm except at the centre opening. This method of clamping the diaphragm firmly in place irre-

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spective of the outer shell is rapidly coming into use and would seem to represent the best practice. As shown in Fig. 66 the loosening of the cap or falling apart of the shell cannot in any way affect the instrument. The diaphragm cannot change its position or come in contact with the pole pieces as all parts of the receiver are forced together under heavy pressure in addition to being bolted. The wires connecting the coils to the binding posts cannot break off, as flat strips of brass are used, which are incased in hard rubber insulation thereby preventing short circuits.

The lodgment of dirt in the receiver, especially metal particles, is prevented owing to the brass containing case being almost air tight.

The standard Bi-polar receiver used by the Bell Company is shown in Fig. 67. The case is in three pieces, the body, tail piece upon which the binding posts are mounted, and the cap.

The magnets are made from steel bars 3½ inches long, .63 in. wide and .26 in. thick. At the rear end these are bolted together with an iron bolt and iron filling piece, and thus form a U shaped magnet. To give the instrument sufficient weight a piece of lead is secured between the magnet bars.

The end carrying the binding posts is fastened to the iron filling piece by means of a screw. A screw eye is provided to which the tie string on the receiver cord should always be fastened so as to take the strain from the cord conections.

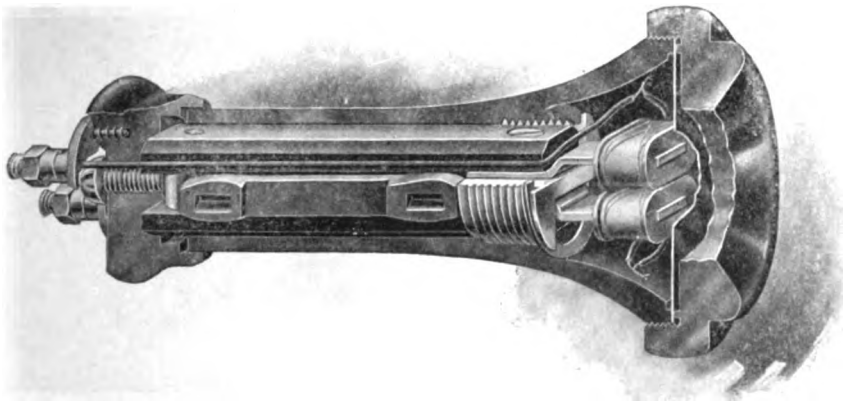


Fig. 67.

The binding posts are connected to the two spool windings, which are wound in opposite directions and connected in series. Bolted between the ends of the U shaped magnet and the pole pieces is a brass block, threaded to engage a thread on the inside of the shell. The adjustment is accomplished by turning the entire magnet structure in the shell until the tops of the pole pieces are a sufficient distance below the edge of the shell. A pin is then driven downwards through the edge of the brass piece and into the body of the shell, thus securely locking the adjustment in place. The adjustment is unaffected by temperature changes or in fact any thing except the actual breaking of the shell.

Fig. 68 shows the concealed terminal receiver used by the Bell Companies. The construction is self evident. In this type the lead block is

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omitted, the receiver being sufficiently heavy to actuate any standard switch hook.

The receiver shown in Fig. 68 is typical of several instruments now on the market. It is a very efficient instrument and represents the latest model of receiver equipment with the exception of the instruments wherein the diaphragm is secured in place by a metal cap which type would seem to possess the advantage of greater mechanical strength.

The adjustment of the modern receiver is usually determined at the factory, and if properly constructed the instrument seldom if ever needs re-adjusting. The average adjustment given magneto receivers is about eleven thousandths of an inch when tin diaphragms are used. This varies to about fourteen thousandths of an inch with ferrotype diaphragms.

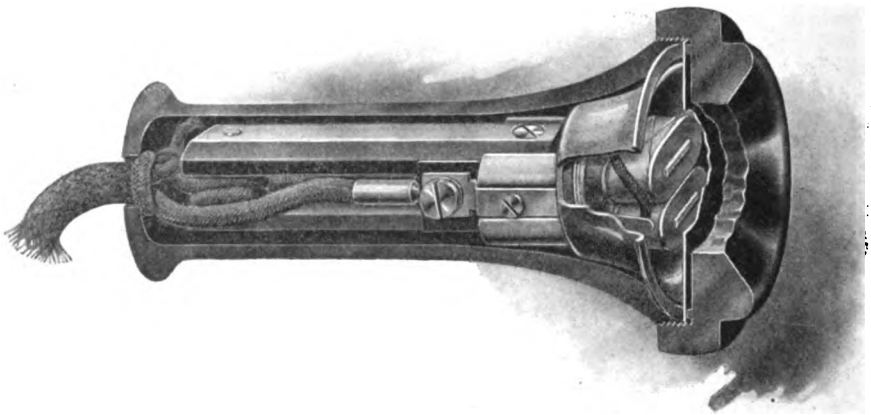


Fig. 68.

If through any cause it becomes necessary to increase the distance between the diaphragm and pole pieces a careful fileing will accomplish the desired result. Great care should be taken to remove all metal particles from the receiver before replacing the diaphragm.

A diaphragm which is bent or dented should never be used, as diaphragms cannot be straightened if once bent, but a new one should be provided.

Always remove the rust from a diaphragm before putting same in place. Screw the cap on hard as the diaphragm must be tightly clamped to give the best results.

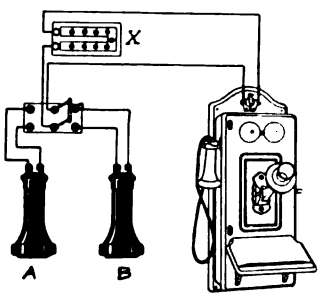


Fig. 69.

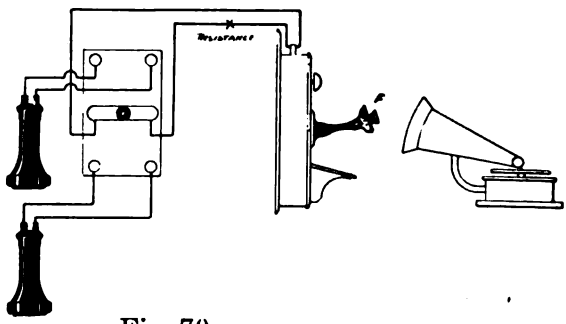


Fig. 70.

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A good rough method of making receiver tests is shown in Fig. 69. Here the receivers to be tested, "A" and "B", are connected to a double pole double throw knife switch, as shown. Wires are run to the line posts of an ordinary telephone, and in series with one wire is connected a resistance box, "X". The speaker at the telephone talks or counts in an ordinary tone of voice, while the party at the receiver listens, first to receiver "A" and then to receiver "B", meanwhile throwing the double pole switch.

Resistances can be inserted in the circuit by means of the resistance box, and the amount of resistance through which the instruments can be heard will determine their relative efficiency.

Receivers, transmitters and other telephone equipment cannot be as accurately tested as other electrical devices, as there are no standards of comparison.

A very good method when the means are at hand for testing receivers is shown in Fig. 70. In front of an ordinary phonograph, is suspended the transmitter "F" connected to a telephone. The receivers under test are connected to the other end of the line, and comparisons are made by

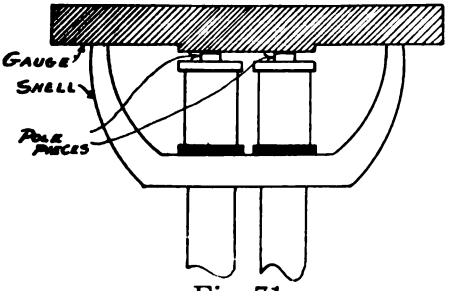


Fig. 71.

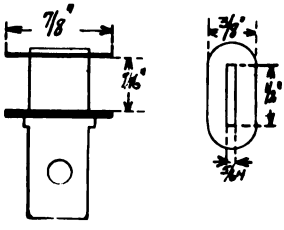


Fig. 71a.

listening to the phonograph. By means of the double pole switch arrangement two or more receivers can be compared. For this purpose it is best to place a speaking record on the phonograph and to repeat the same sentence as each receiver is tried. This method at least enables the same set of words to be used in the same tone, each time. By adding resistance, the comparative efficiency of the receivers can be determined, for, if one receiver can be heard through 100,000 ohms while another can only be heard through 50,000 ohms, the first one is twice as good as the last, provided the articulation is as good.

Where it is desired to test transmitters the positions can be reversed, and a standard receiver can be used at the listening end of the line while various transmitters can be placed in front of the phonograph, the listener finally picking out the transmitter which gives the best results. More complete information regarding transmitter testing is given in another chapter.

A few troubles in the adjustment and winding of receivers may be met with which are easily remedied, but it is better to return the receivers to the factory when the trouble is in the adjustment or other mechanical disarrangement.

A gauge Fig. 71, showing the exact adjustment of a good receiver of a certain make, should be made by taking a bar of metal and fileing same so that the ends will rest on the sides of the receiver case and the centre

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will just touch the pole pieces. Make this carefully. The receivers of the same make under test for adjustment can then be measured by this guage, and if any of them are found out of adjustment, they can be readjusted or returned to the factory.

Coil troubles are readily determined by disconnecting the receiver from the telephone and tapping the ends of the cord on a battery. If no click is heard, the coils are probably open and should be rewound. Test the cord carefully and see that it is O. K. before making this test.

It is easy to determine which coil is open by using another receiver as shown in Fig. 72. By holding one terminal of the testing receiver on the splice between the coils of the receiver under test, the open spool in the damaged receiver can easily be determined.

The dimensions of a standard receiver spool are given in Fig. 71a.

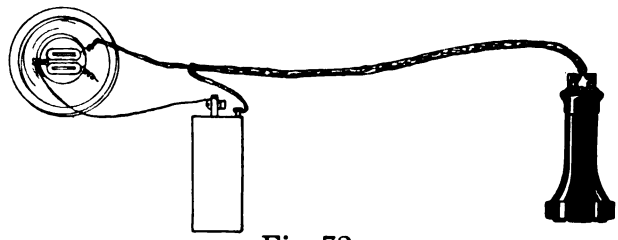


Fig. 72.

For local battery or magneto work each spool is wound with 605 turns of No. 38 silk wire, resistance 50 ohms per spool, or 100 ohms to the pair.

In winding the spools particular attention should be given to have each spool wound in the same direction and then join the two inside terminals together, the outside terminals going to the binding posts of the receiver. This accomplishes the same result as if the coils were wound in opposite directions and connected in series.

A receiver for common battery work has each spool wound with 380 turns of No. 34 single silk wire, each coil measures 12½ ohms. The two inside ends of the coil are connected together, the outside ends go to the receiver binding posts. The total resistance of the two coils is 25 ohms. The receiver is used with closed secondary coils.

A standard common battery receiver has each spool wound with 661 turns of No. 35 silk wire, each spool having a resistance of 30 ohms. The spools are connected in series, as previously described. This is the instrument commonly used with condenser circuit common battery telephones.

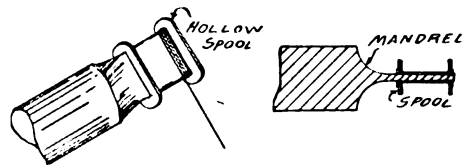


Fig. 73.

Another receiver for common battery work has each spool wound with 580 turns of No. 35 silk wire. This gives each spool a resistance of 50 ohms. The two inside ends of the spools connect together and go to one

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Binding Post and the two outside ends connect together and go to other Post.

Two methods of holding receiver spools that are to be wound are shown in Figs. 73 and 74. The wire should be as evenly wound as possible. Before winding, the core of the coil should be carefully insulated with one or two layers of paper. The wire should be prevented from coming in contact with the heads by paper or fibre washers.

To secure an accurate balance the number of turns on each spool should be the same, and it will be found that if the same number of turns on each spool is obtained, the resistance will be the same for each spool.

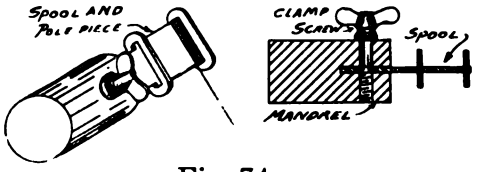


Fig. 74.

The spools can be wound nearly full : then a layer of paper should be put on the spool, and the last layer of wire can be easily and smoothly wound which gives the spool a finished appearance. The outside terminal wires should be doubled and brought out and soldered to the terminals.

Before winding the spool, a heavy wire should be soldered to the wire with which the spool is wound, and one or two turns of this wire should be wrapped on the spool, the splice carefully insulated by wrapping with paper, and the regular winding process begun. This prevents the fine wire from being broken.

A good revolution counter for winding receivers and other coils is shown in Fig. 75. This is an inexpensive device and is indispensible where accurate winding is to be done.



Fig. 75.

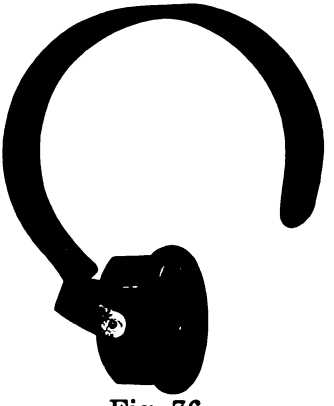


Fig. 76.

A simple revolution counter can be made from a clock of the usual "alarm" variety, by removing the escape wheel and soldering to the axle

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of the minute wheel a piece of flexible shaft made by wrapping some steel wire in a tight spiral. Attach the end of this shaft to the winding machine and upon turning same, the hands of the clock will be found to move. By marking the distance over the dial that the minute hand moves for each 10 revolutions of the machine a reliable revolution counter can be made which can be instantly set back to zero by turning the setting button in the usual manner. It will be found that about 480 turns per hour is what the average clock will indicate, that is, when the minute hand moves once around the dial, it represents 480 turns.

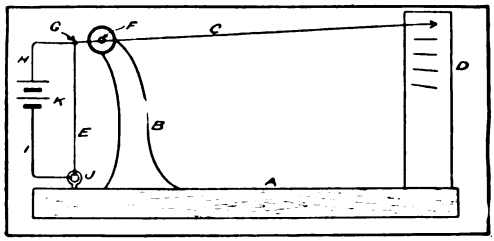


Fig. 77.

Fig. 76 shows the usual form of head receiver used for switchboard work. The magnets are formed from round punchings from flat stock, while the pole pieces are formed from soft iron same as in the hand receiver. In construction and operation this instrument is identical with the hand receiver previously described.

*To those of our readers experimentally inclined, or those desiring to audibly witness the passage of an electric current through a conductor without the usual concomitants of a magnet and diaphragm, which is, as far as the knowledge of the writers extends, the only known means of hearing the flowing current; the following experiments will doubtless be of interest.

Some years ago while experimenting along other lines one of the writers devised a plan, Fig. 77 to demonstrate and compare the expansion of metals due to the heat of the electric current passing through the same.

Referring to Fig. 77, A represents a base provided with an arm B, to which is attached at fulcrum F, a long lever or pointer C, capable of moving in the fulcrum F in a vertical arc, the long or arrow end traversing the degrees D, which are merely empirical but spaced about sixteen to the inch.

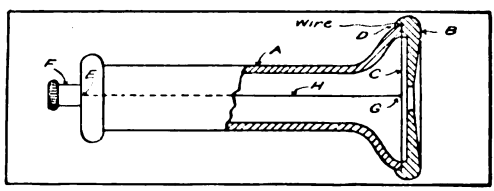


Fig. 78.

To the short end of the pointer at G is attached two wires, E and H, the former being the wire under investigation and the latter wire intended

*Am. Tel. Journal.

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to conduct the current from the source of power K to one end of the experimental wire E; the other end of wire E is attached to the screw eye J, and by means of the screw eye may be adjusted until the pointer registers with the topmost degree. Also attached to J is a wire I, leading to the opposite pole of the source of energy. Under these circumstances it was found that with small wires E such as, say No. 30 copper, the expansion of the wire with even a single cell of carbon battery was most marked indeed, registering for copper several degrees, each time the circuit was completed and retiring to zero whenever it was opened. With other metals in place of wire E, different expansions were noticeable and an interesting and instructive comparison on the expansibility of various metals was made possible.

Some time since, this old experiment was in some manner brought back to the attention of the writers when it occurred to them that there were other and possibly more useful or commercial possibilities along the same lines; accordingly the following arrangement was devised, Fig. 78.

A is the shell of a telephone receiver, B is the usual cap, C the diaphragm and attached thereto electrically and securely, at point G, is a wire H, the other end being similarly connected to binding post F at point E; the binding post being so arranged that tension can be applied to the wire H and through it to the diaphragm C. At D is connected a wire to the diaphragm and another wire is connected to the binding post as shown. Now these two conducting wires are attached to a source of current, the diaphragm C and the wire H form a portion of the conducting path, and the passage of the current through this circuit is not only plainly

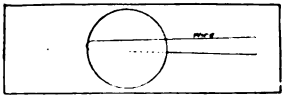


Fig. 79.

audible whenever the circuit is made or broken but more surprising still it actually approximates in sensitiveness the ordinary telephone receiver and most surprising of all, it will receive and produce speech. Our first effort to use it as an ordinary receiver was with a central energy system of that type in which the receiver is placed directly in the path of the current. In view of our previous experiments and the conclusion that we had already naturally reached, namely, that we were dealing simply with the expansion and contraction of a metal due to heat, the alternate elongations and retractions of the wire H being communicated we were scarcely prepared to credit our ears when we later discovered *that a condenser might be inserted in the circuit without excessively modifying the results.* We then continued our investigation as follows, from the results of which we are now inclined to believe that molecular movement of some sort rather than heat is the basis of the action. We reasoned that if five inches of wire produced a certain loudness of sound, ten inches would produce more, because the amplitude of the diaphragm movement would be increased by the greater expansion of that length of wire. This did not prove to be the case, but as the apparatus at hand did not admit of anchoring the end of the wire at the back end of the shell, we concluded that that fact was the cause of the failure. We then tried a coiled wire of German silver reasoning that that would be the equivalent of a longer wire. With this arrangement the results were mediocre and about that time we discov-

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ered much to our astonishment that it was wholly unnecessary to anchor the back end of the wire or to have either it or the diaphragm under stress as we at first supposed. These discoveries directed our attention to the molecular hypothesis and we accordingly tried the following: Discarding the wire H we substituted for the same a wire wound around the diaphragm as per Fig. 79, making it a part of the circuit.

With this plan we reproduced all the results of the previous methods which seemed to point most strongly to the molecular movement theory. The addition of more convolutions or the use of only a single wire drawn across the top of the diaphragm appeared to make no appreciable change, but with an additional diaphragm placed over the top of the other the loudness was increased.

Our experiments were limited to copper and German silver wire and to light iron diaphragms and we have often thought it would be interesting and possibly useful to follow up the line of investigation, but our time and attention being engrossed in other directions, we have been unable thus far to do so. It is possible a receiver practically devoid of self-induction and resistance might be devised and it is perhaps not beyond the bounds of possibility to produce a receiver more sensitive than the common permanent magnet type. What bearing would this receiver have had upon the telephone patents in 1876?

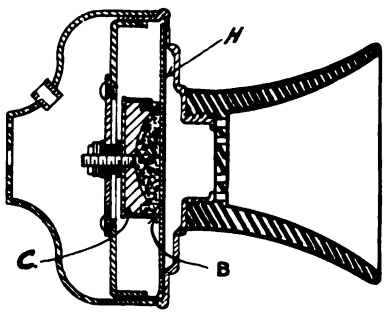




Fig. 81—82.

TRANSMITTERS.—The next important part to be considered is the Transmitter. An early type extensively used, is shown in Fig. 81.

The Diaphragm H is a thin disc of Carbon, and also forms the front electrode. Supported behind this is the carbon block electrode C. Between C and H is placed a quantity of small carbon balls known as "Globular" carbon. These are held in place by the felt ring B.

This instrument in various types was extensively used, and gives remarkably good results, as the transmission is not only clear and distinct, but is entirely free from metallic sounds.

The chief objection to this type is the easily broken carbon diaphragm which also absorbs moisture from the breath. This penetrates to the globular carbon causing same to "pack" or adhere together, making the instrument inoperative.

When repairing this type, no adjustments are required, it only being necessary to replace the diaphragm if broken, and see that the proper

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amount of globular carbon is used. Do not fill the chamber full, three fourths full is the proper quantity; and see that the felt ring is in proper position to keep the carbon from falling out.

It is advisable to coat the front of the carbon diaphragm with some moisture resisting compound such as lampblack mixed with shellac.

The circuit through this transmitter is from the frame supporting the diaphragm across the globular carbon to back electrode C, which is mounted on an insulated support.

While this is an excellent Local Battery Transmitter, it is not suitable for Common Battery. It is a low resistance transmitter, and passes more current than modern types, thus necessitating frequent battery renewals.

A rear view of the complete instrument is shown in Fig. 82.

The transmitter now in common use is the so-called "solid back" type which has replaced all earlier models. A sectional view of the "solid back" as used by the Bell Company is shown in Fig. 83.

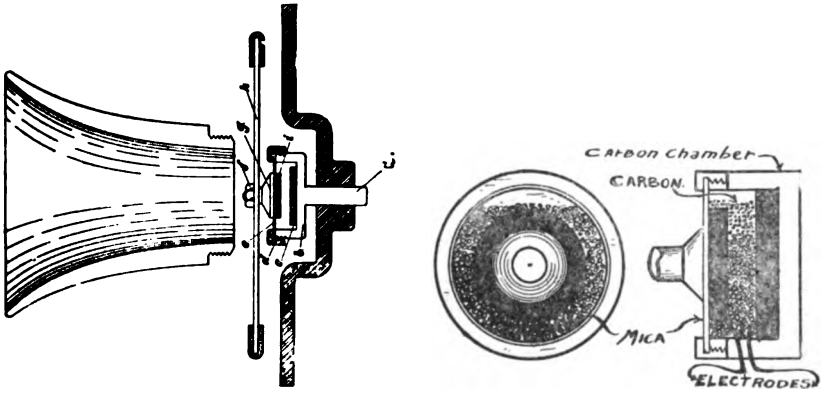


Fig. 83—84

The diaphragm *h*, 2½ in. diameter is made of aluminum .021 in. thick, and is painted on the outside to prevent corrosion. The diaphragm is attached to the carbon electrode *i* by means of the brass stem *g*. The electrode *i* is insulated from the other parts of the transmitter frame by means of the mica diaphragm *e* about .0015 in. thick, which is clamped in position by means of the ring *b*. .0005 in. variation in thickness of the mica will cause a variation in the efficiency of the instrument. Granular carbon of uniform size is placed between electrodes *i* and *c* and when the transmitter is spoken into, the varying pressure of electrode *i* against the mass of granular carbon between it and electrode *c* causes a variation of the current.

No. 40 granular carbon is usually used for local battery transmitters, No. 60 or 80 being used for Common Battery work. The Bell companies use the common battery or high resistance transmitter for both common and local battery telephones, and when 3 cells of battery are used (for local battery) the results are very satisfactory and a saving in battery maintainence is claimed.

The distance between the electrodes in this type of transmitter is about 1-16 inch, and this distance determines to some extent the resist-

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ance and efficiency of the instrument. It is highly important that the two adjacent surfaces of the electrodes should be absolutely parallel and that they should be highly polished. This can be accomplished by rubbing them on a lapping plate (a smooth piece of iron with fine grooves across it) or piece of smooth slate, using some dry red lead and finishing on a smooth soft cloth. When assembling a transmitter the fingers should never touch the surface of the electrodes, and the carbon should be absolutely dry, clean, and of uniform size. The separation of the electrodes should be such that at least three of the carbon granules used if in a straight line, will have room to lie between the surfaces.

In refilling the chamber with carbon, care should be taken to use the same *size* and *grade* of granules as originally used. Do not fill the chamber too full, leave a space at top of chamber, as shown in Fig. 84.

Fill the chamber, then tap gently on bottom to shake carbon down. Don't expose top of button but always leave space at top as shown.

The current for operating this transmitter should not be less than .14 of an ampere (measured at the terminals of the transmitter), nor should it at any time exceed .32 ampere.

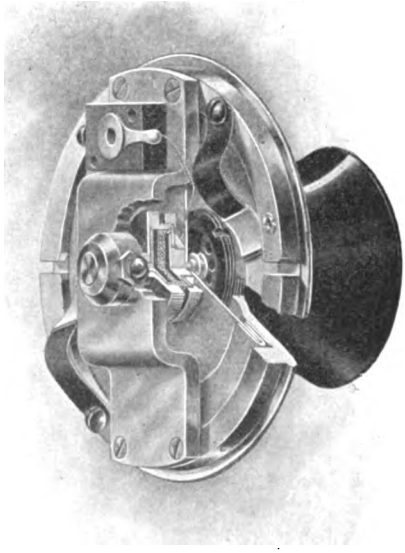


Fig. 85.

Fig. 85 shows a complete "Bell" transmitter with a section cut away to show the different parts.

The frame or case of this transmitter is connected to one side of the circuit, which, for some classes of work is objectionable. To obviate this the transmitter shown in Fig. 85a was devised. The arrangement of the various parts is practically the same as in the standard Bell transmitter, except the cell is mounted on a stamped back, as shown. This back, carries two insulated lugs to which the circuit wires are connected. The

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frame is not connected to the circuit, because the rubber band around the diaphragm also encloses the edge of the metal cup carrying the cell. The cell cup and diaphragm are held in the frame by the two felt tipped dampening springs.

The dampening springs are used in the majority of transmitters to limit undue vibrations of the diaphragm, which often cause annoying "side tone." In other words the instrument is too responsive to slight noises.

The average resistance of transmitters varies from a few Ohms to 100 or more, depending upon the carbon used, etc., transmitters for common battery being of higher resistance than those for local battery.

The Bell transmitter as previously described is the result of many years of experience and is undoubtedly a very satisfactory instrument, it's clearness of articulation being particularly noticeable. The circuit through this transmitter is from the brass bridge carrying the stem *a*,

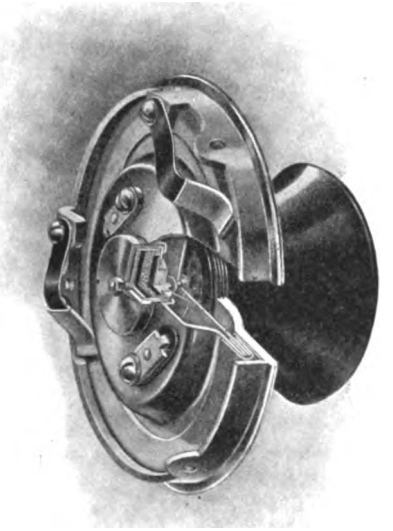


Fig. 85a.

Fig. 83, which is connected to the back electrode, through the granules to the other electrode connected to the brass piece *g*. Most of the instruments now manufactured, resemble this instrument to a marked degree, and to describe one is to describe them all except in detail, many manufacturers having improved upon the original instrument.

Many transmitters patterned after this instrument are open to the objection that in time they will pack, the carbon having a tendency to settle to the bottom of the cell where it forms a solid mass, thus short circuiting the instrument. Another objection would seem to be the fact that the diaphragm carries the weight of the brass piece and front

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electrode, and that in addition to this, the motion of the diaphragm is restrained somewhat by the mica diaphragm. The nuts which secure the front electrode to the diaphragm are another source of annoyance, as these cannot be painted and consequently may corrode after the transmitter has been in use some time. It is necessary to remove the nuts when disassembling the transmitter, and the mica diaphragm is often broken when doing this.

The Western Electric Co., who make the Bell transmitters, claim to use carbon prepared from coal, especially fine and hard, obtained from a special vein. Their instruments are certainly free from any tendency to "pack" and are very uniform in quality, thus showing good workmanship and careful inspection.

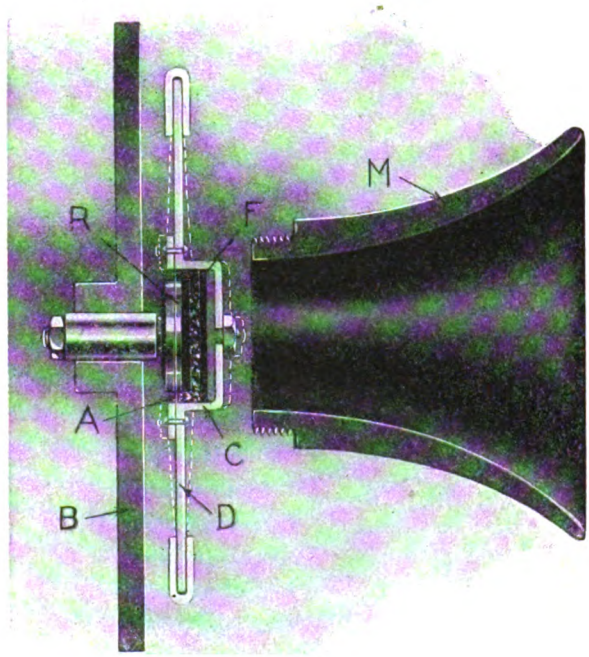


Fig. 86.

As the different Bell companies invariably return all transmitters requiring repairs to the factory, several features which would tend to make their instruments easy to repair, have apparently been passed over, the aim evidently having been to produce an efficient instrument of permanent construction.

The transmitter manuactured by the Kellogg Switchboard and Supply Co. represents a departure from the type previously described. A sectional view of this instrument is shown in Fig. 86.

The cell C. is stamped in and forms part of the diaphragm D. In the cell is secured the front electrode F.

The rear electrode R is mounted on a stem and supported in the centre of a mica diaphragm A, the mica being fastened to the main diaphragm

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by a small ring and rivets as shown, thus closing the cell, in which granular carbon is placed. The rear electrode R is held rigidly by the stem which is secured to the back bridge.

Referring to the figure it will be seen that the entire cell containing the front electrode and granules is vibrated when the instrument is spoken into, this causing the granular carbon and the front electrode to approach and. recede from the back electrode. This action is different from the Bell instrument, where the motion is a piston effect produced on the granules which are stationary, by the front or movable electrode only, the back electrode being stationary.

In the Bell transmitter there is:

One stationary cell, one stationary electrode, one movable electrode, a mass of granular carbon subject to compression between the two electrodes.

In the Kellogg:

One movable cell, one stationary electrode, one movable electrode, a mass of granular carbon moving with the moving electrode and subject to compression between the electrodes.

Owing to the entire cell being in motion the instrument does not pack and a very efficient instrument is produced which is particularly economical in battery consumption.

By providing an insulated terminal for the wire coming from the diaphragm which forms one side of the circuit, and insulating the stem of the back electrode from the bridge, the shell of the transmitter forms no part of the circuit.

This transmitter represents a radical departure from early models, which were usually variations of the White "solid back" or Bell transmitter.

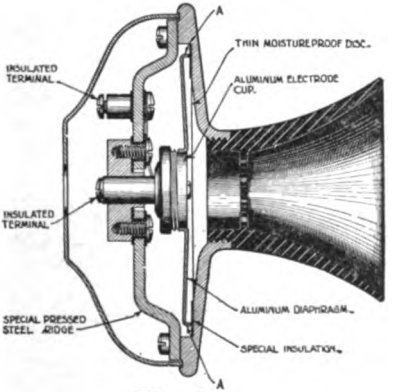


Fig. 87.

The next type to be considered is represented by the Dean Elect. Co's instrument shown in Fig. 87 which is indeed a radical departure from former models.

The figure plainly shows the arrangement of the various parts, which should now be familiar to the reader.

The main aluminum diaphragm is formed with a hole in the centre, having an annular flange turned inwardly. This engages the aluminum electrode cup which has a metal electrode secured in the front and a carbon electrode mounted on a mica diaphragm in the back. The action of this

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instrument is similar to the Kellogg instrument, as the front electrode, cell, and mass of granules move, while the rear electrode is stationary.

While the cell is in contact with the main diaphragm, it does not form part of same, therefore the diaphragm may be removed and a new one substituted without changing the cell.

Owing to the diaphragm being stiffened by the annular ring or flange around the centre opening, no dampening springs are necessary in contact with the diaphragm.

Owing to the initial outward tension given the diaphgram, if the circuit is kept closed and the transmitter is left at rest—such as when a receiver is accidentally left off the hook—the heating effect of the current flowing causes the diaphgram to expand outwardly, thereby increasing the distance between the electrodes and causing the resistance to increase to a considerable extent. A saving in battery consumption is thereby affected.

The edge of the diaphragm is turned outwards and rests against a ring of oiled cloth, thus doing away with the often troublesome rubber band.

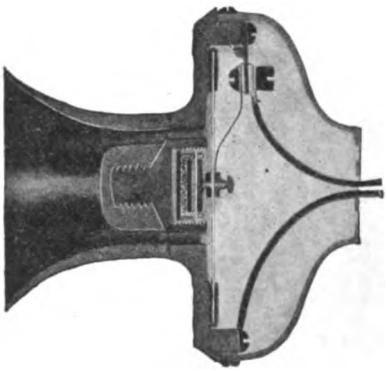


Fig. 88.

The main diaphragm in this and several other makes of transmitters, is protected by a disc of thin moisture proof substance such as celluloid or oiled silk, which takes the place of the black enamel used in the Bell and other transmitters.

The use of a fine wire connection between the front electrode and the terminal is eliminated in a very clever manner. The back electrode stem is mounted on an insulated block; this forms one side of the circuit. The front electrode is connected to the circuit through a light spring which rests on the rear ring holding the mica diaphragm in place, this spring being connected to an insulated terminal mounted on the bridge.

This transmitter represents a very unique and simple form of construction, the mechanical design presenting several features which make it distinctive as a type and typical of modern practice.

A peculiar form of construction is shown in Fig. 88 which shows the transmitter manufactured by the Interstate Elect. Mfg. Co.

The cell is cast in the front. A stationary electrode is mounted in the bottom of the cell as shown. The other electrode is mounted on a mica disc as usual, and occupies the position as shown in the Figure.

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Suitable openings around the cell permit the sound vibrations to reach the diaphragm which is attached to the insulated electrode.

The circuit of this instrument is from the shell or case, through the granular carbon to the electrode attached to the diaphragm. A suitable connection leads from the diaphragm to an insulated terminal located on a projecting lug formed on one side of the front.

The method of attaching the mouth piece is entirely different from other makes. The mouth piece screws on a projection formed on the front. The holes in the mouth coincide with those in the front thus permitting free access for the sound waves.

This form of construction permits of assembling the instrument without the use of a bridge. It would seem very difficult to insulate the working parts of this model from the case, owing to the front electrode being mounted on the case itself.

The operation of this instrument is most peculiar. It would seem to work oppositely from any other, as the sound vibrations first lessen the pressure on the granules. The increase in pressure and consequent lowering in the resistance of the instrument only taking place when the diaphragm springs back past the neutral point after receiving an impulse from the sound waves.

The presence of the granule chamber directly in the mouthpiece opening does not seem to affect the transmission. The fact that the connection between the diaphragm and the electrode is open to the corrosive action of the breath would seem to be an objection to this type, although no trouble from this source has been reported.

The usual dampening springs, not shown in the cut, are used to eliminate over sensitiveness.

A radical departure from the types previously described is the use two diaphragms. An instrument embodying this feature is shown in Fig 88*a*.

The diaphragms C and D are connected to the electrodes E and F, these electrodes being insulated from the containing cell by means of mica diaphragms. Granular carbon is placed between the electrodes, and the two diaphragms and cell structure are supported by a suitable mounting.

The mounting is enclosed by a case A, so shaped that the sound waves are equally distributed to the diaphragms.

The current passes from one diaphragm and electrode through the granular carbon to the other electrode in the usual manner, the circuit wire being marked 1 and 2 in the figure.

This model represents an attempt to secure a greater extent of movement between the two electrodes, and consequently a greater variation in the resistance of the circuit. As the instrument is of comparatively recent invention, no very accurate data as to its efficiency as compared with single diaphragm types is at hand.

There are quite a few models of the double diaphragm construction. The one shown in Fig. 88a is representative of the type, none of which have come into extended use.

The construction of the transmitters described thus far is such that only a variation in the amount of a current flowing in one direction is accomplished.

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Fig. 88*b* shows an instrument designed to convert the vibrations of the diaphragm into alternating impulses.

The arrangement of the electrodes is such that their operation is similar to a pole changing switch. Four resistance cells containing granular carbon are used, these cells being arranged in pairs. The vibration of the diaphragm increases the pressure in one pair of cells, and decreases the pressure in the other pair. The current is thereby switched in alternately opposite directions through the induction coil.

Referring to the figure, G is the stationary electrode provided with carbon faces. The end stationary electrodes are shown at K and J. Between these the movable electrodes M and N are placed. These are connected to a stem connected to and moving with the diaphragm.

The movable electrodes are connected with the battery, and the fixed electrodes with the coil circuit, as shown on the right of the figure at A and B.

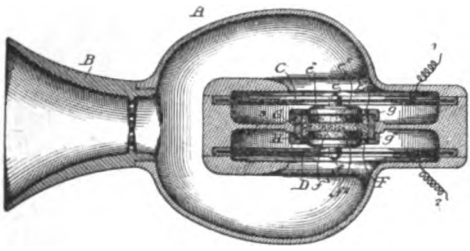


Fig. 88a.

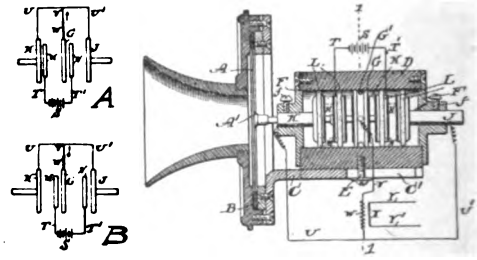


Fig. 88b.

The operation of the device will be understood by reference to A and B. When the movable electrodes are impelled to the left the resistance to the passage of a current between the electrodes N and G and M and K is diminished, while it is increased as between electrodes N and J and M and G. Consequently the greater part of the battery current will pass over the wire T, the movable electrode N, the stationary electrode G upward through the wire connection V, thence through the wire connection U to the stationary electrode K, and thence through the movable electrode M and wire T to the battery.

An impulse to the right as shown at B reverses conditions, producing a downward current through the wire V the changes from the one condition to the other being gradual and without sensible interruption, the result being that the current practically flows in alternate directions through the primary of the coil producing, it is claimed, an increase in the efficiency of the instrument.

In all the instruments previously described, the diaphragm forms or is connected to one of the electrodes. A departure from this method is illustrated by the transmitter manufactured by The Sumter Telephone Manufacturing Company and shown in Fig. 89.

The principal feature in this instrument consists of mounting the cell containing the granules and front electrode upon resilient springs, and, by means of two points or pins, transmitting the vibrations of the diaphragm to the cell. These pins are purposely located at points outside the centre of the diaphragm, preferably one third the distance between the centre and the edge thereof.

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Referring to the figure, A indicates the front plate or shell. Resting against this is the usual diaphragm D insulated therefrom by the oiled cloth ring E.

Attached to the front plate A at four points, is the rear casing F, which is secured by screws G so that it can be readily removed.

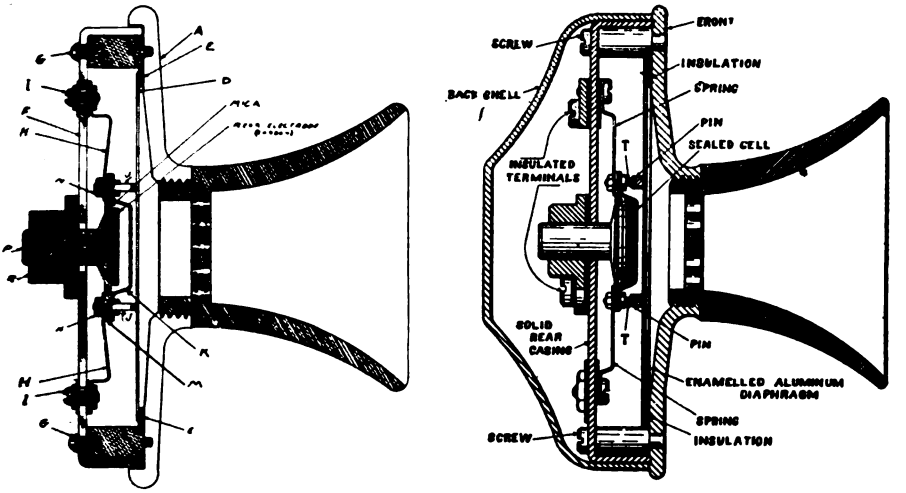


Fig. 89.

Secured to the rear casing F by two screws I are the springs H which extend towards the middle of the rear casing and are attached to the edge of a plate shaped cell K, the inner side of which is platinum, and forms the front electrode. This cell contains the granular carbon. The cell is closed by means of a mica disc supporting the rear electrode. This disc is secured in place by the washer M; all of the parts including the springs H are secured together by the screw threaded ends of the two posts or pins J, which are secured by the nuts N. Two shorter screws and nuts are also used to securely close the cell.

It will be noted that by adjusting the stationary electrode stem P in the support R, the tension or stress maintained on the resiliently supported cell K, and consequently the pressure of pins J on the diaphragm D may be varied to obtain the best results, and once this adjustment has been obtained, the instrument may be taken apart, the rear casing carrying the complete cell removed, and the diaphragm taken out and renewed, after which the instrument may be reassembled without adjustment.

As all diaphragms are subject to corrosion, any means to enable their ready change constitutes quite an improvement in the instrument.

By referring to the foregoing it will be observed that when sound waves strike the diaphragm, the latter is set in vibration, which is of greater force or amplitude at points beyond the centre. These amplified vibrations are transmitted to the pins J, J, so that the pins have an oscillatory motion, which is conveyed to the cell K.

The entire cell, together with its supporting springs being under strain, is peculiarly susceptible to the delicate vibrations of the pins, and the cell is caused to approach and recede from the rear or stationary electrode, which causes a variation of the current in the usual manner.

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It will be observed that the motion imparted to the cell is irregular in character owing to the pins being out of centre with respect to the cell, therefore the vibrations transmitted from the main diaphragm, instead of being uniform as is the case with transmitters connected to the cell at a single point, is irregular and uneven, and the consequent variation in the pressure on the granules considerably increased.

In the majority of transmitters the tendency of the diaphragm is to vibrate *inwardly* when actuated, and to return to a neutral or central position after each impulse.

In this transmitter, owing to the cell being held under tension, the tendency of the diaphragm is to vibrate *in and out.* Instead of tending to only *increase* the pressure from a normal point, the pressure is *increased* and *diminished* thereby causing a much greater current variation.

The normal or "at rest" resistance is not as small as when the diaphragm is actuated and moved inwardly, nor as great as when the diaphragm springs outward, owing to the pressure of the cell supporting springs.

The actual construction of the instrument embodies several features of merit. The necessity for dampening springs is avoided, the pressure on the diaphragm being applied through the two pins by the cell supporting springs.

The rear casing encloses and protects the cell and supporting springs. The screws I, I are insulated from the rear case by rubber bushings, and one of these screws is arranged to serve as one terminal of the instrument and connects the circuit to the front electrode without the use of a fine wire, which is easily broken and hard to refasten.

The rear electrode is held by a support R, which is insulated from the rear casing and which also carries the other terminal.

The pins J and J are provided with small hard rubber tips where they rest on the diaphragm, and consequently the diaphragm is not electrically connected. This is the first transmitter employing this form of construction.

From the above it will be seen that the frame or case, and diaphragm form no part of the circuit, which at all times is confined entirely to the cell and electrodes.

As the cell is fastened with small nuts and screws, it is easy to disassemble. This however is seldom if ever necessary.

The usual form of back shell is used when the transmitter is mounted on standard wall or desk sets. When mounted on the small iron box residence type of phone, the ordinary back shell is omitted, the inner rear casing serving to perfectly protect the parts, as only the terminals are exposed.

Owing to the increased action secured by this construction, the instrument can be given quite a high resistance without sacrificing the efficiency. This results in a saving in battery consumption. For long distance work three cells may be employed, and it is said that some remarkable results in long distance transmission have been secured with this instrument.

By adjusting the position of the rear electrode stem, any degree of pressure on the diaphragm can be secured, thereby enabling "side tone" adjustments to be easily accomplished as the instrument can be made more or less sensitive as occasion demands.

The various types of instruments so far described are typical of modern practice. To illustrate every type that has been invented would

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be a hopeless task as there are at present (1908) about two hundred and fifty patents granted on this piece of equipment, the majority of these being variations of the general types herein described.

Current consumption is a vital point to be considered in local battery transmitters. A low resistance transmitter will necessitate renewing the batteries every few months; with a transmitter of moderate resistance, the batteries will last twice as long. It is necessary to use an instrument of comparatively low resistance to secure the necessary efficiency, but in a great many instruments on the market owing to greed for volume this has been carried too far—the result is a quickly exhausted battery, and consequent expense.

By using especially prepared carbon and electrodes, it is possible to produce an instrument possessing ample volume and yet use a minimum of current. With an induction coil primary of 1 ohm and two ordinary dry cells in good condition, the average local battery transmitter will pass from .250 to .320 ampere. This should not be taken as representing the amount of battery necessary for operation. Some transmitters will talk very well with only .050 or .075 ampere. They will however, *unless a resistance is placed in circuit* with them, pass .200 or .300 ampere, when in actual use. Therefore some of the claims for efficient operation, *and battery consumption,* made for the same instrument is somewhat amusing when it is not what will *operate* the transmitter that counts, but what actually passes through the instrument.

The method of adjusting solid back transmitters varies but little among the different types, it being customary to loosen set screw holding the back electrode stem. The transmitter should then be talked into, and after the granules are shaken up by this, the set screw is tightened. This really means that the transmitter is self-adjusting.

It will be found more practical to return defective transmitters to the factory for repair, except when the trouble is due to an accumulation of corrosive matter between the diaphragm and the front shell of the transmitter. This can easily be remedied by cleaning same and placing a new rubber band on the transmitter diaphragm, but if the trouble is in the adjustment of the transmitter such as the position of the buttons or electrodes, or the granular carbon, etc., or a fractured mica diaphragm, it is much better to return the transmitter to the factory. Several of the later types have eliminated the rubber band entirely and substitute a non-rotting oiled cloth, as previously described.

Some manufacturers have made it a practice to cover the front of their transmitter with a sheet of thin celluloid to render same impervious to moisture. This is of course necessary whenever the construction of the transmitter is such that a crack or seam exists in the front of the instrument through which moisture could penetrate to the vital parts. One very satisfactory method of eliminating the trouble due to corrosion is to coat the entire front of the diaphragm with baking enamel, same as a bicycle frame, which is glass hard and waterproof.

The means provided for attaching the wires to the transmitters is an important item. It is best to provide machine screw terminals under which the cords leading from the telephone can be attached. It is presumed these cords are equipped with eyelets or clips, but the terminals should also be of such construction that wires can be easily attached.

In conclusion it might be said that only an instrument which is finished in the best possible manner should be used. It is now customary to nickel-

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plate or black oxidize the parts such as the bridge, terminal screws, etc. in the better class of instruments. It might be said that a very good indication of the quality of a telephone factory's product may be arrived at by close scrutiny of their transmitters and receivers, and it will be found that the factory devoting the greatest care and attention to details in the manufacture of transmitters will prove reliable in many other respects.

INDUCTION COILS.—The function of the induction coil as used in connection with the telephone was described in chapter one. A brief review of this will not be out of place, however.

The simplest telephone line imaginable would consist of two receivers connected in series as shown at A, in Fig. 90, but such a circuit is only good for a short distance, as the currents generated are too feeble to transmit the speech intelligently for any distance.

The invention of the transmitter, or electrical valve, rendered it possible to talk over a much longer distance. This, in addition to the transmitter and battery at each station resulted in the arrangement of the circuit as shown at B, Fig. 90. To obtain any results with this circuit it was necessary to connect the receivers so that the battery current flowed through them in such a manner as to strengthen the pull of the magnet on the diaphragm.

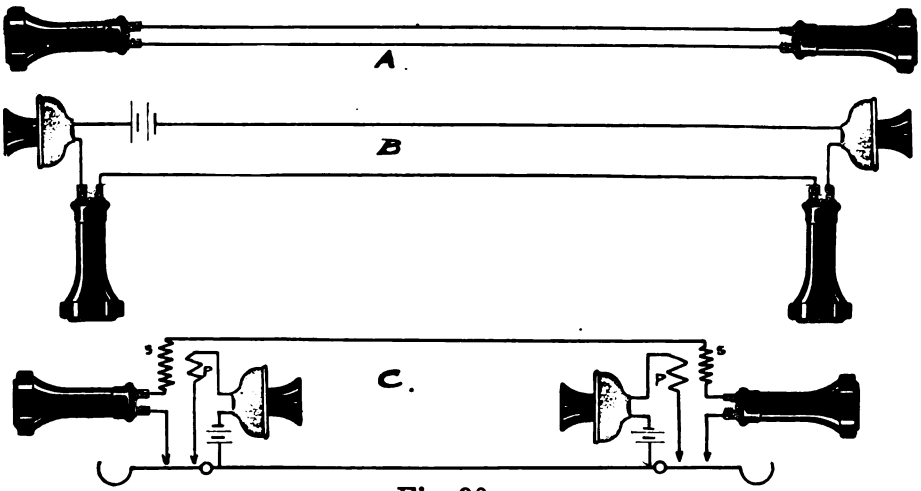


Fig. 90.

In this circuit, the effect of the current passing through the transmitters will be approximately proportional to the changes in the total current traversing the circuit. These changes are produced by the variations which the transmitters offer to the flow of electricity from the battery due to the increase and decrease of the resistance in the transmitters caused by the sound waves striking the diaphragms, thereby varying the distance between the electrodes.

A circuit of this kind can be divided into several parts which prevent the flow of electricity.

First: There is the resistance of the line wires, which vary according to their length, material and size. This is principally ohmic resistance. We will assume that this portion of the circuit does not exceed 50 ohms.

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Second: There is the resistance of the batteries.

Third: There is the ohmic resistance of the receivers, which are 100 ohms each.

As the receiver coils are wound on iron cores, their inductance is high, and the actual resistance they offer to the high frequency voice currents is considerable.

Fourth: There is the variable resistance of the transmitters which ranges from a fraction of an ohm to 50 or 60 ohms.

From this it will be seen that a line, as previously described, may offer a resistance as high as 2000 ohms, owing to the impedance, while its ohmic resistance is not more than two or three hundred ohms. We will suppose the transmitter is capable of varying the resistance of the circuit 2 ohms. It will then be able to change the resistance of the circuit about one two-thousandths of its value, which is all the power it possesses to change the total current flowing. Owing to this, and the low voltage of the current, the results are not satisfactory over lines ordinarily met with in exchange work.

The induction coil was applied to the telephone by Thomas A. Edison in 1878 with a view to improving this condition. Fig. 90 at C shows a line with the coils in circuit with the transmitter and battery. The "primary" winding "P" (so termed because it is associated with the primary source of power, the battery) consist of a few turns of wire of low resistance, while the "secondary" coil, (so termed because secondary or induced currents flow through it) has a much higher resistance, and is wound with a great many turns of fine wire. This is connected to the receiver and line.

The induction coil accomplishes the following:

First: It provides a circuit for each transmitter that can be arranged to possess low impedance, thereby allowing the variation in the transmitter contacts to form a large percentage of the total current flowing.

Second: It removes both transmitters from the line circuit, thereby decreasing the total resistance of same.

Third: As the transmitter is of variable resistance, its presence directly in the line is objectional: the induction coil removes this objection.

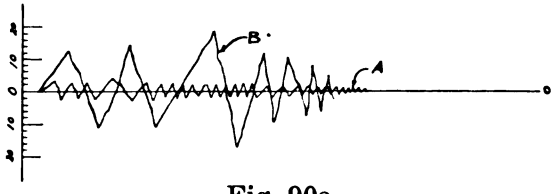


Fig. 90a.

Fourth: It greatly increases the transmitting power of the telephone as a whole. This can be illustrated by reference to Fig. 90a, where "A" represents the variation of current produced in the circuit when the transmitters, receivers and batteries are in series, while "B" represents the same line, under the same conditions, when induction coils are used. It will be seen that the variations produced are much greater with the induction coil. This is due to the fact that when by the action of the coil, a variation of current is produced between the primary and secondary

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windings, the variation is in proportion as the number of turns in the primary is to the number of turns in the secondary. That is: if there are 10 turns in the primary, and 100 turns in the secondary, the ratio is 100 divided by 10, and the increase in voltage is 10. If two volts A. C. be applied to the primary and one ampere of current flows, the volts at the terminals of the secondary will be twice the secondary turns divided by the primary turns, and the current will be 1 multiplied by the primary turns, divided by the secondary turns.

The loss due to the resistance of the line is proportional to the square of the current which is employed, while the power transmitted is proportional to the product of the volts times the amperes.* Therefore by increasing the voltage, the same amount of energy may be transmitted at less loss. Owing to the fact that the transmitter will burn if the voltage is increased, it is impossible to operate it except with a low voltage current, but by using the induction coil, the low voltage large current of the primary or local circuit, is transformed into a small current at a high voltage in the secondary, which will overcome the line resistance and cause sufficient current to pass to operate a receiver over the longer lines.

There are no satisfactory methods of mathematically determining the proper proportion for induction coils. Coils vary widely in their construction, a wide difference in size and number of turns often giving satisfactory results. In actual practice induction coils are manufactured for the particular instrument they are to be used with, and the usual method of determining the best induction coil for a given instrument is to test several different types and select the best.

Induction coils are usually assembled by taking two fibre or wooden heads, and glueing or otherwise fastening a paper tube between them. The paper tube is then filled with as much fine iron wire cut the proper length, as it will hold, No. 24 being the usual size. This wire should be tightly packed in the tube, in which it is securely held in place by driving two or three small iron brads into the core wires, thus spreading them apart. Soft iron wire should be used for the core, avoiding the use of short lengths and bent pieces.

While the heads can be made of wood or some other suitable material, fibre is preferable. The terminals should be of brass or German silver. Machine screws are sometimes provided for easily attaching the wires.

The primary winding in the majority of coils consists of not more than three layers of wire ranging in size from No. 22 to No. 28, the resistance of the primary ranging from .39 to 1-½ ohms. The primary is covered with a layer of paper, and the secondary winding is begun. This consists of a wire ranging from No. 28 to No. 34 gauge, cotton or silk insulated, varying in resistance from 18 to 250 ohms. The outside of the coil is then covered with paper, the wires are soldered to their respective terminals, and the coil may be considered complete.

One type of coil which is accepted as standard by some of the largest manufacturers, is of the dimensions shown in Fig. 91. Heads 1 inch or 1⅛ inch square. The primary consists of 240 turns of No. 26 B. & S. G. single cotton covered wire put on in 2 layers. The primary is covered with one layer of paper. The secondary consists of 2160 turns of No.

*This statement is not entirely accurate for A. C., but is given to convey the idea of the operation of the coil. With A. C. the power factor due to the lag of current behind the voltage makes this simple calculation impossible.

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28 B. & S. G. single silk covered wire. The primary has a resistance of .9 ohm, and the secondary 24 ohms. This coil is used for local battery or magneto work.

It is well to make the primary of as high resistance as possible without lessening the efficiency of the coil, as this decreases the drain on the battery. It is also well to keep the resistance of the secondary as low as possible when the coil is used in bridging telephones, as when a high wound coil is used, the voice currents are hindered from passing through the coil by the impedance of same, and are, therefore, forced through the ringers.

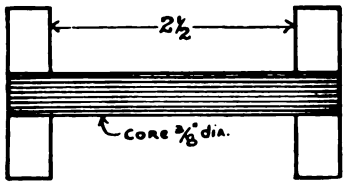


Fig. 91.

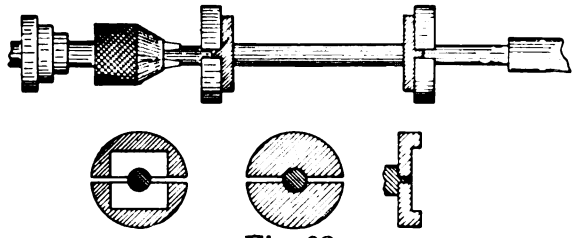


Fig. 92.

A coil with a secondary resistance of 250 ohms wound on the same spool as shown in Fig. 91 has the same primary, and a secondary with 12 layers of No. 36 B. & S. G. single silk covered wire.

The generally accepted belief is that coils having small cores and small windings give better results than coils with large cores and high resistance windings. While the large cores give louder transmission, it is poorer in quality. In making experiments of this nature is should be remembered that in talking over a large coil at the transmitting station to the small coil at the receiving station, the small coil at the receiving end will always give better results than when two small coils are used together, while the small coil will generally show less efficiency when the positions are reversed, owing to the added impedance of the high winding of the large coil.

Two small coils however, all things considered give better results than two large ones. It has been found by testing, that when the same kind of coils are used at each end of a line, the large coils give louder results, but the speech is not as distinct as when the small coils are used, as the transmission with the small coil is considerably clearer but somewhat weaker. As it is clearness of speech that is desired, the small coils are therefore the best.

Different chucks for holding induction coils while they are being wound are shown in Fig. 92. These chucks can be held in a hand drill clamped in a vise; or a regular winding machine or small lathe can be used.

All makes of magneto coils are wound in the same direction, i. e., the primary and secondary are both wound without reversing the position of the coil.

The arrangements of the terminals on various makes of induction coils is somewhat confusing, as it will be seen by reference to Fig. 93, which shows three coils, "A", "B" and "C". At "A" the primary winding is connected to terminals 1 and 2, and the secondary to terminals 3 and 4, each set of terminals being located on the respective heads. At "B", one secondary terminal is located on one head of the coil, while the two pri-

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maries and other secondary are located on the other end of the coil. At "C" one secondary is on one end of the coil, while one primary and secondary are connected together and attached to one of the terminals on the other end of the coil, and the last primary is also connected to a terminal on the same end.

Fig. 93a shows how the coils may be connected so as to accomplish the same purpose. The usual type of wiring is shown, and from this figure it will be noted that coils A, B, or C, are interchangeable although the terminals are different.

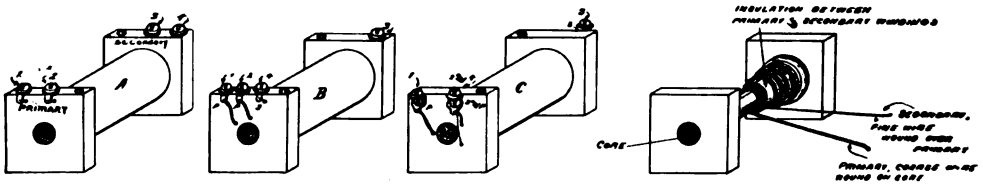


Fig. 93.

The construction of a magneto coil is shown on the right, Fig. 93

The primary wire is wound directly on the paper tube, or the core is covered with paper and the primary winding is begun. After the primary winding is finished several layers of paper are placed over it, and the secondary is then wound to the desired resistance. The complete coil is covered with paper or book-binder's cloth, which should be shellacked to render it moisture proof.

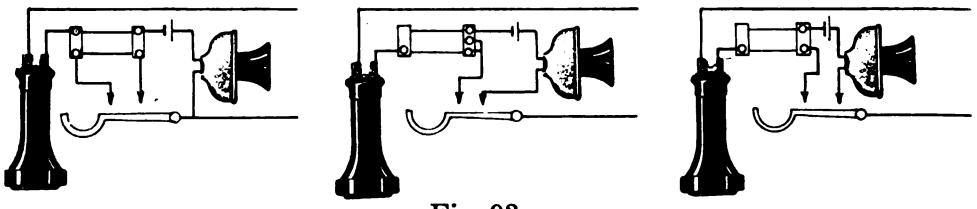


Fig. 93a.

One method of comparing induction coils is shown in Fig. 94. Here the switches, "A", "B" and "C" are connected to various induction coils

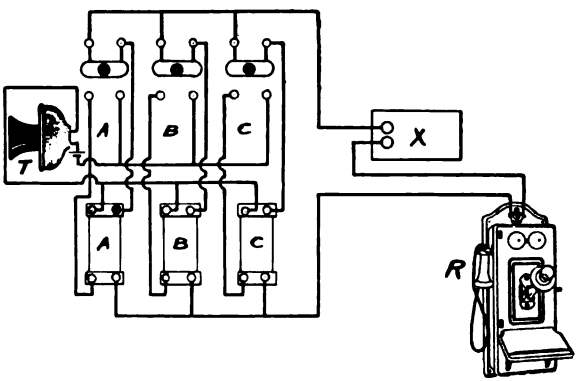


Fig. 94,

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as shown. After the equipment is connected up, the listener at "R" hears a person, or the phonograph at "T" speak, and by increasing the resistance "X", the comparative efficiency of the coils can be ascertained.

The type of coil with two windings as just described, is the only one used in commercial telephone equipment. Various coils with three or more windings have been tried, but except for special purposes, have not come into general use.

A coil with three windings is shown at A Fig. 95. Over the usual primary and secondary windings is placed a third winding consisting of the same (or more) turns as the secondary. This third winding is termed the "Tertiary".

For telephone instruments the coil is connected as shown at A. The line connecting to secondary, and receiver to tertiary.

Sometimes an additional receiver is placed in circuit at X. The practice of using two receivers is quite common in some European countries and this method of using an additional receiver without inserting same in the line current is sometimes used. It would seem that simply placing both receivers in series with an ordinary coil, would prove as satisfactory a method as any.

When the circuit shown at A, Fig. 95 is used with noisy lines, owing to the receiver being removed from the direct line circuit, a slight gain in freedom from foreign noises is observed. This circuit however, is not quite as efficient for receiving as the ordinary two winding coil.

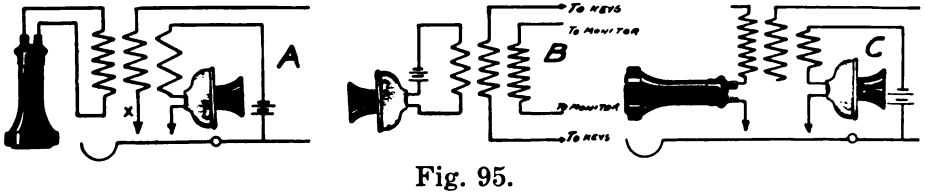


Fig. 95.

The arrangement shown at B, Fig. 95 is often used with switchboards and the three winding coil gives perfect results. The Teritary winding is connected to the Monitor's or Manager's desk and enables them to "listen in" without the knowledge of the operator, as closing the circuit of the Tertiary winding does not affect the side tone of the operator's set to the same extent that closing the secondary circuit does. Operators are often enabled to tell when some one is observing their work, by listening for this "side tone" which the use of the three winding coil eliminates.

The coil shown at C, Fig. 95 represents an attempt to arrange the telephone circuit so that leaving the receiver off the book would not affect ringing on the line. The secondary is wound in the usual manner and cut at the centre, or two wires are run on the coil side by side. The latter method is to be preferred.

As the two parts of the secondary winding are in inductive relation to each other, in-coming high frequency voice currents will be repeated from one to the other, thus establishing a circuit through the receiver in the usual manner.

The ringing currents, owing to their low frequency, will not have sufficient effect on the coils to cause a flow of current, in fact the gap in the winding acts like an open circuit, to the generator currents, thereby enabling the phone to be rung even if the receiver is off the hook.

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As this arrangement accomplishes nothing more than a repeating coil or transformer effect, a loss is present both in transmitting and receiving. This arrangement is now seldom used, condensers of ¼ or ½ M. F. capacity being inserted in the receiver circuit. These accomplish the same result with much less loss.

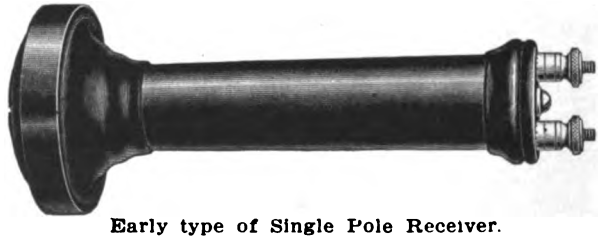
Other arrangements of the windings have been tried, such as dividing the coil in the middle and winding the primary on one end, and secondary on the other; putting the primary on top of secondary; putting an additional primary over the secondary, and connecting both primaries in multiple, etc.; but none of these methods have ever proven superior to the standard type for regular service.

The coils used in magneto switch boards and common battery telephones will be described elsewhere in connection with the equipment they are used with.

The tests for and location of trouble in induction coils is very simple. The usual fault is an open secondary winding, which can be easily ascertained by connecting the coil in series with a generator and bells. If it is impossible to ring through the coil, the secondary is open. An open primary can be tested in the same manner. Aside from this fault in the primary or secondary windings, trouble seldom if ever happens in properly constructed coils.

It is always best if a coil is suspected of being in trouble, to simply change the coil for a new one, as sometimes it may have short-circuited layers which are not easy to locate, but cause a perceptible falling off in transmission.

The Receiver, Transmitter, and Induction Coil are the parts of the complete telephone used in receiving and transmitting speech. The complete Telephone instrument consists of a combination of talking and ringing parts, and is described in the next chapter.



Early type of Single Pole Receiver.

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CHAPTER IV.

MAGNETO INSTRUMENTS AND CIRCUITS.

The complete telephone instrument is a combination of the talking and ringing equipment, mounted in a suitable cabinet which is adapted (in magneto instruments) to accommodate the transmitter batteries.

As the various parts have already been described, only their circuit connections and general assembly to form a complete instrument will be discussed. It should be remembered when a series or bridging instrument is described, that the generator, shunt, ringer coils, etc., are adapted for series or bridging work, as the case may be.

Little need be said regarding the details of the complete instrument such as locks, hinges, cabinet work, etc. These parts have of late years been so perfected that little if any cause for trouble in them exists. The old style lock has given place to the more reliable screw fastening, thus enabling the door of the instrument to be opened readily. Any one could open the old style of lock formerly used, by removing the escutcheon plate with a screw driver, so the lock was really of no value. Should it be necessary to seal a modern instrument equipped with screw fastening, it is simply necessary to cover the head of the screw with sealing wax and stamp a monogram or other seal which cannot be easily imitated, therein. Usually two screw fasteners are provided, at the top and bottom of the door.

The hinges in all modern instruments are provided with spring connections between the sides so that a metallic connection is formed which does not pass through the joint. This applies where the hinges are used as part of the circuit across the door to the ringer or other parts. The hinges are now seldom used in the talking circuit of the instrument, a flexible cord being used instead, thus making an unbroken circuit directly from the transmitter to the other parts.

The instrument is usually installed by fastening same to the wall, and the holes in the back board through which the screws pass should be protected by metal eyelets which prevent the back board splitting in case too large a screw is used.

If there are wires in grooves in the back board, the grooves should be filled with beeswax to prevent trouble in case the instrument should be mounted on a damp wall, which might cause a ground if the wire was exposed.

The finish of the cabinet has really nothing to do with the operation of the instrument, but the manner in which it is put together has. The wood should be well seasoned and so joined that there is no possibility of it ever coming apart.

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Quartered sawed oak is probably the most generally used wood. Walnut has been extensively used, but is rapidly going out of use owing to its scarcity.

The use of metal cabinets is rapidly becoming general, especially in hospitals and other places where it is necessary to frequently cleanse the instruments from disease germs. The metal cabinets can be washed with solutions which would prove fatal to polished wood work.

Fig. 96 shows the compact type cabinet now in general use for magneto equipment. A 5 bar instrument is shown and the cabinet does not differ, except in width, when a 3 or 4 bar generator is used. The general arrangement of the parts is well shown in the illustration, and various makes differ but little from the one shown. In some makes the shelf supporting the generator is omitted, the generator being mounted on a bracket attached to the backboard. Sometimes the induction coil is mounted on the door instead of in the upper part of the cabinet.

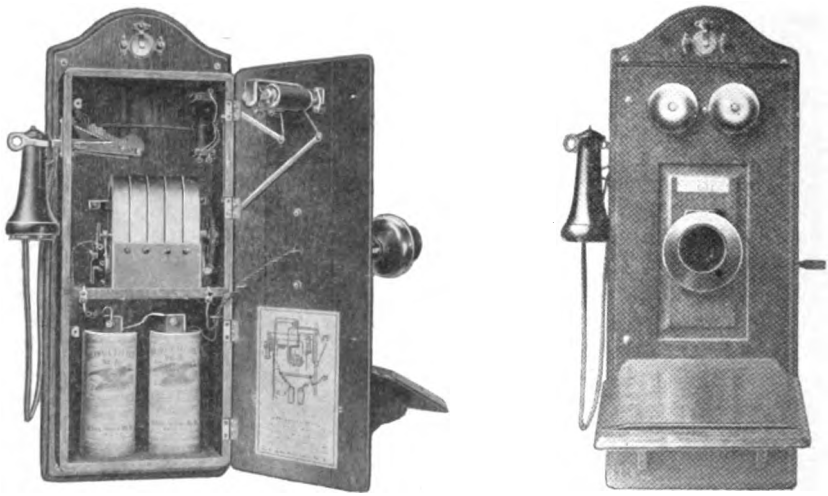


Fig. 96.

Fig. 97 shows another type of cabinet which possesses some advantages. The arrangement of the various parts is as shown, the batteries being placed in a compartment at the bottom of the cabinet as shown in Fig. 98. This type has the advantage of a good writing desk, and also resembles modern common battery instruments, so that the set may be readily rewired in case the system is changed from Magneto to Common Battery, without the instrument looking out of place when compared with the regular Common Battery type.

While the general arrangement of series and bridging circuits has been discussed, the usual types of wiring will be shown together with some special circuits, to show that by rearranging the various parts, nearly any desired result may be accomplished.

Fig. 99 shows the old series circuit. When the receiver is off the hook, the generator and bells are completely cut out of circuit. Fig. 100 shows a later type. When the receiver is on the hook, the receiver circuit is short circuited and a clear circuit through the bells and generator

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exists. When the receiver is off, the generator and bells are short circuited. The advantages of this arrangement is that the bells are never completely cut off, for if the bottom hook contact fails, the incoming ringing current could find a path through the receiver, and the line would not be open which is the case with the first circuit, should the bottom hook contact fail.

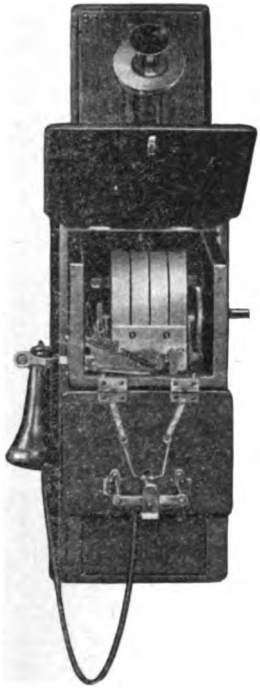


Fig. 97.



Fig. 98.

In both of these arrangements the generator winding is normally short circuited by the shunt springs. The ringers are from 80 to 250 ohms resistance, the latter being more suitable for exchange work where there is only one instrument on a line.

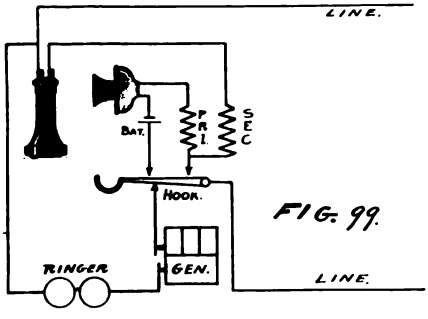


FIG. 99.

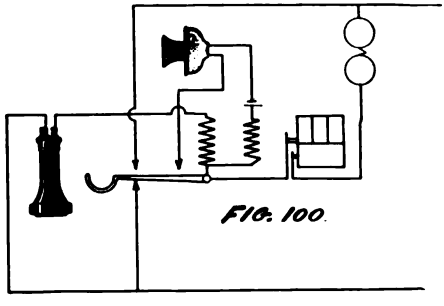


FIG. 100.

The usual bridging circuit is shown in Fig. 101. The talking circuits are the same as in the series. The bells and generator are bridged across the line, the generator winding being normally open.

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The circuit shown in Fig. 102 is often used. The generator is equipped with shunt springs so arranged that the ringer is short circuited when the generator crank is turned, which prevents vibrations from the gongs producing unpleasant ringing noises when the receiver is taken off. This also removes the ringer from the circuit, thereby lessening the load.

In some makes of bridging instruments the generator shunt springs are so arranged that the armature winding is normally short circuited, which, it is claimed, prevents damage to the winding from lightning and other sources.

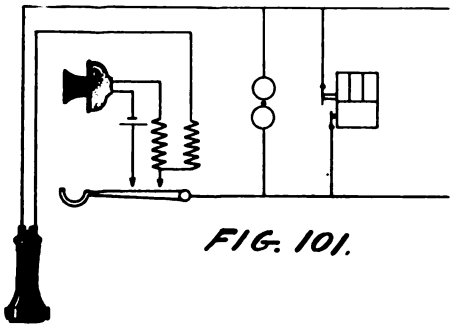


FIG. 101.

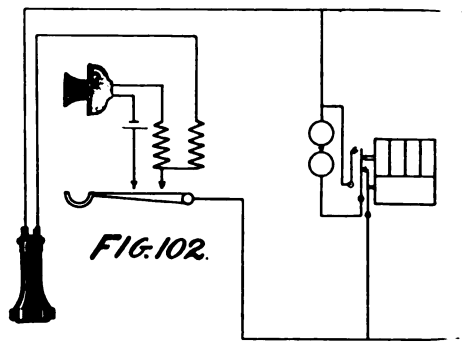


FIG. 102.

Generators in bridging instruments have from three to six bars or magnets, depending upon the class of service they are intended for.

Line conditions such as length, size wire, etc., determine to a great extent the number of instruments that can be placed on one circuit. The fact should be always kept in mind that as all the bells ring at once, great confusion will result if more than a reasonable number of instruments are used.

The actual number of instruments it is possible to operate on one line is only limited by the power of the generators and sensibility of the ringers. One manufacturer claims that 4 bar 1000 ohm ringer instruments will operate satisfactorily 12 per line, and if 1600 ohm ringers are used, 20 per line, and that 5 bar 1600 ohm instruments will operate 25 per line, or more, depending upon line conditions.

1600 ohms is becoming a standard resistance for bridging ringer movements. The 1000 ohm ringers ring strongly but only a few can be put on one line without using very powerful generators. 2000 and 2500 ohm ringers do not give a very loud ring, the stroke being rather weak owing to the small amount of current that can force its way through the high resistance coils. The 1600 ohm ringer gives a sufficiently powerful ring to insure satisfaction, and permits the maximum number of instruments to be placed on one line.

For short lines with only five or six instruments, 3 bar generators can be used with success. A three bar bridging generator has a lower resistance winding of larger size wire, and greater output than a series generator.

Four bar generators are the standard for bridging service, and the greatest number of instruments it is practicable to operate on one line may be successfully rung with them. Where line conditions are very

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severe, or where a large number of instruments are used, 5 bar generators are desirable.

All instruments on the same line must have ringers of the same resistance. The generators may have 3, 4 or 5 bars as this will not have a general effect on the line, the generators only being in circuit when the crank is turned.

It is perhaps needless to state that series and bridging instruments cannot be used on the same line. While the talking equipment of the instruments is the same, the series ringer is of such low resistance that it practically short circuits the entire line for ringing if bridged on, while if put in series it will probably not get sufficient current for its operation.

Of course instruments of different makes can be used on the same line if of the same resistance. It should be remembered that one inefficient instrument will affect all the others to some extent, and it is therefore better to have all the instruments on the same line of the same make, selecting equipment of known quality.

On bridging lines when a receiver is accidentally left off the hook, or when a person wilfully listens in, it is impossible to ring over the line to other instruments, as the entire line is disabled owing to the low resistance path formed from one side of the circuit to the other, through the secondary and receiver of the telephone where the receiver is off.

To remedy this evil a small condenser is inserted in the receiver circuit, as shown in Fig. 103. 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 in Fig. 104. 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.

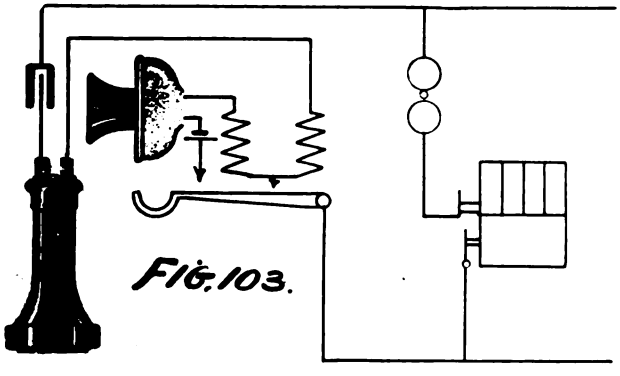


FIG. 103.

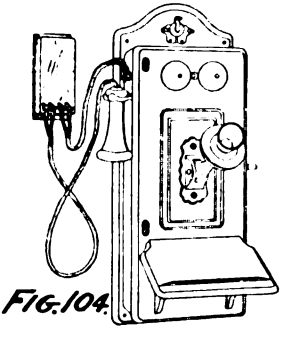


FIG. 104.

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.

Condensers for this purpose are usually small in size and of ¼ or ½ M. F. capacity. Nearly all standard makes of bridging telephones are furnished wired for condensers, which can be easily put in later if

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required. Condensers can be used in the secondary circuit of nearly all bridged talking circuit instruments.

It is often desirable to have bridging telephones so wired that a subscriber can call the central office for all connections or for other parties on the same line, thereby giving the operator a chance to keep a record of all calls made. Such service is very advantageous. The subscribers are not required to give their own signals, which is a difficult feat for some to perform, and the calling of the exchange does not ring the other bells on the line which in a great measure prevents the curious from listening in.

To accomplish this a so-called "direct current" generator is wired in the circuit as shown in Fig. 105. The current delivered from this generator is of such a nature that it does not affect the ringers bridged across the line. The generator is of the regular type with the addition of a small commutator on the end of the armature shaft which is so placed that only one pulsation or alternation is given for each revolution of the armature. This current being always in one direction will not ring the bells bridged on the line but will throw the drop signal in the Central Office. The drop should not be of more than 100 ohms resistance. A condenser can be placed in the receiver circuit of this instrument, same as shown in Figs. 103 and 104.

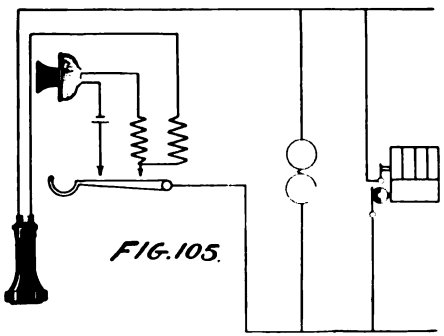


FIG. 105.

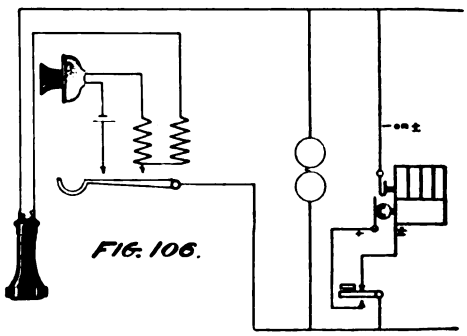


FIG. 106.

It is sometimes desirable to arrange this circuit so that the phones can call each other or central, separately. When this is done a generator is used designed to give both pulsating and alternating current. An ordinary bridging drop is used at central, and an extension bell is also bridged on the line. By simply turning the crank on the phone, alternating current is generated which rings the bells on the line, the bell at central, and throws the drop. As both bell and drop at central are operated, the operator need not answer, as it is apparent that some one on the line is wanted.

Each phone is equipped with a push button which when pushed, connects pulsating current to the line instead of alternating. This pulsating current will not ring any of the bells, but will throw the drop, and the operator, seeing the drop fall without the bell ringing, will know the call is intended for the central office, and can answer. The circuit of the instrument using both alternating and pulsating current is shown in Fig. 106.

Pulsating or so called direct current generators are further described on page 178. Both the above methods can be used with either grounded or metallic lines.

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A peculiar method of calling central without ringing the phones on the line, for use with grounded systems, is shown in Fig. 107. An ordinary ringer is taken and the clapper ball is removed. To the striker rod is soldered a piece of tin about 1½ inches square. The ringer is mounted on a suitable piece of board, and the square piece of tin is allowed to project into a glass of ordinary kerosene oil. A contact is arranged to make connection with the striker rod when same is moved all the way to one side and a counterbalance weight is put on top of the striker, all as shown in Fig. 107.

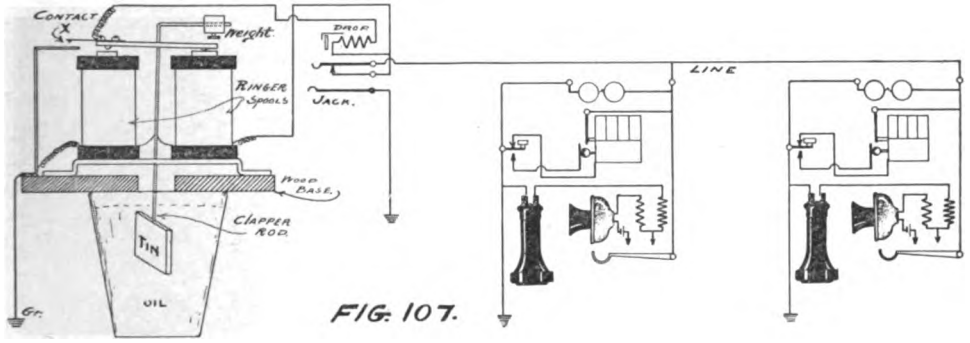


FIG. 107.

This arrangement is bridged on the line at Central. The drop is connected as shown. The generators in the telephones on the line are equipped as shown in Fig. 106. The telephones call each other with alternating current by turning the crank without pushing the button, and alternating current traverses the line in the usual manner and rings the bells bridged thereon. At the same time the ringer at Central is operated, but owing to the immersion of the square piece of tin in the oil, the clapper will not move sufficiently in one direction to close the contact X.

When it is desired to call Central from one of the phones, the button is pushed and the crank turned, this delivers pulsating current to the line, which will not affect the ringers bridged thereon, but as it is a current operating in one direction, the ringer at Central if connected in the proper manner, will draw its armature to one side thereby closing the contact X; as soon as this is closed, the drop is bridged across the line and is immediately thrown. It will be observed that it is necessary to so connect the special ringer at Central that the pulsating current will flow through same in the proper direction to pull the armature to the proper side and close the contact X. This arrangement is easily made, and when properly constructed gives satisfaction.

Figs. 105 and 106 are particularly adapted for calling Central separately from the telephones over grounded lines. When metallic lines are available, a circuit using the regular alternating current generator and a push button may be used. This is shown in Fig. 108.

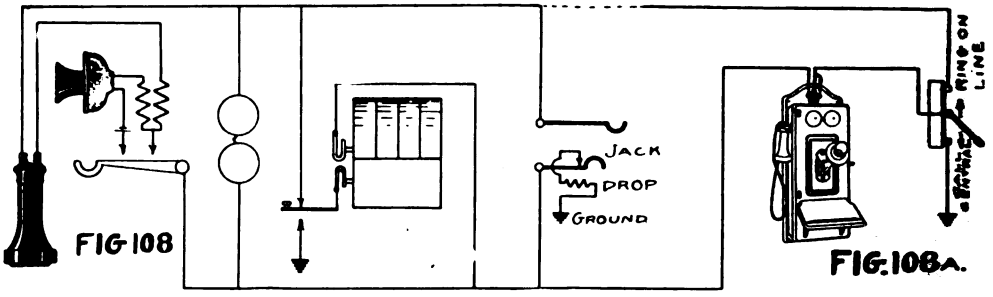
When the button is pushed current traverses one line only and the ground, passing through the drop at Central and operating same, as shown in Fig. 109. It will be noted that there is no circuit from one line to the other, and consequently the bells in the other telephones on the line do not ring.

When the crank on any 'phone is turned without pushing the button, the current traverses both of the line wires as shown in Fig. 110, and

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rings the bells bridged thereon, but the drop at Central does not fall as there is no circuit to the ground.

It is sometimes desired to use ordinary Bridging telephones not equipped with the buttons, for this system. These can be easily arranged to work in connection with a single pole double throw knife switch, arranged to connect one side of telephone to ground or to line, as desired. This arrangement is shown in Fig. 108a.



Care must be taken to connect these instruments in such a manner that when the button is pushed the generator current is connected directly to that side of the line to which the drop is connected at the Central Office. If this is not done, the current will pass through all the bells bridged on the line to get to the proper side of the line to find a circuit through the drop. It is simply necessary when connecting the 'phones to try them with the lines in one position, and if they are not properly connected, reverse the lines.

While the system described above is perfectly satisfactory for use in most localities, still where there are high tension power circuits in proximity to the telephone line, some noise will be caused by the line being unbalanced by reason of one side being connected to ground through the drop. When it is desired to eliminate this trouble, it is customary to equip the 'phones with a 5-spring push button arranged to short circuit

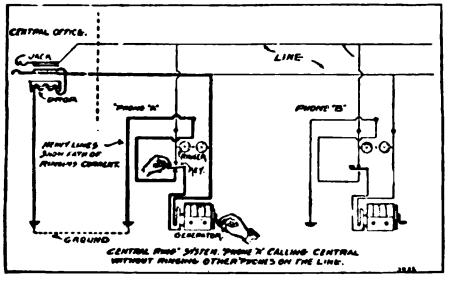


Fig. 109.

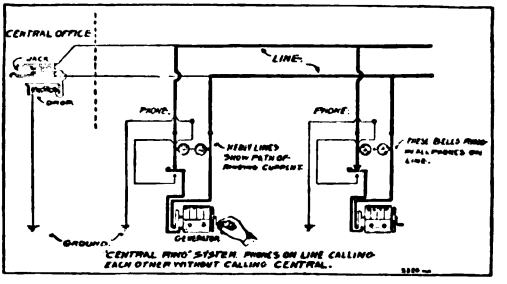


Fig. 110.

both the lines, connect one side of the generator thereto and connect the other side of the generator to ground. The lines are brought into an impedance coil at the Central Office; to the center of which is connected the line drop as shown in Fig. 111. This impedance coil may consist of an ordinary ringer with the armature screwed down against the pole

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pieces. From the center point, where the two coils are joined together, run a tap to one side of the drop which should be about 100 ohms resistance. When a button is pushed, current flows over both sides of the line and the ground, and throws the drop. As the drop is connected to the center or neutral point between both the lines, the amount of ground on each side of the line is equal and a balance is thereby preserved.

Another method is to make the drop winding in two parts, as shown at A, Fig. 111. The centre point is connected to ground. Care must be taken to secure an equal number of turns of the same resistance for each winding. The windings must also be placed on the core in opposite directions so that when a current is traversing the line wires (as when the 'phones on the line call each other) it will not throw the drop owing to one winding opposing the other.

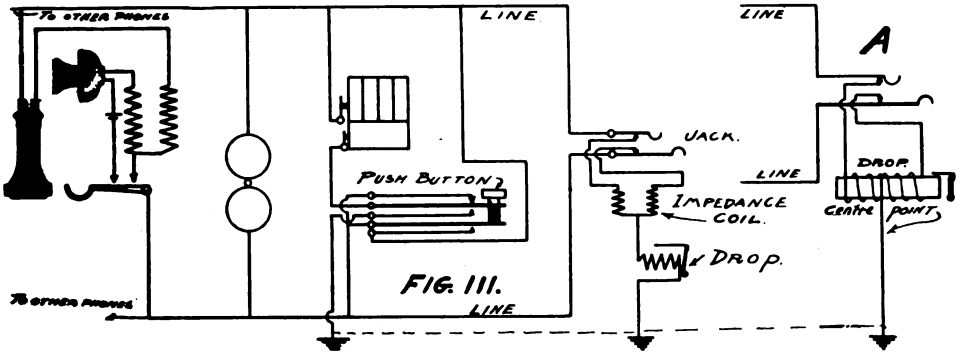


FIG. 111.

When putting up the 'phones equipped with the five spring buttons, it is not necessary to do any testing out to locate each side of the line. Connect 'phones same as an ordinary Bridging line.

It will be observed when using either of the above arrangements for calling Central by means of push buttons, that there is no ground on the line when a plug is in the jack at the Central Office, and that talking is at all times metallic, thus enabling the highest class long distance service to be given with 'phones equipped in this manner.

When the arrangement shown in Fig. 109 and 110 is used the clear out drop may be bridged across the cord circuit and the middle point of the winding grounded. The drop will then respond when a button is pushed.

The two parts of the winding need not be in opposition to each other, simply ground the centre point of a winding all in one direction.

This arrangement of the clear out drop cannot be used when the 5 spring buttons are used, in which case the clear out drop is operated by giving one short turn of the generator crank without pushing the button. This will cause all the bells to ring, but this is not a great disadvantage, as the conversation would be completed and listeners would only be notified of the termination of a conversation and not its beginning.

The common method of wiring wall sets is to use bare tinned copper wire of from 19 to 22 gauge, run in grooves in the back board and brought through holes at the proper points for connection to the various parts. The grooves are filled with beeswax and this protects the wires from moisture and holds them in place. The use of staples to hold the wire in

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position should be avoided and all splices should be made inside the cabinet where they can be seen. The use of bare tinned wire is preferable to the use of cotton-covered or "Annunciator" wire, as with the latter, if the wire is broken inside the insulation, the break is very hard to locate. With this method of wiring in grooves, a wire is rather hard to trace and inspect, it being necessary to remove the telephone from the wall.

Lately the "Cable wiring" method has come into extensive use. Double silk and cotton insulated wire is used, of the same high grade as used for switchboard key cables. Each wire has a different colored insulation and the wires are formed into a cable and placed in the cabinet. The connections to the various parts serve to hold the cable in place, and the ends of the wires connecting to generator, coil, etc., are equipped with clip terminals. As each wire is a different color and in plain sight, testing is facilitated. The circuit arrangement of the instrument can also be changed very easily as the cable is usually only soldered to the hook springs and hinges. By this means the grooves and holes in the back board are eliminated and the wiring is more compact and neatly arranged.

One company which has furnished several thousand instruments wired in this manner, report that less trouble results from lightning than when bare wire is used. The possibility of short circuits is also lessened, as the cables are boiled in beeswax and shellacked.

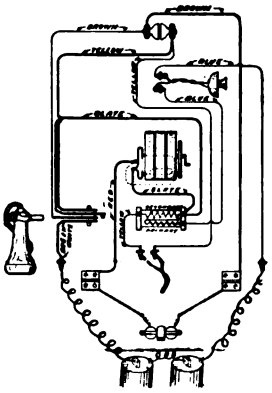


Fig. 112.

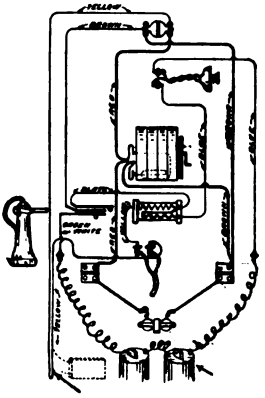


Fig. 113.

Figs. 112 and 113 show the series and bridging circuits of cable wired sets.

The portable Desk Telephone or Stand, has always been a very popular type, but its high cost of maintainance has prevented it from coming into comparatively extensive use.

As a Desk Stand is portable, it naturally receives more handling and rough treatment than a wall instrument. The cords being necessarily flexible are also subject to wear. As the parts must be more compact than in the wall type, stability and strength is often sacrificed to weight and neatness of appearance, thus rendering the instrument weak mechanically, short lived, and hard to maintain.

Recently great improvements in the mechanical construction of Desk Stands has taken place, so that many of the instruments now offered are not only graceful in design, but also rigidly constructed and assembled

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in such a manner as to be free from complication and as easy to maintain as the average wall set.

Typical of modern practice is the Desk Stand furnished by The Sumter Telephone Mfg. Co., and shown in Fig. 114.

The base is formed from stamped steel and is enameled or nickle plated. A heavy stamping is mounted vertically in the centre of the base and supports the transmitter and hook mechanism. A split stem encloses the hook contacts, this casing and in fact all parts of the instrument being insulated from the circuit.



Fig. 114.

To inspect the hook contacts, the knurled nut at the top of the casing is loosened, as shown in Fig. 115, this permits the removal of the stem casing, which exposes to view the entire hook mechanism, as shown in Fig. 116.



Fig. 115.



Fig. 116.

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The hook contact springs are arranged to play between stops of hard rubber, which keep them in permanent adjustment. A separate spring is used to raise the hook lever, which is not dependent upon the tension of the contact springs for its operation. This raising spring is of round steel, enameled, and can be adjusted to properly operate the hook with any weight of receiver.

The Hook lever is made removable for ease in shipment or in case of breakage, by attaching same to the hook mechanism with a screw as shown in Fig. 117, which clearly shows how the lever may be removed or a new one inserted without readjusting any of the other parts.

In this type of stand, only the cord terminals are located in the base, the induction coil and other parts being mounted in the Magneto Box.



Fig. 117.



Fig. 118.

Access is obtained to the base of the Stand by taking one screw out of the center of the enameled steel felt covered bottom, which when removed exposes to view the cord terminals and connections to hook springs and other parts.

From Fig. 118 it will be seen that standard tips are used on both ends of the cord.

Wires are soldered to the cord terminals and connect to the hook springs, receiver cord terminals and transmitter. There are no sliding or contact connections used in this stand which is entirely operative with all wiring and every part in view, when the casing and bottom are removed.

The bells, generator and induction coil for use with the stand are assembled in a small box, the complete outfit being shown in Fig. 119. The line, battery, and cord terminals are located upon a strip located upon the left side of the box and holes are provided for the entrance of the cord and wires, by this means all terminals and connections are enclosed.

The Dean Elect. Co. use a different method of assembling the various parts, and combine them so that they are readily removable from each other. Fig. 120 shows a Dean stand disassembled. The vertical upright carrying the transmitter and hook lever, is provided at the bottom with a catch which holds it in place. When in place the notched lever connected to the receiver hook engages the hook contact springs which are placed in the bottom of the stand, moving them sideways.

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The flexible wires from the transmitter terminate in two contact pins which engage springs in the base of the stand, when the stem is placed in position. From this it will be seen that the stem carrying the hook

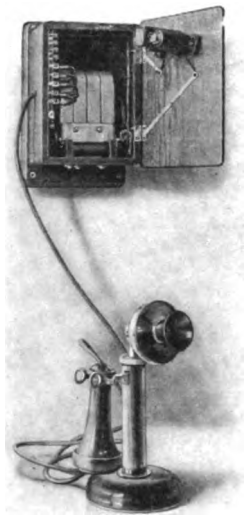


Fig. 119.

lever and transmitter can be unlatched and removed entire from the stand without unfastening any wires.

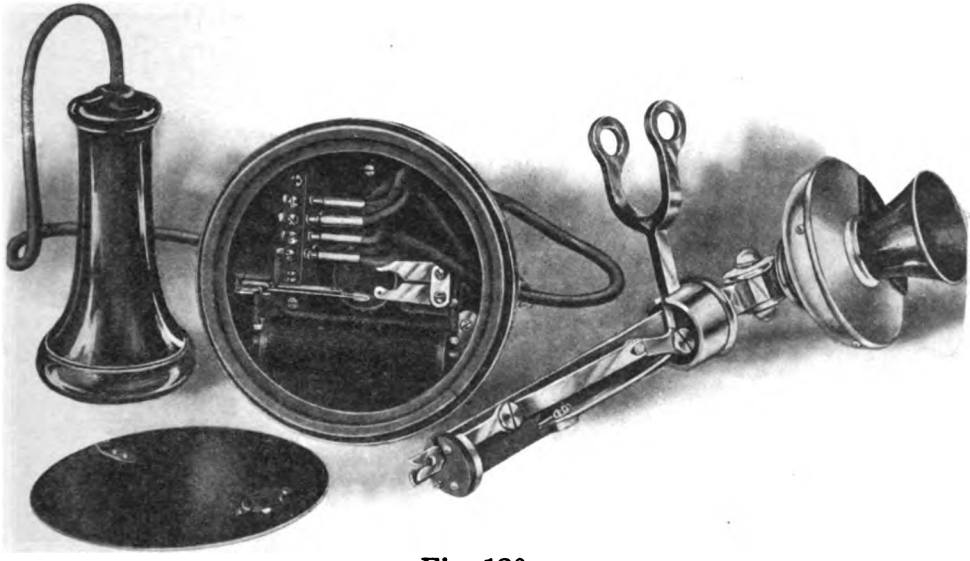


Fig. 120.

The bottom of this stand is removed by inserting a screw driver blade in a slot and turning to the left, this exposes all the parts except the hook lever, which is removed from the upright tube by pressing a release spring as previously described.

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A very original feature of this stand is the interchangeable circuit plate shown in Fig. 121. This carries all the wiring of the stand except the two cords to the transmitter. The induction coil, hook springs and cord terminals are mounted on this, so that each stand is complete so far as the talking parts are concerned. This circuit plate may be removed and another substituted, arranged for Common Battery, should a change from one system to the other ever be made, this change accomplishing a complete rearrangement of the circuits.

In this stand the base is provided with a leather ring to prevent marring furniture. This takes the place of the felt often used in other makes, and is very durable. The stem of the stand is covered with a hard rubber sleeve, and the base is either nickled or black enameled.

The magneto box used with this stand is similar to the one shown in Fig. 119 except that it only contains the generator and ringer. A cord rack or small terminal block is provided to which the line, battery, and magneto box connections are brought and connected to the cords. A 4 conductor cord is standard with this company for series and bridging work, the series circuit arrangement being shown in Fig. 122 and the Bridging in 123. In the latter circuit the ringer is short circuited when turning the crank.

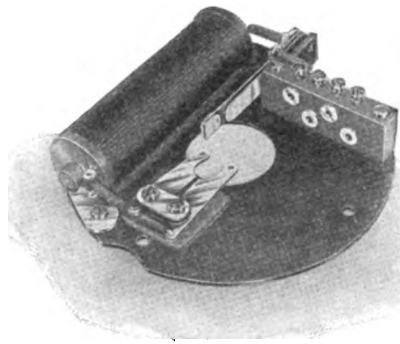


Fig. 121.

The two instruments just described will serve to show that the Desk Stand has reached a high state of development, and will compare favorably with wall sets as to cost of maintainance. The two types shown illustrate the two prevailing methods of assembling the parts. In one type the Desk Stand carries the hook switch, transmitter, and receiver only, while in the other type all of the talking equipment is carried in the stand.

The circuit combinations possible with Desk Stands are as numerous and varied as with the wall type. The following will serve to illustrate some in common use, in addition to the series and bridging circuits of the Dean set, shown in Figs. 122 and 123.

Fig. 124 shows the circuits of the Stand when the coil is mounted in the magneto box. A 5 conductor cord is used to permit using the stand for either series or bridging work. The magneto box wiring is quite unique and is shown in Fig. 125. Four wires are brought to the generator terminals, upon the connection of these depends whether the set is series or bridging.

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For Series, the slate and green-white wires are connected to generator. For Bridging the red and and slate wires connect together and to

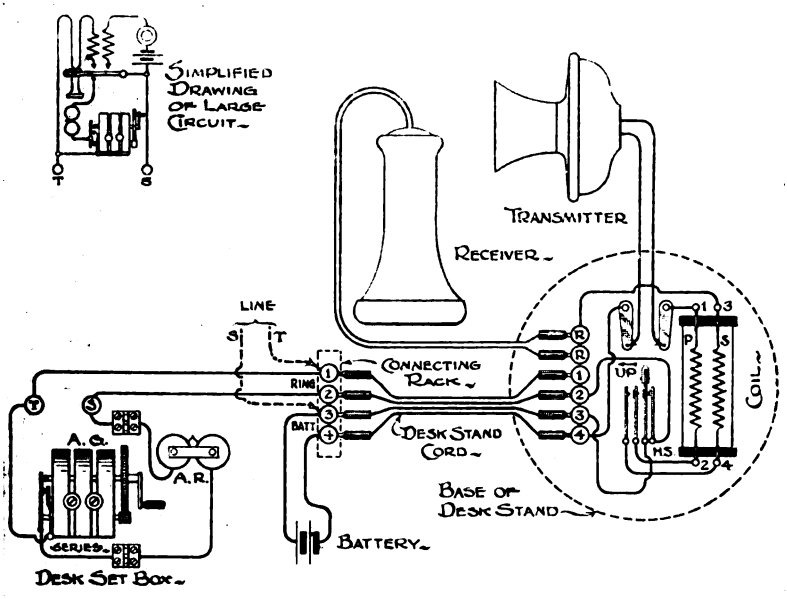


Fig. 122.

one generator terminal, and the brown wire to the other. The marking of the terminals and colors of the wires enables the circuits to be readily traced.

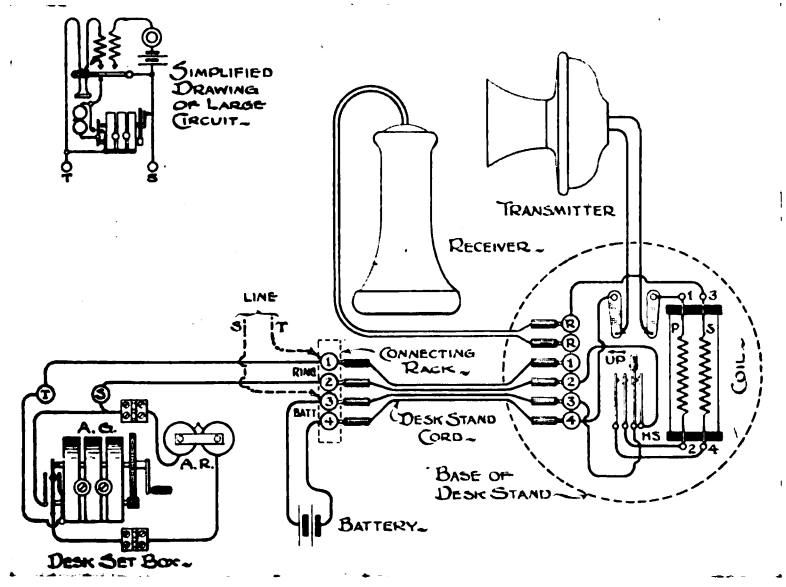


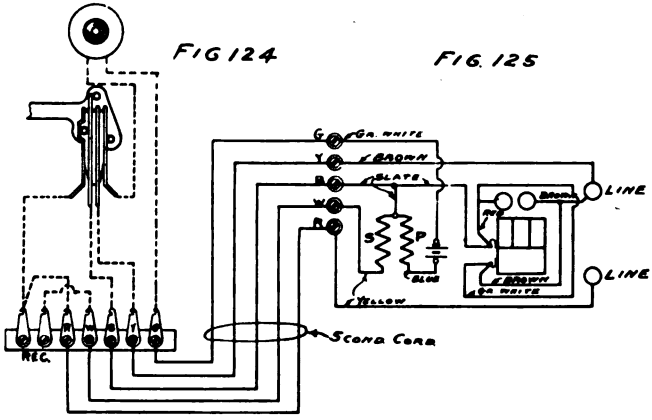
Fig. 123.

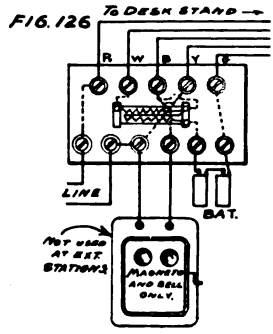
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Sometimes it is desired to use a Desk Stand as an extension instrument, without bells or generator. With stands of the type carrying the coil in the base this is accomplished by simply omitting the magneto box. With the type of stands not carrying the coil it is necessary to provide one mounted on a block as shown in Fig. 126 which shows the line and battery connections.

Should it ever be necessary to add a magneto, this can be done by attaching same to the two posts provided, otherwise nothing is connected to these posts.

Condensers can be used in the receiver circuits of desk stands by putting them in series with the receiver. Any of the special circuits described in connection with wall sets can be used by simply rearranging the desk set circuit connections, for this reason they will not be described here.





The location of troubles in the complete telephone instrument are comparatively simple if sound judgment is used as to their *proper* location. If the instrument will not talk, it is folly to examine the generator and ringer, and if there is ringing trouble it certainly will not be found in the transmitter, induction coil, or receiver.

In locating trouble in Desk sets, the cords are the first part that should be thoroughly examined. If a scraping noise is the trouble, examine each cord tip where it is joined to the conductor, as often this joint is imperfect or a loose connection formed.

If a break is suspected in the conductor, the cord should be disconnected from the stand, and each conductor tested by placing same in series with a receiver and battery. Shake the cord, and if the conductor is partially open, a scraping noise will be heard.

The use of a receiver for making general tests should appeal to every trouble man on account of the simplicity of the operation. It is only necessary to place a cell of battery in series with the receiver to locate breaks or opens, by placing the suspected wire in series with the receiver and battery.

Hook contacts that are suspected of not closing properly, generator shunts, push button contacts—in fact any wire or contact can be easily tested in this manner.

Coils and windings of all descriptions may be tested by this method, but some practice is necessary to secure accurate results, as a coil can be

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completely open and yet a click will be heard in the receiver owing to the inductive relation between the two parts of the broken winding.

The majority of desk stands are now equipped with transmitters in which the working parts are insulated from the shell. When this is the case, sometimes through the failure of the rubber band on the diaphragm, or failure in the insulation of the other parts, the transmitter will "go short" on the metal frame of the stand, and cause trouble. This is easily located by testing the transmitter or changing same.

This trouble also occurs at the hook switch, the insulation between the circuit springs and the hook lever mechanism becoming defective. This is located by testing with a magneto bell.

The best practice would seem to be that of completely insulating every current carrying part from the frame of the stand, as this will prevent the user from receiving a very unpleasant shock, which can and does happen should the user be standing on a damp floor and pick up the stand before the operator had ceased ringing on the line, especially if a power generator is used and one side of same is grounded.

Often desk stands are placed on the top of steam radiators or other metallic bodies connected to the earth. This often happens in offices where the radiator is near a window and forms a convenient place to keep the stand. If the stand is not insulated, as soon as the protecting felt on the bottom becomes worn, the line becomes grounded as soon as the stand is placed on the radiator. In magneto work this does not matter so much but in Common Battery exchanges it is a source of great annoyance and is hard to locate and still more difficult to prevent, unless the instrument is insulated.

Tests for the location of troubles in the various parts have been described, but a few general tests will be given. When testing an instrument, *first disconnect the line wires,* otherwise the trouble may be in the line or house wiring and not in the instrument. Modern instruments have reached such a state of perfection that nine out of ten troubles reported will be found in the line and not in the instrument. In the following tests the line wires are supposed to be disconnected from the instrument.

BELLS DO NOT RING WHEN OTHERS CALL.

With receiver on the hook, turn crank; if the bell rings, bell is O. K.; if not, bell needs adjustment or is burnt out by lightning, or small wire leading into bell coils is broken. If series, connect line posts together before testing. Examine hook contact.

Place fingers across line posts and turn crank; a smart shock should be felt which indicates that 'phone wiring to line posts is O. K. If series, short circuit Ringer before testing with fingers for generator current.

YOU CANNOT RING ANYBODY.

Test with the fingers as explained above. If you do not feel any current, and if you can't ring your own bell, the generator is out of order. See that spring on left-hand end of generator makes good contact with axle of wheel when crank is turned, or generator may be burnt out by lightning. If generator turns hard, winding may be short circuited or insulation between shunt springs is bad.

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YOU CAN HEAR OTHERS, BUT THEY DO NOT HEAR YOU.

Examine the batteries. Left-hand wire in 'phone should go to zinc post or can of battery; then carbon post or post on rod in center of can should go to zinc post of next battery; the last carbon post should go to clip on cord which goes to transmitter. All connections must be tight. Batteries don't last forever. When you use the 'phone, the batteries are being used up, and where use is frequent, batteries only last six or seven months.

Connect line posts together with wire, lift off receiver and speak into transmitter. You should hear yourself talk perfectly and loud. If talk is weak, the batteries are probably exhausted. Examine hook contacts; hook springs should come together firmly when hook goes up. Examine connections on induction coil, see that all connections are tight.

YOU CAN TALK TO OTHERS BUT CANNOT HEAR.

Connect line posts together and proceed as above. If you can hear yourself talk, 'phone is O. K. and trouble is in line. If you cannot hear, examine receiver cord, which is probably broken. Unscrew ear piece of receiver and note if diaphragm is bent or dented; if so, get a new one, as you can't straighten it. Dust out receiver and screw cap firmly in place. Be sure and replace diaphragm right side up. Examine hook contacts.

If a new receiver cord does not help, try a new receiver; if this does not cure the trouble, the induction coil is probably burnt out by lightning, or there is a broken wire in telephone.

SPUTTERING NOISES WHILE YOU TALK.

Connect line posts with piece of wire. Talk into transmitter and shake receiver cord; also test transmitter cord and all connections, sometimes too much battery (never use more than 3 cells) will cause a frying noise. If 'phone talks clear without noise, look for trouble in loose joint in line.

Always clean Lightning Arrester, removing carbon dust (if any) from between line and ground plates. This dust often causes trouble and this should be the first part to be examined.

One important part of the complete instrument which has not been previously referred to, is the Lightning Arrester. This is usually located upon the top of the cabinet in Wall sets. Desk sets are not equipped with arresters as a rule, because the magneto box, upon which the arrester would be placed, is often mounted underneath desks and in other locations near inflammable materials liable to become ignited if the arrester should spark heavily, which often occurs.

Early types of Arresters consisted of two metal plates with saw tooth edges, connected to each line binding post. The saw teeth were placed close to another plate having similar teeth, this plate being connected to the ground. A hole was provided for inserting a metal plug, so that all three plates could be connected together, thereby grounding the line. The plug was often placed in the arrester and forgotten, thereby putting the instrument out of business and, on bridging lines, disabling the entire line.

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The saw tooth arrester is shown in Fig. 127. Owing to the teeth being of metal, serious arcs and flashes took place if the arrester was subjected to a heavy discharge, and sometimes the teeth would melt together, permanently disabling the instrument. An improvement in this device consisted of making the ground plate of carbon, which is a non fusible substance capable of withstanding severe currents without melting. This resulted in the arrangement shown in Fig. 128 which is typical of the form of Arrester with which all modern wall sets are equipped.

The Carbon disc is kept from coming in contact with the line plates by the mica disc. This disc has a number of holes punched in it to provide a ready path for the lightning discharges, which are supposed to jump from the metal line plates to the carbon ground plate and flow to ground, without passing through the instrument.

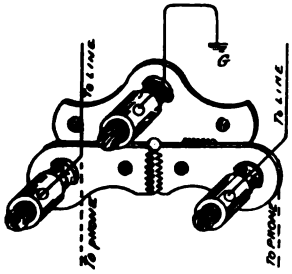


Fig. 127.

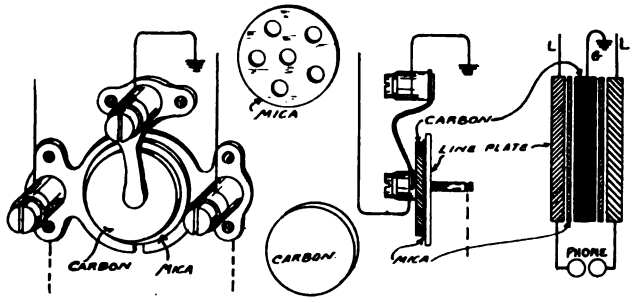


Fig. 128.

Sometimes fuses are combined with the arrester. The fuses consist of short pieces of easily fusible wire, and are placed in series with the incoming line, usually before it reaches the Arrester. As a protection against lightning, fuses are practically worthless, the lightning often burning out the instrument without disturbing the fuse.

When the telephone line is exposed to crosses with wires carrying heavy currents, fuses are necessary as they protect the instrument against such currents, and a combined carbon and fuse arrester is advisable, but where lightning protection only is necessary, fuses will be found worse than useless, as they are often blown by slight discharges without serving any purpose except to put the telephone out of service until they are replaced.

The Lightning Arrester usually forms part of the line terminals on the telephone and the ground terminal, or one connected to the carbon plate is usually the middle one.

On Metallic lines, the lines connect to the outside terminals and a ground wire to the centre, this wire serving only to act as a passageway for the escape of the lightning current from the Arrester.

On grounded lines, one of the line terminals is connected to the ground terminal, and in this case the ground wire forms part of the ringing and talking circuit. The incoming line wire is connected to the other line terminal.

As the wooden cabinet is not a good place on which to mount a piece of equipment which is liable to spark, and as the insurance regulations require these devices to be mounted on bases of non-combustible material

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and placed where the lines enter the building so as to protect the inside wiring as well as the instrument, some other device was necessary.

This led to the development of the type shown in Fig. 129, which consists of three carbon plates separated from each other by perforated mica, the parts being mounted on a porcelain base. The outside plates connect to the line wires, and the centre plate to the ground.

All of these arresters depend upon providing a path to ground for the lightning, which is supposed to jump across the space between the line and ground plates, instead of passing through the instrument.

This, it will be observed is only a side path to ground, and sometimes the Arrester failed to work, owing to the current rushing by the Arrester,

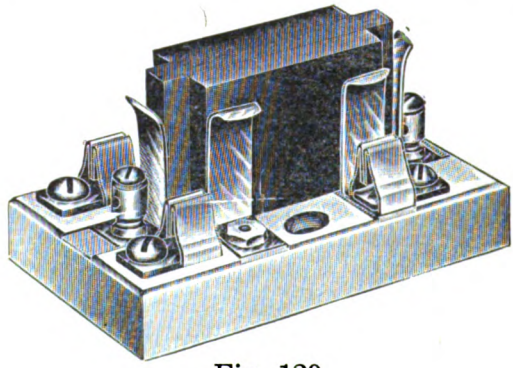


Fig. 129.

a poor ground connection, or too great a space separating the ground and line plates. The space between the line and ground plates should not exceed .005 in. and less than this is better.

When the mica is very thin, the carbon dust caused by the current passing between the plates, often causes a ground on the line. The blocks should therefore be frequently removed from the Arrester and cleaned.

It will be seen that all types of Arresters arranged with plates adjacent to a grounding medium, do not offer any opposition to the lightning entering the telephone, but only offer a path to ground, so placed that under favorable conditions the lightning would take this path, instead of continuing on into the instrument.

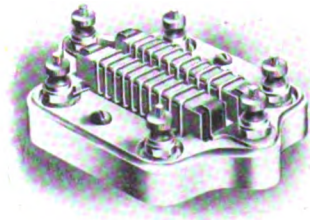


Fig. 130.

An Arrester offering direct opposition to the passage of lightning currents *through* it, is shown in Fig. 130. Two coils, each convolution of

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which forms a rectangle, are inserted directly in the circuit between the line and the telephone. The core around which the coils are formed, is of carbon, and the coils are prevented from direct contact with same by strips of mica which only leave the edges of the square blocks exposed. These cores are connected to the ground. The operation of this device is as follows.

When the incoming lightning reaches the Arrester it encounters the coils, which are in the circuit between the line and the instrument. Lightning currents are alternating in character and possess enormous frequency, therefore when they encounter the coils which have many abrupt turns and convolutions, their progress is greatly impeded.

At each bend in the coil, the tendency of the lightning is to follow a strait line, it therefore flies off, which action is helped by the presence of the grounded carbon blocks which attract and take the charge, carrying it safely to ground.

A lightning discharge abhors a conductor having kinks or abrupt turns, therefore the coils act to choke back the current and prevent its entrance to the telephone. In addition, the coils are in close proximity to a grounding medium which deflects and safely carries the current to ground.

The coils have a resistance of only a fraction of an ohm, and do not offer any appreciable resistance to talking and ringing currents.

The principle used in this Arrester, that lightning will not pass through a coil having abrupt turns or angles, readily explains why ringer and other coils are sometime destroyed by comparatively slight lightning

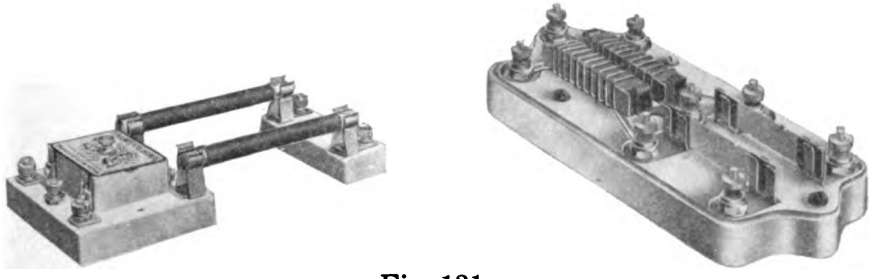


Fig. 131.

discharges, as the wire is very fine and cannot stand the strain of the tremendously high frequency current which is always seeking to travel in a straight line, consequently the wire is disrupted. This often occurs without the coil being actually burnt, the wire having the appearance of being broken.

The arrester shown in Fig. 130 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. 130 being a lightning arrester only, for use on 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. Fused types are shown in Fig. 131, the lines are connected to the fuse end.

Figs. 132 and 133 show the Multi Discharge arrester connected on grounded and metallic lines. Many of these arresters are extensively

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used in rural line work, as they are free from troubles due to the collection of carbon dust between the line coils and ground blocks. While the space between the coils and blocks is only .003 or .005 in. this space is open, and the dust is free to fall out, in fact it is blown out by action of the slight flash which accompanies the operation of the device.

Later models of the Multi Discharge arrester are provided with covers which completely enclose the working parts.

The Multi Discharge Arrester was the pioneer choke coil device especially designed for telephone use. Several other Coil Arresters are now offered, but these use a circular coil, and usually place the grounding medium on the outside of the coil in the shape of a shell, usually of metal. None of these devices are especially efficient nor approach the original

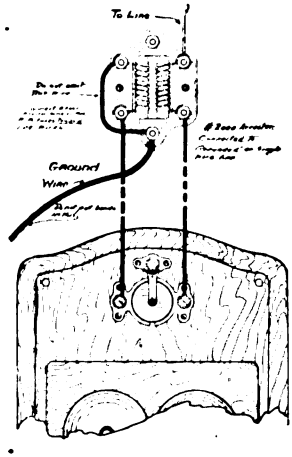


Fig. 132.

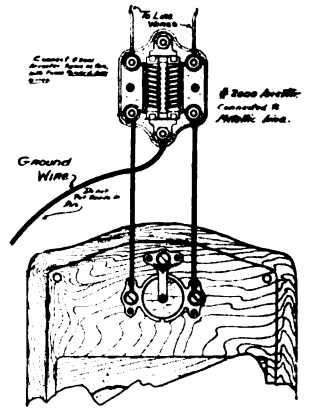


Fig. 133.

model in this respect, owing to the absence of the *square coil having abrupt turns or angles in every convolution.* Upon this depends the efficiency of the device, and to ignore this is to ignore the principle upon which the device depends for its successful operation.

Careful attention should be paid to securing a good ground connection for any type of arrester, otherwise the device will not operate perfectly and the instrument will be damaged.

The ground wire should not be of less size than No. 14 B. & S. guage *copper* wire, and should be free from *short bends, curls or kinks;* it should be as *short* and *straight* as possible.

When it is necessary to make a turn, the bend should never have less than one foot radius.

Support the ground wire on knobs from the arrester to ground connections. In towns where water or gas pipes are laid, connection can be made to them, and a good ground is assured.

A soldered connection can be made, but for the water pipes, a clamp shown in Fig. 132a should be used. On gas pipes the wire can be wrapped

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as shown in Fig. 132b first fileing the pipe bright, then solder the wire coils together and if possible solder to the pipe.

In locations where no water or gas pipe is available, a ground rod is used. One satisfactory method is to take a piece of iron pipe, preferably galvanized, flatten one end and drive into the earth to the required depth, leaving about 6 in. above the ground, to this solder or clamp the ground wire. A ground connection must reach *permanent moisture* to be satisfactory.

This is assured when connection is made to a gas or water pipe, but is not when a rod is used, unless the rod is driven deep enough to reach the damp strata under the surface soil. Usually six or eight feet is sufficient but in stony, clay, or sandy soils, especially in mountainous countries, fifteen or twenty feet may be necessary.

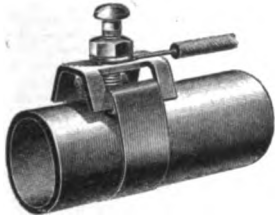


Fig. 132a.

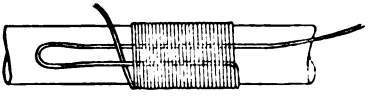


Fig. 132b.

When connecting to gas or water pipes, never connect to a lead pipe, and always connect as near the street, or where the pipe enters the building, as possible.

If a gas meter is used, the ground wire must connect to the main pipe *before* it reaches the meter. Never connect to the house side of the meter.

In some cases a connection can be made on the house side of the meter, provided a piece of wire is connected from the house to the street side of the meter thereby bridging or connecting across same so that a path is provided for the lightning and so that in case the meter is ever removed, no interference with the telephone ground will result.

The location of troubles in lightning arresters are so apparent that they will not be described here. A ground caused by dust collecting between the line and ground plates is easily tested for by ringing across from one block to the other, and is remedied by removing the dust.

An open fuse is easily located by bridging the terminals with a piece of wire and testing to see if the circuit is closed.

All telephones connected to aerial lines or cables, should be provided with arresters. Where the lines are entirely underground, as in some of the large cities, the usual practice is to omit the Arrester, as the lines are not exposed to lightning, and arresters are unnecessary.

There is another device termed a "sneak circuit" arrester, used to prevent small continuous currents caused by the telephone line becoming crossed with other wires, from entering the instrument. These are described elsewhere.

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CHAPTER V.

MAGNETO SWITCHBOARDS.

It soon becomes evident there is a limit to the number of telephones that can be satisfactorily operated on one line, therefore some means must be provided for connecting two or more lines together. A device of this nature is called a "Switchboard."

A simple arrangement of this nature for connecting two lines, is shown in Fig. 134. Ordinary switches are used. The lines are connected as shown, and an extension bell is bridged across each line to act as a signal.

A telephone instrument is connected to the blades of the switches, and by throwing switch A or B the phone may be connected to line A or B. By throwing both A and B the two lines are connected together.

One of the extension bells may be dispensed with by keeping the phone switch always on A or B and receiving the calls over that line on the bell in the phone.

A better arrangement is shown in Fig. 136. A double throw key is used, and one bell only. When the key is thrown to the right, the phone is connected to the line coming in on that side, and when thrown to the left phone is connected to left hand line. When key is in the central position, the two lines are connected together.

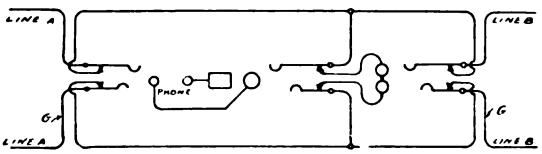


Fig. 134.

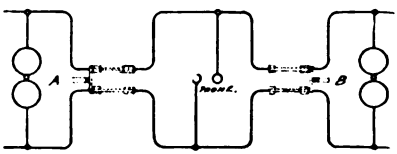


Fig. 135.

The bell on the switch box is always connected to the line which is *not* connected to the phone, so at no time is either line "cut out" but both lines can always signal the central phone regardless of the position of the switch.

Another arrangement is shown in Fig. 135. Here a plug and jacks are used. The plug is a connecting pin having an insulated brass tip portion to which is attached one of the circuit wires, the sleeve part of the plug forming a terminal for the other circuit wire. The jack consists of two springs arranged to make contact with the two portions of the plug when it is pushed between them. The jack is arranged with two additional

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springs which break contact when the plug is inserted, and to which the extension bell is connected.

By inserting the plug in one or the other of the jacks, the telephone is connected to the respective lines, and the extension bell is left connected to the line not in use. By plugging into the centre jack the phone is connected to both lines at once.

This arrangement can be used with as many lines as there are jacks provided, and by means of a pair of plugs any two lines can be connected together. A bell bridged across the cords will ring, thereby notifying the attendant when a disconnection is desired.

The circuit arrangements shown in Figs. 134, 135, and 136 are for metallic lines, if used with grounded lines, a ground wire would be connected to the terminals marked g. This equipment is also supposed to be used with bridging lines.

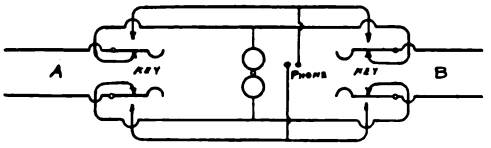


Fig. 136.



Fig. 137.

Many uses for the three arrangements just described will occur to those operating two or more lines. Often a long line may be cut in two, thus facilitating the use of same as both ends may be used at the same time. The ringing is also simplified as only one half the phones need be rung at once, thereby lessening the number of signals and load on the line.

It will be seen that where a number of lines are brought together at one point, some compact arrangement is required to handle the connections, as a number of the switches just described would prove too cumbersome. A complete switch of the key variety, the circuit of which is shown in Fig. 136, is about 8 in. square and is illustrated in Fig. 137. Ten of these would occupy several square feet of space and are not as easy to operate as if the equipment was all in one cabinet. This led to the development of a more compact signal, which is commonly known as a "drop."

The earliest type of Switchboard signal or drop consisted of a coil of wire at the rear end of which was suspended an armature or piece of iron provided with a latch which projected forward and engaged a shutter, so placed that when the latch was raised by reason of the armature being drawn towards the coil, the shutter was released and fell down exposing a number in view of the operator, who thereupon plugged into the jack which was mounted separate from the drop in the lower portion of the board. An early form of drop is shown in Fig. 138. This is of the double coil type, the coil not being armored. When a number of unarmored drops are placed side by side cross talk may result caused by inductive leakage between the coils. To prevent this the coils are encased in armor, as shown in Fig. 139, the iron tube completely enclosing the coil and preventing any leakage of the magnetic lines.

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With the unarmored type, the attractive power of only one pole of the coil is available and two coils are used, whereas, when the armor is placed on the coil, the pull of the coil on the armature is greatly increased as the armor forms one pole, and the end of the core the other, consequently only one coil need be used

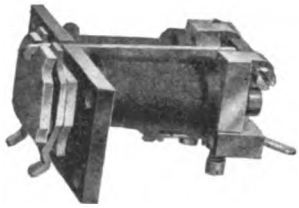


Fig. 138.

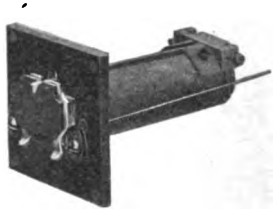


Fig. 139.

No doubt this drop is familiar to every telephone man, and that it is a very efficient arrangement, is proven by the fact that thousands are in use, especially by the Bell Companies, who developed this type to its highest degree of perfection, both mechanically and electrically.

The fact that the drop had to be restored after each call necessitated a great deal of work on the part of the operator, and therefore one of the first improvements was to combine the drop and jack so that the drop shutter was automatically restored by the insertion of the plug in the jack. This type of equipment has been on the market for a number of years, and exists in a great many forms which differ from each other only in mechanical construction, arrangments of the various parts, etc. The usual form of construction is such that the jack throat or opening is located immediately below the drop shutter, and one of the jack springs is so arranged that it protrudes from the jack sufficiently to engage the shutter when in a fallen position, and the act of inserting the plug in the jack causes this spring to throw the shutter upwards, and thereby restores same. Sometimes the plug restores the shutter by direct contact therewith, the spring being eliminated.

The highest development of this type of combined drop and jack may be illustrated by the Dean Elect. Cos. drop shown in Fig. 140. The drops

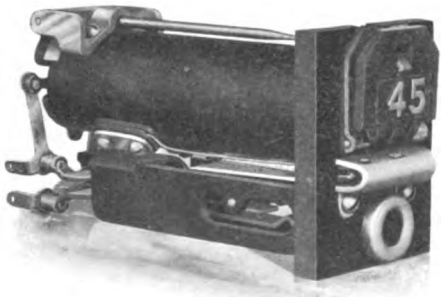


Fig. 140.

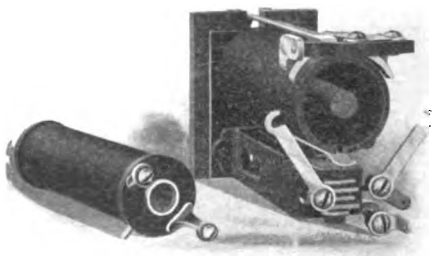


Fig. 141.

are mounted on metal strips about 6¼ in. long × 1¾ in. wide each strip carrying five drops. The drop and jack are insulated from this mounting plate so that same is never any part of the talking or ringing circuits.

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The drop winding which is really the only part requiring removal, is on a removable spool having a hollow core, and is designed to slip over a permanent core riveted into the drop shell and made a part of it, as shown in Fig. 141. This permits of a very efficient magnetic circuit being secured as the tube and core are practically one piece.

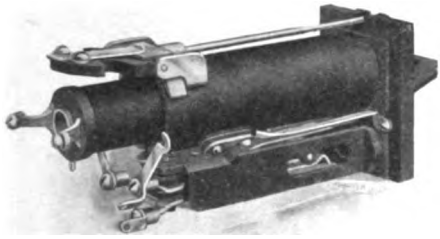


Fig. 142.

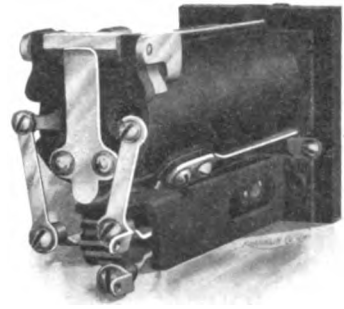


Fig. 143.

The drop winding is provided with terminals as shown in Fig. 142, and the coil is simply slipped into the shell as shown in the figure, and is securely locked into position by a steel catch. The connection between the winding and the jack springs is accomplished by the connecting links or short punchings shown in Fig. 142, screws being provided for holding these as shown.

Instead of removing the armature which would be necessary if same was held in place by pivot screws, it is hinged as shown in the figures, so that it can be swung up out of the way. A spring action similar to that used in a pocket knife blade is employed to hold the armature in the normal position in front of the drop core. This arrangement obviates the necessity of any adjustments being made when a coil is removed or replaced.

Fig. 143 shows a drop with the coil in place. The wires are soldered to the small lugs provided with eyelets, shown connected to the jack springs. The wires can be removed from the jack by loosening the screws holding these lugs and the necessity for unsoldering the wires is thereby obviated.

The operation and details of the drop are evident from the illustrations. Fig. 143a shows the arrangement of the night alarm contacts, which are very positive in action.

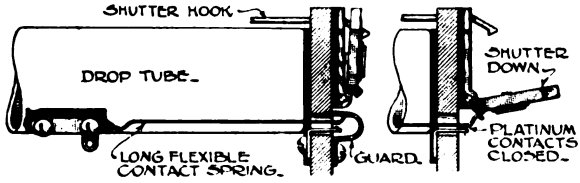


Fig. 143a.

This drop well illustrates the present development of the self restoring combined drop and jack type of construction, when the armature is

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located at the rear of the drop coil, and the shutter is released by a hook moving *upward* when the drop armature is actuated.

Another type of combined drop and jack is illustrated by the drop made by the Monarch Tel. Mfg. Co., and shown in Fig. 144.

The armature is mounted in front of the drop coil. When armature is actuated the shutter is released by the hook moving *downwards.*

The action of the night bell springs is apparent from the figure, also the method of restoring the drop shutter.

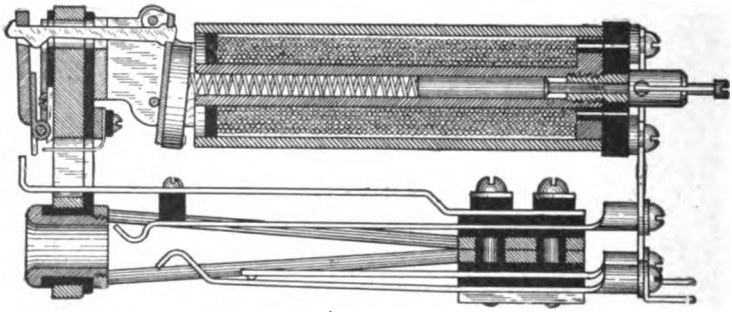


Fig. 144.

Means for adjusting the armature is provided in this drop. The core of the coil is drilled to admit a long spring, the tension of which is regulated by the screw at the back of the drop, by turning this screw the tension on the drop armature may be regulated thereby making the drop more or less sensitive.

The necessity for this adjustment is that sometimes it is desirable to have the drop buzz in unison with the number of rings given on the line, and by adjusting the spring, each drop can be adjusted to the varying conditions of each line. This makes this drop a signal ringing drop. Other types use a different arrangement, as will be described later.

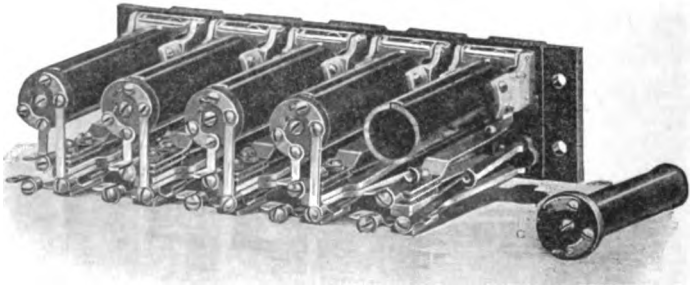


Fig. 145.

Fig. 145 shows how the coil is removed. A pin in the coil head engages a slot in the armor and the coil is locked in place by giving same a slight turn to the right. The connection between the drop and the jack is made in a similar manner to that in the Dean drop.

The combined drop and jack furnished by the Western Elect. Co. is shown in Figs. 146, 147, and 148.

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In place of the shutter employed in other drops, this type is equipped with a sphere revolving on a horizontal axis and so arranged that a portion of its surface projects through a round opening in the mounting plate; that part of its surface normally exposed is black, corresponding with the surface of the mounting plate. When the signal is operated, the sphere revolves on its axle, and the black portion moves up and disappears behind the mounting plate, leaving exposed a polished aluminum surface. The sphere projects from the face of the board a sufficient distance to be visible from either side. Fig. 147 shows the drop in a normal condition, and Fig. 148, when exposed. The sphere is filled with lead and always has a tendency to revolve until the white side is exposed.

When a plug is inserted in the jack its tip raises the tip line spring. This acts on the restoring lever which turns the sphere to its normal position. These drops are wound to 500 ohms and the coil is armored.

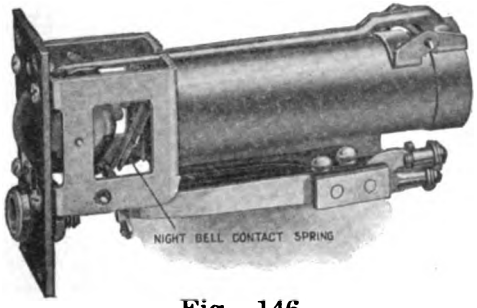
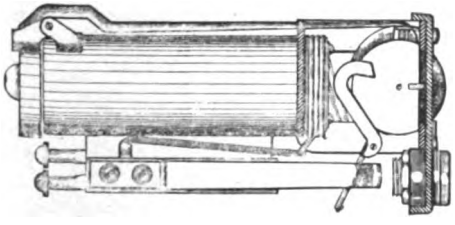


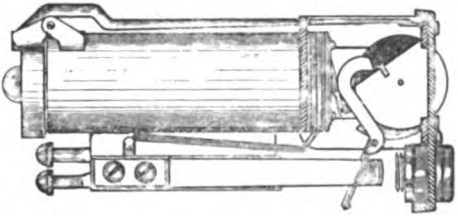
Fig. 146.

A type of drop of the "plug ringing" variety so called because ringing was accomplished by pushing the plug into the jack instead of using a key, is represented by the Sumter Type F drop shown in Fig. 149. This was a very satisfactory drop but is no longer manufactured, this Company having replaced it with the more modern Unitype equipment.



NORMAL POSITION OF TARGET READY FOR OPERATION

Fig. 147.



TARGET OPERATED AFTER SUBSCRIBER HAS CALLED

Fig. 148.

Referring to the figures, the construction and assembly of the various parts will be readily understood. The shutter is supported in its normal position from the back by the rod attached to the armature. When this rod is raised by the armature being attracted by the drop coil, the shutter is released and falls inwardly thus causing the number to disappear from

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view as shown in Fig. 150. When the shutter falls inwardly it closes the night bell contacts N. N. ringing the night bell in the usual manner.

The shutter is restored by the insertion of the plug in the jack, by the tip of the plug coming in contact with a small projection on the bottom of the shutter.

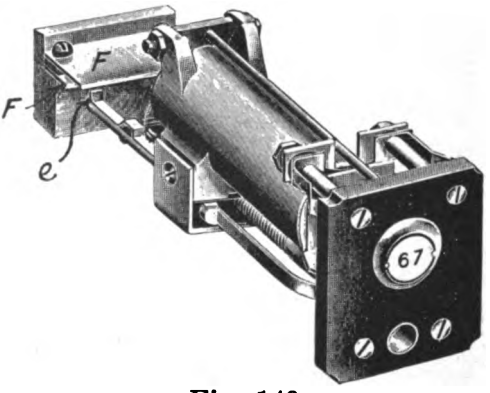


Fig. 149.

To ring on a line when using this drop, it was only necessary to put the plug in the jack and push same in as far as it would go. From Fig. 151 it will be observed that the plug handle does not touch the front plate of the jack but is some distance from it, although the tip and sleeve portions of the plug engage the tip and sleeve springs of the jack so that

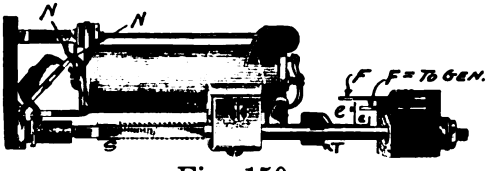


Fig. 150.



Fig. 151.

a connection is formed in the usual manner. Now when the plug is pushed all the way in, or until the handle strikes the face plate, the rubber plunger P Fig. 150 (which is connected to a projecting piece T normally held in position by spring S) is pushed back and forces springs e, e, (which connect to the jack or line springs) upwards, where they contact on ringing strips F F, as shown in Figs. 149 and 150.

The drop coil is removed from this drop by taking off the armature and loosening the screw connections from the jack springs to armature coil. The drops are secured in the board and the wires attached to them by means of the two projecting arms L. L which are equipped with nuts under which the line wires can be placed.

On grounded lines the sleeve side of the jacks must be grounded.

The chief objection to this type of equipment was the breakage of the plug cords, caused by the operator striking the butt of the cord with

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the palm of the hand when ringing. This was a very rapid board to operate, and this type of drop was very popular just before the Multiple Switchboard came into general use, as rapid service could be given. The wear and tear on the cords, plugs and jacks was such, however, that the type of equipment using ringing keys has entirely supplanted the plug ringing type.

Of course when pressure is removed from the plug, it is returned to the normal position by the action of the spring S. When the plug is forced into the ringing position, the tip jack spring rides on the rubber insulation between the tip and sleeve of the plug, this opens the cord circuit so that the generator circuit does not flow over same.

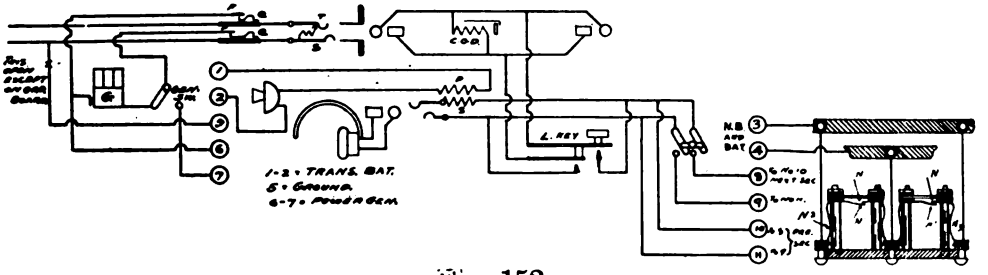


Fig. 152.

Fig. 150 shows that the generator is wired in multiple with the two metal strips F, and F. Under these strips is located springs e, e, which are normally out of circuit with strips F, F, but which are brought into contact with them by the act of pushing the plug into the jack as far as it will go. The current from the generator is then projected directly to the subscriber's line without passing over the cord and plug, thus preventing current "ringing back" through the waiting subscriber's instrument. When through ringing and the plug is released, it automatically returns to the normal position in the jack, establishing the talking circuit.

Fig. 152 shows the complete circuits of a board equipped with these drops. With the exception of the generator circuit, the wiring is the

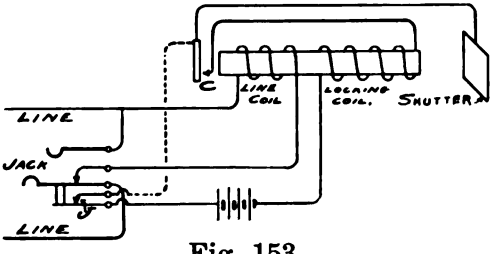


Fig. 153.

same as ordinarily used. The night bell circuit is carried into each drop by the springs N 2 and N 3 which connect to two vertical bars running between each vertical row of drops. These springs connect with springs N and N.

Another modification of the idea of automatically restoring the drop by the insertion of the plug into the jack was to equip the drop coils with a

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double winding. One winding was connected to the line in the usual manner. The other winding was connected in series with a pair of contacts so arranged that when the first winding was energized and the armature drawn towards the core of the drop that this pair of contacts would be closed, and battery would be applied to the second winding which would hold the drop signal displayed until the call was answered, the signal being de-energized by the separation of two contact springs located in the jack. This form of construction, while used to some little extent, is open to the objection of having two windings on the drop core, and necessitating the use of an extra pair of contacts in the jack, and this method also necessitates the maintainance of a battery at the Central Office, the function of which is to hold the signals displayed until the operator answers same. The circuit arrangement is shown in Fig. 153. The shutter is arranged back of a mounting plate and is not displayed until lifted up by the armature. When this occurs contact C is closed and battery is applied to the locking coil, which holds the armature until contact J is broken by the insertion of the plug in the jack.

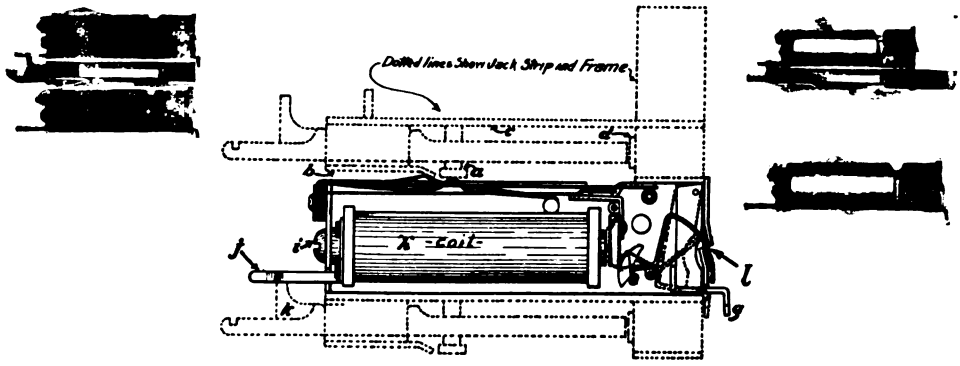


Fig. 154.

In this type of drop, the jack need not be mounted in close proximity to the drop, as it is evident that the act of plugging into the jack will restore the drop shutter without the plug having any mechanical connection therewith.

From the foregoing it will be seen that drop equipment may be divided into two classes, that where the drop is separate from the jack, the jack being located in another part of the cabinet, usually some inches below the drop; and where the drop and jack are combined in one structure and permanently associated with each other.

Another type of equipment is that where the jacks are assembled in strips, usually of ten jacks each, and the drops are unitary structures adapted to be placed in close proximity to the jacks without being permanently combined therewith.

The Unitype drop, manufactured by The Sumter Tel. Mfg. Co. illustrates this type, which is a very successful method of construction, one noticeable feature being the ease with which any drop can be removed from or inserted in the board without the use of tools or unfastening any wires.

Fig. 154 shows a cross section of the drop, which is inserted between

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two strips of jacks. It will be seen that the usual coil *"h"* is connected to the inside contacts *"k"* of the jack immediately below the drop, by means of the two flexible springs *"j"* projecting from the back of the drop coil. When the armature *"f"* moves inwardly by reason of the coil *"h"* being energized, the shutter *"e"* is released and drops through the slot in the front of the drop. When the plug enters the jack, the latch *"g"* is pushed inwardly and restores the shutter *"e"*.

The dotted lines show shutter in the operated position.

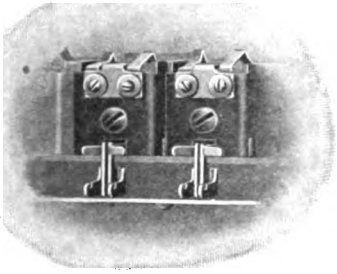


Fig. 155.

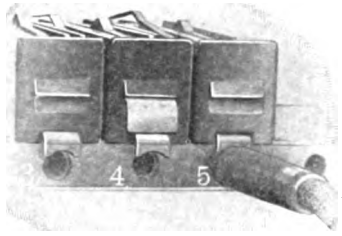


Fig. 156.

Fig. 155 shows a rear view of the drops and jacks and clearly shows the contact springs in the drop making contact with those in the jack, Fig. 156 shows a front view, drop No. 3 being in a normal condition, drop No. 4 shows the shutter exposed, and drop No. 5 shows the plug in the jack, the call answered, and the shutter restored. The small shutter which falls through the slot is white enameled, and makes a very striking signal against the dull black finish of the switchboard front.

It will be seen that the operation of this drop depends upon the law of gravity, there being no springs or double windings and that the drop only has two moving parts, viz., the armature and the shutter. The armature is made with a knife edge, which engages a small wing or projection on the foot of the shutter. This point of contact being very minute, the friction is reduced to a minimum.

The use of pivot screws to support the armature, which are sometimes a source of trouble, is obviated in this drop by using rods upon which the armature and shutter are hung. These rods are simply slipped in and out of the shell, and are held in place by the end of the drop structure which forms the front, and also laps about an inch on each side. By taking two screws out of the sides of the drop this end may be removed, the different parts are then entirely loose and may be taken apart and put together by hand.

By reference to Fig. 154, it will be seen that the drop is equipped with two springs upon the top, these carrying the night bell contacts which are closed when the armature *"f"* is drawn towards the coil *"h"*, the armature *"f"* being located in this position after having once been energized, by the small wing or foot on the shutter *"e"*.

In Fig. 157 is shown a strip of jacks. The jack springs are punched from German silver, and should be long and flexible enough to ensure their making a secure contact without danger of bending. The inside, or cut-off springs of the jack are formed from solid brass. The contact edges are formed with an upturned knife edge which firmly presses

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against the jack springs with a tension of several pounds. This action is non-grinding, and yet a rubbing contact is secured. The jack springs are forced into the solid rubber mounting strip, and as no holes are punched in the springs, their elasticity is unimpaired.

The form of construction in which the springs are mounted edge up, would seem to be superior to that in which the springs are mounted side up, as it is impossible for dirt to find lodgment in the jack, and as each jack strip is open at the top and bottom, the dirt can sift through the board and be blown out with a bellows.

Nothing but the best hard rubber insulation should be used throughout a jack strip, and the metal parts of the jack strip should be heavily nickled, or polished and lacquered, so that corrosion is prevented. The numbers are usually formed by stamping same into rubber mounting face, and then filling them with white lead.

The method of combining the Unitype drop and jack is as follows: A metal mounting frame is provided in which all the jack strips are placed, this eliminates mounting anything on the woodwork which is liable to warp. One end of this frame is shown at "*m*" Fig. 158.

The jack strips slide in the grooves cut in this frame, and a slotted punching *n* slips freely over the screw "*o*". To remove a jack strip from the board, simply loosen "*o*", move piece "*n*" and pull the jack strip out. About 3 ft. of cable is allowed to each jack strip, this slack being formed up so that it does not occupy much space. This being the

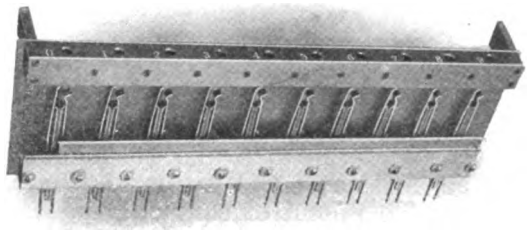


Fig. 157.

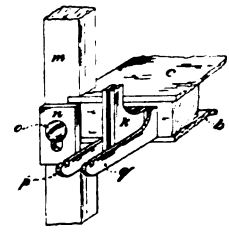


Fig. 158.

case, each strip can be removed about three feet from the board without unsoldering any of the wires attached thereto. The drops are placed upon the mounting plate, "*c*" and are locked in place by the two projecting contact springs on each drop which connect with the inside contacts of the jacks. From the above, it will be seen that a drop can be instantly inserted or withdrawn from the front of the board by simply pulling it out, as there are no wires to disconnect or screws to remove, this feature being shown in Fig. 159.

The drop coil may be removed by loosening one screw and pulling the coil out of the case, as shown in Fig. 159a. Removing and replacing the coil does not change the adjustment of the drop mechanism in any manner nor is it necessary to unsolder any wires.

The improvements in drop construction have greatly reduced the cost of maintainance on Central Office equipment, not only this, but the lines do not have to remain out of service any length of time, as the oper-

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ator or other inexperienced person can remove a bad drop from a working line, and substitute therefor a good drop from a line which is not working.

With the Unitype model, it is often possible to substitute for one of the line drops which may be injured, one of the clear-out drops, which can be withdrawn and used temporarily as a line drop. This will in no way affect the cord circuit from which the clear-out drop is removed, except that no ring-off signal will be secured. As no numbers appear on the drops, a drop is readily interchangeable to any part of the board, the numbers being placed adjacent to the jacks.

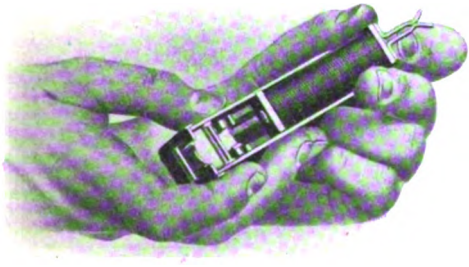


Fig. 159a.

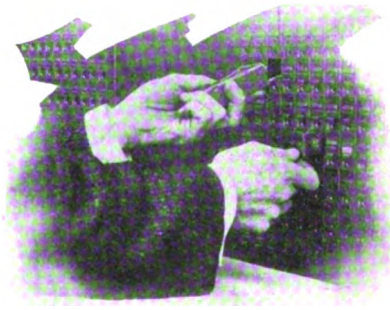


Fig. 159.

The majority of modern Switchboards are numbered from 0 to 99 for each operator's position, beginning at the lower left hand corner of the Switchboard. This makes the numbering uniform throughout a large board, and as 0, 10, 20 30, etc., are always the left hand end numbers on each position, the location of the number is made very easy for the operator.

While the drops and jacks are a vital part of the Switchboard, the operator's equipment is also of the utmost importance. A detail to be carefully considered when purchasing equipment, is the construction of the cords and plugs.

Fig. 160 shows the construction of a standard plug. The tip "*r*" is riveted to a steel stem which is thoroughly insulated from the sleeve or body of the plug, by means of a hard rubber bushing running it's entire length. To prevent the tip which is riveted to the stem from turning, a pin is driven across the entire plug and is insulated therefrom by hard rubber.

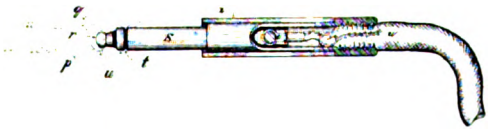


Fig. 160.

One trouble sometimes met with in plugs is that as the plug enters the jack the sleeve spring will wear the rubber insulation between the tip and sleeve. To prevent this in the type of plug shown in the illustration, a brass ring "*n*" is placed on the rubber bushing in such a manner

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that at no time can the jack springs cut into the rubber and cause trouble. The different positions the jack springs assume as the plug enters the jack is shown by the dotted lines.

The plug cord is connected to the plug by screwing same into the threads provided in the brass shank of the plug. The tip conductor of the cord is provided with an eyelet so arranged that it fits easily under the screw placed in the lug going to the tip. The fiber sleeve "x" slips over the plug and forms a handle, being held in place by a small screw. The ends of the cords attached to the Switchboard are equipped with terminals as shown in Fig. 161 which renders their connection very easy. The insulation of the sleeve conductor is usually marked with a colored trace thread which enables the cords to be attached to the Switchboard in a uniform manner.

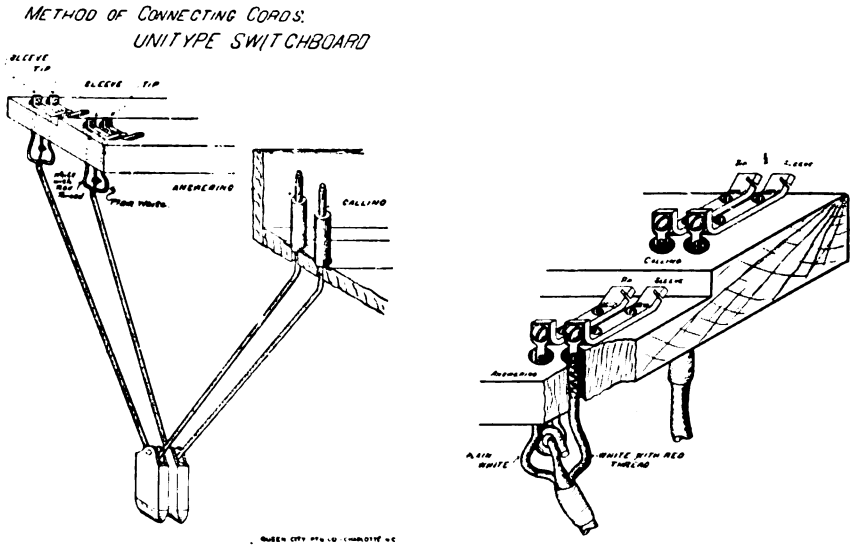


Fig. 161.

The ringing and listening keys associated with the cord circuits are described elsewhere, but in selecting these it is well to pay the greatest attention to securing a type of key in which the springs are long and flexible, and good contact is assured. There are several types of equipment on the market in which the keys can be readily removed from the board as shown in Fig. 162, as each key has an individual set of wires about 6" long, which allows the key to be removed from the Switchboard without unsoldering any connections.

A standard operator's head receiver is shown in Fig. 163. It is the usual double pole variety with the various parts made as small and compact as is consistent with securing the best results.

The usual method of mounting the operator's transmitter is to fasten same to adjustable cords which are equipped with weights which balance the transmitter, and cause it to stay in any position it may be placed. This arrangement will be noticed on the various cuts of Switchboards herein shown, but the more modern and efficient breast operator's set as

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shown in Fig. 164, is to be recommended where the operator is constantly at the board, for several reasons, the principal one being that the transmitter always remains the same distance from the operator's lips irrespective of what position she may be in. Also there is nothing between the operator and the face of the board, and her vision is therefore unobstructed.

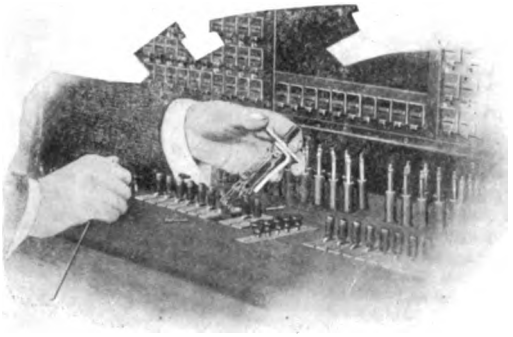


Fig. 162.

When the breast type transmitter is used, a plug with 4 contacts and a jack with a corresponding number of springs is used, two of these contacts carrying the circuit to the transmitter and two to the receiver.

When the suspended type transmitter is used, the operator's receiver jack usually has 4 springs, two of which engage the tip and sleeve of the operator's receiver cord plug, see Fig. 165. The other two or inside springs, connect in series with the operator's transmitter in such a manner that when the plug is inserted in the jack, they close together and thereby allow the battery to flow through the transmitter. When the plug



Fig. 163.

is withdrawn the springs open. This type of plug is adapted for use with cords having standard tips, thus obviating the use of special cords. Operator's cords are usually 6 ft. long.

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The line circuit in magneto boards varies but little among different manufacturers. The drop may be wound to a resistance varying from 80 to 1600 Ohms. The prevailing practice is to wind Series drops to 100 Ohms, while Bridging drops are usually wound to 500 Ohms. It has been found with modern methods of completely enclosing the drop winding in a shell, that 500 ohm drops possess sufficient impedance, and it is



Fig. 164.

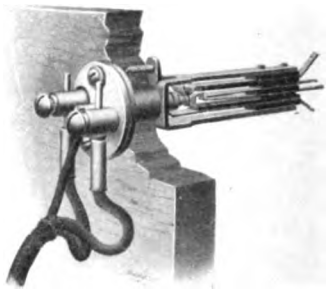


Fig. 165.

seldom that a higher winding is either necessary or desirable. As a rule, the larger the wire used, provided the proper number of turns and resistance is secured, the better, as the finer the wire, the more liable it is to damage from lightning and other causes.



Fig. 166.

The usual line circuit is shown in Fig. 166. Here it will be seen that the drop winding is cut off from the line circuit when the plug is inserted in the jack. This is also accomplished as shown at Fig. 167, where one side of the winding is cut off, which accomplishes the same result.

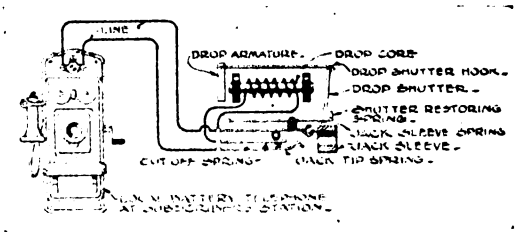


Fig. 167.

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It should be remembered that although a Switchboard may have a capacity of 100 or more lines, each line circuit with its drop and jack is exactly the same, the only difference between a 100 and 500 line board being the number of circuits.

All modern Switchboards are wired for full metallic circuits, and, of course, may be used on either common return or grounded system. In case the board wired for full metallic service is to be used on grounded systems it is simply necessary to connect one side, preferably the sleeve side, of the line jacks to the ground or common return.

A common trouble with drops is their failure to fall when a subscriber calls. This can be the result of a short circuited drop, a bad contact between the springs of the jack, an open wire in the cable leading into the Switchboard, or an open drop winding. It is, of course, presumed that the line leading into the exchange is O. K. up to the point where it joins the switchboard cable.

In testing for trouble in the switchboard it is best to connect an ordinary telephone directly to the pair in the cable leading to the switchboard. If upon ringing, the drop does not fall, one of the plugs on the switchboard should be inserted in the jack. Then ring again. If the clear-out drop connected to the cord in use, falls, it is an indication that the pair in the switchboard cable is O. K. up to the jack. The jack should then be examined to see if the inside springs or ones which connect with the drop, make contact with the long springs when the plug is withdrawn. If this seems to be O. K., a receiver should be connected directly to the terminals of the drop coil winding. If upon turning the crank of the telephone, the sound of the generator can be heard in the receiver, the circuit is O. K. to the drop terminals and it is likely the drop coil is open, and same should be taken out and repaired.

Most of the trouble in line circuits is caused by open drop windings, lightning generally being the cause of this. Every switchboard should be equipped with some form of lightning arrester, which will pay for itself in the saving of drop coils inside of a few months, especially in localities where electrical storms prevail.

It will be apparent that the falling of a drop is hardly sufficient noise to attract the operator's attention, and some additional means must therefore be provided. This is accomplished by equipping each drop with a pair of contacts so arranged that when the drop shutter falls, the contact will remain closed, thereby ringing a bell, which continues ringing until the operator restores the drop. This bell is termed the "Night Bell", on account of its usually being used at night when no regular operator is in attendance.

The usual form of night bell circuit is shown in Fig. 168. When properly constructed, very little trouble occurs, but drops in which the circuit is closed through a hinge should be avoided, as a great deal of trouble has been experienced with drops so constructed. By referring to Fig. 168, it will be seen that when the shutter is down, the contact spring closes the circuit through the bell and battery. One objection to this circuit is that the drop contacts become dirty, the current flow is thereby hindered and the bell fails to ring. This necessitates either increasing the battery or constant cleaning of the drop contacts. To increase the battery means more sparking, and this causes corrosion and more trouble. Usually no more than two cells of battery should be used for the night

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bell circuit. It may be said, however, that the majority of the drops now on the market are provided with contacts so constructed that very little, if any, trouble from this cause occurs.

To guard against the occurrence of this trouble, it is customary to insert a relay wound to about 500 Ohms in series with a 12 volt battery, as shown in Fig. 169. It will now be seen that when the drop falls, the current flows through the relay and drop contacts back to the battery. This closes the relay, and the bell which is in circuit with the relay contacts will ring. It will be observed when this device is used, that the action of the night bell is entirely dependent upon one set of contacts in the relay which can be pointed with platinum and which are easy to adjust, so that instead of having to adjust each individual drop contact it is only necessary to adjust a single contact in the relay. The great advantage of this arrangement however, lies in the fact that relay is exceedingly sensitive to minute currents, and will therefore close, even

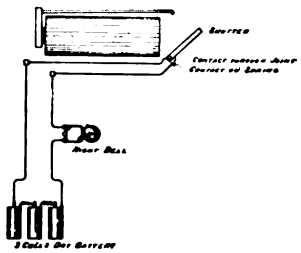


Fig. 168.

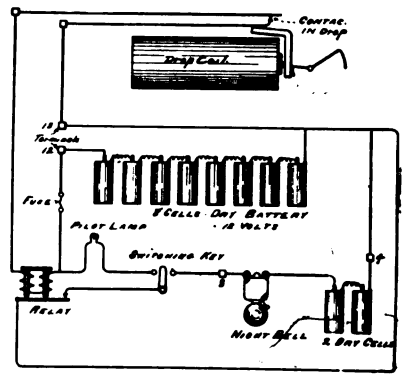


Fig. 169.

if the contacts in the drops are very dirty. A relay of this description wound to 500 ohms, with a 12 volt battery or 8 ordinary dry cells, will close through a resistance of 2000 Ohms, which is more than the night bell would ring through even if 8 or 10 cells of battery were used, connected in the usual manner. Owing to the high resistance of the relay very little current flows, consequently there is no sparking at the drop contacts, which remain bright and clean.

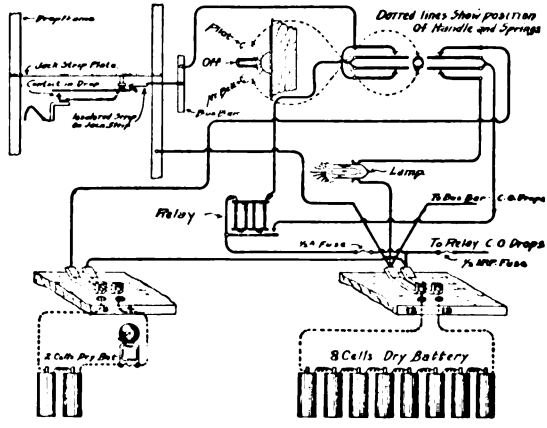
Another desirable feature can be obtained when the relay is used. This is the use of pilot lamps. The night bell, of course, is very desirable when the operator is not in constant attendance at the Switchboard; or at night when the operator has retired, the bell can be placed adjacent to the bed and when a drop on the Switchboard falls, the operator will be awakened by the bell ringing. In the day time if the operator is constantly at the Switchboard, the ringing of the night bell is annoying yet, in some cases it is not desirable to dispense with some warning signal. By using the pilot lamp, the use of the night bell in the day time is obviated, the pilot lamp affording a very conspicuous signal which cannot be ignored. This arrangement is shown in Fig. 170, from which it will be seen that when the relay is operated, instead of the bell ringing, the current will be directed through the lamp which will remain lighted until the operator restores the drop, thereby de-energizing the relay, and putting out the lamp. It is customary to use a white or opal lamp cap for

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the line drop pilot, and a red lamp cap for the lamp connected to the clear-out drops.

A half ampere fuse is placed in the circuit, and a battery of 8 ordinary dry cells may be used. These will last from 6 to 12 months. Sometimes this fuse is blown or accidentally broken, and the circuit fails to operate. Aside from this very little trouble occurs. A switching key to control the lamps and night bell is wired in the circuit as shown.

The line and night bell circuit constitute what may be termed the calling circuit of the Switchboard, and the next circuit to be considered is the cords by which the calls are answered and the different lines connected together.



PILOT LAMP & RELAY CIRCUITS

Fig. 170.

Referring to Fig. 171, two telephones are shown connected to their respective jacks, the drops being omitted as they are out of circuit when the plugs are inserted, while between the two jacks is shown an ordinary cord circuit. It will be seen that the lines are connected together by the heavy lines, which represent the cords, the clear-out drop being bridged directly across the circuit. Owing to the high impedance of the drop it has very little if any effect upon the voice currents which pass from telephone to telephone exactly the same as if the two instruments were connected by a pair of wires instead of the cord circuit.

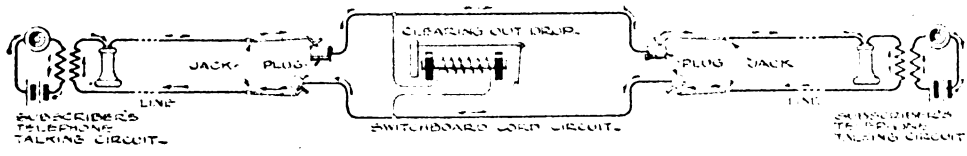


Fig. 171.

Fig. 172 shows the operator in the act of ringing a subscriber; note how the key cuts off one plug so that ringing currents will not affect the

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waiting 'phone. When the handle of ringing key is released the circuit is completed from one plug to the other.

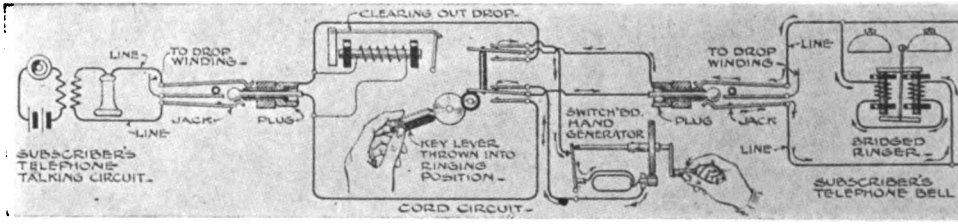


Fig. 172.

Fig. 173 shows the operator in the act of listening and when the key is pressed, the springs move outwardly, and the operator's telephone is connected in circuit. This key is so constructed that when moved into the listening position it will remain there, and this enables the operator to converse with the parties connected, or only one of them, if only one cord of the pair is in use.

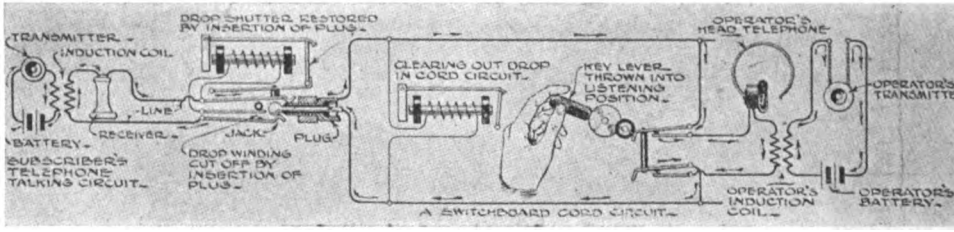


Fig. 173.

In case it is necessary to ring with both plugs, a ring back key is connected in circuit, which operates in the same manner as the key previously described.

There are various forms of ringing and listening keys. When it is necessary to ring with only plug, a key like the one shown in Fig. 174 is used. If the key is thrown in a listening position it will stay there owing to the shape of the springs, while if pulled in the opposite direction, it will fly back to normal when released, thus completing the circuit from one plug to the other.

When it is necessary to ring with both plugs, the key of the type shown in Fig. 175 is used, which is the same as the key previously described, except that an additional set of springs and handle for ringing on the other plug is provided.

The clear-out drops are usually wound to 500 Ohms, and are of the armored type in which the coil is inclosed in a tube or shell. This is absolutely essential, for, as the drops are mounted side by side if the shell is not present cross talk will occur between adjacent coils when two circuits are in use.

The clear-out drop should be very sensitive, as in "ringing off" a subscriber only gives a short turn of the crank, and furthermore, as there

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are usually two telephones connected to the cord circuit, the clear-out drop is, to a certain extent, short circuited by the ringer of one of the telephones. This is shown by Fig. 176, where subscriber "A" is shown in the act of ringing off. At subscriber "B", the receiver is shown on the hook, and the ringer is therefore across the line. Now if this ringer is of 80 Ohms resistance, which is commonly the case with these instruments, it

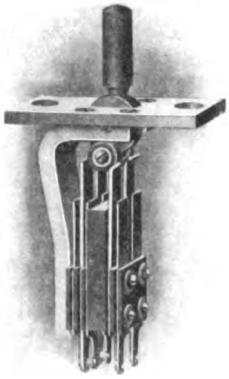


Fig. 174.

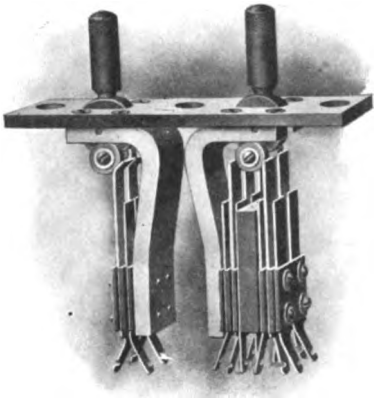


Fig. 175.

will be seen that all the current from subscriber "A's" generator will traverse the line and ring the bell at "B's" telephone, while the clear-out drop, owing to its high winding, will get but little of the current. It therefore becomes necessary to do one of two things, either to decrease the resistance of the clear-out drop, or increase the resistance of the telephone ringers. It is a bad practice to decrease the resistance of the clear-out drop, for in this case when two parties are talking, some of the voice currents would leak through the drop, which does not occur when it is high wound. It is therefore better to use high wound ringers in the telephones, and it may be said that ringers of less than 250 ohms resistance should not be used in telephones for local exchange work.

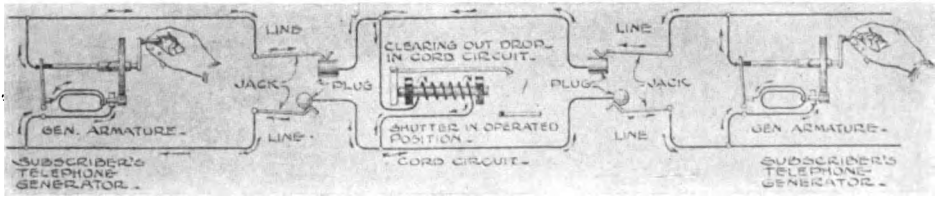


Fig. 176.

In order to adapt cord circuits of the average magneto switchboard to selective party line signaling so that no interference will take place, especially so that the act of calling the exchange or of ringing-off by either of the connected subscribers will not cause the bells of the selective subscribers to ring or even tap, some special arrangement is necessary. This defect is present in nearly all party-line systems when regular cord circuits are used.

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In addition to this a great many party-lines are of sufficiently high resistance between the exchange and the location of the telephones so that the shunting effect of the low wound drop winding at the exchange to the ringing current is not enough to prevent some of the ringers connected to the same line from tapping or even ringing. This question of doubtful operation led one of the prominent manufacturers to perfect a special magneto cord circuit, as shown in Fig. 177, which prevents parties when ringing off, causing the telephones on the connected party-line from ringing.

It will be seen that this circuit differs only from the standard bridged clearing-out drop circuit in that two condensers, "A" and "B" are connected in series between the tips and sleeves of the plugs.

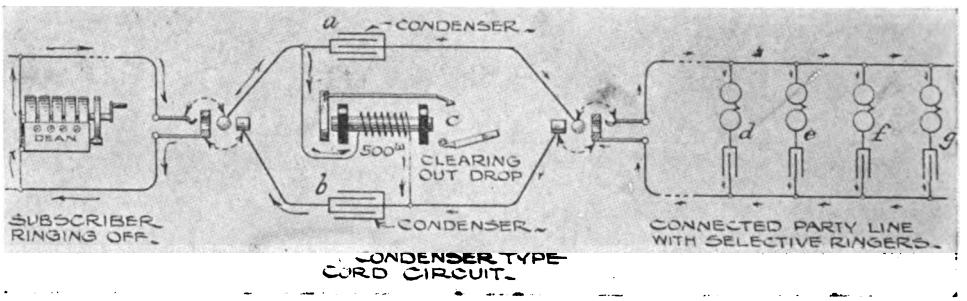


Fig. 177.

The novelty of this circuit is the connection of the high wound clearing-out drop "c" diagonally across the cord circuit so that one condenser is in series with same for the ringing-off current from either connected subscriber; also that the two condensers are in series to any current which would pass through the party line ringers "d", "e", "f" and "g" of a connected line and cause the latter to false signal. The fact that the apparent resistance of the two condensers in series is very high for the low frequency ringing currents, and of low resistance for the high frequency voice currents gives the desired result in both cases. The installation of the condensers in the manner desired does not materially affect transmission, and the method of installing the condensers and clearing out drop in the cord circuit enables same to be used like any other cord. Thus, it is not necessary to put one special plug of each pair into the jack of the party line when making a connection.

This cord circuit also possesses an advantage over the regular type of cord circuit that a low wound series telephone on a short line will not prevent the clearing-out drops from operating, or the accidental short circuit of one of the connected lines will not tie up the line connected to the other side of the cord.

Another circuit arrangement for accomplishing the latter purpose, is shown in Fig. 178.

The 1,000 Ohm drop and 2 M. F. condenser are arranged as shown. When either subscriber "rings-off" the current divides between the drop and condenser. The frequency of the ringing current is so low that the condenser offers a high resistance to the current, thus causing it to flow through the drop, operating same. With this plan, Phones "A" and "B" may be both series or Bridging, or one of each.

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Another circuit is shown in Fig. 179, which has the advantage of a bridged clear-out drop. Here two non-inductive coils "N" "N," are placed in series between the tips and sleeves of the cords as shown, with the drop "D" connected at the center points. Assume that "A" and "B" are connected as in Fig. 178. When the ring-off takes place, the current from station "A", for example, passes to the center point of non-inductive coils "N" and "N", whence it finds two paths, one through the ring-off drop "D", and the other through the telephone "B", via the other halves of coils N and N. Since the two halves of these coils equal 500 ohms resistance, it is immaterial as to what the resistance of telephone "B" is; hence, as in the other case, the telephones may be alike or different. Should the disconnecting current originate at telephone "B", the operation would be reversed, obtaining the same results. Cords so equipped should not be used for connection from "Toll to toll," as it increases the static capacity. No harm results from their use for "Local to toll."

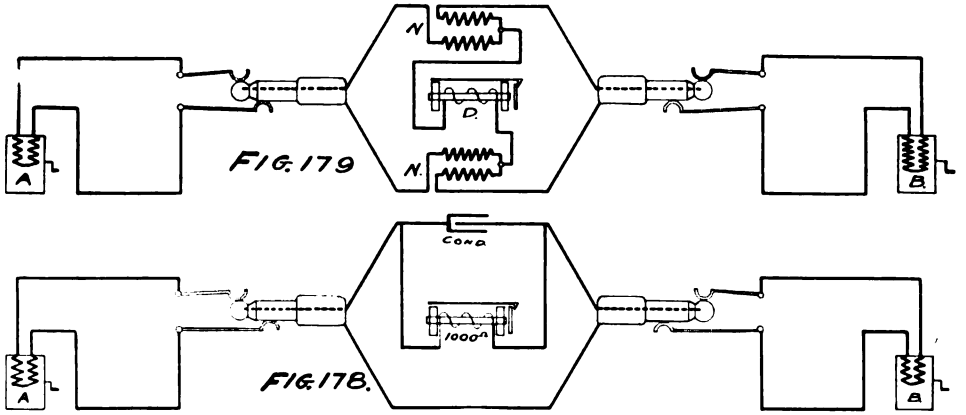


FIG. 179

FIG. 178.

The Monarch Tel. Mfg. Co., have recently introduced a cord circuit to accomplish the same result as the circuits just described, which uses a combination of clear-out drops and lamps, as shown in Fig. 179a.

The two plugs are separated by condensers. The two clear-out drops are bridged on each side of the cord. A ring off signal received on one side of the circuit will not pass through the condensers, but will operate the clear-out drop. The condensers do not interfere with the passage of the talking currents, which pass from one plug to the other in the usual manner.

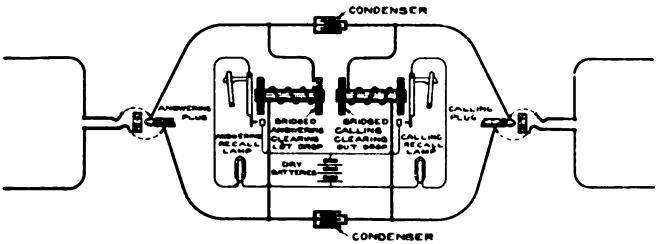


Fig. 179-a.

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The lamps are so connected that upon the clear-out drops falling, the lamps will be lighted, thus affording an additional signal to the operator. This circuit practically assures double supervision on a magneto board, and is unique in this respect.

The actual arrangement of the cord circuits in the usual magneto board is shown in Fig. 180. This shows the calling and answering plugs, their location on the face of the switchboard, and the ringing and listening and ring-back keys. The theory of this circuit is shown in the upper corner of Fig. 180.

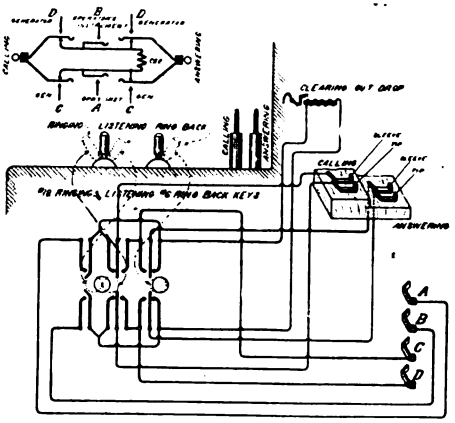


Fig. 180.

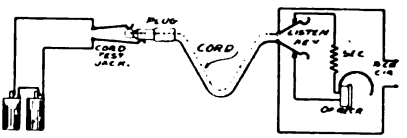


Fig. 181.

The most common trouble with cord circuits is due to defective cords. It is surprising that the majority of small exchanges do not pay more attention to testing their cords regularly. Cord trouble may be suspected, when a scraping, scratching noise is heard, and when at times it is impossible for subscribers to hear each other when connected. The location of this trouble is usually easy. Any jack in the switchboard should be connected to two cells of battery, as shown on left hand side of Fig. 181.

The plug and cord to be tested should be inserted in this jack and the listening key thrown exactly the same as when answering a call. The cord should then be violently shaken, pinched and bent in all directions, especially at the handle of the plug where the trouble usually occurs. If there is the slightest "cut-out" or break in the cord, a loud scraping and scratching noise will be heard every time the loose connection is disturbed.

It is easy to tell when a cord is short circuited. Simply throw the ringing key without putting the plug in any jack and turn generator. If the buzzer which is usually connected in circuit with the generator, operates, the cord is short circuited.

Several forms of cords are in use, the two prevailing types being composed of tinsel, or solid wire conductors coiled in spiral form, as shown in Fig. 182.

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Recently there was placed on the market a cord composed of two spiral conductors of solid wire of special composition, which has proven very satisfactory. When a tinsel cord breaks, it causes a scraping noise before it entirely gives away, whereas, the spiral cord breaks clean, and is therefore not liable to this objection. It is also necessary when using the tinsel cord to form up the ends where they are connected to the plug and wrap the same with wire or thread, whereas with the spiral cord,



Fig. 182.

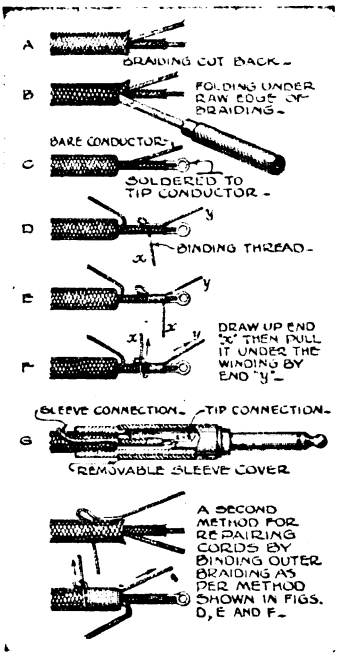


Fig. 183.

the conductors are simply pulled out and bared and the ends connected. The temper can be taken out of the spiral conductors by putting them in a match flame for a few seconds.

The plug end of the cord is the first to show wear and become defective, due to continued handling by the operator, the remainder of the cord seldom causing trouble. A reinforcement is braided into this part of the cord as an extra protection and is made 18" long so that by carefully butting the cord each time it becomes defective, it is possible to make as many as seven plug-end repairs.

In making a cord repair its covering is cut back a sufficient distance to remove the defect. The latter is located by using the cord test jack as previously described. The raw edge of the outer braid is now folded under or pushed back, as shown at "B" in Fig. 183, using a small screw driver for tucking the braid under. This makes an enlarged portion at the end of the cord which will tightly screw into the thread of the plug. The covering of the exposed sleeve conductor (provided with colored insulation) is now cut away, leaving it entirely bare while the tip conductor is bared to proper length to go under its binding screw when inserted

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in the plug, or to receive a tip which later should be soldered to the cord conductor. It is also good practice to bind the raw edge of the braiding of this tip conductor as shown in "D", "E" and "F", Fig. 183.

The sleeve conductor is doubled back when the cord is screwed into the plug so as to make a good contact with the metal body of the latter, care being taken that the cord makes a tight fit. The projecting ends of the sleeve conductor is now cut off flush with the plug body and the tip conductor securely fastened by the clamping screw.

A cord without beeswax filling may be repaired by wrapping with stout beeswaxed linen thread instead of tucking the outside braiding. This is a good method of butting, the binding operation being as shown in the last two views of Fig. 183.

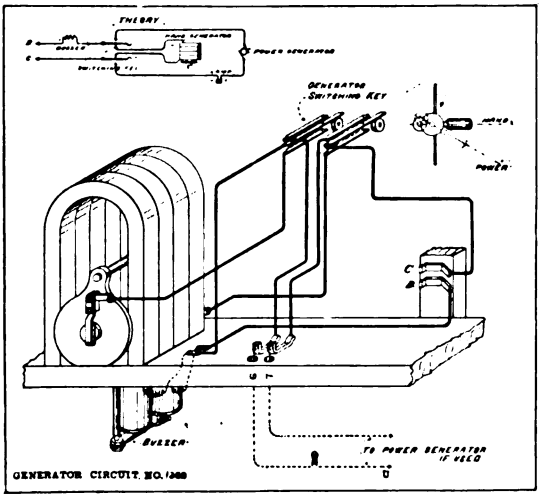


Fig. 184.

The necessity and importance of testing cords regularly, at least once a week, in exchanges no matter how small, cannot be too strongly emphasized. Considering the ease with which cord test jacks can be rigged up, there is no excuse for neglecting this point so vital to good service.

Aside from defect in cords, very little trouble arises in cord circuits. An occasional bad contact will be found in the keys, but it may be said that this seldom occurs, and unless thoroughly familiar with adjusting keys, it is better to leave them alone, or get some one familiar with the equipment to make the necessary adjustment.

Occasionally a clear-out drop fails to operate, in which case the drop winding will probably be found open or short circuited. This can be located in the same manner as an open drop winding, by plugging into a jack connected to a test phone. If upon ringing the generator turns hard, the clear-out drop is probably short. If the generator turns easily, the winding may be open and this can be determined by using a receiver as previously described.

The cord circuits here described are the standard forms generally in use. Each manufacturer has his own method of cabling the different

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wires and arranging the various portions of the equipment, but in principle, the various switchboards differ but little from each other.

The operation of the ringing key has been described, and the apparatus necessary for ringing is shown in Fig. 184.

Here it will be seen that the wires from the generator with which the switchboard is equipped, are connected to key known as the "Generator switching key." When this key is in its normal position the hand generator is connected in series with the buzzer and with C and D, which in turn are connected to the outside springs of the ringing keys as shown in Fig. 180, C being the sleeve side, D the tip. When the generator switching key is turned down, the hand generator is disconnected, and the power generator is connected in circuit. A power generator is adapted to be driven by water or an electric motor, or some other source of power, and may be located some distance from the exchange and the current can be brought into the exchange over wires which are connected to the terminals in the back of the board. In place of a power generator, a pole changer can be used, and will be found most satisfactory for small or medium size exchanges.

The buzzer used in the generator circuit should be wound to a resistance of 80 to 250 ohms. The use of a higher winding should be avoided as it will not allow sufficient current to pass for ringing on heavily loaded lines.

It will be noticed by reference to Fig. 184 that a lamp is inserted in one wire leading from the power generator to the switchboard. This is an ordinary 16 candle power lamp, and is used to prevent short circuiting the generator when ringing on a short circuited line, which, if the lamp was not used, might damage the power generator or pole changer.

If the generator circuit fails to operate, the fingers should be placed directly across the outside springs of the ringing keys. If no current can be felt here, place the fingers across the terminals where the wires connect to the generator, and turn the crank. If no current is felt at this point, the trouble is in the armature winding.

In case it is impossible to ring from the switchboard, before deciding that the trouble is in the generator circuit, all the plugs in the switchboard should be tried. If one will ring O. K., the trouble is not in the generator circuit, but is somewhere in the generator wires leading from key to key. If, however, none of the plugs will ring, it is reasonable to suppose that the trouble is in the generator circuit itself. If it is possible to ring with the hand generator and not the power, it is evident that the trouble is in the power circuit. The fingers should be placed across the terminals in the rear of the switchboard to which the power wires are connected. If current can be felt at this point, examine the contacts of the generator switching key and wiring thereto.

It may be found that neither the hand nor power generator will work, and it may happen that the buzzer is open. To test for this, short circuit the terminals of the buzzer with a piece of wire, and see if it is possible to ring with the plugs. If it is, the buzzer coils should be rewound.

The hand generator for switchboard work should be of the heavy 5 bar type, and it is well to teach the operator to turn the hand generator steadily, and when ringing signals on country lines, to throw the ringing key the proper number of times. This is better than ringing signals by turning the crank, as this destroys the teeth in the gear wheels owing to the sudden jerks.

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It is customary in the better type of switchboards to mount the generator in the back of the board where it is accessible for examination without disturbing the operator. In older boards the generator is located directly under the key shelf where it is in the way of the operator's knees, and the gear wheels catch the clothing. Sometimes it was located inside the key shelf, and to examine it, it is necessary to disturb the operator and interfere with the service. It should therefore be specified that the generator be mounted in the rear of the cabinet. When this is done the shaft connecting the crank with the generator should be provided with a flexible joint so that in case the front bearing gets out of line, no strain will be thrown on the gear wheels. A couple of drops of oil should be applied to the generator bearings occcasionally, taking care not to use too much. Occasionally the contact between the armature pin and spring should be cleaned and the contact examined to see that it is not wearing to an undue extent.

When the same power generator or pole changer is connected with two or more sections of switchboard, particular care should be taken to connect the same side of the power generator to the same side of the cord circuits. By referring to Fig. 180 it will be seen that the C side of the generator circuit connects to the sleeve side of the plugs when the ringing keys are thrown. Therefore the same side of the power generator should go to all the sleeve terminals of the power generator circuits in the various sections of the switchboard. It is also well to use separate lamps in series with this side of the circuit to each operator's position.

If two positions of the switchboard are connected up in opposite directions, and two operators should happen to ring on grounded lines at the same time, they would not only fail to ring, but would short circuit the power generator. Particular care should therefore be taken to connect power generator or pole changer properly.

It soon becomes evident in an exchange of any size, that some automatic source of ringing power is necessary, as the work of constantly turning the hand generator is considerable.

While generators driven by power are almost exclusively used in large exchanges, the cost is prohibitive to the small exchanges. This is due to the fact that current is only required at intervals, while the machine runs all the time and the cost of power to drive same is quite expensive.

By using batteries, power is only used while actually in the act of ringing; but as a battery current is direct, or in one direction, and alternating current is required to ring a telephone bell, some device is necessary to change the direct current to alternating.

A pole changer is a device for this purpose and changes the direct current from a number of cells (usually dry cells) arranged in series to give sufficient voltage, into a current alternating in character which is suitable for ringing purposes.

This apparatus consists of an electro-magnet similar to the magnets in an ordinary electric bell, in front of which is mounted an armature carrying a pair of contacts. The electro-magnet is usually operated by a cell of closed circuit battery (dry batteries won't do) and when in operation the armature carrying the contacts vibrates to and fro, same as the armature and clapper of an ordinary bell.

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The contacts are so arranged that they connect each line leading to the ringing keys in the switchboard, first to one side of the battery and then the other. Thus it will be seen that the direct current is changed at every swing of the armature. This action will be clearly understood by reference to figure 185.

The moving contacts are marked + and —. The vibrator coils are shown connected to the closed circuit battery. Now imagine the moving contacts to be thrown to the *right*. By tracing the circuit, it will be seen that the current from the + side of the 50 open circuit batteries flows through the D. P. switch and out through the + moving contact to the left hand ± terminal, while the — side of the battery flows to the right hand ± terminal in the same manner except that it passes through the relay winding shown in the upper right hand corner. The function of this relay will be explained later.

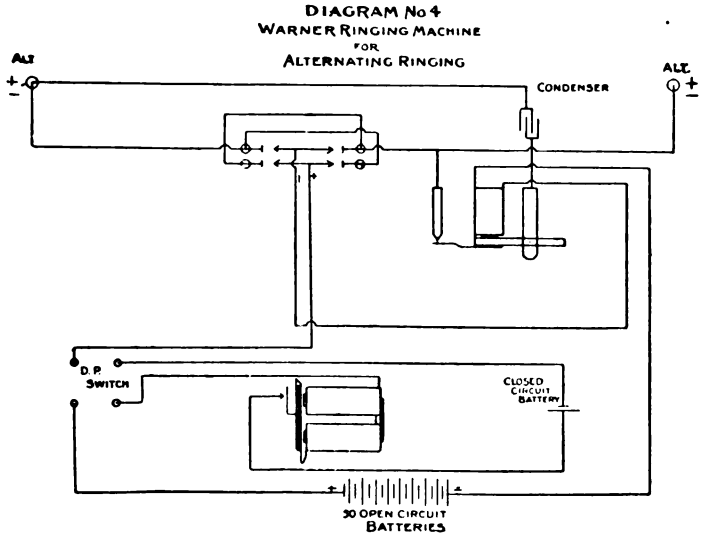


Fig. 185.

Now when the vibrating contacts move to the *left*, this process is reversed and + current is connected to the right ± terminal and — current to the left. Thus a current alternating in character is produced and will continue as long as the vibrator continues to work. It will be observed that as long as nothing is connected to the ± posts, no current will be consumed from the dry cells, the machine being operated entirely by the single closed circuit cell, which lasts for six or eight months, it can then be renewed as follows:

To Make Solution.—Fill the jar with water to line on the inside. Then open the can of granulated potash by cutting out the bottom (which is made of very thin tin) with a pen-knife. Add the potash gradually to the water, stirring the solution constantly, until the potash is entirely dissolved, which will take about three minutes. When the solution cools it may be found necessary to add a little more water to bring it up to the brown line again. Then pour a layer of heavy Paraffin oil (from the bottle furnished) on the solution in the jar, until

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it covers the blue line. In stirring the liquid avoid splashing it. The potash will burn the skin and clothes.

Unless a short circuit should occur, the battery requires no attention until it is exhausted. A short circuit between the plates in the cell or a short circuit outside will destroy the whole battery.

When the cells become exhausted the solution and the remains of the zinc and oxide plates must be thrown away. All the remaining parts can be used again.

To take the cells apart, lift the lids, unscrew the bolts, and remove the zinc and oxide plates. Wash off (with water) the copper frames, bolts and rubber insulators, brightening up the metal where corroded, with emery paper, especially the inside grooves of the copper frame sides. Pour away the solution carefully and set up cells with new potash, oxide plates and zinc according to directions.

In taking the cells apart, the parts that have been immersed in potash must be washed before they are handled.

To ascertain if the oxide plates are exhausted, pick into the body of the oxide plates with a sharp pointed knife. If they are red throughout the entire mass they are completely exhausted and need renewing. If, on the contrary, there is a layer of black in the interior of the plate, there is still some life left, the amount being dependent entirely upon the thickness of the layer of black oxide still remaining.

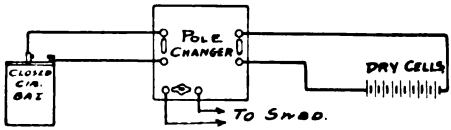


Fig. 186.

Too great stress cannot be laid on the necessity of observing, when setting up the cells, that the top of the oxide plate is fully one inch below the surface of the potash; and consequently about 1½ inches below the top of the oil.

The difference of one inch in the height of the solution in the jars determines the success or failure of these batteries.

The machine is set up and wires from the closed circuit battery connected as shown in Figure 186.

The parts are usually tagged to denote the proper connections. The closed circuit battery should be as close to the machine as possible and connected with not less than 16 *copper* wire. The dry cells can be located at any convenient place, from 40 to 60 cells being used. These are connected in series, the zinc of one going to the carbon of the next, the last carbon and zinc going to the machine. Each dry cell gives 1½ volts.

For local work where the lines are not heavily loaded or long, 60 volts is sufficient. The more 'phones on the lines, the more batteries required. Make the battery strong enough to ring the most distant 'phone and the short lines can take care of themselves.

After setting up the battery and closing switch on the machine, the vibrator should start, if not examine the contact point "E", figure 186a. Start the vibrator gently with the fingers; make sure the closed circuit

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battery is O. K., and properly connected. When the contacts V and W. are in contact with B & D, brushes A and C should be about one-eighth of an inch away from the vibrator contacts on that side and vice versa.

The function of the relay shown at M, in the figure is to prevent the sparking at the contacts A, B, C, D, by connecting the condenser, which is located in the base of the instrument, across the lines whereever the pole changer is used.

If the condenser were permanently connected across the ringing wires, the alternating current would constantly flow through same and the batteries would suffer.

The figure shows the Pole Changer in detail. The letters denote the different parts, the names of which are as follows: O P. Q. M. N. K. and L. constitute the condenser relay. O is an adjustable weight. P is an adjustable post for regulating the throw of armature N. Q is the T shaped frame of the relay. M is the actuating magnet. K is a contact spring, and L is a contact post.

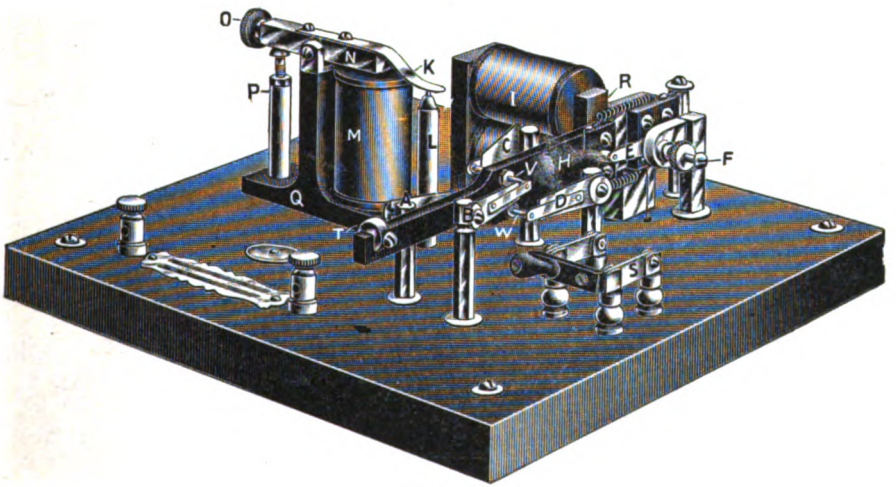


Fig. 186a.

The operation of the relay is as follows: When no current is being drawn from the batteries the armature N is resting on the adjustable post P and the contact spring K is lifted clear off the contact post L. Now, when the operator signals a subscriber the current is brought through the magnet M which instantly draws down the armature N and closes the condenser circuit through the contacts K and L. Thus the condenser is automatically connected across the ringing circuit each time the operator signals a subscriber, and is disconnected in the same manner.

The letters I, R, E, F, H, T, show the principal parts of the vibrator mechanism. I is the electro magnet, and is energized by the current from the single closed battery. This immediately draws the armature R toward the magnet until the circuit is opened at the contact E; then the spring, which supports the armature R and the vibrator tongue H, bring the armature back until the circuit is closed at the contact E; then the magnet again attracts the armature and the operation is repeated

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over and over. It will, therefore, be noted that the operation of the vibrator is as simple as an ordinary door bell. The weight O should be adjusted together with the screw P, until the contact K is only about 1-64 inch away from L. This contact should close every time the machine is used and should open again immediately when the current ceases to flow.

The wires to switchboard are to be run in a most convenient manner. It is convenient, however, to have a buzzer in the power circuit, and if only one board or section is to be supplied with power then the buzzer may be placed anywhere in the power circuit. But if more than one board or section is to be supplied with power, then a buzzer should be supplied for each board, and should be connected as shown in Fig. 187.

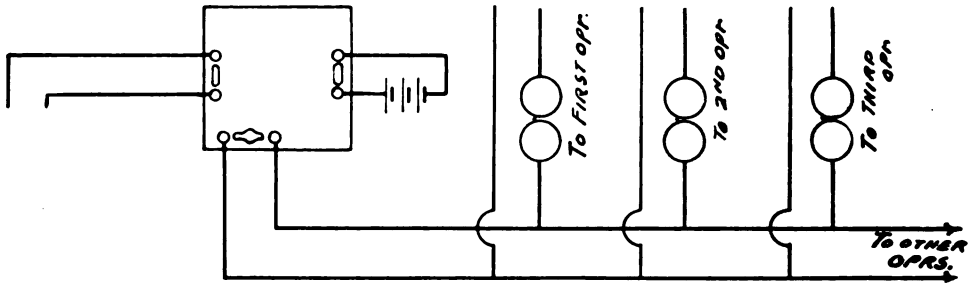


Fig. 187.

Usually switchboards are arranged with a generator switching key already wired in circuit and terminals are provided to which the power generator or pole changer can be connected. This is shown in Figure 184 and it is simply necessary to connect the wires from the pole changer to terminals 6 and 7 as shown in illustration, or other terminals marked for the generator. When more than one section of board is used, it is absolutely necessary to connect the *same* side of pole changer to the *same* terminal in each section. That is, connect all the No. 6 terminals to one side pole changer circuit and all 7 terminals to other side. In series with wire to each No. 6 terminal place an ordinary incandescent lamp, as shown.

The pole changer shown in figure 186a is also arranged to give pulsating direct current for ringing biased bells used in connection with selective telephones. In operation and construction this instrument is the same as the one previously described except that two additional binding posts are provided for the + and — pulsating current. Figure 188 shows these extra posts, which connect to the switchboard as shown in Fig. 245, the ground post being connected to terminal 17, as shown in the figure (245.)

In place of the large number of dry cells necessary with the pole changer any source of *direct* current, such as the ordinary incandescent light circuit not exceeding 110 volts may be used. It is necessary to connect one or more lamps in multiple as shown in figure 189.

To prevent an excessive amount of current from entering and injuring the machine, try one lamp and if this does not ring properly, more current is necessary and another lamp can be used connected as shown.

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Great care must be taken when this method is used to prevent the contacts from sparking. For light ringing this will give satisfaction.

*Experience has shown that a pole changer is an exceedingly desirable and economical device for the small exchange, whose small size is hardly sufficient to warrant the necessary expenditure for the electrical machinery required in the installation of a ringing dynamo. There are very many instances, particularly as the small exchange increases its

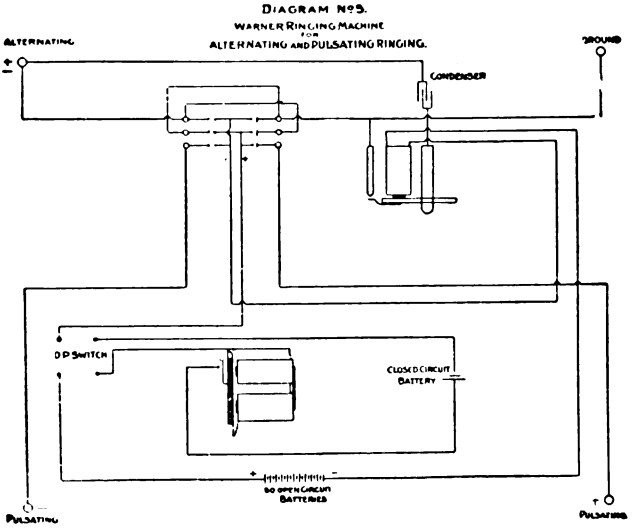


Fig. 188.

capacity, when it is practicable for the wire chief to construct a pole changer out of materials at his hand, and thus avoid the expense of purchasing a machine outright. So, the object of this article is to describe a method that has been successfully put into practice for accomplishing this result.

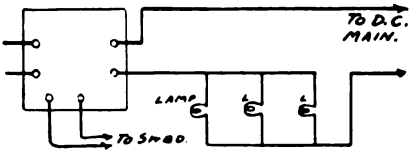


Fig. 189.

The materials required are : A board for a base, 5″ × 9″; one 3″ gong iron box vibrating bell; one ½ M. F. condenser; one single contact relay of not over 80 ohms resistance; six brass binding posts, such as may be taken from old dry batteries; eight platinum hookswitch points; four strips of brass, ⅜ × 1¼″; six inches of light watch spring; a few screws, etc. The bell should be prepared by cutting the frame at the edge of the gong and cutting the hammer rod so as to leave ½″ of stub. To this stub solder a piece of No. 12 iron wire 4″ long, which has been flattened slightly.

* American Telephone Journal.

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Slip over the wire a piece of hard wood 3″ × ¾″ × ⅛″ which has two 3-32″ holes ¾″ apart, as shown at *e*. It may be well not to dress the wood down to dimensions until after it is bored and in place. Place in the two holes two contact pins, made by cutting off the heads of two binding posts and soldering to each end of both platinum points. Place some sort of a light weight on the end of the vibrator, with which to govern the rapidity of its vibration, which should be about twenty complete vibrations per second.

Screw the vibrator to the base, which has been smoothed and varnished, and so adjust it that the points shall be one inch from the base. Cut four pieces of brass, as shown at *a*, and solder to them pieces of spring, as at *c*, and bend together, as at *b*. Bend the spring so it will have only a slight tension against the brass. It will be necessary to draw the temper in the springs, as they are too brittle without. Carefully punch the holes for the platinum points and solder them in on the back, as the springs will not bear much riveting.

Screw these contact brushes to the base so that the points on the pins will strike the points in the springs quite firmly when the vibrator is run with one cell of dry battery. Be sure that both contacts on one side make and break at exactly the same time.

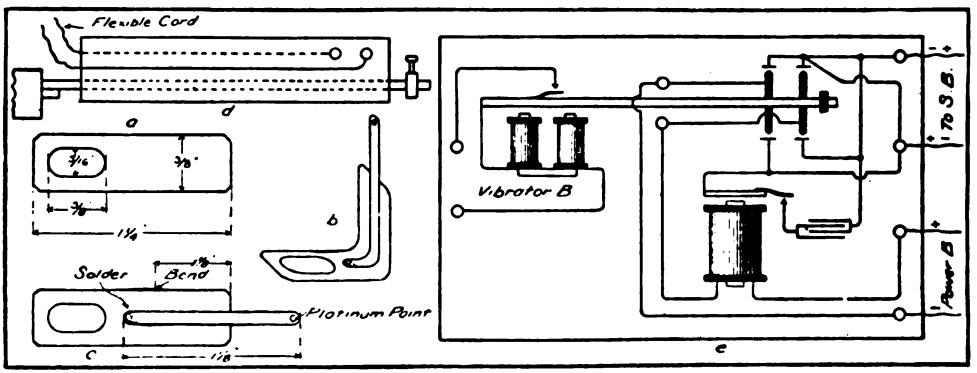


Fig. 190.

Mount the relay in the most convenient manner and make all connections, as shown at *e*. Connection to the contact pins should be made by means of wires brought to the end of the vibrator tongue and connected to posts driven in the base, by flexible cords or coils of wire, as is plainly shown in Fig. 190. The terminals are mounted on the bottom of the base and the machine raised on short legs or the connections brought out to binding posts. The machine will work much better if held firmly and not allowed to vibrate as a whole.

While this machine may appear crude in comparison with the purchased article, when carefully made it will give very little trouble and requires no attention.

A very good substitute for a relay may be made from an old drop by soldering on a piece of brass for a contact and a binding post for a counterbalance. Or even the windings of an 80-ohm bell may be made to serve.

The next portion of the switchboard to be considered is the Operator's telephone or "set." The usual form of operator's set is wired as

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shown in Fig. 191. It is commonly the practice to use three cells of bluestone battery for small switchboards. Dry batteries should never be used for boards in constant service, as they soon become worthless. The bluestone battery is not ideal for this service, but as they deliver a small but constant current and are cheap to install and renew, they are used to a considerable extent.

By tracing the circuit, it will be observed that the transmitter and primary of the induction coil are in series with the battery when the plug connected with the head receiver is inserted into the jack, which is located in the front of the key table. The inner contacts of the jack are placed in series with the battery and transmitter in such a manner that the battery circuit is open when the plug is withdrawn from the jack, which saves the battery when the board is not in use.

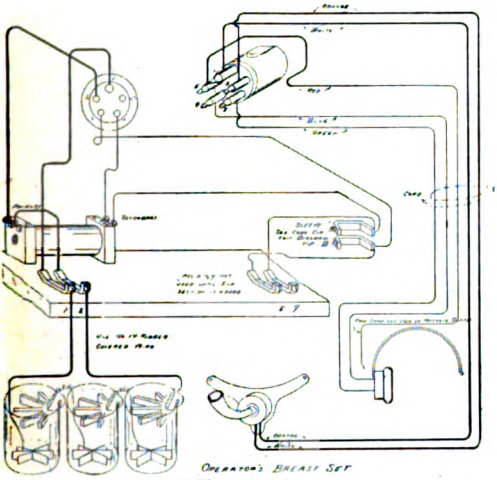


Fig. 192.

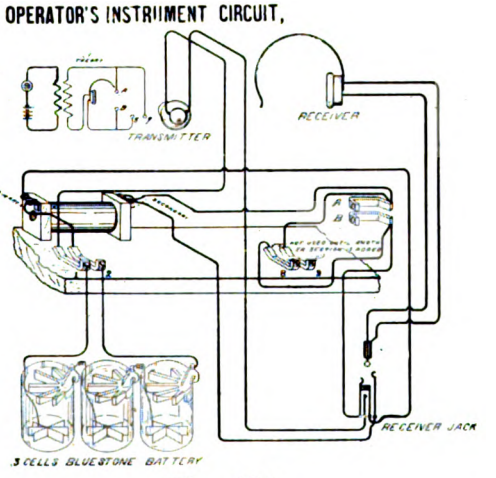


Fig. 191.

The secondary winding of the induction coil is in series with the operator's head receiver, and terminals "A", "B", which connect with the sleeve and tip sides respectively of the cord circuit listening keys shown in Fig. 180 and 193.

When a breast transmitter is used the circuit is as shown in Fig. 192, and a plug with 4 or 5 contacts is used.

Each strand of the cord has different color insulation and should be connected as shown. In renewing cords it is important to see that the cord is properly connected.

The secondary of the operator's induction coil is usually wound to a higher resistance than coils used in telephones. This is to prevent the cord circuit from being short circuited when the operator "listens in" on the same. The usual resistance is 100 to 250 ohms.

Many different types of coils are used. Some manufacturers use coils of special design with large cores and winding space, so as to secure powerful transmission.

The operator's circuit is very simple. It is easy to trace the primary circuit from the battery to the transmitter through the primary and jack contacts, back to the battery circuit, while the secondary winding of the coil is in series with the operator's head receiver, and the listening con-

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tacts of the keys in the cord circuits. By referring to Fig. 180 it will be seen that when any key is thrown, the secondary winding of the operator's induction coil and the receiver are bridged directly across the cord circuit.

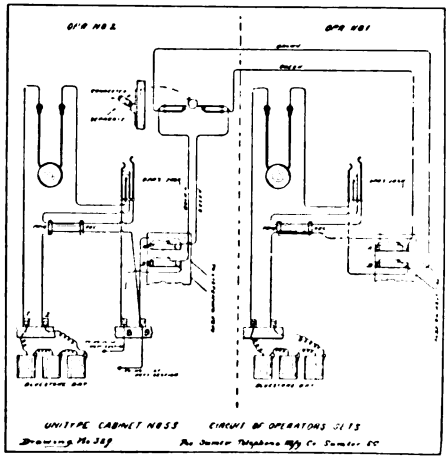


Fig. 192a.

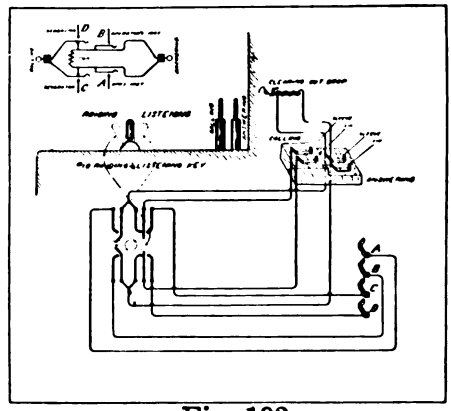


Fig. 193.

The troubles met with in this circuit are few, usually consisting of broken transmitter or receiver cords. If the operator can hear the subscribers but the subscribers cannot hear the operator, the trouble is either due to a short circuited secondary in the induction coil, or to a defective transmitter or broken cord leading thereto, or the batteries are in bad condition. When this trouble occurs, first test the battery by removing wire from terminals in rear of board, and connecting to these terminals two cells of dry battery. If this cures the trouble, it will be apparent that the trouble is in the bluestone cells and they should be re-charged as described in the chapter dealing with batteries. If this is not the case, connect an ordinary series telephone to the terminals of the operator's set and push the operator's receiver plug into the jack. See that the contacts in the jack close, and if so, turn the crank on the telephone or test set. See if the circuit is complete which will be denoted by the bell ringing. If the circuit is not complete, the transmitter cords should be carefully examined and it will probably be found that one is broken. If this is not the case, short circuit the primary of the induction coil, and if the circuit then tests all right, the trouble is an open primary, and a new coil should be substituted.

It should be remembered in making the following tests to have one of the listening keys thrown in a listening position, with one of the plugs connected with that pair of cords short circuited by wrapping a piece of wire around the sleeve and tip.

If the operator cannot hear the subcribers, the first thing to examine is the receiver cord. It is usually better to substitute a new cord. Then with the listening key thrown and plug short circuited as above described, short circuit terminals A, B, or short circuit the wires running from the operator's set to the keys. If by talking into the operator's transmitter, the set tests all right, the trouble lies between the point

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short circuited and the next key, but if the set will not talk, look for a short circuit in the induction coil, a broken wire or bad contact between the operator's plug and jack, or between the point short circuited and the operator's set, but not in the keys, as the trouble is not past the point short circuited, but between operator's set and that point.

The receiver should also be tested by connecting it to an ordinary telephone as the winding of same might be open. If the operator complains of hearing a scraping noise when talking to a subscriber, and this happens with any cord circuit, it is an indication that there is a loose connection in the operator's circuit, or that the switchboard cords are bad. To locate this, either short circuit the terminals A, B, or the wires running from the operator's set to the keys. If the scratching noise disappears, the trouble is not in the operator's set, but in the cords or keys; whereas, if the scratching noise continues, the trouble is in the wiring of the operator's set.

When the switchboard consists of more than one operator's position, it becomes necessary to provide some means for connecting the positions together so that one operator can handle the entire switchboard at night, or at other times when necessary.

This is accomplished by wiring the operator's set as shown in Fig. 192a, where it will be seen that a key is provided, which, when thrown, will connect two operator's sets in multiple. By this means, one operator can use any of the cord circuits of the switchboard at will without having to change her receiver plug from one jack to another.

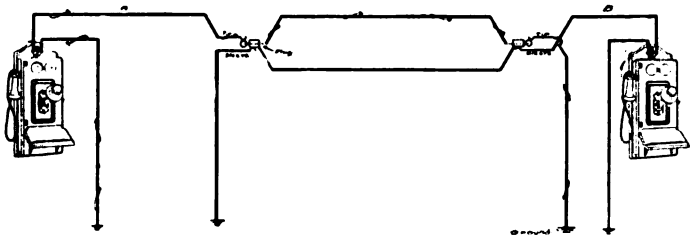


Fig. 194.

In addition to the cord circuit shown in Fig. 180, it is sometimes customary to wire the cord circuit with only one ringing key so that all calling must be done with the front plug of each pair. This is shown in Fig. 193.

One very important fact to be kept in mind, is that the tip of one plug should be connected to the tip of the other.

A trouble often met with in grounded systems, is that when two grounded lines, either of which is all right by itself, are connected together, they are both "dead," and cannot talk or ring. This can be due to connecting up one line to the tip of the jack, while the sleeve is grounded, and the other line is connected to the sleeve of the jack, and the tip grounded. By tracing the circuit, which is shown in Fig. 194, it will be seen that both lines are short circuited. The remedy for this is to connect up all grounded lines one way—i. e., connect all the line wires to the tips of the jacks and ground the sleeves.

All modern switchboards are wired full metallic, and when connecting them up, care should be taken to observe which wire of each pair in

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the jack cable goes to sleeve of jack. These wires are usually the ones with solid color insulation and should be connected to the ground if grounded lines are used.

Sometimes this trouble is caused by the cords themselves being reversed, i. e., the tip of one cord being connected to the sleeve of the other, as shown in Fig. 194a. This can be tested for with a bell and batteries as shown in Fig. 195.

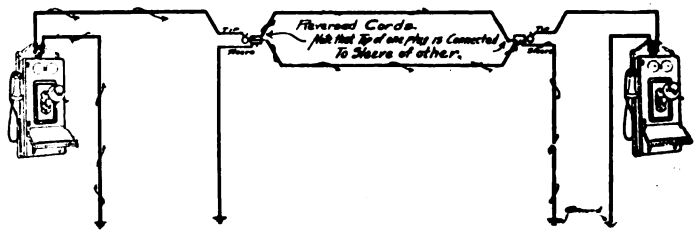


Fig. 194a.

Touch one wire on tip of front plug and other wire on tip of back plug, and the bell should ring, if not, the cords are probably reversed and should be changed.

By examining the cords, it will be seen that the sleeve or tip conductor has a colored thread running through it, for the purpose of identification. Some manufacturers place the colored strand in the conductor to the tip in the plug, while others place it in the sleeve, but in all cases, it will be found that all the plugs purchased from any one manu-

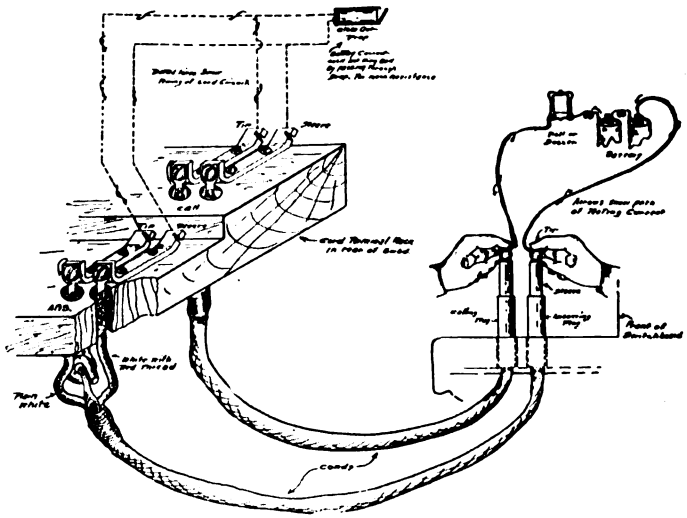


Fig. 195.

facturer will be connected the same way, with both tips connected to the terminals on one side and both sleeves to the terminals on the other. If this is not done a great deal of trouble will result, especially where grounded or common return wire lines are used.

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The circuits already described of the operator's set and line circuits, are the standard circuits of the average magneto switchboard, but there are many additional circuits, which in a way, may be regarded as special but which are necessary in certain cases. For instance, when 2 or 4-party selective ringing is used, the cord circuits must be able to perform other functions in addition to these already described.

"*In an exchange where the local lines are grounded and toll or trunk lines are metallic, it is often the case that while both the local and toll lines are quiet enough by themselves, as soon as a short grounded line is connected to a long metallic one the combination becomes so noisy as to make it impossible to carry on a conversation over it with any degree of satisfaction. This is especially true if there is an arc light circuit in town. In such an event it is quite possible that even some of the local metallic circuits, if the insulation is low or they run very close to the arc light circuit, will begin to hum in a very lively fashion as soon as connected to toll lines.

To meet such a condition as this it has long been known that the proper thing to do is to install a repeating coil in a switchboard cord circuit, so that the local line need not have any metallic connection to the toll line. This will usually cut out the greater part of the noise. Although good coils for this purpose can be bought from a number of manufacturers the writer believes that there are still a considerable number of telephone men who would like to make such a coil for themselves, and put it in their own switchboards. This article will tell some of the points which must be looked out for in selecting the material for such a coil, and show how to make it easily and cheaply in such a way that a man in almost any town can get everything that is put into it at small trouble and expense, and fit it together without the use of special machinery.

Types of coils.—In the first place, a man who is going to build a repeating coil has to consider that repeating coils can be roughly divided into two classes. Those in one group are designed to repeat both ringing and talking currents. Coils of this type can be placed directly between two line circuits, and will repeat the "rings" from one line to the other as well as the conversation. They are known as "Ring-through" coils.

Coils of the other type are designed to repeat voice currents only. These coils are usually wired into the cord circuit of the switchboard in such a manner that it is not necessary to ring through them, and are known as "Talk-through" coils.

On making a close examination of successful commercial coils in these respective classes, and studying the discoveries which have been made in the process of their development one finds that the principal variations in construction which will be noticed are: More or less iron in core; magnetic circuit open or closed through shell; winding of high or low resistance and of heavy or fine wire.

The amount of iron in the core.—The telephone repeating coil can be considered as a form of induction coil. It has two windings upon an iron core, both windings usually of the same resistance and number of turns, so that there is no "step down" nor "step up" effect, such as is usually present in other types of transformers or induction coils. It depends for its action upon the fact that when currents, alternating in character, such as voice or ringing currents, are passed through one of the wind-

*American Telephone Journal.

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ings, which may be called the primary, a current is induced in the other or secondary winding, which is identical in character with that in the primary. Taking up this action in detail, it is found that when a current is passed through the primary the core is magnetized. When this current decreases, as is the case with all alternating currents which change or reverse their induction at every alternation, the energy which is stored up in the core in the form of magnetism acts upon the windings, and induces a current in the secondary or other winding from the one through which the exciting current is passing, similar in all respects, except a slight loss in strength and distortion of wave form, to the current which produced the magnetism. Some appreciable time is necessary, however, for an iron core to be magnetized after current is turned on, and for it to give up its magnetism after the current is turned off, or when the current is varied in strength the changes in the strength of the corresponding magetism do not keep exactly in time with the changes in current. The greater the amount of iron, the greater difference does one find in this effect. For this reason the amount of iron to be put into a core is determined by the class of current it is necessary to repeat. If the coil is of the "Ring-through" type, it must repeat currents having a rate of change of about one thousand times a minute and considerable *quantity*. A large amount of iron is necessary to transform this energy with as little loss as possible; that is to say, a large heavy core is necessary when a ringing current of a slow rate of alternations is to be repeated, so that a considerable portion of energy will be absorbed by the core. On the other hand, where small weak currents, such as voice currents, are passed through a coil with too large a core they are muffled and distorted by the slow action of so much iron. The "Ring-through" type of coil is therefore not adapted to secure the very best results in repeating voice currents only, as without the large core the coil will not repeat ringing currents, and with the large core it chokes or muffles the voice currents, which have a high rate of change, about 90,000 times a minute, and are of exceedingly small quantity, the large iron core being too slow to respond magnetically to such rapid changes.

Open or closed magnetic circuit through shell.—In "Ring-through" coils, the outside shell is connected to the ends of the core, so that a complete magnetic circuit is formed. This adds to the amount of iron subject to the influence of the windings, and the shell also prevents leakage from one coil to another when they are mounted side by side, thus making cross-talk impossible.

In the "Talk-through" type the presence of so much iron is undesirable. The core should therefore be separated from the shell, which should nevertheless be retained to prevent leakage likely to produce cross-talk.

Windings.—The windings of a repeating coil are determined by the conditions under which it is to be used. For instance, if the coil is to be used for common battery work, the wire must be large enough to carry the current without heating. The ohmic resistance is of comparatively little importance, as it follows that if a sufficient number of *turns* are put on the coil to properly affect the core, and the wire is of the proper size, the ohmic resistance alone is not a factor, except where the coil is to be bridged on a line, in which case the resistance is made sufficient to prevent any short circuiting effect the coil would have on the telephone bells on the line.

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As voice currents are of minute quantity, wire of very small diameter can be used in coils designed to repeat voice currents only.

The coil to be described in this article belongs to the "Talk-through" class, and, owing to its small size and high efficiency, is particularly recommended for use in the cord circuits of a switchboard. The exact dimensions as given need not be adhered to, in fact, an old induction coil spool and the wire from a discarded ringer or generator, will, if properly assembled, make an excellent coil.

Constructing a coil.—To make the spool, take two pieces of wood about ¼" thick, and of the proper size to fit inside a piece of iron pipe about 2" inside diameter. Bore a hole in the centre of these large enough to slip on a tube made by rolling two or three layers of thin paper on a lead pencil. After making this tube, the separate layers in which should be glued together so that the tube will be quite stiff, glue the heads on the tube with 1 1-16" space between heads. These different parts are shown in Fig. 196.

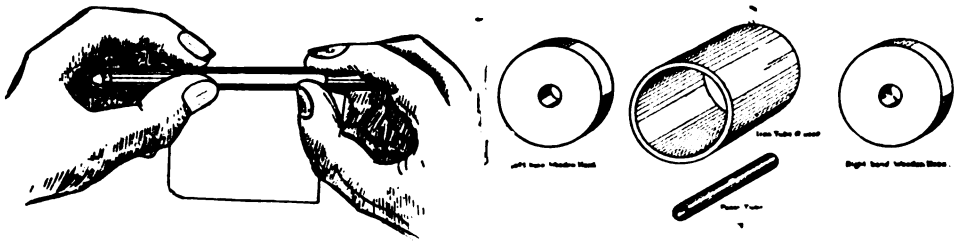


Fig 196.

One head should be drilled for terminals, which can be made from brads or pieces of copper wire, and holes should be made for the wires. Lay this out as shown by Fig. 197. Countersink the wire holes on the back, as shown in the cross section.

Get a stick which will fit into the hole in paper tube. Split one end of this, and fasten the core on the stick. When in place, drive a wedge in the split end of the stick, and the coil will be held firmly. The clear end of the stick can be put in a lathe held in the hand.

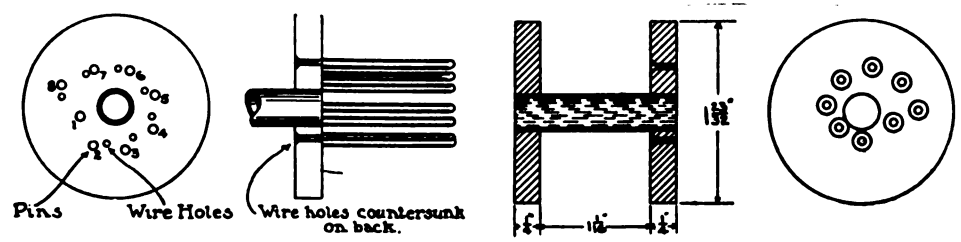


Fig. 197.

The operation of winding the wire on the spool is shown in Fig. 198. No. 32 silk covered wire is used. This is the size usually used on 5 bar generator armatures. The exact size is of little consequence, however. The winding begins at terminal No. 1. Run on 1,400 turns, and bring the end

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out at No. 2. Then cover with two turns of writing paper. The layers should be smooth and firm. The next winding begins at No. 3 and terminates at No. 4.

Continue until four windings are put on, each winding consisting of 1,400 turns of wire, with the two layers of paper between each winding. A good way to count the turns is to count the turns on one layer, then put on the proper number of layers. The wires should be wound on evenly in layers, and should be free from kinks or splices, unless the splices are soldered and well wrapped.

When the coil is completed, the outside layer of wire should be covered with a couple of layers of paper, and the center tube should be filled with as many fine iron wires as it is possible to put into it. The fine wires from an old induction coil core will answer. Next an ordinary tin can of sufficient size to contain the complete coil should be taken. The bottom should be drilled with holes large enough to allow the coil terminals to project without touching the tin.

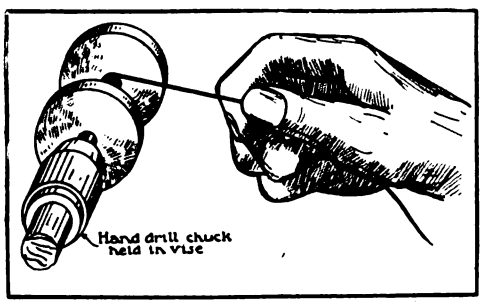


Fig. 198.

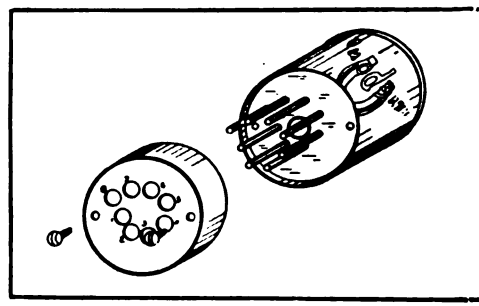


Fig. 199.

A piece of paper should be pasted over each end of the core, so that it will not touch the tin can, and the coil should be placed inside the can and fastened by two screws, as shown in Fig. 199. Then, if it is desired to protect the coil from dampness, the can should be filled with melted parafine or beeswax, and the lid soldered on.

Coils mounted in this fashion can be placed side by side in the switchboard without danger of cross-talk. When only one coil is to be made, the shell can be omitted entirely.

By turning up two iron heads with shoulders to fit inside the iron tube and using two brass bolts to hold heads on tubes, and hold the coil firmly in place, a very satisfactory and convenient means of mounting the coils is provided. This feature is not found in most ready-made coils, which are usually riveted together in such a manner that it is necessary to almost destroy the shell to get them apart.

The next thing is to connect the coil in the cord circuit of the switchboard, so that it can be used to connect any two lines.

Fig. 200 shows a circuit which can be applied to any switchboard without changing the existing equipment to any great extent.

Connect the terminals of one cord directly to terminals 1 and 8 of the coil. If the switchboard is equipped to ring with one plug only, connect the cord you do *not* ring with as above. Also connect the clearing out drop to terminals 1 and 8. Terminals 2 and 7 of the coil are connected to a ½ M. F. condenser, which will prevent the passage of ringing

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currents through the coil, thereby securing the operation of the clearing out drop. Terminals 4 and 5 should be connected together. Terminals 3 and 6 should be connected to the terminals in the switchboard from which the cord connected to 1 and 8 on the coil were taken.

It will be noticed that the clearing out drop will not fall when one of the parties connected rings off. When the party connected by means of the cord wired to terminals 1 and 8 of the coil rings off, the drop will fall, as the condenser opens the repeating coil circuit so far as ringing current is concerned, while it offers no opposition to the passage of voice currents. The condenser can be omitted when it is not necessary to secure the clearing out signal.

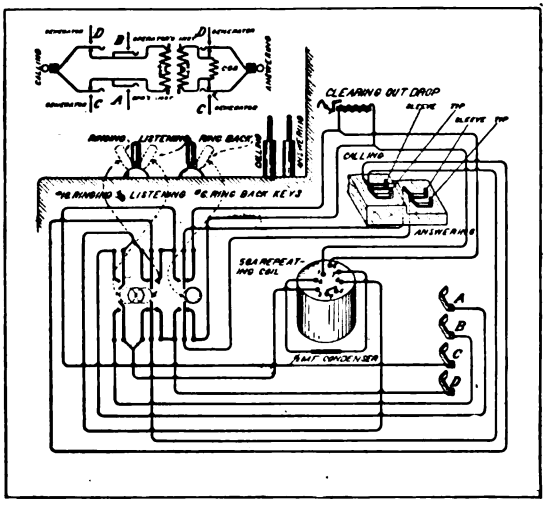


Fig. 200.

The resistances of the windings of the coil here described are about as follows. Of course a difference in the size wire, method of winding, etc., will make some change.

1st	winding, or one next to core	40 ohms
2nd	"	60 "
3rd	"	75 "
4th	"	95 "

As the 1st and 4th windings are in series when connected, their resistance is about 135 ohms.

The 2nd and 3rd windings are also in series, so that they measure 135 ohms.

Each half of the coil consists of 2,800 turns, so that transmission is equally good both ways.

Placing the coil in the cord circuit will not interfere with using the cord for regular service, as it would require an expert to determine the difference between a cord circuit equipped with a coil of this type, and one without it.

A very good "Ring-through" can be made on the same principle as the "talk-through" coil just described, by taking a solid core of *soft* iron 3 1-16 in. long, drilled and tapped in each end for an 8 × 32 screw.

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Get three fibre heads 3-32 in. thick, 1 23-32 in. diameter; place one directly in the centre of the core, and one on each end. This will give two winding spaces, each 1 10-32 in.

Insulate the core with paper, and wind in each space, 21 layers of No. 32 single silk wire, putting a piece of paper between every fourth layer. This must be evenly wound.

When complete, insulate with 2 layers of paper, and wind over this, in each space 24 layers of No. 32 single silk-covered wire.

Connect outside end O of inside winding No. 1, to inside end I_2 of outside winding No. 2. Terminal I of inside winding No. 1, and O_2 of outside winding No. 2, form the terminal of one side of the coil.

Connect outside terminal O^1 of inside winding No. 2, to terminal I^1 of outside winding No. 1. The remaining terminals form the other side of the coil. Each side of the coil is of about 200 ohms resistance.

The Tube to cover coil consists of a piece of iron pipe of proper size, 3 1-16 in. long. The heads are two iron caps or large washers which are held in place by the 8 × 32 machine screws going into the core. Care should be taken to have the heads fit tightly against the core and casing.

The wires should be brought through bushings in the iron heads, 2 on each end, and the coil is mounted on a wooden base by cutting a tin strap to fit around pipe and fastening same securely so that the coil is held firmly in place.

Care must be taken to have all the windings in the same direction and the layers must be smooth.

This coil gives very good results wherever a ring-through coil can be used and will be found comparatively simple to construct; a diagram of the connections and dimensions is given in Fig. 201.

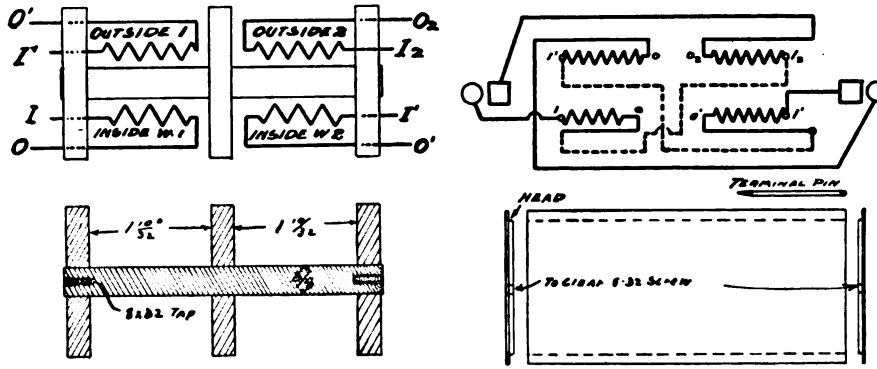


Fig. 201

Another type of ring-through coil is shown in Fig. 201a, which gives dimensions of the bobbins. Each bobbin contains about 2500 turns of No. 30 single cotton covered wire. The core is made from a bundle of soft iron wire No. 24 gauge preferred. The core wires are bent around as shown, until they lap, and are bound together with a piece of wire as shown.

This coil may be placed directly in the line circuit as shown in Fig. 202, the drop circuit being of the usual type where the drop is cut off by

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the insertion of the plug. It is better to place the coil in a cord circuit as otherwise it is necessary to talk through two coils, should two lines so equipped be connected together. Where the coil is put in a cord circuit, this cord can be used to connect any two lines. A cord circuit stripped of all details except the coil is shown in Fig. 202a. No condenser is needed with this coil.

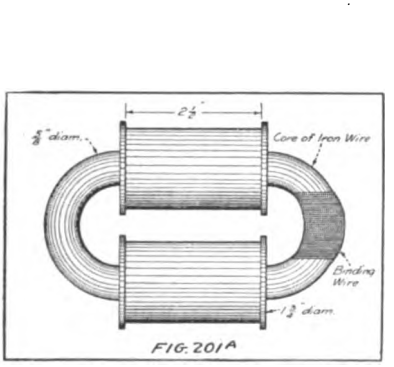
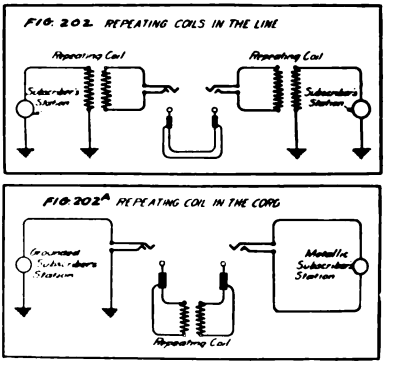


FIG. 201A



If a grounded line is noisy and is connected to a quiet metallic line it will make it noisy also. If the coil is used the quiet line will remain quiet. If both lines are noisy the coil will not reduce the noise.

To insert a "ring-through" coil in a cord circuit, disconnect the terminals of the answering plug from the switchboard, and connect them directly to one of the windings of the repeating coil. The other winding of the repeating coil is connected with the terminals on the cord shelf from which the cord was taken. The resultant circuit is shown in Fig. 203.

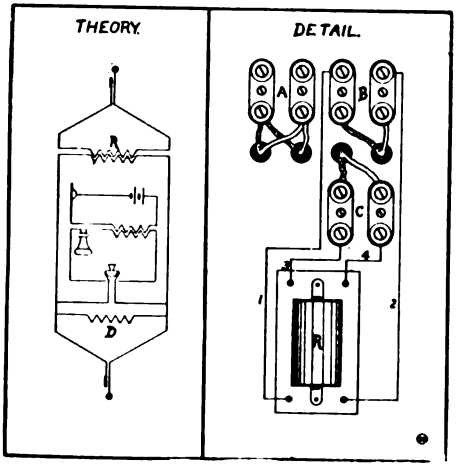


Fig. 203.

Here it will be seen that the currents coming in on one plug, will circulate through one winding of the cord "R". The other cord is entirely separated from the in-coming circuit. This keeps each one of the

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plugs in an entirely separate circuit of its own, the only connection being the inductive action between the two windings of the coils.

The "Ring-through" coils for the reasons previously described, do not possess the greatest efficiency for talking purposes only, and it is better practice to use the smaller "talk-through" coils for switchboard use.

Sometimes it is desirable to have a cord circuit of the usual variety so arranged that by throwing a key, the repeating coil can be cut in. This is accomplished by either putting in another key or equipping the ring-back key with an additional set of springs, so that when the key is thrown, it will remain locked in that position. This circuit is shown in Fig. 204, which differs in no way from the cord circuit previously described except when the key is *not* thrown, the cord circuit is regular in all respects and when the key is thrown, the repeating coil is cut in.

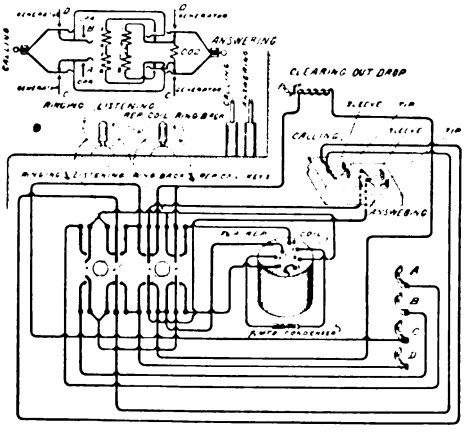


Fig. 204.

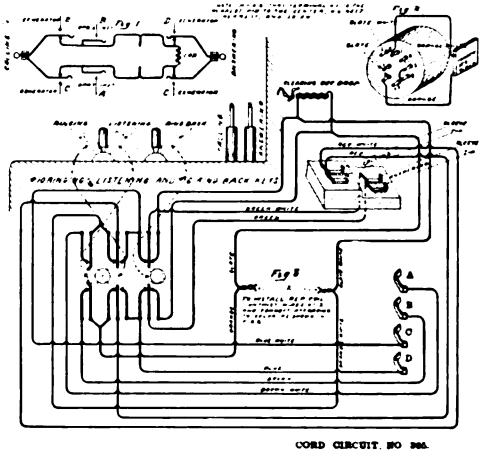


Fig. 205.

Cord circuits equipped with repeating coils are seldom subject to any troubles except those met with in ordinary cord circuits. In addition, it will be found sometimes that the ½ M. F. condenser is short circuited. When this is the case, it is impossible to throw the clear-out drop. To test for this, disconnect one of the wires from the condenser. If the clear-out drop will then operate, the trouble is in the condenser. If the clear-out drop still refuses to operate the trouble is probably in the clear-out drop. If the transmission is bad, the repeating coil may be short-circuited. This trouble can only be located by measuring the resistance of the various windings.

In all exchanges where there are some metallic and some grounded lines, it is better to equip one or more cord circuits, with a repeating coil, and this will be found of material advantage when using 4-party Selective Ringing with Biased bells, as the cord circuits equipped with the repeating coil will prevent the 4-party bell from ringing when the subscriber connected to the other side of the cord circuit rings off.

The majority of manufacturers will wire the cord circuits on switchboard for repeating coils, then if it is found necessary, the coils may be installed later. This is shown in Fig. 205.

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By connecting the colored wires to the coil in accordance with the small diagram in the upper right hand corner, the repeating coil may be installed at any time. The circuit with coil in place is shown in Fig. 200.

The general care of the switchboard is a point which should be carefully considered, and to which very little attention is paid.

Every day or two, the inside of the board should be blown out. Nothing is better for this purpose than a bellows, as this will blow dust out of inaccessible corners without damaging the wires. The rack to which the cords are connected inside the switchboard should be kept free from dust or cross talk will result. The plugs should be regularly inspected and kept clean and bright. Occasionally the plugs can be rubbed with a little dry pumice stone on a cloth. Don't use anything that will tend to wear the plug or insulation between the tip and sleeve. The operator's transmitter mouthpiece should be kept clean. For sanitary reasons if for no other the mouthpiece should be changed occasionally. It is well to provide each operator with a separate mouthpiece which they can use while on duty at the switchboard.



Fig. 206.

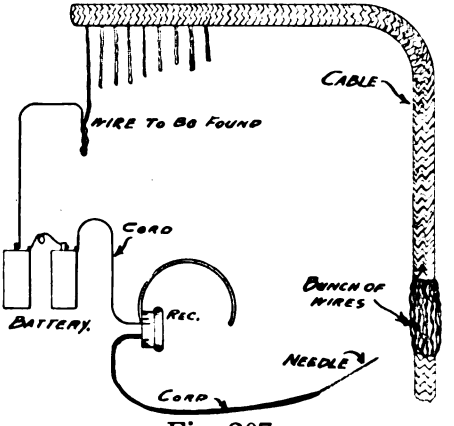


Fig. 207.

The operator should be carefully instructed about putting the plugs into the jacks. Do not allow them to drive the plugs in by striking the butt of the cord with the palm of the hand, as nothing will destroy the cords quicker. The plugs should be placed in the jacks by grasping them by the sleeve, and they should be withdrawn in the same manner. They should not be allowed to fall on the key-table, but should be returned to their sockets by hand. See if the cords are placed in the Switchboard properly, so that they will not cross up and so that the weights will return them to their proper position. If the cords are too long, loop them up as shown in Fig. 206.

The batteries for the night bell and operator should never be located in the bottom of the Switchboard, but should be placed in a closet where they will not be exposed to heat, or some other suitable place where they will not be disturbed.

The selection of proper tools is a matter that should not be overlooked. Some solder and appliances for heating same should be at hand. Resin core solder should be used. This is solder made in the form of heavy wire with a hollow center filled with resin. In using this solder it

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is simply necessary to apply some to the joint, and the use of acid or soldering paste is unnecessary. These substances should be avoided around Switchboards as they will cause corrosion and trouble.

The Switchboard man should provide himself with a long slender screw-driver, a pair of needle point plyers, and a pair of diagonal cutting plyers. These, in addition to a head telephone with a six foot cord to which is attached a pair of "Frankel" tips, constitute the necessary tools for making repairs.

When soldering a wire be sure and have the iron well tinned and hot, applying the solder quickly and not using too much. If the wire is being soldered to a jack spring, a piece of paper should be laid underneath where the soldering is done so that small particles of solder will not fall on other wires below. In soldering, insert the wire in the notch in the jack spring. Don't heat the wire too much, or insulation will unravel, leaving a bare place ½ in. or more, which besides being unsightly, is liable to cause a short circuit. After soldering, the wires should be laced in shape with a button hook, then shellacked in place, using shellac dissolved in pure grain alcohol. Don't use wood alcohol. Have the shellac thin.

In hunting for trouble in a bunch of wires a device like that shown in Fig. 207 will save time.

A battery should be connected to the end of the wire it is desired to find. The other side of the battery is connected to one side of the head receiver, while the other side of the receiver is connected to a long needle, which can be pushed through the insulation on each wire. When the proper wire is located a loud click will be heard in the receiver. This is a much better method than cutting into the wire to locate the trouble.

Upon examining the Switchboard when it is received from the factory it will be found that the wires in the key and line cables are in twisted pairs, each twisted pair forming a metallic circuit. Nothing but twisted pairs should be used, for if the key or line cable is formed of separate strait wires, a great deal of cross talk will result.

If one cord circuit is carefully tested out and the color and lay out of the wires noted, and a sketch made for reference, a great deal of time will be saved, as all the cord circuits in the same board are wired alike.

The usual troubles the Switchboard man has to contend with are broken cords, burnt out line drops, and occasionally, but rarely, defective jack or key contacts. It may be said that 90 per cent. of the complaints against Switchboards may be traced to broken cords, poor operator's batteries, or loose connections between the cable from the Switchboard wires to the terminals in the arrester frame.

The use of soldered connections throughout the Switchboard is undoubtedly ideal from a theoretical standpoint, but in actual practice their use has not been found satisfactory except in large Switchboards which are under the care of experts.

With all due respect it may be said that the average attendant in the average small exchange, does not use a soldering iron with a sufficient degree of proficiency to properly make and unmake soldered connections, therefore the use of machine screw terminals where wires connect to various portions of the equipment, is rapidly coming into use.

After an experience of several years with this construction, the writer would say that same is entirely satisfactory. This is especially true in connection with line drop equipment where it is necessary to remove

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drops frequently for repairs to coils. To make and unmake soldered connections where the coil is joined to the Switchboard cable, is not only a loss of time, but is troublesome, as the wires get shorter and the insulation burns away every time the coil is removed and inserted. With machine screw connections, or with the form of construction where the drop coil is removed without disturbing any connections, this trouble is not present.

As to screw connections being inferior to soldered connections, it may be said that nobody has ever attempted to solder wires fast to a telephone, and very little if any trouble occurs from loose connections on the top of telephone instruments, and in this case, the connections are exposed to rough treatment from all kinds of people. In addition to this, where heat coils are used, four contacts are inserted directly in the lines, and these rely upon springs for good contact, yet very little trouble results. Owing to the ease of making and unmaking screw connections it is advisable to get equipment where this feature is present as much as possible, if the equipment is to be handled by men of little experience.

The selection of a switchboard should be very carefully considered, especially as regards size, and the type of equipment peculiarly suited to the particular class of service to be given.

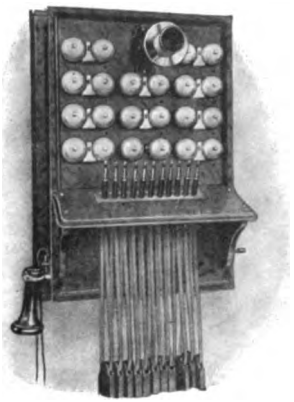


Fig. 208.

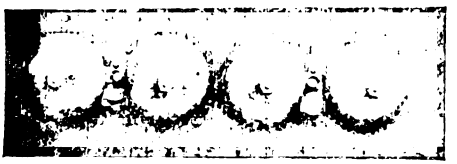


Fig. 208a.

The first point to be considered is the probable future growth or ultimate size of the exchange. If the contemplated exchange has 40 subscribers, it is the height of foolishness to buy a 50 line board, for with 40 subscribers as the initial number, the community will no doubt require one or two hundred 'phones in the near future, after the exchange is installed.

The majority of manufacturers now furnish Switchboard equipment so designed that a cabinet can be secured with room for any number of lines, the future growth of the exchange being taken care of by adding the additional equipment for the lines from time to time as needed. It is not necessary to secure a large amount of equipment in the beginning, this to remain idle for some time, but the equipment need only be secured as required.

Perhaps the simplest form of switchboard devised for small exchanges is the Ringerboard, the type furnished by The Sumter Tel. Mfg. Co., being shown in Fig. 208. Here each line is equipped with a

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ringer and jack, the ringer being of the same resistance as those used in the telephones on the lines. This board is usually used for rural line service. Each bell clapper is equipped with a shutter or indicator which falls when the bell rings, and thus indicates which line is calling. The Western Electric Co.'s arrangement is shown in Fig. 208a and is representative of the majority of these devices.

A plug and cord is connected in multiple with each ringer so that it is only necessary to use one plug to connect two lines, this being done by putting the plug of the calling line into the jack of the line called. When two lines are thus connected together, the bell connected to the calling line is left bridged across the circuit and acts as a clearing out signal.

The ringing and talking is done by the operator with an operator's plug, thus eliminating any ringing and listening keys, push buttons or other devices, which in a board of this size would tend to make the equipment complicated.

It will be observed that as each line is connected to a separate bell, by Central having a certain signal, the operator need only answer when the proper signal is rung.

The operation of this board is as follows:

Suppose No. 2 line wants No. 6. A phone on No. 2 line rings, which causes bell No. 2 on Switchboard to ring, at the same time the indicator falls, upon seeing which the operator inserts the operator's plug in jack connected to No. 2 line. Upon ascertaining that No. 2 wants No. 6, the operator pulls operator's plug out of No. 2 jack and puts it in No. 6 jack and rings, and upon getting the party wanted on No. 6 line, the operator picks up the No. 2 plug and puts it in jack No. 6. This leaves the No. 2 bell connected across the line which acts as a clearing out signal. If necessary the operator can listen in on the conversation by plugging into the jack of No. 2 line, in which case the No. 2 bell is disconnected from the line and the bell in the operator's set is connected instead. These boards are sometimes equipped with regular cord circuits and keys.

The line circuits of this and all other modern boards, are wired full metallic, and can therefore be used on grounded circuits by connecting all the wires going to the sleeve or long springs of the jacks together and running them to the ground. Each twisted pair in the cable is connected to one of the bells and jacks in the switchboard and usually the sleeve wires are covered with solid white, blue or red insulation.

Fig. 209 shows method of connecting the switchboard to various classes of lines, 'phone C being a metallic line, and Phone B a Bridging line. Phone B also shows the connection for the last 'phone on a Series circuit. Phone A is the middle 'phone on a series line.

When connecting switchboards particular care should be taken to secure a good ground connection for the Switchboard if grounded lines are used, or for the lightning arrester if arresters are used with the board.

The operator's circuit of this type of switchboard is shown in Fig. 210. When the use of the board is intermittent, the two coils of dry battery may be used for the operator's transmitter, but in cases where the board is constantly in use, bluestone or "gravity" batteries should be used.

The adjustment of the bells in this type of board is practically the same as adjusting the bells in an ordinary telephone. Care should be

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taken never to bend the clapper rod as this interferes with the proper action of the shutters.

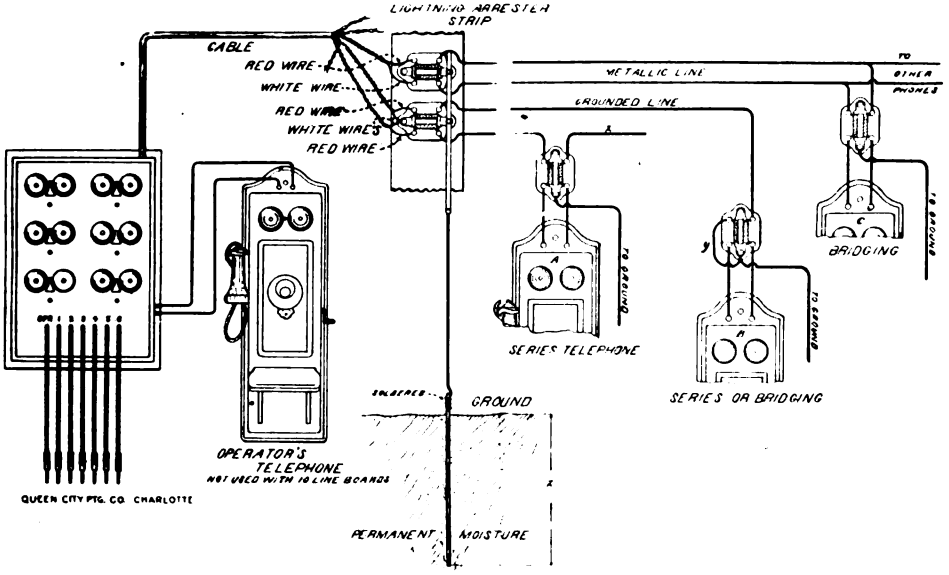


Fig. 209.

A large number of these boards are in use, especially in small exchanges, and the reason for the adoption of this type of board was primarily due to the fact that a switchboard using ordinary drops does

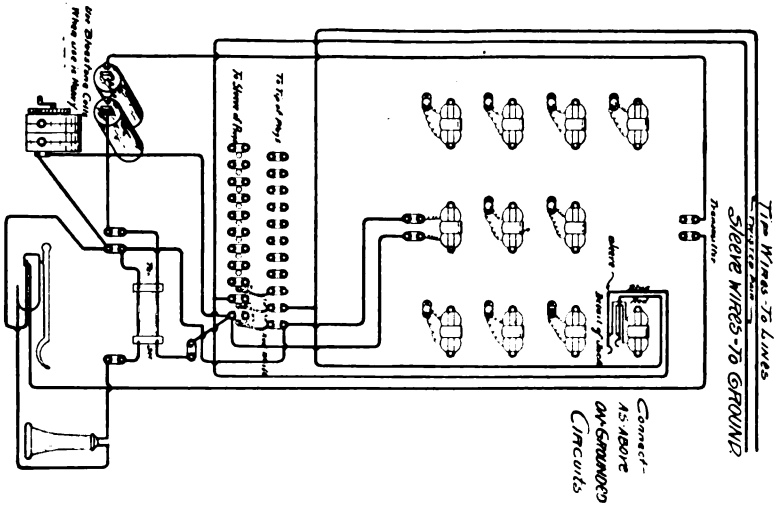


Fig. 210.

not give satisfactory service on Bridging lines where there are a number of telephones on each line, owing to the fact that when the telephones call each other, the drop in the switchboard falls and the operator not

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being able to hear the number of rings, does not know whether Central is wanted or not, and is obliged to answer the call to find this out. There has recently been developed several devices to do away with this trouble, and these devices can be applied to Switchboards using standard drops. Therefore, the ringerboard is now seldom if ever used, it's place having been taken by small boards of standard construction using "signal ringing" or "Relay" drops.

These drops are the same as regular equipment but each time a signal is projected over the line, the contact A shown in Fig. 211 which shows the drop furnished by the Dean Elect. Co., will close a common bell circuit and give a signal that can be heard throughout the exchange. This ringing of the signal bell follows the number and length of rings received over the lines, thus indicating to the operator whether the call is for the exchange or whether one subscriber is calling another on the same line. The shutter of the drop falls at the same time the signal is received, so that when there are a number of these signal relay drops in a switchboard the exact line calling will be indicated. To insure positive operation, the contacts are platinum pointed.

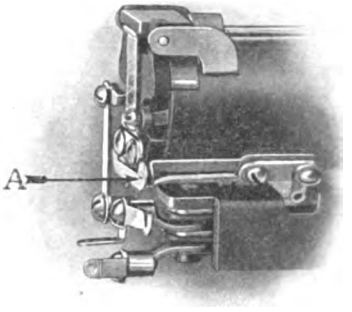


Fig. 211.

Another type of this special drop is represented by the Unitype Signal ringing drop made by The Sumter Tel. Mfg. Co., and shown in Fig. 212 at A. The armature F operates the springs SS so that the contact is closed every time the armature is drawn toward the drop coil H. The springs SS are long and flexible and very easily operated, and therefore faithfully follow the movements of the armature, thus accurately repeating the long and short rings projected over the line.

The Shutter E is released at the first impulse, so that the operator knows which line is calling, as previously described.

In all forms of signal ringing drops the regular night bell contacts are omitted.

The bell circuit used in connection with these drops is shown at B Fig. 212. It is the same as a regular night bell circuit. Sometimes a relay is inserted in the circuit as shown at C, especially if a large bell is desired.

A battery bell having reliable contacts must be used, and so adjusted that it will respond quickly when the drop contacts are closed. This can

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be accomplished by giving the bell a rather close adjustment so that the armature has no tendency to "tremble".

The drop contacts are adjusted so that they close *before* the armature is drawn as near the drop core as it will go. This allows the armature to "rattle" slightly without opening the signal contact and causing a false ring.

These drops can be used in connection with the regular night bell circuit of any switchboard, or a separate bell can be used. The arrangement used in Unitype boards is shown in Fig. 213.

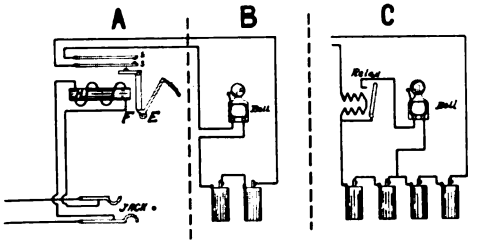


Fig. 212.

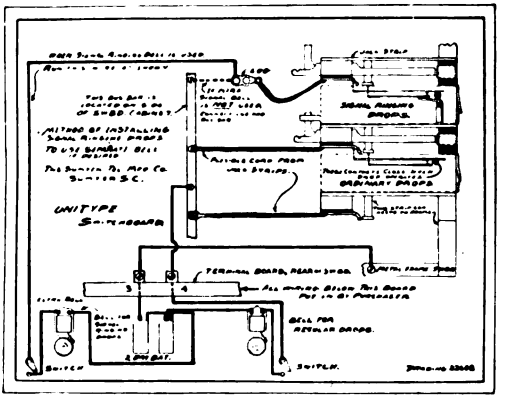


Fig. 213.

The development of the signal ringing drop which can be used in regular switchboards, eliminated the type of board using ringers, and many types of small drop boards of a few lines capacity for small exchanges were developed. Typical of these is the Sumter board shown in Fig. 214.

This board is equipped with an operator's plug, and in operation is practically the same as the ringerboard previously described except that after ascertaining the number wanted, the operator connects the called and calling party by means of a pair of cords in the usual manner, these cords being associated with a bridging clear out drop which falls when these parties ring off. To provide means for the operator listening in, a listening jack is bridged on the cord circuit. To listen, the operator plugs in this jack with the operator's plug.

Fig. 215 shows the internal wiring of a switchboard of this description. The circuits of the operator's set as will be observed, are practically the circuits of a bridging telephone, therefore when the operator's plug is inserted in any line jack it is simply equivalent to connecting a bridging phone to that line.

The circuit of the connecting cords is very simple, the tip and sleeve of one plug being joined to the tip and sleeve of the other. A clear out drop of a high impedance and of about 500 ohms resistance is bridged across the cord thus enabling the ring-off signal to be secured.

The drop circuit is the same as that used in all magneto boards. Plugging into the line drop cuts off the drop in the usual manner.

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In Fig. 216 is shown the method of connecting one of these boards when a lightning arrester of the choke coil or multi-discharge variety is used. The upper line in the figure shows connections for metallic lines.



Fig. 214.

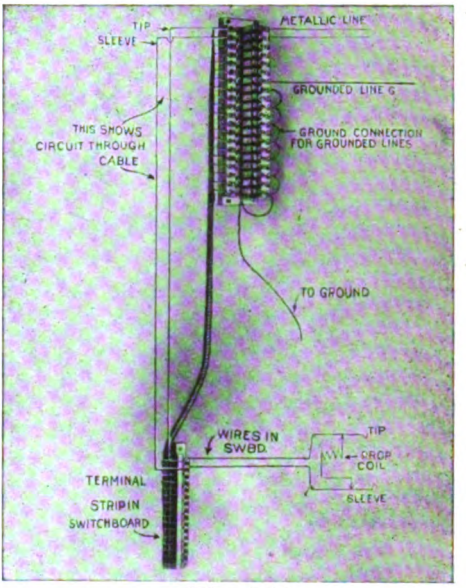


Fig. 216

The lower line shows a grounded line. The wire X from the sleeve terminal being connected to the common ground wire.

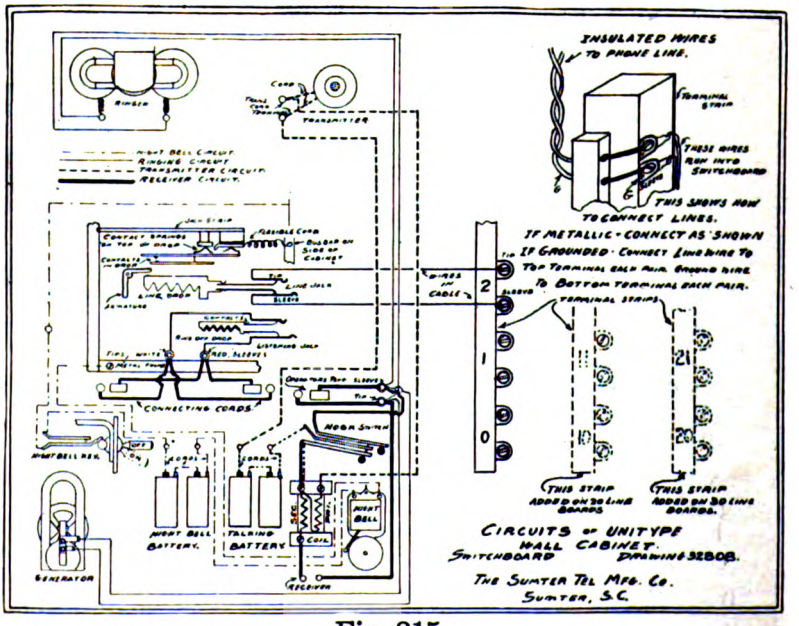


Fig. 215.

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It is well to mention that the approved method of connecting up switchboards is to have the exchange "full metallic" to the cable box located on first pole outside of exchange, and that when grounded circuits are used, the wires are made common or grounded at the terminals in the cable box.

While one of these small boards may be used with ordinary drops, it is much better in all cases where party lines are used, to use the "Signal Ringing" or "Relay Ringing" drops, which may be used with either grounded or metallic lines.

If the exchange exceeds 20 lines capacity, the wall type cabinet is not feasible, as the switchboard rapidly increases in weight. After several years of evolution, the accepted type of regular exchange equipment is that shown in Fig. 217. The arrangements of the various parts which have been described such as cord circuits, keys, drops, etc., is clearly shown in Fig. 218 which shows a Dean board which is typical of the latest and best practice.

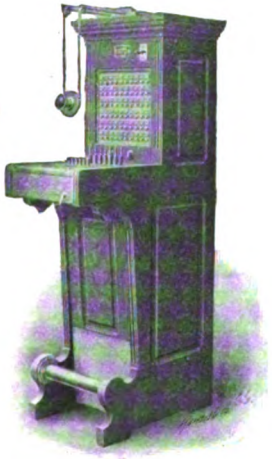


Fig. 217.

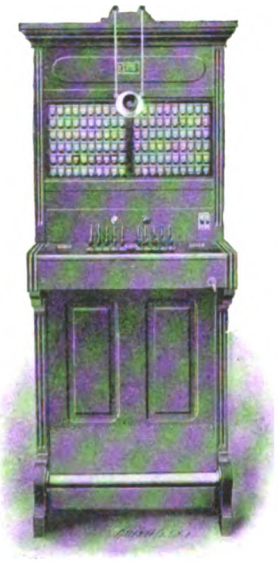


Fig. 219.

One particularly good feature of this style cabinet is that boards of 50, 100, 200 and 300 lines capacity all have the same end dimensions so that two or more boards may be set side by side to form one continuous board. In this manner when using 100 line sections it is feasible to operate 300 or even 400 lines, by purchasing 100 line sections as needed, without the use of transfer apparatus. A 100 line section of this description is shown in Fig. 219.

In some rural communities or where the majority of telephones are in residences and the traffic not heavy, one operator may handle 200 lines, then the cabinet shown in Fig. 220 is practicable.

It should be remembered that the ability of the operator to answer calls is limited, and nothing is gained by placing more apparatus in front of the operator than can be attended to.

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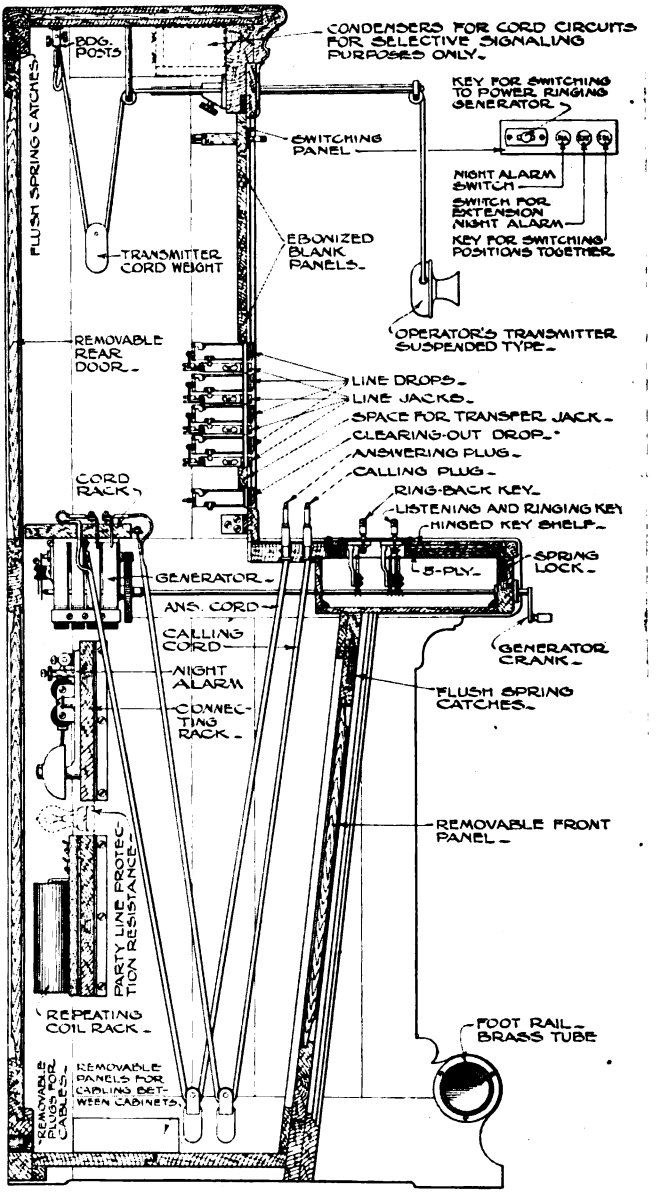


Fig. 218.

When the amount of business to be handled cannot be definitely decided, it is better to install a cabinet with two operators' positions like that shown in Fig. 221.

For toll stations and where tickets are to be made out, etc., a desk type cabinet as shown in Fig. 222 is preferable. This can be secured

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for one or two operator's positions, with pigeon holes on each side of the drop space so that toll tickets, etc. can be filed.

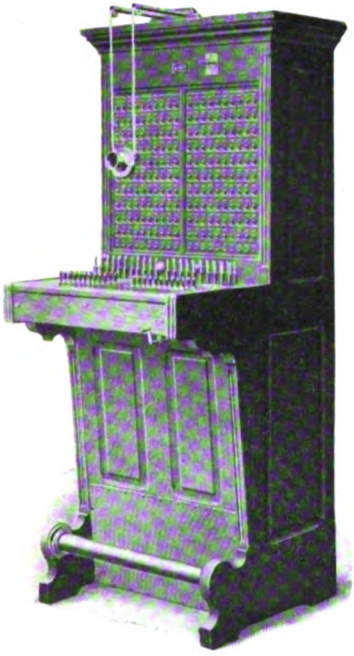


Fig. 220.

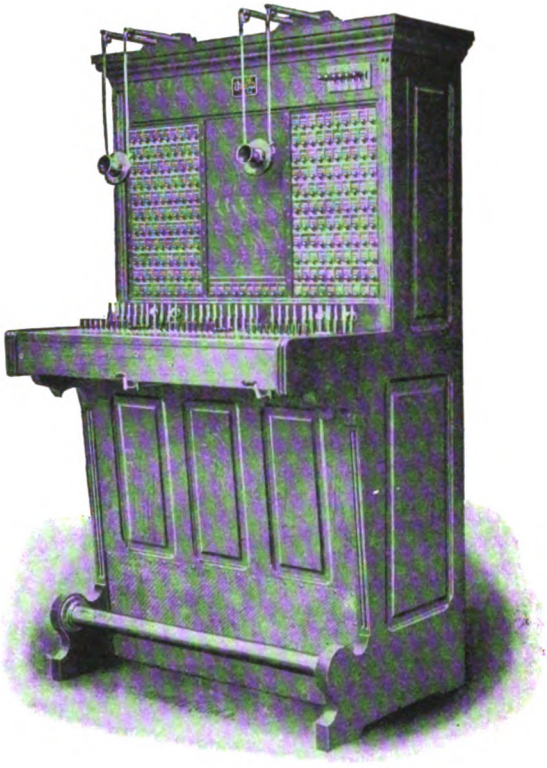


Fig. 221

Drawers are also provided where record books can be kept, which makes this cabinet more convenient than the regular type for such special uses as mentioned above.



Fig. 222.

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A great deal of discussion has arisen as to which is the better system to adopt, Magneto or Common Battery. Both systems have their own advantages. The concensus of opinion of men with years of experience is that the magneto sytem is more practicable for the average exchange not exceeding 500 lines. The principal reason for this decision is that common battery equipment costs more to install, especially the storage battery equipment and apparatus for charging same. The common battery must have experienced men in charge.

The outside construction must be of the highest quality, and in places where the lines run through trees as is necessary in small exchanges, where cable is not used, the foliage must be carefully trimmed or insulated wire must be used for the lines.

The common battery system is impracticable for heavily loaded party lines, and a great deal of the business of the average small exchange consists of lines of this character.

If a magneto line is partially short circuited by the wet limb of a tree, or falls down in the road and is partially grounded, it is still able to work and give some sort of service; but if a common battery line is crossed, the signal in the office is immediately displayed, and remains displayed till the cross is removed, which renders service in the meantime impossible.

The manufacture of magneto telephones has reached such a degree of perfection that the maintenance of the generator—which is the only additional part in magneto telephones as compared with common battery instruments—is practically nothing, so that the only saving in maintenance costs between magneto and common battery instruments is the batteries used at the subscribers' stations.

Now in large exchanges the cost of battery maintenance would be very heavy. For instance: in a city like New York, it would be practically impossible to give telephone service if the batteries in the telephones had to be constantly renewed, which would be the case if they were magneto instruments. But in an exchange of less than 500 subscribers, the cost of battery renewals with the magneto system would not be such an item, when the first cost and maintenance of the common battery is considered, especially when the batteries on country lines are taken into consideration as these would be used with either system as common battery is impractical for long and heavily loaded lines.

The exact size of the system that it is most economical to operate as a magneto or common battery exchange, depends somewhat on local conditions, but generally the magneto system will be found more satisfactory for small exchanges, while for exchanges exceeding 500 lines the common battery will be found more economical in cost and maintenance, and superior in point of service.

One point in connection with this discussion which it is well to keep in mind is that the common battery system does not possess any great advantage over the magneto in point of operating speed, as that point depends upon the proficiency of the operator far more than upon the equipment placed in front of her; this, of course, applies to small systems of one or two operators only. In the magneto system, the subscriber is obliged to turn the crank of the generator when calling Central, whereas, in the common battery system, the subscriber simply removes the receiver from the hook, and in either case the subscriber is *obliged to wait until*

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the operator answers. If the operator is properly trained—with either system, she will plug into the line jack almost before the subscriber has his receiver to his ear.

The great advantage in point of operation that the common battery system has over the magneto, is that the *disconnect* signal is given automatically by simply placing the receiver on the hook. With the magneto system it is necessary to "ring off" by giving the crank a turn, which many people forget to do, and this makes it necessary for the operator to listen and ask if they are through which is a drag to the service, but in small exchanges this is not a fault which seriously interferes with the service.

From time to time various freak magneto telephones have made their appearance, in which Central was signalled by removing the receiver, and the clearing out signal was given when the receiver was replaced. A description of these instruments was given recently in "The American Telephone Journal", from which the following extract is taken:

"About every so often some enthusiastic Independent conceives the idea of revolutionizing telephony so far as the magneto part of it is concerned and devises some new style of "kick coil instrument". By this term is meant one by which the operator on a magneto drop board may be signaled without the use of a generator at the subscriber's station. Because it is just about "every so often" the exchange manager persuades himself, or some salesman does it for him that this time the proposition has really been solved, and into a number of these instruments goes his "hard earned", he to discover only too soon that it is a case of "Stung again, by Heck". Not only does the operator get stung, but so also does the manufacturer, who, experiencing an initial rush on the instrument, loads up on special tools and material, the mention of which at a latter date is amply sufficient to instill a hearty dislike for the one who had the unmitigated audacity to suggest such a thing in the first place.

"The different concoctions of this sort are legion, but as a cold-blooded business proposition do not trust them any further than you can fling Taurus by the tail. On account of the multiplicity of these, I will not deal with them all but simply take as an example one of the most recent, supposing that because it is one of the latest it represents the highest stage to which the idea is advanced.

"The idea featured in this is the common one, that is to use the talking battery as a means for actuating the switchboard drop. But as the talking battery has not sufficient voltage in itself to force enough current through the line resistance to cause an actuation of the drop, it was found necessary to supply some means for transforming the existing conditions as to allow of the desired result being obtained.

"For this purpose a specially constructed coil is placed in the instrument. This coil is in reality a "step up" transformer, that is it increases the voltage and incidentally decreases the amperage. As the voltage of a transformer is in direct relation to the ratio of the number of turns in its primary to the number in its secondary, it was deemed necessary to make the primary of as low resistance and few turns as possible and the secondary just the reverse. So this coil was made with a primary of No. 18 copper wire of one-half ohm resistance and the secondary of No. 24 copper wire of one thousand Ohms resistance.

"The object was to include the primary side of this coil in the battery circuit for a short period on the upward movement of the receiver

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hook, depending upon the impulse of high voltage from the secondary to cause the switchboard drop to actuate. Fig. 223, shows the diagram of the circuit of an instrument so arranged.

"Greed for force brought in the first obstacle. The one-half ohm of the primary is not much of a hindrance to the flow of current and naturally the draw is just about equal to that of a first class short circuit. Of course, the contact is only momentary, but it does not take more than a dozen calls to raise Hob with the strength of dry cells, which we all agree is needed for talking purposes.

"Next came the discovery that when two kick coil instruments are connected through the switchboard and the resistance of the clearing out drop is the same or less than of the ringers on the instruments, the called subscriber upon answering will actuate the clearing out drop, thus advising the operator that the conversation is terminated before it has commenced. If she be one of the genus diligent, the operator will immediately sever the connection, thus advertising the good service afforded by the company and materially assisting the subscriber and enlarging his profanic vocabulary.

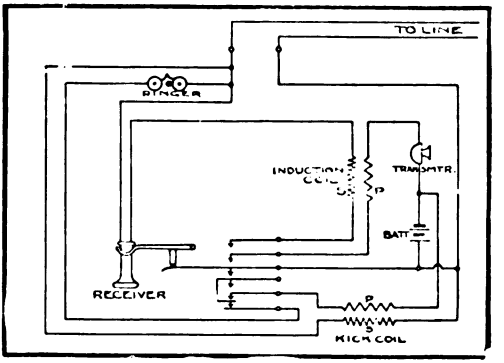


Fig. 223.

"From an economic stand-point it is advantageous in a magneto system to place series instruments on the single subscriber lines in town, but on longer and more heavily loaded lines to use a bridging instrument of higher resistance than the series ringers.

"Imagine now, dear reader, the delight you would manifest when upon finishing a conversation with one of your local friends, the proud possessor of a series instrument, you attempt to gain the attention of the operator for a hurry call somewhere else, and although you right manfully jiggle the hook, never a peep makes she, for she has been admonished against the evils of working the listening key and to always wait for the clearing out signal. However, you do get your former friend back again and again because his bell doth jingle right merrily owing to the fact that the old truth holds good, and electricity takes the path of least resistance, which in this case is through his 80 Ohm bell rather than the clearing out drop in the central office.

"And last, but not least, send your trouble man around to one of these instruments and when he unwittingly gets a screw driver or a pair of pliers across the right springs in the hook switch, he most assuredly will be possessed of the idea that the irascible and implacable brute—that

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incarnate thunderbolt—that monster of the upper deck—an "old horny headed ram", has struck him fair and hard, at which he will inform you in terms in no manner effeminate that you may have your choice of either changing your brand of instruments or forthwith put out the placard for another bug-shooter.

"But seldom is anything created for which there is not some time some use to which it may be placed to advantage. So when you have removed all of the instruments of the kick coil variety, again secured the confidence of your subscribers and explained away the belligerent attitude of your trouble man, just quietly remove one or two of these patient provokers, the kick coil, from the instruments and save them against the day when your faithful pole changer shall go on a tantrum, as pole changers sometimes do, for connected up in the manner shown in diagram Fig. 224, it will carry you over the time of waiting for a new set of springs or a new condenser for the pole changer.

"You will find that from five to ten cells will give you power enough to ring all of the instruments on your longest farmer lines as well as those locally situated.

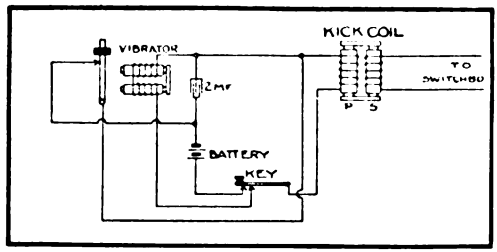


Fig. 224.

"The wires as marked "To switchboard" should be connected to the same posts as the wires from the pole changer. However, it will be necessary to also place the key in reach of the operator so that she may close it when she desires to ring a subscriber, as owing to the heavy draw on the battery it is not desirable to have the vibrator in motion all the time. This arrangement might of course be attached in the switchboard so as to obviate the necessity of the key, but as this is suggested merely in the nature of a "tide over", we will not enter into details.

"With a few more dry cells inserted it might also prove a good thing to attach on your neighbor's cat or the salesman who sold you the instruments, on his next visit to you".

A very efficient kick coil which will work well with two dry cells can be made up as follows (see Fig. 225): The two cores should be made from Norway iron rod three-quarters of an inch in diameter and 3 1-16 inches long, while the two yokes should be made from Norway iron bar with a cross section of three-quarters of an inch by one-half inch. The yokes are attached by means of machine screws, three of which are to be of iron and the fourth (A) of brass. A thin brass washer (B) separates the core from the yoke at the corner where the brass screw A is used. This serves to open the magnetic circuit a sufficient amount to allow the coil to discharge quickly and thereby produce the maximum effect on the line circuit. The spool heads should be made from fibre or hard rubber 1 5-8 inches square or in diameter. All of the iron posts should

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be carefully annealed before assembling, so as to allow the magnetic flux to be set up quickly, as the current flow through the coil is at best of very short duration. The secondary winding should be on the spools next to the core and should have about 3,700 turns of No. 29 B. and S. guage single silk covered wire per spool measuring about 70 ohms, thus giving about 140 for the two spools when connected in series. The primary winding is wound over the secondary and should consist of three layers of No. 19 B. and S. guage single cotton covered wire per spool, giving about 380 turns for both spools and not over 1.2 ohms total resistance. The figure shows the connection of the windings of the two spools, which are both wound exactly alike. The proper connection to the telephone circuit is shown in Fig. 223, the secondary winding or one next to cores being marked S in the figure, and the outside or Primary winding being marked P.

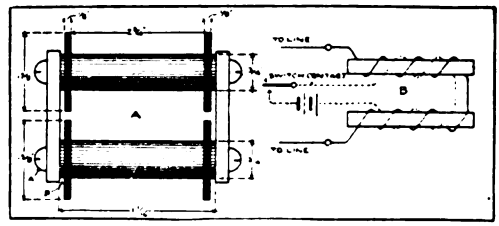


Fig. 225.

As the majority of small switchboards are designed on the unit plan, each section being 100 lines capacity, when additional cabinets are added from time to time to increase the number of lines, some form of transfer equipment becomes necessary, so that the lines ending in front of any one operator can be transferred to the position of any other operator to be connected to any line ending there as the regular cords are not long enough for this purpose. The connection of the said lines is done by means of so-called "Transfer" and "Order Wire" circuits.

For Example. An operator upon receiving a call for a subscriber whose line does not terminate on her position, immediately presses an order wire push button which connects her talking circuit directly with the operator in front of whom the desired line does terminate so as to give the necessary directions for the connection. The subscribers are then connected by means of a designated transfer circuit.

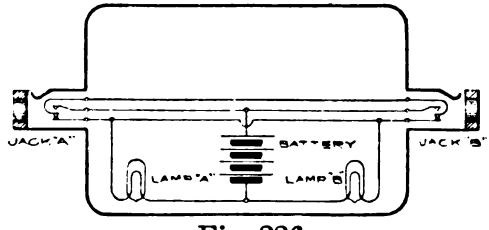


Fig. 226.

There are two kinds of transfer circuits in common use, one of which is a two way lamp signal transfer, as shown in Fig. 226 and the other, a plug ended transfer is illustrated in Fig. 227.

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The two-way transfer extends the subscriber's line to the distant operator's position so that the latter must then handle the call the same as if the line actually terminated on her position, while the plug ended transfer extends the calling cord of the first operator to the distant position of the other, so that the second operator merely inserts the plug end of the transfer into the line designated by the first operator.

The former arrangement requires the use of two cord circuits to complete the connections, but may be used in either direction as its ends are exactly alike, while the latter requires only one cord circuit to complete the connection, but more transfers must be provided as they can be used in one direction only.

The operation of the two-way lamp circuit is as follows: The operator answers the call in the regular manner, and upon finding that a line not within her reach is desired, she immediately plugs the calling cord of the pair used in answering, into the jack of the transfer circuit which terminates on the position in which the jack of the desired subscriber is located. This act lights the lamps at both ends of the transfer circuit, the one in the remote position serving as a signal for the second operator who answers by plugging into the jack associated with this lamp with an answering plug of one of her cord circuits. When this plug is inserted both the lamps are extinguished. The first operator then tells the second operator the number of the line desired, and the second operator completes the connection the same as if the call originated at her position.

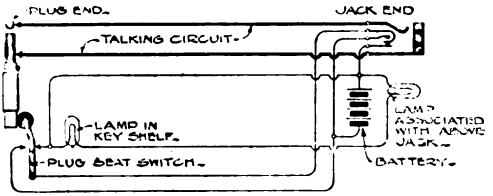


Fig. 227.

At the termination of the conversation the subscribers ring off in the regular way throwing the clearing-out drops present in the cord circuits of both operators' positions.

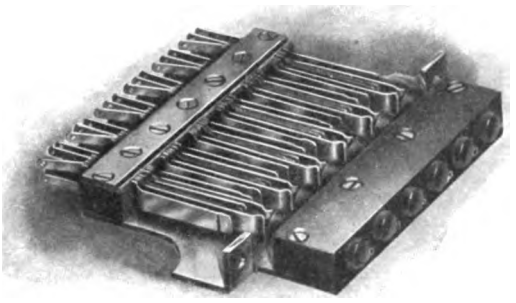


Fig. 228.



Fig. 229.

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The lamps at each end of the transfer circuits are lighted when either of the operators removes the plug from the jack, thus a check is provided on each operator's action and all chance of tying up the connected subscribers is done away with.

While this transfer circuit can be operated as just described, the service will be greatly improved by the use of order wire circuits which immediately call the distant operator's attention to the transfer connection and give her the necessary directions at the same time. A strip of order wire keys is shown in Fig. 228. One key at the calling end of each order wire is necessary. When one order wire to each position of every non-adjacent operator is necessary the key shown in Fig. 229 is used, which consists of a non-locking push button provided with platinum contacts. An order wire circuit is shown in Fig. 230.

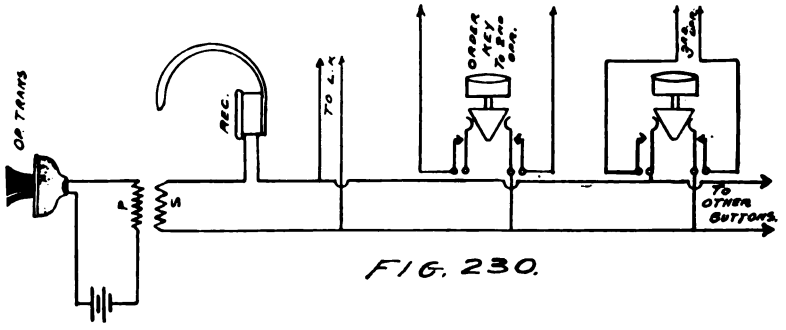


FIG. 230.

In nearly all switchboard cabinets provision is made for installing the plugs and lamp jacks necessary for the above described circuit without changing the existing equipment.

Fig. 231 shows the lamp and jack for one line mounted on a strip.

The plug ended transfer cord circuits shown in Fig. 227 require a special drilling in the plug shelf and special wiring in each position of the cabinet at the time the switchboard is made. It is therefore not recommended except in special cases where the original installation of the switchboard or the ultimate possibilities require a sufficient number of operators' positions to warrant its use.

The lamp circuit of this plug ended transfer is operated at the plug end by means of a reliable plug seat switch. The outgoing end of the circuit requires the same type lamp and jack as is used in the two-way transfer circuit.

A connection is made through a plug ended transfer as follows:

An operator upon receiving a call for a subscriber whose line terminates in a position beyond her reach completes the connection by ordering the distant operator to insert the plug end of a transfer circuit, which extends between the two positions, into the desired line. The latter act lights signal lamps which remain lighted until the first operator plugs into the outgoing jack of this transfer circuit with the calling plug of the cord circuit used in answering the subscriber. These signals serve as a guard and check on the operator's movements and effectively prevent mistakes in making a connection. The first operator rings the subscriber through the transfer circuit, the same as in making a direct connec-

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tion, and when the subscribers are through talking and ring off, the clearing out drop in her cord circuit is thrown. When the cord circuit is pulled down the lamp signals at both ends of the transfer circuit are lighted and remain in this condition until the second operator pulls down the transfer plug. This allows of extremely rapid operation, and prevents mistakes in connection and insures a complete disconnection of the subscriber's line.

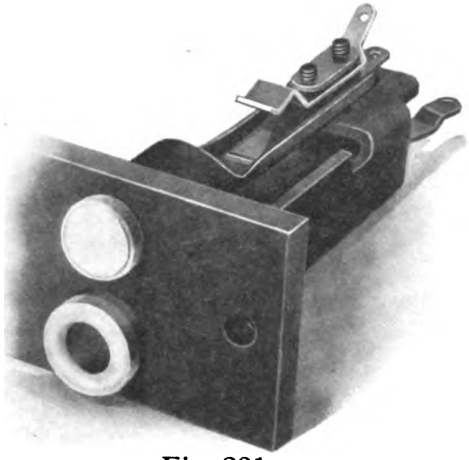


Fig. 231.

The number of transfer circuits necessary in a switchboard depends entirely upon the amount of traffic, but under average conditions two or three trunks of the two-way type between each position and every non-adjacent position will be found sufficient. When transfer trunks are of the plug ended type they can only be used in one direction so there must be provided at least two outgoing trunks for each position to every non-adjacent position. In every case, a surplus number of trunks should be wired in the cabinets to take care of the ultimate requirements.

It is usually the practice to use a 10-volt battery to operate the lamp signals of these transfer circuits. The following combinations are recommended:

Fuller, 6″ x 8″, life 100 ampere hours,

Edison LaLande, 15 cells type R. R., life 300 ampere hours.

Gordon No. 1, 15 cells required, life 300 ampere hours.

Seven Standard Dry Cells.

The lamps in operation require current of about 2-10 ampere. When both lamps are lighted the current consumption may be practically valued at ½ ampere. Thus a 100 ampere battery would light the lamps of one transfer circuit for a period of 200 hours, and as the lamps are used for only a few seconds at a time, the life of a battery is several months or more, and depends more upon the attention the cells receive, evaporation, etc.

A multiple trunking system which has met with favor is briefly illustrated by the following figures.

Fig. 232 shows that there are 10 trunking plugs located at each operator's position. These plugs are connected in multiple with a jack at

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each non-adjacent operator's position. The 0 position has trunking plugs 10-19; second position, 20-29, third position, 30-39, and so on. It will thus be seen that each operator has command of the trunking plugs of the adjoining positions should all of her own be in use.

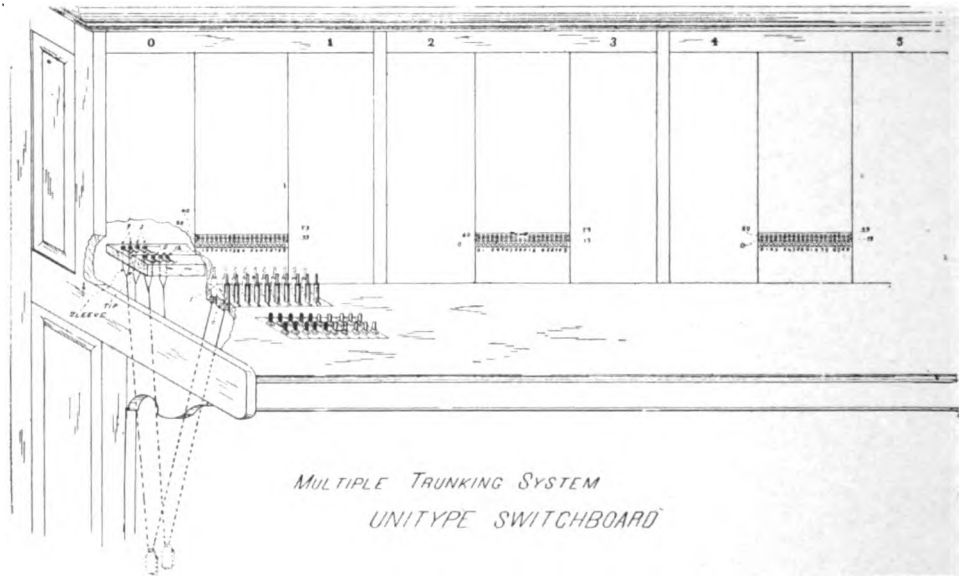


Fig. 232.

Each trunking plug is used with a combined ringing and listening key which enables the operator at the position where the plug is located to listen in on the trunking connection and ring the called subscriber.

The necessary order wire keys connecting the different operators are located immediately adjacent to the trunking jacks. The trunking jacks are located in a panel between each two operators' positions, the switchboard being arranged in sections of two positions each.

Fig. 233 shows the circuits of this arrangement, the plugs being located in front of the operator at each trunking termination, the multiple trunking jacks being located in each non-adjacent section from which the plug is located. Terminals A and B connect to the generator, while C and D connect to the operator's set.

The operation of the system is as follows:

Suppose No. 450 desires to call No. 56. Subscriber No. 450, whose drop and jack are located in front of operator No. 4, operates the line drop which falls. Operator No. 4 thereupon picks up an answering plug on her table and inserts it in jack No. 450. Upon ascertaining that subscriber No. 450 desires to connect with subscriber No. 56, she depresses the order wire key marked 0 and says, "56". The 0 operator thereupon glances at the row of trunking plugs from 0 to 9, and assigns any one of them that is not busy. We will suppose in this instance it is No. 5. The

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0 operator thereupon simply answers, "No. 5" which tells the 4th operator which trunk is to be used. Upon assigning trunk No. 5 the 0 operator picks up trunk plug No. 5 and inserts it in the jack of the No. 56 subscriber's line. She depresses the ringing key in the usual manner and while this operation is taking place, the No. 4 operator is inserting the calling plug of the pair of cords she is using to connect No. 450 into trunk jack No. 5 which is connected with trunk plug No. 5 of the 0 operator's position. The 4th operator does not ring, as all the ringing should be done by the operator at the position where the transfer call terminates.

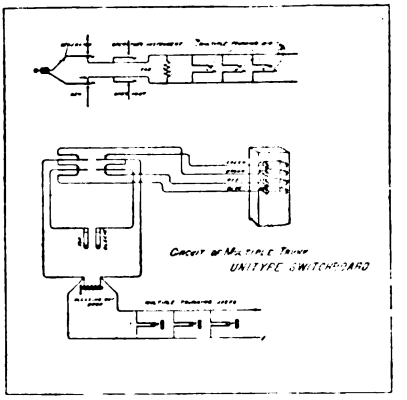


Fig. 233.

When the parties are through talking and "ring-off", the clear-out signal connected to the pair of cords in use at the 4th operator's position will operate, and also the clear-out signal connected to trunk No. 5, which signal appears in front of the 0 operator. Both operators thereupon disconnect their cords.

Upon the clearing-out signal being given the connection should be taken down in the usual manner. If no disconnect signal is given and it is found necessary to take down the plug, the No. 4 operator should depress order wire button No. 0 and notify the No. 0 operator by saying "clear 5".

Should the No. 4 operator receive a call for any 300 or 500 number, which are in the position next adjoining, these connections of course may be made direct by the No. 4 operator, or by handing the calling plug to the operator at the adjoining position and allowing her to insert it into the line jack of the subscriber wanted.

The Order Wire buttons are wired in multiple with the respective operator's telephone sets at each position.

Where it is necessary to use a Repeating Coil in connection with a trunked call, it is only necessary for a cord circuit containing the repeating coil to be inserted in either end of the trunk.

When the switchboard exceeds 400 or 500 lines capacity, the arrangements previously described prove unsatisfactory as the distance between the first and last part of the board becomes too great to reach with cords of ordinary length. When a transfer system is employed considerable extra work on the part of the operator is necessary.

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A multiple switchboard is an arrangement whereby any one operator can reach all of the lines in the exchange without having to reach an undue distance to either side, and without the use of transfer apparatus or the assistance of any other operator.

This is accomplished by a peculiar arrangement of the drops and jacks, and by the use of more than one jack for each line, these additional jacks being termed "Multiple Jacks".

Fig. 234 is a diagram showing this arrangement. Three sections of switchboard are shown for the sake of illustration, it being understood that any number of sections may be used. Line No. 100 is shown terminating in a drop and jack in Position 1, the Jack AJ in this position being known as the answering jack, and being located adjacent to the drop, or in a small panel with the other answering jacks on this position, placed below the multiple jacks.

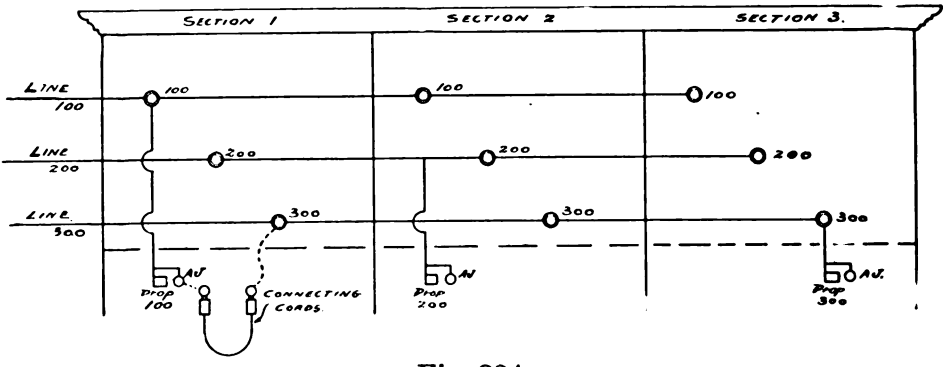


Fig. 234.

It is at once evident that the operator upon seeing drop No. 100 fall, can plug into the answering jack, and upon ascertaining the number of the line desired, for instance No. 300, can plug directly into multiple jack 300 with the calling plug of the pair in use, thus connecting the two lines with one cord circuit just as if they both terminated in front of her, whereas drop No. 300 is located on another section of the switchboard far from her reach.

As a jack for every line is located in each section of the switchboard, any operator can connect any two lines on the entire board.

To prevent more than one connection being made to any line at the same time, a "busy" test was devised so that as soon as one line is connected to another, both lines are made "busy", this fact being readily ascertained by any operator who may attempt to make a connection with them, by a click in her receiver, caused by her touching the plug she is going to use, to the sleeve or metal throat of the line jack. This test is always performed before a connection is made, except when plugging into an answering jack, as when answering a call.

The arrangement of the equipment varies from the forms previously described. Drops and answering jacks for from 80 to 200 lines being placed in front of each operator. Three operators' positions constitute a section, and each section has space for as many multiple jacks as there are total lines in the exchange. It is evident that any one of the three

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operators in each section can easily reach any one of the multiple jacks in that section, or can reach the multiple jacks in the end panels of the next adjacent sections. An additional group of multiple jacks is placed at the left of the first operator and to the right of the last operator so that they also can reach all the lines.

Fig. 235 shows the actual arrangement of a multiple switchboard of two sections, arranged for five operators with a total of 1000 lines. The extra jack panel for the last operator is not shown in the figure.

Sometimes the Drops are placed above the multiple jacks, the answering jacks being located as shown in the figure. This is the case when the electrically restored drop is used.

A little consideration will show that the multiple jacks must always be arranged in regular rotation across the face of the board, but that the answering jacks and drops need not necessarily be arranged in numeri-

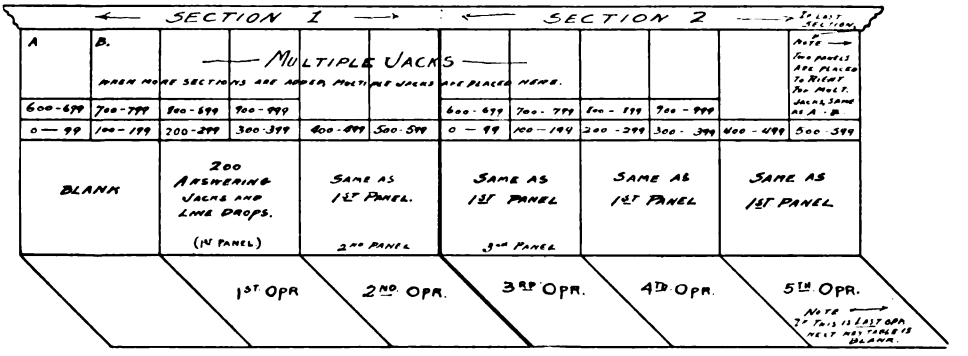


Fig. 235.

cal order in front of each operator. By means of an intermediate distributing frame which is described elsewhere, the lines can be arranged in front of the operators so that each operator will have an equal number of busy lines, and therefore an equal amount of work to do. This is one of the advantages of the multiple board, and this is not possible with other types, as with non-multiple boards, the line jacks and drops must be arranged in regular rotation to prevent great confusion. With the multiple board the multiple jacks are always used for *calling* and are regularly arranged. The answering jacks are used only when a call is *answered* and in this case the operator is guided to the exact jack by the drop signal placed adjacent thereto.

The capacity of a multiple board is limited by the length and height of the sections or jack spaces, that is seldom more than 70 in. long or 36 in. high, as it would be impossible for the operators to reach a greater distance.

The magneto multiple board came into extended use, but has been entirely supplanted by Common Battery equipment, until now few magneto multiple boards remain in service. No attempt to describe all the varied circuits that have been devised will be made, but a few examples will be given to show the development of the type, and to enable the operation of modern equipment to be more readily understood.

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The series multiple circuit, so called from the fact that the line circuit runs through the multiple jacks in series as shown in Fig. 236, was perhaps the first successful circuit to be used on a large scale. The two line circuits A and B shown on the right and left of the figure, each have a drop *d*, one answering jack, and two or more multiple jacks *m*. *m'*.

The insertion of a plug in any one of the jacks opens the drop circuit and connects the tip and sleeve of the plug to the tip and sleeve of the jack in the usual manner.

The cord circuits are equipped with ringing keys; their operation being the same as in non-multiple boards.

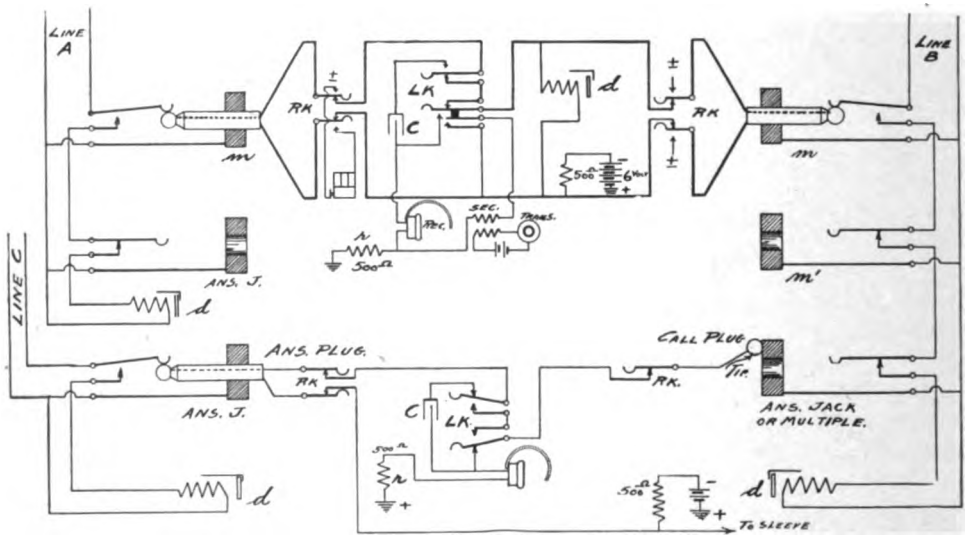


Fig. 236.

The operation of the listening key is somewhat different, as it is used in securing the busy test. Referring to the figure L K shows the listening key. When thrown this bridges the operator's set across the cord in the usual manner, and also puts a condenser C in series with the tip side of the cord to prevent current from the test battery getting into the operator's set from the tip of the plug already in a jack, when making a busy test, and also to form a path for taking currents so the connection will not be broken when the operator "listens in".

The operation of the busy test will be understood by reference to the lower cord circuit in the figure, which represents an operator in the act of testing a busy line. Now assuming a plug to be in any of the jacks of line B it will be seen that current will flow from the 6 volts battery, though the 500 ohm resistance coil in the sleeve side of the cord circuit, and to all of the sleeve thimbles of the line B jacks, thus changing their condition and charging them with a — polarity.

When the operator making the test throws the listening key and applies the tip of the answering plug to any one of the jack thimbles of line B or any busy line, current immediately flows from the jack thimble to the tip of the plug, and through the operator's receiver and a 500 ohm resistance coil *r* to the + or grounded side of the battery, this causes a click in the operator's receiver which notifies her the line is busy.

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It will also be observed that when a line is in use, the test battery can flow over the sleeve side of same through the telephone instrument and back to the tip, so that the tip side of the plug in the jack of the waiting subscriber (Line C in the figure) is charged with test battery. Now if the condenser was not placed in the operator's set as shown by the lower cord circuit in the figure, no busy test would result, for as soon as the listening key was thrown the receiver would be connected to the — side of the battery through the answering plug already in the jack. The condenser, however, prevents the flow of direct current from the answering side of the cord, and the busy test is obtained from using the tip of the calling plug, as just described, the test not being affected by the answering plug being in a jack.

It will be observed that no test will result from touching the plug on the sleeve of an idle line as no test battery is connected to the sleeve of a line jack except when a plug is in a jack of that line.

Three cells of storage battery are used for the test. The connection of the battery through the coils to the sleeve sides of the cord circuits did not materially affect the talking circuits or cause "cross talk" owing to the high impedance of the 500 ohm coils.

A 500 ohm bridged clearing out drop, *d* was used connected across the cord as shown. This was operated in the usual manner, when the connected subscribers "rang off".

Grounded lines could be connected to this type of board, by connecting the sleeve side of the jack to ground through a 500 ohm coil (non inductive) to prevent "dead grounding" the sleeve and thereby interfering with the busy test.

The drops used in this type of board were of the hand restored type, and were mounted over the multiple. Of course mechanically restored drops could be used if the drop and answering jack are associated, but this type of drop was not developed until this circuit was practically abandoned for later and better forms.

The principal trouble with this circuit was found to arise from the series contacts in the jacks. These sometimes failed to close or became dirty, and in a large board of many sections this was very serious. It would seem that with modern jack equipment this would not occur, as jack contacts now seldom give any trouble. In boards of 600 or 800 capacity, there would only be two pairs of series contacts in the multiple, and recently several exchanges have been equipped with boards using the series multiple jack arrangement with modern jacks, and it has proven entirely satisfactory.

Referring to Fig. 236 it will be noted that when a plug is inserted in a jack, the tip side of the line is opened, but the sleeve side is not. This leaves an open wire (which in a large board may be many feet long) to which is attached the drop coil, and this is liable to unbalance the line and cause cross talk, especially if the drop coil is not armored and is adjacent to another coil.

As the multiple jacks and wires connecting same constitute the greater part of a switchboard of this type, many schemes have been devised to lessen the number of wires and jack springs. A board is often termed "two wire" or "three wire" multiple from the number of wires used for connecting the multiple jacks of each line.

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This saving in room was very necessary aside from reasons of economy, when multiple jacks were larger than they are now. When the series multiple board was in use boards of 6000 or 7000 lines were considered large, it being impossible to place more than that number of jacks in a section.

With modern equipment, as many as 18000 jacks can be placed in a section, the jacks being much more compact.

The drops used with the series multiple system had to be restored by hand. Mechanically restored drops were not in general use, and were not adapted to this class of work. The endeavor to automatically restore the drop, and to obviate the contact troubles and other troubles in the series system, led to the development of the Bridging multiple, or branch terminal system.

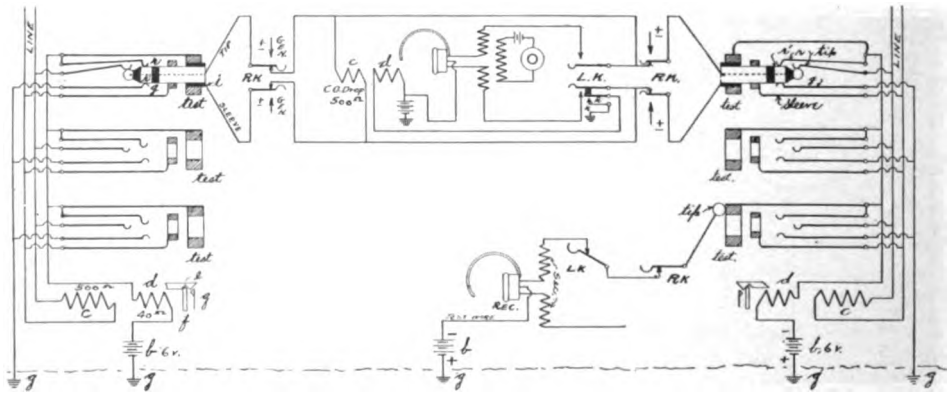


Fig. 237.

Fig. 237 shows the circuit arrangement of this system. The first great difference is the absence of series contacts in the jacks, and the employment of two sleeves or thimbles.

The drop used is of the battery restored type, and is shown in Fig. 238. This is equipped with two coils, the coil *c* being the coil connected to the line and coil *d* of about 40 ohms, serving to restore the drop. Referring to the figure, when generator current traverses coil *c* armature *a* is attracted, rod *b* is raised and shutter *f*, which is quite heavy, is released. This falls against the projection on shutter *g*, which is raised to the position shown in the dotted lines. This displays the number which is painted on the front of shutter *f* at *h*. Shutter *f* only falls outwardly a fraction of an inch, and comes to rest against the aluminum shutter *g*.

Now supposing a plug to be in any of the line jacks, as shown in Fig. 237, a circuit can be traced from battery *b* through winding *d*, to the ring spring *r*, across the metal ring *r'* on the plug to the other or grounded side of the battery by way of spring *g*. This current energizes coil *d* which attracts armature *f* (Fig. 238). This allows shutter *g* to drop back. Shutter *f* is prevented from falling when the plug is withdrawn, by the notch *e* in end of rod *b*.

Referring to the figure it will be observed that the line winding *c* of the drop is never cut out of circuit, but always remains bridged on the line. It is therefore wound to 500 ohms and armored so as to possess

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high impedance, and so as not to cause "cross talk" when the drops are mounted close together.

Only three wires are used in the multiple, the ground *g* being a common wire to all the jacks in the switchboard.

Referring to the cord circuit, it will be observed that the metal ring r' on the plug is not connected to anything, but only serves to connect springs *r* and *g* when the plug is in the jack. It will also be seen that the sleeve or thimble marked *test* does not connect to the plug, but is insulated therefrom by the rubber insulation *i* on the plug.

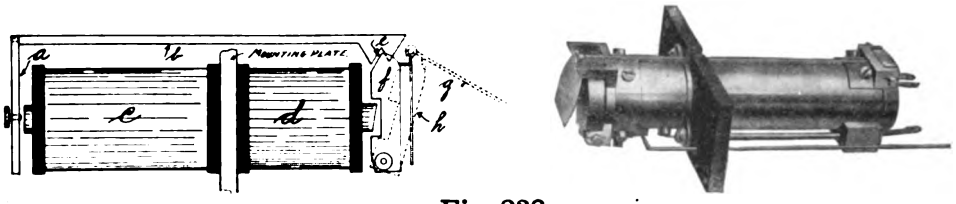


Fig. 238.

After these points have been observed the operation of the circuit will be easily understood. Upon a subscriber signaling the central office the drop would be energized, and upon seeing the signal the operator would plug into the answering jack of the line with the answering plug. This would connect the tip and sleeve of the plug with the line springs of the jack and also close the battery circuit through the restoring winding of the drop, causing same to return to normal.

The operator would then throw listening key *L. K.* thus bridging her receiver and induction coil across the line and placing her in communication with the subscriber. Upon ascertaining the number desired the operator would test to see if the line was busy by touching the plug on the test ring or thimble of the jack of the wanted subscriber's line. This test will be described later. Assuming the line to be clear, the operator would insert the plug and call the subscriber in the usual manner by throwing the ringing key *R K.* While the drop connected to this called line is bridged on the circuit and the ringing current passes through its coil, the shutter will not fall because current is flowing through the restoring winding and the shutter is locked up, which is the case as long as the plug is in the jack. The presence of the drop winding across the line does not materially affect the ringing, owing to the high impedance of the drop.

The clear out drop is bridged across the cord circuit. It is constructed same as the line drop. When the subscribers "ring off" it is actuated, and is restored by the operator depressing the listening key, thereby closing contacts *K, K* and putting battery through the restoring coil *d.* It is customary for operators to "listen in" on a magneto cord circuit to ascertain if the conversation is finished before removing plugs, as subscribers often forget to "ring off", therefore restoring the clear out drop really did not entail any extra work on the part of the operator. This method also insured the drop being restored each time before a cord circuit was used (as the operator had to throw the listening key to get the desired number) which was often not the case with drops that had to be restored by hand.

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The busy test was accomplished as follows, referring to Fig. 237.

When the operator depressed the listening key and applied the tip of a plug to the test thimble of an idle line, no click would result as the test thimble would be connected only to the battery through the restoring winding of the line drop, but if the line was "busy" (a plug being connected thereto at some other section of the board) the operator would get a click in the ear, caused by current flowing through the receiver and induction coil to tip of plug, to the test thimble, to spring r, across ring of plug r' to spring g to the ground or other side of battery. This is shown in lower portion of Fig. 237. It should be observed in tracing circuits in a diagram of this nature that the circuit is completed from ground to ground as shown by the dotted lines Fig. 237 even if no line is shown, this often being omitted for the sake of simplicity in drawing.

The battery is also shown in two or three places in the drawing, and it should be remembered that in reality, only one battery is used.

The induction coil used with this system had a primary of 1-3 ohm, and a secondary of 150 ohms split in the middle, the ends being connected to the receiver as shown. The middle point of the receiver windings or the joint of the two coils, was connected to the battery, so that when the operator "listened in" on a connection, the circuit would not be unbalanced, the ground through the battery being equal on each side of the cord circuit when this arrangement is used. This also prevented a ground on the line interfering with the busy test. Only one coil of the receiver gets current when making the busy test.

This type of board represents the highest development of the magneto multiple board. The largest board of this type had a capacity of 9,000 lines.

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CHAPTER VI.

SELECTIVE AND LOCK OUT SYSTEMS.

Selective party line systems may be defined as those where a number of instruments are placed on one line and any one signaled from the central office without signaling the others.

A two party or "Duplex" system is shown in Fig. 240. A ringing key with two positions is used, or two keys. The phones are connected to the line, which must be metallic, as shown.

When the key is thrown in the J position, the generator is connected to the tip line, the sleeve side of the line being grounded at the key to prevent the R bell from ringing

When the key is in the R position, the operation is reversed, the generator is connected to the sleeve side of the line, the tip side being grounded. This rings the R bell.

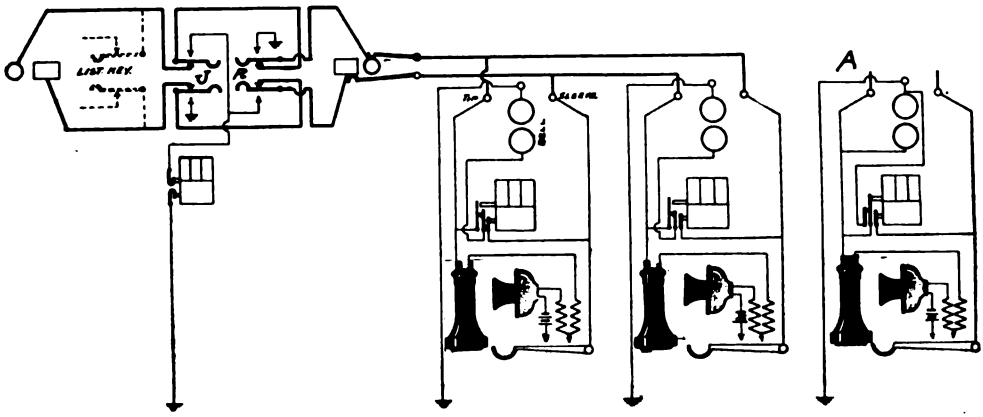


Fig. 240.

The instruments are usually wired as shown in the Figure, the tip line going to left hand line post, and sleeve to right on the J, and the reverse at the R station. A good ground connection must be obtained as the bells depend upon this for a circuit.

It is easy to locate the tip and sleeve sides of the line when connecting the instruments, ask the operator to throw proper ringing key and connect the instrument so bell will ring.

A low wound line drop, (100 ohms) should be used. Calling Central and ringing off from these instruments is accomplished the same as from an ordinary telephone.

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Fig. 240 shows that the ringer is connected from Line 1 to the ground through a contact in the generator shunt, this contact being opened when the crank is turned and current being thereby prevented from going to ground and ringing the other bell on the line.

Sometimes the instruments are wired as shown at A in the figure, line 1 being grounded when the crank is turned.

Switchboards now in use equipped with ordinary ringing keys and having cord circuits like that shown in Fig. 180 or 193, may be easily adapted for duplex ringing by means of a double throw master key, as shown in Fig. 241, and by re-arranging the generator circuit.

Ordinary telephones can be rung when the cord circuits are equipped with duplex keys, by throwing the keys in either position in case the line is a metallic one, but when ringing on grounded lines, it is necessary to throw the ringing key in the first position, which connects the grounded side of the generator to the sleeve of the calling plug. In this case it is supposed that the line wires of grounded lines go to the tip springs of the jacks, and that the sleeves are grounded.

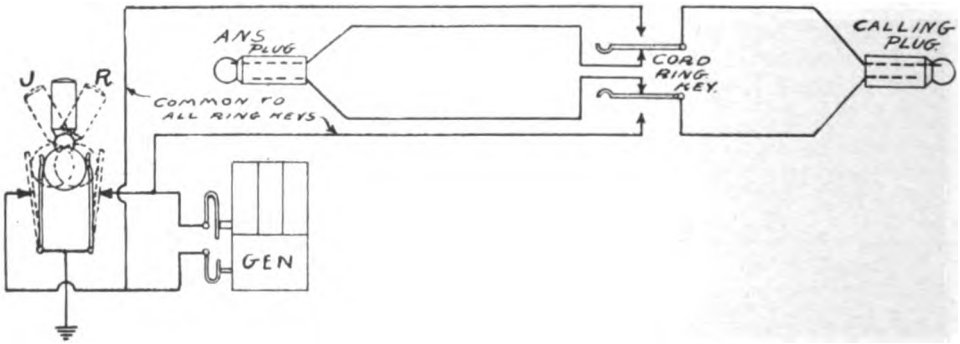


Fig. 241.

Should a subscriber on a party line desire the other subscriber on the same line, the operator should say "Hang up your receiver and I will call you." She then calls both parties by quickly throwing the ringing key in both positions.

The operator should leave a plug in the jack, to denote that the line is busy, and to prevent any connection being made thereto until the parties have finished talking and ring off.

As the modifications of the cord circuit to accommodate duplex ringing are entirely in connection with the ringing equipment, duplex service may be given with common battery equipment. In this case it is necessary to insert a two M. F. condenser in series with the ground wire, or the line would be grounded through the ringer coils.

This duplex arrangement will often allow an extensive increase in the number of telephones on a system, without having to purchase additional drops and jacks for the switchboard, and a sudden growth can therefore be easily accommodated.

In case this system is used in connection with common battery work, a lock-out relay can be installed in the telephones as described in chapter XI, which will give each party on the line secret service without any danger of the other party interfering or overhearing the conversation.

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A Kansas company developed a scheme for duplex service which is noticeable as combining alternating and direct current bells, operated selectively, on a common return system. The plan requires the two telephones to be connected in series, one an ordinary 80 ohm series instrument and the other a series instrument equipped with a direct current generator and a Schwartz bell, which is intended to be rung by direct current, although alternating current will ring it unless hindered in some manner. These bells are wound to 30 ohms for lines up to one-half-mile in length. Over that length 40 ohms is used. If the resistance of the winding is too high, the bell will be rung by the alternating current used to ring the polarized bell.

When operated in series with an 80 ohm bell, using current at about 65 volts, alternated moderately rapidly by a pole changer, it will be found impossible to ring the direct current bell owing to the impedance of the ringers in series preventing a sufficient amount of current flowing to operate it. However, when a direct current of about the same voltage is applied to the line, the special bell will respond vigorously, while the ordinary polarized ringer will not be affected, except by, maybe, a single tap dependent upon the gong to which the tapper may be clinging.

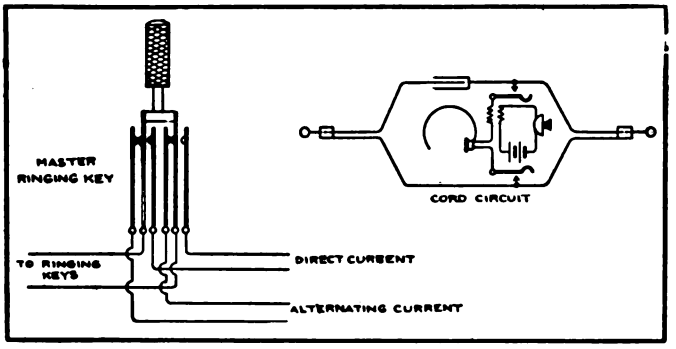


Fig. 242.

The additional central office apparatus necessary to operate the system on the ordinary switchboard is a two-party selecting key, wired as shown in Fig. 242, and a source of direct current, either battery or generator. It is not practicable to use the same battery as is used on the pole-changer, as voltage will vary too widely if other operators are ringing.

There is no change necessary in order to use the standard cord circuit with the system, but to avoid false signals from a ring-off a condenser may be inserted in the circuit as shown in the drawing. Only one is necessary, inserted in the line side, on a common return system.

Fig. 242a shows the two bells as connected on the line. No difference has been observed in placing either bell on the end of the line. During a conversation either party must talk through the other bell, but this seldom causes any trouble. The longest lines on which the scheme has been tried, have a working resistance of about 400 ohms, of which 160 ohms is in the two telephones and heat coils, leaving about 240 ohms as the line resistance. This is much higher than the average. The bells can be rung on lines of any length, provided the voltage of the ringing

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current is high enough to give a current of from .18 to .22 ampere for the higher wound bells.

Four telephones may be rung selectively on one metallic line by the "Biased Bell" system.

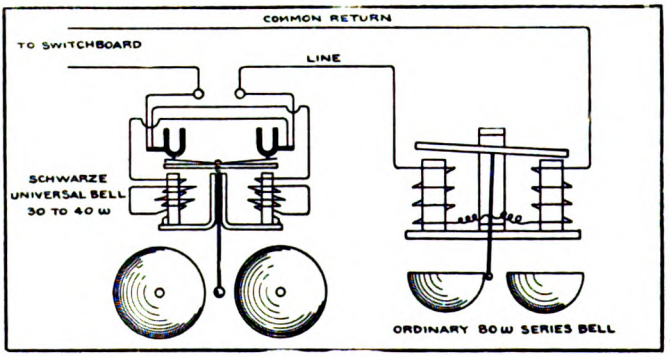


Fig. 242a.

A special generator at the central office is necessary, this to be arranged to deliver pulsating currents of either polarity. The construction of this generator is the same as the ordinary type, except the addi-

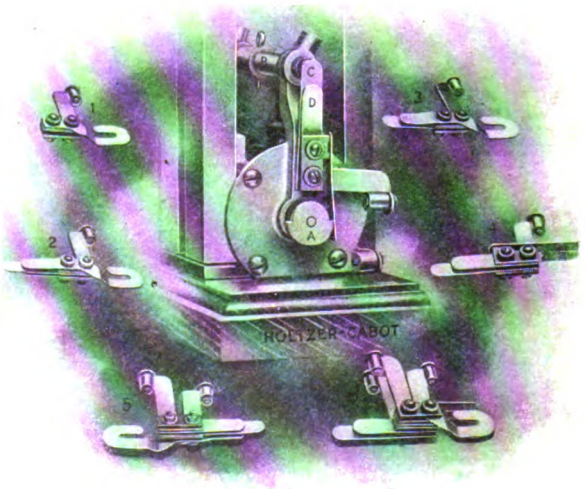


Fig. 243.

tion of a Commutator, as shown in Fig. 243 at A. This is so placed on the armature shaft, that the generator is only in circuit when the projection A strikes the spring on the side, which is only during a part of

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each revolution. This causes a pulsation of current which is always of one polarity (either + or — but never both) depending upon the position of piece A in relation to the armature winding. This intermittent current always in one direction, is termed "pulsating" current. Often in telephone work, this arrangement is referred to as a "direct current" generator, and various arrangements of the contact springs may be made, so that + current, — current, or both; or both + and — and alternating currents, may be obtained from the same generator. Some of the spring combinations are shown in Fig. 243.

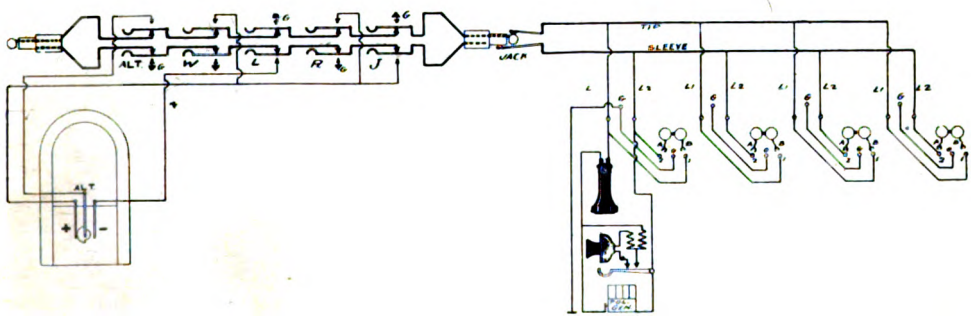
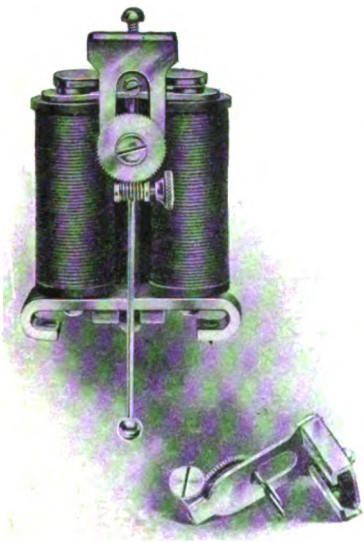
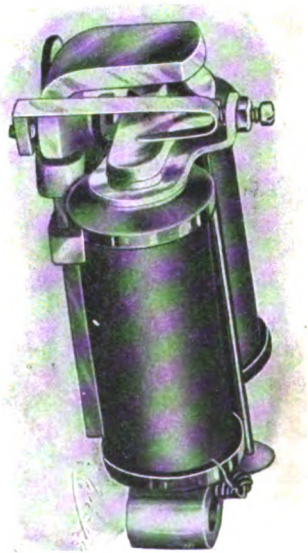


Fig. 244.

Five keys are necessary, arranged as shown in Fig. 244 which also shows the instrument wiring. This is the same as in ordinary bridging instruments except a special ringer is used, and means for connecting the ringer between either side of the line and the ground is provided.



H. C. Co.'s Attachment.



Spring Attachment.

Fig. 244a.

The ringer, often termed a "Biased bell", is equipped with a spring which holds the armature to one side as shown in Fig. 244a, this attach-

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ment being readily fitted to any ringer. If the current is in the proper direction to affect the coil under the free end of the armature, it will be drawn toward this coil, thus causing the ringer to operate.

As the bells are biased they will only respond to a pulsating current in one direction, a reverse current not affecting them. As the direction can be changed by so arranging the connections that the current will flow through the bells in different directions, 4 bells can be put on one line and called selectively.

The direction of current flow usually used to ring four bells is as follows:

Station 1, letter J minus current on sleeve of plug.
Station 2, letter R minus current on tip of plug.
Station 3, letter L plus current on sleeve of plug.
Station 4, letter W plus current on tip of plug.

The opposite side of the cord is always grounded when ringing, as shown in Fig. 244.

This particular group of letters has been selected from a large number because they are totally unlike each other in sound, a feature which must be kept in mind to prevent a great deal of confusion when the subscribers call for connections.

When eight parties are put on one line, the letters A. B. F. and I are used to denote the additional four parties. These follow in the same order and connect same as the J. R. L. and W group. The only exception is that J is *one ring* and A *two rings* with the *same key*. Both in the four party and eight party service when calling central from the telephones, none of the bells on the line will ring.

Stations are so arranged that station J will have its bell bridged from the sleeve side of the line to ground. Station R, or the second party will be bridged from the tip side of the line to ground. The tip line is designated as line 1, the sleeve line as line 2, keeps the line in a balanced condition.

Connecting the Telephones.—Fig. 244 shows wiring of the phones. The left hand binding post of each instrument connects with the tip line, the middle binding post with the ground, and the right binding post with line No. 2, or the sleeve line. The four telephones should be connected exactly the same, particular care being taken not to reverse the position of the lines Nos. 1 and 2.

Upon the door of each telephone will be noticed two clips connected by flexible cords to the bell magnets. The left hand cord is marked A and the right hand one B. Directly under these cords are located three clips, the left hand one of which is connected to No. 2 line post, the right hand one to No. 1 line post, and the centre clip to the ground post. After these points have been observed, the connection should be made as follows, or in accordance with the instructions furnished by the manufacturers.

Station No. 1 or J.....A to line No. 2: B to ground.
Station No. 2 or R.....A to line No. 1: B to ground.
Station No. 3 or L.....B to ground: A to line No. 2.
Station No. 4 or W.....B to ground: A to line No. 1.

When the letters A B F and I are used for the additional four parties, A is connected the same as J, B the same as R, F the same as L,

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and I the same as W. Particular care should be taken to have the telephones connected in the proper manner, as it is possible to connect them and have them ring, and yet not have them connected properly, and this is annoying and a hard trouble to locate at times.

In some makes of instruments, one of the bars in the generator is turned around to weaken the magnetism, and is marked to indicate it is reversed. If, when all four telephones are connected you cannot ring central, turn the reversed magnet around. Do not do this unless absolutely necessary, as when the generator is too strong it may ring the bells on the line. It is better to equip the phones with pulsating generators.

If two bells ring at once, for instance: if when calling J the W bell should ring, the biasing spring of the bell at W should be tightened. Be careful in making this adjustment, and do not bend the springs too much.

Subscribers should be instructed to call for four-party line instruments same as for the two-party phones previously described.

Calling central and ringing off from four-party instruments is done in the same manner as from ordinary telephones.

The resistance of the bells used in four-party instruments is from 1600 or 2500 ohms. Generators should be of low voltage. The line drop should not be wound to a resistance of more than 100 ohms. It is also well to use a low wound clear-out drop, or to use a repeating coil in the cord circuit or one of the special cord circuits described in chapter 5, or when "ringing off", some of the bells on the four party line might tingle.

Four party selective phones can be used as ordinary bridging phones by connecting the A cord on the door to L1 clip and B cord to L2 clip, *and removing the biasing spring from the bell,* thus bridging the ringer on the line and making the instrument same as an ordinary bridging phone.

While not as elaborate or well suited to the wants of a large exchange as some other systems, owing to the necessity of using a ground at each station, etc., yet this system, owing to the simplicity of the central office equipment is very satisfactory for the small exchange.

If desired, a master key can be installed in the switchboard, so that the four-party ringing current can be connected to any cord circuit in the switchboard. This is a very good method, and is recommended to those who wish to change boards now in use. The circuits are shown in Fig. 245. If the best arrangement is desired, *each* cord circuit should be equipped with a separate key, as shown in Fig. 244, as this lessens the work of making a connection, as it is only necessary to operate one key when ringing. The key marked *regular* (Fig. 245), simply releases any of the other keys that may be down, thus leaving the ± current connected for ordinary ringing.

A pole changer or power generator can be used with this system provided same is adapted to give pulsating currents. A resistance lamp must be used in the ringing leads of each position, especially if more than one operator's position is used, so as to prevent dead grounding the generator if two operators should ring with opposite currents, at the same time.

When used with common battery, it becomes necessary to disconnect the bell from the lines except while in the act of ringing, or the line

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would be grounded through the bell. This cannot be accomplished by using a condenser, as the condenser would change the pulsating current to such an extent as to make it alternating in character and the bells would then ring with any key thrown.

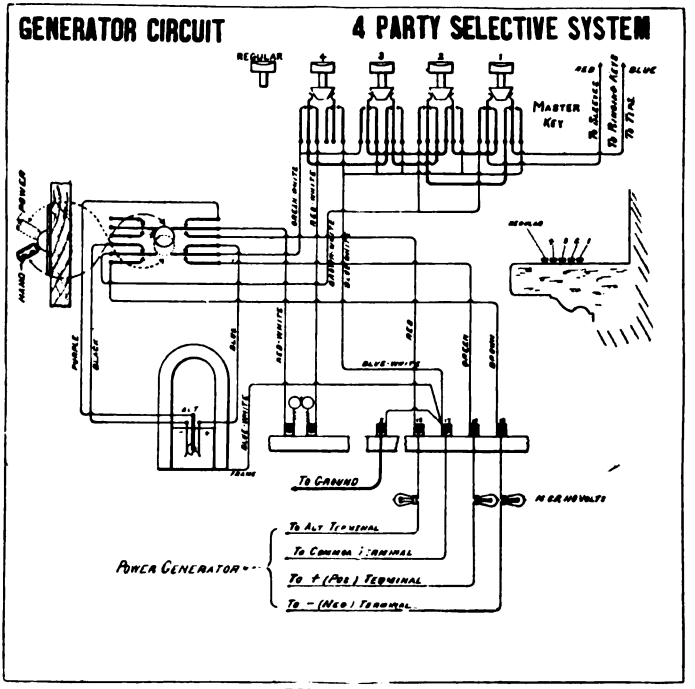


Fig. 245.

By using a relay, and wiring the set as shown in Fig. 246 it is possible to keep the bells disconnected except when ringing. When ringing on the line the contact of the 85A relay closes. This connects the bell to line 2 or 1, depending upon the position of the clips which may be on A or B and the current passes through the bell to ground and back to the central office. The relay is designed to operate with ringing current and has a heavy armature of peculiar construction so the contact remains closed as long as there is ringing current on the line. The condenser does not interfere with the operation of the relay.

This relay is of 2500 ohms resistance. The condenser also offers considerable resistance, and to help deflect the current through the bell, one winding of the induction coil, which possesses considerable impedance, is also included in the circuit. This forces most of the current through the 2500 ohm bell.

Another method of adapting this system to common battery, is to place in series with the bell, a resistance of about 3,000 ohms. This allows a very small current to leak through from the central battery all the time. This is not enough to operate the line signal or relay, and unless a large number of lines so equipped are used, the constant loss of current is not large enough to be of importance.

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The Multiple Frequency Central Energy Selective System represents an improvement over the older system of Pulsating Spring Adjusted Selective Bell equipment.

As early as 1899 this system was perfected by Oscar M. Leich and has been manufactured since that time by the American Electric Telephone Company.

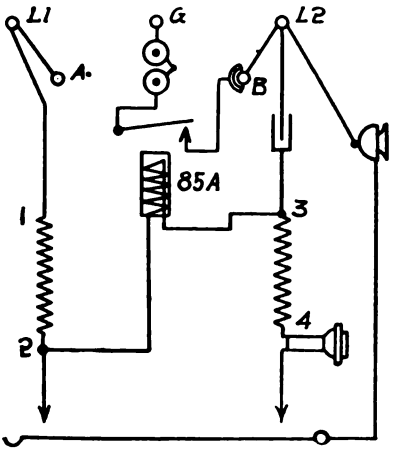


Fig. 246.

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 the instruments have their ringing circuits connected between one line wire and the ground, and the other two are connected between the other line wire and the ground. Each pair of instruments comprises a high and a low frequency instrument. The low frequency instrument is called the "A", and the high frequency the "B" instrument. A selective key having the requisite number of buttons is used at the switchboard for ringing, this selective key serving the purpose of connecting either high or low frequenccy current between either one of the line wires and the ground, that is, sending high or low frequency ringing current over the tip or sleeve of the plug and the ground. Fig. 247 shows the general arrangement of the four telephones on one line, together with the associated ringing key, plug, and generators. One of the generators delivers 2,400 alternations per minute—this is the low frequency machine. The high frequency machine delivers 7,200 alternations. The keys, when depressed, operate either of the telephones marked A, B, C, or D according as either button is actuated. Only one of these selective keys, is needed for each operator's position, as this key is then used in the capacity of a Master Key. It is preferable in those exchanges where a great many selective instruments are used, to equip each cord with a four-party ringing key.

In order to be able to ring the single line or metallic subscribers with the regular ringing keys, it is necessary, when a master key is employed, to depress the button marked AC. These buttons are all locking, that is, they remain in a depressed condition when actuated, until another button is depressed, when the first button is automatically released. In Fig. 247 the talking circuit comprising transmitter, induc-

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tion coil, battery and receiver, is connected between the two outside line binding posts, while the ringing circuit is connected between the middle or ground binding post and the right hand binding post. In the figure A and C are low frequency instruments, and it is seen that their line connections are reversed. The same is true of the two high frequency instruments "B" and "D". It will thus be seen that if ringing current

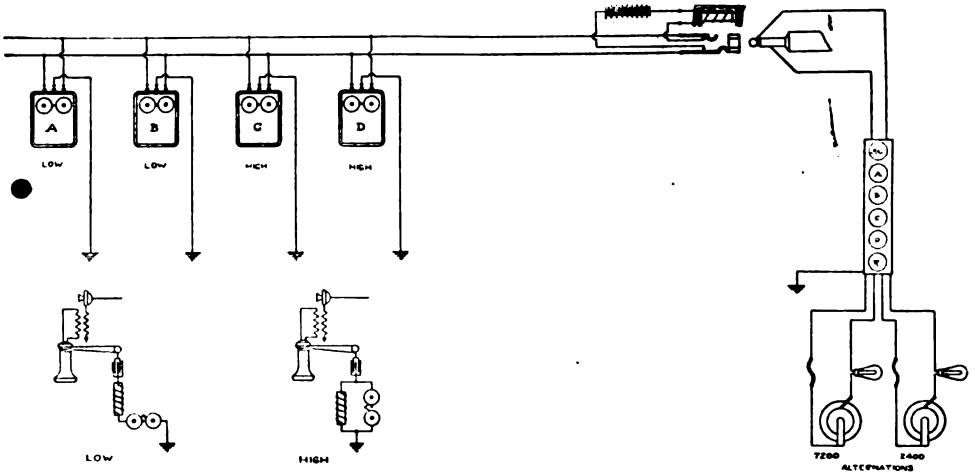


Fig. 247.

of either class is sent over either line wire to the ground, that current is sent through the ringing circuits of two instruments, namely, a high and low instrument, but on account of the difference in construction of these instruments, only one bell will respond, either the high or the low, depending upon whether high or low frequency current was impressed on this line wire. The same is true of the two instruments having their ringing circuits connected to the other line wire on the same circuit.

Principle of Operation.—In order to cause a selective operation of the two bells (the high and the low), condensers and impedance coils are employed.

The arrangement of the ringer circuits in two common battery instruments is clearly shown in Fig. 247. The circuits for magneto telephones are shown in Fig. 248, the ringer circuit being the same.

The low frequency instrument has a ringing circuit comprising a ringer of 1,000 ohms, an impedance coil of 2,000 ohms, and a condenser of 2 micro-farads capacity, all connected in series. This ringer operates on a frequency of 20 cycles per second, or less. It is a well-known fact that the opposition offered to the flow of an alternating current by an impedance coil depends upon the frequency of the current. The higher the frequency, the greater is the opposition, that is, the impedance varies as the frequency changes—in other words, the impedance is increased by an increase of frequency. Just as it is impossible for any of the high frequency talking currents to penetrate or go through a 2,000 ohm coil, likewise it is impossible for a high frequency ringing current to pass a 2,000 ohm coil. A low frequency ringing current, on the contrary, readily penetrates the coil on account of the reduced impedance,

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and has no difficulty in ringing the 1,000 ohm bell connected in series with the coil. In order to obtain an impedance coil in which the impedance may be easily varied artificially, the laminated core is made of E-shaped annealed iron punchings, which can be readily inserted and withdrawn from the coil, if for any reason it is necessary to change the conditions of the coil to adapt the same for unusual line or switchboard circuit conditions. Adding more iron punchings increases the impedance of the coil, and withdrawing the punchings reduces the impedance or opposition to the flow of an alternating current. This action of an impe-

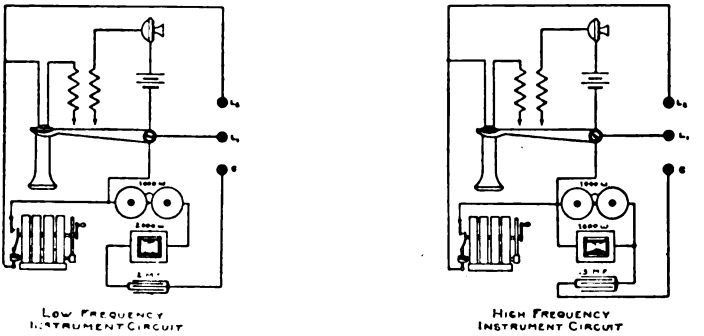


Fig. 248.

dance coil to the flow of alternating currents is unlike the action of such a coil to the flow of a direct, continuous current. To the flow of a direct current an impedance coil offers a constant resistance irrespective of the voltage or amperage of the current, and iron in the coil has no effect on the flow of direct current at all, nor does it change the opposition of the coil to the flow of such direct, continuous current. The coil is shown in Fig. 249.



Fig. 249.

A 2 M. F. condenser is included in series in the low frequency instrument to prevent a metallic grounding of the line. Thus no battery leakage or loss is experienced by the use of this system. The condenser also acts in another capacity, being used to supplement the action of the impedance coil. The opposition to the flow of an alternating current through a condenser varies with a variation in frequency of the current, but this variation is inversely. Thus the impedance of a condenser, that is, its opposition to the flow of an alternating current, decreases with an increase in the frequency, and increases with a decrease in the frequency. Thus the condenser may be made to assist in bettering the operation of the low frequency bell, as it tends to neutralize the effect of the impedance coil at the desired low frequency, but has little or no effect in opposition to the coil at the high frequency. It is well known that a

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condenser may be chosen of the right size to counteract the inductive effect of an impedance coil.

A high frequency alternating current readily goes through the ordinary condenser, and for this reason a condenser offers little opposition to the flow of talking current. The lower the frequency, however, the greater becomes this opposition of the condenser, that is, the greater becomes the impedance, and thus when we go as low as a direct continuous current, or one having no frequency, such as a battery current, the condenser becomes absolutely opaque and does not allow any of this continuous current to pass through.

In the high frequency instrument the ringing circuit is arranged with a 1,000 ohm ringer in series with a three-tenths micro-farad condenser (3-10 M. F.) and a 1,000 ohm impedance coil bridged around the 1,000 ohm ringer. As explained before, the condenser varies in impedance as the frequency of the alternating current varies, and the capacity of the condenser is so chosen that it readily permits the high frequency alternating current to pass through, but almost absolutely bars the low frequency current from passing through, thus the 1,000 ohm ringer or bell is readily operated by the high frequency current, while not enough low frequency current is permitted to pass through it to operate it. Thus the condenser controls the operation of the bell. In order to make the action of the ringer more positive, we bridged the 1,000 ohm impedance coil around it. This impedance coil will divert low frequency current away from the ringer, but is impervious or opaque to the high frequency currents, thus forcing them through the ringer coils. The reason the variation of impedance in the impedance coil is so much greater than in the ringer coils is because the impedance coil has a closed iron circuit.

By removing iron from the impedance coil of the low frequency instrument more current is permitted to go through the ringer coils, while a removal of iron from the impedance coil of the high frequency instrument reduces the flow of current in the high frequency ringer coils.

When the instruments are installed for use, a few precautions must be observed, and if these have been complied with, no adjustment of the instrument is necessary, no matter what the line conditions. It is necessary to have the gongs on the instrument in such position that the bell hammer does not touch either of them when it is resting in its normal state on either side. The gongs will thus be struck by the hammer when it is operating, due to the elasticity of the arm. This precaution should be taken with all telephone ringers whether selective or not. * It is further necessary to see that the armature of the ringer touches the pole pieces when in its normal position on either side. It is also of importance that the ringer armature be securely pivoted in its bearings without any lost motion, so that the armature cannot move up and down bodily, but is confined to an oscillatory motion.

In case there is any difficulty experienced in operating the telephones on some types of central energy circuits, the first thing that should be done is to take a voltmeter reading at the instrument when the ringing current is on the line, and if found too low, the switchboard circuit may be modified, or the ringing generator capacity increased so that the ringing current is ample. A good ground is always necessary. In case the switchboard circuit or ringing generator cannot be changed, a change of

*Not the case with single gong ringers. In these the clapper should hit the gong first.

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iron in the impedance coils will serve to change the characteristics of the instrument so as to adapt them to entirely different conditions. The instruments operate perfectly over a considerable radius of action, and the ease of changing their characteristics makes them exceedingly flexible in their adaptation to all sorts of conditions.

It is of course apparent that line conditions can not change the frequency of the ringing current, and thus the operation of the instruments is independent of line conditions met in practice.

The instruments are admirably adapted for use on two-party lines, in which case there is no necessity for a ground connection. In this case it is necessary to use one low and one high frequency bell bridged metallic on the line.

The advantage of the system lies in the fact that no adjustable springs or relays are necessary for their operation, the conditions under which the system works being purely electrical in character and not mechanical.

In Fig. 248, the ground binding post (marked G) is shown on one side of the line binding posts. This is done for clearness of illustration. In the regular instruments the ground binding post is mounted in the centre, between the line binding posts, and the ringing circuit is connected between the ground binding post and the right-hand line binding post.

In order to do away with the older method of spring adjustment for four-party Magneto systems, the Zabel 8-party Selective system was invented by Max W. Zabel, and has been marketed extensively by the American Electric Telephone Company.

In most Magneto Selective systems it is difficult to prevent false signaling of the party line instruments when a party line is connected with a single line. When the single line telephone rings off it usually rings through the cord circuit and falsely signals some party line instrument. This trouble is not apparent in the Zabel 8-party system.

This system is used very satisfactorily as a 4-party Magneto system and also as an 8-party Magneto Selective system. Any number of telephones up to eight can be placed on a line and selectively rung without ringing any of the others.

The principle of the system consists in dividing the eight telephone stations into four groups of two each. Each telephone is provided with a relay, as shown in Fig. 250, and the two relays of each group are operated simultaneously. Thus when positive battery current is projected on to the sleeve line, relays at stations 3 and 7 operate. When negative battery is projected on the sleeve line, relays at stations 4 and 8 operate. The same is true with regard to stations 1, 2, 5 and 6, which operate respectively when positive or negative battery current is projected over the tip line. Normally, all of the signaling bells have their circuits open, and they are only closed when the relays operate. Thus, for instance, when the group comprising stations 3 and 7 operate, two signal bells are included in the line circuit. The bell at station 3 is included between tip and ground, and the bell at station 7 is included in circuit, which amounts to the same thing as including it between sleeve and ground. If, for instance, positive battery current be projected over the sleeve line both relays at stations 3 and 7 operate. At the same time this is done, however, if alternating signaling current is projected, say, over the sleeve line, the bell at station 7 will operate, but the bell at station 3, which is connected to the tip, will not operate. If, however,

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when the positive battery is connected to sleeve, alternating ringing current is connected betwen tip and ground, then the bell at station 3 will operate, while the bell at station 7 will not operate. The same is true of stations 4 and 8, except that their relays operate with negative battery current. Thus you have a selection of four, and in every one of these four the relays are connected between sleeve and ground. Now, then, to get a selection of eight we duplicate the former stations, but connect the relays between tip and ground. An impedance coil is included in series with the relay, so that the line will not be affected by noises. The impedance coil is wound to over 1,000 ohms. To avoid any tap there might be on any bell, the bells at stations 5, 6, 7 and 8 are connected in

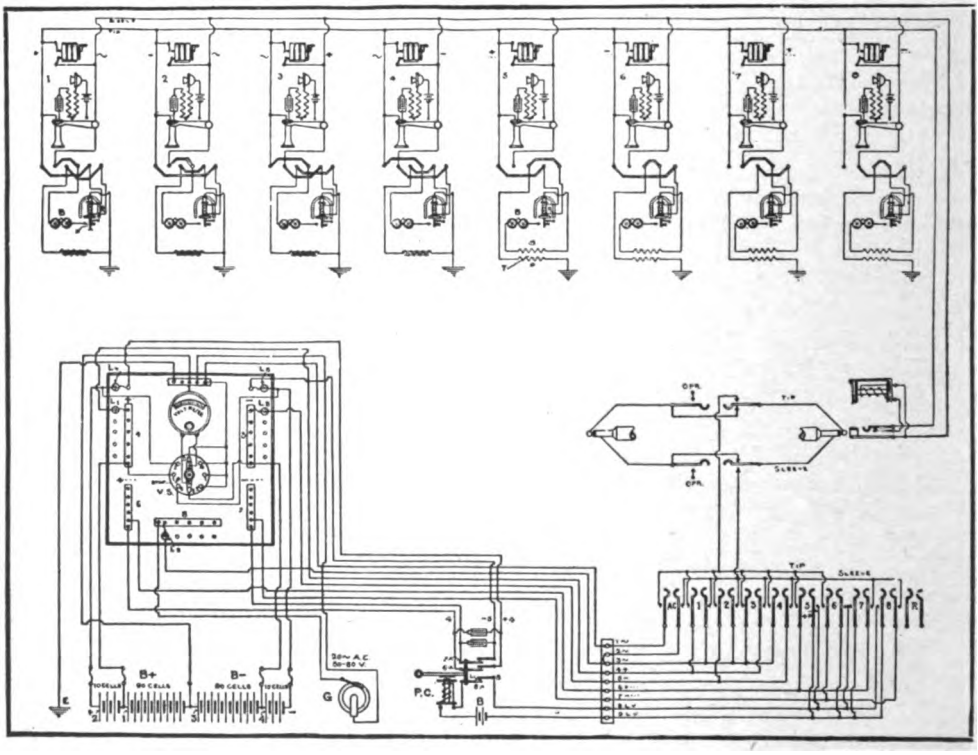


Fig. 250.

the circuit of a secondary coil, wound upon the same core as the above mentioned impedance coil, which acts in this case as a primary of a transformer. Thus, when the bells of these stations are rung, both the battery current and the ringing current flows through the relays. The battery current, of course, will not affect the bell through the transformer, and the ringing current will not affect the relay because the relays are provided with a copper shell, and thus are not responsive to the influence of alternating current, but only responsive to the influence of direct current.

The first four stations are called I stations, and the latter four with the transformer coil, are called T stations.

The system is now manufactured so that no transformer coil, but

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merely an impedance, or retardation coil, need be used with the T stations.

There is a further distinction between the I and T stations, as will be explained later.

The Figure shows a complete diagram of the eight telephones connected to one metallic line, and shows this line entering a switchboard jack and drop and carries the line through the cord circuit, through the springs of the eight-party key and from there into the power board and voltmeter with which are connected the vibrator, the dry batteries—and to the generating equipment which is at present used in the exchange for calling subscribers, and which can be either a power generator, pole changer or hand generator, and which we have indicated for the sake of clearness as power generator shown at G.

The circuits of all the telephones are shown, the I stations at 1, 2, 3 and 4 and the T stations at 5, 6, 7 and 8. These telephones can be connected on a metallic line which enters the switchboard drop and jack of an ordinary switchboard, which has cord circuits having ringing keys, as shown in the illustration.

It will be seen that to change the switchboard to operate Eight-party Selective telephone lines only the Eight-party key need be installed. Furthermore, the regular ringing equipment which the exchange now has in operation will suffice when used in connection with the power board, the wiring of which is shown in this illustration. This is capable

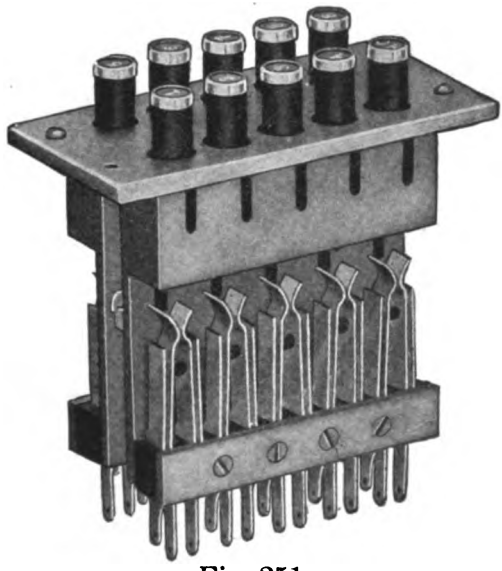


Fig. 251.

of accommodating five complete switchboard positions. Thus the Central Station equipment necessary for an exchange consists of one power panel and one Eight-party key for each position up to and including a total of five positions.

The 8 Party key is shown in Fig. 251 and is provided with 10 Buttons, 8 for the 8 party line instruments, one for regular instruments,

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marked A. C., and a release button R which serves to release any of the others, should they be in the depressed position.

The special relay is shown in Fig. 252. Only these relays are normally connected to the lines, the bells being normally disconnected. A high wound impedance coil being in series with each relay, disturbances are kept off the line.

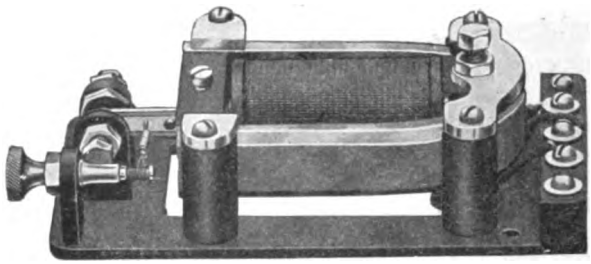


Fig. 252.

The Baird Secret Service System represents a type of equipment whereby nineteen or less parties can be connected on one metallic line and when one party is calling another on the same or a different line, all the other phones on the line are "locked out" and cannot hear the conversation.

This attachment as furnished for use with instruments already installed is shown in Fig. 254, and the circuits of same in Fig. 254a.

This cabinet is entirely separate from the telephone proper. The visual signal, as seen through the window in the cabinet, at once indicates to the subscriber whether the line is "clear" or "busy", without removing the receiver from the hook.

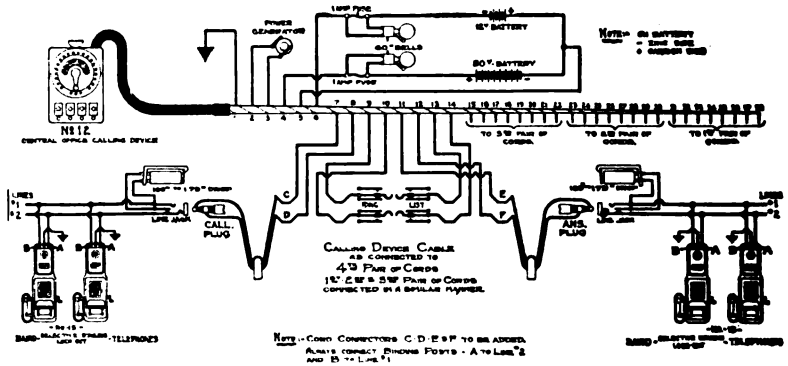


Fig. 253.

The Emergency Call button makes provision whereby any "locked-out" subscriber can, in case of urgent need, signal Central Office.

The Method of connecting the Attachment to standard bridging telephones now in use is shown in Fig. 255, which shows the changes in wiring necessary in standard bridging telephones, when used in connection with the Secret Service Attachment. Simply open up one side of

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ringer and carry it out to binding post D, then add one new wire from the common point of the primary and secondary on the induction coil to post C. Connect the wires of the attachment to the telephone, and it is ready for Secret Service. (Binding posts C and D may be dispensed with if desired by running wires directly from Attachment to Telephone.)

The Central Office Calling Device, as shown in Fig. 256 contains the mechanism necessary in selecting and automatically ringing the party desired, and locking out all others on a party line equipped with the Secret Service apparatus. It is generally placed on the key shelf or mounted in a convenient place, easily accessible to the operator, and is connected into the cord circuits of any magneto switchboard, as shown in Fig. 257.



Fig. 254.



Fig. 256.

It is necessary to disturb the existing wiring only to the extent of opening up the answering and calling cords, and connecting the Calling Device in series in the manner shown. The cord circuits that are so equipped may be used for regular service when not in use on Secret Service lines.

Description of the Electrical Operation of the Baird Secret-Service System.—The Subscriber rings down the line drop with an alternating current from the subscriber's station "full metalic" in the regular manner. The operator answers. After ascertaining his number she operates her Calling Device which automatically sends impulses first from the 50 volt battery and then from the 12 volt battery alternately out over the line "full metallic". This operates every one of the step-up mechanisms along the line. At the time this stepping-up mechanism is going on and say, for instance, party No. 6 is the party we desire to call, locking him in and locking-out all the rest, this looking-in subscriber No. 6 is accomplished as follows: The Calling Device is arranged so that the first impulse is used for automatically clearing the line at the beginning of a call, should the operator have failed to do so when she received her clearing out signal the last time that the party line was in use. The first impulse, therefore, that affects the subscribers' mechanisms is really

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the second one sent out from the Calling Device, therefore if subscriber No. 6 is the party to be called the operator will have had her plug in her Calling Device at No. 6. At the 7th 50 volt impulse from the Calling Device the little wiper on the ratchet wheel at station No. 6 is in contact with the locking-in coil spring. At that very instant also, the lever on the Calling Device handle is passing the plug on the Calling Device. The passing of this little lever over the plug in the Calling Device dial will cause an alternating current to flow out over the sleeve side of the line

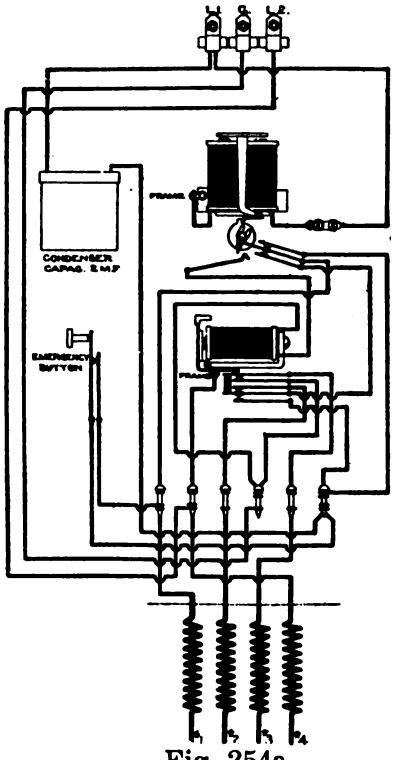


Fig. 254a.

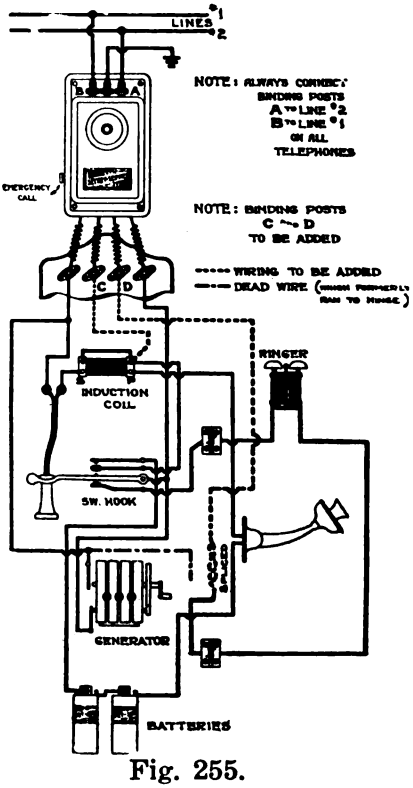


Fig. 255.

through the frame of the mechanism at station No. 6, through the wiper on the ratchet wheel, through the locking-in coil spring, through the locking-in coil to the ground, thus causing the armature of the locking-in coil to operate the group of contact springs which lock subscriber No. 6 in on the line for conversation. The wiper, on coming in contact with the locking-in coil spring, stays there for only one impulse, passing off on the eighth impulse, therefore taking the ground off the line for talking. This action is the same for any number of subscribers along the line, according to the plugs that the operator inserts in her Calling Device dial at Central.

The ringing is done over the sleeve side of the line to ground automatically for a short period by the Calling Device just before it comes to its normal position, and after 20 impulses have been sent out over the line. If the subscriber fails to answer with this short automatic ring, the operator rings him as often as she desires manually, by simply press-

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ing the ringing button situated beneath the key on her calling device, which is in service with the pair of cords used to make the connection. This manual ringing is also done over the sleeve side of the line through the lower contact of the switchhook, through the ringer to ground, through the contact which has already been established, through the set of springs actuated by the locking-in coil. The above covers the description as far as the desired subscriber is concerned.

After the conversation, the party who has been using the line turns his hand generator and clears-out with an alternating current in the usual manner, by actuating the clearing-out drop of about 500 ohms, permanently bridged across the cords.

After receiving the clearing-out signal the operator actuates her key in the Calling Device, thus throwing a 50 volt battery of opposite polarity out onto the line to clear it, or, in other words, restoring same to its normal position.

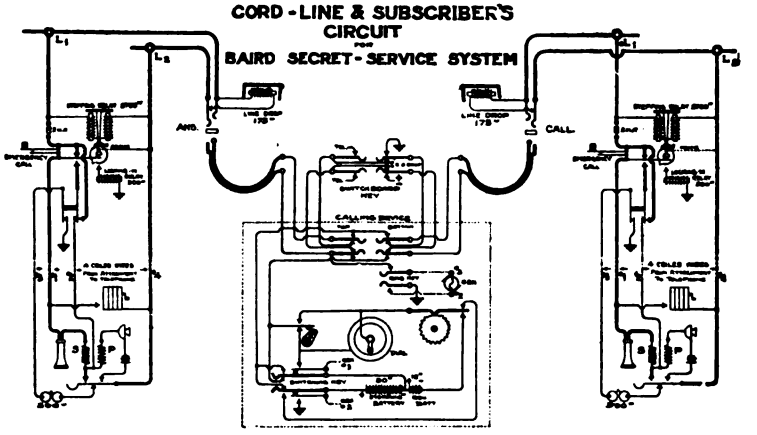


Fig. 257.

The operation of the Emergency Call Button is very simple. If a subscriber having an urgent call desires to signal Central, he presses his Emergency Call Button and turns his hand generator. This throws an alternating current over the line "full metallic", thus throwing the clearing-out drop at Central Office.

Subscriber Calling Central.—To call Central, the subscriber TURNS HIS HAND GENERATOR at the subscriber's station instrument, LEAVING HIS RECEIVER ON THE SWITCHHOOK. This causes an alternating current to flow over the line "full metallic" to Central Office, actuating the line drop corresponding to the party line from which the call is made, notifying the operator that some one on that line desires service.

Operator Answering the Call.—The operator inserts her answering plug in the jack of the line signalling. She then moves her listening key to listening position and requires the calling party's number. This, we will say, is No. 5. Operator then ascertains the number desired, say for instance, No. 15 on the same party line. The operator thereupon restores her listening key to its normal position. She next inserts a peg in No. 5 and another in No. 15 of the Calling Device dial, after which she turns the lever around the dial until it comes to a full stop and locks.

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She then operates the key lever, (which is directly under the dial) corresponding with the pair of cords used in making the connection. By an *upward* movement of this lever the Calling Device is released and returns around the dial to its normal position. By this action the Calling Device automatically sends out on the line a series of *Direct Current* impulses, causing the Lock-Out mechanism, (which forms a part of every subscriber's instrument) to operate. This operation locks out all of the subscribers along that party line, *whether their Receivers are on or off the Hook,* except parties No. 5 and No. 15.

The Calling Device, upon its return from the operated position to normal, not only operates the Lock-Out mechanism at the several subscribers' stations, but also *Automatically Rings the Party Wanted.* (The one in this case being No. 15.) Should the party fail to answer his telephone on this first ring, the operator can ring him *as often as she desires* manually, by simply pressing the ringing key button, located directly *below* the key lever previously operated. When party No. 15 answers, he is in direct communication with subscriber No. 5.

Operator Clearing Out or Restoring the Line to Normal.—After parties No. 5 and No. 15 have finished their conversation they hang up their receivers, and *turn their hand generators* in the usual manner. This actuates the clearing-out drop at Central, and notifies the operator that the parties on that line have finished their conversation. She thereupon operates the key lever under the dial of her Calling Device (corresponding to the pair of cords with which the connection was made), by an *upward* movement in the same manner as when releasing the Calling Device lever in sending out the call. This action sends a direct current (of *opposite Polarity* to that used in stepping up this Lock-Out mechanism in the first instance) out on the line, *restoring to normal* the Lock-Out mechanism of every subscriber's instrument on that party line. She next removes the answering plug from the line jack and the line is again at the disposal of any party on it.

The operation of connecting one line with another is slightly different from the above, but the various operations of locking the subscriber in, etc. are the same.

When properly installed these instruments need little attention, and the re-adjustment of the lock-out mechanism should never be attempted except as a last resort, and then only by some one who is throughly competent to make such adjustments.

The 50 and 12 volt batteries must be kept at the proper voltage.

The line troubles must be promptly cleared as they of course affect this system to a greater extent than on ordinary line. If selector works backwards line is reversed.

This system is typical of step-by-step devices. Hundreds of patents have been taken out on devices of this nature, but with the exception of this and one or two similar systems, they have never come into extended use.

The Homer Roberts selective and lock-out system represents a type of equipment wherein the different stations are only connected to the line when wanted. As many as forty instruments can be put on one line. The following describes in detail the manner of operation and the equipment.

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Paragraphs 1 to 21, inclusive, refer particularly to the line and substations, while paragraphs 22 to 35, inclusive, take up in detail the circuits and mechanism at central in their relation to those of the line and substation.

1 *The Selection of a given Station.* Fig. 258 represents diagrammatically a line of 4 stations, the instruments all being shown in their normal condition. The tip, or left side of the line, is shown as an unbroken conductor, to which is connected at each station the biased ringer B, and, in series with the latter, the coil A, which represents the selecting relay. The sleeve or right side of the line is broken at each station, the outer end of each section terminating in a switch lever 2, which is shown resting on a contact 1. Obviously, if a proper ringing current be sent over the line from central, the bell at station 1 only will operate, since the circuits of the other ringers are not completed. If now, the switch levers at stations 1 and 2 are moved out of engagement with contacts 1 and into engagement with contacts 3, we have the condition shown in Fig. 259. Station 3 is now in circuit and its bell may be rung, the instruments 1 and 2 being disconnected from the right line at contacts 1, while station 4 is still cut off at the contact 3 of station 3.

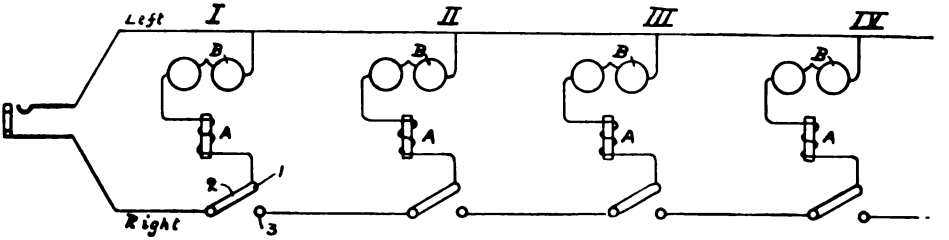


Fig. 258.

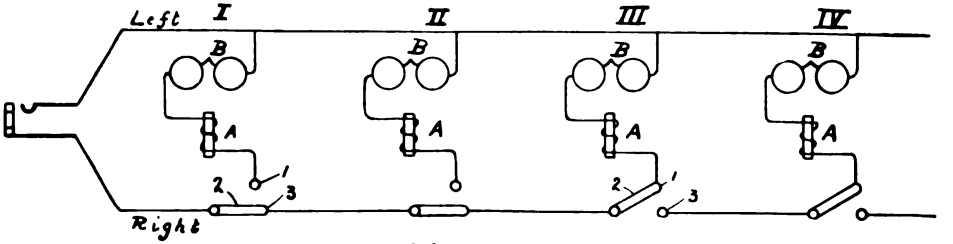


Fig. 259.

2 *The Selecting Relay.* Fig. 260 shows the selecting relay, and Fig. 261 shows diagrammatically the elements of same. The instrument resembles in construction the ordinary polarized ringer. When current is sent through the coil A in the proper direction the end of the armature carrying knob K is depressed, and pushes down spring 1 against the tension of springs 2 and 3, the latch L engaging with spring 2, while the stud P prevents springs 2 and 3 from prematurely coming together. When the current through coil A ceases, springs 1 and 3 rise (2 being held by the latch), and 3 closes contact with spring 2, as shown in Fig. 262.

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3 By referring to Figs. 263 and 264, it will be seen that spring 2 performs the same functions as switch lever 2 in Figs. 258 and 259. Fig. 263 shows a line of 4 instruments in normal condition. To ring the bell at station 1 it is only necessary to send to line pulsating current of the proper direction. Although this ringing current passes through the coil A, it does not affect the selecting relay, which is adapted to be operated by current of the reverse direction only. The bells at stations 2, 3 and 4 do not operate as the circuit is open at each spring 3. Suppose, however, it is desired to call station 3. If a reverse impulse be sent out over the line, current flows through the coil A and ringer B at station 1.

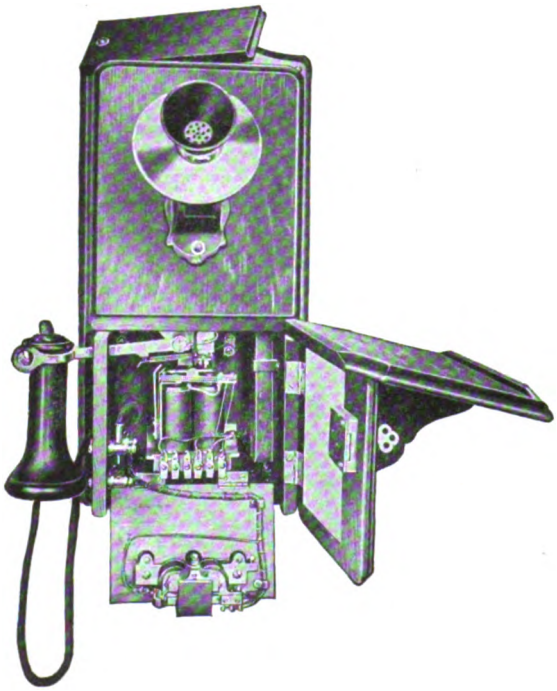


Fig. 260. Wall Set.

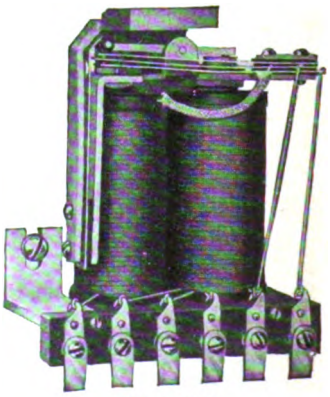


Fig. 260.

This current is of the right direction to operate the relay and not to ring the bell. Under the influence of the current through coil A, the armature of the selecting relay is depressed, bringing the spring 2 under the latch L. At the end of the impulse spring 1 returns to its normal position, and spring 3 rises into contact with spring 2, which is prevented from returning by the latch L. Station 1 is now cut out of circuit at spring 1, and station 2 placed in circuit by the closing of the contact between springs 2 and 3. Current of the right direction thus to latch up the selecting relays will be hereafter designated passing current. Another passing impulse sent to line will in the same manner latch up the relay at station 2. Fig. 264 shows the condition existing after two impulses have been sent to line. It will be seen that stations 1 and 2 are cut off from the circuit which is now completed to station 3 through the springs 2 and 3 at station 1 and station 2. Ringing current sent out over the line will now ring the bell at station 3.

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4 *Restoring the Line.* It is obvious that some means must be provided for restoring the selecting relays to normal after a conversation is finished. By referring back to Fig. 262 it will be seen that the upper end of the latch spring L is bent over in such a manner that when the armature is attracted by current flowing through the coil D, the knob K on rising engages with the bent cam surface and forces back the latch L, permitting spring 2 to return to its normal position as shown in Fig. 261.

5 The coils D are placed in series with the unbroken side of the line, one at each station, a temporary ground at the end of the line being employed to obtain a circuit through all the coils D simultaneously. This temporary ground is obtained by the use of a "grounding" relay at the end of the line. The relation of this instrument to the circuit is shown in Figs. 263 and 264. To restore the line the operator sends out enough additional passing impulses to extend the circuit to the end of the line,

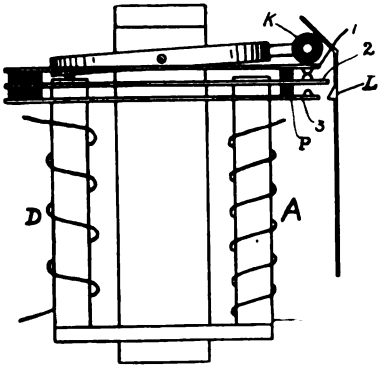


Fig. 261.

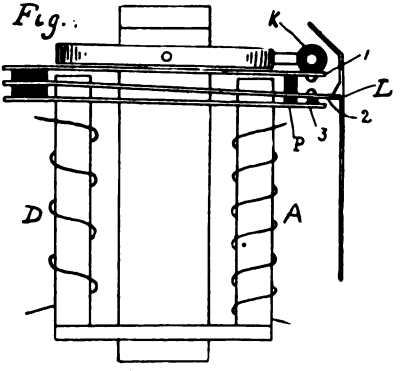


Fig. 262.

and thus brings the grounder G into circuit. This instrument is similar to the selecting relays, but is normally in latched position as shown in Figs. 263 and 264. The winding of the grounder G is connected in such a manner that the next passing impulse throws off its latch, permitting spring 1 to contact with the ground spring 2. The operator now sends a grounded impulse to the left line, current flowing over the left limb through the coils D and the left hand spool of the grounder G to ground. The selecting relays are therefore simultaneously restored to normal. The grounder G is also energized and restored to its normal position.

6 *Differential Winding.* Although the coils D are of low ohmic resistance, it is evident that if a party were talking through a number of stations the impedance thus present in the left line would affect the talking efficiency to some extent. To prevent this there is inserted in the right line at each instrument a coil similar to D and wound on the same spool, connected in such manner as to neutralize the self induction of coil D, as regards current flowing over the metallic circuit. These coils are shown in Fig. 265. These neutralizing windings also prevent any tendency to unlatch intermediate relays when ringing a bell beyond.

7 *The Ringer.* Thus far the ringer B has been considered only as an ordinary biased bell. This instrument, however, also controls the talking circuit of the subscriber. To do this it is provided with a set of contact springs operated in a manner similar to those of the selecting

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relay. When the bell is rung the first stroke of the armature unlatches the group of springs and places the subscriber in talking circuit. When the operator passes on beyond that station the same impulse that latches up the selecting relay also latches up the group of springs on the ringer and thus locks out the station. Fig. 266 shows the general appearance of the ringer.

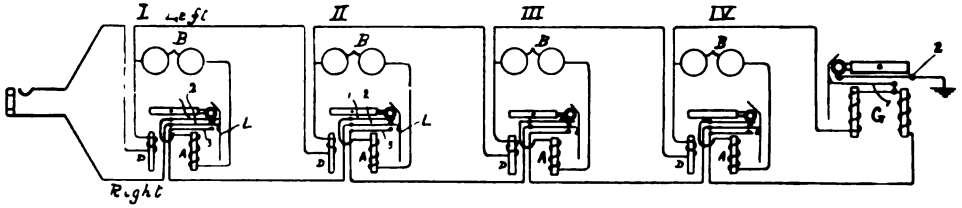


Fig. 263.

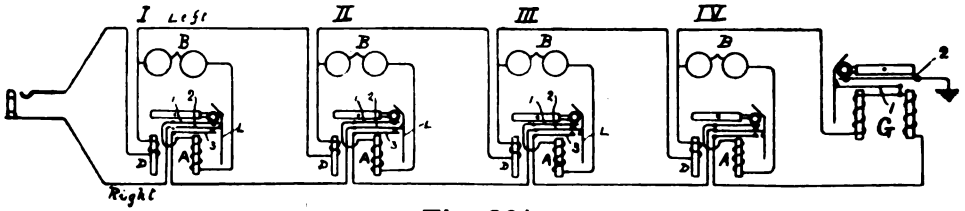


Fig. 264.

8 Referring to Fig. 267, which shows the device in normal (latched) position, it will be seen that in many respects it is similar to the selecting relay. To enable the instrument to operate both as a ringer and relay without interference between the two functions, the tapper rod is pivoted in the armature and provided with a projection on one side, with which the armature engages when the latter moves in ringing direction. The tapper remains at rest when the armature moves in the other (latching)

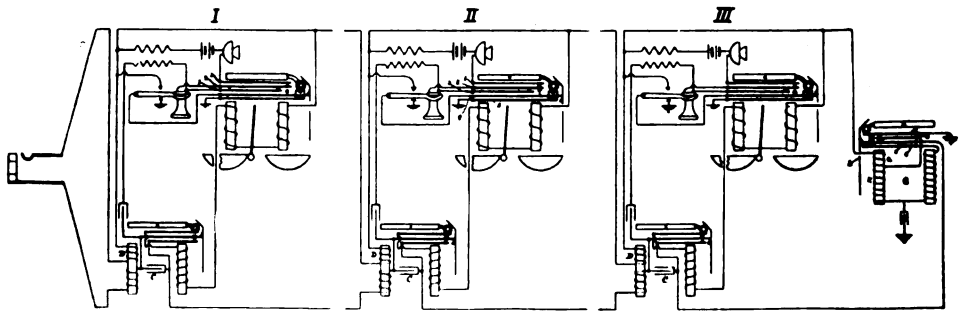


Fig. 265.

direction. By referring to Fig. 267, it will be seen that springs 2 and 3 are normally closed and all other contacts are normally open. The unlatched or talking position is shown in Fig. 268, the contact between

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spring 2 and 3 being open, and the springs 4, 2 and 1 being connected by the upward pressure of the contact pin P. It may be noted that spring 5, which is hooked over spring 4, is never in contact with the latter except momentarily while the armature is depressed in passing (latching) direction.

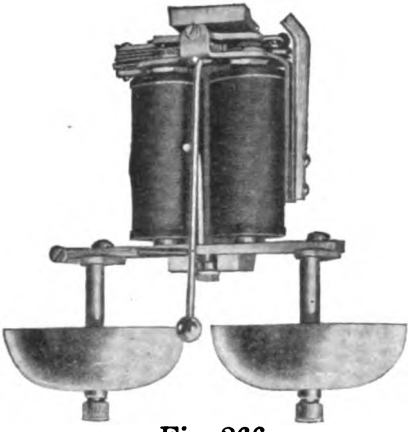


Fig. 266.

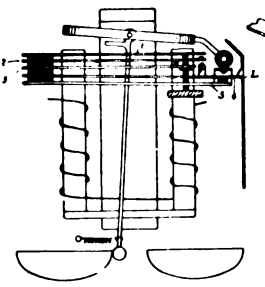


Fig. 267.

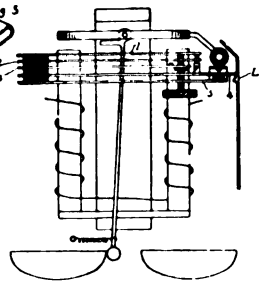


Fig. 268.

9 The relation of the ringer contacts to the subscriber's talking circuit is shown in Fig. 265, which represents a line of 3 stations with station 1 in passed condition, station 2 in talking circuit, and station 3 normal. It will be noted that at stations 1 and 3 the receiver is short circuited by springs 2 and 3, and the listening circuit is also open at spring 2. The local battery circuit is also open whether the hook is up or down, since springs 4 and 1 are not in contact. At station 2, which is in talking circuit, the receiver circuit may be traced from the left line, the upper hook-switch contacts, springs 4 and 2, receiver, secondary, condenser, to the right line, and the transmitter circuit may be traced through the left line, primary, battery, transmitter, springs 1, 2 and 4, and the hook-switch upper contact. It will be seen from a careful inspection of Fig. 265 that owing to the condensers C the continuity of the line for talking purposes is not affected by the position of the selecting relay contacts.

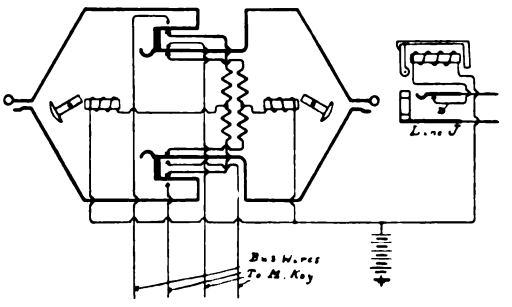
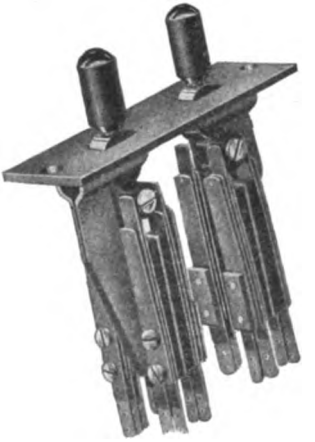


Fig. 269.



Master Key.

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10. *Signalling In.* A central battery is used to operate the line signals, which are ordinary drops. On reference to Fig. 269, it will be seen that one pole of the drop battery is grounded, and the other pole connected to the winding of the drop, which is connected with the tip or left side of the line through spring D. To call central, a subscriber simply takes his receiver from the hook. The three contact springs of the hook-switch are so adjusted that when the hook rises the middle spring makes contact with the top spring before it breaks contact with the bottom spring; all three springs being thus connected during the central portion of the movement. The flash circuit thus formed may be traced from ground through the three springs of the hook-switch, the left side of the line, through the line jack contacts to the drop and through the drop and battery to ground. The drop is thus operated, the shutter falls, and the operator plugs in.



Desk Set.

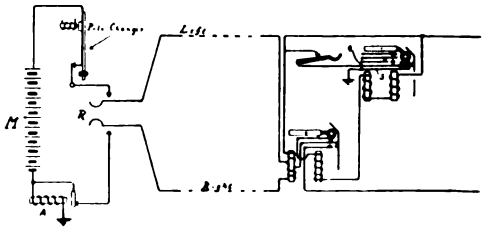


Fig. 270.

11 *Answering Calls.* Since, however, all parties on the line are normally locked out of talking circuit, some means must be provided whereby the operator may place the signalling party in talking connection and leave all the other instruments on the line in their normally locked out position. In fact, the operator must be able automatically to pick out the station that signalled in, and operate the ringer to unlatch the springs controlling the talking circuit.

12 Fig. 270 shows (stripped of all detail) the means employed to pick out in this way the station signalling in. When the operator presses key R, passing impulses flow out over the metallic circuit and sucessively operate the intervening relays, extending the circuit to the station shown. When the current starts to flow through that station the armature of the ringer is depressed and closes the contact between springs 5 and 4. This establishes a circuit from ground through springs 5 and 4 of the ringer, the hook-switch upper contact (the receiver being removed from the hook) over the left side of the line, through battery M and relay A to ground. This operates the quick-acting relay A at central.

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The operation of the latter opens the circuit of the right line and so prevents the operation of the selecting relay at that station. Ringing current is then sent to line; this unlatches the ringer springs and places the subscriber in talking circuit. As a matter of fact a single impulse is thrown on automatically by the operation of the relay A, although for the sake of clearness this is not shown in Fig. 270.

13 If a party signals when the line is busy, he gets no response from central. Assuming that the line is busy, he will simply leave his receiver off the hook. When the party who is using the line hangs up his receiver the supervisory signal is displayed (as explained later) and the operator then locks out his instrument and passes his station with one passing impulse. On again throwing over the key R the waiting subscriber is automatically selected in the same manner as was the first party. If there are no subscribers waiting for service the relay A will not operate until the grounder at the end of the line is unlatched, the selecting relays being then restored to normal automatically (as explained later). After a conversation is finished the whole line should be tested with the key R to avoid missing any waiting subscribers nearer central than the one previously using the line.

14 *Supervision.*—The supervisory signal for each end of the cord circuit consists of a lamp controlled by a relay or a mechanical signal of the central energy type. The latter is shown in Fig. 269. If a subscriber is in talking circuit and he replaces his receiver on the hook he establishes a circuit from ground at his instrument through the lower hookswitch contacts, the ringer springs 4 and 1, the primary circuit, over the left limb of the line to the tip of jack and plug and through the mechanical signal and battery to ground. This operates the cord signal and notifies the operator to disconnect.

15 *Emergency Signal.*—If any party wishes an emergency connection when the line is in use he moves his receiver hook up and down for, say six or eight times. Each movement of the switch hook momentarily brings the three springs together giving a flash ground circuit over the left line through the cord signal, which causes the latter to wink. The series of winks notifies the operator that an emergency signal is being sent in. The operator then throws off the party or parties using the line and picks up the emergency signalling station.

16 *The Grounder.*—In Figs. 263 and 264 the grounder is shown as being an instrument similar to the selecting relay, but with one winding only. As will be seen later, it is desirable to be able to restore the selecting relays to normal position without being required to run past the end of the line and unlatch the grounder. To do this it is obviously necessary to establish a ground at any time at the end of the left limb of the line, and it is also necessary to be able to release this ground after the restoring operation.

17 Referring to Fig. 265, which shows the grounder G in its normal position, it will be noted that the end of the coil K is grounded through a condenser. If a grounded battery of the right polarity be applied to the left line the condenser will receive a charge which will pass through the coils *a* and K. This will cause the armature to be depressed, closing the contact between springs 1 and 2. When this occurs, a direct holding circuit may be traced from ground through springs 1 and 2, and the coil *a* to the left line, allowing the current to flow from central over the left line through coil *a* which holds the contacts 1 and 2 closed as long as the

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current is on. The coils D of the selecting relays being included in the left line are at the same time energized and restore to normal whatever selecting relays have been operated. When the current is removed the coil *a* is de-energized and the spring 1 raises the armature, the contact between springs 1 and 2 is broken and the ground released.

18 When restoring the line in the usual manner as previously described in Par. 5, the last passing impulse kicks off the latch L and the spring 2 rises into contact with spring 1 and spring 3 rises out of contact with spring 4. The reason for opening the circuit between springs 4 and 3 will be explained later on in the more detailed description of the central equipment.

19 *Connecting Two on the Same Line.*—If a subscriber wishes to talk with a party on the same line, he must call central in the usual manner by taking off his receiver. On being automatically picked out and placed in talking circuit by the operator he will give her his number and the number required. Suppose he is No. 5 and wishes to talk with No. 3. To call No. 3 it is necessary to have the selecting relays in normal position. The operator therefore restores them to normal in the manner described in Par. 17. She then selects and rings No. 3 in the usual manner, this act completing the connection. The talking circuit of No. 5 is not destroyed by the unlatching of the selecting relays, as, although the contacts between springs 2 and 3 at stations 3 and 4 are now open, the voice currents between the two subscribers pass freely through the condensers bridging the gaps. These condensers (which are shown at C in Fig. 265), being of small capacity, do not interfere with the proper operation of the bells and relays.

20 Suppose, however, No. 5 calls for No. 7. To ring No. 7 the operator sends to line two passing impulses and then throws on the ringing current, which places No. 7 in talking circuit. The first passing impulse however, which passed station 5, besides latching up the selecting relay, at the same time latched up the ringer at station 5, which is therefore thrown out of talking circuit, and it is necessary to give back to No. 5 his talking connection. To do this the operator restores the selecting relays in the manner previously described, and then selects and rings No. 5, the two parties then being connected.

21 In either case after the two parties are through talking, the operator must first send to line a sufficient number of metallic passing impulses to latch past the further instrument, both subscribers then being locked out. She then clears the line in the usual manner.

The Central Office Equipment and its Operation.—Four Key movements are employed to perform the various operations of the system, viz:

22 (1) *PASS.*—This key movement simply passes one station. If that station is in talking circuit, it also latches up the ringer group and locks out the subscriber.

23 (2) *RING OR SELECT.*—This key movement simply rings on the line; when used in combination with the dial selector, it selects and rings the particular station desired.

24 (3) *RESTORE.*—This key movement restores to normal whatever selecting relays have been latched past regardless of whether the line has been partially or wholly built up.

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25 (4) *RUN.*—This picks out and places in talking circuit any subscriber who has signalled. If there are no calling subscribers waiting, the line is automatically restored to normal condition.

26 All these operations may be performed on either end of any cord pair, the same selective apparatus being used in each case. To permit of this without undue complication of the cord circuit, a special key is used in each cord circuit which enables any pair of cords to be trunked over to the master key set, of which latter there is one provided in each operator's position. As the operator's listening circuit is bridged across the master key set, she is enabled to listen in when she throws over the cord key, which locks like a regular listening key. The master key set is also provided with supervisory signals which take the place of the regular cord signals when the cord key is thrown over.

27 Fig. 271 shows the special selective equipment for one position.

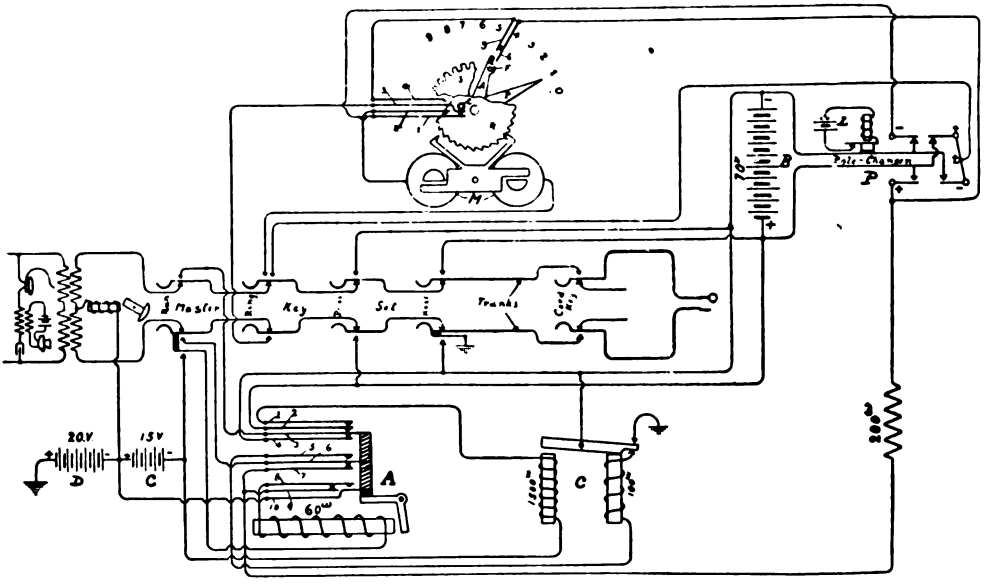


Fig. 271.

Fig. 272 shows the selector mechanism. To avoid confusion only one end of the Master Key is shown, one-half of the cord trunking key being omitted from the diagram for the same reason, Fig. 269 showing the cord circuit proper. D indicates the battery used to operate the supervisory signals and drops. The battery B supplies the current used to operate the bells and relays out on the line. At P is indicated the vibrating reed of a pole changer, which transforms the direct current of the battery B into pulsating current of two polarities. The local battery which vibrates the pole changer is shown at L.

28 *Picking up Signals.*—To call central the subscriber takes off his receiver, this act throwing the drop as previously explained. The operator then plugs in and throws over the cord key which places the master key in operative relation with the line. Pressing the running key then closes a circuit from the + pole of the pole changer through 200*w* resistance, springs 7 and 6 of relay A to sleeve side of running key and over

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sleeve to line and the external circuit, returning over the tip to the outside contact on tip side of running key, springs 3 and 4 of A relay, to the negative pole of the battery B. Passing impulses therefore flow out over the line and successively operate the selecting relays, extending the circuit to the party who has removed his receiver from the hook. As soon as the current starts to flow through that instrument the armature of ringer and relay commence to move in latching direction. The instant the ringer armature begins to move, however, it closes the contact between springs 4 and 5. This closes a circuit from ground through springs 5 and 4, and the upper hook-switch contacts to the left line, tip side of cord and running key to spring 3 on A relay, negative pole of battery B, through battery to positive pole of pole changer, 200*w* resistance, springs 9 and 8 of A relay, winding of A relay, two outside springs on sleeve side of running key, batteries C and D to ground. Relay A therefore operates and is held up as long as the running key is closed; the holding circuit may be traced from battery C, and two outer contacts on running key, A relay winding, springs 8 and 10 and back through the battery C.

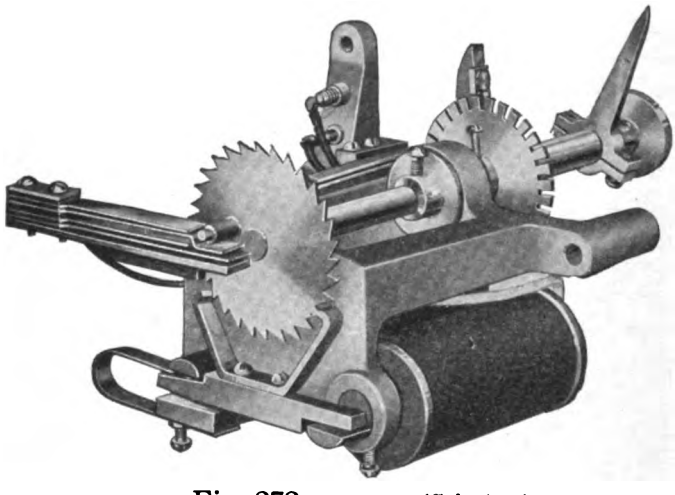


Fig. 272. (Selector.)

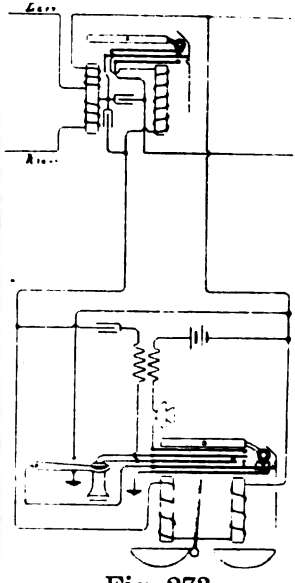


Fig. 273.

The contacts between springs 3 and 4 and springs 6 and 7, now being open, the passing current is cut off from the line, and both ringer and relay armatures return to their normal positions. The closing of the contacts between springs 3 and 2 and springs 5 and 6 of A relay has at the same time established a circuit from the positive pole of main battery, springs 2 and 3 of A relay, outside tip contacts of running key, over the tip and external circuit through the station, back over sleeve, running key, springs 6 and 5 of A relay, 100*w* winding of relay C and through the normally closed contact of C relay to negative side of main battery. Current therefore flows through the station in ringing direction and unlatches the ringer, placing the subscriber in talking connection with the line. On releasing the running key the relay A drops back to normal, as its

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holding circuit is broken by the opening of the contact between the two outer springs on sleeve side of running key. The operator then sets up the required connection.

29 *Restoring the Line.*—When the operator is notified by the supervisory signal that the party has hung up, she presses the passing key. This sends passing current through his instrument, and latches up the ringer, his talking circuit being thus restored to its normal, or locked out condition. She then throws over the running key, and (assuming that there are no more signals to pick up), the selecting relays are successively operated to the end of the line, and finally the grounder is unlatched. As previously explained in Par. 18 the left line is thus grounded through the winding *a* and springs 1 and 2, the contact between springs 3 and 4 being broken. As previously explained in Par. 28 this grounding of the left line causes the operation of the central relay A which cuts off the passing current and applies ringing current across the line. Since, however, the grounder circuit is open at springs 3 and 4, no ringing current flows out over the metallic line, and the 100*w* winding of the central relay C, which is included in this circuit is not energized. A circuit may now be traced from the ground through the grounder winding *a* over the left line, tip, running key, springs 3 and 1 of relay A, the 1500*w* winding of the relay C, batteries C and D to ground. As the 100*w* winding of the relay C is not energized, its centrally pivoted armature is operated by the 1500*w* winding and closes the ground contact. Restoring current now flows from ground through the armature of C relay, negative pole of main battery, through main battery, springs 2 and 3 of A relay, tip side of running key over tip and the left line, through the coils D of the selecting relays, and the grounder winding *a* to ground; as previously explained this restores the selecting relays and the grounder to normal condition.

30 *Selecting a Given Party.*—Suppose No. 4 is the station called for. To set the selector the operator takes hold of the handle to which is rigidly attached the pointer P and the arm carrying the pin F, the whole being free to rotate on the main shaft of the device, placing the pointer P at the given number 4. On pressing the handle the pin F enters one of the slots of the setting wheel S and the operator then turns the pointer back to 0. When in this set condition spring 6 is raised out of contact with spring 5 by the tip of the arm A. The latter in its backward rotation when being set also carried with it the setting wheel S and the ratchet wheel R, to which is fixed the rubber pin C; the pressure of the latter on the spring 3 is therefore removed and spring 3 rises into contact with spring 4, spring 1 also contacting with spring 2. If the operator now closes the ringing key, the escapement of the selector will be actuated by its magnet, current flowing in a local circuit from the $\pm$ pole of pole changer through the two outer springs on the tip side of the ringing key, magnet M, springs 2 and 1 of selector and back to negative pole of pole changer. Under the influence of its coil spring the selector is rotated one notch, and spring 6 returns into contact with spring 5. This closes a circuit from the positive side of pole changer through springs 5 and 6, 4 and 3 to sleeve, out over the external circuit, back to tip and through the ringing key contacts to the $\pm$ pole of pole changer. The passing impulses thus sent out over the circuit from the $+$ side of the pole changer operate the selecting relays out on the line, the negative impulses operating the escapment of the selecting device. When the pole

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changer has sent out 3 passing impulses, the next negative impulse releases the final tooth of the selector, which brings the latter back to its normal position.

31 The contacts 3 and 4 now being open no more passing impulses are sent to line, but through contacts 3 and 1 the selector automatically reverses the circuit, thus sending ringing impulses to line. The local circuit of the selector magnet is also broken between springs 2 and 1. Since three passing impulses have been sent to line the relays at station 1, 2 and 3 have been operated and station 4 placed in circuit. The ringing circuit may now be traced from the ± pole of the pole changer through ringing key and left side of line and back over sleeve, through ringing key outside spring, springs 3 and 1 of selector to negative pole of pole changer. To ring a second time it is unnecessary again to set the selector before pressing the ringing key.

32 If desired, the passing key may be used to select a given station in place of the selector. It will be noted that pressing the passing key simply places the main battery B across the line in passing direction which will operate the relay at station 1. After pressing the passing key three times the circuit will be extended to No. 4 and the bell at that station may be rung with the ringing key. The dial selector is used simply to save time and ensure accuracy in the selection of high numbers.

33 *The Restoring Key.*—When the restoring key is operated the main battery is bridged between the tip side of line and ground. As previously explained in Par. 17, this restores to normal whatever selecting relays have been latched past, besides being employed in connecting the line between central and the seat of trouble if such exists on the line. If she is unable to restore the line by the usual means, which would be the case in the event of an open circuit or short on the line, she can do so with the restoring key. Hence, in case of trouble that prevents the operation of the line beyond a certain station, the seat of trouble is revealed at or just beyond that station.

34 *Line Control.*—It will be noted from the description so far given that the proper operation of the bells and relays on the line does not depend on any contacts under the control of the subscriber, who is at all times unable to prevent the operator from handling the line as she sees fit. The bell may be rung with the hook up or down.

35 *Looping In.*—It is evident from the description so far given that it is necessary to lead the two main line wires through the subscriber's station, i. e., there are four wires at each telephone, two in and two out. To save the expense of running two pairs of wires from the main line in cases where the telephone is situated at some considerable distance, the selecting relay may be placed at the junction with the main line, in which case a slight modification of the wiring, and the addition of another condenser, obviates the running of more than two wires to the subscriber's station. Fig. 273 shows the arrangement of the circuit where the selecting relay is placed on the junction pole.

By a slight change in the instrument circuit, this system may be used with a common talking battery.

Some special tests for the location of line troubles are possible with this system. These are as follows:

Measuring Resistance.—If the exchange is not provided with a bridge testing set, a high resistance dead beat volt meter with double scale (3 volts and 150 volts) will be found very convenient for this pur-

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pose, in any case a volt meter should be used when testing ground resistance at the substations. To measure a resistance with voltmeter use the 3 volt scale, and connect the voltmeter directly in series with two new dry cells. If the deflection is over 150 measure the deflection for each cell separately and add the two together. Suppose the total deflection is 148. Now connect the unknown resistance in series and again note the deflection. Suppose it is 65. The resistance of the 3 volt winding of the voltmeter, which must of course be known previously, we will suppose is 205 ohms. We can now calculate the resistance by the following rule: Multiply the resistance of the voltmeter by the difference between the two deflections and divide the product by the second deflection.

$$\text{Thus } \frac{205 \times 83}{65} = 262 \text{ ohms.}$$

Measuring External Resistances.—(a) To measure the end instrument ground resistance. Instruct the operator to select past the end of the line and unlatch the grounder, thus putting a ground on left. Take out the fuses or heat coils at central and then measure the resistance between left and the central office ground. Suppose that there are 10 instruments on the line, and the line is No. 12 iron 7 miles long, and the total resistance measures 680 ohms. The resistance of the low winding of the grounder is about 125 ohms, and the series windings in left have a resistance of about 20 ohms, the line resistance being about 35 ohms per mile = 245 ohms. The total known resistance is thus 125 + 200 + 245 = 570 ohms; the ground resistance is therefore 110 ohms.

(b) To test the insulation resistance between left and right, unlatch the grounder as before; this opens the metallic circuit between left and right.

(c) To measure the total line resistance select the end phone without ringing the bell, the line resistance will then be the total resistance less the phone resistance (1000 ohms approx). The line resistance thus determined includes the resistance of all the series windings of the selecting relays, (about 45 ohms per station, left winding 20 and right winding 25).

(d) To measure the substation ground resistance, instruct the operator to ring the proper station, then remove the fuses, and connect the voltmeter alone between left and the central office ground. The deflection noted is caused by the local cells in the telephone; when a station has been rung on, the local cells are connected in series with the transmitter and primary between the left line and ground, (when the receiver is on the hook).

These cells, however, may be run down to some extent and to be able to determine the deflection caused by the standard cells, insert them in series in the circuit so as to make them oppose the other pair in the phone. The terminals of the voltmeter must of course, be reversed. If the two local cells were not run down much, there will be little deflection of the voltmeter.

Suppose the original deflection was 48 and the second reading noted is 7. Obviously, if the two standard cells had been in the circuit in place

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of the local phone cells when taking the first reading, the deflection would have been 48 + 7 = 55. The external resistance is

$$\text{Thus } \frac{205 \times 93}{55} = 346 \text{ ohms.}$$

To find the net ground resistance, subtract from this figure the resistance of the transmitter and primary (about 40 ohms) and the resistance of the left line and series windings up to the station being tested.

Voltage of Local Cells.—(e) From the readings taken in the previous case the condition of the local telephone cells may be readily estimated by comparison. Thus, if two new cells would have given a reading of 55 and the second reading was 7, the percentage loss in volts since the cells were installed is

$$\frac{7 \times 100}{55} = 12.7 \%$$

Locating Partial Grounds With Voltmeter.—First determine whether ground is on left or on right. To do this pass to the end of the line without unlatching grounder, remove fuses and then test resistance between ground and each side of line. Suppose ground is on left. Instruct operator to restore line to normal. Again remove fuses and measure the resistance between right and ground. Then have the operator pass station 1 and test again. Assuming that the ground is beyond the second station, the ground resistance should now be about 5 ohms greater owing to the fact that the right line series winding at station 2 has been placed in the circuit instead of the left line series winding. If the total ground resistance is high it is possible that the difference in the voltmeter reading can be hardly noticed, and therefore the voltmeter should be read as accurately as possible. If the next station be passed and the test repeated, the resistance will increase another 5 ohms, and so on down the line until the ground is reached. As soon, however, as the station beyond the ground is placed in circuit the resistance will suddenly increase by at least 25 ohms, since the test current must pass over the right line to the station beyond the ground, and after crossing over to the left line through that station must then return over the left line to the source of trouble.

The location of a ground on the right line may be determined in a similar manner, in this case, however, test the resistance from left to ground. The resistance instead of increasing will decrease 5 ohms for each step until the ground is reached, when the resistance will show a sudden increase of 30 ohms or more.

An easier way of locating a ground on right is to test the resistance from right to ground instead of from left to ground and step down the line as before described. Before the ground is reached, the test current must pass from right line across to left and then from left back across to right through the station just beyond the ground. Thus, as soon as all the stations between central and the ground are passed, the resistance between right and ground will then decrease by about 2000 ohms, as the test current will go direct over right to ground.

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CHAPTER VII.

BATTERIES.

If a piece of zinc and one of carbon are immersed in the proper solution and connected together with a wire, a current will flow from one to the other. When this occurs, the zinc will be eaten up by the solution with more or less rapidity. Other substances besides zinc and carbon may be used, but these are the substances in common use.

The simple cell as alluded to above is shown in Fig. 274. Here it will be seen that the current flows from the zinc through the liquid to the carbon, while outside of the liquid the current flows from the carbon to the zinc. The zinc is termed a minus-electrode, while the carbon is termed a plus-electrode. If the carbon and zinc are not connected by a wire, no current will flow, and the zinc will be very slowly consumed; the circuit would then be termed "broken" or "open." The term "open circuit" battery is applied to any form of battery not intended for continuous work, when the circuit is "open" most of the time. In other words, an "open circuit" battery is intended for intermittent use, such as that in an ordinary telephone, while for a switchboard which is continually in use, what is known as "closed circuit" batteries are used.

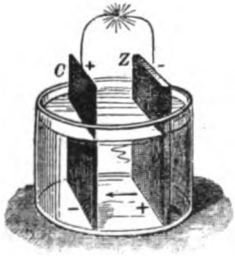


Fig. 274.



Fig. 275.

The part of the circuit outside of the batteries connecting the two poles or electrodes, is termed the external circuit, while the circuit through the liquid of the cell is termed the internal circuit.

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

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

For instance: if three cells giving two volts each are placed in series so that they give a total of six volts, and the internal resistance of

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each cell is one ohm, making a total of three ohms for the entire battery, and the external resistance, or the resistance inserted between the wires connecting the two outside terminals of the three cells equals three ohms, then the current flowing will be six volts divided by three ohms internal resistance, plus three ohms external resistance, the result being one ampere.

The internal resistance of a battery for telephone work should be as low as possible, and the chemicals should destroy the gas which collects on the negative electrode as soon as formed.

When the battery becomes inoperative, due to the collection of gas at the negative plate, it is said to be polarized. This is prevented in the sal ammoniac battery, shown in Fig. 275 by the addition of a substance called peroxide of manganese, which is formed into bricks and placed around the carbon. This chemically unites with the gas formed in the cell, disposing of same. The same action is secured by making the carbon electrode much larger than the zinc.

The sal ammoniac battery polarizes very quickly, but when given a rest it just as quickly recovers. This cell is therefore fairly well suited for telephone use, but is now almost universally supplanted by the dry battery. A standard dry battery is shown in Fig. 276. There are many shapes and sizes, but the general construction and details are the same.

The outside or containing vessel consists of a sheet of zinc of suitable form, with a zinc bottom. This is lined with blotting paper. A piece of carbon is placed in the centre of the cell. The blotting paper is saturated with a chemical solution, and the space between the blotting paper and carbon is filled to with a mixture of powdered carbon and manganese. The battery is filled to within one inch of the top with this mixture; the remaining space is filled with asphaltum, or a substance resembling sealing wax, and the battery is ready for use.

Dry batteries give 1 ½ volts per cell, and deliver on a short circuit from 15 to 20 amperes.

The use of batteries of exceedingly high amperage should usually be avoided in telephone work, and it is generally found that batteries delivering a very high initial current do not possess lasting qualities, and consequently those possessing a reasonable amount of amperage are more satisfactory for telephone work, as a great quantity of current is not desired, while long life is necessary.

There is absolutely nothing to be gained by making dry batteries at home, as the cost of the raw material and labor will amount to double what a cell is sold for, in addition to which commercial batteries will be found more satisfactory in every way; but as an illustration of the process of making dry batteries and for those who desire to experiment along this line, the following method is given:

A form should be made of hard wood of the dimensions desired. Some sheet zinc, No. 10 or 11 gauge should be wrapped around the form and cut to fit, allowing ¼ inch lap to form the seam. Solder, taking care not to get any solder on the inside of the can.

The best solution for soldering zinc is muriatic acid in which is dissolved all the zinc possible. Take one ounce of muriatic acid and add a few scraps of zinc; as soon as the solution stops gassing it can be used. Apply to the zinc by means of a small stick or rag, and solder with a clean hot iron.

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Place the can on a piece of the zinc, and mark around on the inside of the can; cut this out to form the bottom of the can, making a snug fit. Solder the bottom in the can about ⅛ inch from the edge.

A card board lining should now be made. Cut a piece of card board or blotting paper that will fit tightly in the bottom of the can, then line the can taking care that there are no bare places left, and allowing a ¼ inch lap. Have the lining come entirely to the top of the can. A binding post can be soldered to the can, which forms the zinc or negative element of the battery.

The positive pole consists of an ordinary stick of carbon, such as is used in arc lamps or a carbon from an old dry cell can be used if first boiled in water and allowed to dry. If electric light carbon is used a piece should be selected about 6 ½ inches long, or long enough to project ½ inch above the top of the can. The top of the rod should be filed flat on two sides, and a binding post attached, by boring a hole through the carbon and using a machine screw with washer. Soak the end of the carbon to which the binding post is attached in paraffine.



Fig. 276.

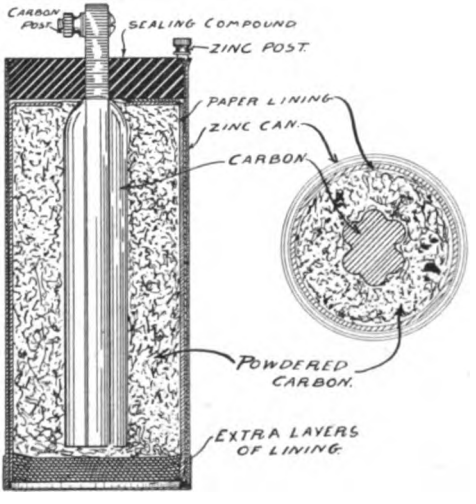


Fig. 277.

The chemicals required are powdered carbon, peroxide of manganese and chloride of zinc. The powdered carbon and manganese can be purchased for five or ten cents a pound. The chloride of zinc should be in powdered form, and costs from twelve to fifteen cents. If a small quantity only of the powdered carbon is desired, take some electric light carbon and break it up into small fragments. These can be powdered up and used with good results.

Make a solution of the chloride of zinc: take four ounces of water and put in it all the chloride that will dissolve; add to this 1 ½ ounces of water; then add two or three tablespoons full of sal ammoniac. Sufficient of this solution should be poured into the can to thoroughly saturate the blotting paper. The can should then be turned upside down and the surplus solution allowed to run out.

The carbon rod is then held in the middle of the cell, while a mixture of equal parts carbon powder and manganese, which has been sprinkled

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with some of the solution used to saturate the blotting paper, is tightly packed around the carbon. The tighter this packing is, the better the batteries will be. Great care should be taken not to break through the lining and that none of the black powder comes in contact with the zinc can, as this will render the batteries worthless. Fill the batteries with the mixture until within ¼" of the top.

Now shake out any loose carbon which may be on top, and carefully turn down the blotting paper all around. Take care the blotting paper does not touch the carbon, as this would be fatal. The blotting paper should be at least ⅜ inch away from the carbon all round, and the blotting paper should be clean. It should not have any black crumbs on top of the paper to come between it and the zinc. After turning down the paper, fill the batteries with sealing wax level with the top of the cell.

The complete cell and method of assembling same are shown in Fig. 277. Most of the materials can be obtained from old batteries. A little experimenting to get the best solution will be necessary to get good results.

As previously stated, there is nothing to be gained by making dry batteries except that it will afford an opportunity for experiment, and in cases of necessity, such as when a special shaped cell is desired, it is sometimes convenient to know how to make them.

Dry batteries are of the open circuit type, and should never be used for switchboards or other heavy service where they are constantly in use, as they will soon fail and once exhausted are practically worthless.

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 sal ammoniac. This serves very well in an emergency case where it is necessary to get a telephone in working order quickly. In case no sal ammoniac is at hand, a strong solution of salt and water may be used. Do not *punch* the holes in such a manner that the zinc case is forced through the paper lining. Cut the holes clean, using a hand drill and ⅛ in. drill.

As dry batteries are principally used in telephones on rural country lines, it is well to caution our farmer friends not to leave their receivers off the hook, and it is well to caution them against half hour conversations, which are not at all conducive to the building up of the strength of the battery.

On farmers' lines where each subscriber pays for the maintenance of his instrument, it is well to instruct the person using the telephone how to replace the batteries in case some become exhausted, particularly 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 instructed to do this, it will very often save the exchange manager a long drive in the country and the attendant trouble and expense.

Another form of cell known as the "Fuller" is often used in long distance service. For a number of years the Bell companies used two of these cells in connection with each long distance instrument. They give highly satisfactory results. The complete cell is shown in Fig. 278.

The negative electrode consists of a heavy piece of zinc in the shape of a cone, to which is connected a heavy copper wire. The positive elec-

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trode is a flat carbon plate. The jar is provided with a wooden cover. A porus cup is provided in which the zinc is placed. The solution for use in this battery is as follows:

Sodium Bi Chromate	6 oz.
Sulphuric Acid	17 oz.
Soft Water	56 oz.

The Sodium Bi Chromate should be powdered and dissolved in the water. Then add the acid slowly. Never pour the water into the acid and be careful not to let any of the acid get on the clothes or in the eyes. The mixture will become very warm, and should be made in an earthen ware vessel and not in glass, as glass is liable to crack. If the Sodium Bi Chromate is not obtainable, Bi Chromate of Potash may be used.



Fig. 278.

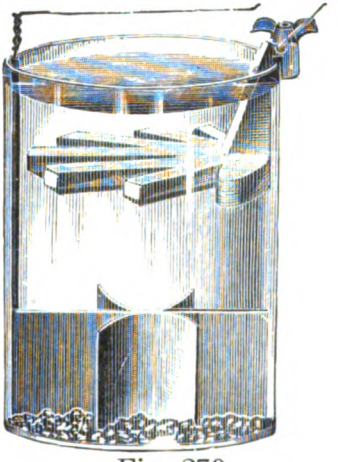


Fig. 279.

The porous cup should be placed in the centre of the glass jar, and the space outside the porous cup filled with the solution until it reaches within one inch of the top of the cup. A teaspoonful of mercury together with the zinc is placed in the porous cup, which is then filled with water, to which is added two teaspoonfuls of common salt. Bring the wire from the zinc up through the hole in the centre of the wooden cover and put same in place. The carbon is then lowered through the slot, and the cell is ready for use.

The jars are about 6 inches in diameter, and 8 inches in depth, and the carbon plates are 4 inches wide, about 8 inches long and ¼ inch thick.

Before putting the zinc in place, it and the wire should be amalgamated by rubbing with sulphuric acid and mercury, so that the bare copper is not exposed to the solution. This prevents the copper from being eaten away.

The Fuller cell gives a little over two volts. Two of these are used in connection with a telephone instrument. The current from one cell is eight amperes. For switchboard work three of these cells may be used, and give good results.

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The carbon plate seldom needs renewing, but the zinc will be gradually eaten away. When the solution becomes almost black the cell is exhausted and the solution should be thrown away. By re-amalgamating the zinc and adding new solution, the battery is again ready for use.

Sometimes the action of the cell can be temporarily renewed by stirring the solution and adding a little water.

Clean carbons, when renewing cells, by scrubbing them with hot water and sand. Remove all the white accumulation before replacing.

Another variety of cell known as the "Gravity," "Crow foot," or "Bluestone " battery is shown in Fig. 279. This battery is widely used in telephone work, and is suitable where a small but constant current is required. This cell possesses a very high internal resistance, and for this reason is not a very efficient battery, but owing to its long life, cheapness, and ease of setting up, it is often used in connection with operator's transmitters on small magneto switchboards.

The positive electrode consists of three sheets of copper fastened together at the middle. To this is attached an insulated wire. The zinc is in the form of a crow foot, with a lug by which it is suspended from the edge of the jar.

The batteries are set up by first unfolding the copper and placing same in jar, as shown in the illustration. Sulphate of copper, or as it is commonly called, "blue stone," is then put in the jar to a sufficient depth to cover the copper. The blue stone should be clean and free from lumps. It is well to wash it thoroughly before putting it in the jar. The jar is then filled with water until the zinc is covered about ½ inch. The wire from the copper should be bent in a sharp loop at the edge of the jar to keep the copper in place and immediately attached to the zinc for ten or fifteen hours before the battery is desired for use.

If the battery is desired for immediate use, a teaspoonful of sulphuric acid may be added to the solution, or teaspoonful of common salt. Do not do this if it can be avoided.

The solution attacks the zinc and produces zinc sulphate. This is a colorless fluid lighter than the copper sulphate which is formed at the bottom of the cell. The dividing line between the two solutions should be half way between the top of the copper and the bottom of the zinc. The dividing line may be easily detected, one solution being a deep blue, the other almost colorless. This accounts for the name, "Gravity Battery," as gravity keeps the solutions apart. The dividing line between the two solutions is termed the "blue line."

If the blue solution rises too high in the cell, some of it may be drawn off by inserting a rubber tube or siphon to the bottom of the cell. The amount of the solution withdrawn should be replaced by adding water on top. If the battery is in constant use, the blue rises upwards. The reverse is usually the case, however, in which case some of the sulphate from the top of the cell should be taken out and replaced by clear water.

Before setting up the battery the top of the jar should be wiped off, and when the zinc becomes so corroded that it represents a black appearance and large accumulations of crystals appear, it should be taken out and cleaned. The lumps can be removed by striking them with a hatchet. Wash well before replacing.

The copper will not need any attention. Occasionally a few more crystals of the blue stone may be dropped in the battery.

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A wooden top can be cut to fit the batteries, and this will prevent evaporation to a considerable extent. This can be held in place by tying a piece of tape around the crack between the top and the jar, which will effectually exclude the air. Varnish this top with Shellac or Asphaltum.

When renewing batteries, save the top solution from the old cells and put it in the new ones. This will start the chemical action immediately, and it will not be necessary to short circuit the cells and wait for the action to take place.

A gravity battery gives very nearly one volt. The internal resistance is much higher than other types, but the cells are easy to set up, cost little to maintain, and with proper care will run from six to eight months without a complete renewal.

Three cells are sufficient for the operator's transmitter on magneto switchboards and it is better to keep the transmitter always in circuit, as a small but constant flow of current keeps the battery in better condition than if it is left open circuit part of the time.

A very successful method of making comparative tests of batteries is shown in Fig. 280. The relay can be made from a pair of ringer spools wound to a resistance of about 50 ohms, or a pair of 80 ohm ringer coils will do.

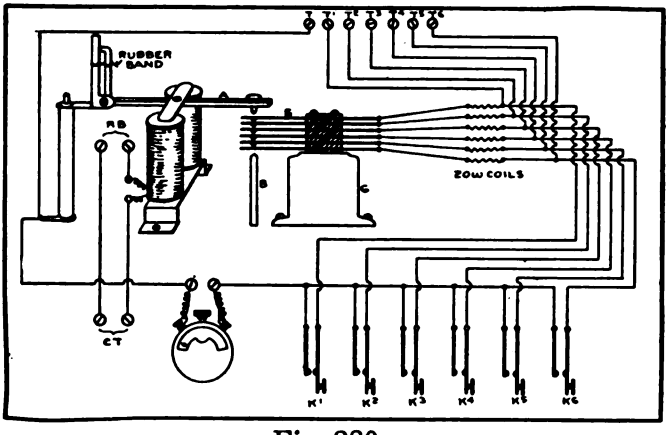


Fig. 280.

The armature A is constructed as shown, and is normally held up by a rubber band. Contact springs, S may be made from old hook springs so mounted that when the relay is operated, all the points will be closed together and a circuit formed from T through armature A to springs S, through the 20 ohm coils and back to T1, T2, T3, etc.

The Terminals CT should be connected on ordinary clock shown in Fig. 281 which is equipped with a pasteboard dial upon which is mounted three contact pieces of copper which occupy the positions shown in the figure. These pieces are connected together and form one side of a circuit, the other side of which formed by the clock body itself.

The minute hand is adjusted by bending so that it will contact on each copper piece in passing, thus closing the circuit for three periods of five minutes each, per hour.

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To terminals RB, connect a battery of sufficient strength to properly operate the relay. A direct current electric light circuit may be used for this provided sufficient lamps are placed in circuit to prevent the relay from sparking.

The Batteries under test are connected in pairs. The carbon side of all the pairs connect together and to T. The zinc side of each pair goes to T1, T2, T3, etc.

Push buttons as shown at K1, K2, etc, as provided for testing the voltage of the different sets, using the voltmeter placed in circuit as shown.

The clock is started and it will be seen that each set of batteries is short circuited through a resistance of 20 ohms (which represents the average resistance of a transmitter and Pri. coil) three times an hour for periods of five minutes each.

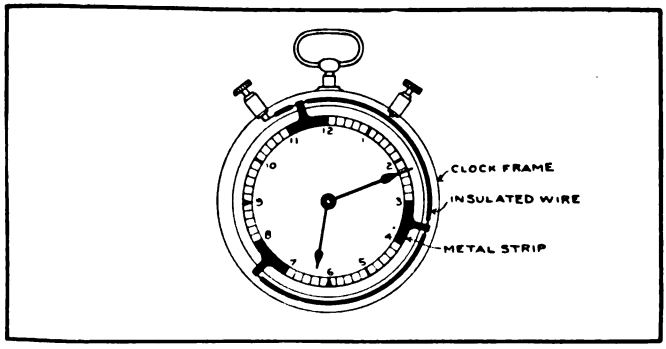


Fig. 281.

The test may be said to equal the use the batteries would get if placed in a telephone used three times per hour for five minutes each time.

The voltage reading should be taken every day at the same time, and immediately before the clock circuit is closed or open. Always test for voltage under exactly the same conditions each time.

When any set falls below 1 ½ volts it is assumed the cells are unfit for service. By this method their life can be ascertained in a few weeks, instead of a year which would probably be necessary if an actual service test were made.

Usually only two or three makes of battery will be tested at once, in which case only two or three springs are necessary on the relay.

The clock may be allowed to run continuously or may be stopped at night. The latter method more nearly approximates service conditions.

Fig. 282 shows a chart for recording the test. This also shows the record of a test of five groups of cells, from which it will be noted that quite a difference between different makes exists, set No. 1 having nearly twice the endurance of set No. 5.

While this test is illustrated as applied to dry cells, any form of battery may be tested in the same manner or two different types may be compared for relative efficiency.

In telephone work the series arrangement of cells is generally used, this is shown at A Fig. 283.

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To find the voltage of a set of cells in series multiply the voltage of a single cell by the number of cells. This shows that an increase in voltage is accomplished by putting the cells in series, but the quantity of current or amperes, remains the same.

Sometimes a multiple arrangement is to be preferred, as shown at B Fig. 283. When it is necessary to temporarily use dry cells for an operator's transmitter at switchboard, this arrangement will serve until the regular cells are recharged and will last much longer than if only two cells are used. With the multiple arrangement the quantity of current or amperes is increased, the voltage remaining the same as if only two cells were used.

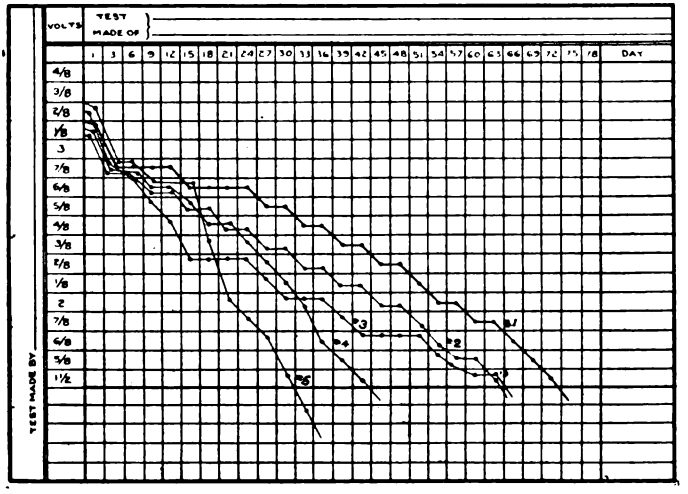


Fig. 282.

To find the current and voltage given by a number of cells in multiple, multiply the current of one cell by the number of cells, this gives the current (Amperes). The voltage will be that of as many cells as there are in series. For instance as shown in the figure, three sets of two cells each are used, and the voltage is that of two cells, the amperage that of 6 cells.

If three sets of *three* cells each were used the voltage would be that of three cells, while the amperage would be the same.

One bad cell in a group of batteries will affect the current and voltage of the entire group. This is because the internal resistance of a cell increases as it becomes exhausted. The power of the good cells is therefore used up in trying to force a current through it. It is therefore poor policy to use old and new cells together, as the old cells are liable to render the combination useless.

A bad cell as shown at C in the figure will render the output of the three good cells practically nothing, care should therefore be taken to test batteries carefully for both voltage and amperage before connecting them up. Cold weather often affects the amperage of dry cells and allowance should be made for this when testing them. After placing dry cells in a moderately warm room, the amperage will rise. The cold has no permanently bad effects.

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The wires used for connecting cells together should be sufficiently heavy to withstand handling, and to be of low resistance. No. 14 is a good size. This should be rubber covered.

The use of spirals or pig tails in the wires connecting the cells should be avoided; while these look nice they introduce an extra and unnecessary resistance in the circuit.

The method of attaching the wires to the cell binding posts should receive careful attention. At D Fig. 283 is shown the right way. When the nut is tightened, the tendency is to wrap the wire more tightly around the neck of the post. The wrong way is shown at E, when the nut is tightened it tends to unwrap the wire and thereby cause a loose connection.

When the type of binding post shown at F is used, the wire should be doubled and twisted as shown at G. The wrapping serves to hold the covering in place, and doubling the wire prevents it from being cut or broken by the screw in the binding post. A good form of connector for dry cells is shown at H.

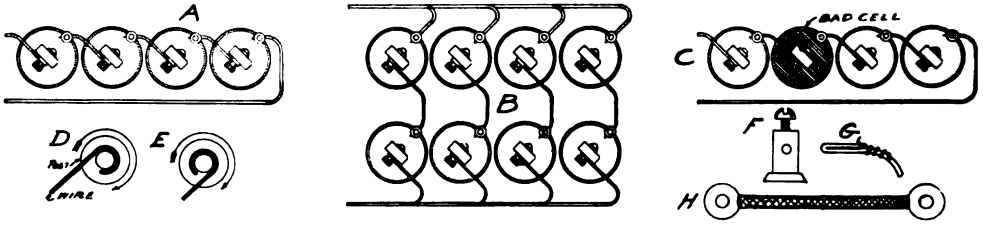


Fig. 283.

In running wires from the batteries to the apparatus, never put both wires under the same tack or staple. Have the wiring as short as possible and free from splices, and when the battery is used for talking purposes and the wires parallel others for any distance. twist the battery wires together to eliminate any disturbance due to induction.

Always put the batteries in a box or other receptacle, where they will be protected from dust and the connections from accidental breakage.

The batteries for a switchboard should never be placed in the board, nor should the operator's transmitter batteries be placed very far away, as the least resistance in the transmitter circuit, the better. Have every connection tight to avoid sputtering noises and loss of power. Look over the batteries at least once a month, and a great deal of trouble will be saved.

Dry batteries should not be purchased and kept on hand, as they deteriorate with age. Do not secure them more than 30 days before they are needed for use, and be sure they are fresh, and just from the factory.

The various batteries so far described are principally used in connection with intermittent work, and with the exception of the gravity or blue stone, and the Fuller cells, should never be used when a constant current is required. When a constant flow of current is required, some form of closed circuit battery is necessary. There are several forms of closed circuit batteries on the market, these being of the caustic soda type using copper oxide and zinc elements. While these are suitable for use where constant current is desired, still for telephone purposes especially in con-

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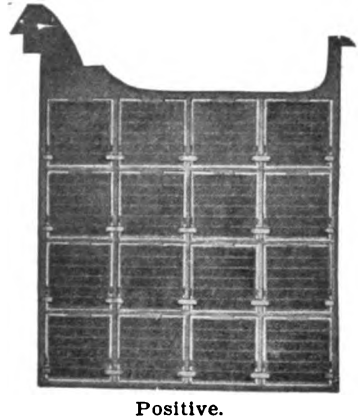
nection with central energy or common battery exchanges, nothing but storage batteries should be used, and nothing but storage batteries have come into extended use for this work.

As the storage battery reaches the exchange completely constructed, it is useless to enter into the deails of manufacture, except to state that the plates are formed from lead. The negative plate consists wholly of spongy lead, while the positive plate is lead peroxide—these are shown in Figs. 284-285. The positive plate is usually formed from a solid sheet of lead in which holes or ridges are punched or rolled, into these the material forming the plate is forced, the ridges holding the same in place.



Negative.

Fig. 284.



Positive.

Fig. 285.

The solution used is pure sulphuric acid and water. Storage batteries give a current slightly over two volts each. It does not matter how large the cell is, voltage always remains the same. Increase in the size, however, increases the amperage.

The storage battery is the same as a primary battery in operation, except that after it is discharged it can again be recharged without the addition of any new material, or without changing the plates, by sending a current through it in the proper direction.

The smaller types of storage cells have two plates, while in the larger cells several positive and negative plates are used. Where there are more than two plates in one cell, there is always one more negative than positive plate, the arrangement being such that one positive is placed between two negatives.

Four small storage cells are shown in Fig. 286. When the cells are received from the manufacturer they should be carefully unpacked, and any excelsior or other foreign substance removed from the plates and the jars carefully cleaned. The manufacturer usually furnishes complete directions for setting up the battery and giving the initial charge, which varies with the different makes. The directions accompanying each battery should be rigidly adhered to.

The best method of connecting cells is to join permanently the terminals by burning the lugs together. In small cells this is not necessary, as bolts are provided by means of which the terminals can be properly connected. Nothing but lead bolts should be used for this purpose; brass

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and iron bolts will corrode and cause local action. The smaller cells are set up with the plates in pairs as shown, which renders all connections unnecessary.

Each cell should be placed on a wooden base painted with insulating paint and should rest on glass or porcelain insulators as shown in Fig. 287. The cells should be placed near a window or other opening so that dust cannot blow in but the gas, which escapes when charging, will have an outlet. Fig. 288 shows how cells are usually mounted.

After the cells are set up the electrolyte should be added. It is important that this should not be put in the jars until just before the current is turned on.



Fig. 286.

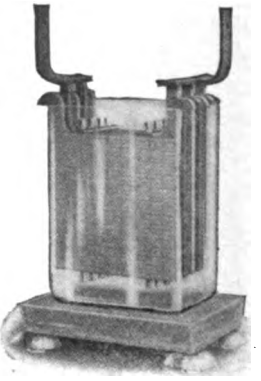


Fig. 287.

If possible the electrolyte should be procured ready mixed from the manufacturer of the batteries, but if this is impossible, a mixture of pure sulphuric acid and water should be used. This should have a specific gravity of 1.200 on the ordinary hydrometer scale, or 23 Baume scale.

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 charging wires in a glass of electrolyte, where, if they are separated about ½″ 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″ 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 it should be borne in mind

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that the initial charge should be as continuous as possible: that is, after once starting the charge it should be continued to the end. Provision should be made to accomplish this if possible, if not, it will take a great deal longer to charge. During the last hours of the first charge the solution will apparently boil and the specific gravity rise. If above the figures given by the maker, water should be added, while, if the specific gravity does not exceed the given point, some diluted sulphuric acid of specific gravity of 1,400 should be added. It is well in giving the initial charge to slightly over-charge the batteries.

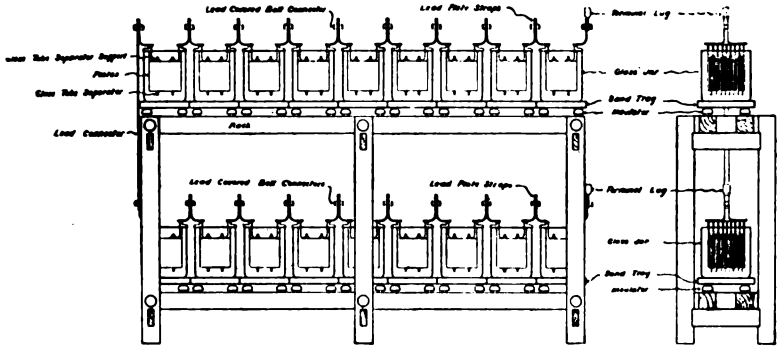


Fig 288.

Storage batteries can be charged by means of any direct current lighting circuit by connecting lamps, as shown in Fig. 289, which shows a small cell. The arrangement is the same for any size battery except more lamps are used. In the case of 110 volt circuit, each 16 C. P. lamp may be rated as allowed ½″ ampere to pass. Therefore if the normal charging

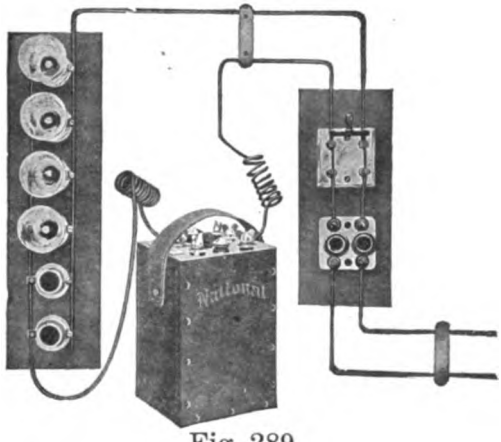


Fig. 289.

rate is 3 amperes, 6 lamps arranged as shown, should be turned on, which will allow 3 amperes to flow through the batteries. It is safe to assert that the charge should be continued at the normal rate until there is no more rise for one-half hour either in the voltage or specific gravity of the cells. The charging should be done often enough to prevent the voltage

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of the cells from dropping below 1 8-10 volts per cell. Never allow the battery to stand completely discharged, or repeated overcharging will be necessary to bring the cells up to normal voltage again.

Every two weeks charging should be continued two hours longer than is necessary to reach the maximum voltage and specific gravity.

The specific gravity is a more reliable indication of the state of the charge than is the voltage. If the specific gravity is made uniform for all cells when fully charged, tests made on one cell will be sufficient for the specific gravity, as well as the voltage of the entire battery.

For the sake of uniformity, the specific gravity should be read at a temperature of 70 deg. F., and should be made 1.200 or some number slightly in excess of this. Allowing for fluctuations due to variations in temperature, the specific gravity should not be below 1.195 nor above 1.215. Heat will lessen the specific gravity, while cold will raise it. Any changes beyond the ranges given by the manufacturers are indications of faults.

Use water and not acid to replace loss of solution due to evaporation, and under no circumstances allow the electrolyte to fall below the tops of the plates.

Observations of the specific gravity should be taken at the beginning and at the completion of the charge. The specific gravity and voltage of each cell in the battery should be observed at least once every week, at the end of the charge, with the charging current on. Each cell should read 2.5 volts when fully charged.

The boiling of the electrolyte causes a fine spray to arise. This loss should be replaced by water, and two or three times a year it may be necessary to add a little acid. This may be done by mixing the acid to the same specific gravity as the solution, and adding sufficient to keep the fluid level at the proper point. Never put undiluted acid in a cell, and if for any reason the purity of the acid is in doubt, it should be carefully tested.

*"The impurities which are most likely to be in the acid and for which tests may be readily made are: Chloride or free chlorine, the salts of iron, copper, mercury, and the nitrates. Particular care should be given to the securing of assurance of the manufacturers, that the acid is manufactured from pure sulphur and not from iron pyrites.

"The tests for chlorine or chlorides is made by taking a test tube partially filled with electrolyte and dropping into it a few drops of solution of nitrate of silver. If chlorine or its salts are present a curdy white precipitate of silver chloride will appear. This chloride turns to a violet tint on exposure to light. If the clear liquid be poured off this white precipitate and strong ammonia be poured on it, it will dissolve.

"Test for iron: The presence of ferrous salts in the electrolyte is shown if a dark blue precipitate falls down upon the addition of a solution of prussiate of potassium. If ferric salts are present in the electrolyte, a solution of yellow prussiate of potassium will give a blue tint. Consequently, if in two test tubes, one of which contains a few drops of yellow prussiate and the other a few drops of red prussiate, a little electrolyte be poured, the two tests can be made at once. If the impurities be present in small quantities there will not be a precipitate formed, but a bluish-green coloration will result.

*American Telephone Journal.

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"To test for copper, place a small quantity of electrolyte in a test tube and add an excess of strong ammonia. If copper is present a bright bluish tint will be given to the mixture. If in large quantities a chocolate-colored precipitate will be formed upon the addition of a solution of yellow prussiate of potassium.

"If mercury is present, the mercurous salts will give an olive-green precipitate with iodide of potassium. To test for nitrates, some diphenylamine should be dissolved in a small quantity of concentrated, chemically pure, sulphuric acid and placed in a test tube. A small quantity of electrolyte is then dropped carefully in the same tube. If a blue color results, nitrates are present. Traces of nitrates are very objectionable, as they cause a suprisingly rapid deterioration of the plates."

In the mixing of electrolyte none other than distilled water should be used.

It is best to charge the batteries during the time of the greatest load. The specific gravity of the elctrolyte will rise rapidly when nearing the completion of the charge. The normal point of this and the voltage will, however, be learned by experience, so that any abnormal gain in the cell will be quickly noted.

The plates should be closely watched to see that they do not curl out of shape thereby short circuiting each other. If any of the cells should show marked difference in specific gravity or voltage, see if any substance has fallen between the plates. If so, it should be removed with a stick or glass rod.

A cell that has been short circuited will require an extra amount of charging after the trouble has been removed, by charging it separately from the others.

The color of the plates is a valuable indication as to the condition of the cells. The negative plates have a light slate color, while the positive plates are a dark chocolate brown. Lightness of color is an indication of insufficient charge. White coating on the plates will seriously interfere with the action of the cells, and should be removed by overcharging and discharging two or three times or by continuing the charge at one half the normal rate for two or three hours after the batteries are fully charged. Sometimes when batteries are put into service a white deposit will accumulate on the plates. This will disappear after a few repeated overcharges and should not cause any alarm.

At least 80 per cent. of the energy in a good storage cell is obtained before the voltage falls below 1.9 volts. The discharge should never be carried below 1.8 volts. Never under any circumstances allow the battery to become completely exhausted. If it is allowed to stand in a completely discharged condition for two or three days, it will be seen that the capacity of the cells will be materially lessened, and repeated overcharges will be necessary to restore them to their normal condition.

If for any reason it becomes necessary to move the batteries or take them out of service, they should be charged fully, and the acid should be siphoned out of the jars. The cells should then be immediately refilled with clear water, and discharged at the normal rate until each cell shows less than one volt. The plates should be removed and allowed to dry, and the acid can be stored for use until the cells are again set up.

Suitable testing equipment should always be on hand. A double scale voltmeter reading to 3 volts on one scale and of sufficient range on the

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other for reading the entire voltage of the battery, together with a Hydrometer reading from 1.15 to 1.25, a glass rod for working about the plates, and a battery lamp for the purpose of examining the plates is very desirable.

For large systems it is well to prepare a charge record sheet, as shown in Fig. 290. By keeping a constant record of the amount of charge

CHARGE

STORAGE BATTERY REPORT

_____ EXCHANGE WEEK ENDING _____ 190__

TYPE OF CELL _____ NO. OF PLATES _____ NORMAL CHARGING RATE _____ AMPERES

SUMMARY OF DAILY READINGS

	Time of Charge		Mean Rate of Generator Output	Total Generator Output	Estimated Plant Output While Charging	Estimated Battery Charge	Estimated Battery Discharge	Maximum Rate of Plant Output	Test Cell Readings. Cell No. _____			
									Specific Gravity of Solution		Voltage	
	Start	Stop	Amperes	Amp. Hrs.	Amp Hrs.	Amp. Hrs	Amp. Hrs.	Amperes	Before Charge	After Charge	Before Charge	* End of Charge
SUNDAY												
MONDAY												
TUESDAY												
WEDNESDAY												
THURSDAY												
FRIDAY												
SATURDAY												

WEEKLY READINGS OF EACH CELL. DATE _____ 190__ TIME _____ A.M. P.M.

Cell Number	1	2	3	4	5	6	7	8	9	10	11
Specific Gravity Before Charge											
Specific Gravity After Charge											
Voltage Before Charge											
* Voltage at End of Charge											
Height of Solution Above Plates											

TEMPERATURE OF AIR _____ °F. TEMPERATURE OF SOLUTION _____ °F.

WATER ADDED _____ DATE _____ 190__ CELL NUMBERS _____

CELL (NUMBERS) EXAMINED WITH LAMP _____

CELL (NUMBERS) WORKED ON _____ (STATE NATURE OF WORK)

REMARKS _____

* Voltage readings to be taken when cells are fully charged and the charging current flowing through at the normal rate.

CORRECT _____ WIRE CHIEF

Fig. 290.

together with the other details as shown in the different columns, a complete record of the performance of the batteries is always at hand, and any slight discrepancies can be noted and remedied.

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In the column *"Time of Charge,"* should be placed the *time* at which the charging current was applied, and stopped.

In column *"Mean Rate of Generator Output,"* place number of *amperes of charging current.*

In column headed *"Total Generator Output,"* should be placed the total *ampere hours,* obtained by multiplying the mean rate of gen. output, by the number of hours of "Time of Charge."

The *"Estimated Current Output While Charging"* is the estimated amount of current used by an exchange during the time of charge, and when a discharge ammeter is in circuit with the storage battery, this can be ascertained by observing the highest and lowest readings of the discharge ammeter, and then taking a figure which will represent the mean rate. From this, the total output while charging can be estimated by multiplying this number by the time the charging machine runs.

The *"Estimated Battery Discharge"* is from the time at which the charging was stopped on the previous charge, to the time the present charge was started.

"The *Estimated Battery Charge"* is the total generator output minus the output while charging.

"The *Maximum Rate of Plant Output"* is the highest reading of the discharge ammeter while charging.

A test cell is selected at the beginning of each week. It is best to begin with cell No. 1 and continue in regular rotation, until every cell is tested every day during the entire week. Have specific gravity and voltage before and after charge noted in columns provided for the purpose, and once a week, take readings of all cells and note specific gravity and voltage in the columns provided. The other records, such as temperature of air, temperature of solution, etc., are self-explanatory.

A discharge sheet as shown in Fig. 291 should be provided with space for taking the rate of 24 hours discharge. During this time the regular charge and discharge of the batteries should proceed without interruption.

A reading is taken of the discharge ammeter every 15 minutes. The Total Plant Output is found by adding all the ampere readings together and dividing by 4, which gives the total ampere hour discharge.

"Battery Discharge" is filled in by taking from the time stopped charging on the previous charge, to the time started charging on the day the discharge readings are taken.

The *"Mean Rate of Discharge"* is found by multiplying the entire discharge in ampere hours by 4, and dividing by the total number of readings taken of discharge ammeter during the test, which is 96.

The *"Excess Charge"* equals the battery charge minus the battery discharge to the time the charging current is turned on.

The *"Total Generator Output,"* or "Total Charge Current Output" is the charging rate times the number of hours the charging current is turned on.

The *"Battery Charge"* is the total generator output minus the output while charging.

The *"Plant Output While Charging"* is the total of the readings of the discharge ammeter while charging.

The *"Percentage Excess Charge"* is the excess charge divided by the discharge.

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The record should be taken beginning at the end of the regular charge on the 10th and 25th of each month.

DISCHARGE

STORAGE BATTERY REPORT

_____ EXCHANGE DATE BEGUN _____ 190__

TYPE OF CELL_____ NO. OF PLATES_____ NORMAL CHARGING RATE _____ AMPERES

DISCHARGE AMMETER READINGS FOR 24 HOURS
READINGS TO BE TAKEN EVERY 15 MINUTES

TIME	A.M. OR P.M.	AMPERES	TIME	A.M. OR P.M.	AMPERES	TIME	A.M. OR P.M.	AMPERES	TIME	A.M. OR P.M.	AMPERES
TOTALS											

TOTAL PLANT OUTPUT_____ AMP. HRS. TOTAL GENERATOR OUTPUT_____ AMP. HRS.

BATTERY DISCHARGE _____ AMP. HRS. BATTERY CHARGE_____ AMP. HRS.

MEAN RATE OF DISCHARGE _____ AMPERES PLANT OUTPUT WHILE CHARGING_____ AMP. HRS.

EXCESS CHARGE_____ AMP. HRS. PERCENTAGE EXCESS CHARGE _____

GENERATOR STOPPED_____ GENERATOR STARTED_____

REMARKS_____

NOTE—This form to be filled in beginning at end of regular charge on the 10th and 25th of each month

CORRECT _____ WIRE CHIEF

Fig. 291.

Once a year, starting with the battery fully charged, a complete discharge record should be made, reading the discharge ammeter every 15 minutes. The battery discharge should be continued until one of the cells shows 1.9 volts. The charging current should then be immediately turned on, and continued until the batteries are fully charged. From

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this yearly peformance of the cells the general condition of the batteries can be determined.

To find the percentage efficiency of the battery:

Find the percentage of the excess charge in the usual manner, and divide it into 100. The result equals the percentage efficiency.

Before beginning this annual test, it is well to fully charge the batteries to 2.5 volts per cell, care always being taken to take the readings with the battery current on. Then reduce the charge to ½ the normal rate, and continue charging until the cells read 2.5 volts, or as near this as it is possible to bring the cells.

The readings for the battery voltage must be taken with the current actually charging the batteries. At the beginning of reading, the charging rate should be equal to the normal charge rate plus the amount indicated on the discharge ammeter.

Starting with cell No. 1, test each cell for voltage and specific gravity every 15 minutes, and proceed in regular order until the last when cell No. 1 will again be the test cell and so on to the end of the test. The testing record should be carefully preserved, as it will show the actual condition of each cell, and also show the efficiency of the battery as a unit.

Where the discharge test is continued through a period when no one is on duty in the exchange, arrangements should be made for constantly keeping the record, as it is of the utmost importance that the action of the cells should be carefully noted.

* In a 400-line exchange six miles from its main office in a town where there is no day lighting circuit, a pole changer is used to supply ringing current. The ordinary closed circuit cell only lasted five or six months, and when it did give out it did so at the worst possible time. By using a portable storage battery a great deal of dirty battery work has been done away with, and better service furnished for both the pole changer and for the switchboard transmitters.

There is no noise in the operators' sets and no cross-talk. The storage cell is charged every three or four days at the main office of the company where there is charging current available. A portable type, 40 Ampere Hour cell is used, and of course, there are two, one being used while the other is being charged.

The exchange troubleman charges them, and it is found that it costs less by this method than to use four-gravity cells for each transmitter and an Edison-Lelande cell on the pole-changer. The service is also better and more reliable.

This method should find more extended use in private branch exchange work, as portable batteries have now reached such a state of perfection and are furnished at such low cost that no objection can be raised to their use. The first cost scarcely exceeds the cost of 6 gravity cells and one cell for the pole changer, while the saving in space is considerable.

† The simple storage cell, or accumulator herewith described, is made of either cast or bored lead plates, as suits the maker, and has a capacity of about ten ampere hours. A large sheet of lead one-eighth inch thick is cut into plates four inches by five inches in size, care being taken to leave a terminal or lug projecting from the plate, as shown in Fig.

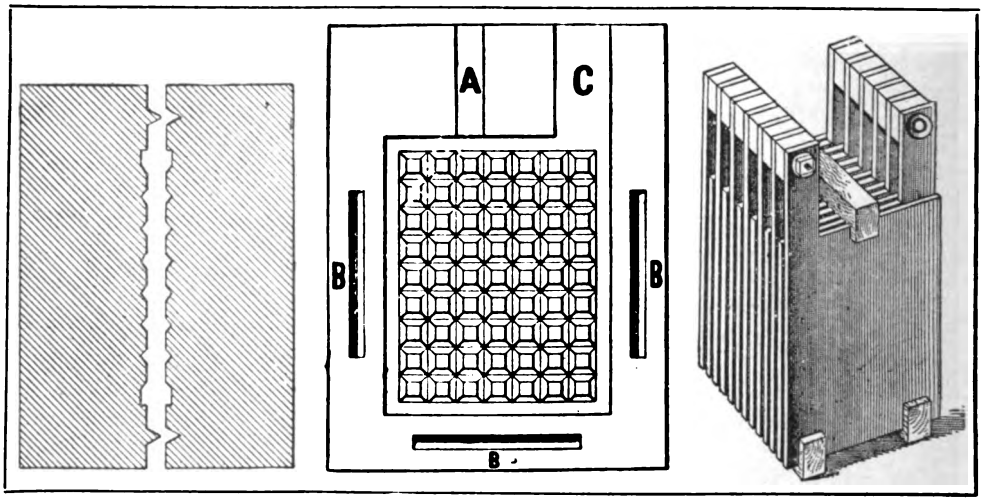
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*American Telephone Journal. †By permission—Scientific American.

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292. It is always best to have the terminals too long rather than too short, for the reason that there are certain gases continually rising from the acid in the jar, which in time may eat away the brass bolt that clamps the plates together; hence the plates make bad connection. After the required number of plates have been cut from the sheet, they are ready to be bored. In order to avoid burning or bruising the plates, clamp them two at a time between two pieces of thin wood in a vice and proceed to bore the holes which should be one-quarter inch in diameter. If the holes are counter-sunk on both sides of the plates after boring, they will hold more firmly.

Probably one of the best simple methods of casting plates is that given by Percival Marshall, which is explained below:



CROSS-SECTION OF MOULD. PLASTER OF PARIS MOULD. ASSEMBLED PLATES.

Fig. 292. Fig. 293. Fig. 294.

On the smooth flat surface of a slab of plaster of Paris, about six inches by eight inches by two inches, or of a sufficient size to allow an inch or more margin around the grid, carefully make the lines as shown in cut, and with a fine chisel proceed to cut away the plaster around the squares, beveling it off to a depth of 1-16th inch. The sectional drawing (Fig. 293) will probably give a better idea of how the plaster and grooves should be cut. A pouring hole is made at C, which also forms the lug of the plate; an air hole at A; and a few grooves at B, or at such places as would be convenient for aligning the other half of the mould when fixing in position for casting. To complete the mould, an exact counterpart of the half already obtained must be made. This can be easily accomplished by filling up all the grooves (except those marked B) with heated paraffin wax, pressing this into position with the fingers, and scraping it off level with the surface of the mould, thereby forming a pattern of one half of the grid. When the wax is cool and perfectly hard, the whole impression may be removed by inserting a pin at one corner. Again the grooves of the mould must be filled with paraffin wax and scraped clean and level with the surface. The first impression should then be laid on its back on the wax at present in the grooves, and the whole mould covered with a thin coat of shellac, care being taken to keep

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the wax pattern in position. After building a wall of wood or heavy cardboard around the mould to a convenient height, the plaster can be poured in. When the plaster becomes hard and dry, the mould may be taken apart, all wax removed, the halves wired together, and the casting of the plates proceeded with. In casting the plates, pure lead and an absolutely clean ladle must be used. Thirteen plates (six positive and seven negative) will be needed to make the cell, but it is better to cast a few plates over and above the number required, as some of them might be defective.

After the plates have been made they are ready to be pasted. The positive plates are placed on a smooth slab and pasted with a stiff mixture of red lead and sulphuric acid (one part acid to two parts water). The negative plates are pasted in the same manner except that a stiff mixture of litharge with the same proportion of acid and water is used instead of red lead. The paste can be pressed into the recesses of the plates quicker and better by using a wooden spatular. In order that the paste may hold tightly, the plates are carefully pasted on both sides. When pasted, the plates should be stood up in a warm place to dry. After they have become dry and hard, they should be assembled in such a way as to allow one positive plate always to be enclosed between two negative plates, and the lugs should be accurately fastened together with long brass bolts, as shown in Fig. 294. In order to keep the plates well and evenly separated, square lead washers are used for the lugs, and wooden racks, well boiled in paraffin, for the plates.

Rubber-coated wires can either be fastened under or soldered to the bolts, after which all connections on the lugs must be throughly paraffined. The whole mass must then be immersed in a jar containing a mixture of sulphuric acid and water (four parts water to one part acid.)

Some little care must be exercised in connecting up the cell, to make sure that its positive pole is joined to the positive pole of the source of supply, and, as the E. M. F. of the primary battery or the dynamo is in constant opposition to that of the accumulator, it is necessary that this E. M. F. exceed that of the latter in order that the current shall flow.

An easy way to determine which is the positive pole, if the source of current is from an electric light circuit or a dynamo, is to hold the two wires in a glass of water, as previously described, or testing paper may also be made by immersing strips of white blotting paper in a thin solution of white starch, and, after drying again dipping them for a few seconds in a solution of one-half ounce of potassium iodide in one pint of water. A piece of this paper, moistened and having the two wires applied to it half an inch apart, will turn red at the negative pole and violet at the positive.

*The time taken to charge a storage cell depends entirely upon its capacity. For instance, if the cell has a capacity of 10-ampere hours, and the charging current is two amperes, the time taken for charging equals 10 divided by 2, which is 5 hours. The formation of the plates in the first place takes a much longer time—anywhere from 25 to 50 hours, with this amount of current. When the plates are fully formed, the positive will be dark chocolate color, and the negatives a dark slate color. The cell will boil and gas freely, and the voltage will reach 2 ½ while the charging current is on. These latter conditions always occur with a fully charged cell. By all means never short circuit, i. e., spark or

*The capacity of the cell affects the charging *rate* more than the duration of charge.—Ed.

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flash the terminals of a storage battery together to see if it is charged; this is very detrimental, and will in most cases ruin any accumulator. A very handy way of roughly telling whether a battery is fully charged, or run down, is to connect a two-volt lamp across any single cell to be tested. If the lamp glows brilliantly, the cell is fully charged, but if it gives a dim light, the cell is discharged. When the voltage reaches 1.7 under discharge, the cell is empty and should be recharged at once. A small pocket voltmeter is best for testing the amount of charge in the cell. The voltage should be taken while the cell is discharging.

The E. M. F. of a lead storage cell is 2 volts, and its amperage (capacity) varies in proportion to its size. Each square foot of positive surface gives about 6 ampere hours; therefore, if you have a battery of four inches by five inches in size and containing thirteen plates (six positive and seven negative), the ampere would equal:

$$\frac{4 \text{ in.} \times 5 \text{ in.} \times 2 \text{ sides} \times 6 \text{ plates}}{44 \text{ sq. ins.}} \times 6 \text{ amp. hrs.} = 10 \text{ amp. hrs.}$$

If it is desired to charge any number of storage cells connected in series, i. e., the positive pole of the first joined to the negative pole of the second, etc., multiply the number of cells by 2 ½, which will give the voltage of the charging current required.

Storage batteries are usually installed with a sufficient number of plates to furnish current for the present needs of the exchange, but the jars or tanks are made of sufficient size so that additional plates may be installed as the exchange increases in size. For this reason when the battery is installed care should be taken to secure jars large enough to permit of the addition of enough plates to give a current output to operate the ultimate number of subscribers the switchboard will accommodate, for at least 36 hours.

It is customary to install two sets of batteries, and to provide duplicate means of charging same, so that one set may be charged while the other is being discharged. While this undoubtedly is the safest plan, as a reserve battery is always at hand, still with modern equipment and methods of charging the additional expense would seem unnecessary as a properly maintained battery seldom becomes inoperative and modern methods of charging and sources of current supply are very reliable. After the exchange has outgrown the initial capacity of the battery and it becomes necessary to add more plates, with some makes of battery it is advisable to re-arrange the old plates so as to form complete cells with them, and use the new plates to form complete cells. New and old plates do not always work well when placed in the same cell owing to a difference in the capacity of the plates, the old ones being undercharged when the new one would be fully or over charged.

In the majority of common battery systems it is customary to ground one pole of the battery. This is done to secure the operation of trunk signals between different exchanges and for the purpose of preventing electrolytic action, which is a form of decomposition or corrosion which results at joints and terminals when the current flows *from* the + pole to the — pole. If the lines should be + and the — pole of the battery becomes grounded, this action would sometimes result, so it is obviated by permanently grounding the + pole of the battery, therefore the leak, if any, from the lines, is always in the opposite direction from that which

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would tend to produce a corrosive action, as this action is present at the + pole only.

The resistance of the leads or main wires between the storage battery and the power board where the battery is connected the various switchboard circuits should be very low, as any resistance in this circuit will cause cross talk. Stranded Conductors are preferable.

This resistance in repeating coil systems should not exceed .07 ohm, including the resistance of the batteries which is but a fraction of this.

In retardation coil systems much higher resistance leads can be used, but in either case the resistance should be kept as low as possible.

The current carrying capacity of the leads should at all times greatly exceed the maximum amperage that the switchboard will ever require. If the resistance is kept within the limits above given, it will be found that in most cases except where the battery is very near the switchboard apparatus, ample carrying capacity will be obtained.

The methods of computing the battery capacity for a switchboard depend upon the type of equipment, etc. The traffic conditions of course directly determine how much work the battery must do, so before the exchange is installed a careful study must be made to determine the greatest load, duration of same, and the other details. This data must be given the switchboard manufacturer who can then easily determine the battery capacity necessary.

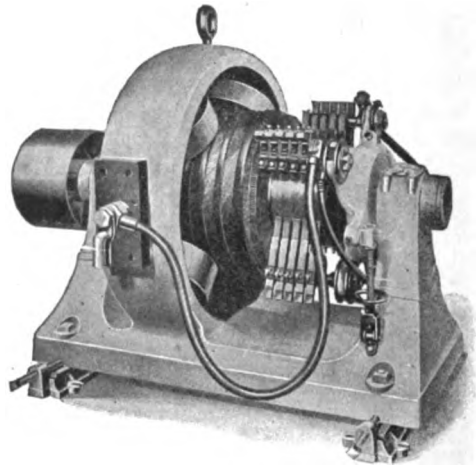
The capacity of a storage battery is usually rated in ampere hours, that is a 40 ampere hour battery would deliver 1 ampere for 40 hours, or 2 amperes for 20 hours, etc. Batteries are usually rated by the manufacturers as having a certain discharge for 8 hours, 5 and 3 hours, never exceed the discharge limits as given. It will be found in most cases that the charge rate is the same as the 8 hour discharge rate, that is if the 8 hour discharge rate is 3 amperes per hour the normal charging rate will be 3 amperes. The nearer a battery is operated within the normal charge and discharge rate, the better condition it will remain in. When the battery is not discharged enough it suffers almost as much as if it is under or over charged.

The method of charging from a direct lighting circuit, as outlined in the first part of this chapter, is exceedingly wasteful and only practical when a cheap source of current supply is available and a battery of small capacity is used.

A very successful method of charging is by means of a motor-generator, the motor being driven by a direct or alternating current of from 100 to 500 volts, and being belted or direct connected to a generator of proper voltage and amperage to charge the battery. The voltage of the generator must always be 2.5 $\times$ the number of cells in the battery. The amperage must be the charging rate of the cells, plus the discharge of the cells at the time they are being charged if they are charged while in service. As an illustration: A dynamo for charging a battery of 11 cells, whose charging rate is 3 amperes, and which are discharged at the rate of 1 ampere, would have a voltage of about 30, ($11 \times 2.5 = 27.5 =$ voltage of battery at full charge) and an output of at least 4 amperes, (3 amp. normal chg. rate + 1 amp. disc.) A regulating resistance is usually inserted in the field circuit of the charging machine so that the charging current can be varied at will.

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A very satisfactory method of charging is to use a gas or oil engine, connected to the dynamo. This method is desirable where there is no available current supply for driving a motor, or where the cost of current to run the motor would be excessive. Care must be taken when securing this outfit to have a special engine, or equip the dynamo with a fly wheel and use a loose belt, so that a uniform speed will be obtained, as an irregular running dynamo may cause noise in the talking circuits. In all cases the charging dynamo should be especially adapted to this work. It should have a large commutator with many segments so that a smooth uniform current will be produced.



Western Electric Co.'s Charging Generator.

The Mercury Arc Rectifier is peculiarly adapted for charging the storage batteries commonly used in telephone exchanges, where only an alternating current service is available. It creates no disturbance on the telephone circuits. The efficiency is high, the first cost and maintenance low, and in addition only a small floor space is occupied. The General Electric Company has recently placed on the market a complete line of sizes up to 50 ampere capacity, especially adapted to meet the requirements of telephone exchanges.

The rectifiers are constructed to give any D. C. voltage required by the batteries. When charging 17 cells, as is commonly done in telephone practice, the rectifier will have an average efficiency considerably greater than a motor generator set of the same capacity. This efficiency is in the neighborhood of 60% and is maintained at partial as well as at full load. If the direct current is delivered at a higher voltage, viz.: when more cells are charged in series, the efficiency will be correspondingly higher. Hence, where possible, it is advantageous to charge two or more batteries in series. This rise of efficiency with the voltage is due to the fact that the voltage drop in the rectifier tube is constant, and therefore the percentage loss is less, the higher the voltage.

The essential properties of mercury vapor as utilized in the rectifier, and the action of the tube is simple, and may be described as follows:

In an exhausted tube provided with a mercury cathode and one or more anodes, mercury vapor in the ionized state is supplied from the

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cathode, when the latter is in the state of excitation. This excitation is maintained only as long as current flows between the cathode and one or other of the anodes. With the ionized vapor present in the rectifier tube, current can flow only as long as the mercury terminal is negative. If, the polarity of the voltage is reversed so that the mercury electrode becomes positive, the excitation, and therefore the flow of current ceases. The two anodes of the rectifier are connected to the A. C. source, and the cathode through the load to the neutral point between the two anodes. Therefore, with the cathode excited, current will flow alternately between the cathode and each anode in turn, the cathode always being negative. Unless some means is provided to maintain the arc over the zero point of the wave, the cathode will lose its excitation, and the tube will not be continuously operative. In order to maintain the arc, the current from the line, after passing through the arc and load, returns to the other side of the line, through a reactance. This reactance is charged during the greater part of each wave, and discharges through the zero point, thus maintaining the arc until the other anode has become positive, when the action is repeated with the second half of the rectifier active. Hence, there is a continuous flow of current in the same direction at the cathode and through the battery, although in other pars of the circuits, the polarity changes. The reactances, in discharging during the zero point of the wave, reduce the fluctations in the rectified current. Thus, a true continuous current is produced with only a small loss in transformation.



Fig. 295.

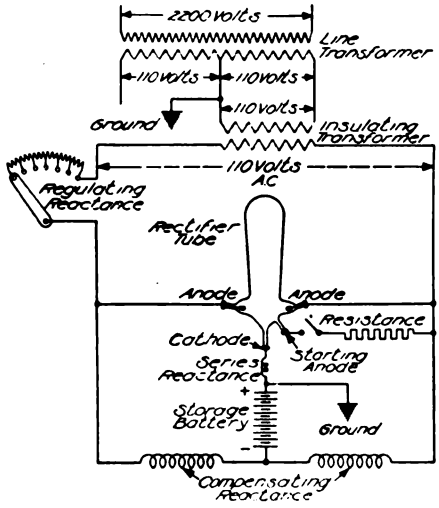


Fig. 296.

The tube is started by a slight rocking motion, which bridges the mercury between the cathode and an additional starting anode, connected through resistance to one of the A. C. lines. When the tube is returned to a vertical position the mercury bridge breaks, and a small mercury

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vapor arc is started which furnishes the initial cathode excitation and enables the current to pass between the cathode and working anode.

The magnitude of the current pulsations depends on the amount of reactance in the circuit. Since in telephone work, an extremely smooth current is required, more reactance is used than is common when the rectifier is employed for other purposes.

Fig. 295 shows one type of rectifier panel used for telephone installations. The panels can be readily operated in parallel with one another or in parallel with other direct current sources, such as engine driven generators or motor generator sets. Fig. 296 shows the circuits of the complete outfit.

An occasional renewal of the tube is the only operating expense aside from the current required.

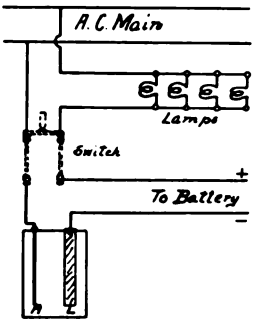


Fig. 296a.

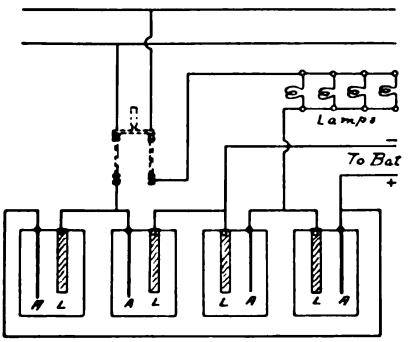


Fig. 296b.

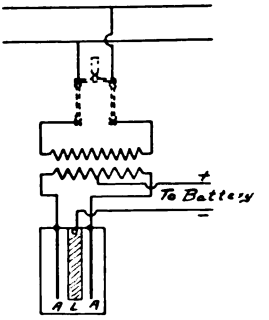


Fig. 296c.

Another type of rectifier consists of a solution in which is immersed one lead and one aluminum electrode. The alternating current is caused to flow in series through the battery and the two rods. This arrangement, which is termed a chemical rectifier, possesses the peculiar property of allowing the current to pass only in one direction, and therefore the alternating current is changed to a direct current pulsating in character.

The aluminum rod is always positive (+.)

This device may be connected directly to an alternating current, a regulating resistance being placed in series with the battery to regulate the current. When this is done considerable energy is wasted, it is therefore customary to use a transformer, and step down the alternating current to about the voltage of the battery, and then pass it through the rectifier. A choke coil may be used for this purpose but is not so efficient.

Fig. 296a shows the connections of a chemical rectifier when connected directly to the A. C. Mains. To protect the rectifier and limit the amount of current flow, lamps are placed in circuit as shown.

Ordinary 6 × 8 battery jars may be used. The solution being 2½ lb. each, sal ammoniac and common salt, dissolved in 6 gal. water. The aluminum (+) electrode is a rod ⅜ in diameter and long enough to reach 5 in. into the solution. The lead (—) electrode is a 1 in. square rod, or sheet of lead ¼ in. thick by 2 in. wide.

As this arrangement only utilizes one half the cycles, it is not efficient, and the method shown in Fig. 296b is recommended.

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Here four jars are used, arranged as shown. Sufficient lamps are used to limit the current flow.

A more economical arrangement is shown in Fig. 296c. A transformer is used, which steps the A. C. current down to about the desired voltage. One lead and two aluminum electrodes are used. With this arrangement a very smooth current is obtained, suitable for charging telephone batteries in exchanges using the impedance coil type of circuits. When repeating coil cord circuits are used, this method is liable to produce noise.

If meters are used on this current, a special form is advisable as ordinary types of D. C. instruments read too low on the rectified current.

Care should be taken not to heat the transformer, or to let the rectifier solution become too warm. The latter can be obviated by using a large vessel to hold the solution, and making the electrodes somewhat larger.

With all types of charging equipment using alternating current, some arrangement is necessary to prevent a noise in the battery caused by the uneven current pulsations. These devices consist of coils, or condensers are bridged across the charging mains. When properly designed and installed rectifying devices may be used to charge the battery at the same time it is connected to the switchboard, without any interference in the talking circuits.

The necessary switches, instruments and other equipment for testing the charging current, and the lay out of the fuses for the different circuits from the battery to the switchboard apparatus are described elsewhere. The various arrangements are as numerous as types of switchboards themselves, each installation often being arranged to meet certain special conditions.

The internal resistance of storage batteries is very low, and should form only a small part of the entire resistance in which they are placed.

Other batteries, especially dry cells often increase enormously in resistance as they become exhausted and it is often necessary to know this resistance, when making calculations as to the total resistance of the circuit.

The internal resistance of a battery may be determined by means of a voltmeter and resistance box, arranged as shown in Fig. 297. Proceed as follows:

Take voltage of D with key open; this will be called D. Then depress key, and take voltage which is D_1 Then the resistance X of the cell is:

$$X = r \times \frac{D - D_1}{D_1}$$

r = Resistance of coil used. This may be varied to obtain the best results.

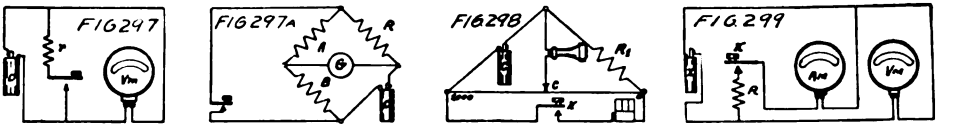
The resistance may be measured with an ordinary Bridge by arranging the connections as shown in Fig. 297a. The resistance X of C is

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

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R = resistance of variable arm, A, one arm of bridge, and B the other arm. The battery is connected to the X posts.

Another method is to use the slide wire bridge which may be constructed from a yard of German silver or copper wire of nearly any guage. This wire is stretched across the scale, as shown in Fig. 298. A known resistance R_1 must be used. Connect battery as shown. A receiver is used in place of the galvanometer, a generator being used for the testing current. Slide contact C along the wire until a point is reached where no sound is heard; then the number of scale divisions on the B slide of the scale, divided by those on the A side, multiplied by the resistance of R_1 will give the resistance of the battery.



Suppose the scale has 1,000 divisions and a balance is found 400 divisions from A. The total length of the scale is 1,000 divisions, and the coil R_1 is 1 ohm. Then the number of divisions from C to B, divided by the number of divisions from C to A and this multiplied by the resistance of R_1 will give resistance of battery. For instance in the example just given:

C to B + 600. C to A = 400. 600 ÷ 400 = 1.5. × 1 (res. of R_1) = 1.5 ohm, res. of bat.

The contact is moved along the wire until no sound is heard in the receiver, then the resistance of the cell is determined the same as for method shown in Fig. 297.

Fig. 299 shows another method, using an ammeter and voltmeter. First measure the voltage without pressing key K. Call this V. Then press key, putting circuit through ammeter A and resistance R, call the voltmeter reading V_1 and the ammeter reading A. Then the resistance of the battery X is:

$$X = \frac{V - V_1}{A}$$

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CHAPTER VIII.

*TESTING TELEPHONE PARTS.

Transmitter Testing.—There are two classes of tests which are applied to transmitters, *a*, routine or factory tests, and *b*, special or research tests. The first class is used in testing the finished product of a factory to make sure that no defective goods are shipped. It is necessarily a rapid test and omits many of the features which would come in if new facts were to be discovered instead of merely passing on the standard qualities of a large number of transmitters. Special or research tests are of so varied a nature that no one description can cover them all. The latter are confined to the laboratories of universities and those manufacturing companies who are striving to better their product.

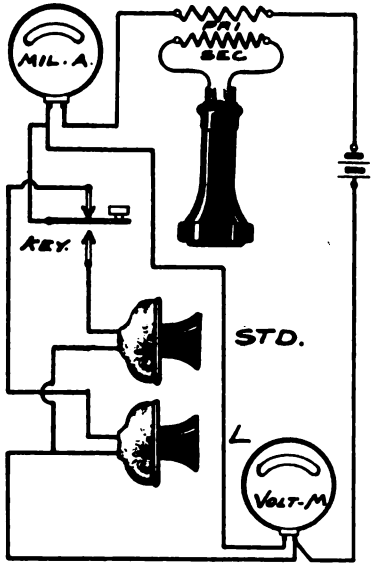


Fig. 300.

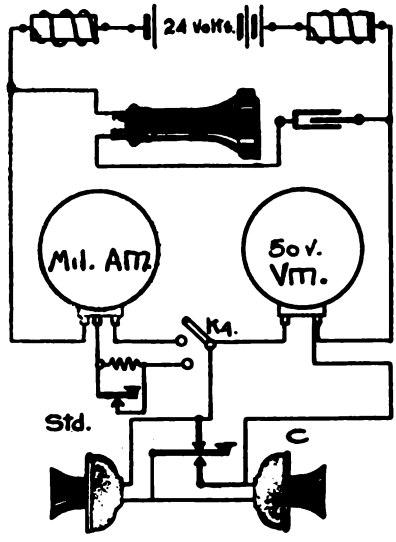


Fig. 301.

Essentially the routine test of a transmitter consists in inserting it into a circuit like the one in which it is designed to operate. The other parts of the circuit are made up of parts of apparatus which are of known excellence.

Figure 300 shows the simplified circuit as used to test local battery transmitters. *Std.* is the standard transmitter, and *L* is the one which

*This Chapter, with the exception of the matter describing standards of Self Induction at end, written by Arthur Bessey Smith, Professor of Telephone Engineering, Purdue University.

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is under test. There is yet no mathematical or other exact test to apply to a transmitter to aid a person in selecting his standard. Out of a large number a careful selection is made by testing the transmitters one against the other, in each case retaining the better one of the two. The ear of a trained observer is the standard. By continually turning his attention to the qualities of all the transmitters he uses, he may become quite expert in detecting those qualities which are not desirable as well as those which go to make up loud and distinct transmission. It is not very hard to make a transmitter which possesses either of these qualities alone, but to be loud without losing in clearness is a very great art.

It will be noted in the figure that the two transmitters are placed in series with a 4-volt battery, the primary winding of a local battery induction coil, and a milliammeter. The receiver is on a closed circuit with the secondary. The standard and the unknown are in series with each other, but one of them is normally shunted by a switch. By operating this switch, the tester can instantly change from one to the other and thus compare them with the most accuracy. It is a noted fact that the eye and ear are very poor in remembering the intensity of the phenomena with which they deal. You can not look at a light on one evening and compare its brilliancy with that of another which you can see on the next night. Yet if you had them side by side you might notice quite a difference. It is even so with sound. The change from one transmitter to the other must be quick, in order that the ear may not forget the loudness and quality. A low reading voltmeter is connected across the transmitter so that its behavior with regard to resistance can be determined. This is one of the valuable aids to the tester in showing up defective assembly and poor carbon. The voltage shown by the voltmeter divided by the current given by the milliammeter gives the resistance, according to Ohm's law. From experience with the regular run of transmitters which the factory is putting out, the tester knows about what the resistance of a good one should be. When a new transmitter has been put in place for test, and the battery circuit closed, the current should rise more or less rapidly, then slow down and stop, fall a little, then rise till it reaches a more or less steady condition. In some cases, the falling back in current may be very slight, only amounting to a stationary position of the needle. But in good transmitters, this peculiar action is rarely missing. After allowing the current to become steady, the tester will talk into it. This should immediately produce a lowering of the current, as when the carbon granules are agitated, they press more loosely on each other and so have a greater resistance.

In Figure 301 is shown the simplified arrangement for testing common battery transmitters. The battery, now 24 volts, feeds to the circuit through two retardation coils having 50 ohms resistance each. The receiver is bridged across the circuit with a condenser in series to keep battery current out of it. Each transmitter in turn is placed across the line with only the milliammeter in series. The battery current is kept in the main circuit consisting of battery, retardation coils, milliammeter, and transmitter. The undulations caused by the transmitter act as an alternating current in the circuit composed of the transmitter, milliammeter, receiver, and condenser. This is similar to the conditions of a short line. By throwing the key, K_4, an additional resistance may be inserted to imitate the condition of a long line. The exact resistance of this coil depends on the severity of the test desired, and may vary with different manufacturers. The resistance of the retardation coils and the voltage

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of the battery also depend on the system, as, for instance, a manufacturer who uses 40 volts on his switchboard, would doubtless use the same on his testing circuit, with retardation coils to suit. The general features of the test are the same as in local battery work, except that the resistance of the transmitter will be higher. Local battery transmitters run from 20 to 35 ohms, while for common battery it is from 50 to 100 ohms. Some people state the resistance of the transmitter at rest. Both the resistance at rest and in motion should be given, though the latter is dependent to some extent on the loudness of the sound which is causing its agitation.

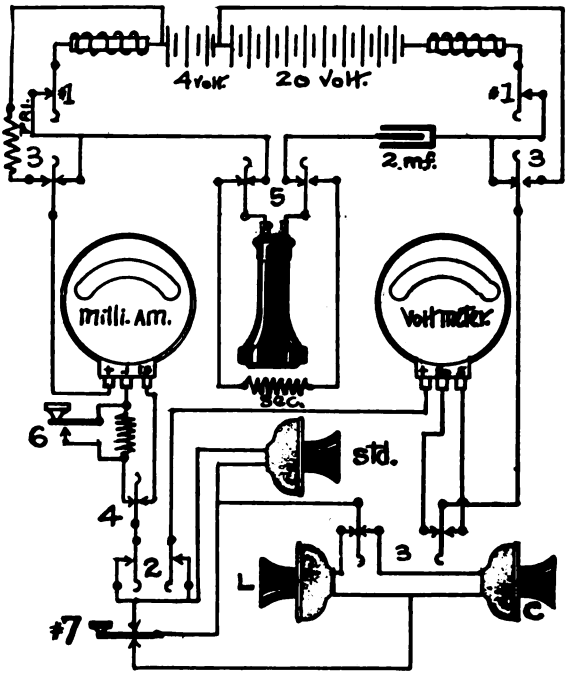


Fig. 303.

Fig. 302 shows how the two circuits of Fig. 300 and 301 are combined into one, with all necessary switching facilities. There are seven keys each operating from one to four springs. The battery is in two groups, 4 and 20 volts each, making a total of 24 volts. In the normal position of all the keys, the battery is on open circuit. Key No. 1 controls the 24 volt battery. It consists of two main springs, each marked No. 1 in the drawing, and operated simultaneously by the same cam. Key No. 2 controls both the main circuit to the transmitters and the plus end of the voltmeter. If we throw keys No. 1 and 2, we get the circuit connection for common battery testing, the same as was shown in Fig. 301. By operating key No. 7, the tester can cut the unknown transmitter out and the standard in.

Releasing both keys puts the circuit again in the position of rest.

Key No. 3 controls the change to local battery testing. It consists of four main springs which are operated at the same time by one cam or lever. They are all marked No. 3 in the figure. The two upper main

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springs do the switching from 4 volts to 24 volts. The lower left spring switches the transmitters, while the lower right spring attends to the voltmeter. Thus with one motion, all the necessary changes are made for changing from common battery to local battery, except switching the receiver and putting in a local battery standard transmitter in the place of the common battery standard. The last operation is easily done as each of the three transmitters is held in a specially designed shell, with spring contacts.

The actual arrangement of keys is shown in Fig. 303. As the keys are all numbered the same in all the figures, further explanation will be unnecessary, except to give a summary of their grouping.

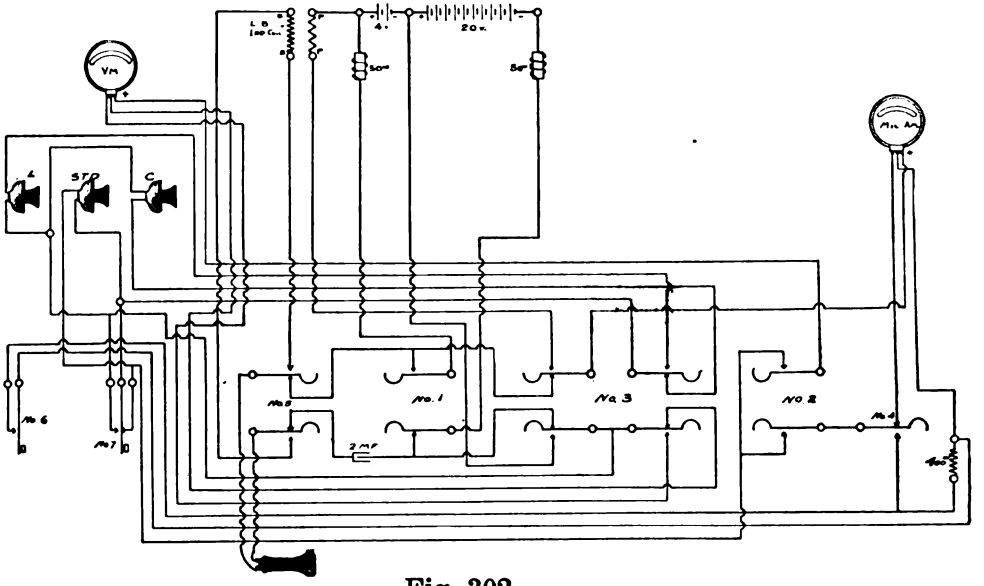


Fig. 302.

For common battery, throw keys No. 1 and 2, leaving all others normal. Operate No. 7 to cut in either the standard or the unknown. Throw No. 4 for line effect.

For local battery, throw keys No. 2, 3, and 5, leaving all others normal. Operate No. 7 to cut in either the standard or the unknown.

Testing the Resistance of Transmitters.—There are two means which are used for the measurement of transmitter resistance, the Wheatstone bridge and the voltmeter-ammeter method. Of the two, the latter is without doubt the more satisfactory. Any steady resistance of reasonable magnitude can be most accurately measured by the bridge, provided the unknown resistance does not contain any electromotive force. The transmitter is on the border line, being sometimes steady and sometimes exceedingly variable. If we take a transmitter which has been out of service for some time, have the room quiet, and measure its resistance thus, we can get very good results with the Wheatstone bridge. The resistance will be rather low, perhaps 10 to 20 ohms in the case of a local battery transmitter. If we now shake it and immediately measure again, we shall find that the resistance has risen and is quite variable, so

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that it is not easy to get a reliable result with the bridge. This is because the particles which before were more or less packed together by the settling action of time and use, are now in a very loose condition and the slightest jar causes them to slide on one another, thus changing the resistance. Since the measurement with the bridge depends on carefully adjusting a resistance, usually with plugs, it takes time. During this the resistance of the transmitter may change very materially. So for all but a very small class of measurements the bridge is not suitable.

In the use of the second plan, a milliammeter is placed in series with the transmitter and a voltmeter shunted around the latter. The former instrument should have a range of from zero to .150 amp. or perhaps 1.00 amp. It should be a good, sensitive instrument, having a very small resistance and negligible inductance. The resistance can be measured on a Wheatstone bridge, taking care that the measuring current goes through it in the direction which will deflect the needle positively and not stronger than the ammeter will stand. A Weston milliammeter with a scale 0-150 milliamperes will have a resistance approximating .3 ohm. The inductance can be best tested by inserting the milliammeter in the primary circuit of a local battery telephone and connecting the telephone to a receiver in another room. Talk to an observer at the distant receiver, meanwhile short circuiting the ammeter and removing the short at irregular intervals. If the impedance is low enough to be negligible, the observer will not be able to tell when the short is on or off.

The voltmeter should be an efficient one, with a scale not very much in excess of that which will be applied to the transmitter. For local battery work 5 volts is a good figure, since 4 volts is what should be applied. For common battery transmitters it may take a 15 volt scale. Be sure that your voltmeter has a high resistance. It should be at least 50 ohms per volt of scale. This makes the 5-volt scale require 250 ohms. 100 to 130 ohms per volt will be better, making the voltmeter from 500 to 650 ohms. If the resistance of the voltmeter is too low, it will make an error in the current reading, which will consist of the current taken by the transmitter plus that taken by the voltmeter. The correction is as follows:

Let I = current reading as per milliammeter.
I_o = true value of current through transmitter.
e = voltage across transmitter, shown by voltmeter.
R_v = resistance of voltmeter.

Then the true current through the transmitter will be

$$I_o = I - \frac{e}{R_v}$$

If the resistance of the voltmeter is high, this correction may be negligible. For instance, there are some voltmeters on the market with a resistance as low as 20 ohms per volt. Suppose that we have a common battery transmitter to test and the scale of the voltmeter is 0-15. This makes its resistance 300 ohms. Suppose we take the following readings, voltage, 5; current, .1167 amp. If we take no account of the correction, we arrive at the transmitter resistance by dividing the voltage by the cur-

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rent, giving 42.9 ohms. If we get the true resistance by correcting for the current taken by the transmitter, we shall have the following:

Voltmeter current, .0167 amp. Transmitter current = .1167 — .0167 = .1000 amp. True resistance, 50 ohms. If a better voltmeter had been used, having 100 ohms per volt, the calculated resistance would have been 49.8 ohms, which is so near the truth as to make closer work unnecessary.

It may be well at this point to consider in detail the features of transmitter resistance. When at rest, the resistance is of some value. Call it R. At first thought one would suppose that when waves of air carrying the voice strike the diaphragm, they would cause a simple, varying pressure on the carbon. That is, the initial pressure would be increased and decreased by a certain value. The crest of the wave in air is the point of maximum pressure, so that it presses hard against the diaphragm. The trough of the wave in air is the point of minimum pressure, so that there is a partial rarification or vacuum in front of the diaphragm. This draws the diaphragm out and makes the pressure on the carbon particles less than it was when at rest. This makes the resistance greater than normal. Let r be the small resistance which is added to the resistance of rest during one portion of the wave, and subtracted from it during the other. In a certain way this is what *does* happen in action. According to this, it would be just as accurate to measure the transmitter resistance with the diaphragm at rest as in motion, for the average resistance would be the same as the steady resistance when at rest. However, when we experiment by taking the resistance of any transmitter while agitated by a steady noise, we find that the average resistance as shown by the voltmeter and milliammeter is higher than when at rest. From this fact we reason that during operation the particles of carbon are kept in motion by the diaphragm and never settle down. Thus the pressure between them is less and the resistance consequently higher. We now review our statement and say that R= average or steady resistance of transmitter while operating. r = small resistance which is added to or subtracted from the average resistance, caused by the changes in pressure.

Of course, the value of r changes from moment to moment with the irregularities of the voice, and is only introduced here to aid in getting an idea of the operation of the transmitter.

The resistance of the transmitter as measured by the means above described consists of several parts.

a. Resistance of wires in the transmitter and all conducting parts, up to the surfaces of the electrodes.

b. Steady portion of carbon resistance, that which never changes. This does not mean the resistance of the carbon in the carbon electrodes, but the resistance of the carbon in the granules and that portion of the contact resistance between the granules which does not change.

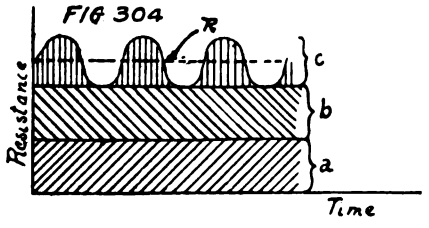
c. The variable contact resistance, which changes from zero to a maximum and back again to zero. It is this portion which does the talking.

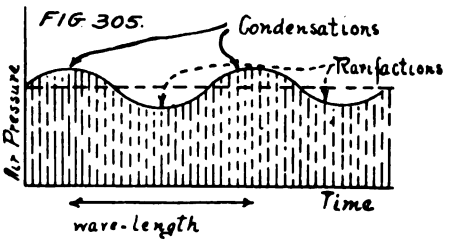
The above analysis of the portions of resistance in the transmitter are better shown by Fig. 304. While operating, the resistance at any instant is composed of three parts, a, b, and c. The last part, c, is the only part which has anything to do with varying the current and so transmitting speech. The figure is not intended to represent any particular sound,

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being any curve in general. The broken line R through the portion, c, indicates the value of the average resistance. The distance vertically from the base line to the line, R, is the average value as shown by the voltmeter test. It is not necessarily true that the resistance varies as much above this line as below it. There are very good reasons for believing that for any steady, musical note, the deviation from the average line *upward* is greater than the deviation *downward*. One reason for this belief is that the pressure-resistance curve for carbon is in form similar to a hyperbola. The other is that such a curve is necessary, if the current in the primary circuit is to be an exact duplicate of the sound wave in air.

The best way to obtain a steady sound for transmitter testing is doubtless the use of a receiver in front of the mouthpiece. Pass a steady alternating current though the receiver, taking it from 60 cycle lighting circuit if no other is available. 2000 or 3000 ohms may be inserted in series to regulate the flow of current if the voltage is 110. The exact value of this resistance will depend on how loud a noise is desired. In order that the best effect may be secured, the receiver must be as close as possible to the transmitter, touching the mouthpiece. If a long series of tests are to be made with the same transmitter, it is best to lash the receiver to the mouthpiece with a few layers of tape. This will close all openings and confine the sound from the receiver, making all of it act on the diaphragm of the transmitter. But if many transmitters are to be tested in succession, merely holding the receiver to the mouthpiece will give excellent results.





The selection and test of the granular carbon used, is highly important. One method of manufacturing the granules is as follows:

Select very pure, hard anthracite coal from which to make the carbon. Cross Creek Lehigh coal is said to be the best, and if trying a new kind, have it analyzed for foreign substances. Look out for slate and anything else, as you want pure carbon. Select clean, shiny, crystalline pieces showing no stratification, no dull appearance of slate, dirt, or other impurities.

Break to size of walnut and inspect again. Finally crush to nearly desired size. Put into graphite crucible and cement the cover on with fire clay. The cover must have a hole in it about half an inch in diameter. Leave this hole open during the first part of the firing till the bulk of the volatile gases has passed off. This is where experience is the only guide, both as to temperature and time. Then plug up the hole and raise the temperature to white heat and hold it there for about 12 hours. The carbonizing must be thorough, for if not, the resistance will be abnormally high.

Let it cool very slowly till cold enough to handle with the hands. Unseal the small hole in cover and pour the granular carbon out. It is not necesssary to remove the cover at each firing, for a new lot of granulated

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coal can be introduced through the small hole. Screen the completed product through two screens. For local battery transmitters, use a No. 60 mesh (60 meshes per inch) and reject all the larger granules which are caught by the screen. Take that which passes through the screen and screen again with No. 65 mesh, rejecting all that passes through. For common battery transmitters screen similarly, but use No. 100 and No. 110 mesh.

A very good way to test the carbon is to put a regular charge of it into a transmitter capsule, electrodes vertical as in use, and pass about one tenth of an ampere battery current through it. Measure current with milliammeter and voltage across the capsule with low reading voltmeter. The main requisite is that the granular carbon shall not change with time. At first there will be some fluctuations till conditions get steady, but if the carbon is good it will settle down to a steady resistance. Fig. 304a shows a local battery arrangement. The cell should stand 4 volts and not hiss, the latter tested by the receiver. Fig. 304b is for common battery granular carbon and should not hiss on one tenth ampere.

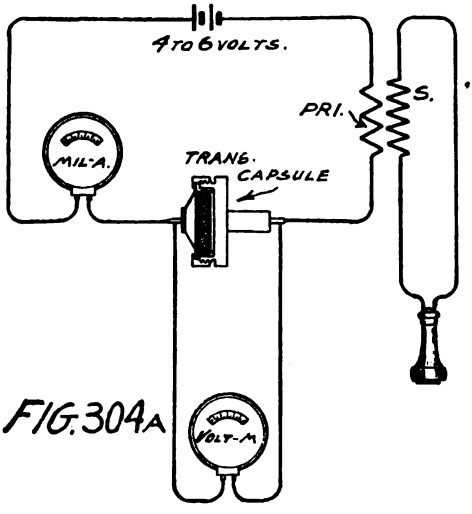


FIG. 304A

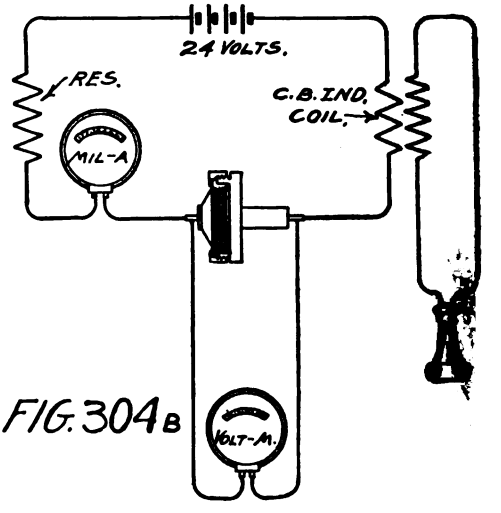


FIG. 304B

Testing of Transmission—Transmission, as used by telephone engineers, is a term applied to the total operation of transmitting the voice from one point to another. It is in many respects similar to transmission as used by power engineers, in that we have an amount of energy in-put at the sending end of the line, and a smaller amount of energy out-put at the receiving end. The ratio of the energy delivered to the energy put in at the sending end constitutes the transmission efficiency. It is the object of good engineering to make this ratio as high as possible. But in the telephone we have an added object of which we must not lose sight. Not only must the sound at the receiving station be as loud as possible, but it must have as nearly as possible the same wave form as the original wave which enters the sending apparatus. This is the same as saying that the conversation must be *clear*. The words which are spoken into the transmitter consist of air waves. An air wave consists of a condensation and a rarification. The former means that the air is compressed slightly more than the normal air pressure as shown by the barometer. The latter means that the air has a slightly less pressure than the normal air

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pressure. A continuous sound means a continuous procession of condensations and rarifications, one after the other, moving at the speed of sound, which is about 1000 feet per second. If we could "freeze" these sound waves into air and measure the pressure at a number of points in a straight line, we could plot a diagram or picture of the wave. We might let a horizontal line represent time and mark off on it from a fixed point the length of time taken for the air wave to pass from one condensation to the next. We can do this by saying that we will let each inch represent 1/100 second. If the sound has about the pitch of one octave below middle C, there will be not far from 125 waves in a second. Then the *length* of the wave will be .008 of a second, which when plotted on our scale (one inch = 1/100 second) will equal .8 inch. If we erect at the various points along this wave length lines which represent by their length the presssure of air at the different instants in the wave, a line drawn through the tops of these vertical lines will show us the form of the air wave. Fig. 305 gives an idea how this may be done. The broken line, P, represents the normal pressure of the air as shown by the barometer. The condensations and rarifications are deviations from this average pressure.

If the sound is a pure, simple musical note, the shape of the wave in air is a sine wave. That is, if the length of a wave be considered 360 degrees, the length of any perpendicular from the broken line, P, to the curve will be proportional to the sine of the angle represented by the number of degrees from zero to the foot of the perpendicular. There are very few purely sinusoidal waves in air, although there are some which closely approximate it. Most sounds have a fundamental or prevailing note with other waves mixed up with it. This is especially true of the voice. When speaking, the fundamental is the general tone of the voice. With men it is lower than with women and children. The voice of a man runs somewhere between 100 and 200 cycles per second, while women's voices come about 300 to 400. It is very difficult to fix the limit, as it varies with different individuals. It also varies in the same person, as when a man raises his voice in calling, or in an excited debate, or lowers it in a confidential talk. The fundamental is the controlling frequency, but superimposed on it are multitude of higher frequencies which are essential to the voice. These higher frequencies are called "upper tones" or "higher harmonics." They are some multiple of the frequency of the fundamental. If we could suppress all the upper tones, we could not tell what a man was saying. All voices would sound alike. It is by the skillful combination of upper tones that the organs of speech form words. Therefore it is necessary that any device for transmitting speech to a distance shall transmit all the frequencies with equal force. Further, it must not change the phase relationship between the various frequencies. If in transmission the fundamental loses half its original force, speech will still be clear if all the upper tones also lose half their forces. But if some of the frequencies are suppressed much more than others, speech will tend to be thick, confused, and hard to understand. It may be very loud, but if the relations between the fundamental and the upper tones are much disturbed it will be hard to understand. It is sometimes better to have the sound weak and clear, than loud and confused. Just how much suppression a given note can suffer without being noticed by the ear is not known. The amount of phase displacement which will not affect speech is also unknown. It undoubtedly differs with individuals, for some people can understand a conversation which others can not.

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Loudness is the test of energy delivered. Clearness is the test of correct wave form. Up to the present time no instruments have been able to measure either of these for the telephone. Loudness may perhaps be measured to some extent by the thermal-galvanometer. For clearness we must yet depend on the estimates of the ear, though it is not impossible that some means may be worked out to reduce even this to a mathematical basis. It is very desirable that it should be done.

The parts of a telephone most tested for transmission effects are the transmitter, receiver, induction coil, and repeating coil. If it is transmitters that we are testing, one of the number is assumed as a standard of loudness and all the others are rated in comparison. It may be that some

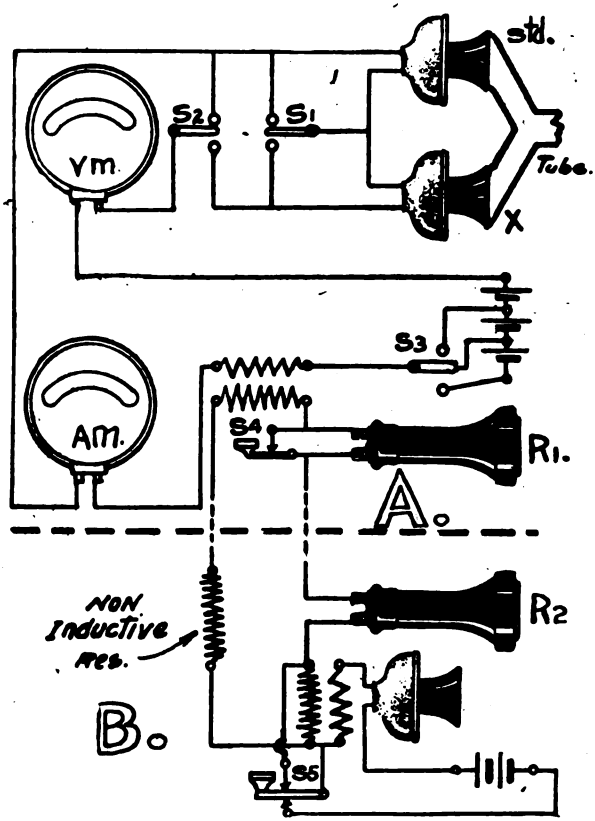


Fig. 306.

are louder than the standard, in which case they will be more than 100%. For clearness, the best method is to take the per cent of words which are correctly transmitted by each transmitter. In this case no transmitter can have over 100%.

Fig. 306 gives the arrangement for testing a transmitter in comparison with a standard, for both loudness and clearness. The two transmitters are each held separately in a suitable holder, which permits the ready change of one for the other or the insertion of any transmitter to be tested against the standard. The forked tube is not absolutely necessary, if the tester who does the talking is careful to preserve the same dis-

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tance from the mouthpieces in all the tests. This is especially necessary in the tests for loudness, as it is materially affected by the position of the speaker's lips. Care must be taken not to make the tube of tin or other metal which will add to the sound spoken by the tester. Its function is merely to insure that each transmitter gets the same quality and loudness of sound.

The standard and "X" are in series with each other, the switch, S, being provided to short-circuit the one which is not being used. It is the main switch used during the test. The battery should be storage cells, with the switch, S_3, to cut in any number from one to three. S_2 connects the voltmeter to the transmitter in use or to the battery. The line connecting the "A" observer with the "B" observer should be as nearly free from distorting influences as possible. This is to place all the burden on the transmitter, so that the faults and good points will be the controlling features. Theoretically the "B" station needs only a receiver, practically it needs also a complete talking outfit so that the two observers can communicate about the work. If the sound produced by the transmitters on test is too loud, a person can not judge correctly which is louder, so we must insert a non-inductive resistance in the line as shown. In order that the line shall be free from inductive forces, S_1 is put in to short circuit A's receiver and S_5 to short circuit B's induction coil secondary. The latter also cuts out the talking battery. Normally, A does not need to hear and B does not need to talk.

TR. TEST LOUDNESS		TRANSM'TR E	TRANSM'TR I	TRANSM'TR R	PR. CKT. R	STD ---------- X ---------- BAT. E M E ---					
STD	REST										
	MOT.					% LOUDNESS				AVE.	%
X	REST					A					
	MOT					B					

Fig. 307.

It has been found that the ear is better able to judge the comparative loudness of two transmitters if words are used with which the listener is familiar than if the list of words is changed. In the latter case the ear is directing part of its attention to identify the words, and in so doing loses part of the effect of the force or intensity. As good a way as any is to count from one up to five on each transmitter, switching quickly from the standard to the "X" between the last number of one series and the first of the next. The observer estimates and records on a prepared form his judgment as to the relative loudness of X compared to the standard. If X sounds to him a little weaker than the standard, he may record 90%. If very much stronger, he may perhaps record 125%. There should be at least three readings taken on each transmitter. Then the observers should change places, not knowing what record the other has made, and run the observations over again. The mean estimate of the two observers should be taken as the true value. After some practice, two men will come surprisingly near each other in an unbiased estimate.

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It is not enough that this comparison alone be made, for much of the value of the test will be lost if certain data about each transmitter is not recorded. Records of current, voltage of battery, voltage across transmitter, both at rest and in motion should be made. For this purpose the form shown in Fig. 307 may be used. In the upper right hand corner record the name and number of the two transmitters. Before beginning the test, record the current and voltage for each transmitter on the line marked "Rest."

Then run through the test, each man filling in his estimates of loudness in the places provided. Then record the battery E. M. F. by throwing S^2 to the lower point. Storage battery should be used so that little or no variation will occur. Also the wire connecting the positive end of battery with the "X" transmitter should be as heavy as convenient, so that the IR drop in it will be negligible. The same should be true of the voltage taps running to S_3. This is so that the difference in current taken by the two transmitters will not perceptibly affect the battery voltage. To get the current and voltage of each transmitter while in motion, the assistance of both testers will be required. Let one of them devote himself to making a steady vowel sound in front of the tube. The other will read the voltmeter and milliammeter. With a little care quite satisfactory results can be obtained even without having to use a receiver as the exciting force. From the various currents and voltages recorded the resistances are easily calculated by the application of Ohm's law.

The best practical test of correct wave form is the clearness with which words are received. Hence the principle of our tests for clearness will be the transmitting of a series of words, having a person hear them and write them down. The per cent of words correctly received forms somewhat of a measure of the clearness of the transmission as a whole. This depends on a number of factors. Each part of the apparatus, transmitter, induction coil, line, and receiver, has a part in the matter. The line can be eliminated by making it distortionless, that is, without capacity or inductance. If the line is short and not in cable, it will be practically distortionless. If resistance coils are inserted, they must be non-inductively wound. This leaves three factors, transmitter, coil, and receiver. How can we test one of them alone without bringing in the faults of the others? If we leave the same coil and receiver in circuit and change only the transmitter, we may reasonably expect that any variations in per cent of words correctly received will be due to that factor which was changed. In the ultimate analysis it may be shown that there is a slight error in this method, but for practical purposes it is sufficiently accurate and within the limits of error of the observers.

For the test prepare a number of lists of words which are of reasonable length and in common daily use. Let there be ten words in each list. Each observer will prepare the lists which he will read to the other, so that the listener will not know what is coming. Reasonable care should be taken in reading the words, for there may be as much difference in readers as in the apparatus. It is this one fact alone which makes testing hard. But with care and practice two men can become sufficiently expert to get excellent results. In this test the quick change from one transmitter to the other is not imperative. It will be well to try several lists on each and take the mean per cent.

The condition of a transmitter is a varying quantity. When new and just installed, the granules are loose and the resistance and resist-

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ance-change high. As it is used and gets old, the granules have a tendency to pack down, which lowers not only the average resistance but the amplitude of change which can be produced by a sound of given intensity. Under which condition shall we test our transmitters? Probably the fairest to all is to shake each a little just before taking the readings on it, in order that it may make the best record that it can. If we were to attempt to let them "age" and test them in that condition, it would be difficult to be sure that they are all in equal condition of aging. And the operation of handling them would shake the granules and so destroy, in a measure at least, the effect of time. For this reason it is customary to agitate each sample just before its test. But it will be well to make some tests as to aging, for it is one of the requisites of a good transmitter that it shall maintain its effectiveness as long as possible.

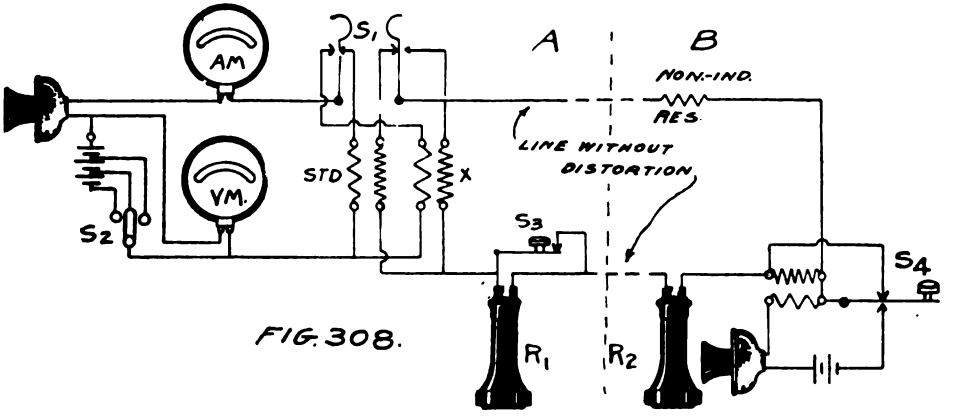


FIG. 308.

For the comparison of induction coils a slightly different circuit is used. Fig. 308 shows how it is arranged. S_1 is the main switch, which is very conveniently an operator's ringing key, though it is better if it will lock in position like a listening key. A listening key which has inside contacts is the best. As before, the line should be short and free from capacity and inductance. The non-inductive resistance is put in the line to reduce the loudness so as to make a comparison more accurate. Its exact value must be found by trial. Only one voltage need be taken, that of the battery. The current should be the average current during a steady sound, in order that some idea may be had of the ampere-turns which the coil employs. The different voltages are for the purpose of seeing what effect, if any, the current strength has on loudness and clearness. It is quite certain that an increase of current will make both coils talk louder, but the question is how it will affect their *relative* loudness. S_3 and S_4 should be left alone except when necessary to hold conversation for directing the work.

In general the same routine is followed as for a transmitter test. Count from one to five on each coil, switching from one to the other between. This should be repeated often enough for the "B" observer to become sure of his estimate of relative loudness.

In the test for clearness, use lists of words as before for the transmitter. The same care as to secrecy of lists, care in pronunciation, exchange of positions, etc., should be observed.

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When it comes to the testing of the receiver, the problem is somewhat complicated by the fact that it is the receiver which we have been using to test the other parts. The test for clearness can be made very easily by using the same transmitter and induction coil and changing receivers. Use the scheme of lists of words and get the per cent of words which are correctly received. But for loudness it is not as easy. We can not quickly change from one receiver to another so as to estimate the relative intensity. Also it is the listener who must make the change and the different feeling of a new receiver will throw him off in his estimate. So we must look about for some other means.

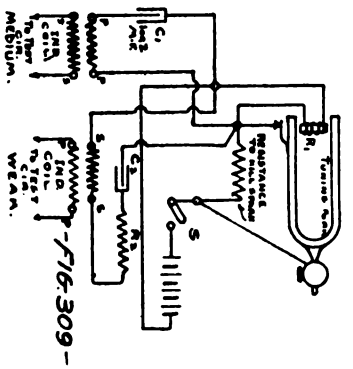


Fig. 309.

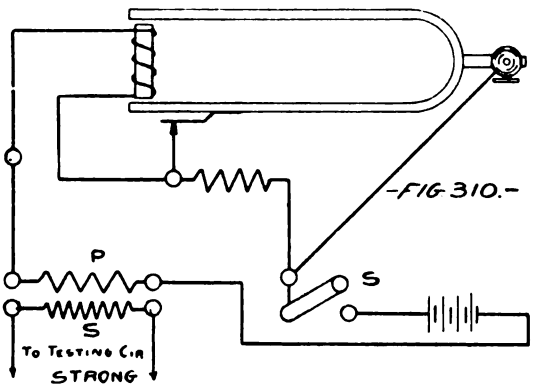


Fig. 310

Since we can not rely on a quick shift from one receiver to the other we must provide some source of current which will be constant at least during the test, and devise some means for registering its effect on each receiver. Fig. 309 shows one very good current generator which the writer has used with the best of success for various kinds of tests. The tuning fork is of the electrically self-vibrating type. If it has no device to reduce or kill the spark at the contact, the user can shunt the gap with a german silver resistance as shown. It should be from 40 to 100 ohms resistance, depending on the voltage necessary to run the fork. The higher voltage will require the higher resistance. For average current, shunt the primary of a local battery induction coil around the working coil, R^1, of the fork. Since the resistance of the primary winding is low, a condenser must be inserted as shown, C^1, to prevent the shunt from robbing the working coil of current.

When the contact of the fork closes, the battery current rises in R^1 and attracts the prongs of the fork. This rise of current in the working coil, R_1, causes a rise in the voltage at its terminals. This charges the condenser, C_1, to flow out. In flowing out it passes through the induction coil in the opposite direction from what it did in flowing into the condenser. This continued action causes an alternating current in the primary winding, which induces an alternating current in the secondary. If a weak testing current is desired, the induction coil can be reversed, putting the secondary next to the working coil. This is also shown in the figure. It now acts as a step-down transformer.

If stronger current be desired than can be furnished by either of the above arrangements, the scheme shown in Fig. 310 may be used. It consists in placing the primary of the induction coil in series with the main circuit, so that it will get the full benefit of the current-change.

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One means for testing the loudness of a receiver consists in passing through it a standard current and holding it away from the ear till the sound is just audible. Measure the distance. Then let the receiver approach the ear till the sound is just audible. Take the distance again. The mean of the two distances will be a measure of the intensity. If we compare several receivers by this method, we shall be obliged to compare their intensities by taking the law of sound into account. This law is that the intensity varies inversely as the square of the distance. Let us state the law mathematically.

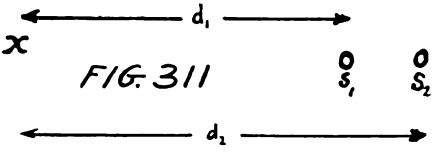


FIG. 311

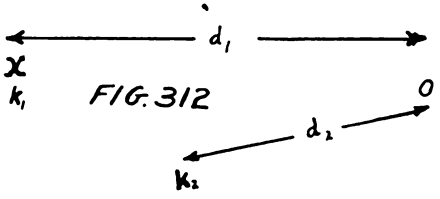


FIG. 312

Let the unit source of sound be that source which will produce unit loudness of sound at unit distance.

Let k = measure of the intensity of the source of sound.
d = distance from the source to the ear.
s = loudness of sound as heard by the ear.

In Fig. 311, let X represent the source of sound and 0 the position of the ear of the tester. If the intensity of the source is k, and the distance to the nearest point d_1, then the intensity of sound observed at that point will be

$$(1) \qquad s_1 = \frac{k}{d^2_1}$$

Similarly, the intensity of sound received at the farther point will be

$$(2) \qquad s_2 = \frac{k}{d^2_2}$$

If we have tested two receivers by the method outlined above, see Fig. 312, we have found that the vanishing point for the standard receiver is d. Call its intensity as a source of sound k_1. Let the same data for the "X" receiver be d_2 and k_2. Treat the standard receiver as unit source since we have no standard by which to measure it. Then all that we can do is to get the ratio between the two "k" values. Since the distances determined are for the vanishing points of sound, the intensity of sound received is the same. That is,

$$s_1 = s_2$$

and we can at once write the equation

$$(3) \qquad \frac{k_1}{d^2_1} = \frac{k_2}{d^2_2} \quad \text{so that} \quad \frac{k_2}{k_1} = \frac{d_1^2}{d^2_2}$$

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The above is the same as saying that the loudness of the unknown receiver measured in terms of the standard is obtained by dividing the square of the vanishing distance for the unknown by the square of the vanishing distance for the standard.

In making the test two persons are necessary, one to listen and the other to manipulate the apparatus. It is essential that the listener shall not know what is happening except as he can hear it. He should not know which receiver is being tested, nor the point at which any sound vanishes. This will keep his mind free from insensible prejudice, which is sure to creep in if not guarded against.

Another method which is believed to be better has been devised by the author. The method of the vanishing point is subject to considerable error from the fact that very slight causes interfere with it. A slight noise in the room makes it hard for the listener to tell when the sound has ceased to be audible. Training enables him to hear at a greater distance than at the start of his work, so that considerable time is lost in getting the ear up to its maximum sensitiveness. It is an aid in finding the vanishing point if the testing current be intermittently cut off from the receiver under test. But with all precautions, it is not a very satisfactory way. It has been found that the ear is better able to judge the equal loudness of two sounds than the vanishing point of either of them. This is specially true if the sounds are not too loud. Fig. 313 gives the outline of the au-

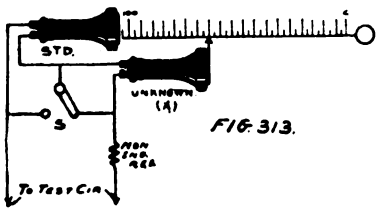


FIG. 313.

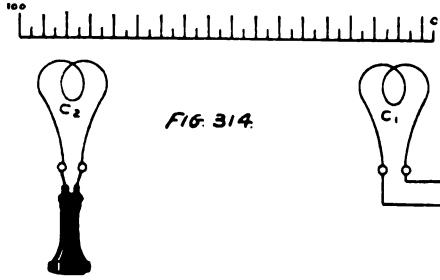


FIG. 314.

thor's method. At one end of a suitable scale is arranged a place for the listener's ear, which must not be in contact with the scale. At the point on the scale which is 100 divisions from the "0" end is placed the receiver which is to serve as the standard. The unknown receiver is mounted on a sliding carriage, which can be moved along the scale. Both receivers have their openings directed toward the zero end of the scale. The two are wired in series with each other, and have a switch, S, which can short circuit either at will. A non-inductive resistance is put in the circuit to the tuning fork to prevent the sound from being too loud, also to keep the current as nearly constant as may be. In working with receivers of different makes, the resistances and inductances often vary considerably. If the resistance of the circuit is low, the receiver which is under test forms quite an appreciable part of the total. If we now shift to the other receiver with its higher or lower impedance, the current will be changed in consequence. This will vitiate our results, as we are comparing the receivers on the basis of equal current. If sufficient non-inductive resistance be inserted, the change from one receiver to the other will not perceptibly affect the current strength. This same resistance will also enable the operator to adjust the loudness to the best degree for estimating equality.

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In using, X is first slid back till there is no doubt of its sound being weaker than that of the standard. This is determined by working the switch which cuts out either receiver. Then move X slowly closer to 0 till the listener can tell no difference between the loudness of the two. Record the scale reading. Then slide X up till its sound is very much louder than that of the standard, and slowly slide it back till the two sounds are again equal. Record this point on the scale. These two scale readings should be not far from each other, and if so take their mean. If the position of the standard is marked 100, point off two places from the mean reading of the unknown and square it.

Suppose the two readings of the X receiver are 110 and 116. The mean is 113. Point off two places, giving us 1.13. Square this, giving us 1.2769 as the intensity of X with respect to the standard. This simplification of formula (3) comes about by making the distance, d_1, equal to unity. Although marked 100 on the scale, it becomes one by pointing off two places. If desired, the scale may be graduated in squares, so that the intensity can be read off at once. Below is given a list of a few points on the scale to show how it will appear if graduated in squares.

Unit's Scale	0	.25	.50	.75	1.00	1.25	1.50
Squares	0	.0625	.25	.5625	1.00	1.5625	2.25

There are two other methods, both depending on finding a vanishing point, which may well be mentioned. One of these is illustrated by Fig. 314. C_1 and C_2 are two coils of wire of the same dimensions, resistance,

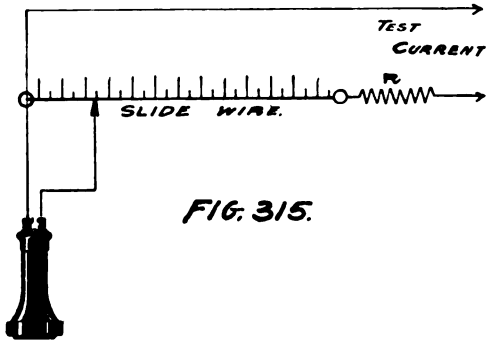


FIG. 315.

turns, etc. Each is wound on a wooden or other non-magnetic frame. C_1 is fixed at the zero end of the scale with its plane at right angles to it. The other coil, C_2, is mounted so as to slide along the scale and is parallel to the first coil. An alternating current in the stationary coil will induce a voltage in the moving coil, and the magnitude of the induced voltage will depend on the distance between the two coils, the current in C_1 being constant. If any receiver be attached to C_2 a current will flow in it, making a noise. In a certain way the distance between the coils when this noise vanishes is a measure of the sensitiveness of the receiver. It is open to the objection that different makes of receivers have different resistances and inductances and the currents will not be equal under equal voltages. This may be to some extent overcome by inserting a non-inductive resistance in series with the receiver as in the second method described. This may require a stronger testing current in C_1.

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The other of these last two methods employs a slide wire and resistance in connection with the testing current. Fig. 315 shows the scheme of the connections. The resistance, R, merely regulates the flow of current so as to enable the observer to bring the vanishing point at any desired place on the wire. The portion of the slide wire between the stylus and the end to which the receiver is attached acts as a shunt to the receiver. As the stylus is moved to the left the sound diminishes till it can not be heard. This point is marked. Then the stylus is moved to the right till sound first appears and another reading taken. The mean of the two is taken as a measure of the receiver. In this test, the loudest and best receiver in this respect will be the one which will stand the greatest short circuiting before the sound vanishes. Therefore, the measure is inversely as the length of the shunt or the reading on the wire. If the reading for the standard receiver is 50 and for the unknown 65 then

$$\frac{X}{Std.} = \frac{50}{65} = .77,$$

which means that the X receiver is weaker than the standard.

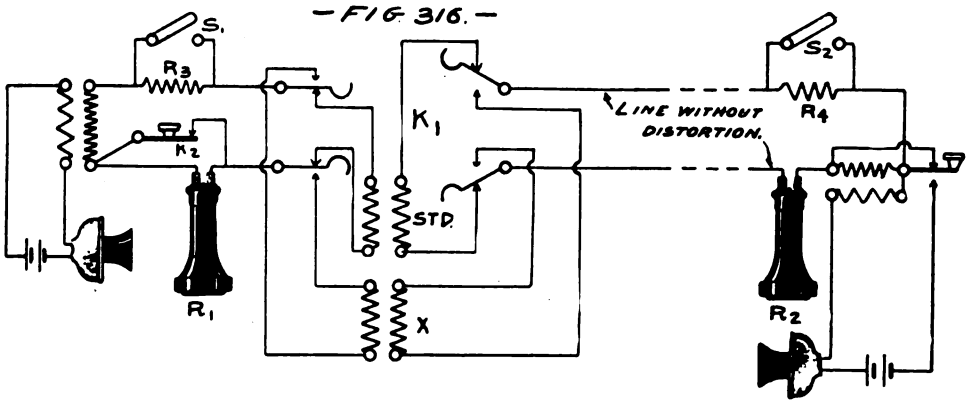


FIG 316.

In testing repeating coils, we have two things to consider. If it is a ring-through coil, both ringing and talking must be tested. Some coils are for talking only and will not need the ringing test, though it is often interesting to see what such coils will do. Fig. 316 shows an arrangement for repeating coil testing for talking efficiency. K_1 is the main key, for it switches from the standard to the unknown or X coil. It is a double throw key, locking in both positions. As wired for this test the lever must be either at the extreme right or extreme left. R_3 and R_4 are non-inductive resistances in the line to control the conditions. A repeating coil is called on to act under two trying conditions, repeating a weak current from a long line into a short line, and the reverse, repeating a strong current into a long, high resistance line. The proper use of S_1 and S_2 will give these conditions. Further directions are hardly necessary, as the tests for loudness and clearness are to be conducted as directed for transmitters and induction coils.

For a power test of a repeating coil, the most thorough would include the total power in watts required to operate it under various loads, the

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analysis of this power into copper loss and core losses, also the determination of inductance, mutual inductance, and angle of lag at various loads. In addition the curve of regulation on the secondary side would be needed. Although all of this data can be very nicely obtained by the use of the Rowland Electro-Dynamometer, it is usually more elaborate than would be required in any case except the advance research. There is one test with the above named instrument which I shall give as worthy of a permanent place in the list of tests which will throw great light on the performance of this very needful apparatus.

The theory of the method for getting the external characteristic curve of a repeating coil is shown in Fig. 317. V_1 and V_2 are two voltmeters, taking the voltage of the primary and secondary windings of the coil under test. A_1 and A_2 are ammeters taking the current in each circuit at the same time. The load resistance is started at an open circuit, or infinity. It is decreased by suitable steps till the load is heavier than there is any possibility of its being in service. Two curves are then plotted, each by laying off on the base line (horizontal line or line of abscissæ) the current values, and at each point erecting a vertical line corresponding to the voltage for that current value. The curve is drawn through the points thus plotted.

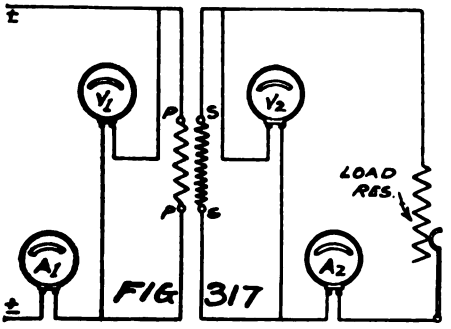


FIG. 317

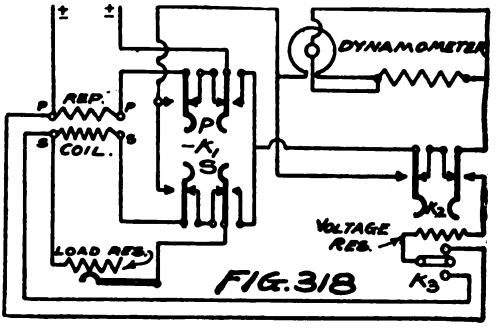


FIG. 318

The ordinary alternating current voltmeter is not suitable for this work as its resistance is far too low and introduces more load on the coil than several bells. Ordinary alternating current ammeters usually have too much internal resistance in the lower ranges and introduce too much error. The Rowland dynamometer can be arranged to possess these errors in a slight degree which may be neglected. Since four instruments would be too expensive it is necessary to have some switching device which will quickly shift the same instrument from one position to another. The same one has connections for both current and voltage readings. In Fig. 318 is shown the circuit for accomplishing this result.

The dynamometer is represented by a large circle for the stationary coil, a small circle within it for the hanging coil, and the two resistances with the regular symbols. *See foot note.

K_1 is the key which throws the instrument into either circuit. K_2 changes the connections from current to voltage readings, while K_3 con-

*For further information concerning the Rowland Dynamometer and its uses the reader is referred to the makers, Leeds & Northrup Co., Phila. Pa., also the writings of Henry A. Rowland, and an article by the same in the Am. Journal of Science for Dec. 1897, entitled "Electrical Measurements by Alternating Circuits."

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nects the high resistance to the proper coil which is being measured. In its normal position, K_1 leaves the circuits free from all apparatus.

To measure current in the secondary it is only necessary to throw K_1, to the "S" position, leave K_2 normal, and make the necessary adjustments of the dynamometer. To take voltage, throw K_2, having previously put K_3 on "S," and make the proper adjustments of the instrument. At all times care must be taken to make such adjustments of the dynamometer proper as will result in the highest possible resistance in the "voltage resistance." Also when measuring current, such combinations of the instrument should be used as will give the lowest resistance. These precautions are to avoid disturbances from the introduction of the measuring instrument into the circuits.

The form of the resulting characteristic curve will be as shown in Fig. 319. The more level the line, the better the coil holds up under load. Curve I shows a coil which has less internal losses than the coil which gave Curve II, although the voltage on open circuit was lower for the former. The study of a set of such curves is very interesting and will show up the capabilities of coils in a way which permits close comparison of coil with coil.

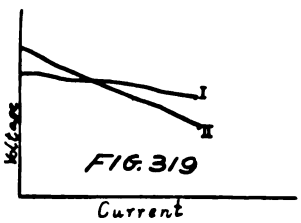


FIG. 319

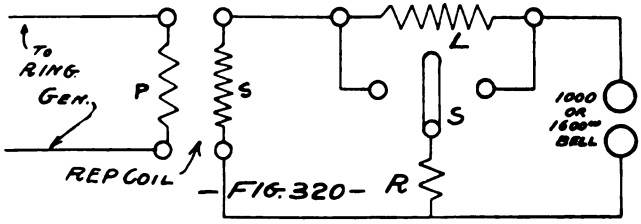


FIG. 320

A simple method of testing the ringing ability of a repeating coil is shown in Fig. 320. The only materials required are a generator, two resistance boxes, a simple two way switch, a bell, and the coil to be tested. It is best to have some power generator to furnish the current, as it will be much more likely to be steady than a hand generator turned by hand. But if care is taken to turn with uniform speed, even a hand generator can be made to give excellent results. If a pole-changer is the source, it will be necessary to do the testing when the machine is idle, for when an operator rings out on a line, it lowers the terminal voltage materially. Let L represent the line resistance and R a leak across the line. Start with the line resistance equal to two or three hundred ohms, and increase the leak till the bell will just ring reliably. Record the resistance. Then make the leak so low that the bell will not ring and decrease it till it will just ring reliably. The mean between the two will be a good value for the limiting leak which may be operated with that certain line resistance. Now increase the line resistance, making it a hundred ohms higher than before. In the same way find the limiting leakage resistance which will ring the bell. Continue in this way till the line resistance has been raised to about 2000 or 3000 ohms. The completed records will give us a series of line resistances with the limiting value of leak for each. These may be plotted in the form of a curve, laying out the line resistances horizontally and the leakage resistances vertically. By plotting the results of several coil tests on the same sheet, it will readily be seen how their performances compare. The coil which will on a given length of line ring

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the bell past the lower leak, is the one which will under trying conditions be more sure to ring the bells on a line.

Care should be taken to use the same generator in testing a series of coils, for if different machines are used, their differences in voltage will lead the experimenter astray. If desired, a common switchboard drop may be substituted for the bell, but there is a possibility of uneven action due to friction at the shutter at the moment of starting to ring. The bell should be the same for all the tests, and should be in the same position.

A good check test is to exchange the positions of the bell and generator. This gives the condition of a subscriber ringing in to central through a repeating coil.

The curve shown in Fig. 320a was taken in the above manner from a ring through repeating coil. Curve No. 1 shows the result when the leak on the line is beyond the line resistance. Curve No. 2 was taken with the leak on the near side of the line resistance. These show how much more effect a leak produces when it is out some distance from central. In other words, the line can stand a worse short circuit near the coil, than it can some distance away. It also shows up the great ability of the coil to furnish large current without pulling down its voltage.

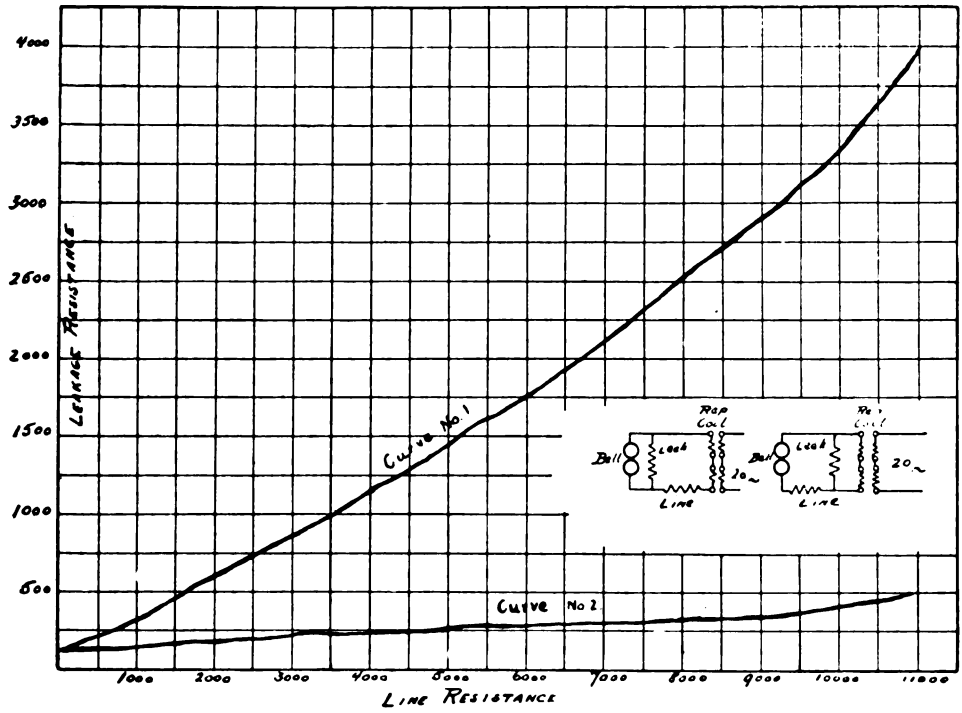
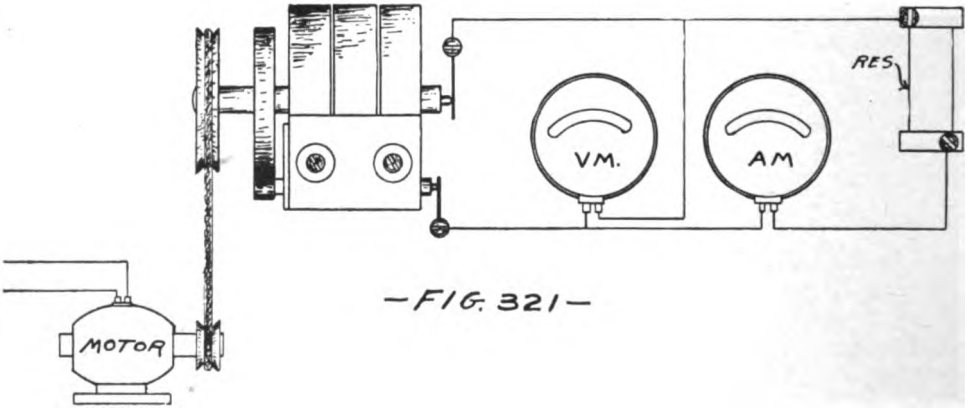


Fig. 320a.

Testing Magneto Generators—A magneto hand generator such as is commonly used for ringing on telephone lines is as much a dynamo as any machine, and can be tested as such. But owing to the peculiarity of having a permanent field it does not behave in the same way. Also on account of using a shuttle armature, the core of which is usually solid iron,

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not laminated in any way, the power losses are much greater than in ordinary generators. This is heightened by the voltage required, which is out of proportion to the size of the machine. This makes many turns of small wire necessary, which increases the internal losses. But we are not hampered by considerations of efficiency as much as the power people, for if a generator will do the work required it will be satisfactory, provided it does not turn unreasonably hard. It is very likely that less than half of the energy expended by the subscriber in turning the crank goes out in the form of electrical energy over the line. But efficiency does come in wherever we can reduce the size and cost of a machine, and yet be as effective in the work.



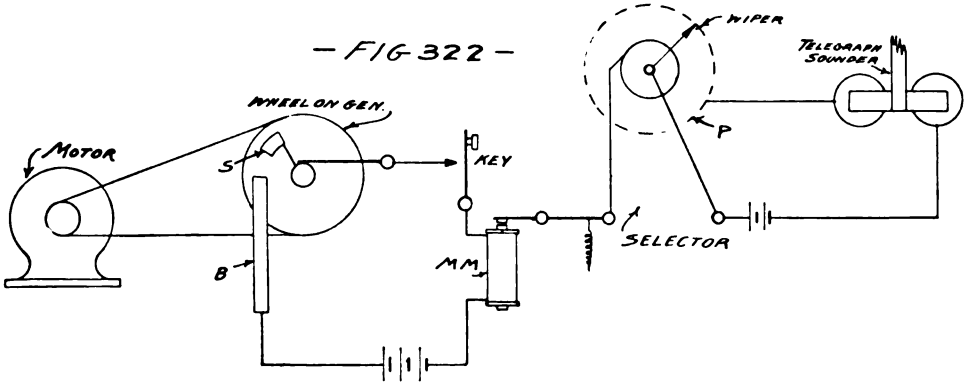
—FIG. 321—

The most thorough test which is ordinarily applied is to take the external characteristic. This is merely the curve of terminal voltage and current delivered to a non-inductive circuit. Fig. 321 shows the theoretical arrangement. The crank is taken off and replaced by a driving pulley, so that a motor, or any source of power can drive it at a uniform speed. The voltmeter and ammeter must be adapted for alternating current. The resistance of the former should be as high as possible. I have found the Rowland Dynamometer the best for the purpose, both as voltmeter and ammeter. The ordinary voltmeter for alternating current has too low resistance.

For taking the speed, the arrangement shown in Fig. 322 has been tried out with the best of success. Fitted to the driving pulley is a segment, *S*, which is connected to the shaft. A brush, *B*, is adapted to touch the segment once in each revolution and close the circuit through the motor magnet, *MM*, of a step-by-step device which is in the figure called the "selector." In my own use I have employed the switch from a Clarke automatic telephone switchboard, as it makes a complete circle in its rotation. The motor magnet drives the wiper over a series of contact points, one of which, *P*, is wired to a telegraph sounder. The return circuit for the sounder is through battery to the wiper. The use is as follows: The wiper is set on the point, *P*. When ready to take the speed, the key is closed for one minute, or some definite time. Every revolution of the driving pulley closes the motor magnet circuit once, moving the wiper forward one point. Once in each revolution of the selector the sounder will click. By counting the number of clicks in a minute and multiplying by the number of points in the complete revolution of the wiper and add-

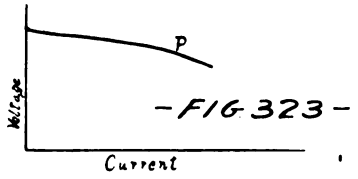
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ing the number of points over which the wiper has run past the point *P*, you can get the revolutions per minute of the driving pulley. Knowing the ratio between the small and large gears, the actual frequency of the armature is easily computed. The best frequency for hand generators is from 16 to 20 cycles per second.



— FIG 322 —

The procedure is very similar to that for testing repeating coils which has been previously described. The open circuit voltage is first taken with the resistance infinity. Then the load is applied to the extent of a few milliamperes, and the voltage taken again. The load is increased a few more milliamperes and another voltage reading taken, and so on till a reasonable limit has been reached. In most hand generators the curve will very closely approximate a straight line for some distance, after which there may be a slight bending downward. The working load should come within the straight portion of the curve. Fig. 323 illustrates the form of the curve. The straight part indicates that the current is not large enough to have a perceptible effect on the magnetism of the steel magnets. The bend downward at P is caused by the large current in the armature, which tends to destroy the magnetic field set up by the steel magnets. The slope of the straight part of the curve is an indication of the electrical losses in the armature. If the line is almost horizontal, the losses are small, but if the line is steep, the losses are large.



— FIG 323 —

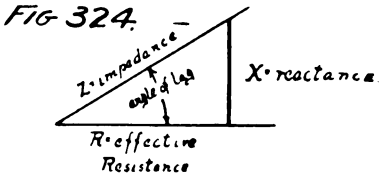


FIG 324 —

Let E = open circuit E. M. F. (when current = zero.)
e = terminal voltage at some selected point on the curve.
I = current corresponding to voltage "e."
R = internal resistance of armature winding.
f = frequency, in cycles per second.
Z = impedance of armature.

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Then $e + IR$ = volts in phase with current. $2\pi fLI$ = reactance volts.

$E^2 = (2\pi fLI)^2 + (e + IR)^2$. Solving for L, we may get the formula for computing the inductance of the armature.

$$L = \frac{\sqrt{E^2 - (e + IR)^2}}{2\pi fI}$$

The impedance, Z, of the armature is given by

$$Z = \sqrt{R^2 + (2\pi fL)^2}$$

In that portion of the curve which is a straight line, the impedance, Z, and the inductance, L, will be constant quantities. In a certain old style hand generator which was tested, the following values were found,

$$E = 63,\ e = 22,\ I = .05 \text{ amp.},\ R = 515,\ f = 20.$$

This gave an impedance, Z, of 965 ohms, and an inductance, L, of 6.5 henrys. The electrical efficiency was 46 per cent.

Hand generators may be tested for their ability to ring a bell over long lines past leakage in exactly the same manner as was described for ring through repeating coils. See Fig. 320 and 320b. The difference between the curves for leakage on either side of the line resistance will give evidence of the amount of internal losses in the armature.

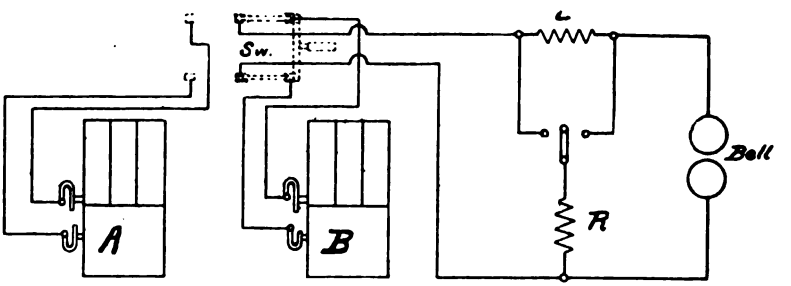


Fig. 320b.

Power Consumed by Polarized Bell.—The following are some results which were obtained on a bridging bell. They do not give the least amount of power on which the bell will ring, but show where the power goes to in the average case. The measurements were made with the Rowland Electro-dynamometer, for current, voltage, and watts. Briefly the method was this: Measure the current going into the bell, and the voltage across its terminals. Measure the watts consumed by the bell. Measure the resistance of the coils by a Wheatstone bridge. Find the apparent power by multiplying the volts by the current. Divide the real power, given by the watts, by the apparent power. The quotient is the power factor, or the cosine of the angle of lag. By this cosine lay off the angle by which the current lags behind the voltage. See Fig. 324. Divide the

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volts by the current, which will give the impedance. Lay off the value, Z, of the impedance on the sloping side of the angle. From the end of the distance representing the impedance drop a line perpendicular to the base or horizontal line. This length will represent the reactance, x, which equals $2\pi fL$, f is the frequency and L is the inductance. The horizontal distance represents the effective resistance, not the resistance of the wire in the coils, but nearly always greater, due to the losses in the iron core. In the following table of results, Set. 1 and Set. 2 differ only in the voltage applied, but it shows that the change in voltage affects other things as well.

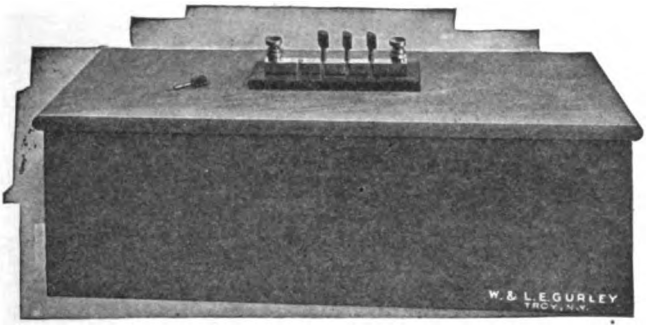


Fig. 324a.

Resistance of bell, 1560 ohms, Frequency, 18 cycles per second.

	Set. 1.	Set. 2.
Current	.01133 amp.	.01017 amp.
E. M. F.	80.384 volts	70.144 volts.
Power, total.	.5849 watts	.4602 watts
Angle of lag.	50deg. 2′	49deg. 46.5′
Impedance	7090.4 ohms	6897.1 ohms
Reactance	5434.1 ohms	5265.0 ohms
Effective resistance	4554.8 ohms	4454.0 ohms
Inductance	44 henrys	42.67 henrys

The above results were not worked out on the drawing board, but were calculated by the above mentioned relations.

In telephone work alternating and intermittent currents are dealt with and consequently the simple direct current relations fail in any computation or test on the telephonic apparatus.

As in direct or continuous current work the *ohmic resistance* offers the opposition to the passage of the current, so in alternating or intermittent current work the *impedance* opposes the passage of the current. The part of the impedance that plays the most important role in telephonic work is the induction in the receivers, ringers, induction or loading coils, etc.

To measure the inductance in these, by far the simplest method is to compare them directly with standards of induction in a manner similar to that used in the comparison of resistances. Such a method has, in addition, the advantage of being a zero method, namely, the inductances are balanced until there is no deflection in the galvanometer.

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To make these measurements it is necessary to have standards of induction of various values and a variable standard that can be increased or decreased by small amounts.

Fig. 324a shows a box form of fixed standards which is particularly adapted to this purpose, as the resistance remains the same whatever inductance is plugged in or out. (As indicated below, it is necessary that the resistance of the circuit must remain the same while a test is being made.)

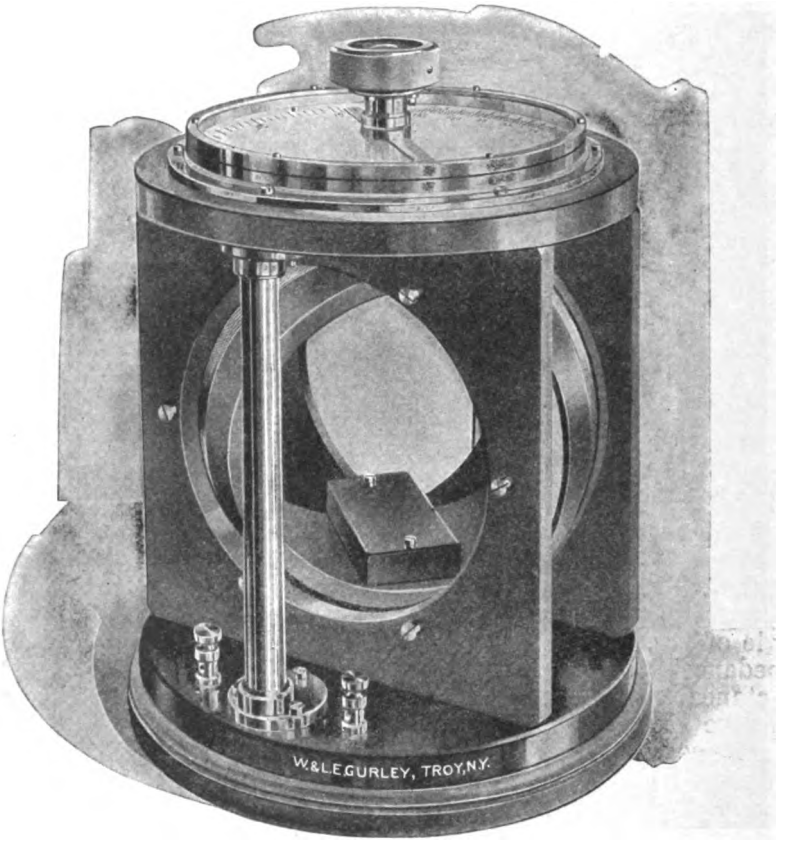


Fig. 324b.

Fig. 324b shows the highest standard type of variable inductance which indicates values below the smallest values given in the box shown in Fig. 324a. The important feature of this variable standard of inductance is its solid and rigid construction. The accuracy of the whole instrument depends upon its maintaining a permanent shape and must not be liable to warp or twist with time or under varying climatic conditions.

An important adjunct in measurement is a *Secohmmeter* or instrument for converting a steady or direct current to an intermittent one.

Fig. 324c show such an instrument designed for the purpose, with special attention given to the reliability of the contacts and the strength and smoothness of the gears.

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To illustrate the use of these instruments the diagram (Fig. 324d.) will show the connection necessary to make a test of the induction of any part of the telephonic apparatus.

To illustrate the use of these instruments the diagram (Fig. 324d.) as shown above, R_4 and R_5 are known non-inductive resistances; L_2 R_2 is a fixed standard of inductance; L_3 R_3 is a variable standard of inductance; R_7 R_8 is a wire giving smaller variations of resistance than the

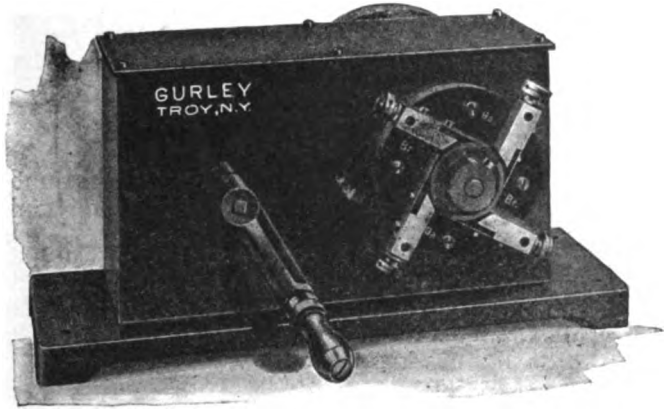


Fig. 324c.

smallest coil in R_6; R_6 is a non-inductive resistance. Having the Secohmmeter S_1, S_2 at rest with the circuits complete through the commutators, make a balance between R_4, R_5, $R_1 + R_6 + R_9$, and $R_2 + R_3 + R_8$ for zero deflection of the galvanometer as in an ordinary resistance measurement. L_2 R_2 is not needed when L_1 is less than the maximum value of L_3. R_6 is used to produce a balance of resistances and is placed between L_1 and R_7 or L_3 and R_7 according as R_1 is smaller or greater than $R_2 + R_3$.

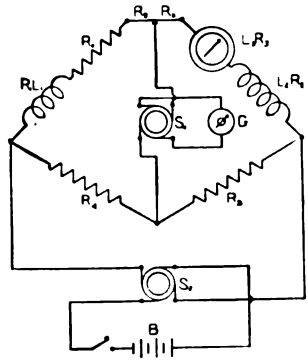


Fig. 324d.

Slowly turn the Secohmmeter and vary L_2 and L_3 until there is again no deflection. If no balance can be obtained L_1 is too large or too small compared with $L_2 + L_3$ and the ratio R_4 / R_5 must be changed and the whole operation for the balance of resistances repeated. A change of L_3 entails no change in R_3 and consequently no change in resistance balance.

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When a box like the one shown in Fig. 324a is used for L_2 the resistance remains constant, however L_2 is changed.

When the balance of inductances is obtained as above, rotate the Sec-ohmmeter rapidly and make the final adjustment for zero deflection with L_3, then L_1 is found from the following relation:

$$\frac{L_1}{L_2 + L_3} = \frac{R_4}{R_5}$$

Cautions. The resistance boxes used should be non-inductive and free from capacity, and therefore the individual resistance arms should not be under 100 ohms and of large wire.

All connections should be as straight as possible.

Foreign magnetic material or strong currents should not be near the apparatus when a test is being made. L_1, L_2, L_3, and L_4 should not be too near one another.

All contacts and connections should be good.

As this method depends entirely on the accuracy of the standards, it is well to observe that they are reliable.

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CHAPTER IX.

TESTING EQUIPMENT AND FAULT LOCATION.

The question of Portable Testing Set and Cable Testing apparatus equipment for the maintenance of tests upon telephone lines is of prime importance. A telephone plant can only give best service when its lines are clear of all troubles. In the light of the present day engineering we must not wait until a fault develops, but must be in a position to foretell such conditions by systematic tests, or if crosses and grounds develop due to agencies beyond our control, we must have the necessary apparatus to locate these troubles promptly and accurately.

The selection of a testing set will depend upon the range of the testing to be done, and the views of the tester, as to the details of construction and manipulation, or the experience of the manufacturer may be sought for recommendations of apparatus to meet particular requirements. In choosing an instrument, the importance of reliability must not be overlooked. This factor is dependent upon the manufacturer, who must insure reliability by good construction. It is a common error to select cheaply constructed apparatus, which while giving results sufficiently accurate for many cases of cable and line trouble, has a short life and must be replaced. Another feature of this class of apparatus is failure to operate at a time when a critical test is to be made. The wisdom, therefore, of selecting testing sets, that are constructed so as to withstand the rough usage to which this class of apparatus is subjected and that have a construction and adjustment which will insure reliability and accuracy, is self-evident.

PORTABLE TESTING SETS.

Definition.—The term "Portable Testing Set" is now accepted to mean some form of Wheatstone or Slide Wire Bridge, complete with galvanometer and battery, mounted in a carrying case and arranged for the measurement of resistances and the location of faults, crosses and grounds by the Murray and Varley Loop Methods. The same set with the addition of other parts can also be arranged for additional tests, but as will be shown later, such tests are only rough, and when precision is required should be made with the instruments included in cable testing apparatus.

Explanation of Wheatstone Bridge.—As stated above all test sets are arrangements of the Wheatstone and Slide Wire Bridges. In order to understand the principles of a bridge arrangement, a discussion will be given.

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The Wheatstone Bridge is named after Sir Charles Wheatstone, to whom we owe its development although invented by Christie. It consists of a system of conductors as shown in Fig. 325 and is the most common of the several arrangements used for measuring resistances.

The current from the battery C is made to branch at 2 into two paths and reunite at 4, so that part of the current flows through the point 1 and part through the point 3. The four parts of the circuit A, B, R and X are known as the arms of the bridge, although it will be stated later that in practice A and B are termed the "Bridge Arms" or "Ratio Arms," R the "Rheostat" and X the "unknown resistance" or "bridge terminals."

When the resistances in the four bridge arms bear a certain relation to each other, then the galvanometer connected at 1 and 3 will show no deflection or a condition of "balance," in which case the bridge is said to be "balanced."

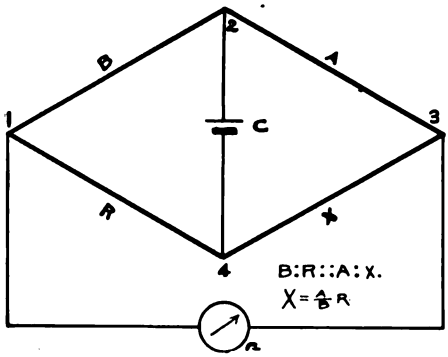


Fig. 325.



Fig. 326.

It is to be noted that any resistances in the galvanometer or battery circuits do not affect the values or ratios of the bridge arms. It is also to be noted that the position of the galvanometer and battery may be interchanged without in any way affecting the law of the bridge. There are certain conditions of use which may require the galvanometer connected from 2 to 4, but this discussion will not be entered into since it does not alter the law of the bridge.

Portable Testing Sets, making use of the Wheatstone Bridge principle, are all connected according to the theoretical diagram shown in Fig. 325. The method of adjusting the bridge, so as to obtain a balance, is to vary the arm R or Rheostat, the arms A and B having been set for fixed values depending upon the resistances to be measured, or to vary the ratio of the bridge arms in relation to a fixed rheostat. The first method is employed in the post office and decade bridges and the second method in bridges of the slide wire type. The arrangements of the various parts are the result of practice and experience in the use and design of this class of apparatus.

The various typical forms to be found in practice will be illustrated and their methods of operation described.

The Portable Testing Set shown in Fig. 326 is the simplest form of Wheatstone bridge and is known as the "Postoffice" pattern. This name is derived from the fact that the general construction was first gotten out

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by the department of telegraphs of the English government, which is under the supervision of the postoffice.

It is conveniently portable and is used for measuring resistances, ranging from a fraction of an ohm to a few megohms. It is also arranged for the location of faults, crosses and grounds by the Murray and Varley Loop Methods.

Reference to Fig. 327 shows the Rheostat or variable arm of the bridge to consist of resistances from 1 ohm to 4000 ohms. The bridge arms have each three coils, 1, 10 and 100 ohms in one arm and 10, 100 and 1000 ohms in the other arm. These resistances are wound with Manganin wire, which is an alloy having a very low temperature co-efficient. Resistances wound with this metal require no temperature corrections.

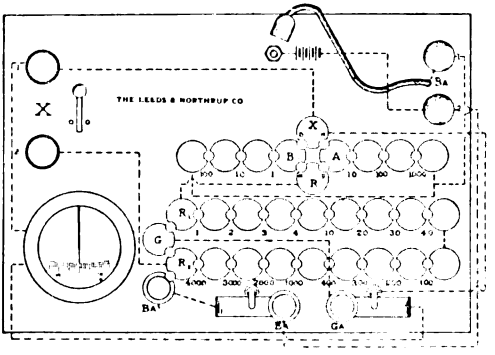


Fig. 327.

The galvanometer is of the D'Arsonval type and is therefore unaffected by external magnetic influences such as dynamos or the earth's magnetic field. It is designed so as to give a maximum sensibility and be at the same time deadbeat and quick in action. It requires no suspending or leveling.

The battery is composed of small dry cells having a high voltage and low internal resistance. They are mounted in a block which can be replaced when the cells are exhausted. A pair of binding posts is provided so that outside battery may be used.

The arrangement and connections are shown in Fig. 327. The dotted lines show internal connections. It will be noted that the arms A and B are not directly joined to each other as indicated in the theoretical diagram, Fig. 325, but are connected to a commutator, Fig. 328, so that the relative position of the arms A and B may be interchanged. The object of reversing the bridge arms is to give the most accurate measurement for certain values of the unknown resistance. This increased accuracy of measurement is in some cases so marked as to warrant care in selecting the bridge arms.

The transposing of the bridge arms must necessarily invert their ratio to each other. The upper block in the commutator is permanently connected to X, and the lower block of the commutator is permanently connected to R. If therefore it is desired to connect either bridge arms to X or R, it is only necessary to place the two plugs accordingly.

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Fig. 329 and 330 give the formula for the unknown resistance when the bridge arms are connected as indicated. It will be noticed on blocks X and R that there are also the small letters D and M. These stand for divide and multiply. They are to serve as a guide in placing the plugs. When the plugs are placed on the diagonal D D the rheostat reading is to be divided by the ratio A÷ B, when on the diagonal M M it is to be multiplied by that ratio.

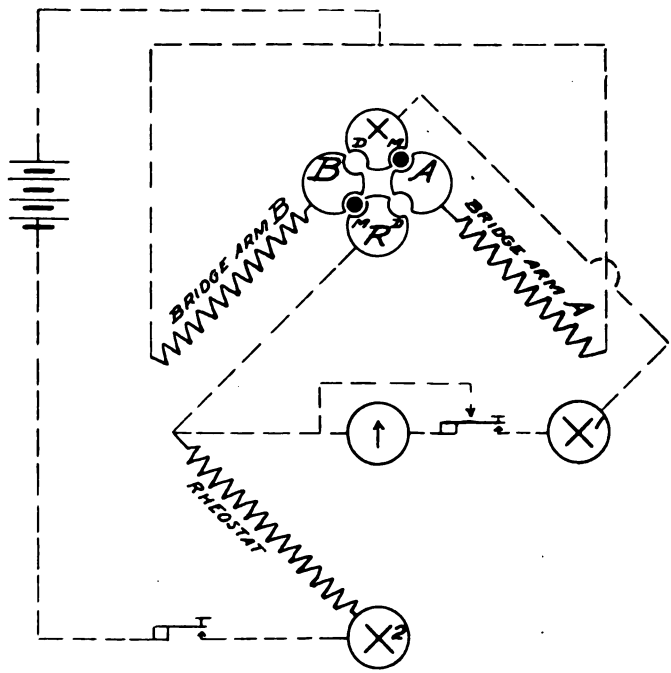


Fig. 328.

Directions for using the Post Office Bridge, shown in Fig 326, *for the Measurement of Resistance.*—Referring to Fig. 328 the unknown resistance X which is connected between the binding posts X^1 and X^2, is determined from the proportion B : R :: A : X whence

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

The proportion obtains, when with the battery current flowing the resistances are so adjusted that no current flows through the galvanometer. Assuming that nothing is known about the resistance to be measured, proceed as follows: Place battery plug in position, connect the unknown resistance between X^1 and X^2, unplug 100 ohms in bridge arm A and in bridge arm B. Connect block R_1 to block G and block R_2 to block Ba^1, and see that all other plugs in both bridge arms and the rheostat are firmly in position. Unplug a coil in the rheostat, 1,000 ohms for example, and close the battery key and immediately afterwards tap the galvanometer key; a deflection in the direction of the plus would indicate that more resistance

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was to be unplugged, and in the opposite direction, less. Bearing this in mind a value will be determined by successive trials which will give a balance or it will be discovered that the unknown resistance is greater than 11,000 ohms, or less than 1 ohm, these being the limiting values of measurement when the same resistance is unplugged in each bridge arm. For many resistances an even bridge does not give the best results.



Fig. 329.



Fig. 330.



Fig. 331.

Best Values.—The best bridge values for each measurement may be obtained from the following table:

Below 10 ohms		1	1000	D D divided by 1000
10 ohms to	100 ohms	10	1000	D D " " 100
100 " "	500 "	10	100	D D " " 10
500 " "	5000 "	100	100	either
50000 " "	5000 "	100	1000	M M multiply by 10
50000 " "	500000 "	10	1000	M M " " 100
500000 " "	11000000 "	1	1000	M M " " 1000

When making resistance measurements, it will often be found that an exact balance cannot be obtained. The galvanometer will deflect to the one side of zero, with a certain resistance unplugged in the rheostat and then to the other side, when the next resistance value is unplugged. In order to make a measurement to the highest degree of precision within the limits of the particular bridge in use, we resort to interpolation or the determination of the ratio of the galvanometer deflections on each side of zero to the resistances unplugged to produce these deflections.

An example will make this operation clear. In the measurement of an unknown resistance it is found that the needle swings toward the plus when 11 is unplugged in the rheostat and from it when 12 is unplugged, and there is a considerable swing in each direction. Noting the amount of the deflection we find that the needle swings .4 division from zero when 11 is unplugged and .2 division when 12 is unplugged. The proper value is consequently nearer to 12 than 11, and in the proportion 2 to 4; we accordingly annex 4-6 to 11, making our rheostat reading 11.7.

If the unknown resistance in the above example had been below one ohm, then we would have unplugged 1 ohm in B and 1000 ohms in A and set the commutator plugs on D D. The final result therefore would have

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been 11.7 divided by 1000 or .0117 ohms. In the measurement of a low resistance, precaution should be observed to close the galvanometer key first and keep the battery key closed as little as possible. As the battery is short circuited through a small resistance in all these measurements, it will be used up unnecessarily if this precaution is not observed.

The "Decade" Wheatstone Bridge.—The portable testing set just described was termed the "Postoffice" pattern, and in order to obtain a resistance value in the rheostat or bridge arms, it is necessary to withdraw a plug.

In the *Decade* form of bridge the resistances are obtained by "plugging in," and furthermore but one plug is required for each row of resistances in the rheostat.

A testing set arranged on the "decade" plan is shown in perspective in Fig. 331, and in plan in Fig. 332. The advantages of the "decade" plan over the "postoffice" plan are numerous and especially so from the standpoint of manipulation. It requires but one plug for each row of resistances and this plug is always in use, even at zero it must be in its position. In the "postoffice" type it is necessary to withdraw plugs and lay

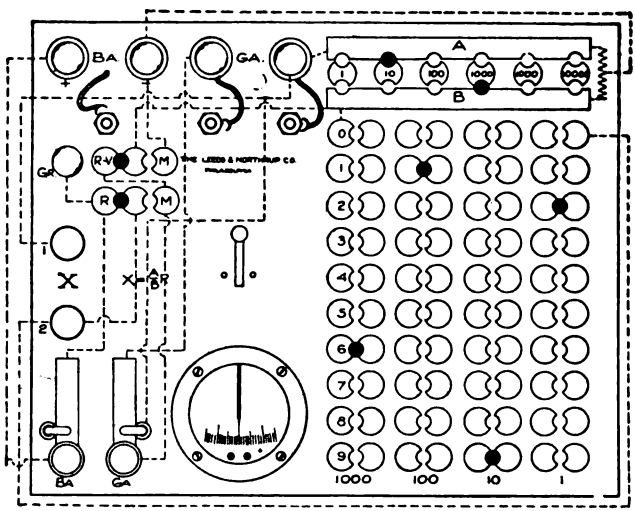


Fig. 332.

them aside, thereby bringing in the possibility of losing them. The use of one plug only to the decade makes it easy to ascertain that this plug is tightly fitted in its place and making good contact. As only one block in a row is plugged at a time, the other blocks are not kept under a strain by having plugs tightly forced between them. This strain on the blocks, which always exists in the postoffice type in which a resistance is thrown in by removing a plug, tends to separate or loosen them. This trouble must be guarded against in the postoffice type by running over all the plugs, to see that they are tightly in position, just before making a measurement. Reference to Fig. 332 will make it evident that on account of the ample distance between the rows, there is no trouble in manipulating the plugs, even when the operator's hands become benumbed by cold, or he has to wear gloves.

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The coils in the bridge arms are also on the "plug-in" plan and by an arrangement shown in Fig. 333, any coil may be used in either bridge arm, thereby avoiding the use of a commutator and two extra plugs.

The coils have one terminal connected to a central bar on the inside of the set, indicated by dotted lines, which forms a common centre; the other terminal is connected to the blocks between the parallel bars stamped A and B. The terminal of the 1 ohm coil being connected to the block marked "1", the terminal of the 10 ohms coil being connected to the block marked "10" and so on. It is thus evident that any coil can be placed in either bridge arm by simply plugging in the desired coil to the bar A or B as required. This arrangement also has the decided advantage that the formula for the unknown resistance is always $X = A \div B \times R$, because the operation of transferring the plug from one side to the other does not interchange the bridge arms A and B in relation to the arms X and R, but only transfers a particular coil from one bridge arm to the other.

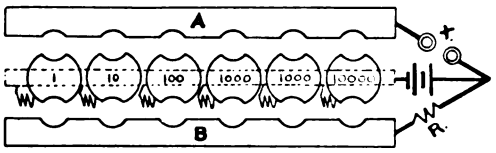


Fig. 333.

The Rheostat, (See Fig. 332) consists of four rows of coils or "decades" as each row is termed, and each row is divided into nine coils each of values 1, 10, 100, and 1000 ohms. As previously stated there is but one plug with its corresponding contact to each unit, ten, hundred or thousand numeral in the total. The decade arrangement is also convenient because it is formed of groups of coils in which each member of a group has a resistance which is the same as that of all the other members of the group. The facility with which a particular setting of the rheostat plugs may be read is very striking.

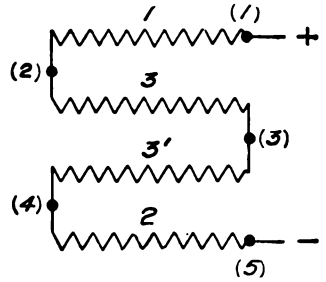


Fig. 334.

Example—Referring to 332, the rheostat setting is 6192, which is very easily read from the position of the plugs. In the postoffice type it is necessary to go through a mental process of adding together odd values. The decade plan generally calls for a greater number of coils than the postoffice type since nine of the one ohm coils are required in the units

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row, nine ten ohm coils in the tens row, and so on. The Leeds & Northrup Co., have, however, a scheme whereby but four coils are used in each row or decade. This is accomplished by a method of short circuiting certain coils, as explained by Fig. 334. Since the manipulation of the "decades" is just the same as if nine coils were used in each, it is not essential to understand the details of the method. Because of its novelty, however, an explanation is introduced for those who desire to become acquainted with it.

Referring to Fig. 334, the resistance coils 1, 3, 3^1 and 2 ohms are connected in series as shown.

Let the terminal of the 1 ohm coil and the 2 ohm coil and the points of union of the coils be numbered (1), (2), (3), (4), (5) as shown in Fig. 334. The current enters at point (1) and leaves the coils at the point (5), traversing 1, 3, 3^1, 2=9 ohms in all. If this series is multiplied by any factor n, then n $(1 + 3 + 3^1 + 2) = n$ 9 ohms. It will be seen that if the points (1) and (5) are connected all the coils are short circuited and that the current will traverse zero resistance. If the points (2) and (5) are connected the 3, 3^1 and 2 ohm coils will be short circuited and the current will traverse 1 ohm. By extending this process so that we connect two and only two points at a time, it is possible to obtain the regular succession of values n (0, 1, 2, 3, 4, 5, 6, 7, 8, 9), the last value being obtained when no points are connected. The following table shows the points which must be connected to obtain each of the above values and the coils which will be in circuit for giving each value:

Value.	Points Connected.	Coils Used.
0	(5—1)	0
1	(2—5)	1
2	(4—1)	2
3	(2—4)	1,2
4	(3—5)	1,3
5	(1—3)	3^1,2
6	(2—3)	1,3^1,2
7	(5—4)	1,3,3^1
9	(0)	1,3,3^1.2
8	(1—2)	3,3^1,2

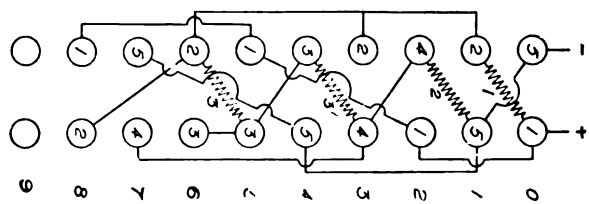


Fig. 335.

Fig. 335 shows the method of connecting these points, two at a time, with the use of a single plug and corresponds to a row or "decade." The circles in the diagram represent the brass blocks forming the plug holes, but for convenience of illustration they are shown, with a considerable distance between them.

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To the first two blocks at the top of the rows, the points 5 and 1 of Fig. 334 are connected, to the second two the points 2 and 5 are connected and so on, no points being connected at the last pair of blocks. It is evident that if a plug be inserted between the blocks 1 and 5, the points 1 and 5 of diagram are connected giving the value 0, if between the blocks 2 and 5, the points 2 and 5 are connected giving the value 1 and so on. The value 9 is obtained when the plug is disposed of by being inserted in the last pair of blocks which have no connections.

In the tens row it is understood that the values used are 10, 20, 30 and 30 ohms, and so on, for the hundreds and thousands.

Directions for Using the Decade Bridge, Shown in Fig. 332, *for the Measurement of Resistances.*—Referring to Fig. 332 the unknown resistance X, which is connected to the binding posts X_1 and X_2 is determined by the formula, $X = A \div B \times R$. Proceed as in using the postoffice type of bridge excepting that the inserting of a plug gives a resistance value, and that but one plug is required for each row of resistances in the rheostat. The blocks marked R-V and R must have a plug inserted in them in order to have the bridge arrangement correct for resistance measurements.

The best bridge values for various resistances are shown by the following table:

Unknown Resistance. Resistance plugged in bridge arms.

	A	B	
Below .9999 ohms	1	10000	Divide by 10000
.9999 ohms to 9.999	1	1000	" " 1000
9.999 " " 99.99	10	1000	" " 100
99.99 " " 999.9	100	1000	" " 10
999.9 " " 9999	1000	1000	Even Ratio
9999 " " 99990	1000	100	Multiply by 10
99990 " " 999900	1000	10	" 100
999900 " " 9999000	1000	1	" 1000
9999000 " " 99990000	10000	1	" 10000

Dial Decade Testing Set.—In this form of Wheatstone Bridge, the resistances in the rheostat and bridge arms, are thrown in or out by the movement of a switch over contacts. In the usual form, the rheostat is made up of 10 one ohm coils, and 9 each of ten, one hundred and one thousand ohm coils, and values of one, ten, one hundred, and one thousand ohms, in each of the bridge arms. The use of dials has the advantage of quicker manipulation, especially when compared with the "postoffice" type of bridge. It is essential, however, that the mechanical construction of the switches be such, as to withstand long and continued use, without becoming tight in their central bearings, or tending to cut the contact studs, over which they move.

The dial testing set shown in Fig. 336, is manufactured by the Leeds & Northrup Company, and has embodied in it several important features, the most novel of which, is the arrangement of the bridge arms. In the usual form of the dial bridge, as above stated, each arm is controlled by a switch which has the objection of introducing a contact resistance directly into the ratio coils.

To overcome this, a scheme for connecting the ratio coils shown in Fig. 337 has been adopted.

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It will be noted that from point X′ to the point M or the ends of the two bridge arms, there are the seven resistances, a, b, c, d, e, f, g adjusted to a high degree of accuracy, and of such values that when the switch S is set on any of the contacts, the ratio A ÷ B will be that marked for any particular setting. Therefore in resistance measurement, the rheostat setting is simply multiplied by the figure to which the Ratio arm points.

The switch S is in the battery circuit and any resistance in its contact does not affect the accuracy of the ratio coils.



Fig. 336.

The manipulation of the bridge is very much simplified since any unknown resistance under measurement is given by the setting of the rheostat for any particular balance, multiplied by the setting of the ratio or bridge arm switch S used in the measurement. If S is set on 1, then the unknown resistance is the rheostat setting multiplied by 1, or it is read directly in terms of the rheostat. If as shown in the diagram S is set on 10, then the unknown resistance is the rheostat setting multiplied by 10; if S is set on .1, then the unknown resistance is the rheostat setting multiplied by .1 and so on; or if A = Ratio Dial Setting, R = Rheostat Reading, then X = AR. The complete connections for this instrument are indicated by Fig. 338.

The rheostat consists of four dials or decades of 10 coils in the units, and nine coils each in the tens, hundreds, and thousands, making a total

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range of ten thousand ohms. The switch construction is such that the dials may be rotated continuously in either direction. This feature is very useful since it is an easy matter to turn from the highest unit in any particular dial to the lowest without the necessity of turn-back through all the other resistances as is the case in many forms of dials. This is accomplished in the instrument illustrated by providing an inner contact

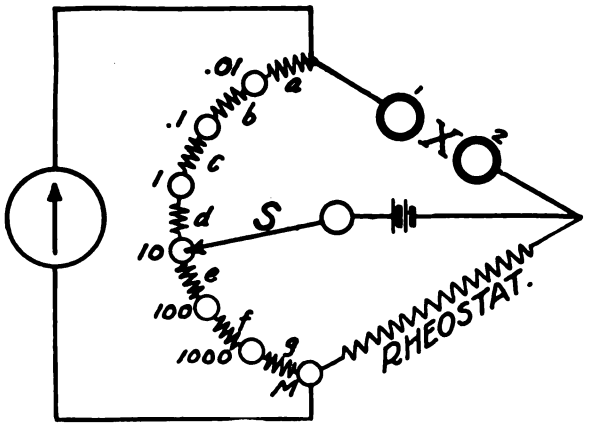


Fig. 337.

ring. The contact brushes in their construction are made up of a number of separate leaves so as to insure good contact by each individual leaf making independent contact. The ends of the brushes are bent so they do not lie tangent to the circle in which they move, and consequently do not wear rings in the blocks.

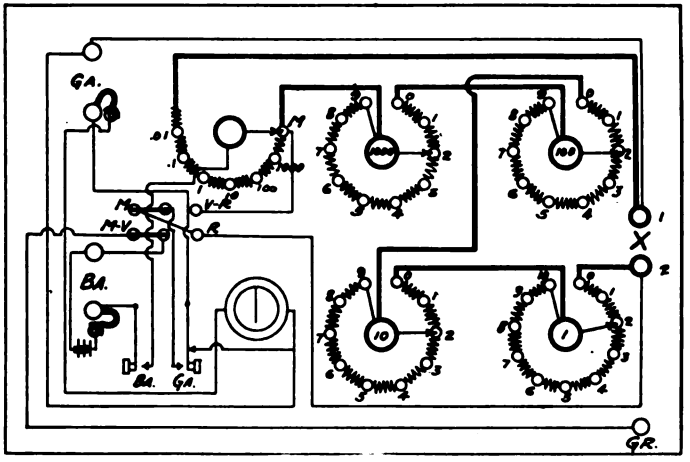


Fig. 338.

The small knife switches are used to arrange the internal connections of the bridge for the various tests that can be made with this instrument, viz., measurement of resistances, location of faults, crosses, and grounds by the Murray and Varley Loop methods, locations of opens, and

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insulation measurements. The last named test should be made with the instruments described under Cable Testing Apparatus, where accuracy is required.

The galvanometer is of the D'Arsonval type and the set also contains batteries with necessary keys, forming a complete unit.

Slide Wire Bridge.—The slide wire form of Wheatstone Bridge is the same in theory as the postoffice or decade type, but differs in the use of a straight wire for the bridge arms. The bridge arms are variable and the rheostat is a fixed value, and it, therefore, differs in these respects from the bridges described heretofore. The scale of the bridge wire can be calibrated so as to read directly in ohms resistance, and it is then called an OHMMETER.

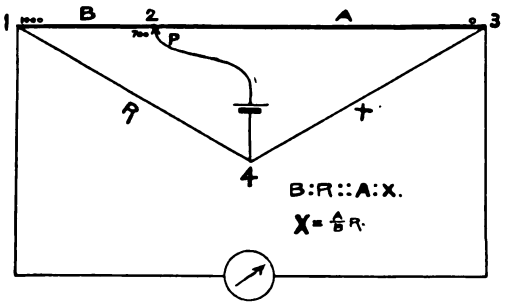


Fig. 339.

Reference to Fig. 339, will show it to have the theoretical connections of the Wheatstone Bridge.

The movable contact P forms the junction point of the bridge arm A and bridge arm B for any particular balance of the bridge. The wire from 1 to 3 is usually divided into 1000 parts and if the wire is uniform in cross section, it will then have a resistance directly proportional to its length, so that the number of divisions between 2 and 3 can, therefore, represent the value of the bridge arm A, and the number of divisions between 2 and 1, the value of the bridge arm B, without referring directly to their resistance in ohms. This is true since the value of the unknown resistance is determined in terms of the rheostat by the ratio of the bridge arms to each other, so consequently, it is immaterial whether we express the ratio in ohms or in length of wire.

If the contact P is at 700, then the bridge arm A will have 700 parts in it, and the arm B will have 1000 parts—A or 300 parts in it. Therefore the ratio

$$\frac{A}{B} = \frac{A}{1000—A}$$

and the formula for the unknown resistance becomes

$$X = \frac{A}{1000—A} R$$

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The bridge wire, in order to be sufficiently long, so as to give accuracy of setting, is usually made one meter. This length of wire would make a portable instrument too bulky, and consequently, it is customary to use a number of shorter lengths joined in series, but having a total length of one meter.

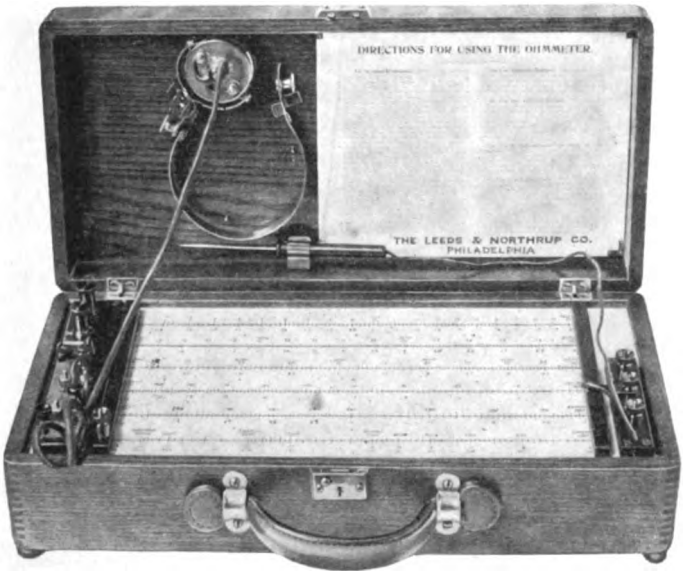


Fig. 340.

A slide wire bridge is illustrated in Fig. 340 and Fig. 341. It will be noted that the bridge wires are joined by terminating in heavy blocks so as not to introduce any extra resistance into the slide wire circuit.

The ratio coils are so arranged that any one of the four values indicated, may be connected in the rheostat arms. The pointer or stylus for moving along the slide wire usually consists of a conveniently arranged touching device with a hard rubber insulating handle.

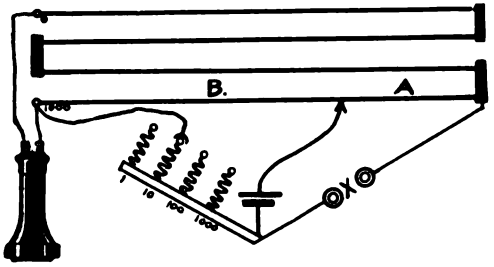


Fig. 341.

The method of operation is to connect the unknown resistance to be measured in the posts provided for the purpose, and touch the various wires until a balance is obtained. The instrument illustrated is arranged

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for a telephone instead of a galvanometer, but a galvanometer can be substituted by connecting it in the same posts.

If the instrument is a Direct Reading Ohmmeter, the wires will have four sets of scale values, one to correspond with each value of the ratio coil.

Lineman's Fault Finder.—This instrument is a Wheatstone Bridge of the "slide wire" type, but has several advantages as compared with the slide wire instrument shown in Fig. 340. In all bridges having stretched wires, in order to secure a high resistance, it is necessary to use fine wires, and this is open to the objection that such wires are not mechanically strong. Another disadvantage of the general form is the use of the hand stylus on the wires. These objections have been overcome in the Lineman's Fault Finder, shown in Fig. 342, by winding the bridge wire helically, insulating the adjacent turns, and then placing the entire wind-



Fig. 342.

ing on the periphery of a disc, about six inches in diameter. The wire is on the inside of the case. The contact is of the brush form, and is operated by means of the hard rubber head in the centre of the scale plate. The scale is divided into 1000 parts, and attached to the head operating the slide contact is an index. This instrument is arranged for the measurement of resistances and the location of faults, crosses, and grounds by the Murray & Varley loop methods. It can also be used for the location of opens, in which case a telephone and source of alternating current is used instead of the contained galvanometer and battery. These two accessories, the latter in the form of a little buzzer or "tone test," are always to be found in a telephone equipment.

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The complete connections and diagrams for each test, with diagrams for operating, will be found fully described on page 307.

This instrument is complete with a sensative D'Arsonval Galvanometer and Battery. The small knife switches are used to arrange the bridge connections, so as to simplify the manipulation of the outfit. The battery circuit is closed by depressing the rubber head controlling the contact on the slide wire, and the galvanometer is also provided with a special key.

The simplicity of design combined with the fact that the results are obtained with very little calculation makes the instrument an ideal one to place in the hands of Cable Splicers and Inspectors. Since the expenses connected with the maintenance and repairs of telephone lines and cables are a very considerable part of the operating expenses of a telephone company, any apparatus which simplifies the location of trouble is of decided importance. The reader is referred to the section on fault location for a complete set of diagrams and working formulae for use with this instrument.

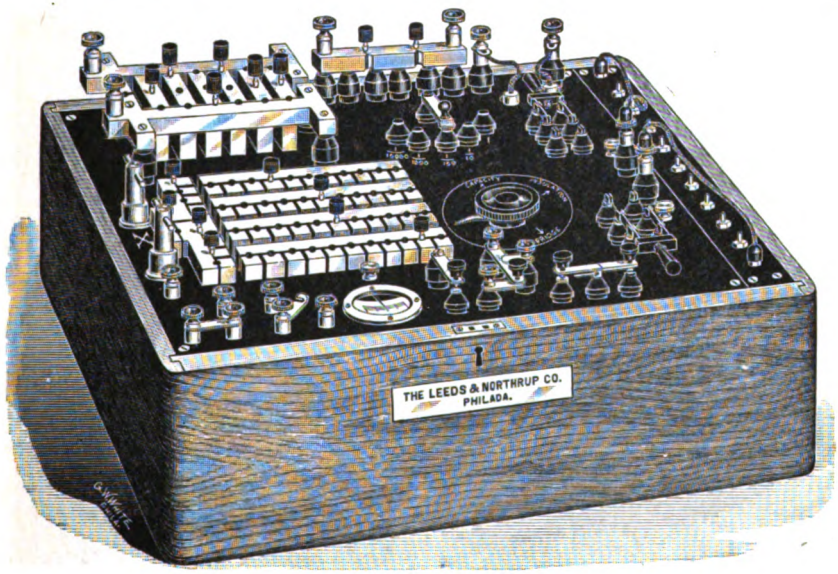


Fig. 343.

Cable Testing Sets.—The term "Cable Testing Set" is applied to an outfit made up of one or more units, and is more extended in its range than the instrument described under "Portable Testing Sets." They generally include the features of an ordinary bridge set, although if arranged only for the measurements of insulation and capacity, the same outfit can not be used for fault location. The measurements with such outfits can be made to a higher degree of accuracy, due primarily to the use of a sensitive reflecting galvanometer, and the fact that all parts are highly insulated from each other, as compared with the testing sets described heretofore.

A number of typical forms will be described.

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Fisher Portable Cable Testing Set No. 1.—This instrument is shown in Fig. 343 and represents the highest development in this class of apparatus. In its design, this set gives the maximum of simplicity, accuracy and convenience of manipulation. The most distinguishing feature of the instrument is the *MASTER SWITCH* by means of which, the connections can be made for the various tests by a single movement, thus avoiding the labor and time which have to be expended in interchanging the connections and memorizing the rather complicated scheme of connections.

In range, this set can be used for the measurements of capacity, insulation resistance, conductor resistance, and the location of faults, crosses, and grounds by the Murray & Varley loop methods.

The following parts are included in the set, as shown in Fig. 344, Decade Wheatstone Bridge, Battery, Galvanometer, Ayrton Shunt, Standard Sub-divided 1-2 Micro-farad Condenser, Standard 1-10 Megohm, Battery and Galvanometer Reversers, necessary Keys for charging, discharging and short circuiting, and Master Switch.

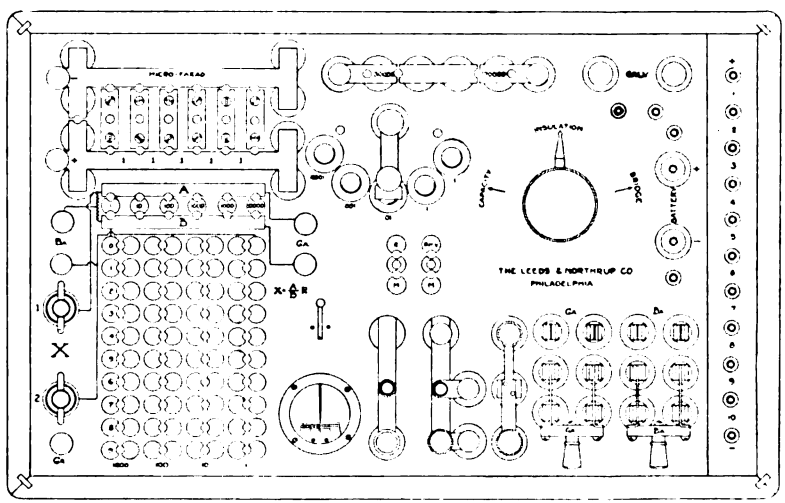


Fig. 344.

The Master Switch, which is a distinguishing feature of this set, and which has been referred to, is illustrated by Fig. 345 and 345a.

When the pointer indicates "Bridge" (See Fig. 344) the two adjacent jaw contacts are connected, Fig. 345a and in the same manner the corresponding jaw contacts which are beneath these two, as indicated in Fig. 345, are connected. The connections from the jaws go to the different parts of the instrument required for the particular test as shown by the index. Thus when making a measurement it is only necessary to rotate the switch so that test and all connections are automatically made.

The connections in the switch are of the knife and jaw type and are thoroughly reliable. The Master Switch can readily be taken apart for cleaning or inspection.

In making measurements of insulation or capacity, all parts involved in the test must be highly insulated so as to reduce to a minimum any leakage between the parts giving a false deflection on the galvano-

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meter. This is especially true when a set is to be used out-of doors and frequently in damp places. To avoid this difficulty, the posts which require such protection, are mounted upon hard rubber pillars with a "petticoat" or groove to increase the leakage surface. A section of one of these is shown in Fig. 346, from which it will be noted that ample insulation surface is provided both above and below the main hard rubber plate. When placed directly on the ground the set as a whole is insulated by means of four rubber insulators, which are mounted on the inside of the lid when not in use. The illustration in Fig. 347 shows the set mounted in this manner.

The connections between the different instruments composing the set are made in all cases by means of heavy bare copper wires which are run through the air from the brass rods projecting through the insulating pillars. The connecting wires are securely fastened by binding against the brass rods with small copper wire, and soldering. They are run at such a distance from each other that there is no danger of their touching. In this way three very important points are secured. The insulation is very high and will not deteriorate, as might happen if covered wires were depended on. All of the connections are very easily inspected and thoroughly reliable contacts are insured.

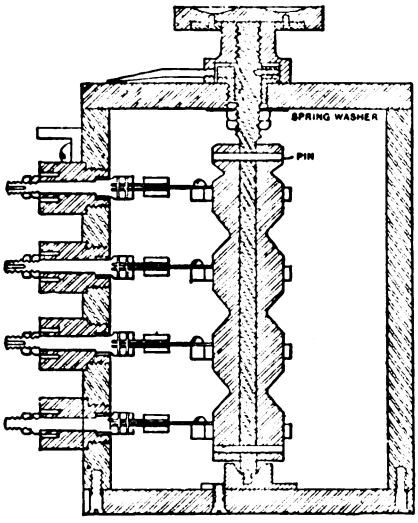


Fig. 345.

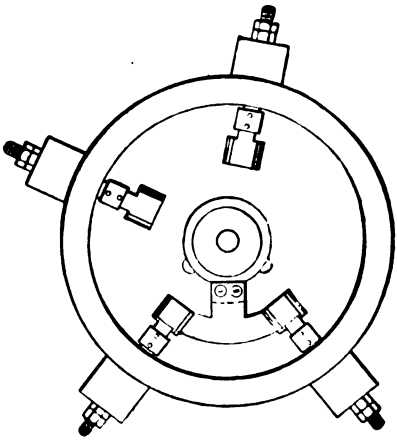


Fig. 345a.

The galvanometer shown in Fig. 348 is a sensitive reflecting D'Arsonval arranged for cable testing and mounted upon a street tripod. The galvanometer can be placed in its carrying case and the tripod folds up as shown in Fig. 349. The Cable Testing Set and Galvanometer case are shown with canvas carrying cases around them for protection.

A brief description of the component parts of the Fisher No. 1 Set will be given:

Wheatstone Bridge is of the plug decade type and is the same as described on page 270.

The Shunt is of the Ayrton Universal type, and hence can be used with galvanometers of any resistance. In addition to general practice it

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is provided with a 1-10000 shunt, and therefore under ordinary conditions can be used with very sensitive galvanometers where the insulation constant of the galvanometer may be several hundred thousand megohms with 100 volts.

The Standard 1-10 *Megohm* is made of two coils of 30,000 and 70,000 ohms respectively, and is provided with plugs by which one or both can be cut out. It is also provided with binding posts at each end, so that if necessary it can be used apart from the set.

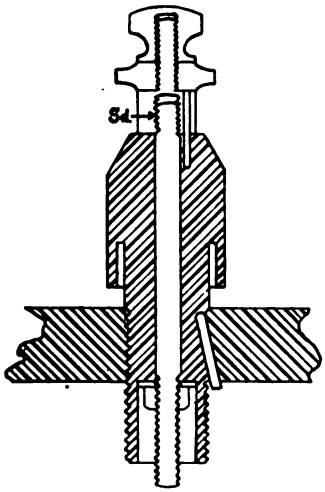


Fig. 346.

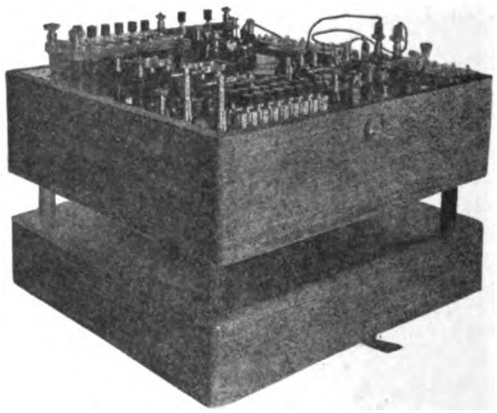


Fig. 347.

The Standard Condenser is sub-divided into 5 sections of 1-10 M. F. each. The sections are connected between parallel brass blocks so that by simple combinations all values from 1-10 up to 5-10 M. F. can be gotten.

The Battery is 10 cells of a type of semi-dry cell which has an E. M. F. of about 1.5 volts per cell when new. It is connected to the Battery posts by means of flexible leading wires.

The Battery and Galvanometer Reversers are the double-throw, double pole type of switches, and with this style of switch there can be no possible question of a bad contact, which is often the case with some types of reversing switches. They serve both as reversers and as a means of breaking the circuit to which they are attached.

The Keys are arranged so as to perform the necessary functions for the various tests. The short circuit key is arranged so that it can be instantly changed from a permanent to a tapping short circuit. By pressing down the button A (Fig. 344) a permanent short circuit is made through a knife and jaw. B is attached to a strip of spring brass, underneath which is a rigid arm. When B is depressed, it first bends the spring, then coming in contact with the rigid arm opens the circuit at A and immediately afterward makes it at B by bringing two contacts together. This contact opens as soon as the spring is released and forms the tapping short circuit.

The Contained Galvanometer is a D'Arsonval and of ample sensibility for all measurements of resistance and fault locations unless the latter are extremely high.

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The External Galvanometer, Fig. 348, is a reflecting D'Arsonval and has in its design certain features which make it easy to set up and operate as compared with the usual laboratory form of instrument. The moving system is visible through a glass window and there is ample clearance between the coil and the core. An index is provided on the coil and core so that it is an easy matter to tell when the coil is swinging centrally in its field. The reading telescope is of a special design of unusually high magnifying power. Although the telescope arm is only 15″ long and the scale 8″ long, the magnifying power is such that the appearance is the same as that of a scale at a meter's distance viewed with an ordinary telescope. The scale has 250 divisions each side of the zero.



Fig. 348.



Fig. 349.

This optical system is one which makes it particularly easy "to find the scale," and in setting the instrument up no delay is occasioned in getting it properly adjusted and focused. The galvanometer is clamped on the head of the tripod by two wing nuts. To remove the instrument it is only necessary to unscrew these a few turns and swing them out.

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The Fisher Portable Cable Testing Set No. 2.—The requirements for a cable testing set can often be met by an outfit which has its parts simplified as compared with the Fisher No. 1 Set, and when the conditions, under which it is to be used, will not require extremely high insulation. These limitations will permit the design of an outfit which is lighter, and consequently such an outfit will be more portable.

The Fisher Portable Cable Testing Set No. 2 has the same range and accuracy as the Fisher No. 1 Set, but the parts are not as highly insulated. Its insulation is such, however, as to be found entirely satisfactory except under the most trying conditions of moisture.

In range, this set can be used for the measurements of electrostatic capacity, insulation resistance, conductor resistance, liquid resistance, the location of faults, crosses, and grounds, by the Murray and Varley Loop Methods, and locating breaks in cables.

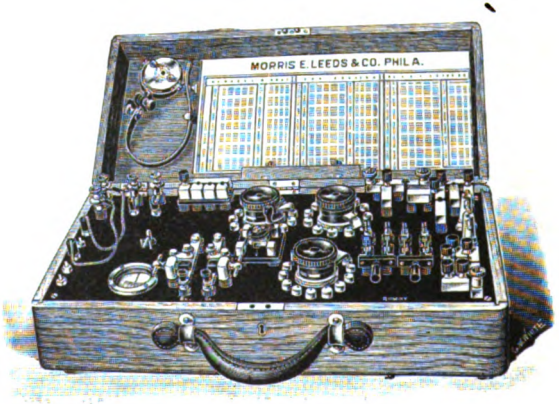


Fig. 350.

This instrument is illustrated by Fig. 350 and Fig. 351. It consists of a modified form of Wheatstone Bridge, rheostat, battery, galvanometer, Ayrton shunt, standard condenser, standard 1-10 megohm, keys, commutator for producing an alternating current, and switches for quickly making changes from one test to another.

The Wheatstone Bridge adopted in this set is a marked variation from the bridges described thus far and is a type known as the Kelvin-Varley Slide. It is a form having the bridge arms variable and the rheostat fixed, as in the slide wire bridge, but the resistances in the bridge arms are made up of resistances in the form of coils. This arrangement gives the slide wire a much higher resistance, and by means of a system of shunting, the coils comprising the bridge wires, can be read to their thousandth part.

The arrangement of the bridge arms is shown in Fig. 352. The points marked G and B are the points of attachment for the galvanometer and battery. At R are represented the four coils of the rheostat any one of which may be used, and at X, the unknown resistance. Between M and N are eleven coils of equal value which form the bridge wire. There is a contact point between each coil and the one next to it. The other coils shown in the series marked "Tens" "Units" are used to sub-divide the coils of the bridge. They constitute what may be called an electrical ver-

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nier, by means of which the bridge wire is sub-divided to thousandths of its total value. The two arrows in contact with the points marked 1 and 3 in the "Hundreds" row and with the 2 and 4 in the "Tens" row represent contact arms which can be moved along to make contact at any of the contact points, but are always at the same distance apart so that they have two coils between them. They are connected to the ends of the row of coils below them so that these two coils are shunted with the entire row of coils below. Consider now the result of this shunting in the case of the "Tens" and Units" coils. The tens are, for example, eleven coils of 80 ohms each. The units are ten coils of 16 ohms each. The two 80 ohm coils between the points 2 and 4 are shunted with the ten 16 ohm coils; 160 ohms is shunted with 160 ohms, and the resistance between the points 2 and 4 becomes 80 instead of 160 ohms. There are then in the "Tens"

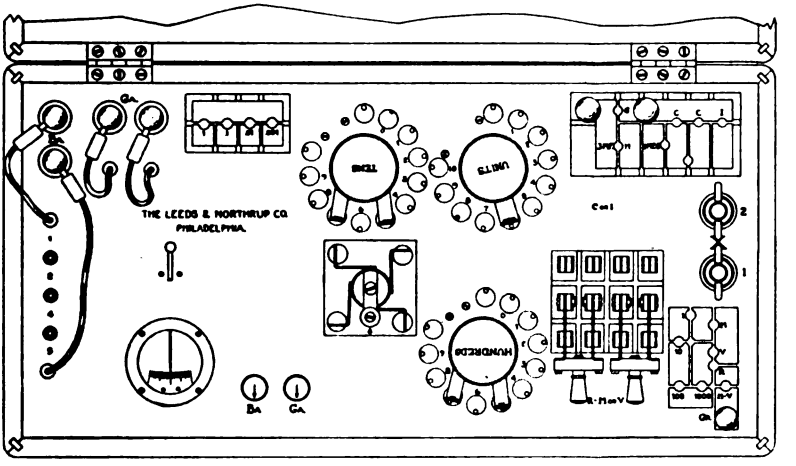


Fig. 351.

series, for any position of the double arms, actually ten resistances of 80 ohms each. The point of the Battery contact may be placed at any position in the "Units" series, thus sub-dividing the shunted coils in the "Tens" series to tenths. The coils in the Hundreths" series are 400 ohms each, and are sub-divided in the same way by those in the "Tens" series. An example will make the use of the bridge clear. Assume that a balance is obtained with 100 unplugged in the rheostat and the contacts in the position shown. The bridge reading is then 237. Call this value A. Then

$$X : R :: A : 1000—A, \text{ and } X = R \frac{A}{1000—A} = 100 \frac{237}{763} = 31.06$$

The calculation of the fraction

$$\frac{237}{763}$$

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would take considerable time and might lead to errors. To overcome the necessity for this is furnished conveniently fastened into the lid of each set, a table giving the values of

$$\frac{1000—A}{A}$$

for all values of A between 0 and 1000. Reference to the table shows

$$\frac{A}{1000—A} = .3106 \text{ for } A = 237.$$

We have, consequently, simply to multiply the value taken from the table by the resistance unplugged in the rheostat to determine the value of X. From this it will be seen the Wheatstone Bridge measurements may be made and calculated very rapidly.

In the actual construction the coils are arranged in three dials as shown in Fig. 351.

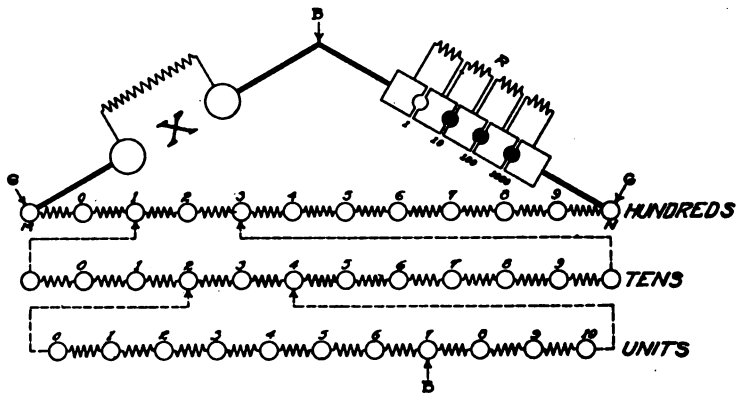


Fig. 352.

The Testing Set shown in Fig. 353, differs from the Cable Testing Sets described thus far in that the parts are made up of separate units instead of being combined and permanently connected. It is useful when accurate measurements of insulation and capacity only are to be made, and finds application by construction companies who wish to make an insulation test on a newly constructed telephone line before turning the line over.

The Set consists of a sensitive reflecting D'Arsonval galvanometer, complete with street tripod and repair kit, Ayrton Shunt, 1-10 Megohm Standard Resistance, and a Standard .3 M. F. Condenser, complete with charge and discharge key. The last named parts mounted in hard rubber cases so that in manipulating them, they may be held in the hand without interference of leakage from the operator to ground.

Insulation Measurements are to be made with the apparatus as shown in the diagram, Fig. 354.

In general, the usual direct deflection method is used. The constant of the galvanometer is determined by observing the deflection due to the

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current from a definite battery through a known resistance (100,000 ohms), the galvanometer being shunted. The deflection of the galvanometer due to the current from the same battery through the insulation resistance to be measured is observed, and from these two deflections the insulation is calculated.

The apparatus and arrangement differ from that usually employed. 1st. In that the battery key is combined with the shunt. 2nd. In that there is no short-circuit key for the galvanometer.

The battery key b is combined with the Ayrton Shunt for compactness and also for convenience in manipulation. The knob a controls the key b and is mounted so that it projects up through the handle which operates the shunt. By depresssing a, the contact b is closed. This is arranged so that it can be locked in the closed position.

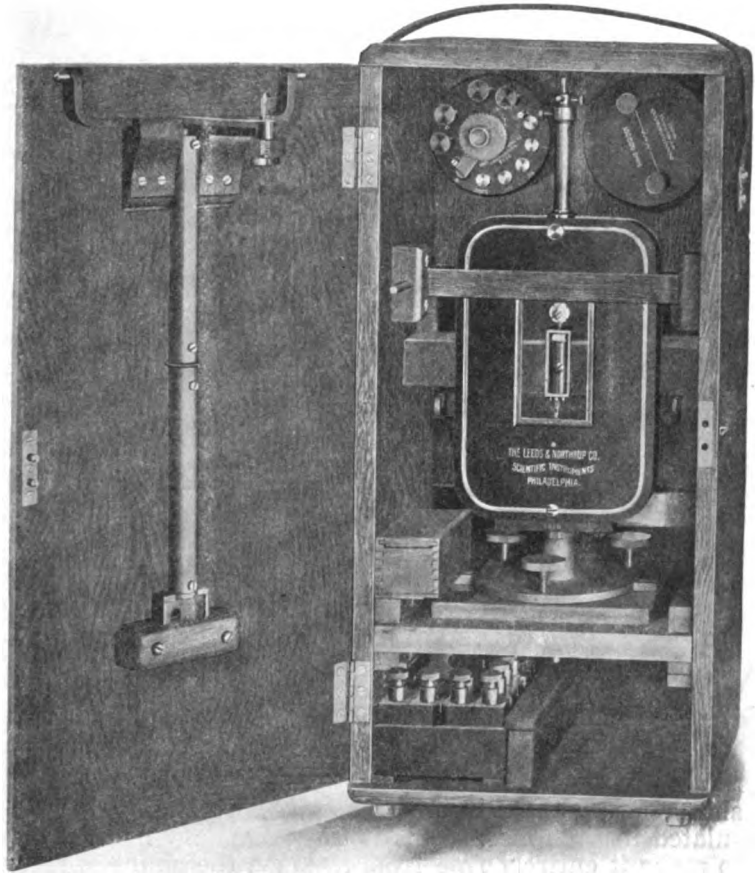


Fig. 353.

The galvanometer short-circuit key is omitted partly in the interest of simplicity of working and compactness and primarily to avoid the bad effects due to using a short-circuit key with a damped D'Arsonval Galvanometer. As is well known, a D'Arsonval Galvanometer damped to

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give a satisfactory period of deflection becomes exceedingly unsatisfactory and sluggish when it is short-circuited. The necessity for using a short-circuit key is avoided by connecting the shunt as shown in the diagram. With the shunt switch on the position zero, the galvanometer is out of the circuit and no current passes through it. The battery key being closed, the course of the current is from one side of the battery through the insulation of the cable (or the 100,000 ohm box as the case may be) to Ga. through a and b, to the other side of the battery. This is the position used during the period of electrification of the cable.

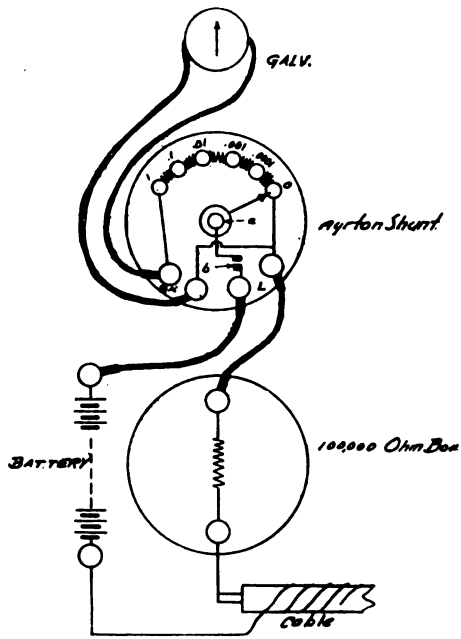


Fig. 354.

This arrangement has the additional advantage of protecting the galvanometer against excessive deflection when a leaky cable is under investigation. The galvanometer deflection is taken by moving the shunt from the position zero toward the position 1, and in the case of a leaky cable, there would be small deflection with the shunt on the position .0001 or .001, and the excessive deflection which the unshunted galvanometer would get could be avoided.

The shunt may be held in one hand while its handle and the knob a are manipulated in the other. This is the customary method of working. In order to make it entirely free from leakage, the shunt is mounted in a hard rubber case.

The 100,000 ohm box is arranged without any provision for short-circuiting the resistance. This is done because in the great majority of cases, it is not necessary to make any correction for the addition of 100,000 ohms to the insulation under measurement. In a few cases where the correction is necessary, it can be made, or the two binding posts can be connected by a piece of wire to cut out the resistance.

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The simplicity of the arrangement and its operation will be made entirely clear from the following directions for making measurements.

Directions for Insulation Measurements.—Connect a suitable battery (100 cells) as shown in the diagram drawing, connecting one terminal of the battery directly to the 100,000 ohm box instead of to the cable. Close battery key b by depressing a and move the shunt to the position .0001. With 100 cells of battery, the galvanometer will now give a readable deflection. Call this deflection D′ and the shunt position S′, then the insulation constant of the galvanometer in megohms will be

$$\frac{D'}{10 \times S'}$$

For instance, if D′ = 80 and S′ as above = .0001, then

$$\text{Const.} = \frac{80}{10 \times .0001} = 80{,}000 \text{ megohms.}$$

To determine the insulation of the cable, reset the shunt at the position zero and connect in the cable as shown in the diagram. Close the battery key b and after allowing a sufficient period for electrification to elapse, move the shunt successively over the position .0001, .001, .01. 1, to 1, observing the galvanometer to see that it does not give too large a deflection. When a readable deflection is gotten, note it and the shunt position. Call this deflection D and the shunt position S, the insulation I to be determined will then be

$$I = \frac{\text{Const.} \times S}{D}$$

If, for example, the deflection D is 40 and the shunt position S is I, the constant as above determined being 80,000, then

$$I = \frac{80{,}000}{40} = 2{,}000 \text{ megohms.}$$

Measurement of Capacity.—For this purpose a one-third micro-farad standard condenser and condenser switch are used. The construction of this and the method of operating it are clearly shown in the diagram. The case is made entirely of hard rubber and the parts are very well insulated so it may be held in the hand without danger of error while making a test.

The method is the usual one of comparing the discharge from the cable with that from the standard condenser. Although the galvanometer is damped the deflections are strictly proportional to the capacities. With a plug in the position "Cab," the deflection due to the cable can be taken, and with it in the position ".3 M. F.", that due to the standard condenser can be taken. See Fig. 355.

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The Location of Faults.

One of the most common and at times, one of the most difficult tests to make, requiring skill and judgment in testing is the location of a "fault." The term "Fault Location" is understood to mean the location of a cross, ground or other similar disturbing influences, which have interrupted perfect service upon a line. The location of "opens" or complete break is usually considered as distinct from ordinary ground and cross location, although in making such a determination the bridge is used in a manner similar to some forms of fault location.

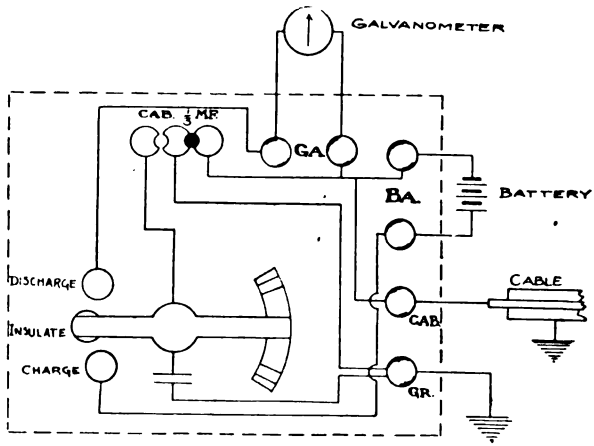


Fig. 355.

The fundamental principles in fault location are quite simple but in many faults, we have to deal with conditions which are variable and often undeterminable, so that the location of a fault is not always reduced to the *SIMPLICITY OF SUBSTITUTING QUANTITIES IN A FORMULA.* This foregoing statement is made, so as not to mask a well known truth among experienced testers, but it is not to be inferred that all fault location must necessarily be a complex measurement. The use of a bridge on line trouble will soon give an inexperienced operator confidence, which in conjunction with a close study of the line conditions, will place him in a position to locate faults with rapidity and accuracy.

The subject of locating faults has been given considerable study and many specialized methods have been adopted. The conditions to be met and cautions to be observed when locating a fault in a submarine cable are quite different from those encountered in land lines. The same applies when locating faults in low resistance conductors, such as power-feeder cables, as compared with the higher resistance telephone circuits.

To give a critical discussion for each case that might arise, is beyond the scope of this article, but the fundamental principles will be shown and attention will be called to some general facts relating to fault location.

The more common methods of locating a fault are by means of the Murray and Varley Loops. The fundamentals of both methods are quite simple but, as will be shown later, each one has special applications.

In making either of the loop tests, it is necessary to have a complete circuit, from one binding post of the instrument, through the fault section, and back to the other binding post. The circuit is called the "loop."

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Theory of the Murray Loop.—As already explained, a bridge is balanced when the arms of the bridge shown in Fig. 356, when A: X :: B : R or

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

and we shall now see that in loop testing, we make use of this bridge arrangement.

In the Murray Loop Test, shown diagrammatically in Fig. 357, the two ends of a loop which has a fault at F are connected to the two arms of a bridge at C and E. It is thus evident that the resistance of the circuit from C to the fault F and from the fault F to E form two arms of the bridge, with b and d as completing arms. The battery connection is grounded at the instrument and flows through the earth to the fault F. The galvanometer is connected as shown.

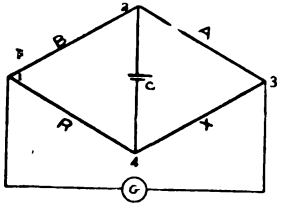


Fig. 356.

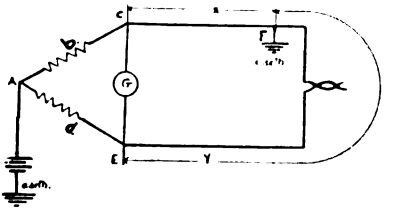


Fig. 357.

When the bridge is balanced b Y = d X
Let L be the total resistance of the loop from C to E.
Then X + Y = L
Therefore Y = L — X

Substituting this value of Y in the above equation,

$$b(L - X) = d\ X$$

$$\text{From which } X = \frac{L\ b}{b + d}$$

The above simple algebraic solution for the fault will be sufficient to show the fundamentals of the Murray Loop Test, and some consideration will now be given to the "practice" of fault location.

The result for X is in ohms, but knowing the size of the conductor, its resistance per unit length can be obtained from any wire table or it can be obtained directly from the formula as will be shown later.

It will be noted that the loop measurement made, is independent of the resistance of the fault, for, just as in the Wheatstone Bridge circuit, any resistances in the battery and galvanometer circuit do not affect the ratio of the bridge arms. When the fault has a high resistance then but little current can flow, and in order, therefore, to increase the sensibility of the galvanometer it becomes necessary to add more battery. If the

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fault in a grounded or crossed conductor were always of negligible resistance, in other words if it were a "dead" short circuit or ground, its location could easily be detected by measuring the resistance from the point of test and back again through the ground or through the other conductor affected in case of a cross. This, however, is very seldom the case and it becomes necessary to employ tests, such as the loop, giving results independent of these resistances.

Murray Loop With Post Office Bridge.—The foregoing remarks will enable the reader to understand the use of the postoffice bridge, which has already been described for the measurement of resistances and the testing sets to be described later, for the location of a fault by the Murray Loop Method. The bridge is shown in plan in Fig. 358 and the theoretical diagram, Fig. 359, indicates the connections when the instructions given are followed. It will be noted that the rheostat of the bridge is the only adjustable arm but so long as we maintain the quality required by the law of the bridge, we can divide any one of the four arms into fixed and adjustable arms.

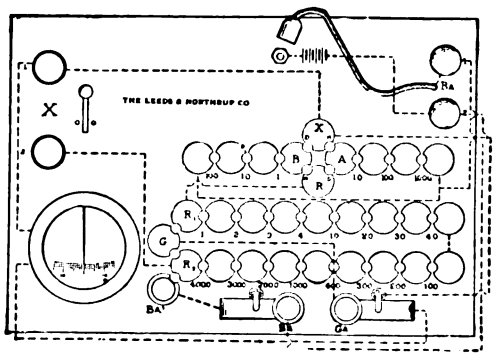


Fig. 358.

Join the faulty and good wires at the distant end of the cable; connect the faulty conductor to X_2 and the good wire to X_1. Measure the total resistance of the loop and call this r. The connections for making the resistance test are the same as described under "Resistance Measurements." Plug R_2 to block G, disconnect R_2 from Ba^1, and connect Ba^1 to ground, or if the fault is a cross, connect Ba^1 to the wire crossed with the faulty wire. Connect B to R and A to X, plug in all the coils in arm B and unplug 1000 ohm coil in arm A. Then vary the rheostat until a balance is obtained.

Letting r = total resistance of loop,
a = resistance to fault,
A = resistance unplugged in bridge arm A.
R = resistance unplugged in rheostat.

Then,

$$a = \frac{R\ r}{A + R} = \text{resistance to fault from post } X_2.$$

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The result obtained thus far is in ohms but the distance to the fault can be expressed in feet by letting L = length of one of the two cables which are assumed equal, since a, the resistance to the fault, and r, the total resistance of the loop are proportional to the lengths, therefore, d, the distance to the fault is:

$$d = \frac{2\ L\ R}{A + R}$$

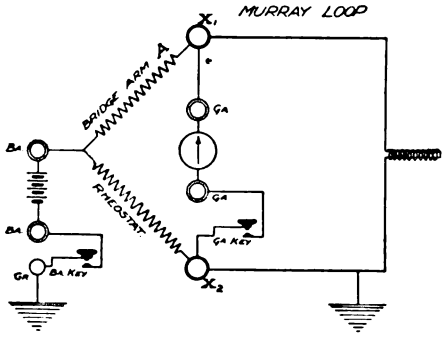


Fig. 359.

Example—The total resistance of a loop, one wire of which was faulty, was found to be 290 ohms. With 1000 unplugged in bridge arm A, a balance was obtained with 208.3 unplugged in the rheostat.

Therefore, the resistance to the fault is

$$\frac{208.3 \times 290}{1000 + 208.3} = 49.993 \text{ ohms.}$$

Theory of the Varley Loop.—In this, as in the Murray test, the two ends of the faulty conductor must be accessible by forming a loop with it and a good return conductor. The connections are indicated in Fig. 360.

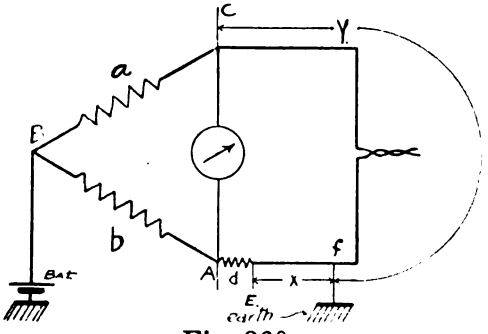


Fig. 360.

It will be noted that in this test an adjustable resistance d (which is the rheostat of the bridge) is added in series to the faulty wire, and as

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may be expected, the law of the Wheatstone Bridge is again applied. The loop C to E contains a fault at f, and if X and Y are the resistances to the fault from E and C respectively, then

$$a(d + X) = bY,$$

And,
$$Y = L - X,$$

Therefore,
$$a(d + X) = b(L - X)$$

From which,

$$X = \frac{bL - ad}{b + a}$$

If $b = a$ then,

$$X = \frac{L - d}{2}$$

It is necessary that the faulty one of the two looped conductors be attached to E or the arm, having the adjustable resistance. If this is not done, after joining up it would be found that no balance could be obtained, then we may be sure that the fault lies nearer C and E.

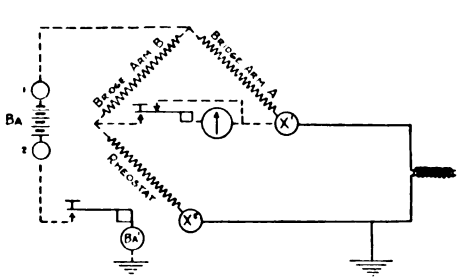


Fig. 361.

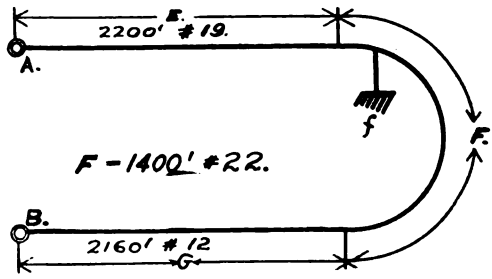


Fig. 362.

Varley Loop With Post Office Bridge.—Join the faulty and good wires at distant end of cable and connect faulty to X_2 and good to X_1. Measure total resistance of loop. Connect R_1 to G and Ba^1 to ground, or, if the fault is a cross, connect Ba^1 to the wire crossed with the faulty wire. Connect A to X and B to R, vary resistance in bridge arms and rheostat until a balance is obtained.

The diagram of connections in Fig. 361 shows the relation of the bridge parts.

r = total resistance of loop.
a = resistance to fault.
A = resistance unplugged in Bridge Arm A.
B = resistance unplugged in Bridge Arm B.
R = resistance unplugged in Rheostat.

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$$\text{Then } a = \frac{Br - AR}{A + B}$$

Example.—The total resistance of a loop, one wire of which was faulty, was found to be 290 ohms. With 10 unplugged in bridge arm A and 100 in bridge arm B, a balance was obtained with 2350 unplugged in the rheostat.

Therefore, the resistance to the fault:

$$\frac{100 \times 290 - 10 \times 2350}{10 + 100} = 50 \text{ ohms.}$$

General Remarks on Fault Location.—Having thus seen the application, of the loop test for the location of a fault, there are certain general facts which must be given consideration.

It is a careful study of these various conditions which will often explain the causes for apparent inconsistencies between results and calculations. The "art" of locating faults is one based primarily upon practice, and the wire chief, who has not the ambition to take a portable testing set and "venture" cannot possibly hope to cope with conditions which are often puzzling and hard to account for.

The first great essential is to be sure, that the various connections are correctly made, and the contacts electrically perfect. If one has to rely upon an unexperienced assistant for making joints and connections on poles or elsewhere, much annoyance may be experienced. Too much emphasis can not be placed upon the making of reliable connections, as any resistance caused by poor contacts, in the loop circuit will enter directly as an error in the location. If, for instance, the assistant in going to the end of the loop, did not join the faulty and good wire in a substantial manner, but had introduced a joint having a resistance of ¼ *W*, and the loop consisted of No. 2. B. & S. Copper Conductor, then the location would be in error about 16 feet. Experience will teach one, however, to frequently detect improper and poor connections by the use of check methods, or by duplicating some of the tests, or by special tests which one has learned to employ.

Use Mate for Good Return.—In any case of cable trouble, if the mate of the faulty wire is good, always use it as the location will be much more accurate. When the good and bad wires are of different pairs, one may be longer than the other, thereby making a slight error in the distance to the fault.

Loop May Consist of Different Sized Conductors.—If the loop is made up of several lengths of conductors of different sectional areas, as often occurs when cable circuits are joined to toll circuits, the distance to the fault is easily calculated, by expressing the different cross sections in terms of equivalent length of one of the conductors in the loop. To make this allowance, the cross sections and the lengths of the different sections must be known and should be reduced to the size of one of the conductors, by multiplying the length of each conductor respectively, by its rated resistance per 1000 feet and dividing the product by the rated resistance per 1000 feet of the size of the conductor to which it is being reduced.

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The following example will explain the process. In the loop shown in Fig. 362, the conductor in the cable section E consists of 2200 feet of No. 19 B. & S., the conductor in the cable section F of 1400 feet of No. 22 B. & S., and the last section G is part of a toll circuit, consisting of 2160ft. No. 12 B. & S.

To reduce the No. 19 and No. 12 in terms of No. 22, we have

$$\frac{2200 \times 8.038}{16.12} = 1097 \text{ ft. of No. 22 is equal in resistance to 2200 ft.}$$

of No. 19.

$$\frac{2160 \times 1.586}{16.12} = 212.5 \text{ ft. of No. 22 is equal in resistance to 2160 ft.}$$

of No. 12.

This makes the total resistance of the loop equivalent to 1097 ft. + 1400 ft. + 212.5 ft. = 2709.5 ft. of No. 22 B. & S. conductor. If the result showed the fault, f is a distance of 1346 equivalent feet from A, of this 1097 feet are in the section E. Consequently, the fault is 1346 — 1097 = 249 feet from junction of E and F.

It is a practice in some cases, where two different sized cables are spliced, to mark on the cable diagram an extra scale for use in fault location. If for instance, the two cables spliced were Nos. 19 and 22, then for the lengths of the No. 19 cable, no extra scale or dimensions would be added, but for the No. 22, an extra fault location scale or dimension would be added. This scale would be double the actual cable lengths, since the No. 22 conductor has twice the resistance of No. 19 conductor. These distances, given by the fault location scale, are used directly in the formula for fault location and the distance to the fault is read off on the fault location scale.

Cable Inspection.—No matter how carefully the cable has been installed, whether it be underground or overhead, too much emphasis cannot be laid upon its being tested and inspected so as to maintain the entire system at its maximum efficiency. The inspection should be done at regular intervals, and attention given to the manholes, covers, protectors, terminals, hangers, junction boxes, etc.

The cables are subject at all times to lightning, electrolysis, chemical action, heat, long continued vibrations, and mechanical injuries, so that the tester must ever be on the alert.

Difficulties in Making Measurements.—Accurate measurements are often prevented by the influence of foreign currents, flowing in the loop or to neighboring circuits carrying heavy currents. If the galvanometer is of the magnetic or Thompson type, any surrounding magnetic disturbances will cause it to show a "restlessness" but since modern testing sets are all equipped with D'Arsonval Galvanometers, which are not affected by neighboring magnetic fields, no further reference will be made to the former type.

Due to foreign currents flowing in the loop, the Galvanometer will sometimes deflect as soon as the galvanometer Key is closed. This trouble is

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sometimes caused by ringing current flowing in and out of a fault due to a ringing generator wire, used through the cable to supply branch exchanges with ringing current. If the testman cannot remove the disturbing current by shutting it off, he had better try another loop, or try the same one some time later.

Induced currents can be set up in a loop by a Morse line operating through the same cable, or by an outside power wire used for a good wire. It often becomes necessary to make use of another loop which may not be so bad.

A disappearing ground is often encountered while trying to locate a fault. This is generally caused by the battery current from the testing set turning a slight moisture ground into gas. Sometimes by waiting for a short time the ground will reappear. By employing more battery so as to get a higher voltage, and taking a quick reading, it is sometimes possible to catch a location. Sometimes the ground can be increased or permanently burned out, by applying ringing generator to the faulty wire. If these methods are not successful it is best to leave the trouble until it becomes worse. A ground that is sufficient to make a line noisy can, as a rule, be located.

Locating Grounded and Crossed Wires.—Preliminary Test.—The first step in fault testing is to ascertain the nature of the fault, by making a preliminary test of the reported trouble. This can be done from the exchange end of the cable. The exchange end of the line should be cut off and the test made directly on the cable conductor terminals. The test consists of determining the electrical condition of the available wires. After making the preliminary test, the plan of the cable should be examined to see if it can be located in a particular branch or terminal by the readings obtained.

Continuity.—To test for broken wires, the conductors should all be grounded at one end of the cable, and the test applied at the other end in the following manner:

Ground one side of a battery to the lead cover of the cable and connect the other side to a galvanometer, voltmeter, electric bell, or telephone receiver. The wire running from the other side of the instrument used, should then be touched consecutively to every wire of the cable. No indication of an electric current is evidence that the wire under the test is broken.

Crosses.—In testing for crosses, bunch all the wires, and connect them to one end of a testing circuit such as is described above; then remove one by one the wires bunched, touching each successively to the other end of the testing circuit. The indication of an electric current shows that the wire touched is crossed with one of the other wires; said wire should then be marked and connected to the bunch and the test repeated until nothing is left but crossed wires, when it is easy to determine between which wires the crosses exist; care must be taken to see that none of the wires are in contact with each other, or the lead cover at the far end of the cable.

Crossed wires are located by the same methods used for grounded wires except that the post Gr. instead of being connected to ground is connected to the wire crossed, with the one used in the test. The location of crosses is usually a more simple test than with grounded circuits, as

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the question of earth currents is entirely eliminated, and E. M. F.'s at the point of contact are of less common occurrence.

Grounds.—If the fault is not due to a cross or open, the resistance to ground of the faulty wires, can be measured in the regular way, as if the unknown in the bridge was conductor resistance. The only exception being that one of the X posts is connected to the faulty wire and the other to the ground. If the fault is due to the presence of moisture the resistance will become greater, the longer the battery is applied.

The availability of a wire for a good return mate can be easily picked out by running over all the wires and having the testing set connected for insulation measurement. If a 100 pair cable is in trouble, it is possible to make a quick test of all the wires, in a few minutes and pick out the best and worst ones.

The condition of the fault can be found practically by the use of a telephone and battery or direct current magneto. The reversed current magneto is not thoroughly reliable because it will ring when the electrostatic capacity of the wire is sufficiently large. However, even with it, in the hands of an experienced man, low resistance faults can immediately be detected by the loudness of the ring and resistance to rotation of the handle.

The methods first mentioned, however, are the most reliable and convenient because they can be applied directly with the Testing Set.

If the resistance of the fault is low, say 100 ohms or less, a few cells of battery will be sufficient to make an accurate location. If the resistance is over 1000 ohms an auxiliary battery of 25 or 50 cells may be needed. For very high resistance faults a reflecting galvanometer should be used in place of the testing set galvanometer.

Two Faults on One Wire.—Having thus found and tagged the good and bad wires the next step is to make the connections for locating the fault. If the good and bad wires are of the same size and length the regular Murray or Varley loop tests as described under the directions for operating the Testing Sets can be applied, the first method being preferred.

Sometimes, when making these tests, it is impossible to get a balance. This is generally an indication of two variable resistance faults at different points, or one of considerable extent, such as might be caused by the presence of moisture over 50 or 100 feet of cable.

Under these conditions an accurate determination of the location of either fault is most unlikely. Generally speaking the calculated result will be nearest the fault of lowest resistance. In all cases the calculated distance must be somewhere between both faults but as there is no practical way of finding the respective resistances of the faults, the probable location cannot even be estimated. The best plan of procedure is to make a rough measurement and calculation, cut the cable at this point, and then determine separately the distance to the fault in each section of cable.

To find whether there are two faults on a faulty conductor, make tests from both ends and if the calculated locations are identical, only one fault exists, if different there are two or more.

The effect of different fault resistance on the calculated results is illustrated in Figs. 363 and 364. Fig. 363 gives a diagram of the Murray loop test on a faulty wire containing two faults of resistances respectively x and y.

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The resistance of both good and bad wires is 100 ohms each, and the resistance to the first fault is 50 ohms and to the second 90 ohms. As the distances and resistances are proportional we can discuss this problem by considering the resistances only.

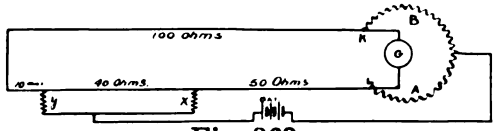


Fig. 363.

Fig. 364 shows a number of curves determined experimentally which give for certain definite values of x and varying values of y the corresponding resistance as calculated by the Murray loop formula which for this case, is:

$$\text{Resistance} = \frac{A}{A + B} \times 200.$$

The resistance to the x and y faults are indicated by horizontal lines and it will be noted that for all values shown of x and y, the calculated resistances lie between these lines.

The full line curves are for values of x used with the connections shown in Fig. 325. The broken line curves are for values of x used when the tests were made from the other end of the faulty wire. It will be noted that the test made from the two ends of the faulty wire with the same values of x and y always give different results, and that they differ most for low values of y. Also that when the resistance of one fault is high and the other low, the calculated resistance is nearest the fault of lowest resistance.

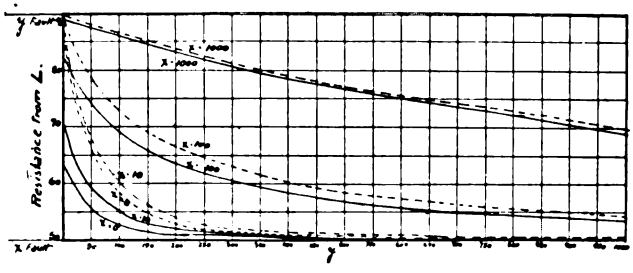


Fig. 364.

These curves are given more as an object lesson to show the great improbability of making a correct location of either of two faults on one wire.

Correction for Lead Wires.—It sometimes happens that the testing instrument cannot be placed directly at the cable ends and it then becomes necessary to employ leading wires between the testing set and cable. When such is the case it is simplest to use leading wires of the same size as the faulty wire. Then the length of these leads must be added to L, the

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combined length of the good and the bad wires, and from the calculated distance to the fault must be subtracted the length of the leading wire connected to the faulty wire. If the leading wires are different in size from the cable wires, then reduce them to the equivalent length of the cable under test, as was explained for locating faults in circuits made up of two or more conductors having different sections.

Check Tests.—In the regular and in some of the special applications of the loop tests, a check test can be made by reversing the good and the bad wires in the arms of the bridge. This change also requires a slight modification in the formula used for solving.

Test Indicating Connections.—A simple method of determining whether a connection has been made at a distant point to a wire which can be connected to the testing set is as follows:

Make preparations for a test of electrostatic capacity by the deflection method and take discharge deflections before and after the connection. If the latter is the greater a connection was made.

This of course only applies when equipped with a more complete cable testing set.

Location of Opens.—When a conductor is actually broken and the return circuit from the break is therefore of a resistance that is practically infinitely high, a new set of conditions are to be considered. In its location we depend upon the fact that any conductor, whether it is in a cable in the earth or submerged in water or an air wire, possesses "capacity" and is in fact a condenser of which it forms one plate with the insulation from the point of test to the break as the di-electric and the other plate being the earth or water.

This capacity is proportional to the length of the conductor so by knowing its capacity per unit length, one procedure is to measure the capacity up to the break and convert it into the length of conductor. This method is open to the objection that the capacity is not always uniform throughout the length of a wire, as variations of 10% or more may occur. In measuring the capacity by this test, the deflection method is used in which the cable is charged with a certain potential, and the discharge is read by means of a reflecting galvanometer. If moisture is present, even in very small amounts, the deflection is liable to be augmented through the action of electrical absorption and the consequent return currents after the instant of discharge. This phenomenon takes place in greater or less extent with all cables and increases with rise of temperature.

A method, which largely removes the above objections and at the same time can be performed by a simple bridge arrangement, with the addition of a telephone receiver and reversed battery current, is to compare the capacity of the open wire from the point of test to the open with the capacity of the good mate.

Referring to Fig. 365, if the capacities C_1 and C_2 are the capacities of an open wire and its good mate respectively, we can balance these two capacities against R_1 and R_2 in the other two arms of a Wheatstone Bridge. Instead of a galvanometer, however, we make use of a telephone and a source of alternating current produced by one or more cells of dry battery. If we adjust the resistances in the bridge so that no sound is heard in the telephone, then the points one and three will be at equal potential, and the cable capacities represented by C_1 and C_2 will be charged with the same difference of potentials, and will contain quantities propor-

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tional to their capacities; but the quantities flowing into the condensers in the same time are inversely proportional to the resistances R_1 and R_2, therefore,

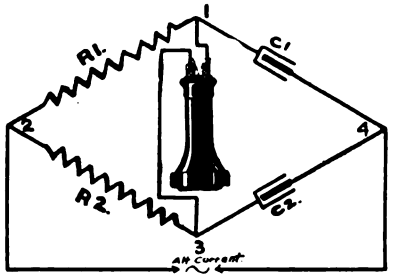


Fig. 365.

$$\frac{R_2}{R_1} = \frac{C_1}{C_2}$$

since capacity is directly proportional to the length and if L_1 and L_2 represent the lengths of the open and good wires, then,

$$\frac{R_2}{R_1} = \frac{L_1}{L_2} \qquad \text{or} \qquad L_1 = \frac{R_2}{R_1} L_2$$

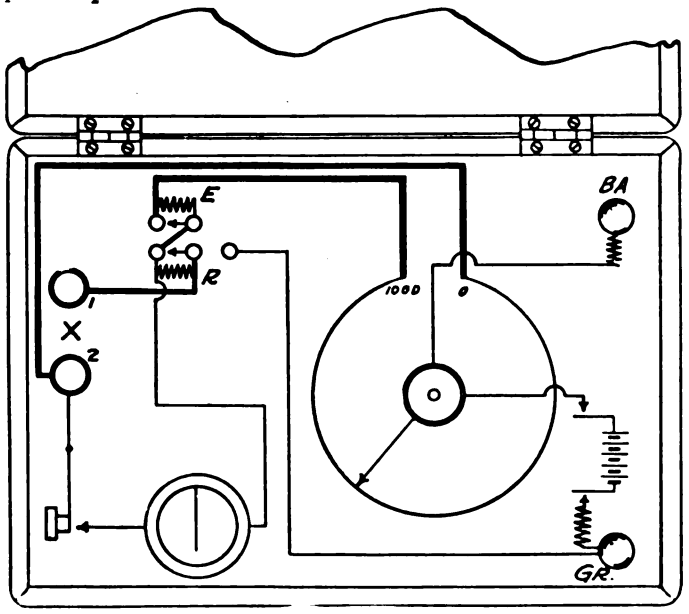


Fig. 366.

The question of allowance for lead wires does not enter unless the leads are very long or where a wire in a cable may have to be used for a leading wire to the faulty cable. A method for allowing for extra long leads will be given under a description of the Fisher Portable Cable Testing Set No. 2.

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The Leeds & Northrup Fault Finder.—This instrument has already been referred to on page 278 as a simplified form of Fault Finder.

It has been designed with a view of reducing calculations connected with fault location to a minimum, also so as to simplify the manipulation as much as possible. It may be used to measure conductor resistance, to measure fault resistance, to locate faults by four distinct tests, and to locate opens using a buzzer and telephone.

Figure 366 shows the arrangement and connections of the resistance, etc.

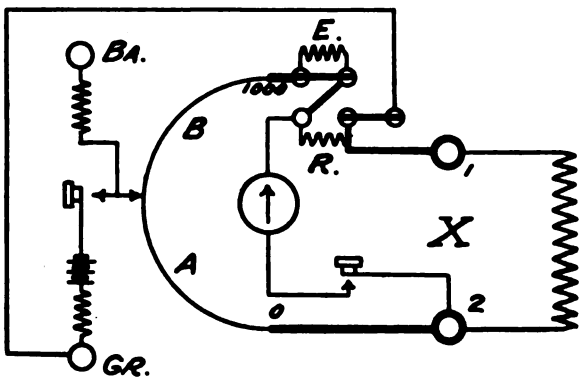


Fig. 367.

The essential feature of the apparatus is the uniform resistance AB, Fig. 367, which is wound in a circle and is about 100 ohms. By a special construction, it is arranged so that contact can be made at any point along it, and it is therefore equivalent to a high resistance wire. It has a moving contact C and a scale of 1000 divisions. In series with this, there are the two resistances E and R. E has exactly the same resistance as the wire AR. R has a resistance of 100 ohms, and is the rheostat of the bridge arrangement. Either resistance may be short-circuited by a small switch. The resistances shown between the ground post and the battery and between post Ba and the battery key are simply to protect the battery and the apparatus from excessive current.

Resistance Measurement.—Fig. 367 shows the proper connections for measuring conductor resistance. As in the ordinary slide wire bridge the resistance X between the two posts X_1 and X_2 is gotten from the formula

$$X = \frac{A}{1000 - A} R$$

To avoid the necessity of solving in each case the fraction

$$\frac{A}{1000 - A}$$

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a table is furnished with the set, giving the value of this fraction for each value of A. The resistance is accordingly determined in each case by simply setting the contact C for a balance and reading from the table the resistance opposite the number on the scale, and multiplying by 100.

Example.—With an unknown resistance connected between the posts X_1 and X_2, the galvanometer showed a balance for a dial reading 387. The number opposite 387 in the table is .6313. Therefore, $X = .6313 \times 100 = 63.13$ ohms.

Fault Locating With the Leeds & Northrup Fault Finder.—First Method.—Murray Loop.—This method is to be used in locating faults where there are two wires having equal resistance, in one of which there is a fault. Connect and set switches as shown in Fig. 368. Connect the good wire to post X_1 and the faulty wire to post X_2. It will be remembered that E is equal to the resistance AB. From the symmetry of the arrangement, it will be obvious that the contact point C would rest for a balance at 1000 on the scale, if the fault were exactly at the junction between the good and the bad wires; it would rest at 500, if the fault were halfway along the bad wire; and at whatever point it comes to rest, the reading divided by 1000 and multiplied by the length of the bad wire is the distance from the instrument to the fault.

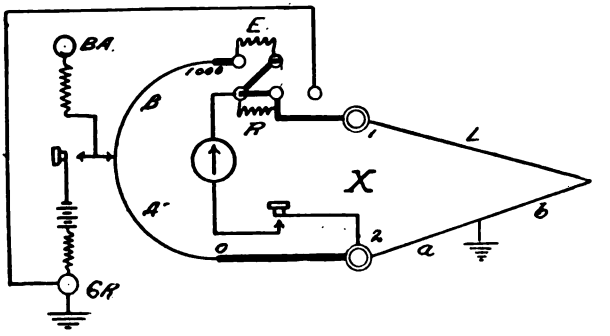


Fig. 368.

Example.—In a pair of equal wires, 5.8 miles long, one is grounded. With the connections made as shown in the diagram, the galvanometer balanced for the dial reading 124. The distance to the fault is

$$\frac{124 \times 5.8}{1000} = .7192 \text{ mile.}$$

Second Method Murray Loop.—This method is to be used for locating faults where the good and the bad wires are not equal to each other. The connections are shown in Fig. 369. It is the ordinary Murray Loop and it will be readily seen that the resistance "a" to the fault will be gotten from the formula

$$a = \frac{A}{1000} r,$$

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where r is the resistance of the loop, and A is the reading of the contact C on its scale. The distance d to the fault is gotten from the formula

$$d = \frac{A\ r}{1000\ M}$$

where M is the resistance per mile of the faulty wire.

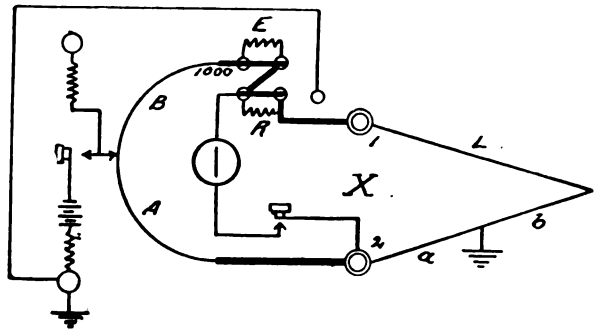


Fig. 369.

In some cases the value of M may not be known. In these cases determine the resistance of the faulty wire, which call R. This may be done by looping it with its mate, measuring the resistance of the faulty loop and dividing by two.

$$M = \frac{R}{L}$$

where L is the length of the faulty wire. Substituting this value for M in the above formula, we have

$$d = \frac{L\ a\ r}{1000\ R}$$

Example.—A wire having a resistance of 16.46 ohms per mile had a ground in it. This was looped with a wire of unknown resistance and the total resistance of the loop was measured and found to be 54.07 ohms. Connections were made as in Fig. 369, and the reading A was found to be 332. Substituting these values in the above formula,

$$d = \frac{332 \times 54.07}{1000 \times 16.46} = 1.09.$$

Third Method. Varley Loop.—This method may be used as a check on either of the above. Connect the faulty wire to X_1 and measure the resistance of the loop, then throw switches as shown in Fig. 370 and

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Let a = resistance to the fault.
d = distance to fault in miles.
M = resistance of faulty wire per mile.
r = resistance of loop.
R = resistance of coil R.

$$T = \frac{A}{1000 - A}$$ (To be gotten from table).

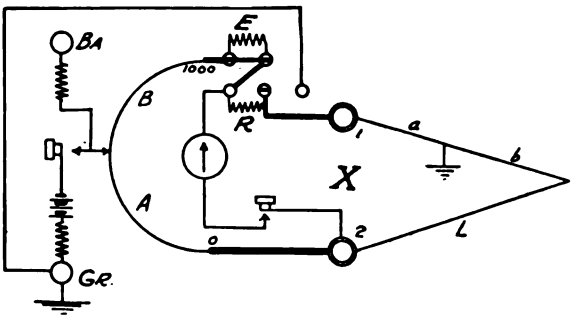


Fig. 370.

From the Wheatstone Bridge relation,

$$a = \frac{r - R\,T}{T + 1} = \frac{r - 100\,T}{T + 1}$$

$$d = \frac{r - 100\,T}{(T + 1)\,M}$$

Example.—A wire having a resistance of 16.46 ohms per mile had a ground in it. This was looped with a wire of unknown resistance and the resistance of the loop was found to be 54.07 ohms. Connections were made as in Fig. 370, and the reading A was found to be 234. From the table, T = .3055, and

$$d = \frac{54.07 - 30.55}{1.3055 \times 16.46} = 1.094 \text{ miles.}$$

Fourth Method.—This method may be used to advantage where the length only of the faulty wire is known, and where there are two other wires which may be used to complete the loop. It is not necessary that the resistance and length of these other wires be known. Figs. 371 and 372 show the connections.

For the first measurement connect the faulty wire to X_2, one of the good wires to X_1, and the post Gr to ground; coils R and E, both short-circuited. Balance in the usual way and call the dial reading A. For the

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second measurement connect the post Gr to the other good wire as shown in Fig. 372, disconnect from ground and get another balance. Call this reading A^1. The distance d to the fault is gotten from the simple formula

$$d = \frac{A}{A^1} L$$

where L is the length of the faulty wire.

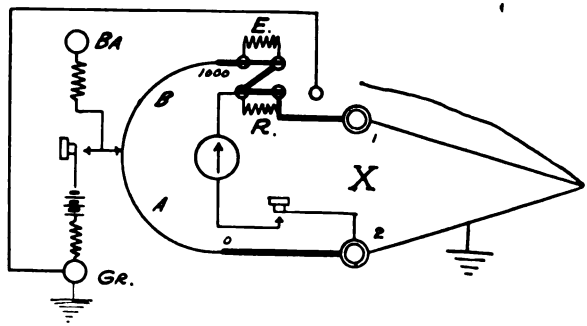


Fig. 371.

Example.—All the wires in a cable 10852 ft. long were found to be grounded so that none of them could be used as good wires. Two wires were selected out of another cable going to the same place by a different route and securely joined to one of the grounded wires at the distant end. This grounded wire and one of the good wires were connected as shown in Fig. 371 and the reading A was found to be 307. Connections were then made as in Fig. 372 and A^1 was found to be 610.

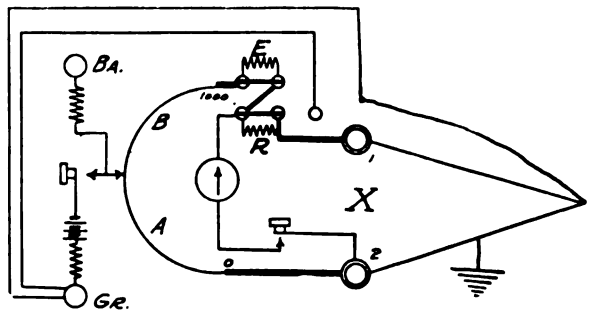


Fig. 372.

Therefore,

$$d = \frac{307 \times 10852}{610} = 5{,}462 \text{ ft.}$$

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Location of Opens With the L. & N. Fault Finder.—These measurements are based on the fact that wires ordinarily have capacity which is proportional to their length. For a brief statement of the theory of the measurements see page 278. In addition to the Fault Finder a buzzer, dry cell to operate it, small induction coil, and telephone are required. These instruments are to be found in any telephone exchange. It is best to locate the buzzer at some distance from the Fault Finder so that the operator cannot hear it.

General Remarks.—Before attempting locations for opens it is well to make two measurements.

1st. The insulation of the broken wire and the insulation of the good wire with which it is to be compared. This may be done as described on page 300. It is best that the insulation resistance be fairly good, but experiments indicate that good results can be obtained by the following methods, even when it is as low as 100,000 ohms, and fair results when as low as 10,000 ohms to 50,000 ohms.

2nd. The resistance between the two sections of the broken wire should be measured. This can be done by joining the broken wire and a good wire at the distant end of the cable and measuring the resistance of the loop. To insure close locations this resistance should be over 100,000 ohms. Fair locations can be made when the resistance is much lower and it is worth while to attempt it even if the resistance is as low as 10,000 ohms. It must be remembered in cases where the resistance is less than 100,000 ohms that the distance to the open will actually be shorter than the test indicates. The amount by which it is short will be small for resistance near 100,000 ohms, and will become greater as the resistance decreases. The difficulty of determining the balance point also increases as the resistance decreases.

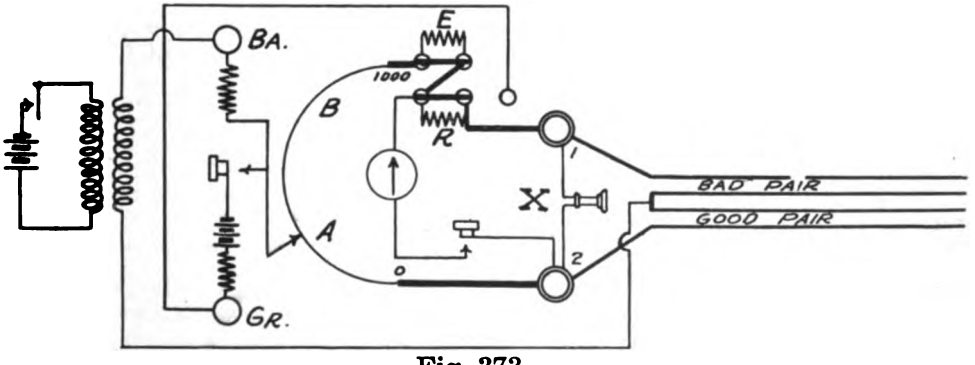


Fig. 373.

Open Wire in a Telephone Cable.—The broken wire will be one of a pair. Select another pair in the cable that will have the same capacity per mile and join together the mate of the broken wire and one wire of the other pair. Connect the broken wire to the post X_1 and the unconnected wire of the good pair to the post X_2. Connect the buzzer to the primary of the induction coil, one terminal of the secondary to the post Ba and the other to the connected wires as shown in Fig. 373. Set switches so as to short-circuit the two resistance coils. Then depress the battery key and move the contact to the point of minimum sound in the telephone.

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The distance to the break is

$$d = L \frac{A}{1000 - A}$$

where L is the length of the good wire.

Examples.—A cable 1.45 miles long had a broken wire in it. It was found that the insulation resistance of the end of this wire was over 10 megohms as was that of the good pair selected to test against it. The resistance between the two pieces of the good wire was also over 10 megohms. Connections were made according to directions and it was found that the balance point was 476. From the table

$$\frac{A}{1000 - A} = .9084$$

and $d = 1.45 \times .9084 = 1.32$ miles.

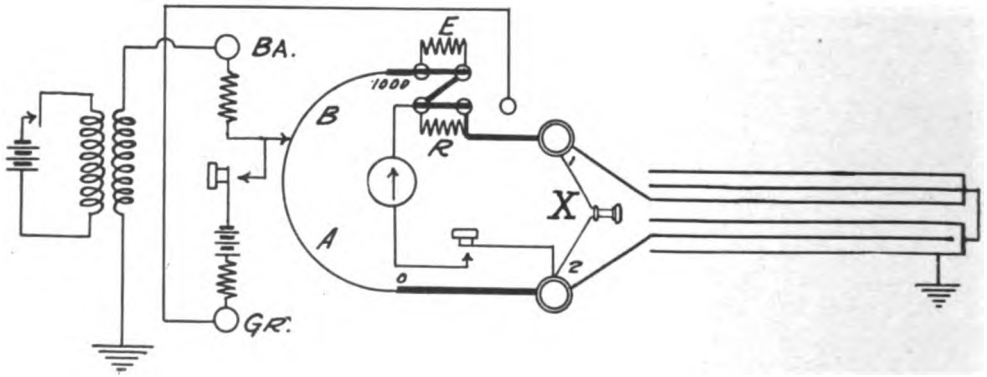


Fig. 374.

Open Wire in Telegraph and Other Cables in which the wires are not grouped in pairs.—Connect broken wire to X_1. Select a good wire and join to X_2 Connect all other wires and ground them, by connecting to the cable sheath. Connect the distant end of the broken wire to the others. Ground the end of the induction coil that is not connected to the post Ba. Make the measurement and calculation exactly as in the preceding case. See Fig. 374.

The accuracy of the location by both of the above methods depends on the good and broken pair, or the good and broken wires having equal and uniform capacity per unit lengths. It is not always possible to select wires that are alike in this respect. In such cases, as for instance where there is no good wire in the cable containing the broken one and a good one has to be selected from another cable the following method may be used.

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Broken Wire and Good Wire Not in Same Cable.—Connect the good wire and broken wire in the same way as shown in Fig. 373, (also described on page 307), and set the pointer for a balance. Call the reading A. Then connect the good wire and the broken wire at the distant end and set the pointer for a new balance. Call this A^1. The connections for this reading are shown in Fig. 374a. The distance to the break will be

$$d = \frac{A\ A^1\ L}{1000\ (A - A^1) + AA^1}$$

where L is the total length of the broken wire.

Example.—A pair of wires containing one broken one was connected up with a good pair in a different cable as shown in Fig. 373. The reading A was found to be 180. The good and bad wires were then joined at the distant end as in Fig. 374a and the reading A^1 was found to be 88. The total length of the bad wire MN was 1.44 miles.

$$d = \frac{180 \times 88 \times 1.44}{1000\ (180 - 88) + 180 \times 88} = .211 \text{ miles.}$$

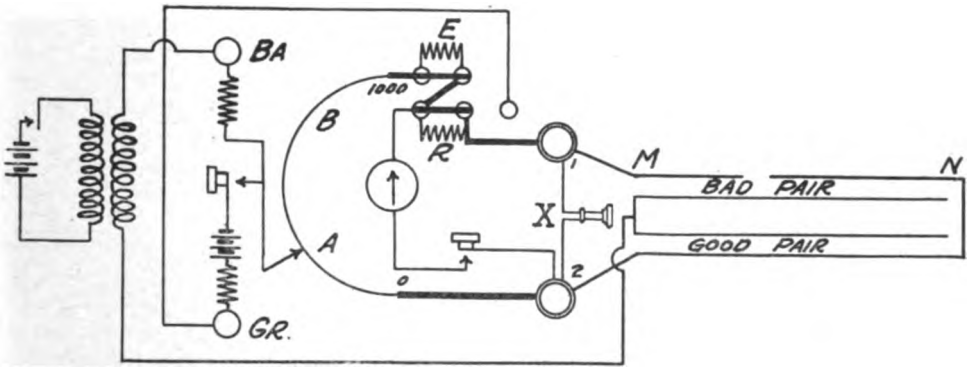


Fig. 374a.

To Use Galvanometer in Series With Battery.—Close both switches. Connect between posts Gr and X_2. The galvanometer will have the maximum sensibility with the pointer at 1000 and the minimum at zero.

To Pick Out Faulty Wires in a Cable.—Close both switches, set the pointer at 1000. Connect the post Gr to the ground or the cable sheath and apply the wires one after another to the binding post X_2. The galvanometer will deflect for a faulty wire.

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CHAPTER X.

MEASURING INSTRUMENTS AND THEIR USES.

*"Before proceeding to describe the various tests which may be made with the voltmeter, it is desirable to study more in detail its construction in order to comprehend how a sufficiently wide range of instruments to perform all tests can be secured. Fig. 375 shows the general appearance of the Weston instrument. If the case be removed, the magnetic system will be seen to consist of a powerful U-shaped magnet (Fig. 376), carrying the pole pieces, *P P*, which are bored out with great care, forming a hole about 1¼ inches in diameter. In the centre of this is placed a piece of soft iron, *C*, carefully turned to leave a space of .04 inch between the poles in which the movable coil must swing. Fig. 377 shows the coil and pointer. The frame of the coil is of solid drawn aluminum, on which very fine wire is wound, the whole being only .015 inch thick. The coil is supported in sapphire bearings and supplied with light spiral springs made of non-magnetic metal, serving to keep the needle under a constant and uniform tension.



Fig. 375.

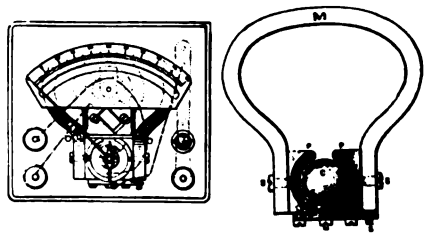


Fig. 376.

As it would be impracticable to place sufficient wire to secure the necessary resistance on the moving coil, a supplementary coil is placed in the case of the instrument. When the voltmeter is a double scale instrument, this coil is divided into two parts, the whole coil being placed in circuit for high voltages, and only a portion for low ones. Fig. 376 shows a skeleton view of a double coil instrument, the dotted lines showing the connection to the terminals, the coil in the base, and the moving coil.

Consider now the action of the voltmeter in the light of Ohms' law.

*American Telephone Journal.

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Assume an instrument of 1,000 ohms in the moving coil and 9,000 in the stationary one, total 10,000 ohms. Suppose this be connected to ten cells of storage battery, giving a known electro-motive force of 20 volts. The resistance of the wires from the voltmeter and the battery is so small in comparison with the 10,000 ohms of the instrument that they may be neglected, and taking Ohms' formula we have $E = 20$ volts, $R = 10{,}000$ ohms,

$$C = \frac{20}{10{,}000} = .002 \text{ amperes.}$$

This is the current which passes through the voltmeter. The needle will deflect say about an inch, and as the battery gives 20 volts, we mark the point on the scale under the needle 20. If now we double the battery to 40 volts, .004 ampere will flow, the needle will deflect two inches and the scale be marked 40. Thus we see that where the voltmeter has a very high resistance compared to the source of electricity, the current which passes through it is exactly proportional to the voltage, and as the deflections of the needle are proportional to the current they are equally proportional to the voltage. It would be just as easy to mark the point where the needle stands with ten cells, .002 amperes, or to mark it 20 volts. So that an instrument can be made, by properly graduating its scale, to read either a large number of volts or a small number of amperes. Suppose the 10,000 ohm instrument to be connected to an unknown source and the needle deflects 3 inches, we know by experiment that 1 inch on the scale means 20 or .002 amp., hence 3 inches mean 60 volts or .006 amperes. If, therefore, we know the resistance of any voltmeter and how much the needle moves for either a given number of volts, or a given number of amperes, we can use it to measure either amperes or volts as we please.

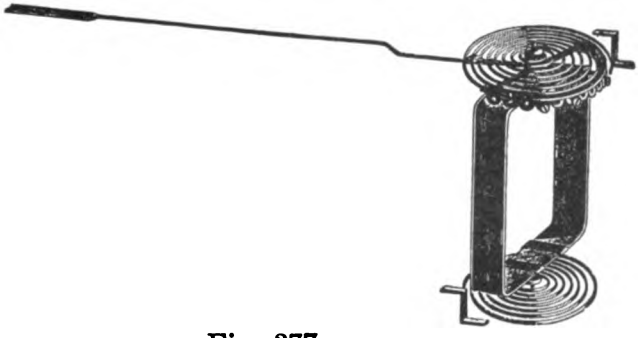


Fig. 377.

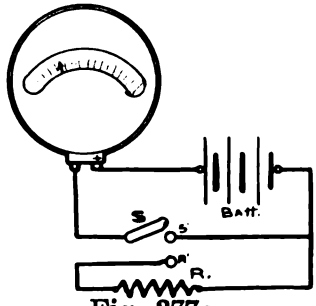


Fig. 377a.

So far the voltmeter has been assumed of constant resistance, but there is a supplementary coil which may be cut out at pleasure, and when removed the resistance is reduced from 10,000 ohms to 1,000. If now it be connected to the 20-volt battery the current will be

$\frac{20}{1{,}000} = .02$ amperes, or ten times what flowed in the previous

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case. Hence the needle will be deflected (if possible) over ten inches instead of one inch and each scale division will have ten times the former value. With the supplemental coil in circuit, one volt or .0001 ampere was represented by one-twentieth of an inch. Without the coil one volt, .001 ampere, gives a deflection of one-half an inch. From these examples we deduce the following rules.

First—The readings are proportional to the current which traverses the coil.

Second—Any instrument may be graduated to read either in volts or in amperes, or both.

Third—Instruments of large resistance will measure high voltages and very small currents, those of low resistance measure low voltages and large currents. Hence high resistance instruments are voltmeters, and milliammeters and low resistance instruments are ammeters and millivoltmeters.

It is easy to see that these principles can be almost indefinitely extended. Instead of winding the movable coil to a thousand ohms it may be wound to five hundred, one hundred, or even a fraction of an ohm. With each reduction in resistance, a larger current will flow with a given electrical pressure, or if the voltage is reduced there will still be sufficient current to give readable deflections. The best method of reducing resistance is to wind the instrument with heavy, coarse wire which will carry heavy currents without danger, and hence a voltmeter is transformed to an ammeter or current measurer by reducing the resistance of its coils and changing the figures on the scale.

To test the condition of dry cells, the charge in a storage battery, or a cable for possible exposure to electrolysis, a low reading instrument is necessary. Such instruments are termed millivoltmeters or milliammeters as the case may be, from the metric system prefix milli, meaning one thousandth. Thus the electrical engineer can measure either the electrical pressure of any source of electricity or the amount of current that is traversing any circuit. Equipped with a voltmeter and an ammeter he can measure both if he pleases, and knowing the current and the electromotive force he can always calculate the resistance."

In Fig. 377a is shown the method of determining resistance with a voltmeter.

The voltage of the battery is first noted by throwing the switch S in the upper position. The switch is then thrown in the lower position and the voltage through resistance R noted.

The first measurement gives a deflection through the resistance of the voltmeter only, while with the switch in the second position, the deflection was through the resistance of the voltmeter plus the unknown resistance to be measured. If the voltmeter has a resistance of 10,000 ohms, and the first deflection was 10, and in the second instance the deflection was 5, then the unknown resistance is calculated as follows:

Multiply the first deflection by the resistance of the voltmeter and divide this sum by the second deflection, then subtract the resistance of the voltmeter.

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For instance.—In the example given above the first deflection was 10. Multiply this by 10,000, which gives 100,000. Divide this by 5, which was the second deflection, which gives 20,000. Subtract from this the resistance of the voltmeter 10,000, which leaves 10,000 ohms, which is the unknown resistance. In this calculation the internal resistance of the batteries is neglected. This may be done in the case of high resistance measurements, as it would only amount to a few ohms.

Expressed as a formula the above may be shown as follows:

V = first deflection
v = second deflection
r = resistance of voltmeter
X = unknown resistance.

$$\text{Then } X = \frac{Vr}{v} - r$$

The Pignolet type of instrument is shown in Fig. 378 and is often used in telephone work owing to its low cost and portability. For telephone work a combination instrument reading in volts and amperes is desirable.



Fig. 378.



Fig. 379.

The voltmeter scale should read from 0 to 50 and from 0 to 5, and ammeter scale reading from 0 to 30. These instruments will measure volts, or volts and amperes and also determine resistance by a simple calculation, thus enabling one compact instrument to be used, not only for measuring current, but for ascertaining the resistance of coils, circuits, etc., detecting and locating grounds and short circuits, and in addition for measuring mil-amperes up to 30 or 50.

The instrument is so adjusted that each division of the voltmeter scale is equal also to one mil-ampere (0.001) and an instrument reading

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to 5 volts has 100 ohms resistance; 10 volts 200 ohms; 25 volts 500 ohms; 50 volts 1,000 ohms; 100 volts 2,000 ohms.

This adjustment permits resistance to be ascertained by Ohm's law that the resistance of a circuit is equal to the volts divided by the amperes $R = E \div I$. To apply the law with the instruments, first measure the volts of the battery used for the test, then ascertain the amperes with the unknown resistance in circuit with the instrument and the battery. Divide the volts by the amperes, which gives the resistance of the circuit including the resistance of the voltmeter; subtract the resistance of the voltmeter and the remainder is the unknown resistance.

For Example.—Suppose the instrument to read 5 volts in tenth scale divisions and to have a resistance of 100 ohms, the battery to have a pressure of 4.5 volts and the mil-amperes to be 20, indicated by the deflection of the pointer of 20 scale divisions, when the unknown resistance is connected in circuit. Then the unknown resistance equals 4.5 volts divided by 0.020 amperes (20 mil-amperes) less 100 ohms (the resistance of the instrument) which gives 125 ohms as the unknown resistance.

With an instrument reading to 50 volts and having a resistance of 1,000 ohms: if the battery pressure were 40 volts and the mil-amperes were 5 when the unknown resistance was in circuit, the unknown resistance would be equal to 40 volts divided by 0.005 (5 mil-amperes) less 1,000 ohms (the resistance of the instrument) which gives 7,000 ohms as the answer.

These examples illustrate the method, and the following tables indicate its capacity or range. The range of measurements for a single instrument may be increased by combining a low and high reading voltmeter in one instrument. For example, 0 to 3 volts and 0 to 50 volts.

The resistance of the battery used for the test is included in the circuit when the measurements are made. The battery should therefore be one of comparatively low internal resistance so that it will not appreciably affect the results when low resistances are being measured. The ordinary small dry batteries answer very well for the purpose.

As it is apparent, this method has not the accuracy nor the range of the Wheatstone bridge, but it answers admirably for ordinary purposes, and adds largely to the usefulness of a voltmeter or volt-ammeter.

The following table shows the scale dimensions for which the pointer is deflected, with the various battery pressures as shown, through the resistance as given:

Deflection of Pointer of Instrument.	BATTERY PRESSURE.							
	4.5 Volts		22.5 Volts		45 Volts		90 Volts	
40 divisions	112.5	ohms	62.5	ohms	125	ohms	250	ohms
36 "	25	"	125	"	250	"	500	"
30 "	50	"	250	"	500	"	1,000	"
22. "	100	"	500	"	1,000	"	2,000	"
15 "	200	"	1,000	"	2,000	"	4,000	"
11.25 "	300	"	1,500	"	3,000	"	6,000	"
7.5 "	500	"	2,500	"	5,000	"	10,000	"
5 "	800	"	4,000	"	8,000	"	16,000	"
3 "	1,400	"	7,000	"	14,000	"	32,000	"
2 "	2,150	"	10,750	"	21,500	"	43,000	"
1 "	4,400	"	22,000	"	44,000	"	88,000	"

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It will thus be seen that a resistance as high as 88,000 ohms can be measured with a pressure of 90 volts, which can easily be obtained in ordinary exchanges where a pole changer is used, as the pole changer batteries can be used for operating the voltmeter.

The simplest measurement that can be made with a voltmeter is to measure battery pressure or voltage. This is accomplished by connecting the terminals of the battery directly to the terminals of the instrument, as shown in Fig. 380. An ordinary dry cell in good condition will give from 1.4 to 1.6 volts.

Always connect the batteries to the high scale first, then if the reading is within the limit of the low scale, arrange the connection so as to read the low scale. The wire from the carbon pole of a battery should always connect to post marked "P.' Do not reverse the current or the pointer may be bent.

We will suppose that a resistance, such as an ordinary drop coil is to be measured. First measure the volts of the battery by connecting the battery directly to the voltmeter, as shown in Fig. 380. In this instance we will suppose the battery to equal 4.05 volts. Then connect the battery and the drop coil to the voltmeter as shown in Fig. 382. In this instance suppose the pointer moves over 20 scale divisions, which represents 20 milli-amperes. The resistance of the voltmeter is known to be 100 ohms. The various figures are set down as follows:

$$4.5 \div .020 = 225.$$

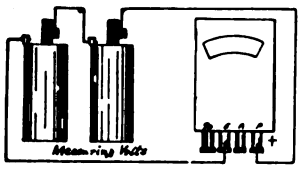


FIG 380

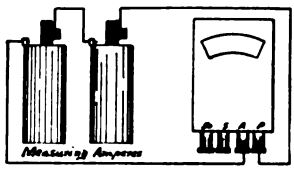
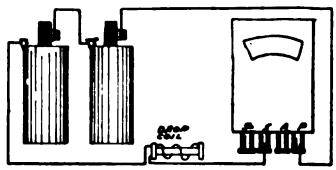


FIG 381


FIG. 382

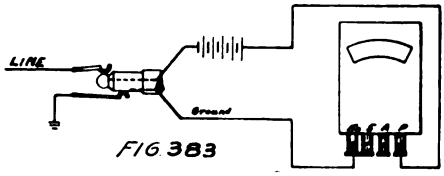


FIG 383

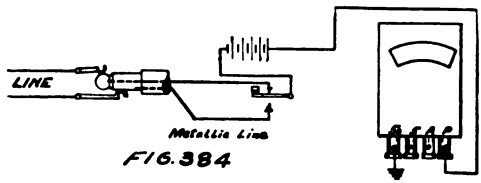


FIG. 384

The unknown resistance of the voltmeter is 100 ohms, and this should be subtracted from the result which leaves 125 ohms, the resistance of the drop coil.

The resistance of various lines can be measured by this method. Here a stronger battery should be used. If it is desired to know the insulation resistance of a line, the line, battery and voltmeter should be connected as shown in Fig. 383. Proceed exactly as before and the result will be the leakage from the line to the earth.

In making this test, in some cases it will be seen that "earth current" will exist, which will deflect the voltmeter, and when the presence of an "earth current" is suspected, it is best to connect the instrument directly to the line and the earth without the battery and note the deflection. Then connect the battery in circuit as shown, in such a manner the earth cur-

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rent and battery do not oppose each other. Then subtract the number of degrees which the earth current deflected the pointer, from the number of degrees which the pointer is deflected by both the battery and the earth current: the difference will be the true voltage used in measuring the resistance of the line, and the calculation should be based on this.

In this case the high scale of the instrument should be used with as much battery as possible, so as to secure as great a deflection as possible.

To measure high resistance such as bridging ringer coil, etc. Connect as shown in Fig. 382, using 20 or more cells of battery, connecting wire from coil to "50" instead of "5" if deflection is too great for the 5 volt scale.



Fig. 385.

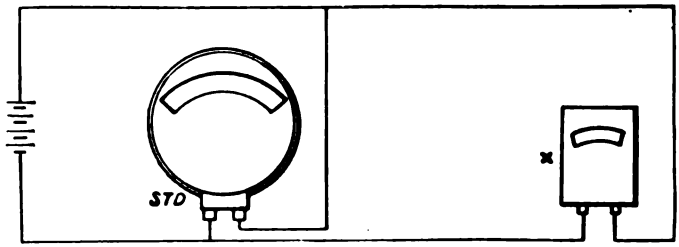


Fig. 386.

In telephone work an instrument reading from 0 to 50 volts, with a resistance of 45,000 ohms, is desirable. The instrument manufactured by the Weston Company is so sensitive that by placing the fingers across the terminals of a 24 volt battery and the voltmeter in series, a deflection of 10 or 15 volts will be shown. This instrument is especially desirable for quickly measuring line resistance and is very accurate.

Voltmeters, milli-voltmeters, ammeters and milli-ammeters have the same general appearance, the difference being in the resistance and manner of dividing the scale. The standard portable instrument shown in Fig. 385 is recommended for use where a standard instrument of the highest accuracy is desired combined with portability. It is well where a number of voltmeters are used by one company, to have an instrument of this description to check the others.

This is accomplished by connecting the battery and voltmeters as shown in Fig. 386. Both instruments should indicate the same unless they differ widely in resistance, which is not usually the case.

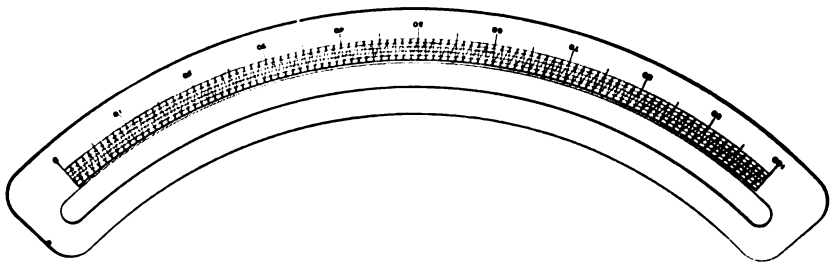


Fig. 387.

The standard instrument described above is equipped with spirit level for accurately placing the instrument, and a scale 12 inches in length, pointer 8¼ inches. The divided lines of the scale are connected

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together by means of diagonal lines drawn through six arcs placed equally distant from each other, as shown in Fig. 387. This arrangement permits the position of the pointer to be read directly to 2/10 of a scale division.

The accuracy of measurement obtainable with this set is 1/10 of 1%, and in the instrument of three ranges, viz. 0 to 150, 0 to 15 and 0 to 3 volts, the indications are readable in the first instance to 1/5 volt, in the second to 1/100 volt and in the third to 1/500 volt.



Fig. 388.



Fig. 389.

Where it is possible to permanently fix the instrument in one place the Weston Round Pattern Meter is desirable. This instrument is adapted for mounting on the face of the switchboard, and is shown in Fig. 388. Where a flush type instrument is desired, the Round Meter shown in Fig. 389, may be used, a hole being made in the switchboard or other place where the instrument is mounted so that the face of the voltmeter is flush with the surface.



Fig. 390.

For exchanges using pulsating current for selective party line ringing, a double scale instrument, as shown in Fig. 390, is often desirable. Here the 0 is placed in the centre of the scale, and the scale reads both to the right and left. This enables the instrument to be permanently connected to a jack and readings taken by plugging in and throwing the various keys as desired, without having to reverse the voltmeter.

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Fig. 391 shows in detail the design of the supporting bracket, core and one pole piece of the American Inst Co.'s voltmeter. Strength and simplicity of design will be noted in the supporting bracket, which is a one piece casting. The pointer is counterbalanced by delicate screws of the grade used in high grade watches. A cylindrical steel pivot supports the moving coil.

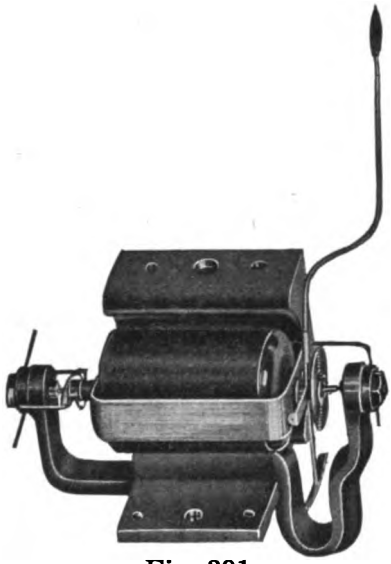


Fig. 391.



Fig. 392.

One feature which may be especially mentioned in connection with these instruments is that all milli-voltmeters intended for use as ammeters with external shunts, are adjustable to a uniform resistance of one ohm, and give full scale deflection with a potential difference of 50 milli-



Fig. 393.



Fig. 394.

volts and are therefore interchangeable. This means that any shunt can be used with any milli-voltmeter. The interior construction of these instruments is shown in Fig. 392 which is typical of the interior arrangement of the various parts in nearly all makes.

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The portable type of instrument particularly adapted to telephone use is shown in Fig. 393, and this instrument with a range from 0 to 50 volts has ½ volt divisions and may be read to a tenth.

The laboratory type of this make of instrument is shown in Fig. 394. It will be noticed that the scale is particularly wide and the divisions uniform throughout.

The Whitney Company in their line of instruments present a different form of construction from that just described. See Fig. 395.

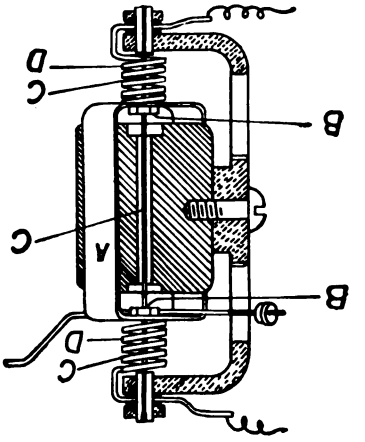


Fig. 395.

To the movable coil "A" are attached ruby jewels "B" of the kind used in high grade watches. Through the holes pierced through these two jewels, is threaded a length of prosphor bronze or steel wire "C", which thus guides the coil and holds it truly centered. To prevent endwise motion two spiral springs D and D^1 are attached to the coil the other ends of same being attached to brackets on the stationary part of the instrument. These springs not only support the coil, but furnish the force opposing its rotation when the current flows. If the instrument is so built the coil A will slide up and down for a short distance without causing any damage.

The above will serve to illustrate the various types of instruments in general use. It should be understood that any make of volt-meter may be used in testing, provided its range is suitable for the purpose.

The polarity of a current can be ascertained by connecting the circuit to the terminals of the volt or ammeter if the instrument is of the type using a permanent magnet and moving coil, such as the Weston or American. There are, however, some types of instruments of the electromagnetic type, in which the permanent magnet is not used, and these will not show the polarity of the current under test. Therefore in making tests for polarity the instrument should be tested (if the type is not known) and it should be positively determined that the instrument will only deflect in one direction when connected.

The + or positive side of the majority of instruments is usually the right, looking at the meter from the front, and this is marked + or P. Do not reverse the instrument or damage may result.

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*"The difference between a volt-meter or pressure measure, and an ammeter, or current measure, has been described and shown to be chiefly in the method of winding the moving coil that forms the active portion of the instrument. There is still another way of making ammeters, which will presently be described; but prefatory thereto let us consider a little the use of the ammeter and the method of measurement to which the joint use of both an ammeter and volt-meter lend themselves. There are many makes of volt-meters, but relatively few of ammeters, particularly of those of high range, as their construction practically presents much more difficulty on account of the heating effect of large currents. The chief external difference between a volt-meter and ammeter lies in the binding posts, which in the ammeter are very large and heavy, to accommodate the powerful leads necessary to carry heavy currents. The office of the ammeter is solely to measure the amount of current which is passing in any circuit. For this purpose the circuit whose current is to be measured must be open and the ammeter inserted in series so that it forms an integral part thereof through which all the current must flow as soon as the circuit is closed. After the insertion of the instrument a reading of the needle indicates at once the current in amperes—nothing could be simpler. Evidently the resistance of the ammeter must be very low, so small, in fact, that it's addition to any circuit will cause no appreciable change. Like volt-meters ammeters can only be built to cover a somewhat limited range in a single instrument, but by getting two or more, any capacity can be secured. For the telephonist the most useful instrument is one reading to about 50 amperes, each scale division representing ½ ampere.

Some methods of measuring high resistance with a volt-meter have been described. There are many cases in telephone work where it is necessary to measure very small resistance, such for example, as would be presented by the blades of a knife switch upon a power board which fail to make good contact. With an ammeter and a milli-volt-meter low resistance of all kinds can be very readily and very accurately measured. The operation consists of connecting the battery, the low resistance to be measured and the ammeter in series and noting the amount of current which flows. At the same time a milli-volt-meter is connected *around* the resistance so that the fall of potential, or the electromotive force which is required to force the current *through* the resistance is also measured. When these two quantities are known, two factors, namely, the electromotive force and the current, in Ohms' formula, are obtained, and it is easy to calculate the third. The telephonist has frequent occasions to measure the resistance of very large and heavy conductors, such as the bus bars on the back of a switchboard, which might be giving rise to cross talk, or the various connections of a common battery through the power switchboard, and its numerous instruments, to the circuits which distribute electrical energy to the telephone switchboard. The method just described is exceedingly convenient for the purpose. It is illustrated in Fig. 396, in which *C B* is a portion of a bus bar or other large conductor whose resistance is desired. *B* is a storage battery or other source of electrical supply, one pole of which is connected to the bus bar, *C*, while the other pole runs to one binding post of the ammeter, *Am*. From the other terminal bar a conductor is taken to the other end of the bus bar. At each contact on the bar care must be taken to make an exceedingly good con-

*American Telephone Journal.

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tact, so that there may be as little fall of potential between the leads and the resistance to be measured as possible. A milli-voltmeter, *mVm*, is attached to the bus bar at the points *C* and *B*, between which the resistance is desired. Now the reading of the ammeter shows the amount of current which flows through the bus bar. A simultaneous reading of the milli-voltmeter gives the fall of potential *between* the points to be measured for resistance, or, in other words, the electromotive force that causes the current indicated by the ammeter. For example: Suppose it is desired to measure the resistance of a copper bus bar ¼″ in diameter and that when the apparatus is arranged, as shown in Fig. 396, the ammeter shows a reading of 2½ amperes and the milli-voltmeter a reading of 5 milli-volts, the resistance is given by the expression

$$R = \frac{.005}{2.5} = .002 \text{ ohms}$$

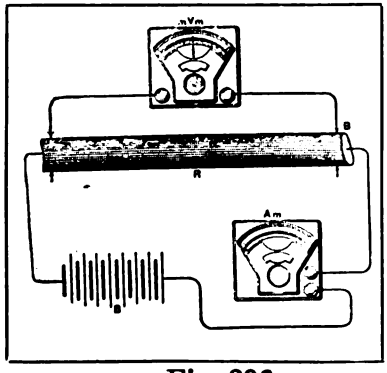


Fig. 396.

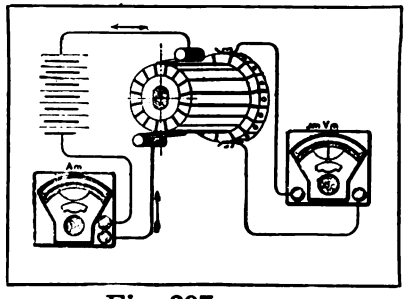


Fig. 397.

The same method may be very conveniently applied to the measurements of the resistance of dynamo armatures. Thus, in case of any trouble with the charging generators of a telephone power plant, this plan forms a convenient way of detecting the existence of either a short circuit or open coils. The apparatus should be set up as shown in Fig. 397, one pole of the storage battery being applied to any commutator section, the other pole running to one terminal of the ammeter, *Am*. From the other binding post of the ammeter a lead is carried to the commutator section directly opposite to the first one. The milli-voltmeter is connected to the same two sections, as shown in the illustration, and from the simultaneous readings of the two instruments the resistance of the armature and its coils may be at once calculated. To test all the coils of a dynamo the contacts may be arranged as sliding springs and the armature slowly revolved under the contacts and thus faults at once detected.

Fig. 398 shows the further application of this method to the measurement of switch resistance, an exceedingly interesting investigation to the telephonist, as in many cases poor hinges and bad blade contacts may give rise to cross talk in the operators' transmitters or even in the subscribers' circuits. As shown in this illustration, the ammeter is connected in series with the switch terminals and the battery, while the milli-voltmeter is connected across the terminals, and the resistance of the switch can be ascertained as soon as the two instruments are read. In Fig.

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399 this method is shown applied to measure the resistance of a switchboard ammeter, such as is commonly supplied to power boards in common battery exchanges, for occasionally a contractor will install an instrument of so high a resistance as to be unsuitable for the purpose, and sometimes the ammeter contacts become loosened and introduce sufficient resistance to cause cross talk. The circuit in Fig. 399 is self-explanatory. In the measurements of small resistance we have assumed an ammeter capable of reading a considerable current and a milli-volt-meter adapted to read small differences of potential. But this method may be extended to embrace the measurement of large resistances by the use of a milli-ammeter capable of measuring small current and of a voltmeter capable of measuring large differences of potential.

To illustrate this modification, suppose a case in which the voltmeter should read 142 volts and the milli-ammeter 10 mil-amperes,

$$R = \frac{142}{.01} = 14200 \text{ ohms.}$$

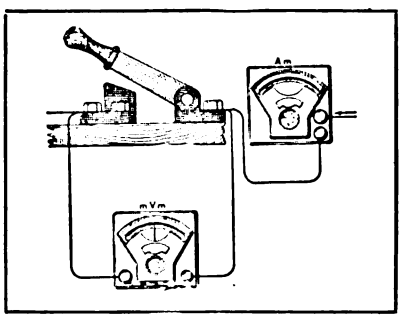


Fig. 398.

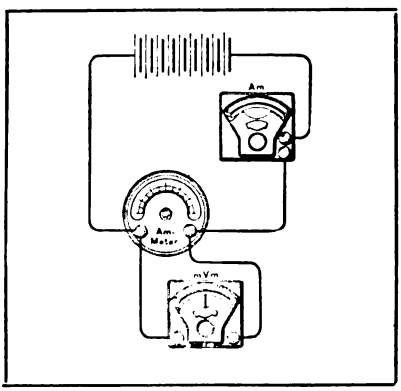


Fig. 399.

From these illustrations it is evident that the possession of a milli-voltmeter and a milli-ammeter and an ammeter and a voltmeter will enable the electrician to make a very wide series of measurements, for with the milli-ammeter and ammeter currents of almost any range can be measured. The voltmeter and the milli-voltmeter enable the estimation of electromotive force through a correspondingly great latitude, and with both instruments all sorts of resistance measurements can be made."

The resistance of voltmeters can be found stamped on the case, or if not, write to the makers giving the serial number of the instrument.

In case it becomes necessary to find the resistance of the voltmeter, proceed to connect up the voltmeter, battery, and a resistance box in series. First take the voltage of the battery without resistance in circuit. Suppose this should be 20 volts, then unplug enough resistance to make the reading exactly 10 volts, or one-half the first deflection, the resistance unplugged will then equal the resistance of the voltmeter. Where the same battery is always used for making tests, it is not necessary every time to

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make a calculation, but if the voltage of the battery remains constant, a table can be prepared showing the value of each scale division in ohms.

One of the most useful applications of the voltmeter to telephone work is the location of various line troubles. It is well to take a reading of every new line installed by short circuiting the line at the telephone. We will assume that the line measures 100 ohms. A record should be made of this, and if at any time a subscriber complains of trouble, corresponding measurements can be made, and if it is found that the line has increased materially in resistance, it is safe to assume that there is a bad splice or other defect on the line.

In common battery work, high resistance voltmeters, reading from 0 to 50, with a resistance of 45,000 ohms are adapted for readily determining the condition of condensers. The instrument can be connected with a key as shown in Fig. 400. When the key is thrown, the condenser is charged and discharged, and the voltmeter will give a "kick" of about 10 volts when a 24 volt battery is used and the condenser is of 2 M. F. capacity.

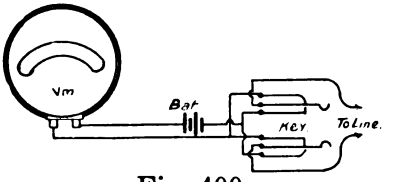


Fig. 400.

The "kick" is proportional to the capacity. In other words: if a 1 M. F. condenser was used in place of the 2 M. F. the "kick" would only be 5, a ½ M. F. condenser 2½ and so on. This is especially valuable when testing four party lines.

When all four parties are connected there are four condensers connected across the line. If one of these parties should be "lost" by reason of the tap from the main line getting open, it is only the work of an instant to determine definitely that one of the parties is "lost" if the "kick" with all on the line has been noticed, as a decrease will be apparent.

As a line has some capacity, it can be roughly determined in the case of a long line whether the "open" is near the office or at the extreme end, by observing the capacity "kick" of the voltmeter. If the "open" is near at hand no perceptible "kick" will result, but if a considerable length of open wire is connected to the voltmeter a "kick" will result in proportion. A little practice will enable accurate judgment to be exercised, but close observation is necessary, as the movement of the pointer is very small. Satisfactory results can only be obtained when the line is absolutely free from grounds or short circuits.

*"We have just shown how all kinds of resistance may be tested by a simultaneous measurement of the current passing, and by the fall of potential on the ends of the conductor whose resistance is desired. Evidently if the resistance of the conductor be known, a single measurement with a voltmeter or milli-voltmeter will suffice to determine the current strength, and thus amperes can be measured with a voltmeter. This is shown in Fig. 401. Suppose R to be any known resistance, and assume V to be the reading of the needle, then the currrent is: C= V ÷ R.

*American Telephone Journal.

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For example, suppose a wire chief wishes to know the current taken from the office battery at the hour of maximum load. Assume the power switchboard bus bars to be 10 feet long ¼ inch thick and 1 inch wide. Such a bar has an area of .250 square inches. One square inch is 1,273,236 circular mills. A piece of copper one circular mil in diameter and one foot long has a resistance of 9.012 ohms, but in the bus bar there are 318,309 circular mills, hence the resistance is

$$\frac{90.12}{318{,}309} = .0002831 \text{ ohms.}$$

Suppose the reading on a milli-voltmeter connected to the end of the bar to be 15 milli-volts, then

$$C = \frac{.015}{.0002831.} = 47.75 \text{ amperes.}$$

There are numberless opportunities to utilize this plan, that will at once occur to the practicing electrician. Indeed all ammeters intended to read very large currents take advantage thereof.

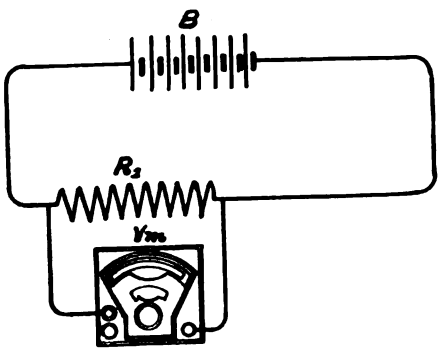


Fig. 401.

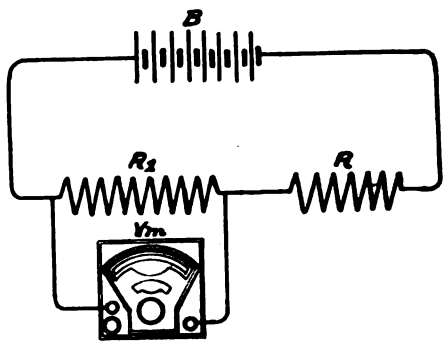


Fig. 402.

To return to the tests to be made with the voltmeter for a moment; there is a handy method for general resistance measurements of medium amounts, such as ringer spools, receiver coils, relays, induction and retardation coils. Set up the apparatus as shown in Fig. 402. B is any convenient battery, R is the unknown resistance to be measured, R^1 is *any* known resistance and V m is the voltmeter. First connect the voltmeter around R^1, and read the needle, calling the deflection V; then connect in the same way around R and read again, getting a deflection V^1; then

$$R: R^1:: V: V^1 \text{ or } R = \frac{R^1 \times V}{V^1}$$

Example.—Suppose $R^1 = 110$ ohms, $V^1 = 15$ volts, $V = 5$ volts,

$$\text{then} \quad R = \frac{110 \times 5}{15} = 36.7 \text{ ohms.}$$

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In this method both upper and lower scales of the voltmeter can be used to secure a very wide range, thus, let $R^1 = 550$ ohms V^1 (in upper scale), $= 148$ volts; V (on lower scale) $= 3$ volts,

thus $R = \dfrac{550 \times 148}{3} = 2{,}710$ ohms; or let $R^1 = 550$ ohms, V (on lower scale) $= 3$ volts; V^1 (on upper scale) $= 148$ volts

thus $R = \dfrac{550 \times 3}{148} = 11.16$ ohms.

A modification of this method, which has already been alluded to, consists in substituting an ammeter for the coil of known resistances, and reading both instruments. This is illustrated in Fig. 403 in which *B* is the battery, *A m* the ammeter in series with it and the resistance to be measured *R*, while *V m* is the voltmeter placed around the resistance as before.

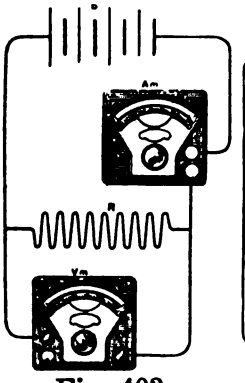


Fig. 403.

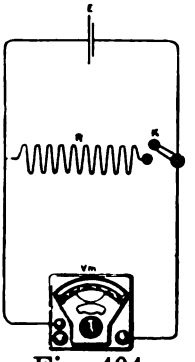


Fig. 404.

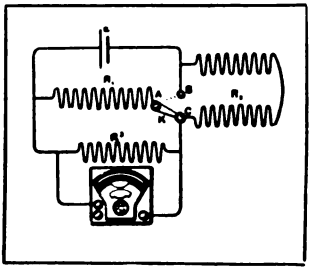


Fig. 405.

Thus $R = \dfrac{V}{A}$ in which *V* is the volt-meter reading and *A* the ammeter.

Example.—Suppose we wish to measure an induction coil; when connected up as shown A $= 3$ amperes, V $= 12$ volts, then

$$R = \frac{12}{3} = 4 \text{ ohms.}$$

The telephonist often must know the internal resistance of a battery or other generator of electricity. This is somewhat of a difficult task, as the thing to be measured is the source of the current and electromotive force used in measuring. It is a kind of "lifting yourself by your boot straps" problem. But with a voltmeter, a known resistance and a switch it can be done. Set up the apparatus as in Fig. 404, in which *E* is the battery of which the resistance is desired, *R* the known resistance, *V m* the

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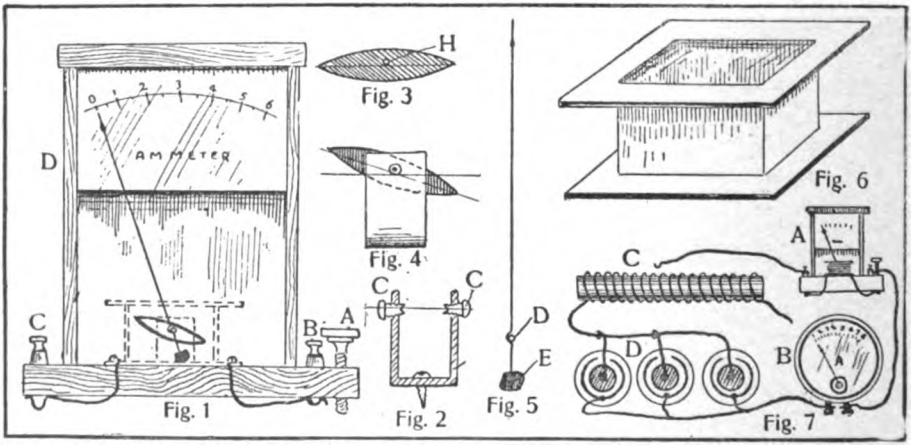
voltmeter and K a key or suitable switch. Read the voltmeter with K open, call the reading E, close K and re-read, calling the second deflection e. Then if r is the desired resistance of the cell

$$r = \frac{R \times E - e}{e}.$$

Example.—Suppose the case of some dry cells R = 4 ohms, E = 1.5 volts, e = 1.35 volts then

$$r = \frac{1.50 - 1.75}{1.35} = .44 \text{ ohms.}$$

This method is liable to be about 5% or 6% in error. If more accurate work is desired the following plan may be used, which requires three resistances, one of which must be a variable one. Connect as shown in Fig. 405 in which E is the battery to be measured, R^1 and R^2 are any two resistances, R^3 a variable resistance like a resistance box, and K a switch which can be placed in contact with either B or C. Adjust R^3 till the deflection of the voltmeter remains the same whether K is placed on B or C, then the resistance of E is exactly equal to R^3 and no calculation is necessary. Here is a third method of exceeding simplicity. Connect a voltmeter (low reading one) in series with the battery and a variable resistance so adjusted as to give a large deflection R^1. Increase the variable resistance of R^2 till exactly half the first deflection is produced. Then if r is the resistance of the voltmeter and R is the desired battery resistance, $R = R^2 - 2R^1 + r$. For example: In the case of a gravity cell $r = 1$ ohm, R^1 16.25, $R^2 = 35.5$, the $R = 35.5 - (2 \times 16.25 + 1) = 2$ ohms."



Complete Ammeter and Details

Fig. 406.

For those who desire to experiment with a view to investigating the construction of voltmeters and ammeters, and thereby become more familiar with their principle of operation, the following instructions will

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prove interesting. The instrument is fairly accurate if carefully made, and will serve fairly well for rough and comparative tests. The figure numbers refer to the various parts of Fig. 406.

*"The only adjustment necessary is that of leveling, which is accomplished by turning the thumb screw shown at A, Fig. 1, until the hand points to 0 on the scale.

First make a support, Fig. 2, by bending a piece of sheet brass to the shape indicated and tapping for the screws, C C. These should have hollow ends, as shown, for the purpose of receiving the pivoted axle which supports the hand. The core, Fig. 3, is made of iron. It is 1 in. long, ¼ in. wide and ⅛ in. thick. At a point a little above the center, drill a hole as shown at H and through this hole drive a piece of knitting needle about ½ in. long, or long enough to reach between the two screws shown in Fig. 2. The ends of this small axle should be ground pointed and should turn easily in the cavities, as the sensitiveness of the instrument depends on the ease with which this axle turns.

After assembling the core as shown in Fig. 4, it should be filed a little at one end until it assumes the position indicated. The pointer or hand, Fig. 5, is made of wire, aluminum being preferable for this purpose, although copper or steel will do. Make the wire 4½ in. long and make a loop, D, ½ in. from the lower end. Solder to the short end a piece of brass, E, of such weight that it will exactly balance the weight of the hand. This is slipped on the pivot and the whole thing is again placed in position in the support. If the pointer is correctly balanced it should take the position shown in Fig. 1, but if it is not exactly right a little filing will bring it near enough so that it may be corrected by the adjusting screw.

Next make a brass frame as shown in Fig. 6. This might be made of wood, although brass is better, as the eddy currents set up in a conductor surrounding a magnet tend to stop oscillation of the magnet. (The core is magnetized when a current flows through the instrument.) The brass frame is wound with magnet wire, the size depending on the number of amperes to be measured. Mine is wound with two layers of No. 14 wire, 10 turns to each layer, and is about right for ordinary experimental purposes. The ends of the wire are fastened to the binding-posts, B. C, Fig. 1.

A wooden box, D, is then made and provided with a glass front. A piece of paper is pasted on a piece of wood, which is then fastened in the box in such a position that the hand or pointer will lie close to the paper scale. The box is 5½ in. high, 4 in. wide and 1¾ in. deep; inside measurements. After everything is assembled put a drop of solder on the loop at D, Fig. 5, to prevent it turning on the axle.

To calibrate the instrument connect as shown in Fig. 7, where A is the home-made ammeter; B, a standard ammeter; C, a variable resistance and D a battery, consisting of three or more cells connected in multiple. Throw in enough resistance to make the standard instrument read 1 Amp. and then put a mark on the paper scale of the instrument to be calibrated. Continue in this way with 2 amperes, 3 amperes, 4 amperes, etc., until the scale is full. To make a voltmeter out of this instrument, wind with plenty of No. 36 magnet wire instead of No. 14, or if it is desired to make an in-

*Popular Mechanics.

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strument for measuring both volts and amperes, use both windings and connect to two pairs of binding-posts."

*"The Galvanometer is an instrument similar in construction to the voltmeter. The uses of the galvanometer have been discussed in Chapter IX and commercial instruments may now be purchased so cheap that little excuse is offered for any one to build them. The construction of a Galvanometer is however, interesting, and helps to a thorough understanding of the principle of operation.

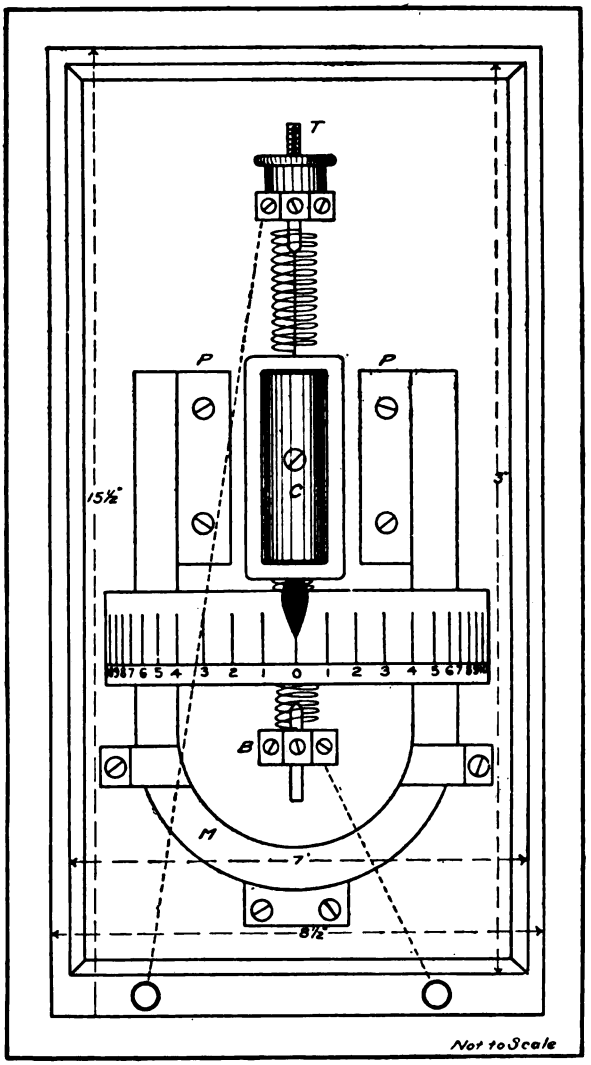


Fig. 407.

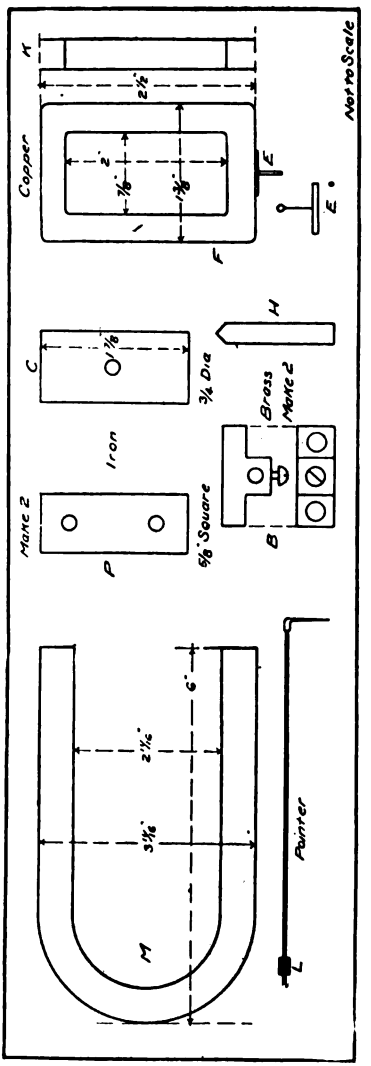


Fig. 408.

"An old telephone generator furnishes excellent magnets for the construction of such a galvanometer. A magnet which a writer in Popular

*Popular Mechanic.

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Mechanics secured from such a source measures 6 inches in length and is made of steel, which is 1/2 inch by 5/8 inch. The more powerful the magnet the better. Its dimensions may vary somewhat from the one used in the following paper, but the reader can easily modify his instrument to suit his needs.

A bottomless box with a glass top will be required, mounted upon a base board, the whole being suited to be screwed to the wall, as shown in Fig. 407. This box is 7 inches by 12 inches outside measurement, and 4½ inches deep. The base board should be 15½ inches by 8½ inches. The box is secured to the base board by two hasps, one on either side, two or three dowel pins helping to hold the box from slipping. This method of securing the box is adopted so the case may be easily removed, giving access to the working parts of the instrument inside.

The magnet used being 5/8 inch wide, two pieces of iron, shown at P, are made for pole pieces. These are ⅝ inch square and 1⅞ inches long and have bored through them two holes 1/8 inch in diameter, through which are to pass screws which are to secure them in place. Secure the magnet firmly to the base board, its pole being 9¼ inches from the bottom, and at equal distances each side of the centre line. A block of wood at each side of the magnet, another at the bottom, and two clamps, one at each side, ought to secure the magnet firmly in place so that it cannot slip. Then screw the pole pieces into place, taking care that they rest firmly against the inner poles of the magnet. This will leave 1 1-16 inch of clear space between the poles, if the dimensions given have been followed. If the magnet used has dimensions differing from those given at M, Fig. 408, allowance will have to be made in the pole pieces, so as to leave the proper space between the pole pieces.

In the exact centre of this space is to be secured an iron cylinder, shown in Fig. 407 and also at C in Fig. 408. This is ⅞ inches long ¾ inch in diameter. It is to be fastened to the base board by a screw passing completely through it. This should leave a clear space of 1/32 inch on each side of the cylinder. It is well at this point to take a very small, sharp chisel and cut two grooves in the base board, these grooves being extensions backward of the spaces between the poles and the cylinder on each side. These grooves are necessary in order to allow the coil shown in Fig. 407 to swing freely in either direction without striking the back board.

Take next a piece of the thinnest copper procurable. It should be very thin in order to be light and to take up as little space as possible. From this sheet copper make a frame such as is shown in Fig. 408. It is rectangular in shape and measures 2 inches by ⅞ inch inside, and 2½ inches by 1⅜ inches outside. Its width is ¼ inch. As shown in the side view at K, it is a frame with the edges bent up so as to form a deep groove running around the face of the frame for holding a coil of fine wire. Where the frame overlaps it must be neatly soldered. At the corners the turned-up edges will be cut away, but this will do no harm. Line the slot in this frame with a layer of thin but tough paper, fastened in place by shellac. This serves to insulate the frame. Then wind the slot full of No. 36 single silk covered magnet wire.

The ends of this coil are left projecting, one at each end. Shellac the outer surface of the coil and set it aside to dry. Now make two little pieces shown at E, Fig. 408. They are made by taking a piece of thin copper, ¼ inch by ⅜ inch, and soldering to its center a projecting wire of stiff brass, ¼ inch long. Flatten the outer end of the brass wire and drill

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a small hole through the flattened part. These little pieces are then bound on to the ends of the coil by silk threads, so that the projecting wires form a spindle about which the coil may rotate. For this reason they must be so adjusted as to project from the exact centre of each end. Also care must be taken, in bending them on, to insulate them from the coils by slipping a piece of thin paper under them. Then the projecting ends of the coil are soldered to these little strips, one at each end, and the superfluous wire cut off.

Two pieces of brass should be made like those shown at B, and also at H, Fig. 408. As shown in Fig. 407 they are to support the coil in position. The hole through B, therefore, should be ⅜ inch from the back side of the piece, and H should slide freely through B, but may be secured by a screw. One of the pieces shown at H should be threaded and provided with a thumb nut as shown at T, Fig. 407. One end of H should be flattened and drilled, as were the ends of the projecting wires on the coil. Now procure some fine silk fibers, preferably of raw silk, and pass one end of the fiber through the hole in the upper wire spindle of the coil, securing it firmly by a drop of sealing wax. In a like manner secure a fiber to the lower spindle. Then, with T in place, Fig. 407, pass the fiber through the hole in T, pull it up until it is of the right length, and fasten with sealing wax. Do the same at the bottom, and the coil will be suspended so as to swing freely in the space between the cylinder and poles.

Current is led into and out of the coil by two very small slender springs shown at the top and bottom. They are made from No. 36 (no finer) German silver wire, coiled around a small pencil so as to make a very weak spring. By carefully removing T, and leaving the fiber slack, the ends of this coil may be soldered to T and to the pivots of the coil. This process should be repeated at the bottom. At S is a circular scale, made of a piece of white bristol board. It projects forward from the instrument, and is bent so as to have the axis of the coil for a centre. The radius of the arc of this circle is 2½ inches. A pointer shown in Fig. 408 is glued to the bottom of the coil, and its front end moves over the card board scale. This pointer is made by taking a strand from a broom, and fitting a thin piece of copper at its outer end to serve as an indicator. The back end of the pointer projects beyond the coil, and is counter-weighted with a small piece of lead, as shown at L.

Thus the silk fibers serve to suspend the coil in place, so that it may swing freely, while the coiled springs encircling the fiber carry the current into and out of the coil, and also serve to bring the needle to 0 after being deflected. Binding posts at the bottom are connected to the upper and lower suspensions as shown.

If the amateur is skillful he can improve the instrument by using two very fine hair springs in place of the coiled German silver springs. These may be secured at a watchmaker's, and besides being more reliable are not so stiff as the German silver springs, and therefore render the instrument more sensitive."

While the construction of a Wheatstone Bridge is something beyond the ability of the average amateur instrument maker, owing to a lack of means to properly adjust the various coils, still there are several forms of bridges that can be easily constructed, and that are fairly accurate. The simplest of these is the so-called "yard stick" slide wire bridge, shown in Fig. 409. The American Telephone Journal gives instructions for making this instrument, as follows:

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"On some convenient board attach two binding posts B and C. Then exactly sixty-two and one-half inches from B and C drive a peg "A". After this is in place stretch a German silver wire of small size, about No. 19 or No. 22, from B to A to C and attach a receiver to the binding posts B and C, thus completing the arrangement of apparatus. To make the test, take the pair of wires that is grounded and short circuit them at the cable box. The good wire of the pair should then be attached to B, the grounded wire to C. Then with the tapper feel along the wire A B until you reach a point at which you get no click in your receiver. This will be the neutral point of balance. Mark this point and measure its distance from A in eighths of an inch.

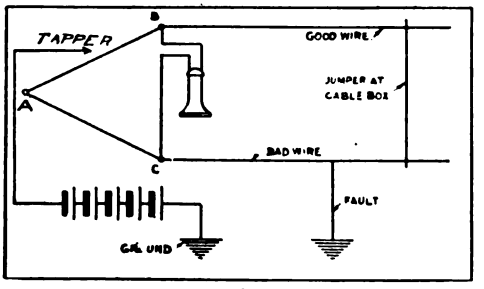


Fig. 409.

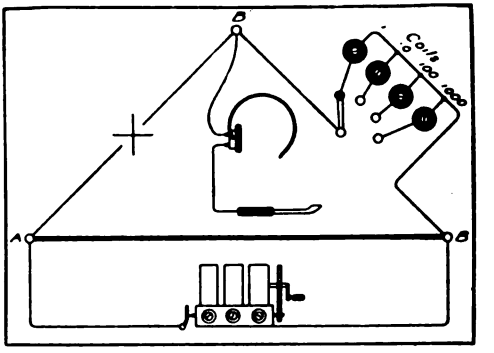


Fig. 410.

You will note that sixty-two and one-half inches equal 500 eighths, so you have 500 from A to B and 500 from A to C, making in all a total of 1,000. Therefore, one thousandth of this, or one eighth of an inch, will equal one one-thousandth of the circuit in your cable. If your cable is three thousand feet long your circuit would be twice that, or six thousand feet, and if one section on your slide wire equals one one-thousandth of your circuit, each eighth of an inch would therefore equal six feet. So if you find the neutral point of balance to be 120 eighths of an inch from A you would have $120 \times 6 = 720$ feet, the distance of the fault from the central office, or having

L = length of cable in feet,
S = spaces from A to neutral,
F = distance from cable box to fault,

then the formula would be

$$\frac{L \times 2}{1000} \times S = F.$$

The above test shows the instrument as applied to locating cable trouble. Of course any other resistance measurements can be made with it.

The Ohmmeter is an instrument often used in telephone work. It is a very desirable form of testing set, and has perhaps reached its highest development in the lineman's fault finder, and similar instruments described in Chapter IX.

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Those who have some mechanical knowledge and a few tools can easily construct an instrument that will be amply sufficient for a great deal of practical work. The ingenious will at once perceive many advantageous modifications that can be made from the instrument here described, and those who desire can elaborate the instrument to any extent that they wish:

*"The materials required in the construction of an Ohmmeter are few. First, there must be a foundation, which may be a piece of carefully seasoned, thoroughly varnished pine, or if preferred, the instrument may be encased in a suitable box, the bottom of which will serve to support the various pieces of apparatus. A resistance wire must be provided. This may be procured from any of the well-known instrument makers.

The best form of resistance wire is that known as Maniganin, which can be obtained in almost any of the ordinary sizes, No. 18 wire averaging about an ohm to the foot, although the resistance will vary greatly with the differences in composition. The actual resistances, however, are not of very great importance, so long as the wire is carefully drawn so that it is essentially uniform in resistance from end to end. A piece of this wire about ten feet in length should be procured.

Upon the foundation board a paper scale is made which would be divided into say 500 or a thousand parts. This scale may be either drawn upon a sheet of Bristol board, or what is still more convenient, a piece of cross section paper, may be used and is numbered from 0 to 500. Five pieces of the resistance wire are stretched over the scale so as to form a continuous piece about 10 feet in length. At each end the wire is secured under some brass plates so that only that portion of the wire which is within the limit of the scale enters into the circuit. At one end of the resistance wire a binding post *A* is attached, which also forms one post to which the resistance *X* to be measured is attached.

For standard resistances it is best to procure four coils, one of 1 ohm, one of 10, one of 100, and one of 1,000. These may be purchased from any instrument maker, but it should be specified that the coils are to be wound non-inductively, that is to say that the requisite wire to make up the specified resistance is measured off and then doubled in the center. The wire is then wound on the spool so that any magnetizing effect is avoided. The four point switch must now be provided to which each end of the standard coils are connected, when they have been mounted upon the foundation board. The necessary apparatus is completed by a receiver, preferably of the head gear type, which is supplied with two long flexible cords, one having a knife edge terminal provided with an insulating handle to act as a detector. There must also be a small hand generator as a source of electricity. If preferred, a battery and vibrating coil or a battery and a galvanometer may be substituted for the hand generator and the receiver. An ordinary battery will not do if a receiver is used, as it is best to have an alternating current so that there will be a plainly audible sound in the receiver when there is a state of unbalance in the circuit.

In Fig. 410 a simplified diagram of the circuit is shown. From inspection of this it is evident that the ohmmeter is simply a modification of the ordinary slide-wire bridge. The same system of lettering is carried through both the figures, and Fig. 411 is a diagram of the circuits as the apparatus is assembled. The heavy full line *A B* represents the resis-

*American Telephone Journal.

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tance wire. At the point *A* a binding post is attached, and from this a connection is extended to the generator and connected to one terminal thereof. From the other terminal of the generator a connection is taken to the resistance wire. Close by the binding post 4 a second similar binding post *B'* is mounted. These binding posts serve to connect the object whose resistance is to be measured to the Ohmmeter. To the binding post *B'* one terminal of the receiver *R* is connected. Also from this point a wire is extended to the center post and the four point switch, while to each of the other posts one of the ends of the various standard coils are attached, as shown in Fig. 410. The other ends of these coils connect to a lead that extends from the generator to the *B* end of the resistance wire.

An inspection of this drawing will show the circuit to be as follows: First, there is a circuit from the generator, through the resistance wire, and back to the generator. If the gap *X* between *A* and *B'* is closed by a resistance or other object there is a circuit in parallel with the wire *A B* formed from *A* to *B'*, thence to the switch through either one of the standard coils to which the switch lever may be connected and thence to the generator.

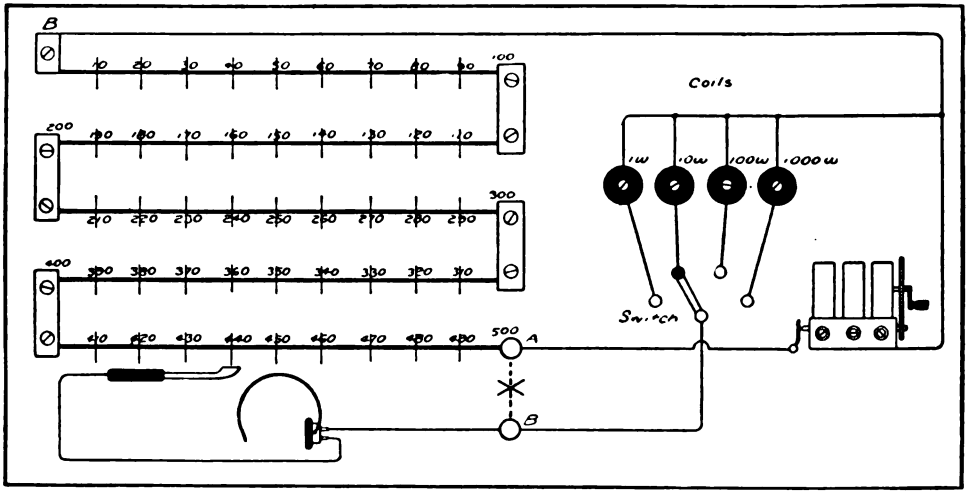


Fig. 411.

To use the Ohmmeter, introduce the object to be measured at *X* between the binding posts *A* and *B*. Place the receiver to the ear, turn the crank of the generator, take the free terminal of the receiver which should be provided with a metallic knife edge with an insulating handle, and pass it to and fro over the resistance wire until a point on the resistance wire is found at which the receiver becomes quiet and the throbbing of the generator cannot be heard. Supposing the scales of the Ohmmeter be constructed as shown in the illustration, and as a concrete example assume that the switch lever is on the hundred ohm coil, and that the receiver terminal stands at 300 upon the resistance scale, the total length of the scale is 500 divisions, the standard coil is 100 ohms, then the following equation holds true:

$$X = \frac{300}{200} \times 100 = 150 \text{ ohms.}$$

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In other words, divide the number on the scale opposite which the receiver contact stands by the difference between this number and the full reading of the scale. (In this example the receiver point stopped at 300. The whole length of the scale is 500.) 500 — 300 = 200 and multiply the coil used by this quotient.

It cannot be expected that an Ohmmeter of this description will have the refinements and the extreme accuracy of the more expensive instruments, yet if carefully made it may be expected to be accurate within 1 per cent., which is usually near enough for all excepting the most refined investigations.

It is desirable to exercise some care in selecting the generator in order to procure a machine which shall be as noiseless as possible, because as the point of balance is found by listening to the receiver any external noise is liable to interfere with the connection of local points. Under these circumstances it is necessary to enclose a generator in a box in order to deaden the noise as much as possible. It would not be a good plan to mount the generator on the same board with the other apparatus, as it will be so noisy as to interfere with the tests. In an exchange where there is a power generator a circuit from that can be used.

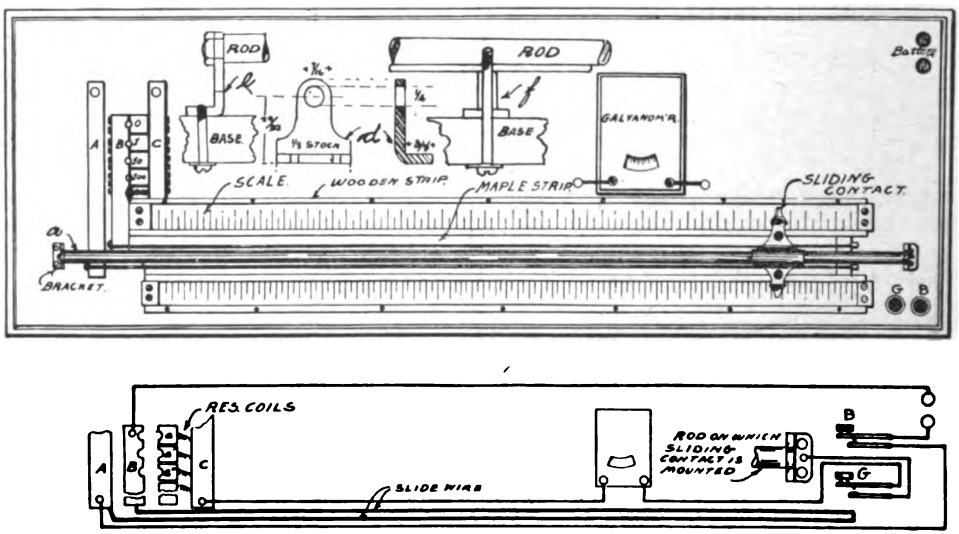


Fig. 412.

If one cares to go to the extra trouble and expense it is exceedingly convenient to wind the resistance wire *A B*, upon a large circular spool and mount it upon a spindle with a contact spring, (which takes the place of the knife edge) arranged to press against the wire on the spool instead of the separate contact in the receiver cord. By this means a very long piece of resistance wire can be used and by counting or providing an indicator to measure the number of revolutions which the wire drum makes, very great accuracy can be secured.

A somewhat more elaborate Ohmmeter may be constructed according to the following plan. This instrument was designed to meet the requirements of a large exchange where the repair department had to constantly test the resistance of re-wound ringer coils, etc. The instrument

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is very accurate and if properly made will not be subject to inaccuracies such as are caused by wear of the sliding contact, etc.

Fig. 412 shows a plan of the instrument, and a simplified circuit of same. The box or case is about 44″ long, 16″ wide and 4″ high. The cover is permanently attached to the box, and projects about ¼″ all around. The box is hinged at the bottom, and the bottom should project about 1½″ all around.

A suitable opening is made for the galvanometer, which should be of the portable, needle type, of rigid construction and ample sensibility. The type of instrument usually used in portable testing sets is suitable.

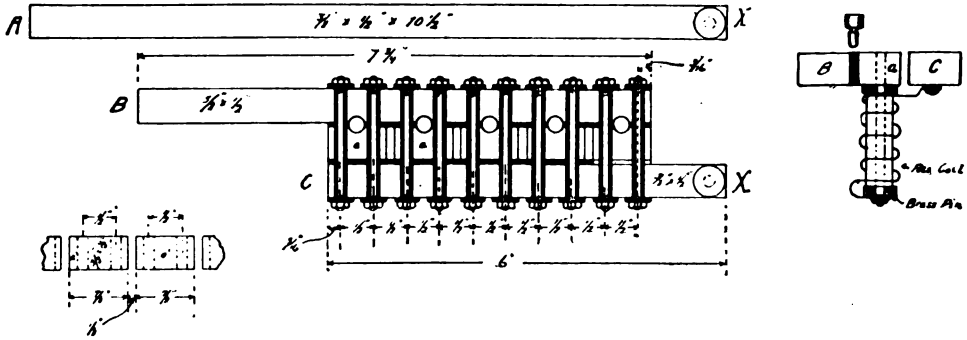


Fig. 413.

The resistance coils must be purchased from the makers. Four of these are needed, of 1, 10, 100, and 1,000 ohms each. These are secured to the brass blocks, *a* a^1, Fig. 413, by means of brass rods, as shown. The four coils and the blocks to which they are connected, are then bolted together, as shown in Fig. 413, which gives the dimensions of the various parts. The holes between pieces *a* a^1, etc., and bar *B*, are reamed with a taper reamer and a substantial brass plug made to fit. It will be noticed that one side of all the coils connect to bar *C*, the other side of coil being soldered to the brass pin in the centre of the coil, which connects to piece *a*. By inserting the plug in any hole, that coil is connected between *C* and *B*.

This method of construction will be found easier for the average amateur than to attempt to make the contact plates as usually furnished by the regular instrument makers, as it is very hard to ream the taper holes, when there is an air space between the sides, as is usually the case.

The bars A, B and C are tapped for screws, so that they can be attached to the top of the box.

Where this arrangement can not be conveniently made, ordinary knife switches or other suitable devices may be used.

A brass rod ⅜″ diameter and 48″ long is made to carry the sliding contact piece. This rod is shown at *a* Fig. 412, and the end brackets for supporting same are shown at *d* and *e* Fig. 412. One centre bracket as shown at *f*, must be made and placed underneath the rod.

A strip of maple about 3″ wide and 2′ 5½″ long should be glued to the top of the box, so as to raise the slide wire sufficiently above the top to permit the scales to be placed underneath the contact slider.

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The contact slider is shown in detail in Fig. 414. A brass tube *a* is taken and made a running fit on the rod, which should be smoothly finished. Across this tube is placed a saddle *e* made of German silver. On top of this is secured piece *b* of brass, which carries contact point *f* and f^1 in each end.

The various pieces are assembled as shown in the figure, *d* being the supporting rod. The contact points *f* and f^1 should normally be out of contact with the slide wires by about 1/8″ but should be arranged to make firm contact when *g* and g^1 are depressed.

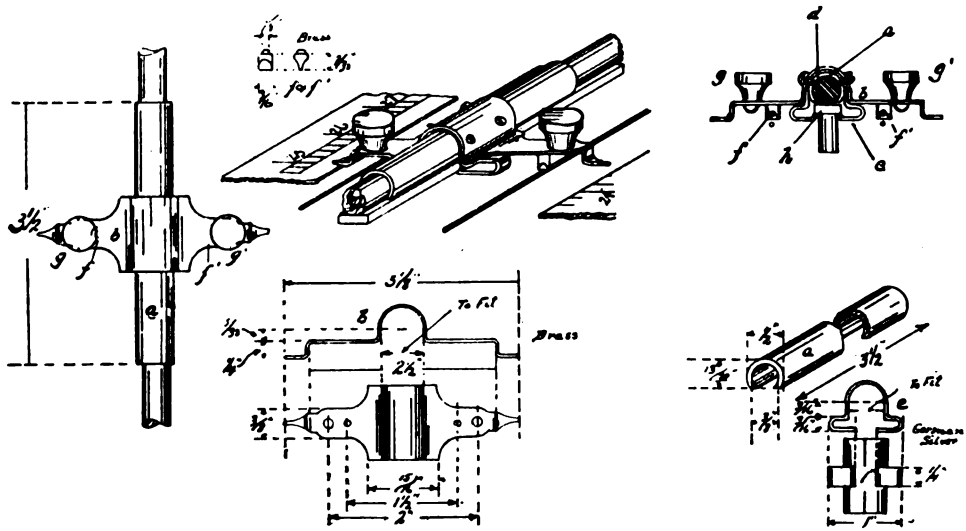


Fig. 414.

This arrangement should slide freely on the rod, over its entire length without binding or cutting.

Two Bristol board scales are securely fastened to the top of the box as shown in Fig. 412, and suitable strips of glass should be prepared to cover these. The glass can be held in place on three sides by a small moulding, and on the side nearest the wire by fitting same into a groove in the maple strip supporting the slide wires. Have the glass fit tightly so that dust cannot penetrate to the scales.

The slide wire is 17 or 18 guage Maniganin or German silver. Stretch the wires tightly across the strip, in which two grooves have been scratched to more firmly hold the wire, and prevent it moving sideways. Permanently fasten the wire at both ends under screws, see that it is perfectly tight, and then shellac the wire into the grooves.

Two keys are provided for the battery and galvanometer circuits. These are marked B and G in the figure, and are of the lever type with positive contacts. Posts are provided as shown, for the battery wires.

Use not less than No. 12 wire to connect the various parts, and remember that the resistance must be kept as low as possible, so that no error will be introduced in the readings of the apparatus.

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This bridge may be used same as the one previously described, by dividing the scales into 1,000 even parts, but a much more desirable method, and one that permits of marking the scale so that the result is read directly in ohms without any calculation, is to connect a standard resistance box to the X posts, and calibrate the bridge by means of same. To do this proceed as follows:

Connect a battery to the Bat. posts; this should be a storage cell, or some other source of current that will not weaken or change during the test. In a common battery office, it can be the exchange battery in series with a fixed resistance of 50 ohms. Connect the resistance box to the X posts and unplug a certain resistance—say 10 ohms. Now put in one of the standard coil plugs—say the 100 ohm plug, and slide the contact along the wires, meanwhile tapping the keys, until a balance is found, and the galvanometer ceases to move from the centre or zero point. Mark this place on the scale, in this case it is 10 ohms. Now unplug 11 ohms and proceed as before; it will be found that the contact need only be moved a short space to find this point. Continue in this manner until the scales have been marked throughout their length.

It will be found that the divisions will be close together at some points and further apart at others, this should not cause any uneasiness if the galvanometer is watched closely and an absolute balance secured for each reading.

Do not let the wires get too warm, which will occur if the battery key is kept constantly depressed. It is better to just tap the battery key.

It is best to use the standard coil nearest the actual resistances the set is being constructed to measure. Calibrate the scales using this coil only, throughout their entire length. If the 100 ohm coil is used, upon changing to the 1,000 ohm coil, the readings will be increased by 10, or if the 10 ohm coil is used the readings will be decreased by 10, and if the 1 ohm coil, by 100.

To illustrate this, suppose the 100 ohm coil is used, and 10 ohms is unplugged in the resistance box, and a point on the scale is located where the galvanometer needle no longer moves; this is marked 10, meaning 10 ohms.

Now change to the 1,000 ohm coil, and it will be found necessary to unplug 100 ohms in the resistance box before the galvanometer will balance at the same point on the scale.

By using the 10 ohm coil, the point that was 10 ohms with the 100 ohm coil, becomes 1 ohm, and by using the 1 ohm coil, it becomes .1 ohm.

It is very easy to calibrate the bridge by using the 100 ohm coil, and then adding an 0 to each figure. When using the 1,000 ohm coil the figures are increased in value by this cipher, thus 10 reading 100, 50 reading 500, and so on. Or the value is decreased if the 10 ohm coil is used. Thus 10 becomes 1, 50 becomes 5, and so on.

The complete instrument is shown in Fig. 414a. If carefully made and calibrated it is very accurate, this depending upon the accuracy of the resistance box used, and the accuracy of the relative resistance of the standard coils used in the bridge.

The bridge is of course more accurate for readings made using the same coil as used when calibrating the bridge. A slight inaccuracy may be noticed when the other coils are used; to test this proceed as follows:

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Use 100 ohm coil, unplug 100 ohms in resistance box, note balance point on scale and mark this 100.

Change to 1,000 ohm coil, unplug 1,000 ohms in resistance box, and balance should be same as before.

Change to 10 ohm coil, unplug 10 ohms, balance should be same as before.

As the instrument is direct reading it is very convenient where a large number of measurements are constantly being made.

Change to 1 ohm coil, unplug 1 ohm, balance should be same as before.

Every exchange should be equipped with a voltmeter, and this is usually mounted upon a desk type switchboard, and is usually termed a "test table" or wire chief's desk.

A simple arrangement of this character may consist of an ordinary telephone equipped with a volt-meter of the type shown in Fig. 379. Any bridging telephone may be used, the voltmeter being mounted on the door where the bells are usually placed. Two double throw keys are necessary, wired as shown in Fig. 415. While the complete phone wiring is shown, it will be understood that this exact wiring need not be adhered to, as any standard bridging phone may be used, provided the keys and voltmeter are connected as shown.

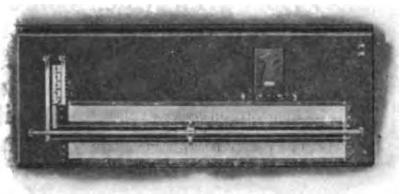


Fig. 414a. Complete Ohmmeter.

When No. 1 key is thrown to the left, thereby operating the springs on side marked A the batteries are connected directly to the voltmeter, and when thrown to the right side B is operated, the battery, voltmeter and line are in series, and the resistance of the line, short circuits, etc., can be measured in the usual manner.

To test for a ground on the side of the line marked L in the figure throw Key No. 1 to B and Key No. 2 to B, this will ground line 2, and thereby show the leakage from line 1 to line 2 or ground.

Throwing Key 2 to A will reverse the process, and ground line 1.

Ordinary ringing and talking tests are made in the usual manner.

In large exchanges it is customary to furnish a much more elaborate equipment, and to supply the wire chief with a small switchboard equipped with various testing applicances adapted to rapidly locate both line and equipment troubles.

The circuits of a standard wire chief's desk, as furnished by the Western Electric Co., are shown in Fig. 417. This equipment is especially designed for use with the standard common battery switchboard equipment furnished by this company.

A three conductor plug is used, the sleeve of which is connected to a 180 ohm resistance coil, so that when this plug is placed in any jack, the

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cut off relay or restoring coil, if it is a line ending in a battery restored drop, will be operated.

Keys 1, 2, 3, 4 and 5 are ringing keys. No. 1 connecting ± current to the ring of the plug and grounding the sleeve for ringing ordinary bells and keys 2, 3, 4 and 5 connecting to + and — current for pulsating party line ringing. Key D also forms part of the ringing combination, as by means of this key 100 or 660 ohm resistance lamps are inserted in

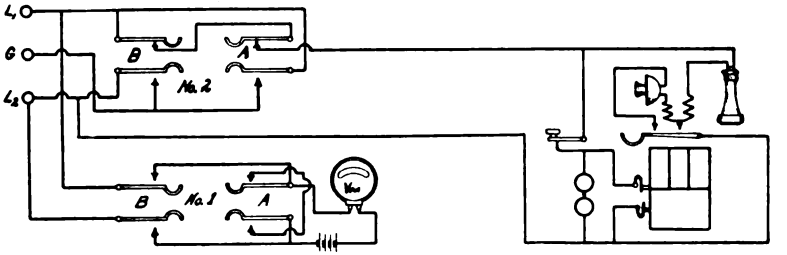


Fig. 415.

the ringing circuit, thereby enabling the bells to be adjusted to ring properly through these resistances, which represent the resistances inserted in the ringing leads of the local and trunk operators' positions at the main switchboard.

Key 6 is an ordinary listening key which connects the wire chief's talking set to the test plug, through the repeating coil, which supplies bat-

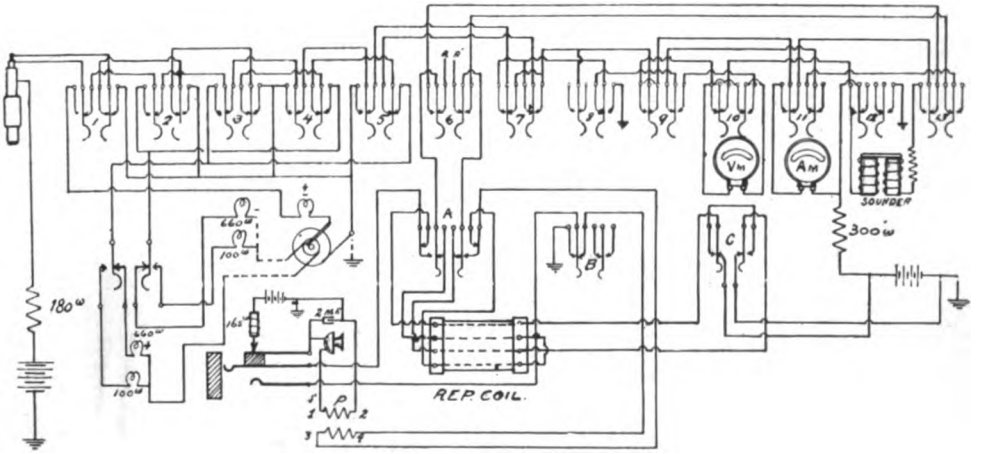


Fig. 417.

tery to the line under test, same as an ordinary cord circuit. Key A cuts off the battery, and connects the test plug directly to the secondary circuit of the wire chief's talking set, thus making the circuit same as a magneto line, by removing the battery from the line under test.

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Key C accomplishes the same result but puts the repeating coil in circuit between the wire chiefs' talking set and the line under test.

Key B when thrown, grounds one side of the receiver, to enable listening tests to be made from line to ground.

The wiring of the wire chief's talking set is practically the same as that of an operator's set at a common battery switchboard. The transmitter is in series with a 165 ohm impedance coil and the 17 ohm primary of an induction coil. The secondary circuit consists of the receiver and secondary of coil in series, with a 2 M. F. condenser and the line. The operation of this circuit is fully described in connection with common battery switchboard.

Key 7 is a reversing key, whereby the ground side of the circuit which is normally on the tip of the plug, is changed to the ring and the battery side of the circuit applied to the tip.



Fig. 418.

Key 8 when thrown, grounds the ring side of the cord circuit. By tracing the circuit from battery, it will be seen that the voltmeter is normally in series with the ring side of the circuit, and that the tip side is open at Key 6. Now by throwing Key 9, if a ground exists on the ring side of the line, the voltmeter will immediately indicate this, but if the circuit is O. K. or the ground is on the tip side of the line under test, it will be necessary to throw Key 8 before the circuit is completed.

If the ground is on the tip side, it can be located by throwing Key 7.

Key 10 disconnects everything from the test circuit except the voltmeter, which is bridged directly across the cord. Throwing Key 8 will then ground the tip side of the voltmeter and cord circuit, and by Key 7 the ground may be reversed.

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Key 11 places the milli-ammeter in circuit same as Key 9 did the voltmeter. A 100 ohm resistance coil is in series with the ammeter to protect it from damage in case of a dead short circuit on the test line. This resistance should be subtracted from the result when making resistance calculations. Key 12 short circuits this coil, where it is necessary to remove same from the circuit in order to obtain sufficient deflection. The ammeter usually has a range of 300 milli-amperes.

Key 13 places the 125 ohm sounder in series with the ring side of the circuit in series with a 300 ohm resistance coil, used to prevent an excessive flow of current. The sounder is very handy for making tests as it can, for instance, be left connected to a line upon which work is being done, and when the trouble man calls in, the sounder will call attention to the fact, if the wire chief is busy in some other part of the room.

Experience is necessary to become proficient in quickly making tests with this equipment, but the layout here given is the result of much practical experience and experiment with a view to simplifying the circuit as much as possible.

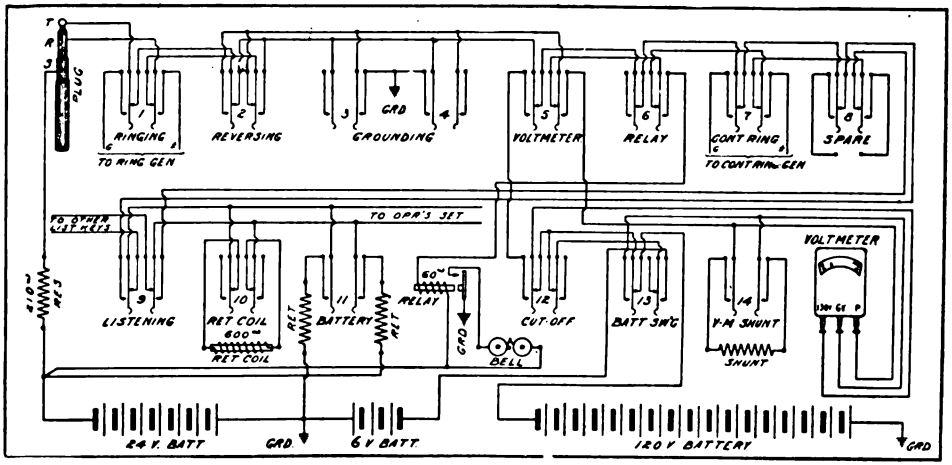


Fig. 419.

The general appearance of a wire chief's desk is shown in Fig. 418. The ammeter and voltmeter are usually of the Weston make. The location of the apparatus is plainly shown in the illustration.

A circuit differing in detail from the one just described, is shown in Fig. 419. This is arranged to work in connection with the common battery equipment furnished by one of the large manufacturers. The American Telephone Journal describes the operation of the keys as follows:

"The wire chief's board is provided with jacks connected to plugs terminating on the multiple board which are inserted by operators in case of trouble appearing in the jacks of line in trouble and still other jacks are provided for testing trunks to the main distributing frame.

The plug shown in Fig. 419 is inserted in the jack of the cord connected to the line to be tested, and by the proper manipulation of the keys shown, any of the customary tests may be made.

Key No. 1 is a ringing key which allows the wire chief to ring out on the line, thus determining whether the subscriber can be "raised" or not.

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Key No. 2 is the reversing key which reverses the entire testing equipment with respect to the tip and the ringing sides of the line being tested.

Keys Nos. 3 and 4 are for grounding the different sides of the line. Key No. 3 grounding the ring side and No. 4 the tip side.

Key No. 5 is the voltmeter key which when operated together with Key No. 1, bridges the volt-meter on to the line for making the desired tests.

Key No. 6 is the relay key and is connected, as you will note, in such a manner as to operate the 60-ohm relay when there is a ground on the line, thus causing the ground signalling bell to be actuated. This is a test for ground on either side of the line, as the line may be reversed by the actuation of key No. 2 by the wire chief.

Key No. 7 is a continuous ringing key; that is, a key to which the leads of a continuous ringing generator are connected. This may be used in place of key No. 1 in signaling the instrument desired.

Key No. 8 is left spare in order to provide for any future contingencies.

Key. No. 9 connects the cord circuit to the wire chief's talking set so that conversation may be had upon the line. The inner contacts of this key are connected to other listening keys where more than one wire chief's position is installed, and may be left unoccupied where but one position is used.

Key No. 10 bridges the retardation coil across the line so that when the wire chief is talking to some person through the board, by throwing the retardation coil key, the supervisory signal in front of the operator is extinguished, thus allowing the wire chief, by throwing the listening key No. 9, to carry on any conversation he may desire, and by returning key No. 10 to its normal position the supervisory signal will light, thus advising the operator that the use of the line is no longer required and that the connection may be taken down.

Key No. 11 is for the purpose of connecting battery cord circuits through repeating coil or retardation coil for any particular purpose that may be desired where the full force of the battery is not required.

Key No. 12 cuts off the battery from the voltmeter. Where quick readings are desired, this key may be operated rapidly.

Key No. 13 is for connecting the six volt battery to the low scale of the voltmeter.

Key No. 14 is for connecting the shunt across the low reading scale of the voltmeter in order that by comparison of this winding with the total resistance of the voltmeter circuit and by the application of the voltmeter shunt principle of measuring, an increased reading may be obtained on the voltmeter where the trouble is of such a nature that a sufficiently large deflection for easy reading would not be obtained where the force of the battery was flowing through the voltmeter, the line and the trouble, in series.

In this circuit a voltmeter has been employed for the purpose of making the measurements, as with this instrument the necessary tests can be performed more readily and with greater degree of exactness in a given time than by other means. Sometimes a Wheatstone Bridge is substituted, and so arranged that it may be conveniently and rapidly connected to or

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disconnected from any line on which the wire chief may be desirous of making a test."

The 6 and 120 volt batteries may consist of ordinary dry cells.

There are several other circuits used in connection with the wire chief's testing equipment, but as it is only intended to refer to the arrangement and use of the instruments used, at this time, a description of these circuits will be given later.

Portable test sets for linemen's use, consist of a telephone instrument compactly arranged so as to be easily transported. A set for use on magneto systems is shown in Fig. 419a. It consists of a magneto buzzer and 2 bar generator in series, and a special receiver. A switch is arranged to cut the receiver in and out of circuit.

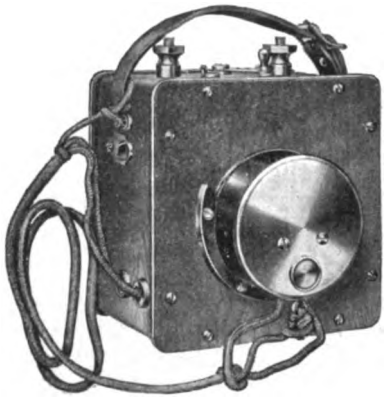


Fig. 419a.

A regular transmitter and batteries are sometimes furnished, and the generator may be equipped to give pulsating current so that central may be called without ringing the phone bell on the line.

In common battery systems the generator is unnecessary, and it is customary to furnish the trouble man with a transmitter and receiver in series, and contained in one handle, as shown in Fig. 419b. The cord is equipped with snap clips, to facilitate attaching the set to the line wires.

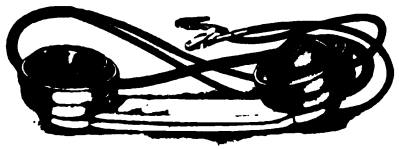


Fig. 419b.

On common battery work, it is possible to use an ordinary head receiver, using it as transmitter and receiver. If it does not transmit well when first connected to the line, reverse the connection, so the line battery will flow through it in the proper manner.

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CHAPTER XI.

COMMON BATTERY EQUIPMENT.

The main difference between magneto and common battery systems is that with the common battery system, the central office is signaled by merely removing the receiver from the hook, while with the magneto system it is necessary to turn the generator crank. Upon finishing the conversation, it is not necessary to ring off, as this is automatically performed by replacing the receiver on the hook.

From this it is evident that there must be a current on the line wires all the time so that when the receiver is taken off the circuit is closed and the operator at the central office is thereby notified that a conversation is desired.

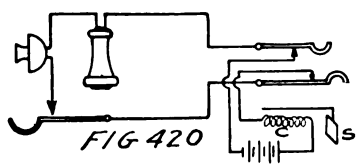


FIG 420

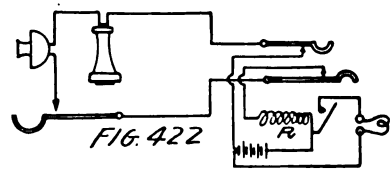


FIG 422

With the common battery system a different class of signals may be employed from those used in magneto work. The usual drop or signal used in magneto work has a shutter which is restored by hand, or by inserting the plug in the jack, and so designed that when the shutter falls after receiving the first impulse from the generator, it remains displayed until restored by the operator. This is necessary or the subscriber would have to continually turn the generator to display the signal until the operator answered. In common battery systems the signal is displayed as long as the receiver is off the hook until the call is answered.

Two types of common battery signals are in common use. One is the so called visual signal which consists of a drop with the shutter so attached that it is displayed when a current passes through the coil.

Another type of signal that is used extensively in larger exchanges is a miniature incandescent lamp mounted back of a small glass cap. The lamp is lighted by the operation of a relay, which will be described later.

Fig. 420 shows the arrangement for signalling when a visual type of signal is used. The battery may be from 20 to 48 volts, and the signal may have a resistance of 80 to 500 ohms. When the circuit is closed by the removal of the receiver from the hook, current will flow from the battery, over the tip line, through the transmitter and receiver and through the sleeve side of the line and the visual signal winding C, to the battery.

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This causes the armature of the visual to be attracted, and the shutter S is displayed. When the plug is inserted in the jack, the circuit through the signal is broken, and the shutter is no longer held in the exposed position.

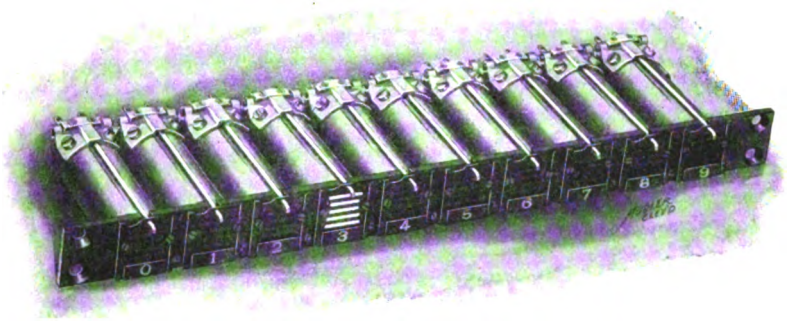


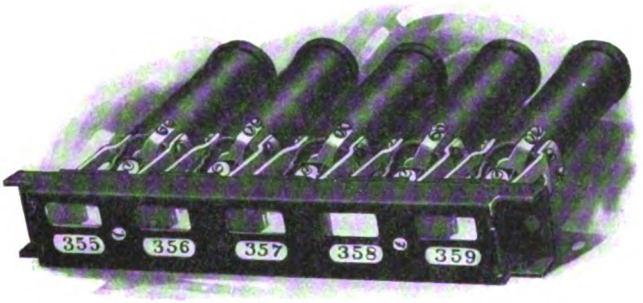
Fig. 421.

A strip of visual signals as furnished by the North Electric Co. are shown in Fig. 421. When in the normal position the shutters are hidden by the front plates, but when the visuals are actuated the shutters are displayed through the slots, as shown in the figure.



Western Electric Visual.

Fig. 422 shows the circuit when lamps are used. Here a relay, *R* is placed in the circuit, the lamp being controlled by the contacts of this relay. It is obviously impossible to include the lamp directly in the line cir-



Monarch Tel. Mfg. Co., Visual.

cuit, as if sufficient battery was used to light the lamp through the resistance of a long line, it would burn up on a short line. By using the relay, the lamp is always subjected to the same current, as the resistance of the lamp circuit is not variable.

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It may be stated that Figs. 420 and 422 show in theory only, the visual and lamp signal methods of operation. Both of the circuits shown are only suitable for small boards, and other equipment is necessary in connection with common battery calling circuits, especially in large boards. These figures however, show that the exchange may be signalled with the common battery system, by simply removing the receiver from the hook thereby completing the circuit through the signal apparatus at the switchboard.

One difficulty encountered in this system is the fact that while the circuit at the telephone must be kept open when the phone is not in use, the ringer must be connected to the line so that Central can call the phone. This was accomplished by winding the ringer to a resistance of several thousand ohms, and bridging it on the line, as shown in Fig. 423 and adjusting the line signal so that it would not operate through the high resistance ringer but would operate when a low resistance path was afforded through the receiver and transmitter. This method proved very unsatisfactory for the reason that a small but constant leakage of current occurred through the ringer, and in an exchange of several hundred lines, this leak became large enough to be serious.

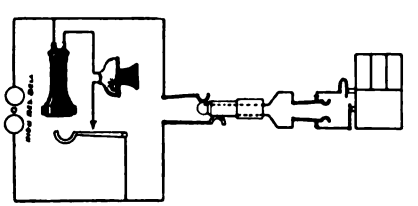


Fig. 423.

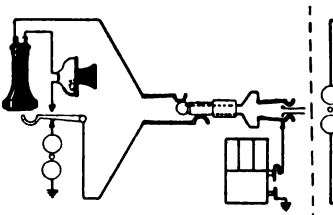


Fig. 424.

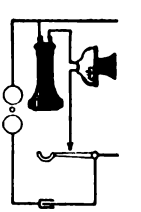


Fig. 425.

The constant flow of current through the polarized ringer, also had a weakening effect on the magnet. The signal or relay also required frequent adjustment, as it would "stick" after having been pulled up, by reason of the small current passing through the coil. These troubles caused this method to be abandoned.

Another scheme was to connect the ringer from one line to ground, as shown in Fig. 424. While this removed the objection of the current always flowing through the ringer, it is objectionable to use the ground for ringing and for this and other reasons this method was abandoned.

The standard and now universally used method of arranging the ringer circuit, is to place a condenser in series with the ringer, as shown in Fig. 425. The condenser is the same as an open circuit to the direct current and no current passes, while to the ringing current which is alternating, it offers but little opposition, consequently the ringer is operated. The usual arrangement is to use a 1,000 ohm ringer and 2 M. F. condenser, this always being the case where the condenser forms part of the talking circuit, otherwise a 1 M. F. condenser and 500 ohm ringer may be used. In the following circuit diagrams it will be understood that a ringer and condenser form part of the circuit. These are sometimes omitted for the sake of clearness.

From the foregoing it will be understood how the phone may call the Central office, and be called. It is also apparent that where there is more than one phone on a line, that the phones cannot call each other, as Central

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must do all the ringing. This is the case except in some special cases as described later.

The generators are of course eliminated from common battery instruments, and also the batteries, the transmitters being supplied from a battery at the Central office, this usually being the same battery that is used for operating the line signals.

Fig. 426 shows one method of supplying battery to the transmitters. The battery is placed in the cord circuit as shown. A separate battery for each cord circuit may be used or, if the battery is of very low internal resistance, such as a storage battery, all the cord circuits may be connected to the same battery, as shown in Fig. 427. Under these circumstances conversation is possible between phones connected by plugs of the first pair, while phones connected to the second cord circuit are also talking. While only two cord circuits are shown in the figure, it should be remembered that any number could be connected to the battery.

Phones connected by the second cord can talk owing to the low resistance of the battery at the centre points, (these usually consisting of heavy copper buss bars) and very little cross talk from the first cord will result. This is the principle of the method of supplying talking battery, in the common battery system.

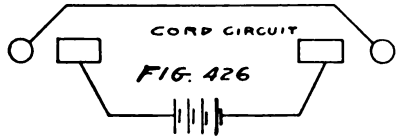


FIG. 426

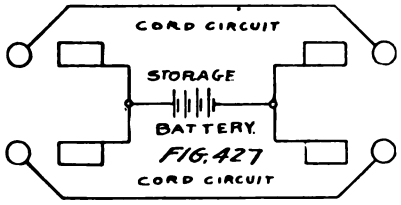
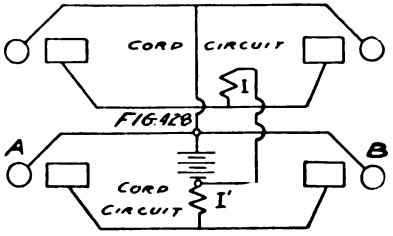
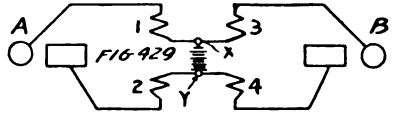


FIG. 427





The circuit shown in Fig. 427 has some serious faults; one is that unless the buss bars and battery are of very low resistance cross talk will result.

Fig. 428 shows a partial remedy for cross talk. The impedance coils I I^1 are inserted between the battery and the sleeve side of each cord circuit. It will now be seen that while the impedance coils will permit sufficient direct current to flow out to each cord circuit to supply the transmitters, the impedance of the coils will prevent the voice currents from being short circuited by, or from flowing into the battery, and they flow directly from telephone to telephone. This arrangement successfully prevents cross talk, as voice currents from one cord cannot affect another, owing to the impedance coils.

It is evident that if the line connected to plug A, Fig. 428, is of less resistance than the line connected to plug B, that most of the current will flow over the A line, and the B line will not get enough battery to properly operate the transmitter. This is remedied by using the arrangement shown in Fig. 429, which is the method usually used by the Bell Companies.

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A Repeating coil is used, with 4 windings, all wound on the same core.

Windings 1 and 2 form one half of the coil, 3 and 4 the other. As the current for each line flows over the windings connected to that line only, the resistance of one line can in no way affect the current supply of the other. The voice currents from line A are repeated from windings 1 and 2 of the coil, to line B through windings 3 and 4, but any stray currents from other cord circuits which may be present at points X and Y, are prevented from getting into the cord circuit by the impedance of the coil, which acts same as an impedance coil in respect to any alternating current that may attempt to flow into the cord circuit from points X and Y.

There are several other methods of supplying the battery to the transmitters and these are described in connection with complete switchboard circuits.

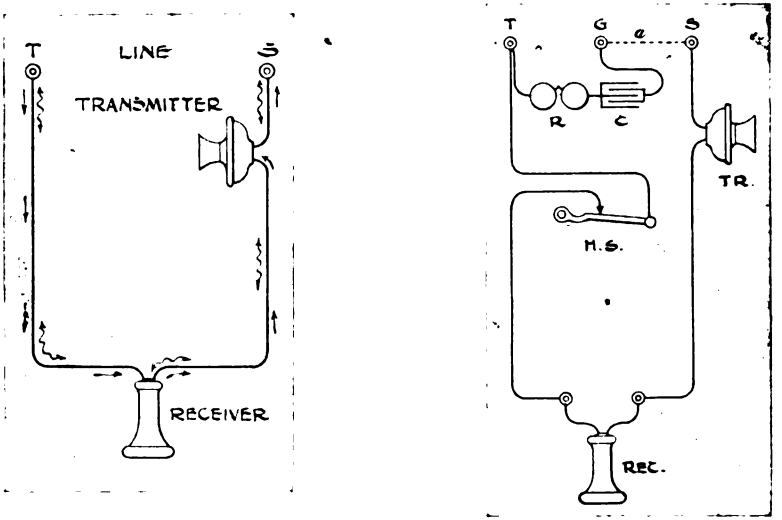


Fig. 430.

So far, the circuit arrangement of the subscriber's telephone has not been considered, and for the sake of clearness the transmitter and receiver have been shown in some of the drawings connected in series. This arrangement is shown in Fig. 430. Here the receiver and transmitter are in series so that the entire direct current flowing from the central office, used for signalling purposes as well as for transmitting, passes through the receiver coils.

Unless the receiver is connected so that this steady flow of current increases rather than diminishes the efficiency of its magnet, a serious loss in efficiency results. It is at once apparent that this type of circuit is not practical for ordinary exchange work, as the accidental reversal of the line conductors at the distributing frame or at a manhole or pole, will cause a reversal of current through the receiver and a consequent weakening of the magnet, and the receiver is not in a condition to give its maximum sufficiency.

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An increase in the magnetism due to battery flowing through the coils in the proper direction, is often sufficient to pull the diaphragm into such close proximity to the pole pieces that its vibration is interfered with. For these reasons this circuit is used to a very limited extent, usually only in private telephone installations where the line wires remain constant in their resistance and are not as subject to reversal as the wires of outside plants. In attempting to secure the best results and yet prevent the flow of current through the receiver so as to give it unhindered action, a variety of means have been tried. Fig. 431 shows one circuit in common use.

Here the receiver is placed in a local circuit formed by one winding of the induction coil, while the transmitter and hook contacts are placed in circuit with the other winding. The strait single headed arrows show

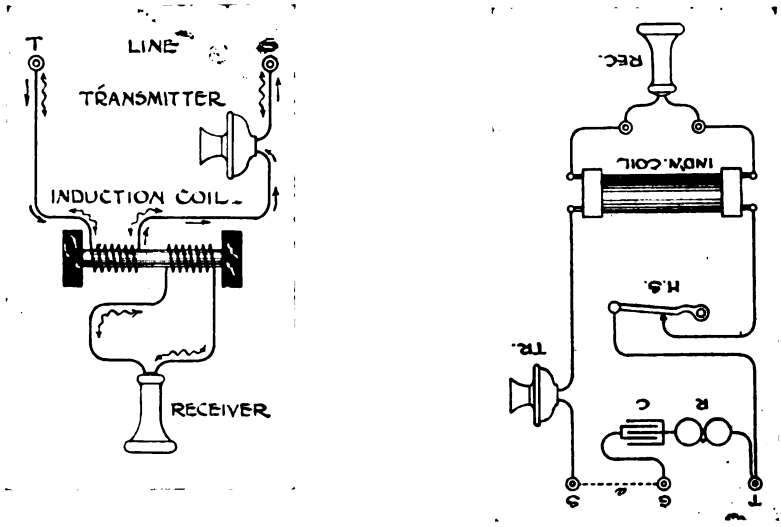


Fig. 431.

the path taken by the direct current, while those with double heads represent the voice currents. The incoming voice currents are induced from one winding of the coil to the other. The coil commonly used in connection with this set is of the following dimensions, the core consisting of No. 26 iron wire 7-16″ in diameter and 4⅛″ long. Heads 1⅛″ square, 5-16″ thick. Space between heads, 3½″. Two layers of paper are placed over the core. The first winding consists of 1450 turns of No. 26 single silk covered wire put on in 8 layers of 180 turns each. One piece of thin paper is placed between each layer. This winding is wound from left to right, the coil is then turned over, and two layers of thin paper are placed over the first winding. The outside winding is then put on, which consists of 1062 turns of No. 26 single silk covered wire, put on in 6 layers of about 180 turns each, with a piece of paper between each layer. The terminals are brought out and numbered as follows:

Inside end of inside winding	No. 1.
Outside end of inside winding	No. 2.
Inside end of outside winding	No. 3.
Outside end of outside winding	No. 4.

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Terminals, No. 1 and 2 connect to the receiver, No. 3 to the line, and No. 4 to the transmitter. The resistance of each coil should be about 10 ½ ohms. Another coil of smaller dimensions with a winding space of 2 ½ inches, head 1⅛ by ⅜ thick, with a core ⅜ inches in diameter, has an inside winding of 1320 turns of No. 26 single silk wire 8½ layers, with outside winding of 1320 turns No. 26 put on in 10½ layers, each winding having a resistance of 10½ ohms. The receiver used with this instrument is usually wound to a resistance of 25 ohms.

This circuit arrangement transmits very well, but it is slightly deficient in receiving qualities, as the voice currents reach the receiver entirely by the inductive effect of the coil, the receiver having no actual connection with the line wires whatever.

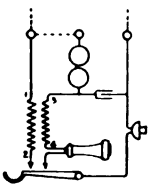


Fig. 432.

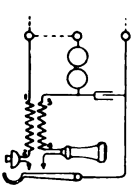


Fig. 433.

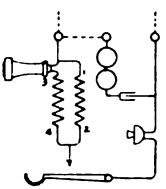


Fig. 434.

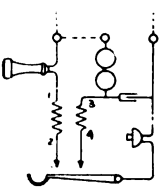


Fig. 435.

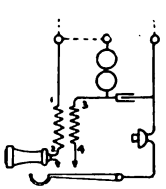


Fig. 436.

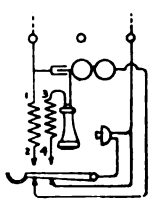


Fig. 437.

The circuit arrangement usually employed by the Bell Companies is shown in Fig. 432. The dimensions for the standard induction coil being as follows: Core of 24 iron wire 7-16″ in diameter, and 4¼″ long. Heads 1⅜″ square and ⅜″ thick. Winding space 3½″. Enough paper is wound over core to make same ½″ in diameter. The inside winding consists of about 1400 turns of No. 31 single cotton covered wire, put on in six layers. Resistance from 26 to 30 ohms. Two layers of paper are put on and then without removing the coil from the winding machine, the outside winding which consists of 1700 turns of No. 26 cotton wire, resistance from 15.5 to 17 ohms, is wound on. The terminals are numbered as follows:

Inside end of outside winding	No. 1.
Outside end of outside winding	No. 2.
Outside end of inside winding	No. 3.
Inside end of inside winding	No. 4.

Connect for circuit shown in Fig. 432 1 to Line: 2 to hook: 3 to condenser, 4 to receiver.

The receiver usually used, is wound to 60 ohms, with 34 single silk covered wire.

When the transmitter is sensitive, and the circuit, Fig. 432 is used, the "side tone" may be objectionable, and to overcome this the arrangement shown in Fig. 433 may be used, with a 75 or 80 ohm receiver.

In Figs. 434, 435, 436 and 437 are shown some arrangements that can be used with this circuit, none of which excel that shown in Fig. 432.

Referring to the coil used in this type, when arranged as shown in Fig. 432, and considering terminals 1 and 2 as the primary, and 3 and 4 as the secondary, if the pri. and sec. are reversed, transmission will be decreased about 50%.

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If it is thought that terminals 1 and 2 or 3 and 4 are reversed, short circuit the condenser and if the coil is O. K., the core of the coil will become magnetized more strongly. If not O. K., the magnetism will decrease; this can be ascertained by holding a nail or other light piece of iron near the core while short circuiting the condenser.

If 1 and 3 are reversed the telephone will have very little side tone. The instrument may talk fairly well as the transmitter and receiver will be in series. Test for this by reversing the line wires, whereupon the pull of the receiver magnets on the diaphragm will be noticeably weakened. If 2 and 4 are reversed, the effect will be the same.

Mr. M. Blight, in The National Telephone Journal, clearly describes the operation of this coil as follows:

"The incoming speech currents pass from the "+" line through the 15-ohm winding of the induction coil, and then divide, a portion going through the transmitter, and a portion through the receiver, 30-ohm winding of coil and condenser (see Fig. 438.) The currents which thus reach the receiver direct are so small as to be practically negligible, owing to the existence of the much easier non-inductive path offered by the transmitter. The currents that really affect the receiver are induced in the 30-ohm winding of the coil by the passage of the currents in the 15-ohm winding and circulate in the circuit in the direction indicated by the dotted arrows. The slight direct effect, it will be noticed, is in the opposite direction to that of the induced currents.

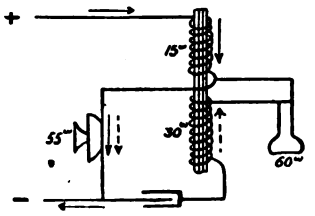


Fig. 438.

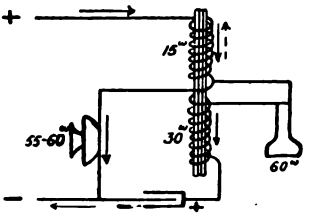


Fig. 439.

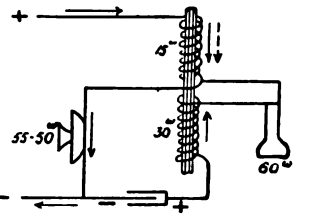


Fig. 440.

Transmitting.—The transmitter acts in two distinctly different ways; first, by varying the resistance of the line circuit, it directly varies the current flowing out through the repeating coil at the exchange, and secondly, by effects induced in the 15-ohm winding of the induction coil, it controls the variation of the line current. To make the operation clear, consider the transmitter diaphragm is moving outwards and its resistance consequently increasing (see Fig. 439). The current flowing in the line in the direction of the arrows is then decreasing. The condenser is normally charged by the potential difference existing at the transmitter terminals. When, with an increase in the transmitter resistance, this potential difference increases, a current flows into the condenser, passing through the 30-ohm winding of the coil in the direction of the arrow. Thus is there induced in the 15-ohm winding an electro-motive force in the direction of the dotted arrow, and this it will be noticed, is opposing the line current and consequently diminishing it. The direct and induced effects of the transmitter thus both assist in the reduction of the line current.

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When the transmitter diaphragm recedes the reverse takes place (see Fig. 440). The line current is strengthened by the induced effect. The falling potential difference across the transmitter terminals causes the condenser to discharge proportionately and a current flows through the 30-ohm winding in the direction of the arrow. This induces an electro-motive force in the 15-ohm winding in the direction of the dotted arrow, which assists the line current and thus further increases it.

Note.—To make the matter clearer, in the above sketches the two windings of the induction coil are shown one behind the other. Actually they are wound in the usual way, one over the other.

This explanation should enable those concerned to deal with any faults that may occur on these instruments. Two faults may be mentioned, one at least of which has a rather unexpected result: a high resistance in the transmitter circuit will have a detrimental effect upon the receiving; and the reversal of one winding of the induction coil in relation to the other will greatly diminish the transmission, but will not sensibly affect the receiving."

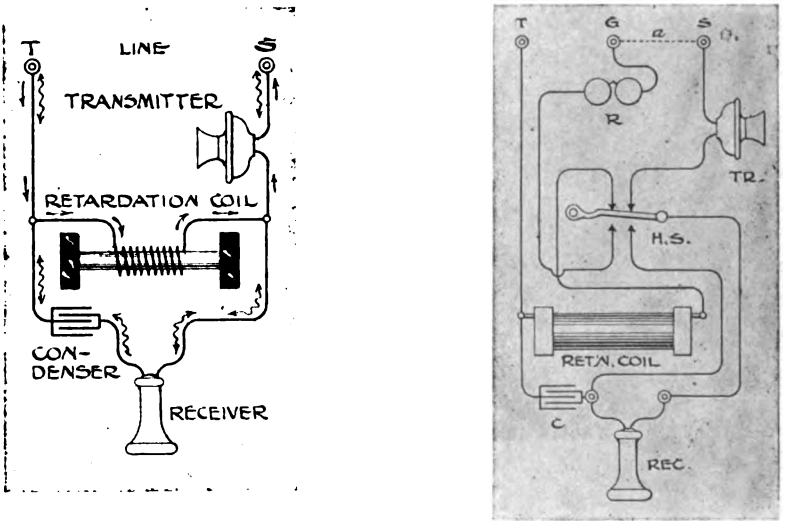


Fig. 441.

Fig. 441 shows a circuit in which a departure has been made from previous forms. Here it will be seen that the condenser is in series with the receiver, the incoming direct currents are therefore barred, as the condenser will not allow the passage of direct current. The transmitter is arranged in series with a retardation coil, the dimensions of which are as follows:

Heads: 1" square, Core ¼" in diameter, 3⅜" long, Winding space 2⅞" wound to to resistance of 25 ohms, with No. 28 single silk covered wire.

Owing to the high impedance of this coil the voice currents will not pass through it and are therefore, forced through the condenser and receiver. It is possible to use a high wound receiver as it is removed from the transmitting circuit, and this circuit has been found very satisfactory.

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It is possible to make a coil same as the above of only a few ohms resistance, with the same impedance. When this is done, the condenser may be omitted from the receiver circuit, the receiver being connected to the terminals of the coil. The only direct current that will pass through receiver would be that due to the drop in voltage existing across the terminals of the coil. This arrangement is seldom used.

The Balanced Bridge Coil, represents another type of circuit. This is shown in Fig. 442, and employes the principle of the balanced Wheatstone bridge to keep the direct current flow from the receiver, while the voice currents which are alternating in effect are forced by a combination of retardation and low resistance, located in the arms of the bridge, through the receiver.

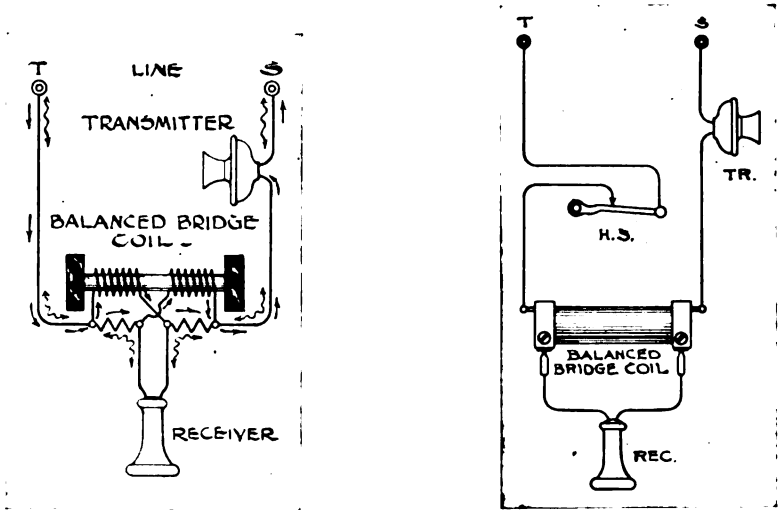


Fig. 442.

Fig. 443 shows a simplified diagram of this circuit in which A and D are retardation coil windings, and B and C non-inductive resistance windings. The bridge is balanced for the direct current flow indicated by the single headed arrows, by making the ohmic resistance of the four arms such that the Wheatstone's bridge equation, A:B::C:D is balanced. There will then be no direct current flow between the points 2 and 3, as their potential is the same, and the receiver, which takes the place of the galvanometer in the regular testing bridge, will be free from direct current action. The bridge, however, is out of balance for voice currents, which cannot penetrate the high retardations A and D, and are thus forced through the receiver and non-inductive resistance A and C in the path indicated by the double headed arrows. In practice all of the coils of this bridge are wound on one spool and internally connected so that as far as external appearances or connections are concerned, it resembles a standard induction coil, as shown. The resistance of the four windings are approximately 20 ohms each for A and B, and 30 ohms each for C and D. The total resistance of the non-inductive windings B and C, which are in series with the receiver, is therefore only 50 ohms, thus offering no ap-

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preciable obstacle to the voice currents, the receiver being practically in the line circuit direct, and in a position to receive the maximum available incoming transmission with no distortion or losses.

While it is not necessary for this bridge coil to be absolutely balanced for the best transmission, it is found convenient to make this adjustment very accurately by the means shown in Fig. 444. After the four coils are wound on the spool and tested separately they are soldered to the terminals 1, 2, 3 and 4; the non-inductive winding C being left purposely slightly of greater resistance than necessary so as to allow for taking up of the inequalities of manufacturing. At this stage the coil is inserted in the circuit of the special testing set illustrated, with a 24 volt battery connected to the terminals 1 and 4 and with a very sensitive galvanometer between terminals 2 and 3. The insulation of the adjacent wires of the non-inductive winding C is then scraped back from the loop end E until a point is reached where the short circuited wires bring the needle of the

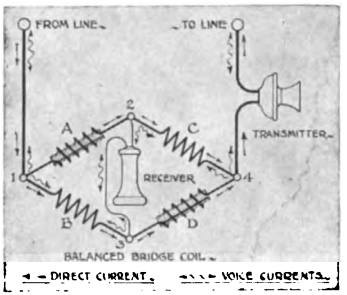


Fig. 443.

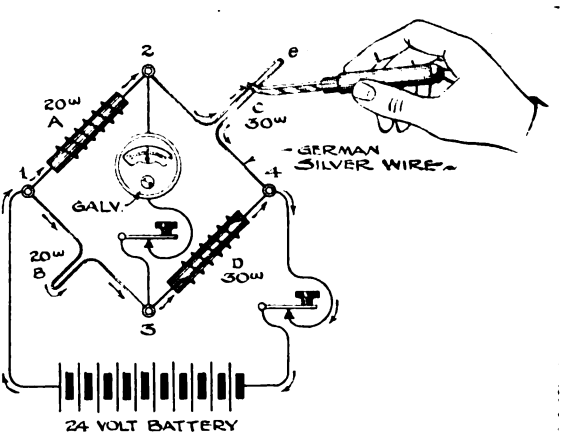


Fig. 444.

galvanometer to zero, thereby indicating that no direct current is flowing through the bridge 2-3. The wires are then soldered at this point and the bridge is thus given a permanent balance. In actual practice the conditions are less severe than in this test, as the galvanometer is replaced by the telephone receiver and the flow of battery current in the external circuit is reduced to less than one-tenth of an ampere by the combined resistance of the switchboard retardation coils, the line and the telephone transmitter.

The transmitter receives its current from the line circuit through the two 50-ohm halves of the bridge as indicated by the single headed arrows, then through the transmitter, the joint resistance of these paths being 25 ohms, so that the transmitter obtains the full amount of current for which it is designed.

Side tone is greatly reduced which is an important advantage in long distance conversation, as the subscriber can hold the receiver tightly to the ear while talking, without the deafening effect usually produced.

One advantage that this circuit would seem to possess is the fact that the use of the condenser in the receiver circuit is obviated. As the con-

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denser offers a resistance to the voice currents in proportion to its electrostatic capacity—about 325 ohms for a 2 M. F. condenser, and 650 ohms for a 1 M. F. condenser.

A circuit based upon the use of a receiver designed so it will not be demagnetized by direct current, although placed directly in the line circuit, consists of this special receiver and a transmitter in series, as previously shown in Fig. 430. The novel features lie in the design of the receiver, which is shown in Fig. 445.

*"It will be noted that in place of the ordinary pair of receiver coils employed, there are four coils on the receiver. The coils *A* and *B* are in series, as are also the coils *C* and *E*, and the two groups are in parallel. The coils *B* and *E* are actuating coils, while the coils *A* and *C* are designed to prevent the demagnetization of the receiver or the buckling of the receiver diaphragm. Coils *B* and *E* are wound in the ordinary manner and act upon the receiver diaphragm in the same manner as in the ordinary receivers. The coils *A* and *C* are wound in opposition to the coils *B* and *E* respectively, and their action is to oppose magnetism set up by the direct current in the coils *B* and *E*.

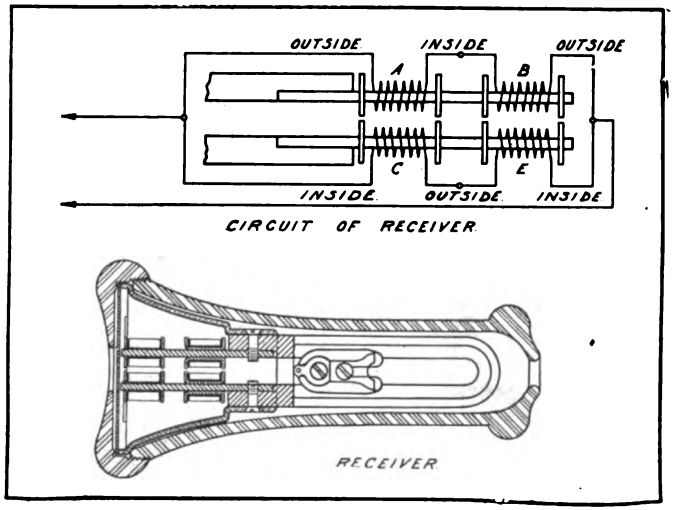


Fig. 445.

The magnetism produced by the transmitter battery flowing through the coil *B* is neutralized by that produced by this same current in coil *A*. The same is true of coils *C* and *E*, and it is evident that as the coils *A* and *B* and *C* and *E* respectively are in series, the effect of this transmitter current will be neutralized, no matter what the length of the line may be. The two groups are placed in parallel merely to reduce the ohmic resistance of the entire receiver, so that the transmitter will get its full current.

It is evident that if the coils *A* and *C* were made in the same manner as coils *B* and *E*, they would oppose not only the magnetism produced in coils *B* and *E* by direct current, but also that produced by the talking currents, and would thus reduce greatly the efficiency of the receiver. To obviate this, the coils *A* and *C* have a copper sheath over the core and copper

* American Telephone Journal.

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heads on the spool. In actual practice the head and sheath are in one piece of copper. The effect of a copper sheath around a core is well known. It kills the action of the coil, due to any alternating currents of high frequency. It also reduces the impedance of these coils to alternating currrent.

It is evident then that with a receiver of this design we have a balanced receiver as far as direct current is concerned, and that in respect to the voice currents we have a receiver in which the action of the primary coils *B* and *E* is the same as an ordinary receiver, and the action of coils *A* and *C* is absolutely killed, not only as regards magnetic action, but also in regard to impedance. We have then in this circuit actuating coils *B* and *E* in series with non-inductive resistance *A* and *C*, and these resistances *A* and *C* are in parallel. As this resistance is low and is non-inductive, there is no effect from this resistance on the talking current."

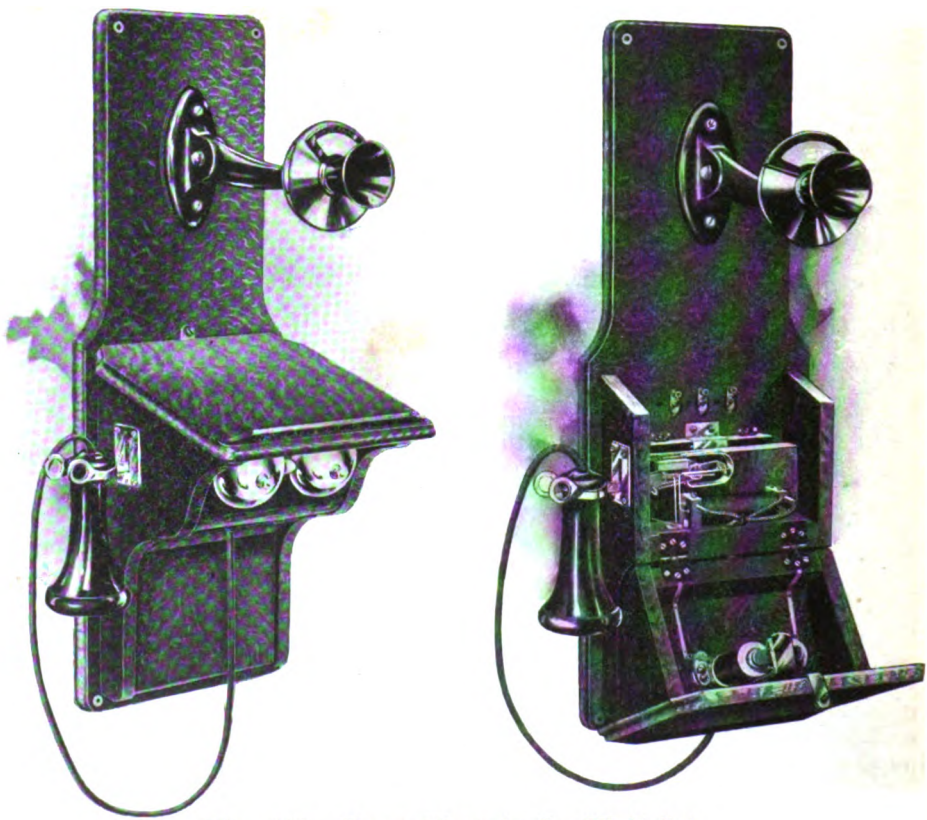


Fig. 446. Dean Electric Co. Wall Set.

Such a circuit depends for its action upon the variation of the total loop resistance by the transmitter, and the maximum variation should be obtained by this method, owing to the low impedance of the receiver, and the absence of the induction coil.

The receiving should be very good as the receiver is in the direct line circuit, without any loss due to condensers or coils.

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The circuits so far described represent those in general use, and any of them can be used with any common battery board. It is advisable however to use an instrument circuit especially adapted to the switchboard it is used with, and usually supplied by the same manufacturer.

Fig. 446 shows a standard wall set. The front of the telephone including the shelf is made in one piece, thereby exposing the various parts of the apparatus. The receiver cord enters the cabinet through a hole so located as to prevent the entangling of the cord in the hook when the receiver is hung up.



Fig. 447.

It will be noted that the line binding posts are located inside of the cabinet so that the line connections can be brought in from behind the back board, thereby concealing all of the wiring when the instrument is installed for use. This is rapidly coming into favor as it not only removes unsightly wires from in front of the instrument, but also places them so that they are protected from the attacks of the curious.

In Fig. 447 is shown a metal box instrument particularly well adapted for hotel or private house installations. The retaining case is made from heavy sheet steel drawn into shape without seams and finished with enamel.

The internal wiring is done with a special insulated wire formed into a cable. The outer insulation of this wire has distinguishing colors. Fig. 448 shows a view of this instrument open with the parts exposed.

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It is almost a standard practice to use a standard 1,000 ohm Bell and 2 M. F. condenser for the ringing equipment of common battery instruments. The majority of common battery sets irrespective of their talking circuits are so equipped, excepting party line instruments.

Telephones of the desk set type are used to a great extent in common battery work. The circuits of a standard set may be seen by referring to Fig. 449. In this set it becomes necessary to use a separate containing case for the bells and condenser. When the coil is located in base of stand, the circuit shown in Fig. 450 is used.

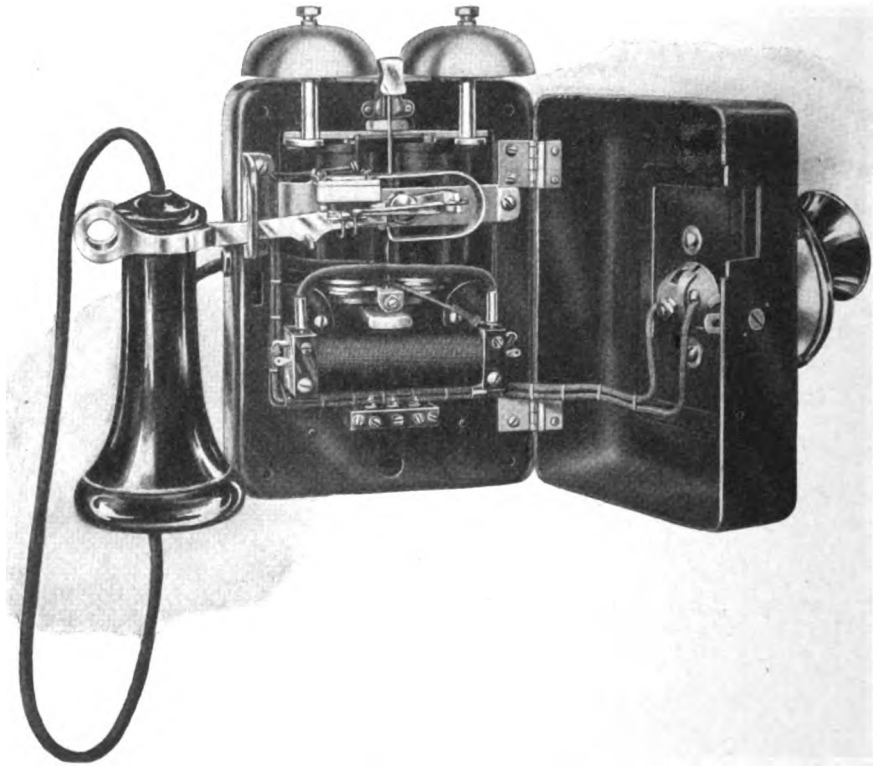


Fig. 448.

All modern common battery telephones can be furnished to work in connection with the various selective ringing systems now on the market. Another excellent feature obtainable with common battery instruments is the ability to equip each phone with a lock-out relay, by means of which it is possible to give private service on a line of several telephones. Heretofore lock-out instruments have been regarded with suspicion by the telephone public, as the words "lock-out" usually suggest a complication of springs and wheels with their attendant central office equipment which requires additional work on the part of the operator, or which costs a great deal to maintain.

The advantages of using a lock-out system are many. Among the first to be considered is the fact that this is a ready means of increasing the revenue of an exchange without any outlay for expensive line con-

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struction, as for instance, four telephones equipped with selective ringing and lock-out devices can be placed on the same line, and each one of these telephones can be rung without ringing the other parties. When any receiver is removed from the hook, the other three parties are cut off the line, and the party talking has control of same until finished. In this way it is possible to increase the number of telephones and consequently the revenue, without increasing the number of lines, and without materially increasing the cost of equipment or maintenance charges.

One device on the market for accomplishing this result consists of a relay of peculiar construction which is attached to each telephone on the line, the contacts of the relay keeping the associated transmitter and receiver circuits normally open. These talking parts are accordingly inoperative until the relay is pulled up by current from the central office.

It can readily be seen that if some means were provided to make it impossible for one relay to operate while another on that line was pulled up, the fact of one station being in on the line would lockout the balance. To provide for this advantage is taken of an effect which is present in every central energy line, that of the voltage between the lines being greater when the lines are open than when a low resistance, such as the transmitter at some station is put across. The relay has two windings, one

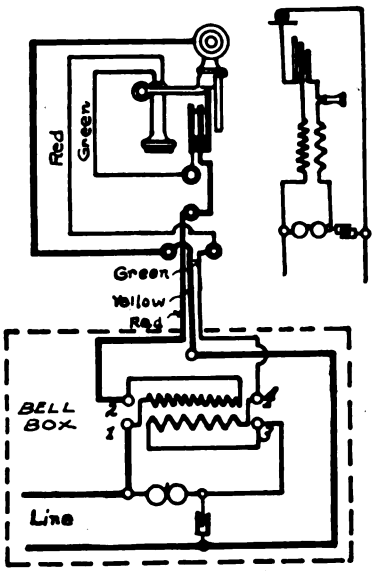


Fig. 449.

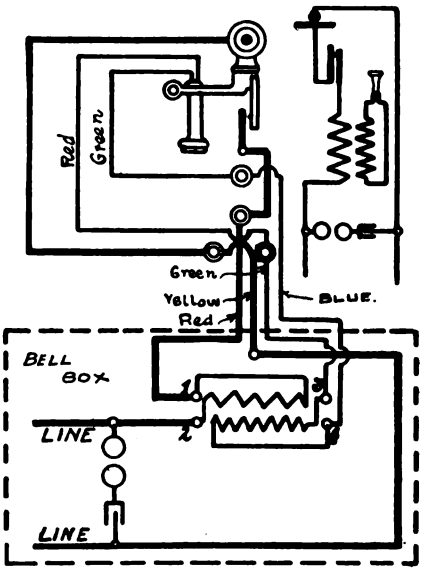


Fig. 450.

of about 1,000 ohms and another of about 20 ohms. When one lifts his receiver from the hook switch, battery flows through the 1,000 ohm winding across the line. If no other station is across, there is voltage enough to pull the relay up. As soon as this is done the relay contacts close the receiver and transmitter circuit and also the 20 ohm winding, thus putting a low resistance path across the pair. Since most of the resistance of the line is then in the impedance at the central office, the voltage across the pair falls too low to pull up any other relay on the line, consequently, the relay at any other station would not get enough current to operate, since when the relay is normal the transmitter and receiver circuits are open and a subscriber attempting to get in on the line is locked out.

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The circuit of the relay as applied to a telephone is shown in Fig. 451. Inspection will show that a circuit through the high coil is closed by the switch hook. The transmitter and receiver are inoperative, their circuits being open at the relay contacts. If there is no one else on the line the relay pulls up on operating the switch hook, thus closing the receiver contact and giving battery to the transmitter through the holding coil of 20 ohms. This holding coil has two functions: First, to hold the armature securely after it has once been pulled up, since the low path of the 20 ohm coil and transmitter will drain practically all the current from the 1,000 ohm winding. Second, to act as a retardation coil for the voice currents. The condenser and receiver are in a shunt circuit around this 20 ohm coil, consequently, the self induction of this coil will force the voice currents to go through this condenser path, thus the telephone equipped with the lock-out does not require any induction coil.

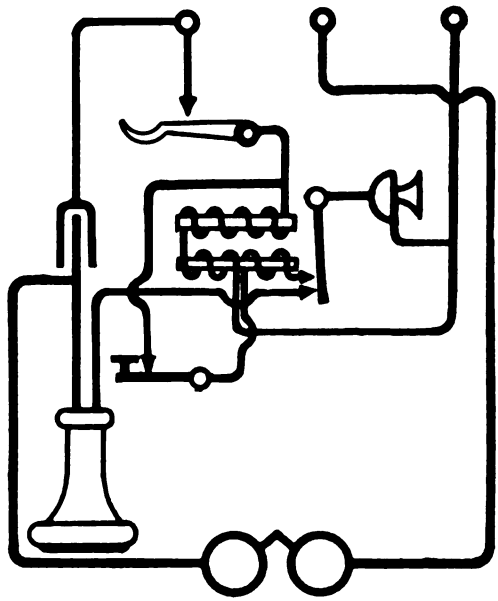


Fig. 451.

From the foregoing description it will be seen that the action of this lock-out is automatic. No additional operation is required by either the operator or the subscriber. The action of closing the hook switch throws the relay into circuit and as soon as it pulls up, throwing the low path across the line, no other relay will operate because all the available current is drained from the line.

In practice the relay is made as shown in Fig. 452 and is mounted on the telephone as in Fig. 453.

The adjustments of the relay are few, since from the foregoing description it will be seen that proper adjustment consists in getting the relay to pull up at one voltage and not to pull up at a lower voltage. The relay is provided with an adjustable banking arm which controls the distance of the armature from the pole pieces. By bending this brass banking arm the distance of the armature from the pole pieces and the voltage at which the relay will pull up may be easily and effectively controlled.

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The adjustments, if any be needed, are made as follows: First, after connecting telephone to line, lift the receiver and see that relay pulls up, if not, it may be made to do so by adjusting the brass banking arm attached to the armature, so that the relay armature is brought nearer the pole pieces. Second, have another party get in on the line, and work hook switch at station being adjusted. The relay should not pull up when the second station is across the line. If the relay does pull up under this condition, it may be adjusted by bending the brass banking arm to throw the armature farther from the pole pieces.

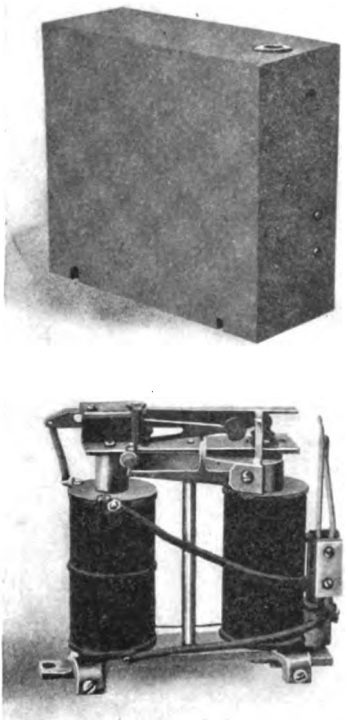


Fig. 452.

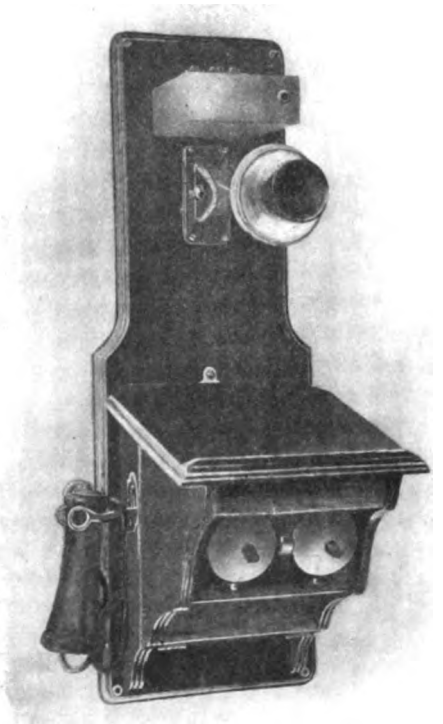


Fig. 453.

It is only in rare cases that any adjustment is necessary. Under normal conditions of party line work where all the stations are close together, the relays will work as they are sent adjusted from the factory.

Where there is a larger line resistance between the first and last station on the line, the line voltage at the near station may not be lowered enough when the far station is across the line to prevent the near station from getting in. In this case, the relay at the near station will have to

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be adjusted by throwing the armature further from the pole pieces, so it will not pull up when the far station is across the line.

The button shown in Fig. 451 is for the purpose of handling a reverting call. Central tells the originating party to hold his button until the second party answers. This button is in the low circuit and when that is open a second party can get in on the line.

The relay at the originating station is held up by current through the 1,000 ohm winding, consequently, this station can hear the second one answer. The originating party then releases the button, thus giving battery to his own transmitter and the two are in on the line.

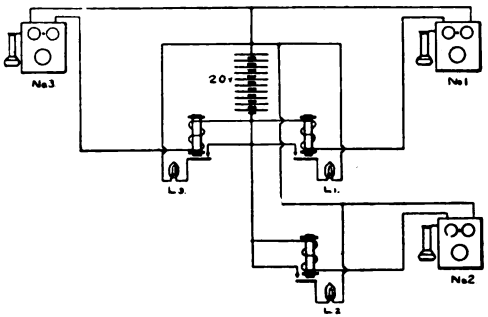


Fig. 454.

While the general method of calling the central office from the telephones has been referred to no detailed description of the means employed has been given. While visual signals may be employed, their use is now almost entirely confined to private branch exchange work, a private branch exchange being a small switchboard located in a building or otherwise, with the telephones in the immediate vicinity connected thereto, this board being connected with the main exchange by means of trunk wires.

Small incandescent lamps are universally used in the larger boards and a relay becomes necessary to operate the lamp as it cannot be placed in series with the line, and as it is desired to economize in space as much as possible. The relays are therefore mounted in a frame separate from the switchboard, usually in another room, and are connected to the lamps as shown in Fig. 454.

The following description by J. C. Kelsey, of the standard circuit in general use by the Bell Companies, is taken from the American Telephone Journal. It describes in detail this circuit, which is in extended use. The circuits of the telephones are not shown in all the figures as these can be any of the forms previously described.

"Lamp signals are used as shown in Fig. 455, and by making them depend upon the relays, R^1 R^2 and R^3, the closing of the contacts of which completes circuit through the battery and a lamp of proper pressure for the battery, which may be assumed to be twenty-two volts, (11 storage cells) the act of taking the telephone off the hook will light the respective lamp, as station No. 1 lights lamp L^1. To insure that the operator shall observe the signal an additional circuit is shown in Fig. 455, which should be particularly observed, as it is the basis of the common night bell signal. Through NBR, the night bell relay, all current passes to the lamps. If any lamp is lighted, it takes enough current to magnetize this

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relay, so when any lamp lights, the night bell relay is pulled up, and sounds a vibrating bell from a separate battery, which calls the operator's attention."

"Fig. 456 shows one line, with the relay, R^1, and night bell relay, NBR. The party taking the telephone off the hook, energizes R^1, causes NBR to close its contacts through VB, the vibrating bell. But means must be provided for the operator to talk to the parties calling. Therefore the jack, J, is connected to the line, tip T, to the positive side, ring R to the negative side, and the sleeve S, open, between the relay, and the telephone."

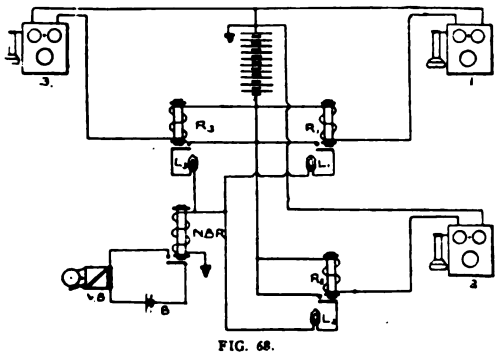


FIG. 68.

Fig. 455.

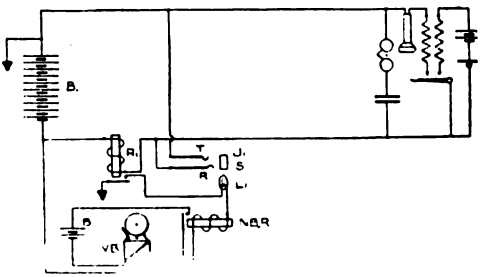


Fig. 456.

"We may also assume that the positive terminal of the battery is earthed, so that in our drawings, any connection shown as earthed, as L^1, really means that it is connected to the positive terminal. Convenience in drawing also demands that several batteries be shown, but all of which are the same battery, if the grounded connection is shown."

"If instead of three stations, we consider from now on, one of not less than one thousand, the multiple board will be composed of five sections, and each operator will have the entire thousand lines, terminating in jacks, within her reach, which may be represented as in Fig. 457 where J^1, J^2, J^3, J^4, and J^5 are the multiple jacks, and J^6 the answering jack, directly above the lamp L^1. The sleeves are connected in multiple for reasons soon to be explained."

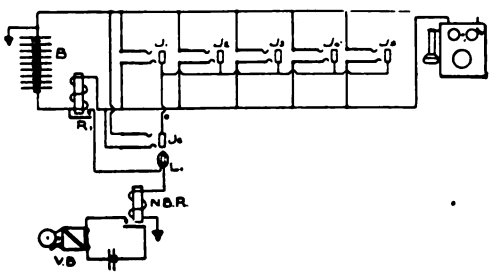


Fig. 457.

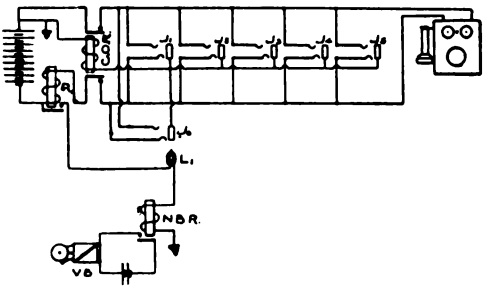


Fig. 458.

"In the local battery service, on multiple boards, to keep the drop from falling, when a multiple operator rings on the line, the jacks are

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made, so that the entrance of the plug cuts off the signal apparatus, and leaves the operator in direct connection with the subscriber. If in common battery service, when the multiple operator called a party, and he answered, the lamp would light up in front of the answering operator, and she would plug in, only to find that some one else was using the line, making much confusion. It becomes imperative that the entrance of the plug shall cut off the line battery and relay, and reintroduce battery to the subscriber through the cord circuit. This must be done electrically by the presence of battery on the sleeve which shall flow through a cut-off relay, from the sleeve of the jack. This act opens the line between the relay and the first jack, as shown in Fig. 458, COR being the cut-off relay, actuated by the entrance of any plug."

"As battery exists on the sleeve of the plug, assume a lamp in series, between the battery and the sleeve, which lights when the plug is inserted in the jack, according to Fig. 459, at the same time the cut-off relay is opened. But opening the cut-off relay deprives the subscriber of battery, and he cannot talk, so the act of plugging in must reintroduce battery, and this is the origin of the vicious clicking in the ear just before central speaks. It is caused by the cutting off process, for the induction coil of the telephone is charged. The sudden opening of the line allows it to discharge and expend itself in the receiver."

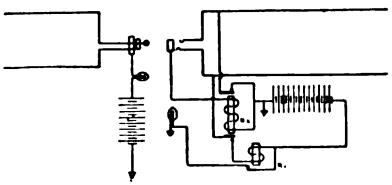


Fig. 459.

"If all the cord circuits were furnished with battery as shown in Fig. 460, the system would be in a sorry plight from cross-talk, so impedances are inserted between the battery and the sides of the cord circuit, according to Fig. 460a, which shows an ordinary repeating coil, with the middle terminals attached to the battery. Each winding of the coil is about 20 ohms, with enough iron in the core to prevent any stray impulses from other cord circuits."

"Still the circuit is deficient, for at present nothing affects the cord lamp, whether the subscriber's telephone is off the hook or not. How shall this lamp be made to signal the position of the receiver? The answer is, put in another relay, placed in the cord circuit according to Fig. 461, between the ring of the plug and the battery in such a manner that it shall control the lamp circuit."

"But we all know that it is undesirable to have a relay directly in the talking circuit. How can we obviate this objection? By providing a path for the voice currents around the relay that is now inductive.

"Fig. 462 shows the windings of the non-inductive relay. In this case, the copper winding or the inductive winding is wound close to the core, and the german silver winding of few turns on the outside. The non-inductive winding has nine times the resistance of the inductive winding, and consequently takes but a small fraction of the exciting current, and only weakens the relay but slightly.

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"If a lamp is paralleled by a shunt of one-third its own hot resistance, it is unable to receive sufficient current to heat the filament to more than a dull red. This is taken advantage of in extinguishing the cord lamp. Fig. 463 shows the non-inductive relay contacts in the act of closing a resistance 1/3 R, about the lamp R, which will cause the filament to burn a dull red. In addition, an opalescent shade is placed over the lamp, which, when the filament is reduced to a dull red, gives the effect of total extinguishment, and which, when lighted, mellows the light rays so that they are not offensive to the eye.

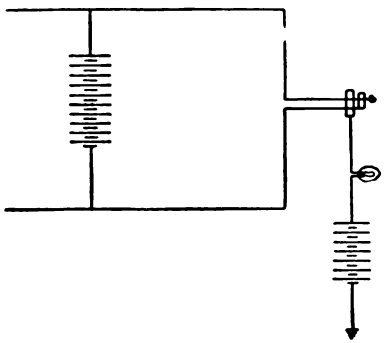


Fig. 460.

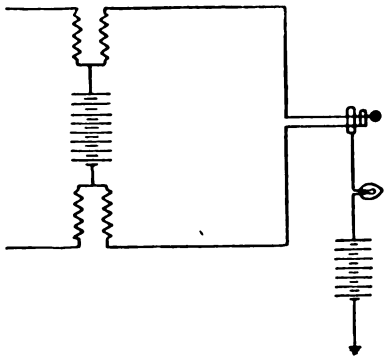


Fig. 460a.

"Fig. 464 shows the application of the shunt, 1/3 R, to the answering cord circuit. The act of plugging in cuts off battery, restores it again, and if the receiver is off the hook the relay R^2 is energized, and closes its contacts, putting 1/3 R in shunt with cord lamp, CL, and putting CL out. When the subscriber hangs up the receiver, battery can no longer flow through R^2 because the circuit is open. It therefore releases its contacts, which open circuit of 1/3 R, and allows lamp, CL, to burn at its full brightnesss. The operator knows that the subscriber has hung up the receiver, and pulls down the connection.

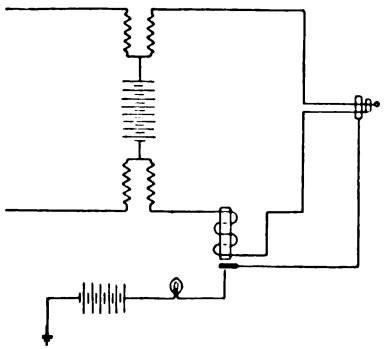


Fig. 461.

"So far we have considered only the answering part of the cord. The calling cord possesses the same characteristics of the answering cord as regards the position of the relay, and the action of the calling lamp. The general characteristics of the complete cord are shown in Fig. 465. The

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calling cord is provided with keys, both for ringing, talking and listening to the subscriber. Fig. 465 shows the four sections of the repeating coil, R^1 P^1 and R^2 P^2 belonging to the answering cord, and R^3 P^3 and R^4 P^4 the sections belonging to the calling cord. They are all wound on the same core, and serve the same purpose as they did in local battery service, that of connecting grounded and metallic lines without unbalance. When both parties have their receivers off the hooks, both lamps, ACL and CCL, are out, because relays R^2 and R^3 are energized by the current passing out to the subscribers' stations through them. When both parties hang up, R^2 and R^3 release contacts, because no current flows.

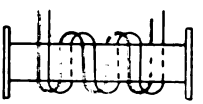


Fig. 462.

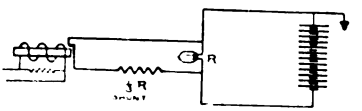


Fig. 463.

"The repeating coil shown in Fig. 465 consists of four sections of wire, each one having two terminals brought out. All four coils are wound on the same core. When used with common battery, the coil should be connected up as shown in Fig. 465. If used with local battery the outer terminals of R^1 P^1 and R^2 P^2 are connected to one-half of the line and the inner terminals connected together. Similarly the outer terminals of R^3 P^3 and R^4 P^4 are connected to the other half of the line, and the inner terminals connected together.

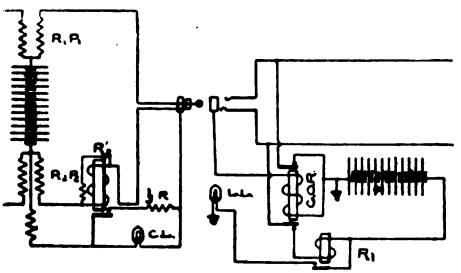


Fig. 464.

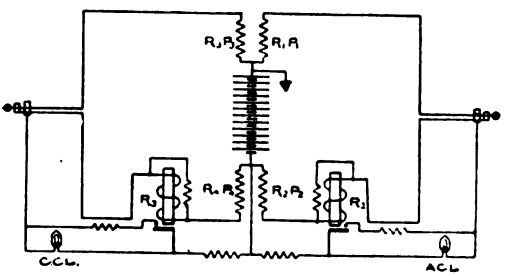


Fig. 465.

"In this manner battery is supplied to all cord circuits of this kind, and the impedance of each of the windings guards against the invasion of cross-talk, while the repeating coil, as a whole, removes the possibility of unbalance. Each half of the coil repeats into the other half, just as if the battery was not present. It seems strange that a wave can pass through the battery solution and not interfere with the induced wave it has created, but the battery has such an infinitely small resistance that it acts like a short circuit path, where everything can pass.

"The development, so far, shows one cord circuit ending in two plugs, the answering and the calling exactly alike. But the calling end is equipped with a double key, which permits of ringing with one pair of contacts and listening with the other. According to Fig. 466 the ringing key is so arranged as to cut off the circuit behind, so that ringing back in the wait-

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ing subscriber's ear is avoided. Another reason is that the half of the repeating coil and battery would short circuit the generator current for single line ringing, and the ground at the battery would prevent party line ringing. The listening set is connected in bridge, so that the operator may talk to either answering or calling parties.

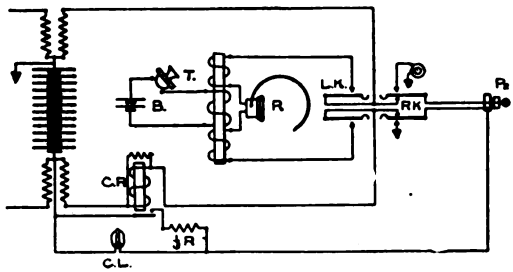


Fig. 466.

"Fig. 466 shows a local battery operating set, which can be bridged on any pair of cords in the operator's position. The system is usually so large that there are many branch exchanges, that necessitate as many order wire connections, usually accomplished by a row of buttons, generally in strips of ten, at the right hand side of the switchboard. Depressing any one of the keys, puts the telephone set in direct connection with the "B" operator, at the receiving end of the order wire, belonging to that key.

"This is shown in Fig. 467 in which O^1 K^1, O^2 K^2, etc., are the order keys, placed in the operating set in connection with "B_1", "B_2", etc.

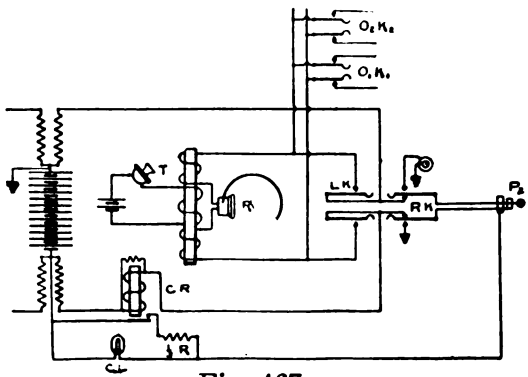


Fig. 467.

"At night, the various "B" operators are not at their positions, from lack of business, and it is customary for an "A" operator. who wants a trunk call, to depress the order key of the exchange desired, and ring on the order wire. This operates a bridge drop at "B" end of the order wire, and lights a lamp, which will cause the night bell to ring. This calls the night operator to the receiver, who takes the order. The key used for trunk ringing is shown in Fig. 468, as RDK, for the ring down key is so arranged that any of the "A" operators may ring on any of the order wire keys without ringing back.

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"Looking at Fig. 466 it is seen that if the calling cord is plugged up, it lights the calling lamp, and the operator, throwing her listening set across the cord circuit, will put out the lamp as if the called party had answered, because the receiver and the secondary of the induction coil act like a subscriber's instrument. This would cause a confusion of signals, which is remedied by the addition of a condenser, placed at K in Fig. 468. The condenser also saves the operator's ear from a click every time she throws in her listening key, because it prevents the sudden pull of a 24 volt battery on the receiver diaphragm, and does not in the least interfere with transmission.

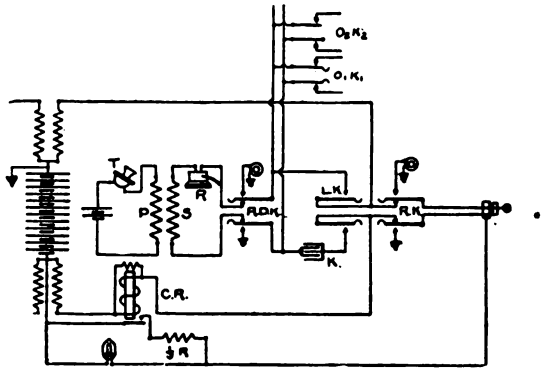


Fig. 468.

Fig. 469 is a local battery operator's set, with T as the transmitter, B, the four-volt local battery, P, S and R, the primary, secondary, and receiver respectively. Suppose that it is desired to have all the transmitters on the common battery, ranging from twenty to forty volts. Then according to Fig. 470, the transmitter is placed in the primary circuit.

"But if one puts the receiver to his ear he will find something wrong, for there is a frying noise, and the transmitter will become very hot. This is due to the ability of the more powerful storage battery to force excessive current through the transmitter, and additional resistance must be added, sufficient to prevent the transmitter from heating or frying.

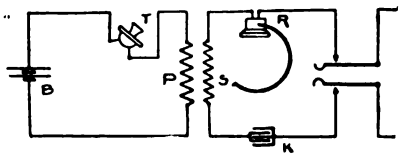


Fig. 469.

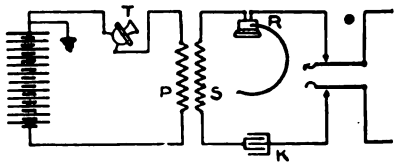


Fig. 470.

"When several talking circuits are connected to the same bus bars, there is a likelihood of cross talk. If every talking circuit was connected directly to a large storage battery, the cross-talk might be avoided, though there is still a probability of its presence. It is not practical to connect directly to the battery, for there must be suitable switchboards with apparatus provided for proper distribution. Therefore, to prevent cross-talk in the primary circuit, the resistance must be changed to inductive resistance, called retardation. This retardation guards against the

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entrance of stray electrical impulses, because all electrical impulses have an aversion to passing through coils with iron cores. It is in this manner that the repeating coil windings, around an iron core, guard the cord circuit against the intrusion of impulses. This is shown in Fig. 471, in which RET is the retardation coil.

"But a serious objection arises. We have deliberately inserted a coil with an iron core directly in the transmitter circuit. This will cut down voice currents, so that the transmitter is virtually useless. One can hardly hear hard tapping of the transmitter. Something must be done to overcome the retardation effect of this coil, so that the impulses generated by the transmitter will not be destroyed. This is accomplished by the ever useful condenser. It is connected in the primary circuit, so as to divide it equally, the transmitter and primary in one half, and the retardation and battery in the other half, as hown in Fig. 472.

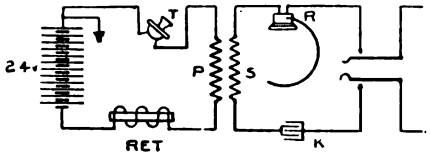


Fig. 471.

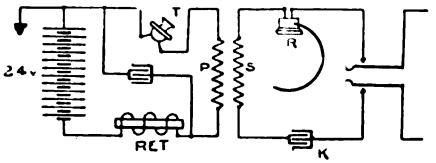


Fig. 472.

"The answering cord is connected to the repeating coil on the tip, or positive side, and to the repeating coil on the ring or negative side through the relay AR. Looking at Fig. 473 we find the sleeve of the plug connected to the negative battery through a lamp, AL. As there is twenty-four volts battery in this particular system, it seems fitting to wind the cut-off relay, of equal resistance to the lamp, so that it will divide the voltage of the battery. Supposing one-tenth of an ampere is necessary to heat the filament of a 12-volt lamp, then the hot lamp resistance is about 120 ohms.

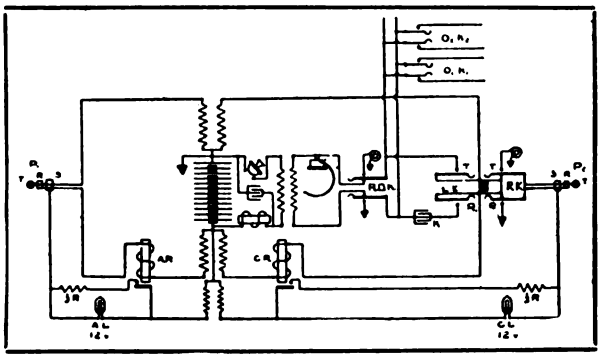


Fig. 473.

This would make the resistance of the cut-off relay also 120 ohms, which we will assume to be correct. If the lamp has a hot resistance of 120 ohms, then one-third R will be 40 ohms. When the operator inserts the answering plug into the jack of a calling line, the lamp, AL, does not light, because AR has become magnetized, owing to the fact that it is in the line of battery supply to the subscriber. AR being energized, pulls up

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its contacts, bringing the shunt resistance 1-3 R, around AL, and robbing it of nearly all its current, which provides a supervising signal.

"It is in the calling cord that most of the apparatus is used. It can not be said that the primary circuit of the transmitter belongs to the calling equipment, yet the secondary part of it does, for the operator has the power of putting her talking set on every pair of cords. Looking at Fig. 473 we find that the only similarity to the answering side is the sleeve connection. The sleeve is connected to battery through a 12-volt lamp, CL, which is lighted upon plugging into a jack of a line wanted, the cut-off relay sharing the average twenty-four volts with the lamp, CL. As in the answering cord, when the receiver is off the hook, relay CR is energized, being in the path of current to the called subscriber. This causes the relay contacts to close, bringing 1-3 R around the lamp, CL, and extinguishing it, providing a supervisory signal.

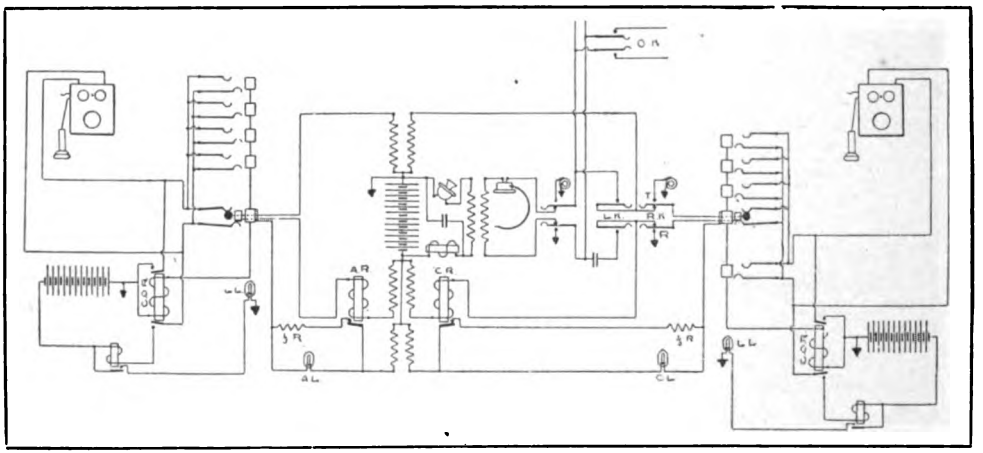


Fig. 474.

"The tip of the calling plug does not connect directly to the positive terminal of the repeating coil. It passes through the contacts of the ringing key RK. Also the ring of the plug has to pass through the contacts of key, KR, thence back to the repeating coil terminal through the relay, CR. Were it not for such a connection, when the operator rings a party, she would ring back in the waiting party's ear. So when she rings, the hard rubber cylinder shaped piece, directly under the cam handle, wedges the two springs, T^1 and R^2, and raises them simultaneously against the generator contacts, which allows the ringing current to flow through the subscriber's bell. When she releases the cam handle of the ringing key, the wedge forces the key to normal.

"The operation of the talking key, LK, is different. It does not open any circuit. It only bridges the listening set across the line, so that the operator may talk to either party. The reverse action of the cam handle forces the wedge underneath against springs, T and T, raising them into contact with the secondary terminals. But in this case, the wedge has proceeded so far as to prevent its recovery, except manually. This is necessary, because the operator may have to write as well as talk.

"The strip of order keys, O^1 K^1, O^2 K^2, etc., are connected by a strap directly to the ring down key, RDK. The condenser is placed be-

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tween springs R of ring down key, and contact is made when the listening key is used.

"Fig. 474 shows a complete connection between two common battery subscribers. Both telephones are off the hook, both cord relays are energized and therefore both lamps are out. Both cut-off relays are open, and consequently, the line lamps are both out. If one party hangs up the receiver his supervisory lamp lights. The party whose lamp is still out is not ready to clear out. If another party is desired, the subscriber is supposed to raise and lower the receiver hook, which flashes the lamp and attracts the operator's attention.

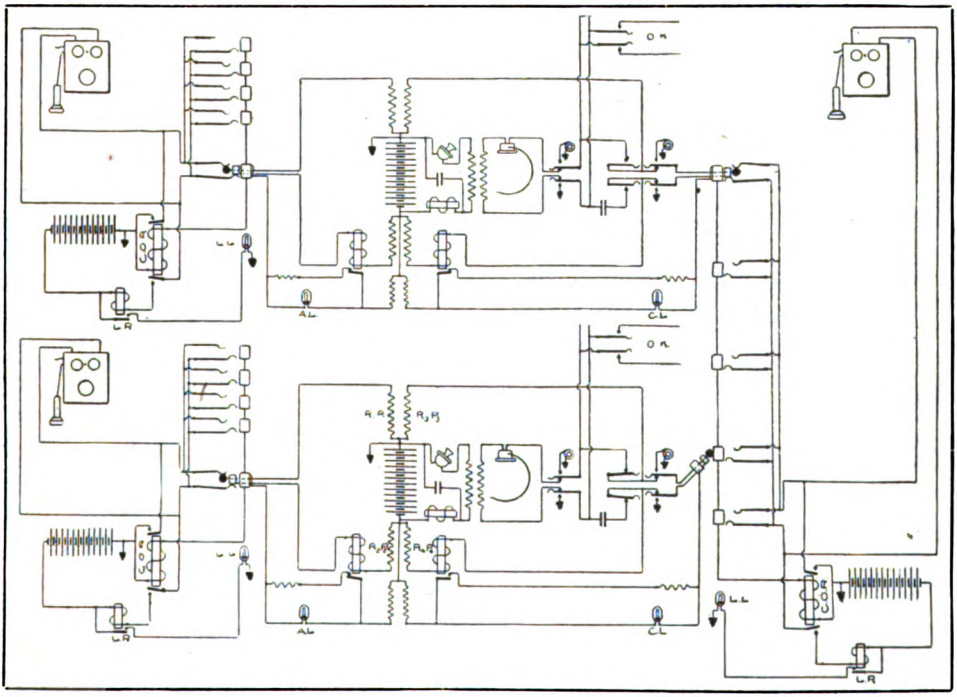


Fig. 475.

"Fig. 475 shows a complete connection between two parties, and another operator is in the act of testing. The original sleeves of the jacks of the now busy line had a potential of that of the earth. If the operator had tested before the preceding operator had taken possession of the line, the touch of the tip of the calling plug to the sleeve of the jack would have had no result.

"If the second operator touches the tip of her plug to the sleeve of jack which is busy, the battery existing on the sleeves will find a path through the tip of the plug, and back to ground through one quarter of the repeating coil.

"Touching the tip to the sleeve, the battery of the upper cord circuit flows through the lamp to sleeve, thence through the contact of the key, to the quarter of the repeating coil, R^3 P^3, through to the positive side of the battery.

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"The operator's key being closed, the wave induced by this energy passes through the only path it can find, the bridged telephone set. If the subscriber is waiting at the answering cord end he will hear the test, because his half of the coil also induces a rush of current which finds a path through his telephone set.

"Fig. 476 shows the outline of a busy test, just as the tip is withdrawn from the sleeve. The plug is shown without the ring and sleeve, as these are not used in receiving a test. It shows the listening key closed, putting the receiver across the line.

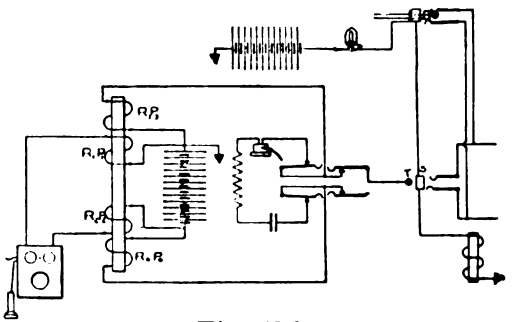


Fig. 476.

"Fig. 477 shows the outline of a talking circuit between two parties of a common battery repeating coil system, with the old local battery telephones still in use. AR and CR are the cord relays, and the RP's the quarters of the repeating coil. While the batteries are shown in the telephones their presence is in no sense necessary to the operation of the system, and they are in fact never used."

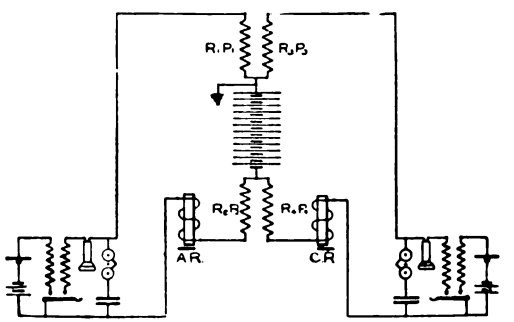


Fig. 477.

The foregoing description of a common battery system if carefully studied, will lead to a good understanding of the various parts, their purpose and operation. The circuit as described is in extensive use, but is not the circuit now employed by the Bell Companies. This late circuit is somewhat different in arrangement and a description of same will be found elsewhere.

Typical of modern practice is the switchboard installed at St. Louis, Mo., by Stromberg-Carlson Telephone Mfg. Co. This is probably the largest single switchboard in the world.

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The line and cord circuits are shown in Fig. 478. The line circuit is of the three wire bridging multiple type, employing a cut-off relay for removing the line relay from the circuit during a conversation.

As shown in Figure 478, the outside line cables terminate on one side of the Main Distributing Frame, and jumper across to the protective apparatus located on the opposite side of the frame. From the arrester equipment the circuit is continued to the side of the Intermediate Distributing Frame nearer the Main Frame. This side of the Intermediate is termed the multiple side, the cables leading to the multiple jacks being soldered on the same clips with those from the Main Frame. On the second side of the Intermediate Frame two sets of cables also terminate, one running to the answering jacks in the regular subscribers' positions of the switchboard and the other to the relay rack. The two sides of the Intermediate Distributing Frame are connected by means of triplex jumper wires.

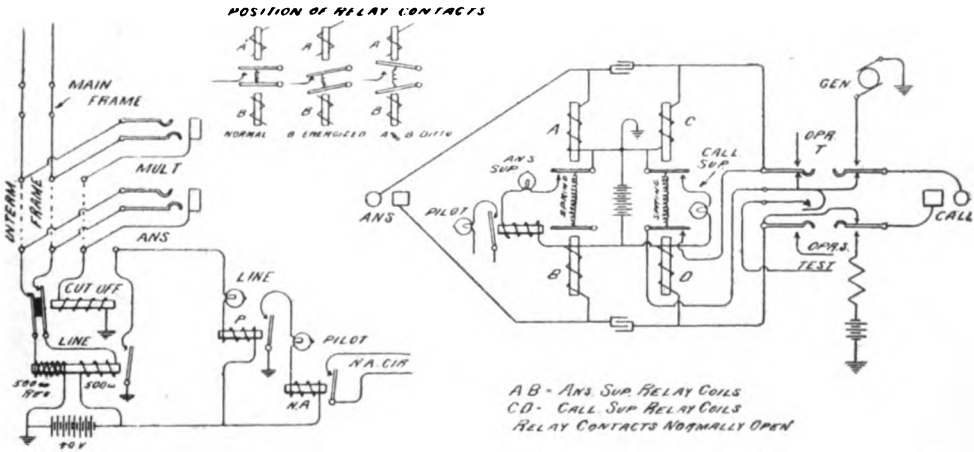


Fig. 478.

S. C. Co. Line and Cord Circuit.

Now in considering the action of the circuit it will be borne in mind that at the subscribers' instrument a condenser, in series with a ringer, is connected across the line. Under normal conditions the path of the battery current through the instrument is interrupted by the presence of the condenser, but by raising the receiver from the hook, a complete circuit is established through the transmitter and induction coil. Tracing the circuit back to the central office it may be followed through the two distributing frames, through the "break" contacts of the cut-off relay, thence through the two windings of the line relay and to battery. Being energized by this current, the line relay closes its one make contact, completing a local circuit from the positive side of the battery, through the line lamp, the low resistance line pilot relay, and to the negative side of the battery. The illumination of any line lamp thus causes the line pilot relay in the same position to close a set of make contacts, throwing the line pilot lamp, which is located behind a large white opal beneath the answering jacks, directly across the battery. A second make contact is provided on the line pilot relay, that auxiliary pilot lamps may be lighted on the monitor's desk as an aid in supervising the work of the operators, and in

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some cases for lighting minor line pilot lamps on adjacent positions, that each operator may more readily notice unanswered calls on the positions to her right or left and lend assistance to her neighboring operators. The circuit of each major line pilot lamp throughout the board is completed to the negative side of the battery through the winding of a low resistance relay located in the first position. In case the switch in this position is closed, the make contact of the latter relay completes a battery circuit through a vibrating bell as a night signal.

The operator, when she sees a line lamp flash, raises one of the answering cords—the cords nearer the face of the board—and inserts the plug in the jack immediately below the glowing signal. At once a circuit is established from sleeve battery through the lower coil of the relay marked answering supervisory, out on the sleeve side of the plug to the thimble of the answering jack, and thence through the winding of the cut off relay and back to battery. Energized by this current the contacts of the cut off relay are opened, thereby removing the line relay from the circuit. As the line relay's circuit is no longer complete, its armature drops back and the line-lamp is extinguished. From the sleeve side of the answering plug a second circuit may be traced through the sleeve spring of the answering jack, out on the line and back to tip spring of the jack to tip side of plug and through the upper coil of the previously mentioned supervisory relay. The relays used in this cord circuit are of a peculiar construction as shown in Fig. 479.

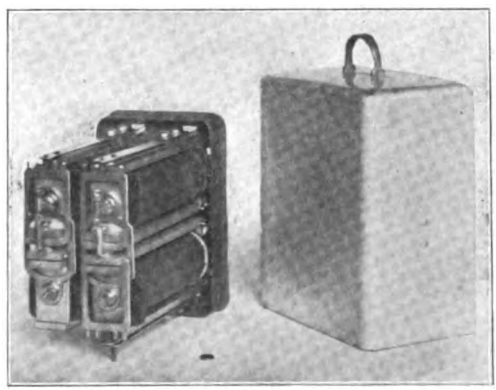


Fig. 479.

Each relay in effect consists of two separate relays, with a mechanical interaction between their respective armatures. The armatures are located between the relay spools, and so constructed that both are normally held at the upper end of their play by a spiral spring. Stirrups from the ends of the armatures hold the relay contacts in the open position. Now when the lower coil is energized the lower armature is attracted downward against the action of the spring, allowing the upper armature to drop with it, and closing the relay contacts. But, when the upper coil receives current, its armature is attracted upward, again opening the upper set of contacts. When closed, the upper contacts on either relay complete circuits from battery to their respective answering and calling supervisory lamps located on the keyboard directly in front of the corres-

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ponding cord pair. Normally, as is the usual practice, both lamps are dark, and after plugging into the answering jack no change occurs as current is flowing through both coils of the answering supervisory relay.

Besides serving the function of supervisory relays the two windings on these relays also act as impedance coils, blocking completely the path of the alternating voice currents in the direction of the battery, and at the same time maintaining the battery feed for talking purposes at a constant value.

Having plugged in, the operator throws the corresponding cord key into the locking or listening position, which bridges the operator's set across the cord and enables her to speak to the calling subscriber. After ascertaining the number desired, she raises the calling plug of the same cord pair and touches the tip of the plug as a busy test, to the thimble of the nearest multiple jack on the required line.

Referring to the line circuit, it will be seen that the thimbles of jacks on unengaged lines are at the potential of positive battery, and as the tip of the calling plug at this time is at the same potential, no sound will be heard and the operator proceeds to plug into the jack. But in case the tested line is in use, current flowing from the sleeve of the plug, over which this second connection has been established, to the cut-off relay of the tested line, materially reduces the potential of every thimble multipled with the engaged jack. At the touch of a plug to such a jack there is a rush of current from the engaged thimble through the tip side of the testing cord, through the make contact of the listening key, and through a special winding on the operator's induction coil, completing the circuit to positive battery. A distinct click is thus produced in the operator's receiver, and she at once informs the calling subscriber that the line is "busy." Owing to a break contact in the listening key the busy click is not heard at the subscriber's instrument.

In plugging into the called subscriber's jack, battery at once flows through the lower coil of the calling supervisory relay and over the sleeve of the calling plug to the cut-off relay, as in the case of the calling line, and the "busy" also put on the multiple.

A non-inductive resistance wound on the line relay is included in one side of the line circuit, which without sacrificing the efficiency of the relay, serves as a protection from short circuits on lines using pulsating grounded party ringing. In this case it becomes necessary to reverse the polarity of the battery on the line relay.

Returning to the cord circuit, it will be seen that a circuit is completed at this stage of the connection through the upper contacts of the calling supervisory relay and calling supervisory lamp, as only the lower relay coil is energized. To throw ringing current on the line, the key is pulled in the non-locking position, the generator circuit being connected to the two outer springs of the ringing key. The two break contacts shown on this key cut the answering portion of the cord circuit off, that current may not pass back over the line and produce a buzz in the calling subscriber's instrument. At first glance it might appear that this act would interrupt the flow of the battery current, which holds up the cut-off relay, but while the circuit established through the lower coil of the supervisory relay is broken, a new circuit is established to negative battery over the "make" contact on the sleeve side of the ringing key, and through the generator circuit as will be described later. Upon the called subscriber's receiver being removed from the hook, a current is established over this line as on

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the calling line, and the upper coil of the calling relay being energized, the calling lamp circuit is broken.

The parties are now in a position to converse, and the action of the talking circuit will next be considered. Let us assume an instant at which the transmitter diaphragm at the calling station is at the extreme outward end of a vibration caused by the voice of the party talking. The transmitter resistance is at this moment at its maximum, and the current flow at the minimum. Obviously, as the current flow is kept constant by the impedance of the supervisory relay windings, the potential at the two condensers in the cord circuit is at a maximum, and the condensers receive a charge. At the next instant the transmitter diaphragm has swung to the opposite extreme, and due to the lowered resistance, the potential at the condensers drops and they impress their charge on the circuit. In this manner the transmitters receive a varying amount of current, while not the least fluctuation is noted in the total battery flow. Owing to the induction coils in the local instruments, the talking currents are alternating in character, and pass through the condensers from one line to another without opposition, though in effect the action would be much the same without induction coils at the local stations, the continual charge and discharge of the condensers being equal, though in reverse directions on opposite sides of the cord circuit. These condensers also serve the important function of separating the cord into two sections for purposes of supervision.

If, after a connection has been completed, the operator wishes to "listen in" the talking circuit between the subscribers would be broken but

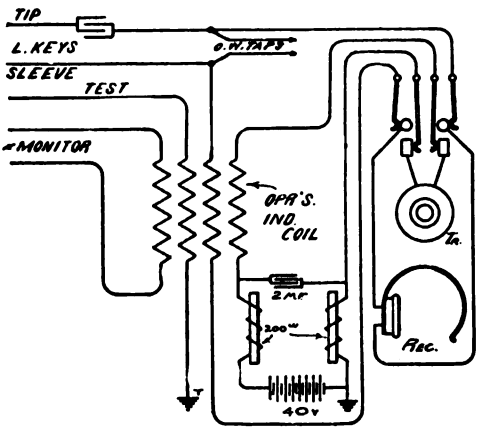


Fig. 480.

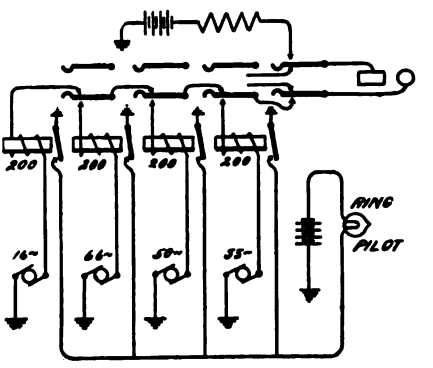


Fig. 481.

for a shunt path, which was established around the listening key through the lower contacts of the calling supervisory relay, when the lower coil of the latter was energized. Upon both parties hanging up, the circuit through the upper coils of the supervisory relays are broken and both supervisory lamps at once appear as a disconnect signal. As the party originating a call is supposed to control a connection, the answering supervisory lamps are connected to negative battery through the low resistance winding of a supervisory pilot relay. The latter causes a lamp to light behind a red opal, near the line pilot lamp at any time an answering supervisory lamp may flash.

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The operator's circuit used in connection with this line and cord circuit is shown in Fig. 480, the two leads marked tip and sleeve running respectively to the outer springs on the tip and sleeve sides of the listening keys.

In this manner the receiver, in series with the secondary of the induction coil, is bridged across a cord circuit whenever a listening key is thrown. A condenser also is inserted in this portion of the operator's circuit, that battery from the cords may not find a path through the operator's set. The induction coil used in this circuit is provided with four separate windings, the primary, secondary, test and tertiary. The practice of providing separate primary and secondary windings enables the operator's transmitter to be isolated from the line, thus securing the maximum percentage of variation in the resistance of the transmitter circuit as in local battery practice. Otherwise the action of the transmitter circuit is quite similar to the talking circuit previously described. The test winding, to which reference has already been made, is of very high resistance in order that an appreciable amount of current may not be drawn from a busy line jack when tested, and serves as a primary winding only when the "busy test" operation is performed. The terminals of the tertiary winding are in most exchanges wired to listening in jacks or keys located on the monitor's desk, this winding being designed only as an aid in observing the work of the various operators.

Fig. 481 illustrates the latest practice adopted in the Stromberg-Carlson Telephone Mfg. Co.'s four-party harmonic ringing systems. The key used in this system consists of the usual combined listening and ringing cam, and three ringing buttons. By pressing the cam in the ringing direction, with all the buttons normal, a circuit is established from the outer spring on the tip side of the ringing key, through the series of contacts on the buttons, and thence through a 200 ohm ringing relay to the 16 cycle generator, completing the circuit to the sleeve side of the ringing key through battery, and a low non-inductive resistance.

It may now be seen how the battery current is supplied over the sleeve side of the calling plug to hold the cut-off relay energized, during intervals while ringing current is impressed upon the line. The non-inductive resistance is inserted in this circuit only as a guard against excessive flow of current due to accidental short circuits which might occur upon the line. In order to ring a party with the 33 cycle frequency, the button adjacent to the ringing cam is depressed, cutting off the remaining keys, and establishing a circuit through a second ringing relay to the 33 cycle alternator; the ringing cam is then thrown in the usual manner to call the party, the button remaining down until either the ringing cam is thrown in the listening position or another button is depressed. Parties rung by the 50 and 66 cycle frequencies are obtained in a similar manner by pressing the second and third buttons, respectively.

The "make" contacts of the four ringing relays are wired in parallel, and by closing any one a circuit is established through the ringing pilot relay, placed behind a green opal beside the line and supervisory pilots.

Thus far connections only have been discussed which might be completed by one operator, in the multiple jacks, appearing on her own switchboard. In systems consisting of more than one central office, provision must be made for trunking the calls between the various offices and a part of the operators in each exchange are designated as the trunking or "B" operators, performing no service other than completing incoming

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calls from neighboring offices. Let us assume as an illustration of trunking practice that a subscriber whose line terminates in an exchange designated as East, wishes to speak with No. 672 on the "West" exchange. The regular operator at the "East" office on whose position the line signal appears answers the call as usual with one of her answering cords and learning that the desired party is on the west office, presses an order wire button which connects her head set to a line terminating in the operator's set on a "B" position at the "West" office, as shown in Fig. 483.

A switching key is included in this circuit at the "B" position in order that the order wire may terminate in a visible signal at times when an operator is not continually at the position. With the switching key in the position shown, a circuit is established from battery through the relay, the "A" operator's head set, as shown in Fig. 480 and one of the "A" operator's order wire buttons, when the latter is depressed, causing the lamp to light in the trunk position behind a large white opal similar to the line pilot. This pilot lamp is not used, however, at times while an operator is constantly at the position.

The "A" operator at East now instructs the "B" operator at "West" that "East" wishes No. 672. The "West B" operator now selects an unused trunk from the "East Exchange," say No. 6, which terminates in a plug on her position and repeats back to the "A" operator at "East," "No. 672 on trunk No. 6." This trunk terminates at the "East" office in a series of jacks multipled throughout the board in much the same manner as the regular subscriber's multiple, and the "A" operator at the latter exchange now proceeds to complete the connection by placing her calling plug in the nearest trunk jack No. 6.

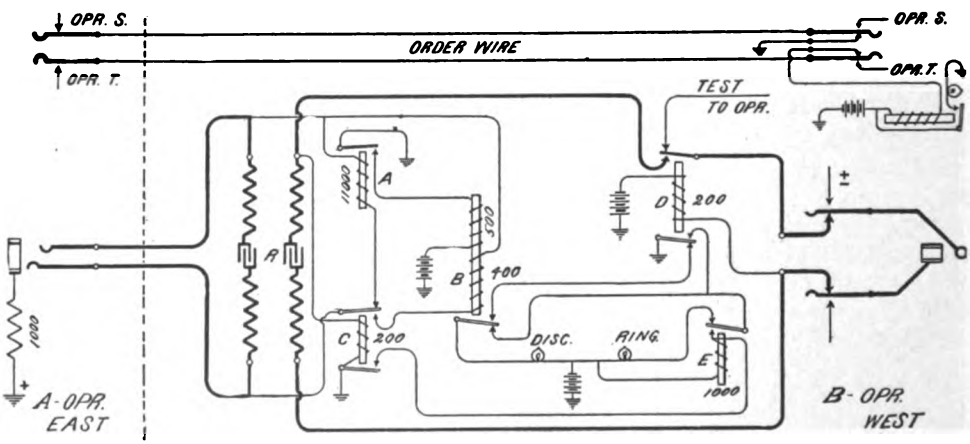


Fig. 483.

Referring to Fig. No. 483, the trunk circuit diagram, it will be seen that in place of the cut off relay, which was used on the line circuit, an impedance coil has been substituted through which current from the lower coil of the calling supervisory relay of the cord circuit is established from the calling plug of this cord circuit over the sleeve side of the trunk to the West Exchange, through the break contact of the relay C, and the winding of the relay A, completing the circuit back to the "East" Exchange on the tip side of the trunk. However, the winding of the relay A is of very high resistance and sufficient current does not find its way back to the "East" Exchange to extinguish the calling supervisory lamp. The arma-

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ture of relay A is pulled up by this current, and its one "make" contact throws one of the windings of the relay B directly across the battery. This latter relay at once causes one contact to break and another to make establishing a circuit from negative battery through the disconnect lamp, the "make" contact of relay B, the "break" contact of relay D and returning to the positive side of battery. Meanwhile the "B" operator at West Exchange has raised the trunk plug and performed the busy test upon the desired line in the usual manner, the circuit being traced from positive battery through the test winding of the operator's induction coil, the upper "break" contact of the relay D, the inner contacts of the ringing key to the tip of the plug. Assuming that no "busy" click is heard, she proceeds to plug into the jack No. 672. A condition quite similar to the regular cord circuit's action is here encountered, current flowing from negative battery through the winding of the relay D, out on the sleeve side of the plug and energizing the cut-off relay of the line. The upper make and break contact of the relay D, removes the test winding of the operator's induction coil from the circuit, and completes the tip side of the trunk circuit through from this direction to the repeating coil R. The lower "break" contact of the relay D opens the circuit that would otherwise have been established through the disconnect lamp, while a new circuit is completed from positive battery through the "make" contact of the relay D and the break contact of the relay E, the ringing lamp and to the negative side of battery. The "B" operator now rings on No. 672, and continues to ring at intervals until the called subscriber answers, which is indicated to her by the ringing lamp associated with this trunk being extinguished. The ringing lamp circuit is broken in the following manner. At the time the receiver is removed from the hook, a complete circuit may be traced from negative battery, through winding of relay D, out over sleeve side of line, returning on tip side of line through winding of relay C to positive battery. Energized by this current the lower make contacts on relay C close, furnishing a path for battery through the winding of relay E. Besides opening the lamp circuit, this relay when once pulled up, will be seen to lock up, irrespective of any succeeding action of the relay C.

Another important function is performed by the relay C, the current from the "East" exchange over the sleeve side of the trunk being switched through the low resistance winding of the relay B instead of relay A, allowing sufficient current to flow to extinguish the calling supervisory lamp at the "East" exchange.

The two parties are now in a position to talk, the conversation being carried on through the repeating coil R, and each exchange furnishing the battery feed for its respective subscriber. The duty of supervision falls entirely to the "A" operator at the "East" exchange, and at the time No. 672 hangs up the receiver, relay C falls back to its normal position again switching the winding of relay A into circuit and lighting the "East" calling supervisory lamp. As usual when both supervisory lamps appear, the cords are taken down by the "A" operator and current ceases to flow through both relays A and B. The armatures of these two relays having returned to normal a circuit may be traced from negative battery, through the disconnect lamp, break contact of relay B, make contact of relay D to positive battery, lighting the disconnect signal, and the trunk plug is returned to its seat.

Should the "B" operator at the "West" exchange have received the "busy" test upon touching her trunk plug to the thimble of the multiple

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jack, instead of plugging in, the trunk plug would have been inserted in a jack known as the busy back. The peculiar noise from this circuit notifies both the subscriber and "A" operator that the desired line is busy.

Fig. 484 shows the details of the busy back circuit, which contains an interrupter so arranged as to alternately make and break a battery circuit 22 times during approximately .17 of a second, and then holding the circuit broken for .057 second. This machine is connected in series with a series of impedance coils and the primary of a repeating coil; across the secondary of the coil, the busy back jacks are connected directly in parallel. On the sleeve side of the latter circuit an impedance coil is connected to positive battery, serving to light the disconnect lamp while the trunk plug remains in this jack.

In exchanges where the busy back signal is required for trunking purposes, busy back jacks are also usually placed at the disposal of "A" operators, and the busy condition is never reported verbally to a subscriber.

In Fig. 485, is illustrated the method of construction adopted by the Stromberg-Carlson Telephone Mfg. Company for its multiple switchboard sections of the so called nine panel type, the jack space for each sec-

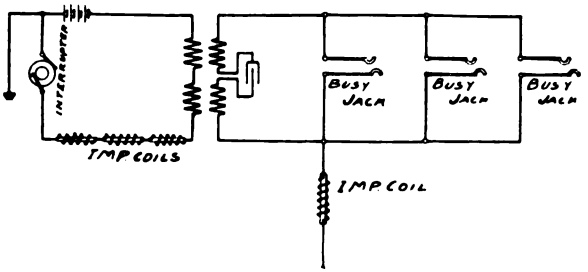


Fig. 484.

tion being divided into nine panels or three panels for each operator's position. This particular section as shown is practically ready for shipment from the factory, a portion of the iron frame and the greater part of the woodwork having been removed. As will be noted, the keyboard of each operator's position is provided with 16 four party keys and thirty order wire buttons; each of the latter are so lettered as to indicate circuits to the toll board, chief operator's, monitor's and wire chief's desks as well as neighboring exchanges. The manner of forming a hinge in the wires leading to the keyboard and of connecting the various keys and supervisory lamps is clearly shown on the keyboard to the right of the front view. The line, supervisory and ringing pilots for each position will be seen on the rail immediately above the keyboard. Directly over the supervisory pilot lamp may be noted an individually mounted jack and push button key, by means of which each operator is enabled to test the cord circuits in her position for open or short circuits. The operator's jacks for each position are mounted in duplicate that monitors may assist on momentarily overloaded positions and to enable the relief operators beginning work before the relieved operators leave their positions. An extra operator's jack mounted at the extreme right of each section is provided for the use of the supervisory operator in answering the operator's calls for information or assistance, which are indicated by an eight candle power signal lamp mounted above the top of the board every sixth section.

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In Fig. No. 486 may be seen the operator's plug and jack in greater detail and also the style of breast plate transmitter, and receiver furnished by this company.

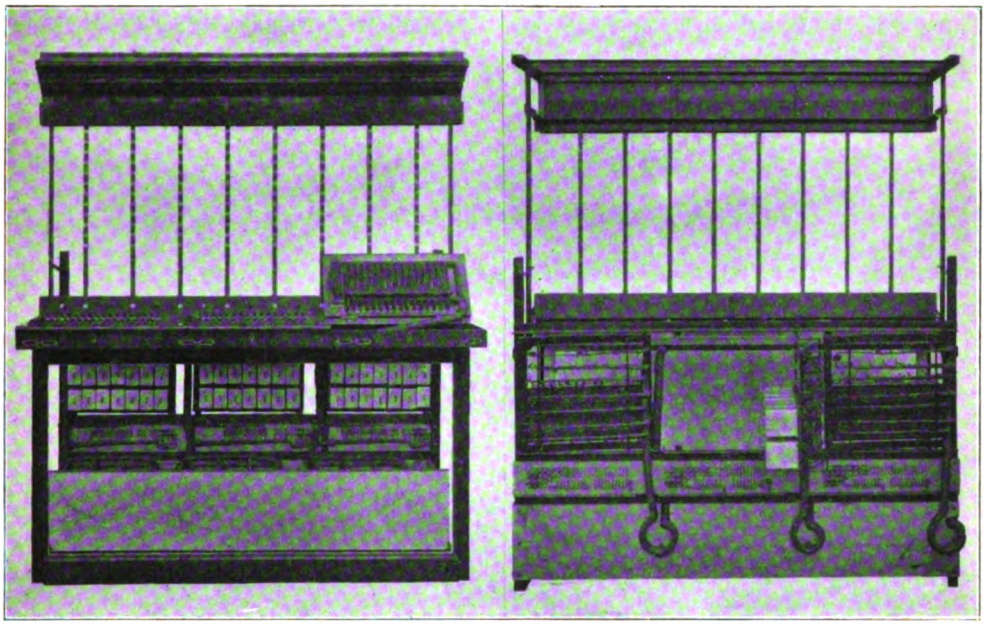


Fig. 485.

The method of mounting the supervisory relays on a hinged gate at the rear of each position is also to be noted, this practice providing the greatest degree of acessibility both for the relays, relay wiring, cords and terminal board connections. One section of this type of board has an ulti-

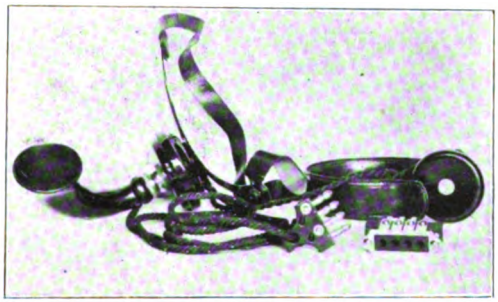


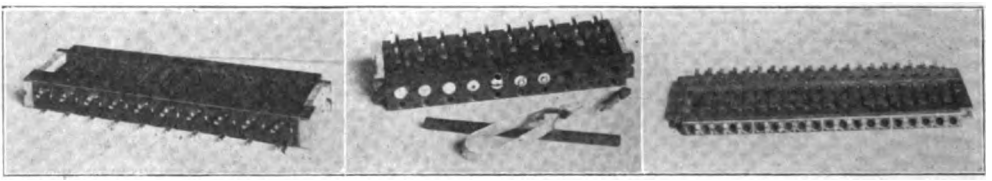
Fig. 486.

mate capacity of 10,800 subscriber's lines in the multiple space, 360 outgoing trunk jacks and 630 answering jacks or 210 answering jacks per position, though it seldom occurs that the latter are all equipped. The answering jacks are mounted ten per strip, the type used in this board being shown in Fig. No. 487; directly above each answering jack and in the same mounting are seen the associated line lamp jacks, and also a line

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lamp and various types of lamp caps, a number with markings as used for service designation. Tools for removing lamp caps and burnt out lamps may also be seen in the cut.

The multiple jacks are of the same type as the answering, but mounted twenty per strip and separated into groups of five by white dots. Five strips of these jacks or 100 jacks are known as a bank, a thin white holly strip attached to the top strip of each bank separating the adjacent banks and by means of the number plates seen on the stile strips, Fig. 485, any bank may be readily located.



Rear of Jackstrip. Answering Jacks. Multiple Jacks.

Fig. 487.

The line and cut-off relays are quite similar in general design to those previously described in this company's cord circuit, though each relay consists of but one spool, as shown in Fig. 488.

The magnetic circuit of these relays is composed wholly of the best quality of Norway iron and in order to cut down so far as possible the reluctance of the magnetic path, the end of the armature and the pivot piece

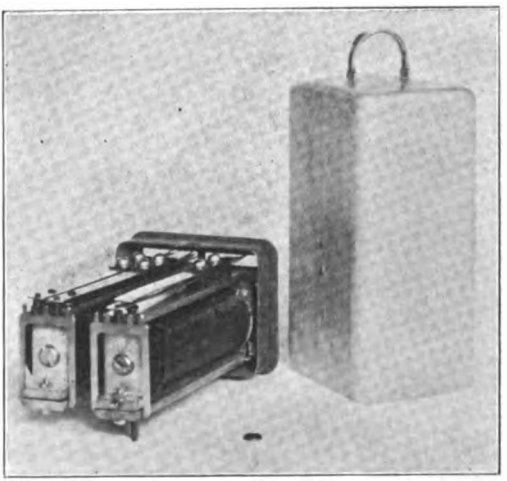


Fig. 488.

from which it is suspended beneath the coil, are accurately milled and held firmly in contact by a stiff brass spring. At the front of the relay the armature normally rests upon the head of a small bolt extending up into the heel iron. When energized, the armature approaches the heel iron, but metallic contact between the two is prevented by a small stirrup slipped over the previously mentioned bolt and the heel iron. The adjustment of the relay is also secured by means of this bolt into the heel

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iron, and by a lock nut above the latter. Motion is transmitted to the german silver springs mounted on the brass bridge above the relay coil by means of a light brass yoke extending upward from the armature. The contacts, as usual, are of platinum rivets.

These relays are mounted on steel mounting strips, twenty line equipments per strip, each set of relays being protected as are all relays of the Stromberg-Carlson Company by aluminum casings. This type of casing, besides furnishing a perfect shield from magnet influence and dust, is extremely light, sightly, and does not corrode.

In Fig. 489 is shown the Stromberg-Carlson four party key, the action of which has been described in connection with the cord circuit. The key

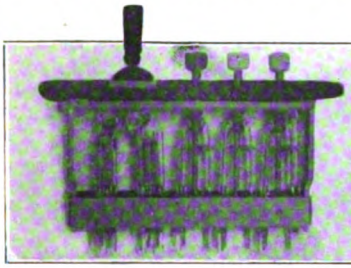


Fig. 489.

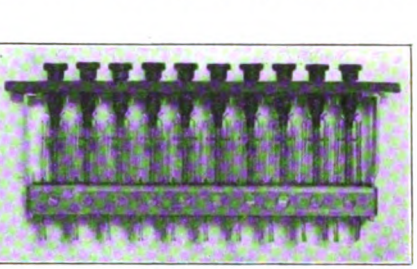


Fig. 489a.

top is of steel with a Bower Barff finish, while the buttons reading away from the cam are colored respectively, blue, white and red. The springs on this key contrary to the usual practice are mounted at right angles to the axis of the key and due to this construction the keys may when required, be mounted on closer centers than has otherwise been found possible. The plunger of each key is provided with a key stop, which when being depressed pushes a tumbler extending the length of the key immediately below the key top, to one side. When fully depressed, and this key stop has passed beneath the tumbler, a spring at the end of the key throws the latter back into the normal position, locking the plunger in the de-

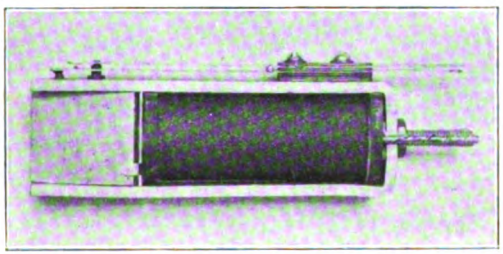


Fig. 490.

pressed position. Any other button which may be pushed at a later moment, momentarily throws the tumbler far enough to release the stop on a depressed key, the spiral spring restoring the released plunger to normal. The tumbler is also thrown far enough by the cam when in the listening position to release the stop of any key plunger; the spring at the end of the key always returning the tumbler again to the normal position.

The order wire keys as shown in Fig. 489a are also mounted on a steel mounting plate finished in Bower Barff, ten per strip, somewhat similar to the construction adopted for the four party key.

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The relays included in the ringing circuit for the purpose of lighting the ringing pilot lamps are necessarily of special design as they are actuated by an alternating current of comparatively low frequency. The armature of such a relay must have sufficient inertia to hold the contacts closed while the energizing current and the magnetic flux pass through the zero value in changing direction and at the same time sufficiently sensitive to readily respond when ringing on the longest lines. This company has met the problem of a ringing relay in the form as shown by Fig. 490.

The armature of this relay is pivoted in a vertical position at the extreme end of and between two legs of soft Norway iron, which extend to

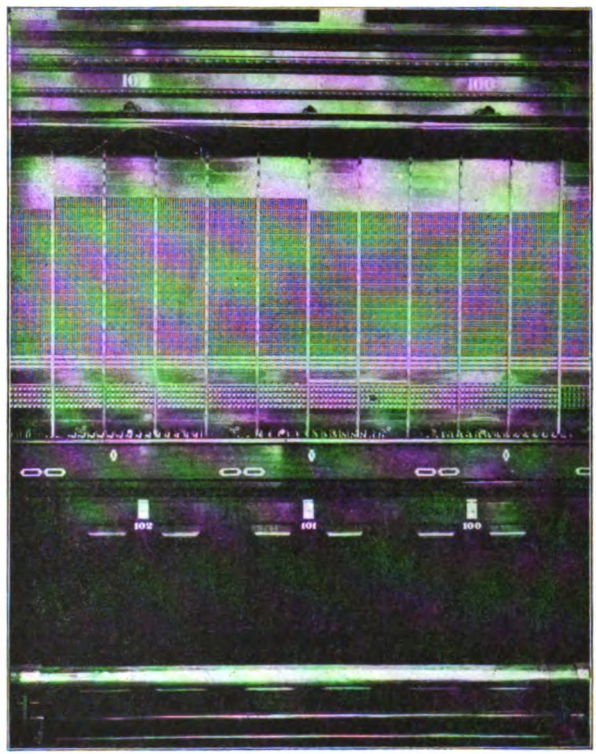


Fig. 491.

the core at the rear of the coil. An insulated cam extends from the armature through the upper leg and rests against a globular shaped depression in the actuating contact spring above. The tension of the latter spring normally holds the armature thrown to one side of the core, but when the relay is energized, the armature is at once drawn over against the tension of this spring into the field of maximum magnetic flux, closing the contact above.

In Fig. No. 491 may be seen a regular section of the Stromberg-Carlson Co.'s ten panel type switchboard as installed in the main office of the Kinloch Telephone Company, St. Louis, Mo. This style of section is designed for an ultimate of 17,000 lines in the multiple space, 840 outgoing trunk jacks multipled every seven panels, and 600 answering jacks. The type of jacks used on this style of switchboard is the same as already il-

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lustrated though necessarily mounted on somewhat closer centers. In order to bring so large a number of multiple jacks within the reach of one operator, the practice is adopted of lowering the plug shelf somewhat on this type of board, the key shelf being mounted on a slight angle sloping downward from the operator.

The "B" or trunking sections of this exchange are constructed on the same lines as the "A" board, but two operator's positions, however, being equipped in each section. As no answering jacks appear in the "B" board, the multiple jacks are placed somewhat lower than the regular sections. The front protection panels have been removed and keyboards opened on a "B" section in Fig. No. 491a, showing something of the inner

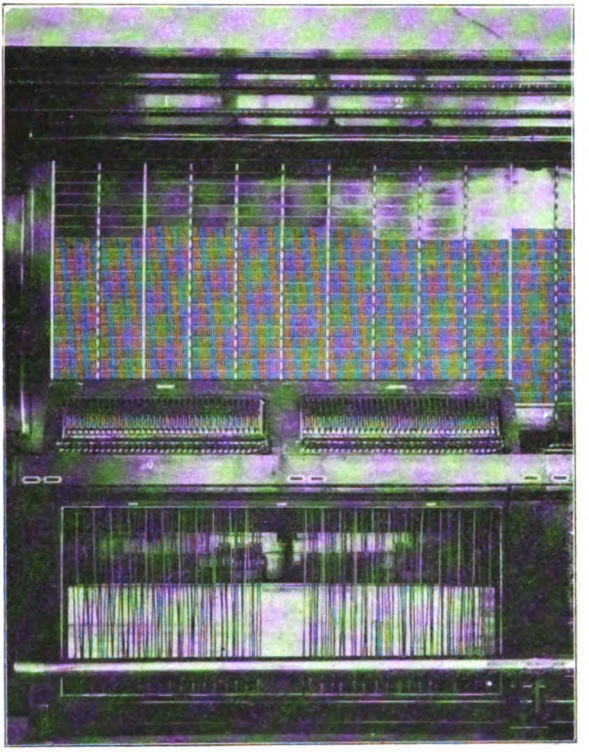


Fig. 491a.

construction. Figure No. 491b illustrates the rear of one of the regular sections. The regular multiple cables will be recognized near the top of the cut, with the outgoing trunk multiple directly below, while the answering cables are placed on evenly spaced wooden blocks on the floor of the section, allowing air to circulate freely around them. The answering cables, it will be seen, are covered by a false floor composed of removable trap doors. The rear curtains are composed of wood and roll up much the same as the cover of a roll top desk.

As described in a preceding paragraph, all supervisory and miscellaneous operator's relays are mounted on swinging iron gates. Behind the relay gates are removable panels which expose the cords.

Especial attention in boards of this size is devoted to protection against damage by fire. Each section is isolated from its neighbor by

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heavy sheet steel bulk heads, while within each section the multiple cables are separated from the answering cables by a fire proof screen. All woodwork surrounding the cord and keyable compartment is also covered with a non-inflammable material, so that a fire originating at this point may not damage any other part of the system.

A portion of the St. Louis regular subscribers' or "A" board is illustrated in Fig. 492. This office at present contains thirty-seven regular sections equipped with 12,500 lines and ten "B" or trunking sections. The chief operator's desk is placed at the head of the stairs, while a portion of the monitor's desk, which at present consists of six positions, may be seen to the left of the stairway.

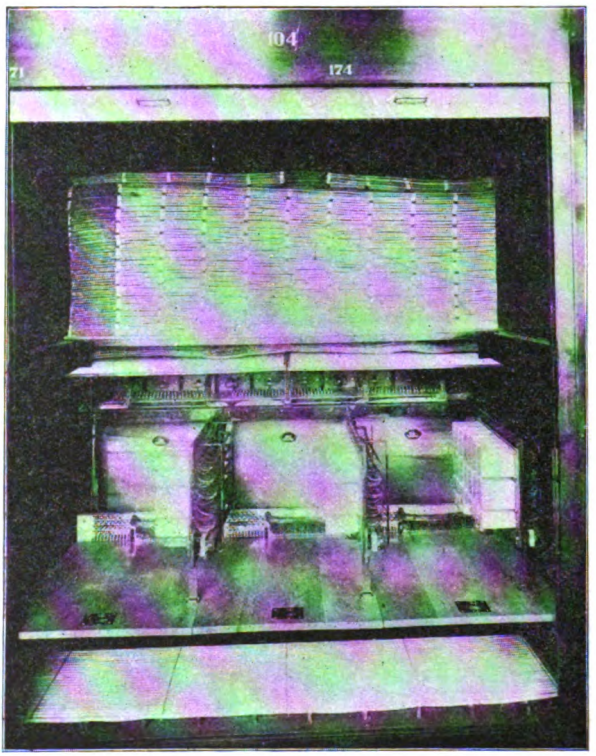


Fig. 491b.

The cabling on the St. Louis installation is also of interest, the general practice adopted by this company for connecting the main distributing frame, intermediate distributing frame and relay rack being clearly shown in Fig. No.493; in this exchange, however, a line circuit slightly modified from that previously described was used, the relative position of the relay rack and intermediate frame being reversed. This practice requires a set of line relays to be permanently associated with each multiple line throughout the board, while the circuit we have shown requires a set only for each answering jack equipped, the total number of relays installed by the latter method often being considerably less than the multiple, or only the actual number of lines operated. In Fig. No. 493, the main frame is located at the left, the intermediate at the right, and the relay bays between. In another view of the same room, Fig. No. 494, the an-

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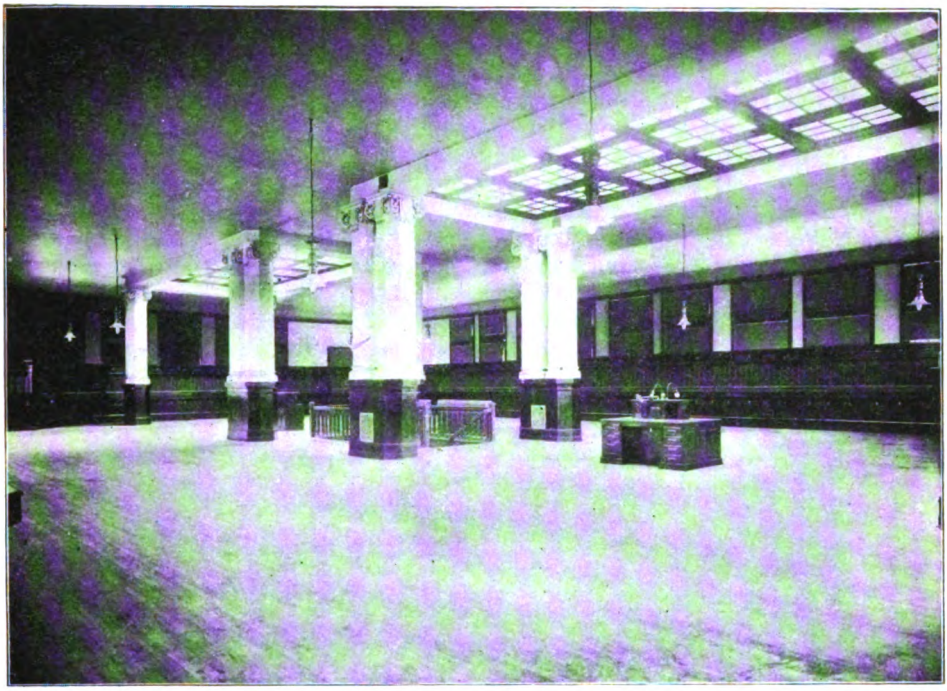


Fig. 492.

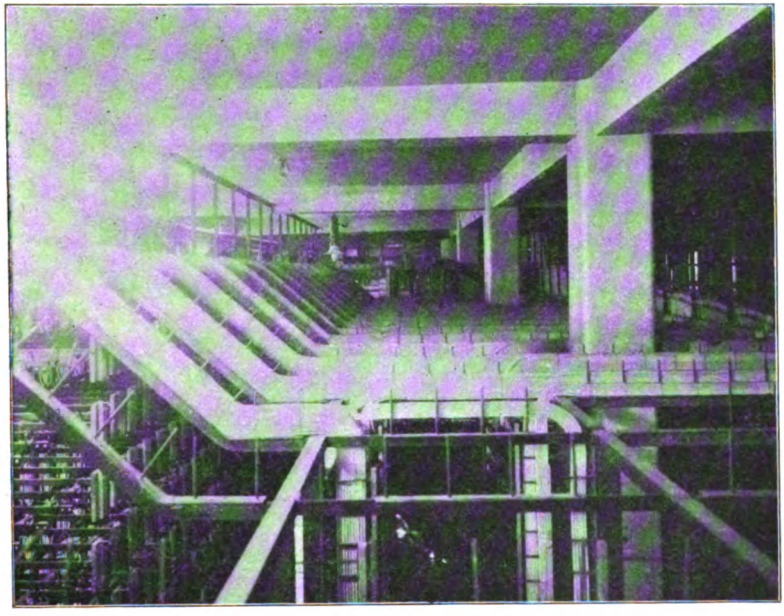


Fig. 493.

swering cables running to the intermediate frame may be seen at the upper right hand corner, while slightly below and running across the view are the multiple cables, both from the regular and trunk boards.

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Fig. No. 495 illustrates the St. Louis Machine equipment and also the portion of the power board containing the fuse distribution panels.

The machine equipment, which is designed to carry the ultimate capacity of the exchange consists of duplicate sets of Holtzer-Cabot motor-generator charging sets, and direct connected multi-cycle ringing generators. The motors on the charging units both operate off of the direct current power circuit in the building, running at 800 revolutions per minute. The charging generators, each have a full load output of 500 amperes at 52 volts. Each ringing unit consists of four generators, furnishing 16.66, 33.33, 50.00 and 66.66 cycle current respectively, direct connected to a driving motor. To one end of each ringing unit's shaft are also geared the usual howler and busy back attachments. One ringing set is driven from the building's power circuit, while the other, for emergency use, is operated off the forty volt storage battery. Duplicate sets of storage batteries are also provided, each set consisting of 20 lead lined tanks with

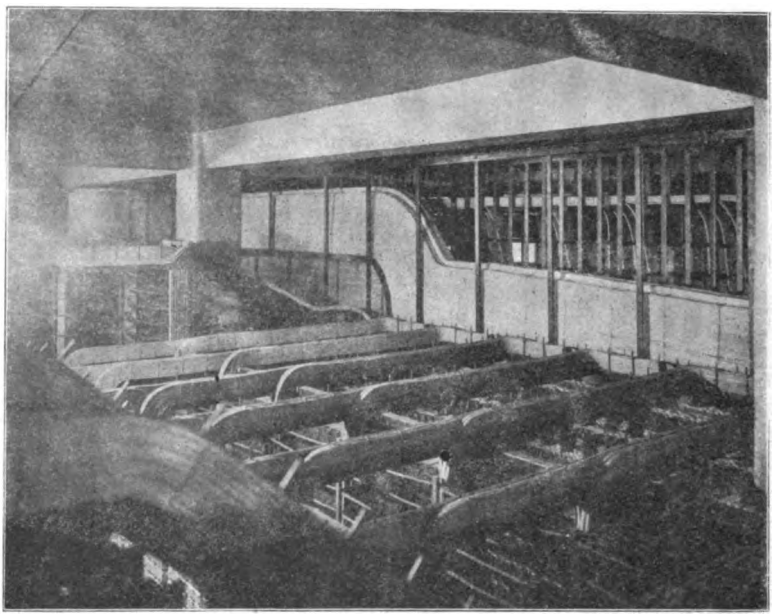


Fig. 494.

sufficient elements equipped to furnish at present a capacity of 2,720 ampere hours or a total of 5,440 ampere hours for the exchange. This capacity, it is estimated, is sufficient to operate the entire system, including all desks and the toll board, for a period of 36 hours without recharging.

The circuits of the Multiple common battery switchboard furnished by The North Electric Co., are shown in Fig. 496. This circuit is typical of those where a double wound cord relay is used.

The circuit is perfectly balanced, the supervisory relays Z and M are split wound and so connected as to feed battery to both sides of the lines through equally balanced windings, the cut-off relay E being in circuit with the third conductor of the multiple and cord.

When the supervisory relays Z M are energized the supervisory lamp circuits are open and high resistance coils 20 and 42 substituted which permit only enough current to pass over the test sleeves of the jacks to

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hold up the cut-off relays E, E^1 and maintain a busy test on the answering and multiple jacks.

The supervisory relays being split-wound the circuit is adapted for use with common return or ground return lines.

The only contacts introduced into the transmission circuit are the tip and ring contacts of the plugs with the jacks and those of the ringing key; the supervisory relay windings being connected directly to the tip and ring strands of the cords eliminates all relay contacts in the talking battery feed to the cords and lines.

The relays are not required to work in parallel (the halves of the cord circuit being separated by condensers T and R) and there being no bridged coils the operation of all relays is very positive.

The operation is as follows:

When subscriber A removes his receiver, current from battery passes through conductor 7, normally closed contact 5, conductors 3 and 1, sub-

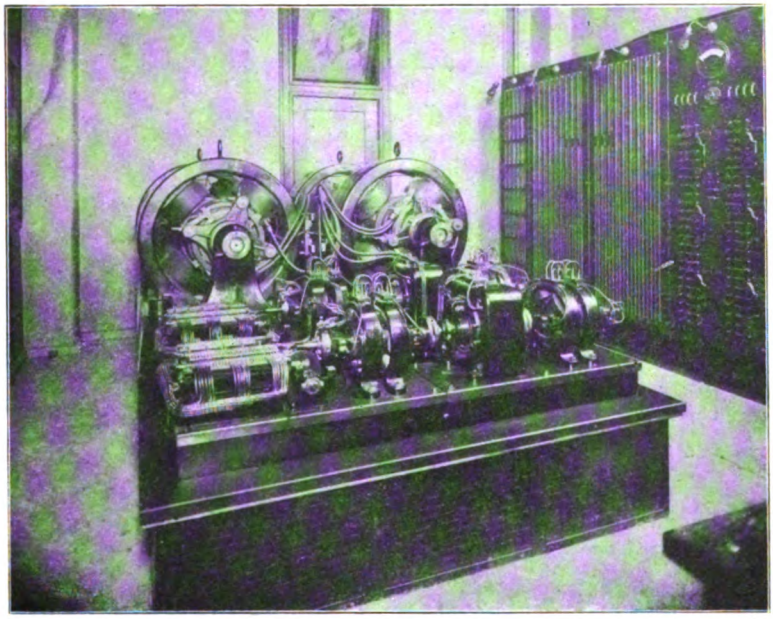


Fig. 495.

station set, conductors 2 and 4, normally closed contact 6, relay R, conductor 10 to battery. Line relay F is energized, contact 9 closes and illumines line lamp G. The operator inserts answering plug H in answering jack D, current then passes from battery through conductor 15, winding S of relay Z, conductor 13, tip strand 11, tip of plug and jack, line conductor 1, substation A, line conductor 2, ring of jack and plug, ring strand 12, conductor 14, winding V of relay Z, conductor 16 to battery, thereby furnishing talking current to substation A. Relay Z operates to open contact 18 and close contact 17, thereby opening the circuit through answering supervisory lamp J, short circuiting coil 21 and establishing a circuit from battery through cut-off relay E, conductor 8, sleeve of jack and plug, conductor 19, high resistance coil 20, conductor 24, contact (now closed) 17, conductors 25 and 16 to battery. Relay E operates to open contacts 5 and 6, disconnecting relay F from the line, relay F is de-

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energized, contact 9 opens, extinguishing line lamp G. The operator connects her telephone set O by means of key K, takes the order, and tests by placing tip of calling plug I to the sleeve of multiple jack C^1. If the line is disengaged, the sleeve of the jack and tip of the plug are of the same polarity (positive) and the operator's receiver produces no click. If the line is engaged the sleeve of the jack is of negative polarity (being changed from positive to negative by the sleeve of some other plug) and a busy click is produced in the operator's receiver. Should the desired line be free, the operator inserts calling plug I in multiple jack C^1 establishing a circuit from ground through cut-off relay E^1, conductor 8^1, sleeves of jacks D^1 C^1, third strand 41, supervisory lamp N and contact 37 in multiple with coils 42 and 43 in series, conductors 33 and 32, to negative bat-

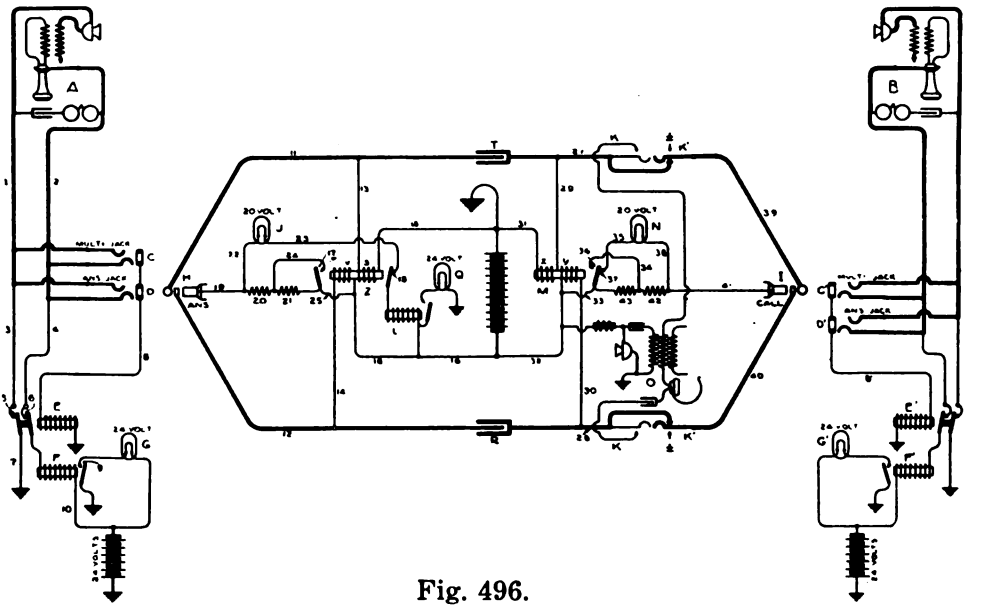


Fig. 496.

tery. Cut-off relay E^1 operates to disconnect line relay F^1 from B^1s line. Upon insertion of plug 1 in jack C^1, B's line is rendered busy by changing the polarity of the jack sleeves from positive to negative (the third strand of the cord being of negative polarity). The operator then presses the ringing key K^1 which connects the ringing generator with B^1s line. The generator may be either grounded or metallic. Until B removes his receiver, supervisory relay M is not energized and lamp N remains illumined. When B removes his receiver, current passes from battery through conductor 31, winding x of relay M, conductors 29 and 27, key K-K^1, tip strand 39, tip of plug and jack, line circuit, ring of jack and plug, ring strand 40, key K^1-K, conductors 28 and 30, winding y, conductor 32 to battery. Relay M operates, first to open contact 37 thereby extinguishing lamp N and second to close contact 36 short circuiting coil 43 and allowing the high resistance coil 42 to remain in the third strand circuit. When either substation receiver is replaced the corresponding supervisory relay operates to close its normally closed contact (18 answering, 37 calling) and the supervisory lamp is illumined. With the answering supervisory relays Z, one spring of contact 18 is commoned and connected to supervisory pilot relay L. When lamp J is illumined, relay L operates to illu-

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mine supervisory pilot lamp Q. The removal of the plugs restores all parts to normal and lamps J. N and Q are extinguished.

The common battery circuit used by the Kellogg Switchboard and Supply Co., is shown in Fig. 497. Two batteries are shown as supplying energy to the cord circuits, but one battery may be used if desired. The operation of this circuit is described by W. S. Henry in the American Electrician, as follows:

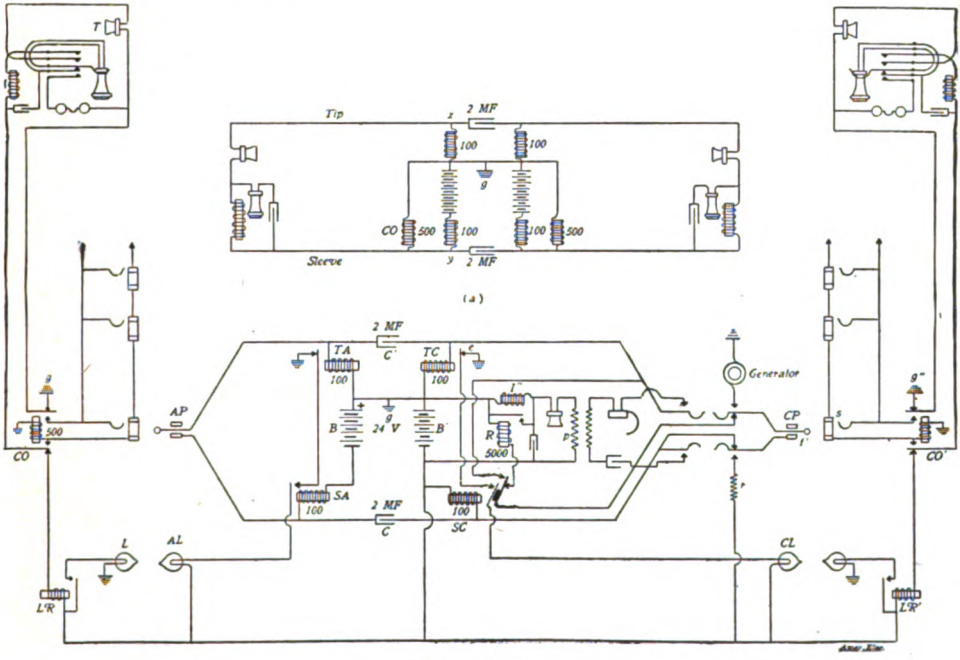


Fig. 497.

"When the receiver rests on the hook the condenser in the subscriber's instrument prevents the flow of battery current through the subscriber's telephone; but when the receiver is taken off the hook, sufficient current flows from battery + B' through g—g'—T—I—line relay LR—B' to cause LR to attract its armature, thus causing the line lamp, L, to light. The operator replies by inserting the answering plug, AP, in the proper jack and closing the listening key.

"Current will flow from B through g—cut-off relay, CO— sleeve side of circuit—relay SA back to B, which causes the 500-ohm cut-off relay CO to attract its armature, thereby cutting out the line relay, LR, which in turn extinguishes the line lamp and also connects the two-line wires to the jack. Current can now flow and close both the supervisory relays, SA and ST, because the line circuit is closed at the subscriber's instrument. The closing of the relay, ST, opens the circuit through the answering supervisory lamp, AL, and thus prevents the lighting of the latter at this time. The operator can now communicate with the subscriber. The operator's receiver and a condenser are connected in series across the cord conductors, but there is also a condenser, CC, in each cord conductor between the operator's head set and the subscriber's line circuit.

"The operator proceeds to complete the connection by touching the tip of the calling plug, CP, to sleeve, s, of the jack belonging to the line

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wanted. If the line is busy, due to a plug being in a jack of that line at some other section, a click will be produced in the operator's receiver in the following manner: Current flowing from a battery through a 100-ohm relay — sleeve side of some cord circuit — sleeve, *s* — tip *t'* of calling plug — *a* — 5,000-ohm test relay, *R*, to ground, causes *R* to close its circuit, which short-circuits the impedance coil, *I''*, thus producing a sharp increase in the current through the primary, *p*, which causes a click in the operator's receiver. The operator then informs the waiting subscriber that the line called for is busy. If the line is not busy, *s*, as well as *t'* will be at the same potential as the ground; relay *LR* will not be affected and no click will be produced. If the line is not busy, the operator inserts the plug in the jack, which will operate the cut-off relay *CO'*. She then opens her listening key and closes her ringing key.

"Current now flows from *B'* through the ground — cut-off relay, *CO'* — sleeves, *s*, of jack and plug — resistance, *r*, back to battery, thus holding the cut-off relay closed while the ringing current flows from the generator through the tip side of the line—subscriber's bell and condenser—sleeve side of line—resistance, *r* — battery *B'* — ground to generator. When the ringing key is released, current flows from *B'* through ground —cut-off relay, *CO'*—sleeve, *s*, of jack and plug—relay, *SC*—back to battery, which keeps both relays, *CO'* and *SC*, closed.. The closing of *SC* causes current to flow from *B'* through ground —*e*— calling supervisory lamp, *CL* (which it causes to light) to battery. The lamp, *CL*, will remain lighted until the subscriber called takes his receiver off the hook. Current can then flow from *B'* through relay, *TC*—*t'*—tip side of line—subscriber's transmitter and impedance coil—sleeve side of line—*s*—relay, *SC*—back to battery. This causes the relay *TC* to close, thus opening the circuit through the calling supervisory lamp *CL*, which is an indication to the operator that the called subscriber has answered his telephone call. All three relays—*CO, SC, TC*—are now energized, and the condition of the circuit while the two subscribers are holding a conversation is shown at (*a*).

"It will be seen from this diagram that each subscriber's circuit is supplied with current from a separate battery, there being a 100-ohm relay, which also acts as an impedance coil, between each terminal of each battery and the line wires. The battery and one of these relays on each side of the cord circuit are shunted by a 500-ohm cut-off relay whose resistance is sufficiently high not to deprive the line circuit of all the current necessary for the operation of the transmitters, and yet not too high to cause this 100-ohm relay to open when the receiver rests on the hook switch.

"As stated, each subscriber's transmitter receives current from a separate battery through two inductive resistances, that is, relays. A fluctuaction of current in the original subscriber's circuit produces a similar fluctuating difference of potential between points, *x y*, which will produce a fluctuating flow of current through the called subscriber's circuit.

"When the subscribers hang up their receivers, the supervisory relays, *TA* and *TC*, are deprived of current and hence release their armatures, which cause the supervisory lamps, *AL* and *CL*, to light, thus notifying the operator that she should pull out the plugs, which restores the circuit to its normal condition."

Another form of busy test from that just described is also used with this system. The test relay, instead of short circuiting the impedance coil in the primary circuit of the operator's set, is arranged to put battery

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on a third winding on the induction coil; this by induction gives the busy test as previously described.

The trunking circuit used by the Kellogg Company is shown in Fig. 498. The jack on the right is located on the A operator's position or the one at which the call originates. The rest of the equipment is located at the B operator's position or the one at which the call terminates. This latter may even be another exchange, several miles from the A or originating position.

The trunk jacks may be multiplied throughout the A exchange, same as the regular subscriber's jacks, so that every operator may have access thereto.

If a subscriber calls in at exchange A and wants a subscriber who is connected with exchange B the operator at exchange A who receives the call pushes her order wire button which is marked "B". The wire from the "B" order wire button terminates at the head telephone of one of the incoming trunk operators at exchange B. The operator at exchange A then tells the incoming trunk operator at B over the order wire circuit what subscriber at B exchange is wanted. The B exchange incoming trunk operator tells the A exchange operator which trunk to use. The A operator then plugs into the corresponding out-going trunk jack in her section. This puts battery on the sleeves of all the jacks connected to the trunk, and makes same "busy", so that no other A operator will use the trunk, which might otherwise happen, through an error in understanding the trunk assigned.

Battery now flows over the trunk from the A operator's cord circuit, and operates relay R^1 at the B board, which pulls up its armature. The purpose of this relay is explained later.

The resistance of this relay (15,000 ohms) is so great that the supervisory relay in the calling cord of the A operator's position is not operated until this 15,000 ohm relay is short circuited by relay R^2 as will be described.

The B operator tests the line called for with the trunk plug. The test circuit is shown from the armature of relay R^3, through test relay and 3rd. winding of induction coil. If the line being tested is busy, the test relay will be operated, because battery will flow from the sleeve of the busy line through test relay to ground. This causes test relay to close, and battery flows through the 3rd winding of the induction coil, causing a click in the operator's receiver. This being the case the B operator puts the trunk plug into the jack marked "busy back" and a peculiar signal or tone is transmitted to the A operator on the trunk, notifying her the line is busy. Plugging into this jack will also flash the supervisory lamp in front of the A operator by operating R^2 and thereby alternately cutting R^1 in and out of circuit, thus giving a visual as well as audible signal to the A operator.

If the wanted line is not busy, the operator plugs in same and rings, the cut-off relay of this line is operated in the usual manner and trunk relay R is also operated as it is in series with the cut-off relay. When the subscriber answers, relay R^2 is operated, this closes a pair of contacts which short-circuit R^1, and remove it from the repeating coil circuit, this coil separating the incoming battery from the A operator, from the B battery, while providing a path for the voice currents.

If the A operator plugs into the jack of the designated trunk line before the trunk operator at the B exchange inserts the corresponding trunk

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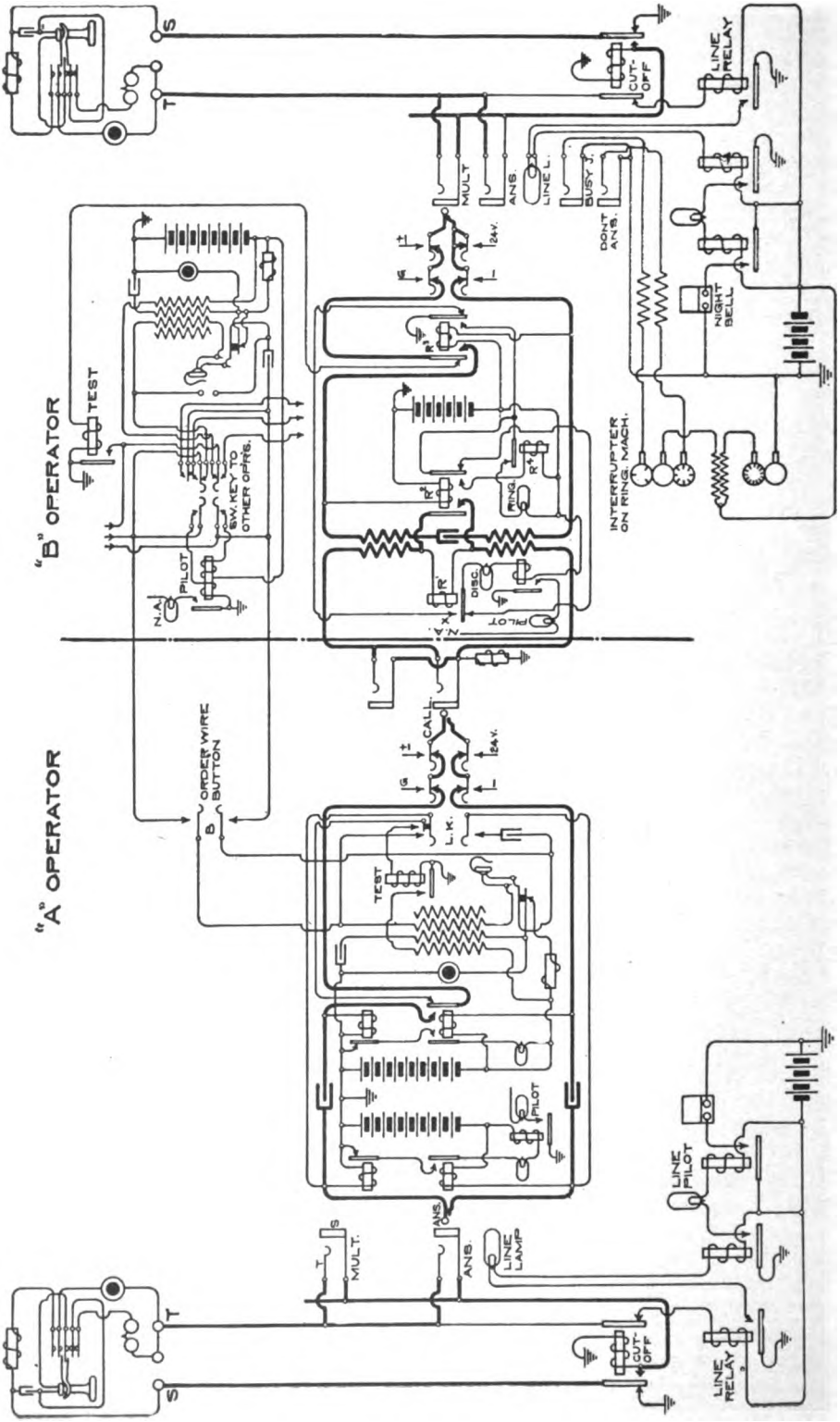


Fig. 498.

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plug into the jack of the called line, or if the A exchange operator plugs into a jack other than that of the trunk assigned, the disconnect lamp associated with the correct or incorrect trunk at the B exchange will light, thus serving as a guard against inaccurate connections. However, as soon as the trunk plug has been inserted in the multiple jack, the disconnect lamp will be extinguished, in case it has been lighted, and the ringing lamp will light. This lamp remains lighted until the subscriber removes his telephone from its hook.

If the operator plugs into the trunk before the B operator puts up the plug, the disc. lamp will light because it will be grounded by contact X of relay R^1, this ground being derived from the back contact of relay R^3. When R^3 is operated, this contact is broken and the disc. lamp extinguished.

Supposing the B operator puts up the plug before the A operator plugs into trunk jack, then the disc. lamp will light because ground is applied to the lamp through relay R^3 to armature of relay R^2, and bottom contact of R^1. As soon as R^1 is operated by the A operator plugging into the jack the disc. lamp is extinguished.

The ringing lamp will remain lighted, after the plug is in a jack until the party answers and thereby energizes R^2, which energizes relay R^4 which cuts the battery off the ringing lamp, this is really the local supervisory signal.

The operation of the "Don't Answer" jack is similar to "Busy Back" previously described. The operation of the pilot lamp connected to the trunk disc. lamps will be readily understood by reference to the figure.

Fig. 498 also shows the arrangement of the pilot and night alarm circuits used with this switchboard.

When the subscriber at the B exchange replaces his telephone upon its hook, the calling lamp at the A exchange will light as R^2 opens, thus inserting the resistance of R^1 in the A cord circuit and the A operator—the "A" subscriber having also hung up his receiver—will remove the connection. The act of removing the calling plug from the outgoing trunk jack at the A exchange will light the disconnect lamp at the B exchange by allowing R^1 to open and the B operator will then take down the connection.

The common battery system furnished by the Vote-Berger Co., is unique in so much as no relays are used, either in the line or cord circuits.

For reasons which have been previously discussed, it is impractical to place the line lamp directly in circuit with the line battery, therefore relays are used in all systems but this, to actuate the lamp, which is placed in a local circuit. To eliminate these was the problem. The solution of this problem was found in the use of iron wire ballast. Iron wire ballast had been used for years in power work and in conjunction with the Nernst lamp. The action in conjunction with the Nernst lamp came the nearest to fulfilling telephone conditions, and deserves some little consideration. An iron wire of .002 inch in diameter is placed in series with the filament of a salt of a rare metal used in the Nernst lamp to protect this filament from fluctuations in voltage. The filament which is used is extremely sensitive to slight variations in current. It has a negative co-efficient which has an extremely sharp curve at the point of best illumination. If placed on a power circuit without precaution a slight increase of voltage will cause an increment of current to be forced through the filament. This reduces the resistance of the filament, which will again allow more current to pass through. The result is that a variation of one and a half

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volts on a one hundred and ten volt circuit will burn out a Nernst lamp instantaneously unless the filament is protected. After a great deal of experimenting, the ballast already mentioned was designed and found to protect absolutely this extremely sensitive filament. As used by the Nernst Lamp Company, the iron wire is spiraled and held between porcelain discs, the whole being sealed in a glass bulb filled with hydrogen gas. For the purposes of the Nernst lamps, this ballast seems to leave nothing to be desired. With a variation of less than 10 per cent in current, the resistance of the ballast is increased or decreased 100 per cent, which will fully protect the illuminating filament.

When it was attempted to apply this same ballast to a telephone line, it was found that it failed for two reasons. First, the iron wire, on account of the presence of the hydrogen gas, radiated the heat so quickly that a current of .4 of an ampere was needed to heat it to a sufficient temperature for illumination. It is, of course, impracticable to send such a current out over a subscriber's line and impracticable to use such a current in a subscriber's lamp. The second reason for failure of this type of ballast was that a variation of 100 per cent was found to be insufficient to take care of the varying lengths of subscribers' lines. It was thought at first that this 100 per cent range could be easily increased by heating the wire to a higher temperature if the first objection could be overcome. Experiment proved, however, that when a ballast of this type was heated to a higher temperature than it was designed to withstand, the wire be-

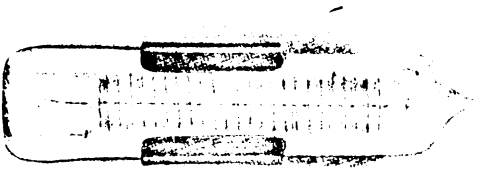


Fig. 499.

came soft and the light spiral coils would collapse and pull apart from their own weight.

After considerable time was spent in both theoretical and practical investigation, it was found that if a wire .001 of an inch in diameter were sealed in a vacuum, it could be brought to the operating point by .07 of an ampere, which is normal current for a telephone signal lamp. Also, it was established that this current is easily sent over subscribers' lines of any practical length.

The next question to be solved was a means of mounting this wire so as to allow it to be heated to a high temperature, thus giving a greater range of variation of resistance. This was the hardest part of the problem, and was finally solved by the design of a ballast mount, as illustrated in Fig. 499. The inner tube of the ballast has a deep thread cut into the glass. The bottom and sides of this thread are purposely roughened. The fine iron wire is then wound in the thread and the whole sealed in the outer bulb, in which a vacuum is maintained. With a ballast of this style the wire is supported throughout its whole length, but on account of the roughness of the thread does not lie in intimate contact with the glass. In such a ballast the wire may be heated to so high a temperature that it be-

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comes red and soft. The only result is that it droops down against the sides of the thread and remains thus supported. It is impossible for it to break of its own weight, as is the case with the Nernst type of ballast. After the perfecting of this piece of apparatus, it was found that a ballast was obtained that would give a variation of 1,000 per cent in its resistance with very slight increase of current. This, of course, is more than is needed to offset the variation between the resistance of any practical telephone lines to subscribers' stations. With the question of the ballast solved, the line circuit was complete. The ballast line lamp, subscriber's line and power are all placed in series, as shown in Fig. 500. The ballasts for all subscribers' lines are exactly alike, no difference being made in long or short lines. The voltage of the battery is such that on a long line the current sent over the subscriber's line is sufficient to illuminate the line lamp. In this instance the ballast remains cold. When the ballast is in a subscriber's line of zero, or approximately zero resistance, the increment of current that is added on account of the difference in resistance of the lines is sufficient to increase the resistance of the line ballast approximately 700 per cent. On all commercial lengths of lines this means that the line lamp gets practically the same current, whether the subscriber's telephone is located in the exchange building or several miles distant.

The cord circuit without relays was somewhat more difficult to design. The final design however was very simple. When an operator's plug is inserted in a line jack, and the subscriber's telephone is removed from

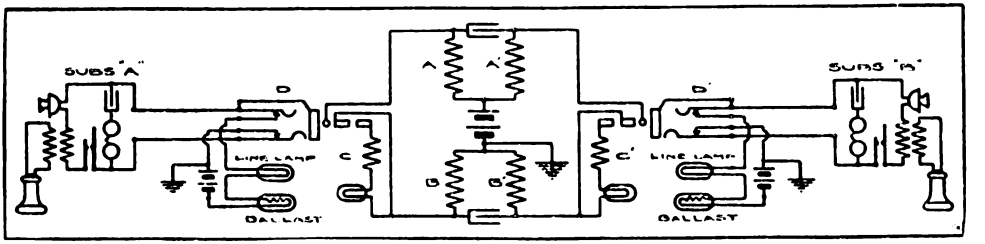


Fig. 500.

the hook, we have battery flowing through the cord to the subscriber's telephone and jack. If we place across this cord a signal lamp and an impedance coil to prevent the loss of voice currents, and design the resistance of the battery feed coils, the resistance of the lamp, and impedance correctly, it is evident that the subscriber's line loop will form a shunt on the supervisory lamp. If this supervisory lamp circuit is of sufficiently high resistance, it is evident that the resistance of the longest subscriber's line in practical use will be low enough to shunt out the supervisory lamp. When the subscriber's telephone is hung upon the hook the shunt is removed and the lamp receives its full current, giving the disconnect signal.

A combination of this circuit with the line circuit already described gives a switchboard of great simplicity. It will be seen that there are no moving parts anywhere in the system, and no contacts except where the signal lamp is cut off at the jack by the insertion of the plug. For large exchange work, where a multiple is desired, the line circuit has been so modified in conjunction with the cord circuit that these contacts are done away with. In the larger boards there are no contacts except between the tip and ring of the plug and tip spring and ring spring of the jack.

The line and cord circuit is shown in Fig. 500 and the operation is as

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follows: Subscriber A desires to talk with subscriber B. A removes his telephone and battery flows through the following circuit: Positive side of battery flows through the contact of jack to subscriber's line, through subscriber's instrument back on the second side of line to the second cut-off contact of jack through line signal lamp, through line ballast to battery.

Now the operator, seeing the illumination of the line lamp, places the answering plug in the jack corresponding to subscriber A's line. The insertion of the plug lifts the tip and ring spring from the cut-off contacts, hence removes battery lamp and ballast from the line. Battery for the subscriber's transmitter then flows from grounded side of battery through impedance coil A, through the key contacts, through the tip of

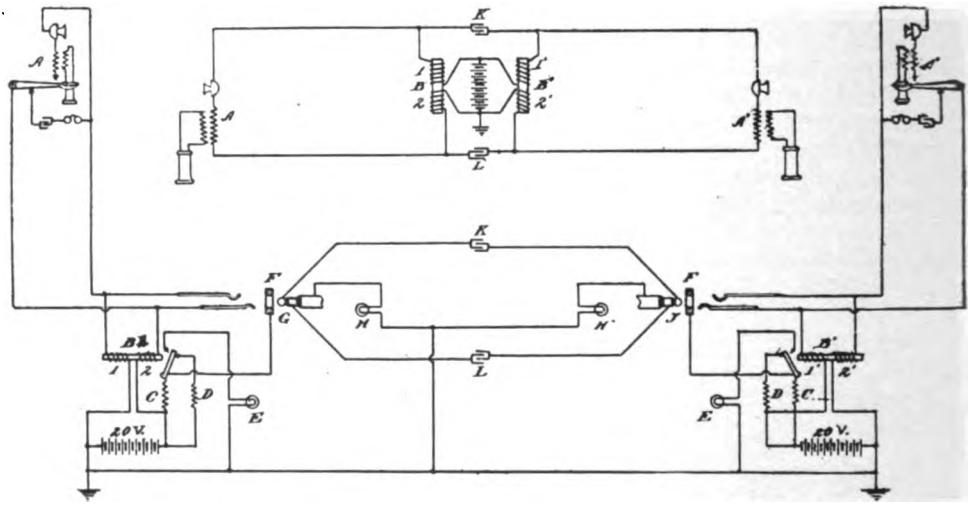


Fig. 501.

the plug, tip spring of jack, subscriber's line, subscriber's instrument, second side of subscriber's line, to ring spring of jack, ring of plug, contact of key and impedance coil B to battery. The supervisory lamp, which is permanently attached to the tip of the plug, is connected through the impedance coil C to the sleeve of the plug. When the plug is inserted in the jack the sleeve of the plug is connected to the ring by the wire D in the line jack. As a subscriber's instrument shunts this supervisory lamp and impedance coil, the lamp is dark. The operator learns by inquiry that subscriber A desires to communicate with subscriber B and inserts the connecting plug into the line jack corresponding to the line of subscriber B and rings. Until B answers, we have battery flowing from grounded battery through impedance coil A′, through key contact, tip of plug, through supervisory lamp, impedance coil C′, sleeve of plug, sleeve of jack, ring spring of jack to ring of plug through contact of key impedance coil B′ to battery. As this supervisory lamp has no shunt, it is illuminated, and when subscriber B takes his telephone from the hook and answers to the ring, the resistance of his line, including his set, shunts out the supervisory lamp. Both lamps then remain dark until the subscribers are through talking, when each lamp will be illuminated by the act of the subscribers hanging up their telephones, which removes the shunts from the corresponding supervisory signals, giving a disconnect signal to the operator.

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A circuit using only one relay per line, and no relays in the cord equipment, is shown in Fig. 501. Battery passes to each line through windings 1 and 2 of relay B which serves as an impedance coil, preventing talking currents from passing from the lines into the battery. When a subscriber removes the receiver from the hook, relay B is energized and draws up its armature, lighting the lamp E, through resistance C.

*"Upon the operator answering the call, she picks up the plug G and inserts it into the spring jack F. Upon examining the calling circuit, it will be observed that the ring of the plug is connected to the lamp H, and that this lamp is connected to the plus side of the battery, and that the line lamp E is connected to the same side of the battery.

"Now, assuming that the armature of the relay B is in its upward position and the plug G placed into the spring jack F, the lamp H is shown connected in parallel with the lamp E. If it is considered that the lamp H is of a much greater capacity; that is, that it requires more current to light it than the lamp E, and that the resistance C permits the passing of only enough current to light the E lamp, it is obvious that the H lamp, with its large current requirements and connected in parallel with the E lamp, takes enough current away from the E lamp for practically extinguishing it, but owing to the limiting of the current supply available

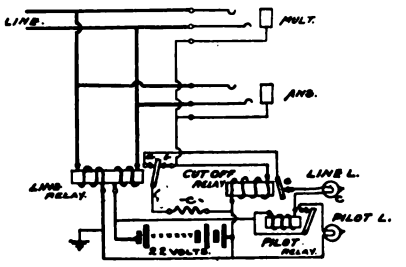


Fig. 502.

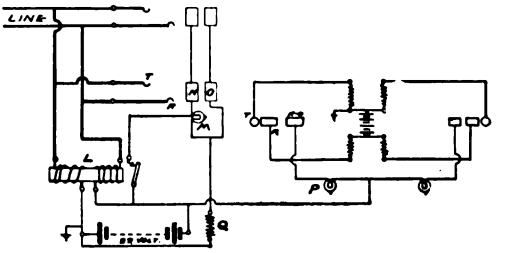


Fig. 502b.

through the C resistance the H lamp will not produce a signal. The moment, however, that the subscriber hangs up his receiver, it results in de-energizing the B relay and this permits of the armature connecting to the C resistance coil and ring of jack F falling back upon a contact to which is connected the D resistance, which is similar to the C resistance, differing from it, however, in the respect that it is of a somewhat higher resistance. The moment that the armature falls back the lamp E is, of course, cut out of circuit and the combined parallel resistance of C and D is low enough for permitting the lamp H to receive a sufficient amount of current for lighting it. Upon the operator observing the clearing signal, the plug would, of course, be withdrawn and no change take place in the line circuit other than cessation of the current passing through the resistance C and D.

"The tip and sleeve circuits of the answering and calling plugs are connected together directly through condensers K and L."

While this system possesses the merit of great simplicity, it also possesses the disadvantages of no pilot or night bell circuits, and in order to permit the use of these, it is customary to furnish a second relay, wired in the sleeve conductor in such a manner that when a plug is inserted in

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a jack, this relay is operated and opens the line circuit. This arrangement is shown in Fig. 502. When the subscriber signals, the line relay closes contact a, putting a ground on contact c and lighting line lamp through pilot relay which also operates, lighting the pilot lamp. When the operator plugs in battery current passes through the supervisory lamp H Fig. 501, to the sleeve of jack, and through the cut off relay which opens contact c, and extinguishes the line, and pilot lamps. The cord lamp H is not illuminated, owing to the high resistance of the cut-off relay, which is usually 500 ohms, this being in series with the lamp.

When the subscriber hangs up, the line relay falls back, thereby closing contact b. This short-circuits the high resistance cut-off relay, and sufficient current now passes through resistance C to light the supervisory lamp.

Another circuit using only one relay per line, and operating on a combination of the impedance coil and repeating coil principles, is shown in Fig. No. 502b. When the subscriber calls relay L draws up its armature, lighting lamp M. Upon the insertion of a plug the jack thimbles N and O are short-circuited thereby extinguishing lamp. The supervisory lamp P is now in circuit but is not illuminated, owing to the resistance Q which is in shunt with the cord lamp as long as relay L is energized. When the subscriber hangs up and relay L opens its contact, battery flows through the cord lamp and resistance Q, and the lamp is illuminated.

It would seem that the line relay windings could be given a high resistance, and the talking battery fed through the repeating coil in the cord circuit, or like the system shown in Fig. 501, battery could be fed through the line relay and the cord circuit consist of two condensers or a repeating coil with condensers between the centre terminals.

The preceding brief descriptions of some systems in common use, will serve to demonstrate that many different circuit combinations are

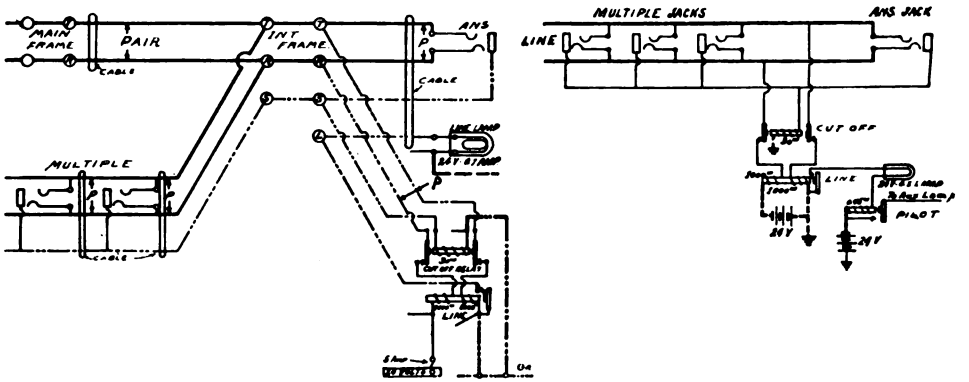


Fig. 503.

possible; to describe each one in detail would be almost impossible, nor is this necessary, for a thorough understanding of any one system, will enable one to become familiar with any other after a short experience therewith.

The system in most general use, is probably that used by the various licensee companies of the American Bell Telephone Co. This apparatus is furnished by The Western Electric Co., who have developed this line of equipment to a high degree of perfection. As this system is in such

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extended use, a detailed description of the apparatus may be of interest, as there is hardly a large city in this country which is not equipped with some of this apparatus.

The general characteristics of this system have been referred to, and shown in Fig. 475. A later line circuit is shown in Fig. 503. The first difference between this and the older circuit is the double wound line relay, each winding 1,000 ohms. This high resistance materially reduces the amount of battery necessary, and also eliminates the loud click in the ear present in the older system when the receiver hook is moved up or down or when the operator plugged in, as when answering the call.

Fig. 503 shows the arrangement of the equipment, the wiring through

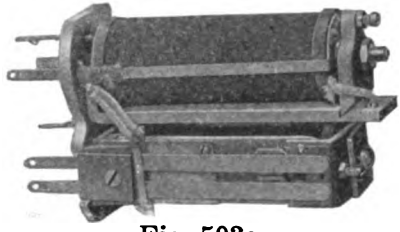


Fig. 503a.

main and intermediate frames, etc. The connections of the multiple and answering cables in the intermediate frame are such, that when looking at the frame on the answering jack side, the first or outside clip is the tip, next the ring, then sleeve and lamp wire. Three conductor or "triple" jumper wire is used to connect the answering and multiple jack sides of the frame, the usual colors being red, white and blue, the tip being white, ring blue and sleeve red. This color scheme is also used for the plug cord conductors.

Fig. 503a shows the line and cut-off relay, these being mounted together. A mounting plate holding ten of these units is usually provided. The top relay in the figure is the line relay, the bottom the cut-off.



Fig. 503b.

Referring to Fig. 503, it will be seen that the wires between the multiple jacks and the intermediate frame consist of one pair and one single wire for each line. These are usually formed into a cable of flat or oval cross section, as shown in Fig. 503b. It is absolutely necessary that all talking wires be paired, or cross talk would result.

The multiple cables contain 63 wires each, twenty pairs, twenty singles and one spare pair and single. Each pair and single has a distinguishing color of insulation to enable them to be easily located.

The answering jack cables are similar to the multiple, except they may consist of 83 wires, twenty pairs for talking and twenty pairs, one

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wire of each for the sleeve and one for the lamp. The plain or solid color wires of the pairs usually connect to the tips, the code or colored wires to the rings, and the single wires to the sleeves.

The majority of troubles with the line circuit are due to careless soldering in the frames and at the jack terminals. The greatest care

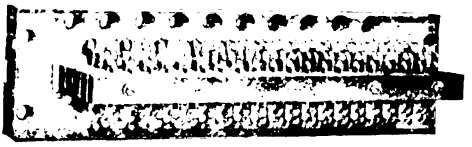


Fig. 503c.

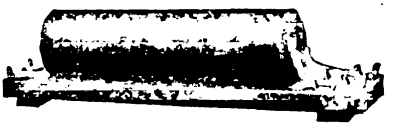


Fig. 503f.

should be taken to secure perfect connections and when working in the multiple, after replacing a jack strip, carefully examine all terminals to see that no wires are broken or no jack spring ends in contact.

Sometimes an open wire occurs in the multiple. This is easily located by connecting a line lamp to the tip and ring of a plug. Start at the



Fig. 503d.

last multiple and plug in, the lamp will not light until the break has been passed, and when this occurs, the break will be found between the point tested and the last point, usually at a jack spring.

An open sleeve is denoted when it is impossible to put out the line lamp by plugging into the jack, this being located by plugging in each

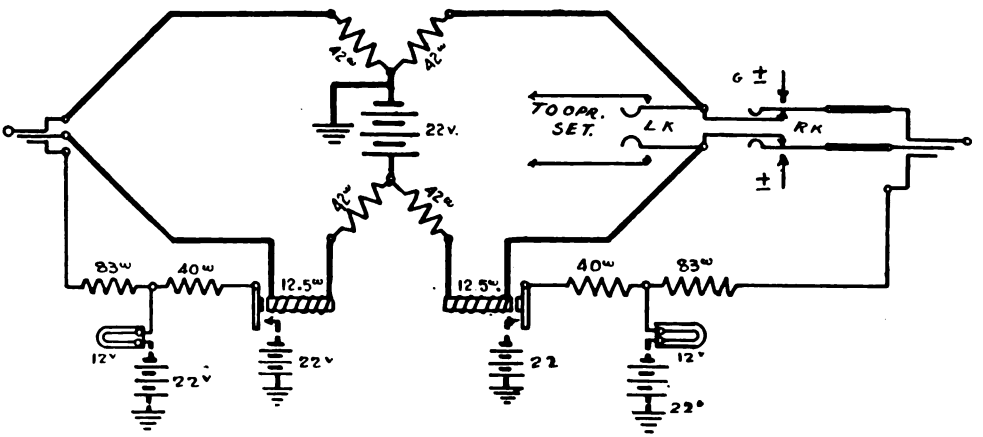


Fig. 503e.

multiple jack. It is usually due to a broken wire or, rarely, by an open cut-off relay.

Short circuits in the multiple are often caused by lead pencil points, due to the operator having a pencil in her hand when answering a call, and sticking the point in a jack, breaking the point off. These "shorts"

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can usually be distinguished from others, by their causing the line lamp to flash, or burn intermittently.

Often pieces of solder become lodged between the terminals on the frames, or a jumper wire is pulled too tight, thereby causing two termi-

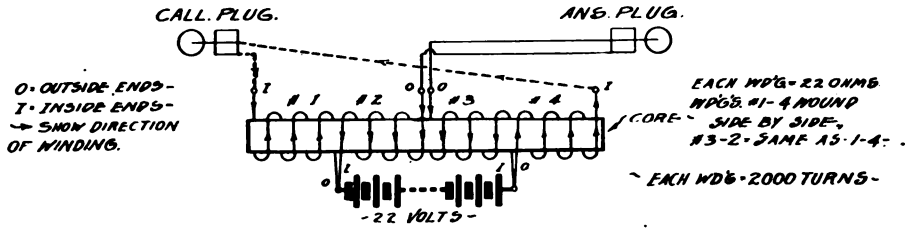


Fig. 503g.

nals to close together. The frame terminals are close together as shown in Fig. 503c and care must be exercised when making connections. The same applies to jack strip connections. As shown in Fig. 503d, the jacks are mounted very close together and neat work is imperative when soldering the wires thereto.

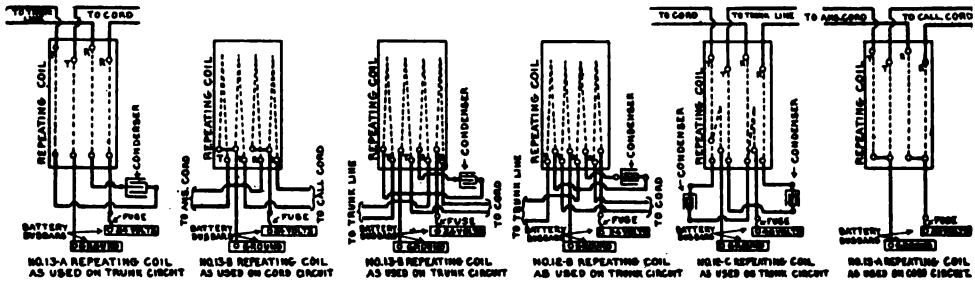


Fig. 503h.

Fig. 503e shows the cord circuit. The repeating coil used in the older installations is of the type shown in Fig. 503f.

This coil has a core about ½ in. diameter and 7 in. long. The winding spaces are about 3 in. long, a head being placed in the middle. The windings vary in resistance depending upon the type of coil, from 45 to 22 ohms. The wire is 26 or 28 cotton covered, from 1,800 to 3,000 turns



Fig. 503i.

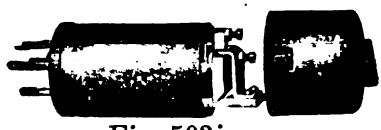


Fig. 503j.

on each winding. In each space is put two windings, the wire run on side by side. Each end is wound in the reverse direction from the other, so that when the coil is connected in circuit, the windings are in relation to the core and each other as shown in Fig. 503g, from which it will be seen that a non-inductive relation exists between the windings connecting to each cord, and voice currents meet no opposition to circulating in this

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path, while the coil as a whole offers great opposition to voice currents that may try to flow outwardly from one coil through another. The core is made large and of fine iron wire, so that these stray impulses may be killed, and in addition, the coils are encased in a heavy iron tube, so that they may be mounted side by side without danger of cross-talk.

Trouble seldom develops in the repeating coil. The arangements of the terminals on different types is sometimes confusing. Some of the terminal arrangements will be observed from Fig. 503h, which also shows some of the combinations possible with these coils.

A later type of coil is shown in Fig. 503i. Here the windings are of 23 ohms resistance wound on a ring core of soft iron wires, the whole being encased in a heavy iron shield filled with rosin, in operation these are the same as the coils previously described. It is customary to put two of these coils on the same base, to facilitate mounting in the standard coil rack.

The next important part is the supervisory relay, as shown in Fig. 503j. This has a $\frac{3}{8}$ in. core, and winding space $1\frac{5}{8}$ inches. The copper

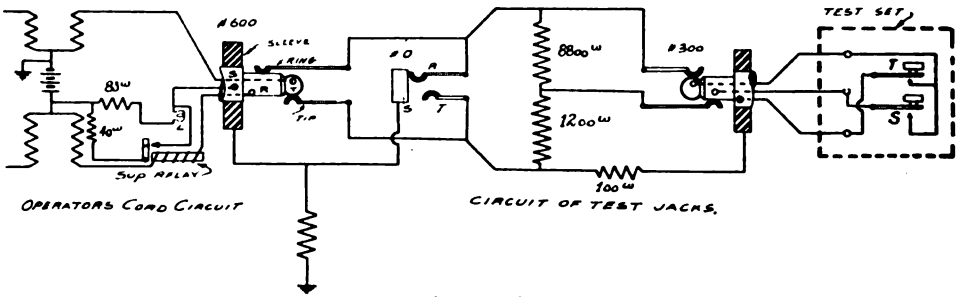


Fig. 503k.

winding measures about 21 ohms and consists of 1,800 turns of 28 silk covered wire. As this relay is in series with the talking circuit, this number of turns would have considerable impedance, therefore about 15 feet of 30 gauge German silver wire, having a resistance of about 31 ohms is doubled and placed over the copper winding and connected across same. This gives the relay a total resistance of only 12.5 ohms, and makes it entirely non-inductive.

The adjustment of this relay is an important factor in the successful operation of this system, therefore special means for testing same is provided. It is customary to wire two jacks in each section, usually the 0 and 600 jacks (these being at the extreme ends of the average multiple) to the test equipment, also a jack midway between these, for instance No. 300.

The test is made as follows, referring to Fig. 503k. The portable test board is equipped with two strap keys and a plug as shown, and the plug inserted in 300 jack. The cord containing the relay under test is put in jack 0 or 600 whichever is nearest. This should light the supervisory lamp, owing to the ground on sleeve of test jacks, the resistance corresponding to a cut-off relay. It will be seen that a resistance of 10,000 ohms is now across the cord, and the supervisory relay should *not* operate as this is a high limit, set to allow for leaky lines, etc.

The key marked T is now depressed, and 8,800 ohms of this resistance cut out. The supervisory relay should now operate, putting out the cord lamp. The relay should *release and light the lamp when key T is released* and should be adjusted accordingly.

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If the relay does not release when the key is released there is danger of the relay sticking on a leaky or low resistance line, and no supervision would result.

The key marked S is now depressed, and all the resistance is cut out except 100 ohms. The relay now gets the full battery pressure and should work freely and not freeze. 100 ohms is taken as representing the least possible resistance the relay will ever work through, this about representing the heat coils and subscriber's set, on a line of no resistance.

In adjusting this relay care should be taken to use the special wrenches provided for the purpose, and to adjust so that the relay is not

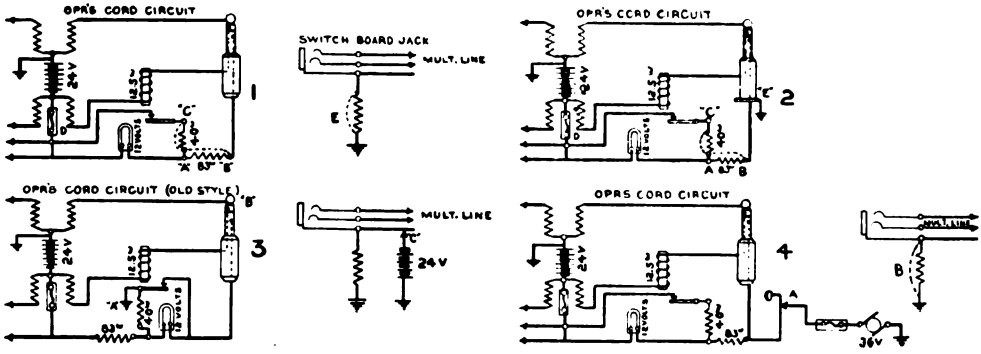


Fig. 503l.

sluggish in action. A little practice and observation will enable rapid and accurate adjustments to be made.

To test for "cut outs" or broken cords, put plug in test jack and depress S key, listen with operator's receiver while shaking the cord and the defect will manifest itself by the usual scratching or scraping sound.

Sometimes the cords will burn from various causes. Some of these are shown in Fig. 503l, and are as follows, referring to the numbers in the figure.



Fig. 503m.



Fig. 503n.

(1) Heavy fuse at D. 40*w* coil C connected at B instead of A. 40*w* coil C short-circuited. Res. coil or relay E short-circuited.

(2) Heavy fuse at D 40 *w* coil C connected at B instead of A. 40 *w* coil C short-circuited. Plug seat at E grounded on frame of switchboard. Tip and ring crossed at F.

(3) Armature A grounded on mounting plate. Tip and ring short circuited at B. Sleeve of jack crossed with battery at C.

(4) Service meter key at A sticks, resistance coil B short-circuited (or key sticks, plug seat grounded.)

The next piece of equipment is the 40-83 ohm resistance in the sleeve of the cord. This is shown in Fig. 503m. It consists of a winding of Ger-

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man silver wire on a flat mica mounting, re-inforced with a brass frame. A centre terminal not shown in the figure brings out the tap between the two parts. This resistance sometimes becomes open, which can be easily tested for by putting one side of a receiver to ground, and applying the



Fig. 503o.

other side to first one terminal or the other of the coil, the open side will be the one where no click results.

The lamps used in the cord circuits are adapted to 12 volts. In appearance they are similar to the line lamps, except usually the filament consists of a single turn instead of two laps. The lamp is shown in Fig. 503n.

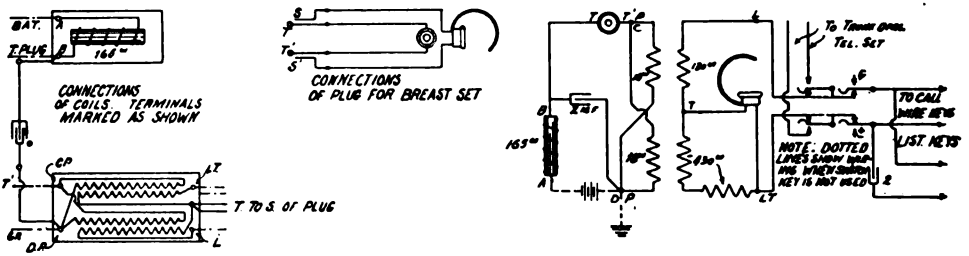


Fig. 503p.

The cords and plugs are similar to those used in magneto systems. A Western Electric cord is shown in Fig. 503o, and repairs should be made to these as explained in connection with Fig. 183.

The operators' circuit is shown in Fig. 503p. The transmitter and receiver are of the same general description as those used in magneto



Fig. 503q.



Fig. 503r.

systems. The induction coil is of peculiar construction, and really consists of two coils, mounted side by side, as shown in Fig. 503q. Each spool has a 18 ohm primary and a 145 ohm secondary. A non-inductive resistance of 350 ohms is wrapped around one of the coils, and the receiver is so connected that it is in a bridge composed on one side of one winding of 145 ohms, and the non-inductive resistance, and on the other side of the

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other 145 ohm winding and the line, the latter being considered equal to the 350 ohm winding. This arrangement is to eliminate side-tone.

Sometimes a different coil is used, as shown in Fig. 503r. This coil has a $^{7}/_{16}$ core and winding space about $3\frac{1}{8}$, a primary of 1,000 turns, 10

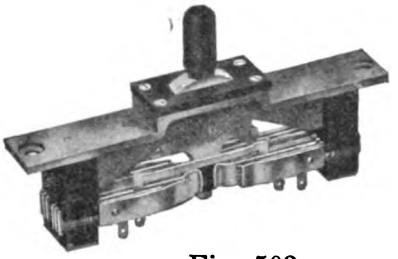


Fig. 503s.

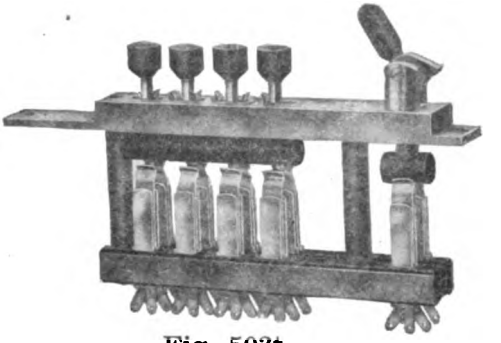


Fig. 503t.

ohms, and two secondaries of 2,000 turns each, the first one measuring about 60 and the second about 240 ohms. The top secondary, or tertiary winding is connected to the monitor's desk.

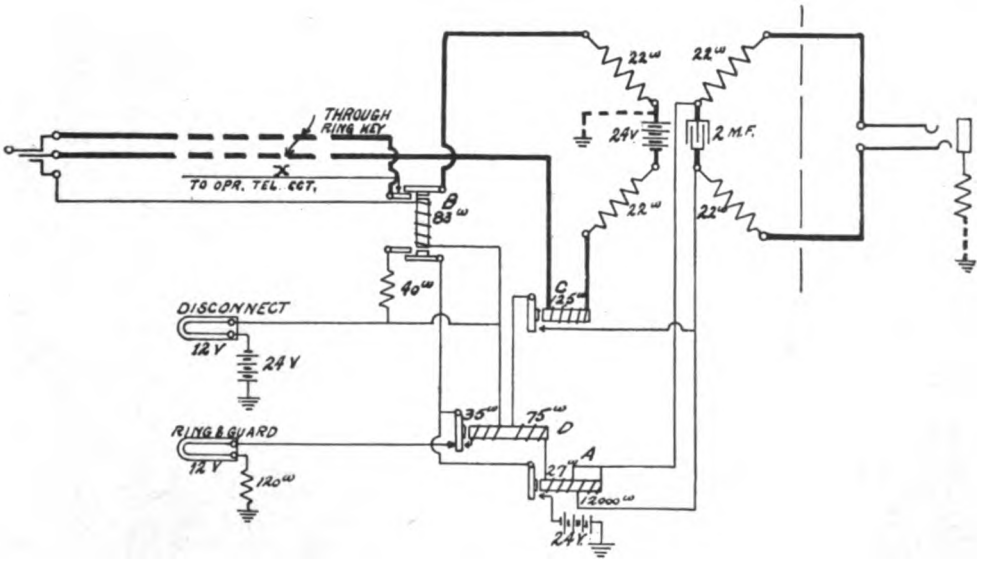


Fig. 503u.

When either of these coils are used, an impedance coil of 165*w* resistance is placed in circuit as shown.

The keys shown connecting to the trunk operators' set, and to call wires, will be referred to later.

While the ringing and listening keys are associated with the cord circuits they will be referred to here. These are of various types, the usual form being shown in Fig. 503s. This is a very reliable key and seldom needs adjustment or repair.

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Where four party ringing is in use, the key shown in Fig. 503t, is used. The handle as shown is the listening key, the buttons, the ringing keys.

The cord circuit previously described will answer for connecting any two lines on the same board. When a trunked connection or one terminating in another office is to be handled, some other arrangement is necessary.

Fig. 503u shows a trunk circuit used with the Western Electric No. 1 switchboard. The originating, or outgoing end of the trunk consists of a jack, to the sleeve of which is connected a resistance equivalent to that of a cut-off relay.

Assuming that an operator at this end of the trunk wants connection with some subscriber in the exchange where the trunk terminates, she depresses an order wire key which puts her in connection with the trunk operator, who tells her what trunk to use. She then plugs into the trunk jack with the calling plug of the pair in use.

Now tracing the current over the trunk, it will be noted that the only path available is through the 12,000 winding of relay A. The resistance of this is so high, that the supervisory relay in the calling operator's cord is not operated, and the cord lamp continues to burn. Relay A, however, draws up its armature, thereby putting battery on the ring and guard lamp of the trunk, which is illuminated. The trunk operator now takes (if she has not already done so) the trunk plug, and applies the tip to the sleeve of the jack of the wanted line; if this line is busy she will get the busy test in the usual manner, because the tip of the plug is connected to her listening set, same as with the ordinary cord circuit when a key is thrown. This is explained in detail later, but it should be noted that the tip is only connected to the operator's set through contact on relay B, and when this is energized the operators' set is disconnected from the trunk, and tip of plug connected to trunk circuit instead.

Assuming the wanted line to be idle the operator inserts the trunk plug. Battery now flows through the disconnect lamp, and through relay B which is operated, but the disc. lamp does not light because the 40w shunt is placed around it by B, this shunt going to battery via armature of A. Relay B cuts off operator's set. The operator now rings in the usual manner, and, when the subscriber answers, relay C, which is the supervisory relay, operates. This puts the 75 ohm winding of relay D in series with the 27 ohm winding of relay A and puts this total of only 100 ohms across the incoming trunk. This extinguishes the supervisory lamp in the cord of the operator at the calling office and, as relay D is drawn up, the ring and guard lamp is also extinguished. Now at the same time, the armature of D makes contact with its 35w winding, and battery immediately flows through this path thus holding D locked after it is once pulled up by current through its 75 w winding, and making it independent of any future action of relay C.

While the parties are talking, all lamps are out, but when the calling subscriber hangs up, and the calling operator removes the plug from the trunk jack, relay A immediately releases its armature, which causes D to release; the disconnect lamp now lights, owing to the 40w shunt being opened at armature of A. Seeing the disconnect lamp light the operator takes down the plug. Now should the reverse condition of affairs happen, and the trunk operator remove the trunk plug from the jack before the calling operator had finished with the trunk, the guard lamp would

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immediately light thereby notifying the trunk operator, because the armature of A would supply the guard lamp with battery, and relay D would release as soon as the trunk plug was removed, thus completing the circuit. This prevents mistakes, and enables the calling or "A" operator to handle the connection at all times.

Fig. 503v shows the trunk operators' set. The various parts have been described except the repeating coil, the terminals of which are mark-

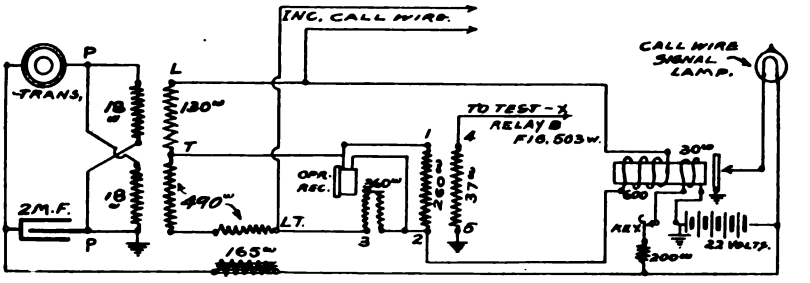


Fig. 503v.

ed 1, 2, 4, 5. The wire marked *X* goes to the contact *X* Fig. 503w and is for the purpose of making the busy test.

Suppose this wire *X* which normally connects to the tip of the trunk plugs, is touched on the sleeve of a busy jack, immediately battery flows from the jack to tip of plug, across contact *X* Fig. 503u to winding 4-5 of repeating coil and to ground. This induces a current in winding 1-2 which the operator hears as a click in her receiver, thus notifying her the line is busy.

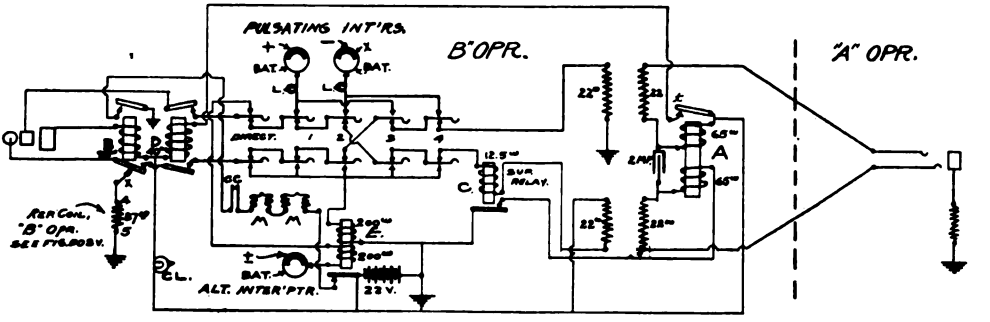


Fig. 503w.

The incoming call wire goes to the order keys on the A operators' positions of other offices.

Bridged across this call wire is an ordinary battery restored drop, so that when the operator is absent from the board the calling operators can attract attention by ringing down this drop thereby lighting the call wire signal, as shown. A key is provided for restoring this drop.

When the trunk circuit shown in Fig. 503u is used, it is necessary for

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the operator to keep on ringing the subscriber until he answers. A trunk with automatic ringing is shown in Fig. 503w.

Upon the A or calling operator plugging into the trunk, a ground from the tip of her cord circuit is put on the *t* winding of relay A, operating same. This draws up its armature, putting battery on relay D. Now if the trunk operator has put up the trunk plug (after making the busy test same as before) relay B is energized, and, when D operates supervisory lamp CL is extinguished. Relays B and D complete the trunk plug circuit through the tip side of repeating coil to ground, and the ring side to battery through supervisory relay C. In addition to this relay A also puts ground on the ringing key common contact CC, which is closed when any button is depressed. Ringing current is supplied to the keys through the windings of relay E which is of peculiar construction, and adapted to operate only through the low resistance path afforded the ringing current when a receiver is off the hook on the line being rung on.

The ringing key is so constructed that when any button is depressed, common contact CC is closed and a circuit closed through the magnet coils

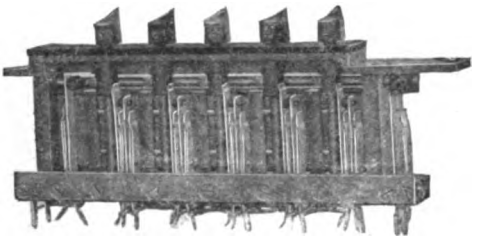


Fig. 503x.

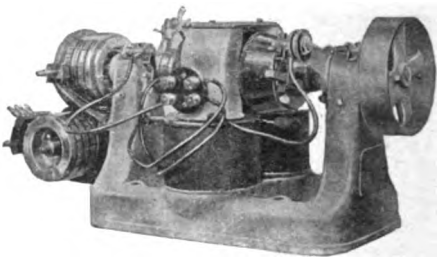


Fig. 503y.

MM, which hold the plungers locked. A key of this construction is shown in Fig. 503x. Instead of depressing the buttons when ringing, they are pulled sideways.

Now suppose the operator has placed the trunk plug in a jack, relays A, B and D are operated, and she operates the ringing key, say the regular or alternating button. Immediately ± current flows from the interrupter INT, through relay E, out over the line, through bell and condenser and back again. This continues for 3 seconds, then battery is connected in place of the ringing current, for 2 seconds, and so on. Relay E is not operated, owing to the high resistance of the bell and condenser in the circuit. It will be seen that this ringing will go on indefinitely without any action on the part of the operator after she once sets the key. When the subscriber answers it affords a low resistance path for the current and relay E immediately operates. This breaks the holding circuit through key magnets MM and the key is released and the circuit completed through relay C. This draws up putting a ground on the ring side of the trunk through relay A, and extinguishing the supervisory lamp in the A operator's cord, which remains out as long as C is closed, and lights again when C opens. Seeing this the A operator takes down her plug, this releases armature of relay A which releases D and, as this shunt is

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removed lamp CL lights, and the trunk operator takes down the connection.

The battery is connected in circuit with the ringing relay during the silent period, so that in case the subscriber should answer during that interval, the relay would be operated, and thereby avoid any delay and the subscriber getting a ring in the ear. The automatic alternate connection of the ringing and battery currents to the keys is accomplished by drums or commutators on the ringing machine as shown in Fig. 503y. The segments are of varying lengths, thereby permitting the currents to remain

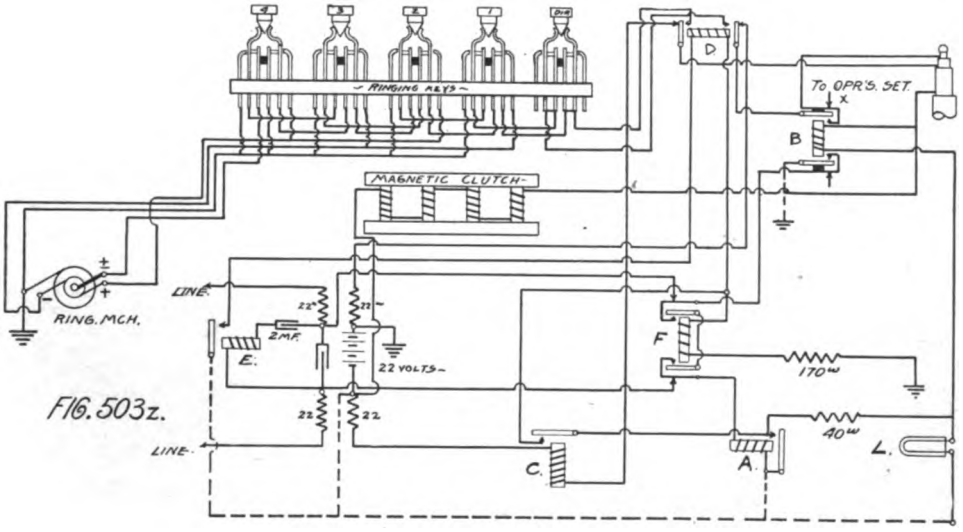


FIG. 503z.

Fig. 503z.

connected for long and short periods as desired, with proper intervals between.

With all the preceding trunk circuits, the trunk operator rings the wanted subscriber, therefore she controls the connection to this extent. It is desirable that the operator at the outgoing or originating end of the trunk, be able to ring the wanted subscriber, thereby having entire control over the connection. This is especially desirable in long distance work, where the long distance operator has a message for some subscriber in a local exchange, the terminus of the trunk.

Fig. 503z shows a trunk circuit in which the A operator can ring the B subscriber at will. This is known as the Long Distance toll trunk, and is commonly used between long distance office, and the district exchanges in large cities.

Referring to the figure, when the long distance operator plugs into the trunk, relay A is operated, and closes its contact putting a shunt around the disconnect lamp L. The trunk operator tests with the trunk plug in the usual manner, and plugs into subscriber's jack with the trunk plug. This operates relay B, which completes the circuit from tip of plug to trunk circuit wiring, the tip being normally opened at relay B. Now the usual circuit can be traced from the battery and ground, through repeating coil and relay C to the plug. The ringing key is now operated by the

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trunk operator and is held locked by the magnetic clutch. This puts ringing current on the inside contacts of relay D, which however, is not operated, therefore the ringing current does *not* pass to the plug. The long distance operator now calls the subscriber by *ringing on the trunk*, this current operating relay E, which is responsive to ringing currents only, and is not operated by battery current, owing to the condenser in series with same. This relay is of peculiar construction, having a very heavy armature so arranged that it is slow acting and does not open its contact

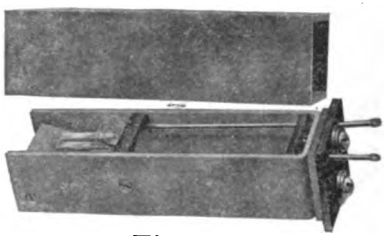


Fig. 504.

owing to the rapid impulses of the ringing current, but remains closed after once operating, as long as ringing current is passing through it. This relay is shown in Fig. 504.

When E closes its contact, battery flows through D, which operates, bringing the tip and sleeve of the trunk plug circuit in contact with the ringing current and ringing the subscriber. Everything is cut off but the plug when relay D operates.

To keep the disconnect lamp from lighting during this operation, when E closes, an additional circuit is established to ground through F,

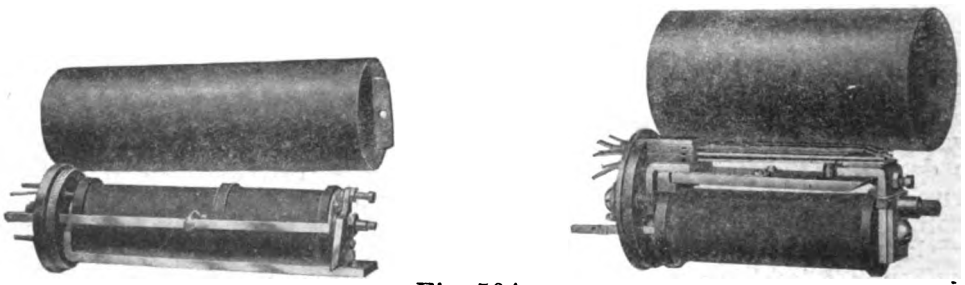


Fig. 504a.

which puts a local ground on A holding it closed and thereby keeping lamp L from lighting.

It will be seen that the long distance operator can call the subscriber at will, and that the ringing is entirely under her supervision. When the subscriber answers, relay C operates and puts battery on F, which closes and operates A, thus keeping lamp L out during the conversation. This closing of relay C also puts battery on D in such a manner that it cannot be energized, thereby preventing it closing and ringing in the ear of the subscriber in case the long distance operator should ring, after subscriber answers.

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When the call is completed and the long distance operator removes her plug, relay A is released and opens, removing the shunt from the lamp L, which lights. The operator thereupon removes the trunk plug, which extinguishes the lamp and also releases the clutch on ringing key.

The adjustment of the various relays used in these trunk equipments, is comparatively a simple matter and is the only attention the circuits need in the way of special maintenance. Various forms of relays, as furnished by the Western Electric Co., for this work, are shown in Fig. 504a. The supervisory relay C Fig. 503z is adjusted by means of a test similar to the regular common battery cords, this being described in connection with Fig. 503k. It is necessary to have a plug in the long distance jack end of the trunk when making these tests, so that the entire operation of the trunk may be observed, it being customary to plug the trunk into a jack connected to an ordinary subscribers' set, and then simply "flash" the hook to test the relays.

When trunks with automatic ringing are used, such as shown in Fig. 503w, some means for testing the relay through which the ringing

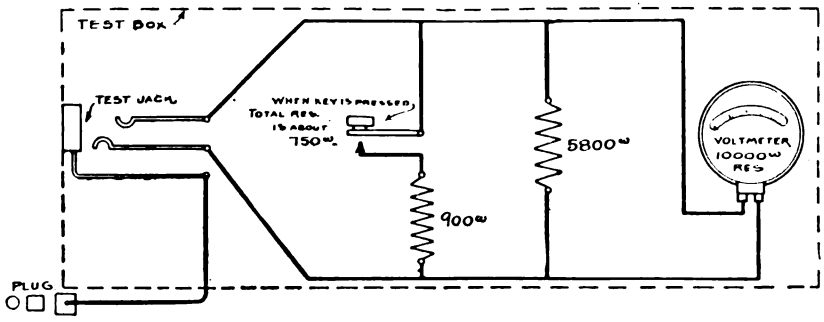


Fig. 504b.

current passes (E in the figure) must be provided. This relay is designed to be operated by ringing or battery current when the line circuit is closed by the removal of the subscriber's receiver from the hook. This relay must not be operated when the circuit is closed by the 1,000*w* bell, and 2 M.F. condenser in series, which is the case when the subscriber is being called and the receiver is on the hook. In other words the combined impedance and resistance of the latter circuit is too great to allow sufficient current to flow to operate the relay.

One winding of the relay is in series with the ± current going to the "direct" key. When the receiver is taken off the current divides, part flowing through the bell, and part through the transmitter and coil, this latter circuit is of sufficiently low resistance to permit sufficient current to pass to operate the relay, the current returning over the tip line, to ground at ringing key.

The other winding of the relay is in series with the common or ground lead going to the 4 party keys. When a 4 party phone of the standard biased type, equipped with relay, as shown in Fig. 246 page 183 is called, the pulsating current is connected to the line through the 100*w* resistance lamp and flows out over the line, returning through the four relays and condensers bridged thereon. These relays operate, connecting the four ringers to the lines, two between each side and the ground. We have seen that the ringing current is not continuous, but passes

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through an interrupter on the ringing current for two seconds, and battery for five seconds. The battery will pass through one of the windings of the relay, depending whether a "direct" or party line key is operated. As the battery current will not pass through a condenser, no current will flow through the relay during the time it is in circuit with the battery, unless a receiver is removed.

The relay must be adjusted to work under two conditions, first with two 1,000 ohm bells and condensers bridged across a metallic line, and secondly, with four 2,500 ohm relays with condensers in series, the relays adapted to close a circuit through ringers to ground.

A test set for accomplishing a satisfactory adjustment of the relay under these conditions, is shown in Fig. 504b. It consists of a 10,000 ohm volt-meter, in parallel with a resistance sufficient to make the combination measure about 3670*w*.

A second resistance is provided and connected with a key as shown, and when in circuit the entire combination measures about 722*w*.

To use the set, the plug connected therewith is placed in any multiple jack, so that a ground is placed on the sleeve of the jack in the test set. The trunk plug is now placed in jack on test box. A plug is now placed in the outgoing end of the trunk and relays A, B and D, (Fig. 503w) being operated, upon depressing any ringing key, the ringing current will be connected to the trunk plug, and flow through volt-meter and resistance in test box. The relay is now adjusted so it will *not* operate unless the

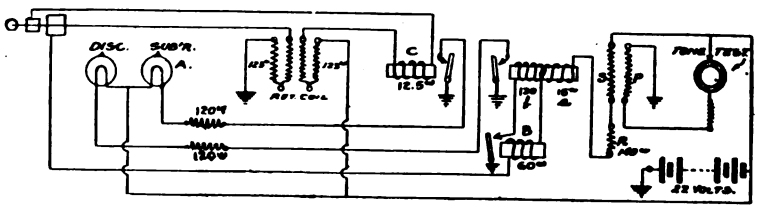


Fig. 505.

key in test box is pressed, thereby putting the 722 ohms across the circuit. When this is done, the relay should operate when either the "direct" or any party line key is used.

When adjusting these relays care must be taken to see that the battery voltage is about normal, 22 volts.

This test set affords an excellent method of testing the ringing current and connections to the keys for reversals. A double scale volt-meter should be used, so that it will not be necessary to reverse same. By noting the correct voltages and direction of deflection for each party line key, a reversal is quickly located.

Those familiar with long distance work, realize the confusion caused by a subscriber calling for a long distance connection, and then, while the long distance operator is getting the connection, which sometimes requires 20 or 30 minutes, some one calls for the party making the call and the line becomes busy, just as the long distance operator is ready to notify the party wanting the call, and has the toll line waiting. To prevent any

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delay, and hold the line of the party asking for the call, so that no operator will put up a local connection on this line until the L. D. operator has finished, the "tone test" circuit has been devised.

Figure 505 shows the circuit. Each operator is provided with one or more tone test plugs, located upon her table. A subscriber asking for a long distance call, is connected to the long distance operator in the usual manner. After his wants have been ascertained, the long distance operator notifies the local operator to hold the line for long distance, and to accomplish this the local operator inserts the tone test plug in the answering jack of the line.

Immediately current flows through secondary of repeating coil S, through resistance R, through winding a of relay A, through relay B to sleeve of plug, energizing the cut off relay connected to the line in the usual manner and cutting off the line relay and lamp connected to that line. Relay B is also energized, and draws up its armature, putting a ground on the reverse winding b of relay A which is therefore not energized, the two windings opposing each other.

Now if another operator somewhere at the switchboard should get a call for this line, when she tested to see if the line was busy, she would hear a peculiar hum or "tone" due to the interrupted current flowing in the primary of the transformer S which is in circuit with the sleeve of the line, through the sleeve circuit of the tone test plug. She would accordingly report the line "busy." The "tone" is caused by interrupting the battery by means of a commutator on the power generator of the exchange.

If for any reason the subscriber should wish to call before the tone test plug is removed, upon taking the receiver from the hook, battery would flow through the windings of the RET. coil and relay C, and the latter drawing up its armature, would light lamp A, whereupon the operator would answer in the usual manner.

Now supposing the tone test plug to be in the line jack, and the long distance operator is ready to complete the connection. She orders the trunk plug placed in the jack. The trunk operator does this, disregarding the tone test, which serves as a check to notify her that she is putting the long distance trunk plug into a line being held for a long distance connection. As soon as the trunk plug is inserted in the multiple jack of the line, an additional circuit is established from the sleeve to battery, through the sleeve relays in the trunk plug. This immediately causes relay B to let go its armature, because B is shunted by the lower resistance of the trunk cord relays. This removes the ground from winding b of relay A, and as the opposing influence of the B winding is no longer present, relay A closes its contact and the disconnect lamp B is illuminated. Sufficient current will pass through the a winding to operate A without closing B. The operator, upon seeing lamp B operate, knows the long distance operator has completed the connection, and removes the tone test plug.

When a line is in trouble, for instance short-circuited, some means becomes necessary to keep the line lamp from burning steadily and annoying the operator. This can be accomplished by plugging into the line, thereby operating the cut-off relay. This method is however not advisable, as it would permanently disable the line until repairs were made.

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A circuit for plugging up a line, so as to keep the line lamp from burning, and yet have the circuit in such condition that should the trouble disappear, the subscriber could still signal the operator is shown in Fig. 506. The plug is located upon the switchboard, usually upon the blank table of the first section. Suppose a line to be in trouble, the plug is inserted in a jack connected to that line and key K pressed. This energizes relay A which closes its contact, putting battery through one winding of the repeating coil, the lamp, and on sleeve of plug, energizing the cut-off relay and putting out the line lamp. Now should any operator receive a call for this line, and test same in the usual manner, they will hear the "out of order" tone, a hum similar to the "tone test" and caused

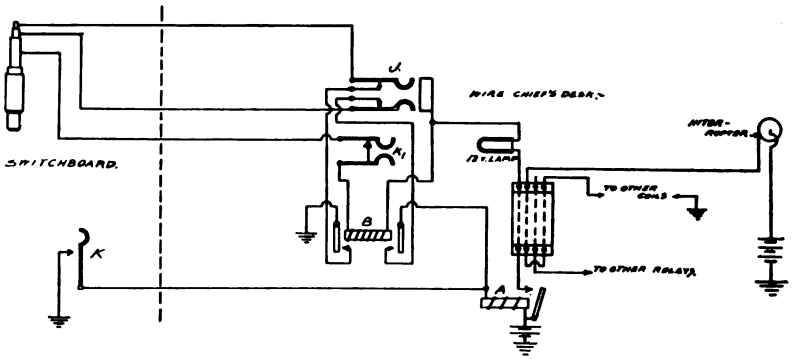


Fig. 506.

by interrupted battery flowing through the windings of the repeating coil as shown, this causing a noise in the sleeve circuit. The operator accordingly does not connect to this line but reports same as "out of order" to the subscriber wanting the connection.

From a study of the circuit it will be seen that when relay A operates, it puts battery through relay B, which gets its ground through the sleeve of the plug via. the key K_1 and the cut-off relay. Relay B closes its contacts, putting a ground on the tip side of the line, and battery on the ring side, through relay A. Now as long as the line is short-circuited, or grounded on the ring side, relay A will remain closed serving as a signal to the wire chief that the line is out of order, but if the short circuit or other trouble is cleared relay A releases its contact, and as this opens the lamp and sleeve circuit, the lamp is extinguished, and the cut-off relay released and the line restored to its normal condition and the line lamp ready to respond, should a call be made. Should the trouble re-occur, pushing the button K will again set relay A and the trouble lamp and circuit again put in operation.

The jack J is provided for the wire chief to test from. The usual procedure when using this circuit, is for the monitor at the board, as soon as a trouble occurs, to plug same up, and press key K. This lights lamp on wire chief's desk and seeing the light, he plugs into the jack, and by pressing K_1, thereby flashing the line lamp in front of the operator, ascertains the number of the line and proceeds to clear the trouble.

From the foregoing, it will be seen that a line in trouble is automati-

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cally transferred to the wire chief's desk, and that it is not necessary for him to go to the switchboard to test, or ascertain the line in trouble.

On common battery systems when the receiver is left off the hook, a steady signal results, and some means should be provided in every exchange to call the subscriber's attention, and cause him to replace the receiver. Ringing in the usual manner will not do this, as the low resistance path afforded the ringing current through the transmitter circuit prevents the bell from ringing.

A simple device for producing a howl in the receiver to attract the subscriber's attention, consists of an ordinary magneto induction coil

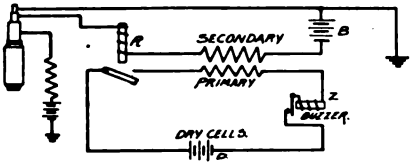


Fig. 506a.

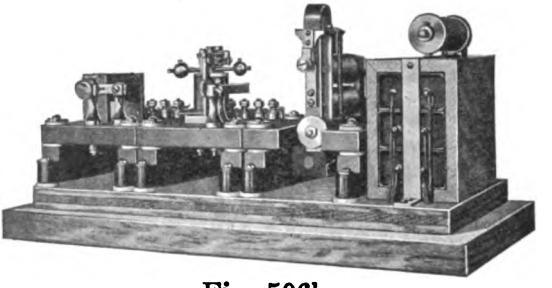


Fig. 506b.

arranged in connection with a relay and battery, as shown in Fig. 506a. The relay R is a supervisory relay same as used in the Bell cord circuits. Battery B is the 22 volt exchange battery. When the plug is inserted in a line jack, the sleeve resistance operates the cut-off relay in the usual manner, and connects the coil circuit to line. This causes relay R to close. Buzzer Z, being in series with the primary of the coil, rapidly breaks the circuit from the dry cells D, causing a loud howl or hum in the secondary which is transmitted to the receiver, the diaphragm of which gives forth a loud howl, and attracts the subscriber's attention. When the receiver is replaced, relay R releases and the howl is stopped.

The buzzer consists of an ordinary battery buzzer or bell, and three or more dry cells may be used. A condenser can be bridged across the buzzer contacts to prevent sparking.

This arrangement can be used in magneto exchanges by omitting the relay and battery in the secondary circuit, and connecting the secondary directly to the plug. When this is done, the plug must be removed from the jack, and line tested to see if receiver is hung up, as there is no way to make the buzzer stop working, when used on magneto system.

This arrangement is not powerful enough in some cases, so it is customary to equip the ringing machine with a commutator having a great number of divisions, thereby producing the howl, and to connect this circuit to the line. The current must not be too strong, or it will demagnetize the receiver.

A machine for producing the "howl" "tone test" and "busy back" is shown in Fig. 506b. In operation it is similar to the motor driven devices, but is designed for very economical battery consumption, so it will run from storage or dry cells and therefore may be used where there is no power available.

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The machine is mounted in a wooden case with glass top, and may be mounted in any convenient place, usually on the side of the converter or pole changer cabinet. The figure shows an outfit for two signals; others are provided by supplying other movements.

It is at once evident to the most casual observer that the only reason for the use of the foregoing circuits with their automatic ringing and disconnect features, etc., is a saving in time. Therefore *time* is really what the telephone company sells, especially in long distance work. The timing of messages and equipment necessary to do this accurately, forms a most important part of the exchange equipment.

THE CALCULAGRAPH is a machine for computing and recording *elapsed time.* In other words, it substracts the time-of-day a telephone toll conversation commences from the time-of-day it is finished, and prints the difference—the actual time in minutes and quarter minutes consumed in the talk. Incidentally, it also records the time-of-day the toll circuit was put up and the conversation commenced.

On the records made by the Calculagraph, the charge for toll service is reckoned in accordance with the schedule in vogue. Such schedules are made up, sometimes on a mileage rate—air line between towns and cities; sometimes on the nearest railroad distance and sometimes the rates are arbitrarily fixed to meet competition, without reference to distance.

Calculagraphs have been used in telephone exchanges in the United States for about twelve years, the first lot of machines having been installed in 1895.

These machines are now (1909) quite generally used throughout the United States and Canada in all telephone exchanges where toll business is handled. They have also become part of the standard equipment of toll switchboards in governmental telephone exchanges in Europe, Asia Africa and Australia.

The use of toll circuits is an important part of the stock in trade of a telephone company. It is that which the company sells to the public at so much per minute and as such, it represents money just as fully as does the stock carried by any merchant. The public should pay for all it takes.

The Calculagraph tells exactly how much use of a toll line is chargeable to the public including "excess time" or time extending beyond the period of the initial or minimum charge.

Prior to the introduction of the Calculagraph in telephone exchanges, great difficulty was experienced in accurately recording the time consumed in the use of toll lines. It was generally conceded to be physically impossible for a toll operator to observe the time-of-day visible on a clock dial and write it down with pencil when the use of a circuit was commenced, to repeat this operation when the use of circuit was discontinued, then subtract the one record from the other and get an accurate result, at least, that this could not be done without neglecting some of the other duties of operating.

Various expedients were resorted to: sand glasses, stop watches, time stamps and other devices were tried, but were discarded as impracticable. Messages were timed at both ends of a toll line and both outward and inward operators made out tickets, monitored the connection, repeating at intervals the question, "Are you through?" etc. Talking circuits over expensive toll lines were held up and "pay business" delayed while send-

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ing and receiving operators compared and adjusted the differences in their records of elapsed time on the previous message. (There usually were differences.) It was known by telephone managers that with methods and appliances then available, errors in timing messages were likely to be made by either or both operators, but it was assumed that the average of the two records of time elapsed would be "approximately correct." Outward and inward toll tickets were therefore carefully compiled, compared and audited at considerable expense of clerical labor. Telephone toll service was charged for according to distance covered, in even periods of five minutes each. A fraction in excess of the initial period being charged for as another full period, and any time beyond ten minutes being charged as fifteen, and so on. Concessions and compromises in charges for toll service were frequent and unavoidable.

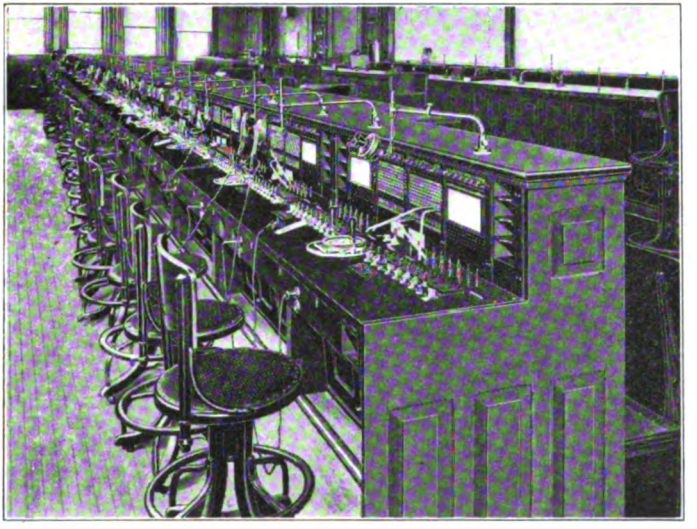


Fig. 507.

Fig. 507. Calculagraph mounted on Toll Switchboard of Am. T. & T. Co., New York City.

After the installation of the Calculagraph in telephone exchanges for timing toll messages the following reforms became possible and were at once inaugurated by the principal toll line companies in the United States. The practice of timing messages at the receiving end of the line was discontinued and no inward tickets were filled out. The inward operator was therefore able to handle twice as much business as formerly and twice as much as the then outward operator was given. The expense of printing, compiling, comparing and auditing inward tickets was saved. The outward operator, relieved of the mental and manual effort required to observe and write down the times of commencing and finishing and to subtract the one from the other, was made more efficient in the other duties of operating. Talking circuits over toll lines were no longer held up and were available for "pay business" at all times. The mechanical record of elapsed time made by the Calculagraph on the outward switch-

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board was relied upon by both users of service and the company's officials to be absolutely accurate and no concessions in charges for service were necessary.

The system of charging for service, by full periods of five minutes each, was changed so that all "excess minutes" after the first period were

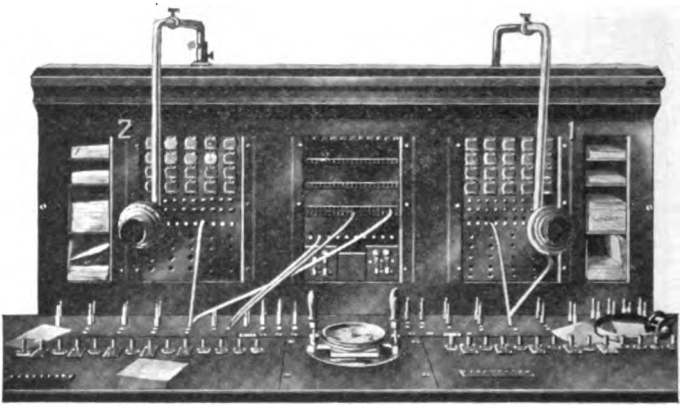


Fig. 507a.

charged pro-rata, or at a proportionate rate per minute. By many of the telephone companies the initial period of charge for toll service was reduced from five minutes to three minutes, and by several companies to two or one minute.

These changes in method of charging for toll service had often been discussed but never were thought possible or practicable until the install-



Fig. 507b.



Fig. 507c.

ation of the Calculagraph, which made the timing of messages a matter of certainty instead of estimate. The Calculagraph insured payment for all "excess minutes" used. There was no longer any doubt as to whether or not excess time had been used and no occasion to "give the customer the

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benefit" of such doubt. The Calculagraph enormously increased the revenue from toll serivce; in some cases such increase was sufficient to pay a dividend on the capital stock of the company. The Calculagraph directly benefitted the public (the consumer of telephone toll service), by establishing an equitable basis for charges and by a reduction in the length of the period for the initial charge.

The best method of mounting the Calculagraph on a toll switchboard is to sink it in the keyshelf midway between two operators so that the ticket plate of the machine shall be substantially flush with top of shelf. So placed one machine may be used by both operators.

Two styles of cases for Calculagraphs are provided for this purpose. In the one designated case "B" shown in Fig. 507b the weight of the machine is supported by four large screws, which pass down through the wood into iron pillars of the case below the keyshelf.

Case "C" shown in Fig. 507c is provided with a flange which rests on top of the keyshelf and the machine is secured against rotation by wood screws through the flange.

The former style of case is preferred by some because it presents a neater appearance when mounted and the latter is preferred by others

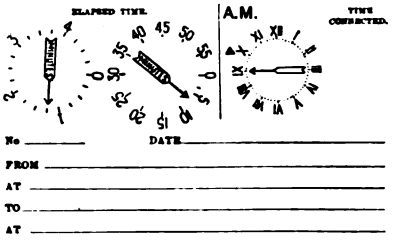


Fig. 507d.



Fig. 507e.

because it is more easily fitted and can be mounted without the services of a skilled wood-worker.

In small exchanges where toll lines are sometimes made to terminate at the end section of a local switchboard, the Calculagraph may be mounted on an extension self supported by iron brackets at the end of switchboard. In such exchanges the Calculagraph is also frequently mounted on an iron pedestal secured to the floor. Such pedestals are adjustable in height. Calculagraphs for use on pedestals should be ordered in case "A". They are secured to the pedestal by screws through the bottom of case.

Model 6 Calculagraph is the type of machine best adapted for use in timing toll messages; other models of Calculagraphs are made for use in different industries.

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The record made by Model 6 is shown in Fig. 507d. It indicates that the toll circuit was connected at 9:45 A. M., and that the line was in use 6¼ minutes.

To commence a Calculagraph record, place card in left end of slot, face down, with top of card against back of slot and slide it toward the right until it hits the guide post. Push right operating lever outward until the rear end of cam touches top of main plate; this prints the time-of-day. See Fig. 507e.

Then, without releasing hold of the operating lever or changing position of card, pull lever inward until front end of cam touches main plate; this prints the two elapsed time dials. Remove card and commence other records on other cards in the same manner. See Fig. 507f.

To close a record, at the end of a period of time under measurement, place the card containing the beginning of that record back into the slot



Fig. 507f.



Fig. 507g.

in the same manner and in the same position as in Fig. 507f. and pull the left hand operating lever inward until its cam point touches the plate; this will print arrows in the centre of the two elapsed-time dials. The arrows will point to figures of the dials which represent the time which has elapsed, since that record was commenced. See Fig. 507g.

The paper of which cards are made should be heavy enough to remain flat while being shoved into the slot of the Calculagraph. The operator will handle such cards more rapidly and insert them more accurately than if made of thin paper which will crumple when pushed into the slot.

Any quality of paper on which a lead pencil will make legible marks will be suitable for cards, but paper having a glazed surface will not receive satisfactory impressions from the printing dials.

Booklets containing more detailed information in regards to mounting, using and repairing the Calculagraph, are supplied by the manufacturers and are usually packed and shipped with the machines.

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CHAPTER XII.

HARMONIC PARTY LINE SYSTEMS.

The name Harmonic Party Line System has been given to a system of selective bells for telephone party lines which has come into very general use in the last four years among the independent telephone companies of this country. Referring to Kempster B. Miller's book, "American Telephone Practice," you find the following passage which I consider the most lucid explanation of the principle involved in this class of systems which I have ever seen. He says:

"These systems, with one exception, make use of the fact that every pendulum or every vibrating reed has a natural period of vibration, and that it can be made to take up this vibration by the action of a succession of impulses of force occurring in the same frequency as that in which the reed or pendulum vibrates. A familar example of this is found in one person pushing another in a swing. The swing has its natural period of vibration depending on the length of the ropes, and a gentle push applied at proper intervals by the person on the ground will cause the swing to vibrate with considerable amplitude. If the pushes are applied at intervals not corresponding to the natural period of vibration of the swing, many of them tend to retard rather than help its vibrations, so that a useless bumping results, producing but little motion."

When a tuning fork is struck near a piano, which is in perfect tune, a corresponding note of the instrument will sound out clearly. You have already probably noticed that when you make a musical sound in a room either by whistling, singing, or playing a musical instrument, that some object, such as the globe of a chandelier or the strings of a piano will produce the original sound. In the foregoing illustration the sympathetic tone was produced by impulses of force transmitted through the medium of the air from the original sounding body to the one reproducing it. When the tuning fork was sounded, the resultant air vibrations came into contact with every string in the piano, but they were strong enough to move only the one which happened to be in tune with them. We can imagine that the noise made by the firing of a revolver in the same room would cause all the notes of the piano to sound at once regardless of pitch. The pendulum of a clock or the balance wheel of a watch is kept in motion by the almost infinitesimal blows of their escapements, which blows are applied at exactly the proper instant, but we also know that both a clock and a watch run faster when first wound, when the spring is strong, than when nearly run down. For instance, in Mr. Miller's illustration of the swing, it is evident that if the individual doing the pushing were suffic-

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iently strong he would be able to operate the swing regardless of whether the impulses of force employed occurred in the natural period of vibration of the swing or not. I mention these exceptions to the laws of harmonic vibrations to bring to your notice the importance of the strength as well as the frequency of the impulses of force applied. We come now to the application of the foregoing principles to the commercial selective party line system. All that is necessary to accomplish this result is to distribute your tuned devices, which in this case are the bell armatures, at the telephone subscribers' stations, and operate them by electromagnets energized by alternating currents of electricity of the proper frequencies and strengths sent over the telephone lines. Selective systems of this kind both for telegraphy and telephony were early designed.

Mr. Miller says: "This idea was used in telegraphy before the birth of telephony. A number of currents of different rates of vibration were impressed upon the circuit by as many different transmitters, each particular rate of vibration being capable of operating a reed in one of the receiving instruments and producing no effect on the other. By this means each receiving instrument was capable of picking out only those signals sent by the transmitter having the same rate of vibration, and thus all of the transmitters could be used simultaneously in the same circuit, producing a system of multiplex telegraphy." One of the earliest systems of this kind was that invented by Thomas A. Edison and patented in 1877.

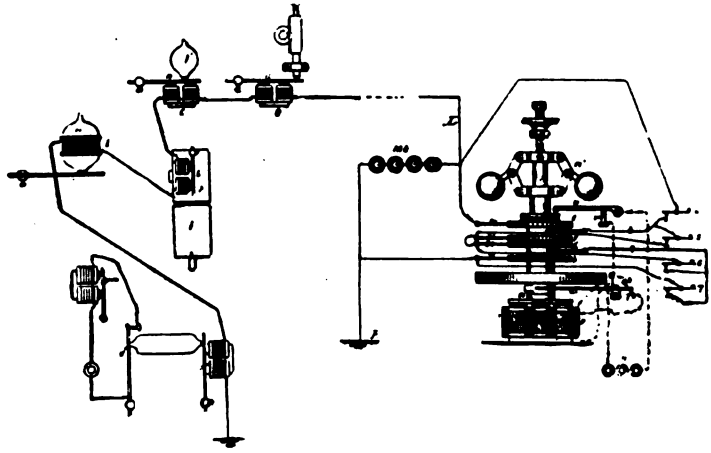


Fig. 508.

Fig. 508 represents a copy of the patent drawing. In Edison's system a series of magnets, whose armatures were reeds tuned to respond to different frequencies, were connected in series in the line. At the side of the drawing is illustrated a mechanism for producing the pulsating currents of proper frequencies. In front of each armature, you will notice, is a small Helmholtz resonator to increase the volume of sound. It was possible by means of this combination for a number of messages to be sent over a line simultaneously. A great many harmonic telegraphs have been invented, prominent among the inventors are the well known scientists, Elisha Gray and Professor Rowland.

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The first harmonic selective party line system was that invented by J. B. Currier and patented by him in 1881, and used for several years by the New England Bell Telephone Company. Fig. 509 represents a copy of the patent drawing. In this system the electromagnets with their armatures, which in this case contained the bell tapper, were arranged in series in the line the same as in the Edison harmonic telegraph. Currier produced his pulsating currents by means of pendulums of different lengths, which pendulums were provided with contacts for interrupting the ringing current.

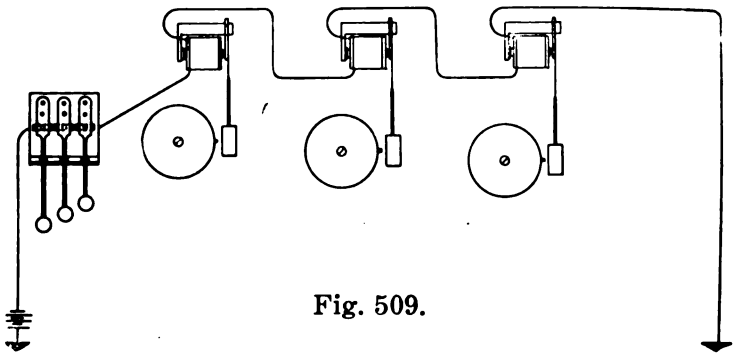


Fig. 509.

The next improvement invented in this line was the system of J. A. Lighthipe's, patented in 1895, which was used to a limited extent by the Bell Telephone Company on the Pacific coast, Fig. 510. Lighthipe's system is almost identical with the harmonic selective party line systems in use today. He was the first one to introduce the condenser in series with the bell across the line to prevent the central office current from flowing through the magnet coils.

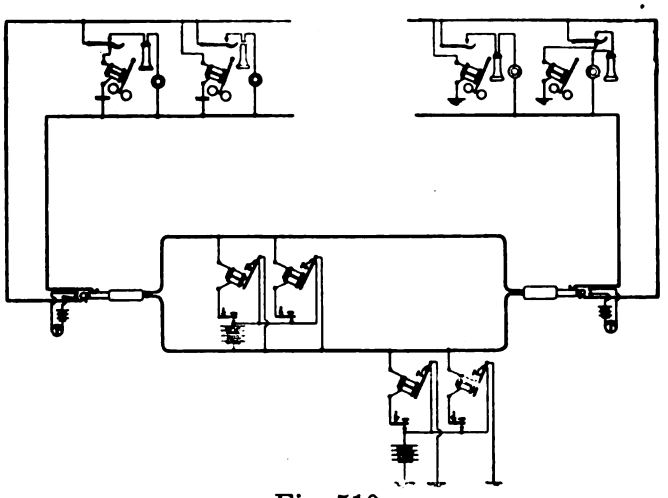


Fig. 510.

It is very easy to see and understand why early harmonic systems were not an entire success. Two things are necessary for the successful

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operation of systems of this class, the current impressed on the ringing mechanism must be of constant frequency and of approximately uniform potential. When we look back on early telephonic conditions, we see that these things were not available. How could we expect to deliver a current of constant frequency and potential to our bells when we had bad lines, no storage batteries, no ringing machines, and if we had had this apparatus we would not have had the splendid sources of electric power at present available to operate them with. What has really made possible the use of harmonic party line systems has been the introduction in the last few years of modern engineering methods into the telephone business. With the advent of the educated telephone engineer came good lines and modern power apparatus, making possible the use of much more refined central office and sub-station apparatus.

Early telephone experts never expected that the time would come when each telephone subscriber would be provided with an individual metallic circuit, consequently a large amount of work was done by them along the lines of developing selective party line systems. I myself remember that in St. Louis, in the early eighties, a system which employed the "step by step" mechanism was used and as high as sixteen parties were rung selectively on one line; this was known as the "Bliss" system. All one has to do is to investigate the United States patent records to convince himself that there is nothing new in selective systems; every possible combination of "step by step" mechanisms, polarized relays, and, in fact, every device known to the mechanician and electrician, were combined to produce different kinds of party line systems.

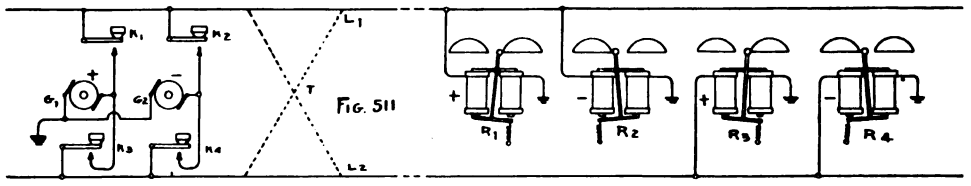


FIG. 511

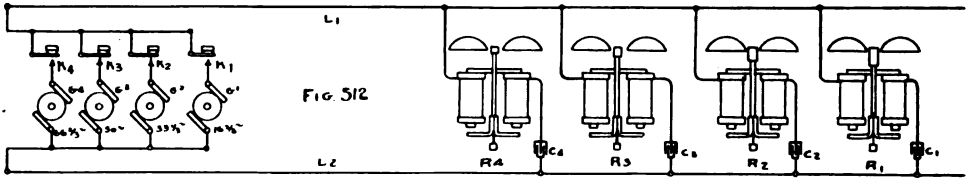


FIG. 512

If a committee of telephone engineers were asked to decide the question as to what things were most desirable in a party line system, their report would be as follows: No earth connections, no relays, no adjustable springs or weights, no step by step mechanisms, and that the ringing of the bells should not be appreciably affected by the capacity or resistance of the line. The only way that such a specification could be satisfied would be to have bells whose operation depends upon mechanical tuning.

In order to bring out clearly the advantages of a system using clean metallic circuits as compared with those using earth connections, it will be necessary to describe briefly the latter.

Referring to Fig. 511, we have represented a subscriber's telephone line consisting of wires L_1 and L_2. Connected to earth from the L_1 line are the bells R_1 and R_2; connected to earth from the L_2 line are the bells

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R_3 and R_4; bells R_1 and R_3 are responsive to pulsating currents of positive sign and bells R_2 and R_4 to pulsating currents of negative sign. Generator G_1 furnishes pulsating current of positive sign and generator G_2 pulsating current of negative sign. The switches, K_1, K_2, K_3 and K_4 are provided at the central office for connecting current of the proper kind to line.

When we consider a system such as that illustrated in Fig. 511 we find that the following objections are present: on account of the presence of earth connections at the sub-stations, the lines are susceptible to bad inductive disturbances, due to electric railway, alternating power and lighting circuits and telegraph. It is apparent that in order that subscribers be rung selectively that each bell be connected to the proper side of line. In other words, the operator when she wishes to ring stations 1 and 2, projects either positive or negative pulsating current on to the L_1 half of the metallic circuit, and when she wishes to call stations 3 and 4, she connects plus or minus current to the L_2 side of the line.

Now, if a line be transposed, say at T, to prevent inductive troubles, or if the wire chief at the central office happens to get a jumper reversed in the process of making a cross connection on the distributing frames, the currents sent out would go to the wrong side of the line, and a wrong subscriber be called, thus causing endless trouble. This class of faults is constantly occurring to my knowledge. In installing telephones in a system such as Fig. 511, the installer is always obliged to locate accurately the proper side of the line before connecting it to the telephone, which operation entails expense and chances for mistakes. When an operator in this system rings a subscriber, say No. 4, with the minus pulsating current, and during the process of ringing the subscriber removes his receiver from the telephone hook, part of the current is carried over to the other half of the line and the bell connected to it which responds to like current, (No. 2) will consequently give a false ring.

Now we come to the description of a modern harmonic selective system. Referring to Fig. 512, L_1 and L_2 represents the two sides of a metallic circuit telephone line. R_1, R_2, R_3 and R_4 are mechanically tuned telephone bells, each having connected in series with it a one microfarad condenser across the line. G^1, G^2, G^3 and G^4 are generators designed to ring them. K_1, K_2, K_3 and K_4 are switches used by the operator for connecting the currents of proper frequency to line. It is evident that no transposition of the line at any point or of the terminals of the instruments can affect the operation of this kind of a system, and inasmuch as each bell responds to an entirely different current, no "cross rings" can be produced by the removal of the receiver during the process of ringing. It is also evident that when telephones are being installed, they can be connected to the line without care or reference to polarity, in the same manner that incandescent lamps are connected to a lighting circuit.

Two of the first problems that present themselves in designing a harmonic party line system are the selection of currents of proper frequencies and voltages and the method of producing the same. Elisha Gray found during his experiments with harmonic telegraph, that frequencies which were related in a ratio of 1, 3, 5, 7 and 9 produced the least interference. It is evident that to produce currents whose frequencies are related in the above manner, it would be necessary, if one driving motor were used, to use belted or geared transmission which is not desirable. It was found that currents whose frequencies were related

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in a ratio of 1, 2, 3 and 4 were sufficiently non-interfering for commercial purposes. Currents or frequencies of 2,000, 4,000, 6,000 and 8,000 were finally adopted and were generated by a set which consisted of a motor direct connected to 2, 4, 6 and 8 pole generators, the whole outfit running at a speeed of 1,000 revolutions per minute. A set of this kind is illustrated in Fig. 513. It was found by experiment that high frequency bells required more power to operate them than the low frequency ones, and consequently it was found necessary to step up the voltages of the generators as the frequency increased. The voltages which were finally found to be the best were for 16 2-3 cycles, 60 volts; for 33 1-3 cycles, 100 volts; for 50 cycles, 135 volts; and for 66 2-3 cycles, 180 volts. These harmonic ringing sets are provided with a governor, by means of which the speed of the motor is kept constant regardless of the vibrations of voltage in the power circuit.

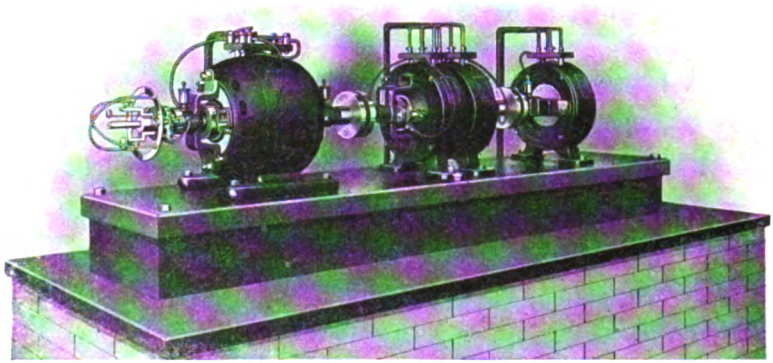


Fig. 513.

We now come to the design of the harmonic bell itself. The following points are essential to a successful harmonic ringer: Its armature must be in perfect tune with the current designed to operate it; it must remain in tune, after once leaving the factory, indefinitely; it must be interchangeable with the ordinary single party telephone ringer, for the reason that a great many of the operating companies find it necessary to change over their old to the new system; it is desirable that the general appearance of the ringer after being installed be the same as that of the ordinary single party ringer, it being sometimes desirable that the telephone users be in ignorance of whether other subscribers are using party or single line service.

Figs. 514 and 515 represent a modern harmonic party line ringer. The design of this ringer is very similar to the ordinary telephone ringer with the exception that all of its parts are more massive. The principal difference lies in the fact that its armature is mounted upon a spring instead of being pivoted. The construction and mounting of the armature is shown in Fig. 514. Each complete armature consists of two punchings P^1 and P^2, a flat steel spring S, a steel tapper rod T, a weight W, and the mounting block B. In riveting together the punchings P^1 and P^2, the lower end of the mounting spring S and the upper end of the tapper rod T

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are firmly attached to the armature as a whole. The part of the tapper rod which is fastened between the punchings is knurled so that it will not slip. The upper part of the mounting spring S is clamped between the block B and plate D which are fastened together by means of two heavy iron rivets. All the riveting in connection with the armature is done in a power press in order that the highest possible rigidity be obtained for the completed article. The block B is provided at its two ends with threaded

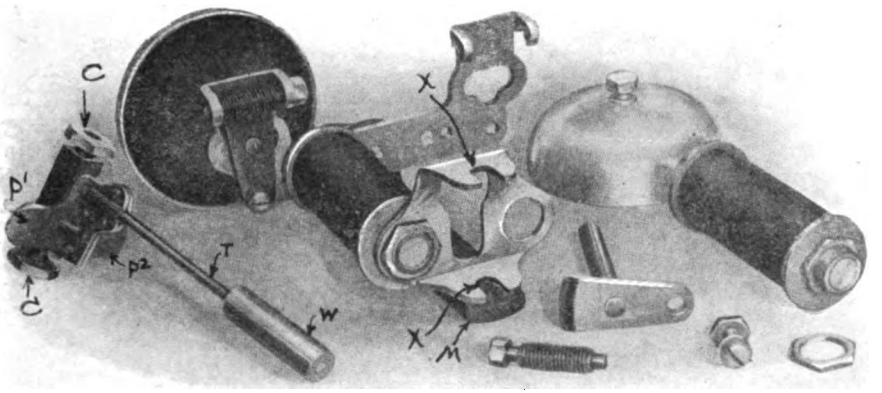


Fig. 514.

trunions C, designed to fit into the slots X of the ringer yoke. After the block B has been slipped into place it is held by the clamping of two heavy nuts provided on its trunions. It was found necessary to make the tapper rod T very much more rigid than that used in the ordinary ringer for the reason that if it was not so, false vibrations would be set up in the tapper

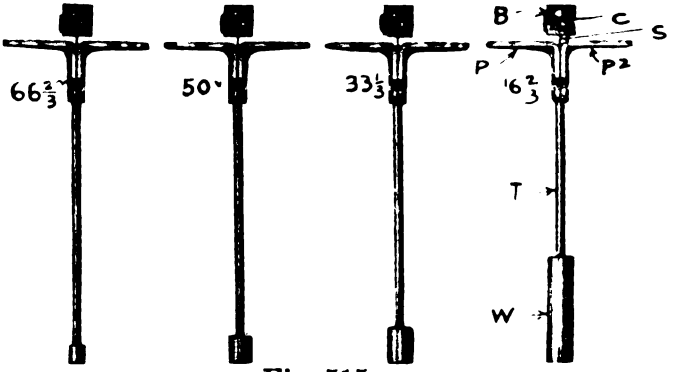


Fig. 515.

rod between the weight W and the armature. In the manufacture of the spring S, special spring steel is purchased in the shape of long ribbons of the proper thickness and width, similar to heavy clock spring, and then cut up and perforated in an ordinary punch press. It was found necessary as shown in the accompanying illustrations, to provide these ringers with a very massive micrometer adjustment for the gongs, otherwise the

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heavy tapper weights would batter back the gongs out of adjustment during the process of ringing.

The method of tuning these ringers is as follows: A set of standard adjusting weights exactly similar to those shown in Fig. 515 with the exception that they are provided with small set screws to clamp them to the tapper rod, are used. The bell to be tuned, minus the gongs, is clamped in a very rigid frame and a very weak current of proper frequency is applied to its electromagnet. On account of the current being extremely weak, the armature will not operate unless it be in absolute tune with it. The tuner raises and lowers the tuning weight until a position is reached in which the armature vibrates violently; when the weight is in this position he knows that the armature is in tune. He then scratches the tapper rod at the upper end of the weight with a small file, and removing the testing weight, he pushes on an exactly similar one by means of a small press provided for the purpose. It can be seen by this construction there are absolutely no adjustments to be tampered with by unskilled labor. A steel wrench is furnished for the different nuts of the ringer, so that there is no excuse for the telephone repairmen using their pliers on them. The assembled armature is now slipped into place, clamped in the proper position by means of the nuts C, Fig. 514. A proper air gap between the mag-

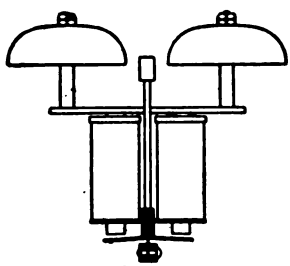


Fig. 516.

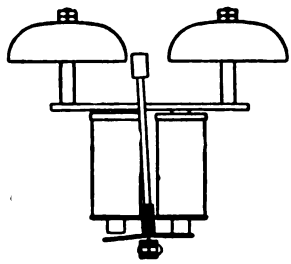


Fig. 517.

net pole piece and the armature is obtained by raising and lowering the yoke which supports the armature. This is done by means of adjusting nuts threaded over the magnet cores as shown in the accompanying illustrations. The gongs are not placed in position on their posts until the bell is mounted in the telephone box. In fact the bell will operate as a buzzer without the gongs, thereby showing that its proper work is not dependent upon the presence or absence of the same. The armature and tapper rod normally stand in the central position with reference to the pole pieces of the magnets and gongs (Fig. 516). On account of the normal position of the armature, with maximum air gaps, giving a minimum magnetic pull, it will not be affected unless the energizing currents are in exact tune with it. When the proper current is thrown on to the line, the ball will then be thrown into violent vibrations, and the ends of the armature brought into contact with the pole pieces, which are bare. The armature in this position is very strongly attracted and comes to a sudden stop on the pole pieces. The gongs are so adjusted that the tapper ball will have to spring about one-thirty-second of an inch in order to hit them. When the armature is alternately coming into contact with the two pole pieces of the permanent magnets, the magnetic pull is so great that it is impossible for the striking of the gongs to throw it out of tune. The ringing position of the bell is shown in Fig. 517.

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It is a well known fact that a device in tune with the energizing force is many times more efficient than one which is not. In working with these absolutely tuned bells I have found that they can be constructed to give any degree of sensitiveness.



Fig. 517a. Dean Electric Co. Harmonic Ringer.

While the motor generator ringing machines previously described serve their purpose, they necessarily limit the use of the harmonic system of ringing to such exchanges as can obtain the necessary electric current

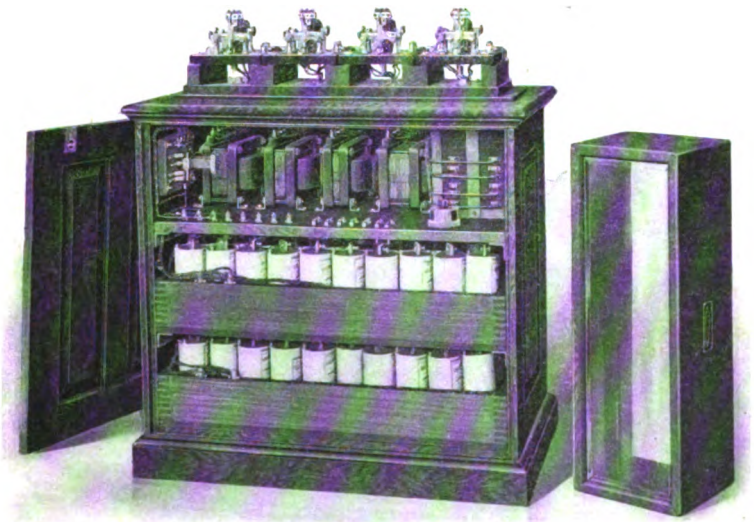


Fig. 518. Dean Electric Co. Harmonic Converter.

for their operation. These machines are furthermore expensive in first cost, also in operation and maintenance, when compared to the cost of a telephone switchboard and the cost of current required to operate it.

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Thus many small exchanges have been prevented from installing the harmonic system, and a big demand created for a simple and inexpensive method of producing the harmonic currents without the necessity of special power circuits and without a big current consumption. The harmonic converter shown in Fig. 518 is a result of this demand. It is made up of four separate units each consisting of a pole changing vibrator, a transformer adapted to the frequency of its associated vibrator and designed to give the proper voltage in its secondary winding for the operation of the harmonic ringers previously described, and a condenser also suitably proportioned to the electrical conditions of the circuits. These units are shown with their connecting wiring in Fig. 519. It will be seen that the vibrators, V_1, V_2, V_3 and V_4 have electromagnets operating armatures similar to the action of an ordinary electric house bell. Upon

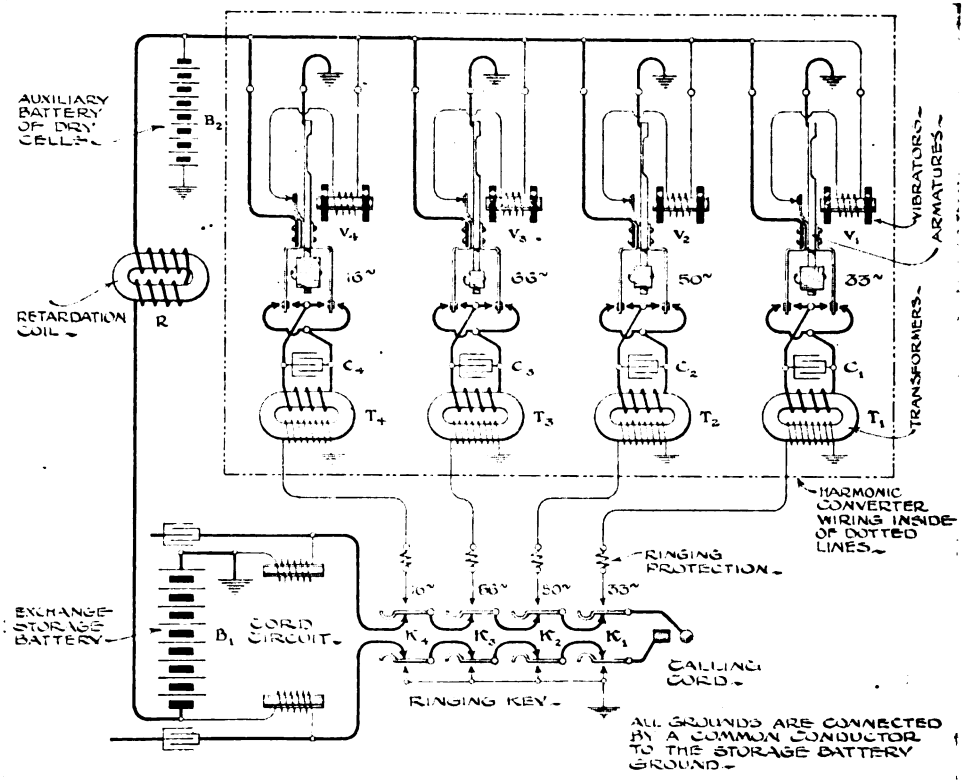


Fig. 519.

these armatures are mounted two springs, which are connected to the terminals of a source of direct current supply. Four contacts are arranged, two on either side of the springs, so that when the armature is drawn up the current will be allowed to flow through the primary winding of the transformer, and when the armature swings back, these latter contacts are cleared and the other two contacts are made, causing current to flow in opposite direction through the same primary winding.

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The condenser C, which is placed across the primary winding of the transformer, takes up the discharges from the coil and prevents sparking at the vibrator contacts. It also assists in rendering the alternating effect in the primary winding more uniform and efficient. One of the secondary terminals on each of the transformers is connected to a common conductor, and together with conductors from the other four free terminals, serve to carry the four frequency ringing currents to the switchboard.

Unlike the direct connected motor driven multi-frequency generator, the separate units of the harmonic converter allow the use of the most desirable frequencies for non-interference in ringing. Thus in some harmonic converters, eight different frequencies are generated, each tuned so as to operate its proper bell without causing any of the remaining seven bells bridged across the same line to ring. This eight party selective system, without the use of grounds or third-wire connection, is only one possibility of the harmonic converter, and represents what can be done in practice if the demand should arise. An incidental advantage in the use of separate units for each frequency is that each vibrator will continue to operate perfectly even though one or more of the other converters or associated apparatus is disabled. In every case the regular subscribers can be rung, as any of the frequencies can be used for this purpose; also all party line subscribers can be rung excepting those affected by the disabled frequency. Thus the use of a duplicate set of harmonic converters is not imperative, although desirable, as the repairing of a defective part can be easily made.

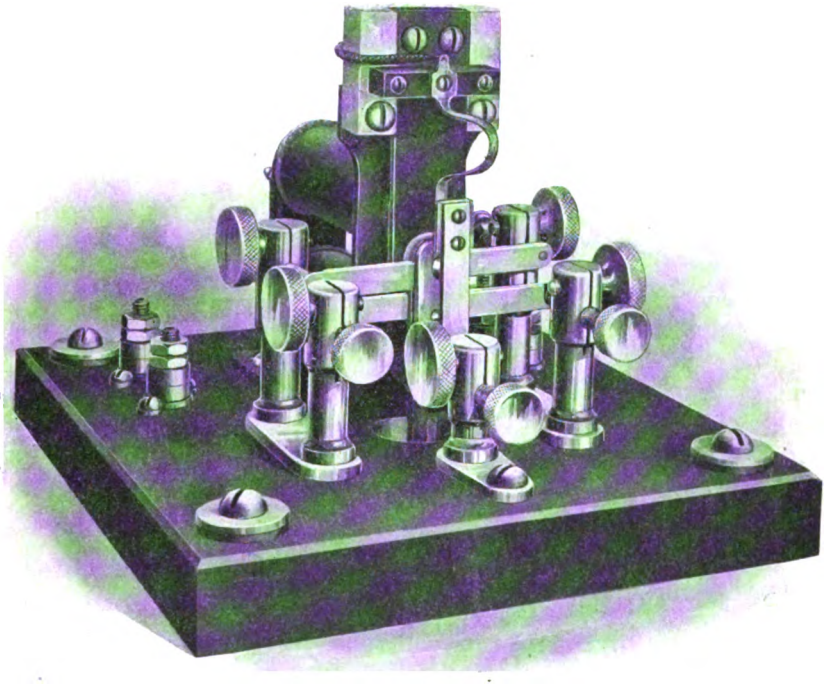


Fig. 520.

The vibrator or pole changing mechanism of the harmonic converter, shown in detail in Fig. 520, is made with massive parts rigidly put to-

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gether so that the continual vibration of the armature will not work them loose. The armature itself is made from one piece of tempered steel cut away at its upper part so as to form a thin spring portion as shown in Fig. 519. This construction obviates the use of rivets, and gives a solid portion of the metal at its top which can be rigidly held in the vibrator frame. The reduced portion of the armature is made rather long so as to give a free and easy armature movement and an indefinite life to the spring. At the lower end of the armature is attached an adjusting weight which is used to get the final tuning of the mechanism to the proper frequency. These weights can be raised and lowered during the process of tuning, and securely clamped in place at the proper position. The main difference in the rate of vibration of the armature is obtained, however, by making its reduced or spring portion of different thicknesses, the highest frequency having the thicker spring. Vibrators constructed on these lines do not vary perceptibly from a uniform rate of vibration, even with great changes in the voltage of the operating circuit. The only noticeable effect is the variation in the amplitude of movement, but this has not been found a serious obstacle when operating within the limits of the voltages usually met with in practice, a change of thirty to forty per cent in the case of storage batteries. A governing mechanism is therefore unnecessary, as the proper frequency is always maintained.

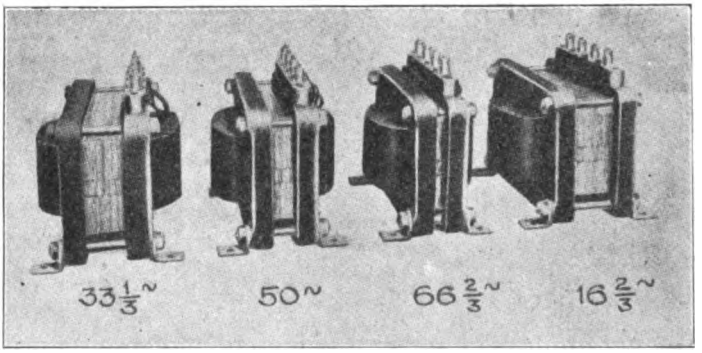


Fig. 521.

The transformers used in the harmonic converter are built after the pattern of those used in electric lighting, with a very efficient closed magnetic circuit. The amount of iron as well as the design of the windings are varied to suit the frequency and voltage required at the secondary terminals, the lowest frequency having the greatest amount of iron and the smallest voltage. The transformers shown in Fig. 521 are of fifty-five watts capacity each, excepting that of the low frequency which is made for twenty-five watts, as not so much power is used in ringing the low frequency bells. The most efficient design of these transformers was found by experiment rather than by following the regular formulæ used in transformer design. When made according to the latter, the exciting or no load current is excessive, due to the character of the alternating current produced by the pole changers. As subsequently shown, the transformers finally adopted are very economical in current consumption, and will stand a very heavy overload.

The first experiments on the harmonic converter were directed to-

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wards reducing the number of contact points in the vibrators, and the most promising scheme developed was the use of a double primary transformer with a vibrator having two contacts, arranged one on either side of the armature, and so connected as to cause current to flow, first in one primary coil of the transformer and then in the other coil but in opposite direction. Thus an alternating current was produced in the secondary winding. Condensers were placed across each of the primary windings of the transformers to reduce sparking at the contacts and assist in the circuit action. It was found, however, that the use of two primaries greatly reduces the efficiency of the transformers, giving less out-put and a greater no-load or exciting current than when one primary is used. Also the breaking of the current at one vibrator contact, which necessarily has a comparatively small amount of movement, limits the output of the machine as well as restricts its use to low voltage primary circuits.

A multiple break and a complete reversal of the current in the vibrator, as shown in the perfected harmonic converter, were thus found necessary to correct these evils. The breaking of the current at the two contact points simultaneously not only reduces the voltage at each break to one-half that of the primary source, but doubles the distance of contact opening in the circuit, thereby allowing the harmonic converter to be operated from the higher voltage primary power circuits.

It has been found in practice that the various frequencies used in the harmonic system of party line ringing, when produced by properly designed alternating current generators, give no noise in the talking circuits or inductive disturbances in the lines when ringing. This is probably due to the character of the alternating current which has a curve approaching that of a true sine wave. The use of a transformer and condenser in a harmonic converter tends to smooth out the current curves produced by the pole changing vibrators so that the quiet effect of the sine waves is obtained.

Another and more important problem presented itself when operating the harmonic converter from a storage battery of a common battery exchange, as the rapidly recurring changes in potential, due to the action of the vibrators, is sufficiently strong to make the entire talking system noisy. When the exchange battery is of large size and the taps for the harmonic converter are taken directly off its bus bars, this noise is only slightly perceptible. But any disturbances of this nature are not to be tolerated in a modern exchange installation, so that efficient means had to be produced to entirely overcome this defect. The use of a retardation coil of sufficient impedance to kill the noise in the talking circuits cuts down the efficiency of the harmonic converter to such an extent that its output is not great enough to ring the bells of the party line system. However, a device was produced as shown in the diagram, Fig. 519, which allows the use of a very high impedance coil and still retains the full efficiency of the harmonic converter. This retardation coil is placed in the supply or feed wire between the main exchange battery B_1 and the harmonic converter, and between them is bridged or floated an auxiliary battery B_2. Like poles of this battery and the main exchange battery are connected to the same wires, so that the auxiliary battery is kept constantly charged, and in fact, is called upon for no discharge except when the electromotive force, due to the main battery is choked down and prevented from providing a peak current, the deficiency being then momentarily supplied for each wave by the auxiliary battery. In fact, the auxiliary battery may be called

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an equalizer, since it really takes up and absorbs the noisy back surgings, which would otherwise produce a disturbance in the entire common battery system. This auxiliary source of current supply can be a small storage battery, or even electrolytic cells, but in practice ordinary dry cells have served the purpose.

The power consumption and actual results obtained in practice from harmonic converters with fifty-five watt transformers will serve as an example of the possibilities of this piece of apparatus. With a twenty-two volt source of current, it requires less than 0.58 of a watt to operate the four vibrators, while with the primaries of the transformers connected, this consumption is increased to about 6½ watts. The latter figure represents the total no-load power required when the harmonic converter is connected for regular exchange work. This machine will furnish power to ring simultaneously over fifty fully loaded lines of four bells each, and while an excessive load, it yet remains in the safe limits of operating. Such a machine will do easily all the ringing of an exchange of 6,000 lines.

When no direct current source of power is available, primary batteries can be successfully used for operating the harmonic converter. In the case of small exchanges, dry cells are used to a large extent. In any event it is desirable to have the primaries of the four transformers normally disconnected from the vibrators so that the no-load current will be at a minimum. This is done by means of a magnetically operated switch or relay, which is in turn operated by contacts on the ringing keys. As previously stated, the total no-load power consumed is less than 0.58 of a watt—the energy required for keeping the vibrators in motion.

The foregoing description of the development of the Harmonic principle, and its application to telephone work, was written by William W. Dean, and is reproduced here by permission of "Telephony."

The Dean Electric Co., have been notably active in the development and perfection of this system, especially the perfection of the vibrating converter. The following instructions for the care of converters applies particularly to the Dean machine, although the general instructions for tests and the location of troubles, etc., can be applied to the several other makes of machines now on the market.

The Harmonic Converter (registered Trade-Mark) is designed to produce four alternating currents of different frequencies from one direct current source in a manner similar to that employed in an ordinary single type pole changer. A direct current of low voltage (our standard Converter is designed for 22 volts) is first changed to an alternating current by a pole changing mechanism and then stepped up in pressure by a transformer so as to give a voltage sufficient to ring regular or party line ringers on all kinds of telephone circuits. Condensers are placed across the primary windings of the transformers so as to prevent sparking at the pole changing contacts, and also to assist in the action of the transformers.

The complete Harmonic Converter, as covered by these instructions, includes four sets of elements just described: i. e., a pole changing vibrator, a transformer and a condenser for the latter. In some cases each set alo contains a condenser in series with a non-inductive resistance, the whole being placed across the motor contact of the vibrator to prevent sparking as subsequently described under the heading "To Prevent Spark at Motor Contact."

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The Harmonic Converter is designed to operate with an extremely small current consumption, about 1-40 of that required by the machines available before its advent, and its design is such as to require very little attention. Like all other electrical apparatus, the Harmonic Converter is susceptible to troubles if neglected, although it may continue to operate, even when abused, but with inefficient results. However, inefficient operation, in time, will produce permanent defects which are sure to disable the machine. Therefore, we have compiled the following instructions taken from personal observations and from valuable suggestions received from several of the users of the Harmonic Converter.

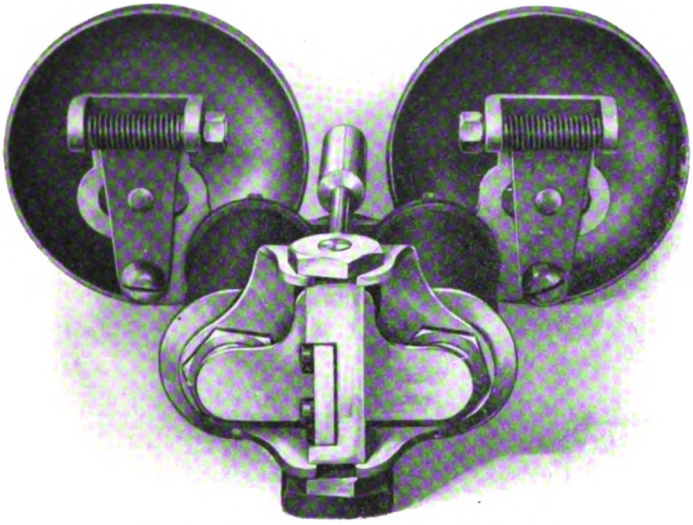


Fig. 522. End View Dean Ringer.

The instruction card found inside of the door of the Converter cabinet gives detailed information regarding that particular machine. The material herein contained is of a supplementary and general character.

Following are some brief answers to questions regarding the Harmonic Converter which will assist in its proper installation and care:

What source of current is required for operating the Harmonic Converter?

A direct current such as can be obtained from a storage battery or primary battery. If the proper wiring is used and the service not too heavy, dry cells can be employed. We make a special Harmonic Converter for the latter purpose.

What is the proper voltage of battery current for operating the Harmonic Converter?

It should be kept at about 22 volts, never lower than 20 or over 24, if the best results are desired. See the instruction card attached to Harmonic Converter for the extreme limits.

If storage batteries are used for operating the Harmonic Converter, how many cells?

Eleven cells connected in series. Under normal conditions this battery will give 22 volts or about two volts per cell. When the cells are

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being charged, the voltage will increase to over 2½ volts per cell, giving a maximum of about 28½ volts for the eleven cells. This is too high for good results and we recommend that a tap be taken off the 9th cell so that the Harmonic Converter can be operated at its normal voltage during the charging period. See "Battery Reversing Circuits" for wiring of an end cell switch.

If dry cells are used for operating the Harmonic Converter, how many?

When the cells are fresh sixteen in series will be sufficient as each cell gives about 1½ volts making a total of 24 volts. If No. 6 dry cells are used, it will require four sets of these series arrangements connected in multiple or a total of sixty-four cells.

The voltage of a dry cell will gradually fall below 1.5 after being in use for a short time so that more cells must be added to each series in order to keep the operating current at its normal or 22 volts. Always add the same number of cells to each series but never more than two, making a total of 18 for each series, or seventy-two in all. See "Battery Reversing Circuits" for wiring of a Dry Cell Harmonic Converter.

How long will dry cells last if used to operate the Harmonic Converter?

This depends entirely on the amount of ringing done and the method of operating the Harmonic Converter. If a starting relay is used and the vibrators are operated only when ringing, a sets of cells should last at least six months on a small exchange (two operators' positions). The life of the battery will depend on the grade of the cells and their care. If directions are followed it will not be necessary to replace all of the cells at one time. See "Care of Dry Cells."

How can worn out cells be detected?

1. By testing all cells with a reliable ammeter at least once a week and replacing those which show a low discharge (not less than 2 or 4 amperes when discharged continuously for five seconds) with fresh cells.

2. By observing the condition of the paste board casing of each cell. If moist or west, the cell should be replaced immediately as it will short circuit and spoil adjacent cells, also dry out and become useless. In any event such a cell will make the whole series, in which it is connected, ineffective.

How can the battery of a common battery exchange be used for operating the Harmonic Converter?

1. By using the extra or duplicate exchange battery if the exchange is so equipped. A switch can be provided so that the battery, not connected to the switchboard, can be used for operating the Harmonic Converter. See Figs. 537 and 538 under the heading "Battery Reversing Circuits."

2. By using the exchange battery direct with our "Noise Killer" to prevent disturbances in the exchange talking circuits.

What constitutes a "Noise Killer" for a common battery Harmonic Converter?

A retardation coil and auxiliary battery, the former preventing the vibrator noise from affecting the switchboard talking circuits and the latter supplying the portion of the current choked out by the retardation coil so that the Harmonic Converter will operate at full efficiency. See "Talking Battery Noise Killer."

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How can the wear on the contacts of the Harmonic Converter be lessened?

1. By reversing the connection of the operating battery periodically so that the current will flow in reverse directions and thereby re-deposit the platinum which is electrically eaten away from the positive contacts and deposited on the negative contacts. See "Battery Reversing Circuits."

2. By systematically inspecting and caring for the contacts. Never allow bad sparking to exist as it will not only wear away the contacts but cause the Harmonic Converter to give an inefficient ringing current, one which will not ring the bells properly and cause noise in the line Circuits. See "Care of Platinum Contacts" and "Adjusting Vibrator Contact Screws."

How often must the operating battery of the Harmonic Converter be reversed to equalize contact deposits?

Once every twenty-four hours, preferably the first thing in the morning.

How often must the Harmonic Converter be inspected?

The condition of the contacts should be observed at least once each week, when the Harmonic Converter is not running, and if necessary any roughness removed from their surfaces. See "Care of Platinum Contacts."

A glass cover is provided over the vibrators so that their condition can be determined at all times when the Harmonic Converter is in operation. It would be well to observe the condition of the vibrators through this cover several times each day and if any of the contacts show undue sparking to remedy the cause at once.

What are the voltages of the ringing current delivered by the type of Harmonic Converter covered by these instructions?

If the operating battery is at normal voltage (about 22 volts) the ringing currents will be as follows:

No. 1 33 1-3 cycles 105 volts,	No. 3 66 2-3 cycles 175 volts,
No. 2 50 cycles 135 volts,	No. 4 16 2-3 cycles 85 volts.

Some of the first Harmonic Converters were made with lower 16 2-3 cycle voltage (about 60 volts). The higher voltage was adopted to assist in the ringing of the regular bridging or rural line subscribers and all Harmonic Converters now are provided for this service.

Will this voltage ringing current break down insulation?

If the proper ringing protection is provided in each of the ringing leads from the Harmonic Converter to the operators' positions no trouble will be experienced. Care should be taken never to allow the Harmonic Converter to get out of adjustment, also to keep the voltage of the operating battery as near normal as possible.

What frequency ringing currents gives best results on ordinary bridging lines?

The 16 2-3 or No. 4 ringing current is best adapted for regular bridging bells. The higher frequencies are too rapid to allow the bell tapper to respond unless the latter is given a delicate adjustment.

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What is the best frequency ringing current for common battery telephones?

The 33 1-3 cycle ringing current will give the best results as the bells in this case are in series with condensers which assist in their action.

How can the Harmonic Converter be made to ring code signals satisfactorily on rural lines?

By keeping the 16 2-3 cycle vibrator operating continuously so that no time will be lost in waiting for its armature to get into full motion. See "Code Signal Ringing Circuit Connections" for diagrams.

What is the proper protection for the ringing leads extending between the Harmonic Converter and each operator's position?

1. Protection relays which act as self-restoring automatic overload circuit breakers. There must be four for each operator, one located in each ringing lead.

2. Incandescent lamps of 16 C. P. 110 volt rating can be used in place of the protection relays. Never use a bell, buzzer, ringing pilot or other inductively wound device on the ringing circuits as the standard Harmonic Converter is not designed for such conditions. Always consult the factory before placing any special equipment in the ringing circuits. Otherwise we cannot guarantee the successful operation of the system.

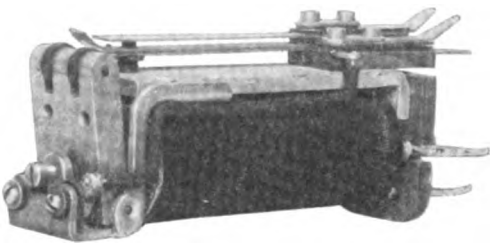


Fig. 522a. Dean Ringing Protection Relay.

GENERAL TROUBLE TEST.

Vibrator Armature Fails to Run:

1. See if motor contact "makes" properly as per "Adjusting Vibrator Contact screws."

2. Test fuse No. 5 in Harmonic Converter and replace if defective.

3. Test battery for voltage and output and if necessary put in good condition.

4. Trace circuit as per diagram and remove defects if any exist.

Vibrator Armature Pulls up against Pole Pieces but does not Vibrate:

1. See that vibrator contact screw "e" breaks contact with its spring "s" when the armature is pulled up against pole pieces. See "Adjusting Vibrator Contact Screws."

2. Test vibrator windings for grounding on core. Replace if defective.

3. Inspect vibrator winding terminals and connecting wires and see that they are not in contact with cores or frame of vibrator.

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Vibrator Armature runs but no Ringing Current:

1. Test fuses Nos. 1, 2, 3 and 4 in Harmonic Converter and replace if defective.

2. See that battery is properly connected to "BP" binding post of Harmonic Converter as per diagram.

3. If starting relay is used see that it is connected properly in circuit as per diagram, also that its armature is pulled up when making test for ringing current.

4. If retardation coil and auxiliary battery (constituting a Noise Killer in common battery exchanges) is used to see that the latter is of proper voltage and output and connected as per diagram.

5. See that pole changing contacts a, b, c and d of vibrator are properly adjusted as per "Adjusting Vibrator Contact Screws."

Vibrator Operates but Ringing Current Weak:

1. See that voltage of battery is normal, about 22 volts, and of sufficient output. If dry battery is used, see "Care of Dry Cells."

2. If a common battery "Noise Killer" is used, test the auxiliary battery for voltage and output and if made up of dry cells, replace with fresh ones when the output is less than 4 amperes. See "Care of Dry Cells."

3. See that pole changing contacts a, b, c and d of the vibrator are properly adjusted as per "Adjusting Vibrator Contact Screws."

4. Remove all "buzzers" or ringing pilot relays from the ringing circuits, such as coils, condensers or broken down insulation in keys and wiring.

5. See that no leakage exists through apparatus bridged across the ringing circuits, such as coils, condensers or broken down insulation in keys or wiring.

Converter Operates but Fails to Ring Harmonic Bells:

1. See that the conditions under the preceding heading are fulfilled.

2. Test each frequency vibrator for proper rate of vibration by one of the methods mentioned under heading "Frequency Testing and Adjusting" and if necessary, change position of weight on vibrator armature.

3. Be sure that Harmonic bells are in proper adjustment, or in other words, have not been readjusted since leaving the factory.

Harmonic Bells Cross Ring:

1. Test battery for proper voltage which is about 22 volts normal and not less than 20 volts or over 24 volts. See "Battery Reversing Circuits" for suggestions regarding battery wiring.

2. Have each frequency of the vibrator inspected as per instructions for "Frequency Testing and Adjusting" and "Adjusting Vibrator Contact Screws."

3. Test the five generator leads extending from the Harmonic Converter to the switchboard for crosses between same, also, if Harmonic Converter is being tested for the first time after installing, be sure that the proper wire is used for the "common" (marked G or GS in diagram) instead of the one of the "frequency" wires (marked 33, 50, 66 and 16 in diagram.

4. Be sure that the harmonic bells are properly adjusted and have not been changed or readjusted since leaving the factory.

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Motor Contact Sparks:

1. See that operating battery voltage is within its proper limits, 20 to 24 volts.

2. Inspect contacts "e" and "s" for roughness and if necessary clean as per "Care of Platinum Contacts."

3. See that the adjustment of contact screw "e" is properly made as per "Adjusting Vibrator Contact Screws."

4. If following the above instructions fail to kill spark, bridge the motor contacts with a non-inductive resistance coil and condenser as per "To Prevent Spark at Motor Contacts."

Pole Changing Contacts Spark:

1. See that the operating battery voltage is within its proper limits, 20 to 24 volts.

2. Have vibrator armature movement sufficient to break and make pole changing contacts properly. See "Adjusting Vibrator Contact Screws" and "Adjusting Motor Contacts."

3. Inspect pole changing contacts a, b, c and d for roughness of surfaces and clean as per "Care of platinum Contacts" if necessary.

4. See that adjustment of contact screws a, b, c, and d are properly made as per "Adjusting Vibrator Contact Screws."

5. See that no leakage exists through apparatus bridged across the ringing circuits such as coils and condensers or broken down insulation in keys and wiring.

6. If following above instructions fail to remedy sparking then test condensers used across transformers for faults such as open or short circuits, also too high or low capacity.

Ringing Noise in Line Circuits:

1. Inspect adjustment of Harmonic Converter vibrator as per "Care of Platinum Contacts" and "Adjusting Vibrator Contact Screws."

2. Test auxiliary battery of "Noise Killer" if used, for proper voltage and output and if made up from dry cells, replace when the output is lower than four amperes. Also test retardation coil of "Noise Killer" for short circuited winding by bridging with a telephone receiver when Converter is in operation. If coil is O. K. a buzz will be heard.

3. If lines are metallic, trouble may be due to improper transposition or lack of transposition.

4. If lines are properly transposed, unbalancing due to leakage to earth will cause trouble. Have tree leakage cleared, also low insulation repaired.

5. Grounded or common return lines are noisy with all kinds of ringing current, more so with the higher frequencies. The only reliable remedy is to make line metallic and transpose.

Buzzing Noise in Talking Circuits of Common Battery Switchboard:

See No. 1 and 2 under "*Ringing Noise in Line Circuits.*"

3. Defective insulation in switchboard wiring, wet cables and dust between key springs sometimes cause generator noises.

4. Some common battery switchboard circuits are unbalanced, and require special wiring to prevent generator noises. In a few cases, the design of the switchboard circuits are defective so that some noise will al-

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ways be induced to the talking circuits regardless of the kind of ringing machine used.

ADJUSTING VIBRATOR CONTACT SCREWS.

The adjusting of the Harmonic Converter springs and screws is a very simple operation but it must be done properly to obtain the highest efficiency as well as prevent sparking at the pole changing contacts. The Harmonic Converter is shipped from the factory with the best adjustment of these contacts and by observing this original adjustment it will be seen that the middle spring "s," Fig. 523, makes contact with its platinum screw "e" and that the four ends of the springs 1, 2, 3 and 4 just clear their respective contact screws b, a, c and d. This is when the vibrator armature is at rest.

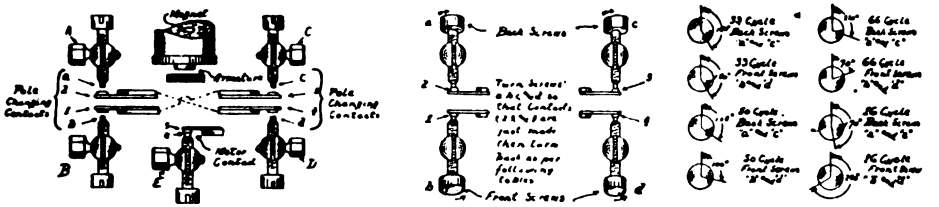


FIG. 523.

All of the necessary adjustment of the contacts is done by turning the platinum screws in or out of their mounting posts as the case might require. The clamping screws A, B, C, D and E are provided to hold the platinum screws from loosening when the Harmonic Converter is in operation. Thus, before adjusting a platinum screw, the clamping screw should be loosened and after the adjustment is complete the same should be tightened so that the platinum screw cannot be turned with the fingers.

Adjusting Motor Contact.—The contact between the middle spring "s" and its screw "e", Fig. 523, is in the portion of the Harmonic Converter circuit which makes that particular vibrator operate. This contact must be made when the vibrator is at rest, the same as a house bell or buzzer. The proper adjustment is obtained by turning this screw "e" in against the spring "s" until the place is reached where the vibrator will not start to vibrate when the operating battery is switched on and the voltage of the latter is at its lowest limit, about 20 volts for a standard Harmonic Converter. Before starting to adjust contact "e" remove fuses Nos. 1, 2, 3 and 4 found on connecting rack of the Harmonic Converter. Fuse No. 5 is in the vibrator circuit and must not be removed in this test. Now turn the screw "e" back about one-eighth turn and test the starting of the vibrator by again switching on current. If the vibrator does not start promptly, it will be necessary to turn the screw "e" back another one eighth turn. Test as before for starting. In this way the vibrator armatures can be adjusted readily for an extreme movement, but its movement should not be sufficiently great to make the armature hit the pole pieces of the magnet when vibrating with the battery voltage at its maximum (about 27 volts for a standard Harmonic Converter unless end cell switches are used as elsewhere explained, then 24 volts will be maximum). Thus, in order to have a safe adjustment, switch on the operating battery

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when it is at its highest voltage (on a storage battery this will be when the cells are being charged and on a dry cell outfit when the dry cells are new and the Converter is just set up, as described under "Battery Reversing Circuits"), and if the vibrator armature hits the pole pieces, turn back the platinum screw "e" until the armature just clears the end of the magnet in its vibration. Be sure that the contact spring "s" rests firmly against its stop at its free end before making the adjustment with the platinum screw. After the vibrator armatures are adjusted so as to start when the operating current is switched on, at both low and high voltage limits—test for proper rate of movement as per "Frequency Testing and Adjusting"—then replace the fuses Nos. 1 to 4 inclusive and proceed with the following adjustments.

Adjusting the Pole Changing Contacts.—The four outside contacts 1, 2, 3 and 4 of a Harmonic Converter vibrator serve to switch the direct current to the primary winding of the transformer so as to flow through the latter in one direction, and on the return movement of the armature, to break this circuit and substitute another connection so that the direct current will flow through the same transformer winding in a reverse direction. This complete reversing of the direct current is maintained as long as the battery is connected to the Harmonic Converter and the vibrator is in motion, thus producing an alternating current for ringing purposes. It will be seen that these four contacts must make and break the full strength of the current used by the entire exchange for its particular frequency and if allowed to spark continuously will cause trouble.

To get the proper adjustment of these four pole changing contacts have the vibrator armature and motor contact adjusted as previously described, then proceed as follows:

See that the contact springs 1, 2, 3 and 4 rest firmly against their respective stops at their free ends. This adjustment is made right when the vibrator is assembled at the factory and should never be disturbed unless new springs are to be put in place, the latter operation being described under the heading "Replacing Platinum Contacts."

It is advisable to adjust one of the contacts (a, b, c, or d) at a time by first turning it through its supporting post so that its end will just touch its platinum contact spring and then turning back the proper amount to leave a small separation between the platinum surfaces. This contact separation is not the same for the different frequency vibrators and must be made as subsequently described and indicated in the following table if the best results are to be obtained.

Vib.	Freq.	Front Contacts	Back Contacts
No. 1	33 cyc.	0.0130″ b & d	0.0130″ a & c
No. 2	50 "	0.0086″ b & d	0.0110″ a & c
No. 3	66 "	0.0060″ b & d	0.0095″ a & c
No. 4	15 "	0.0200″ b & d	0.0150″ a & c

It will be seen that the contact separations are the same for all four screws in the 33 cycle vibrator, while in the 50 and 66 cycle vibrators the separations between the front contacts are smaller than between the back contacts. The 16 cycle vibrator contact separations are smaller for the back contacts than for the front.

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These contact separation distances can be obtained by using a "slip gauge" of the proper thickness, but a more convenient method is to turn the platinum screws back the proper amount after setting them up against the platinum springs as just described. A complete turn of a platinum screw will give a separation of 1-32 of an inch (.031) between the platinum contacts as the thread is 32 to the inch. Now by turning the screws back as indicated separation can be obtained very accurately.

Vib.	Freq.	Contact Screws	Turn Back
No. 1	33	Front b & d	150°, not quite ½ turn
No. 1	33	Back a & c	150°, not quite ½ turn
No. 2	50	Front b & d	100°, slightly over ¼ turn
No. 2	50	Back a & c	125°, slightly over ⅓ turn
No. 3	66	Front b & d	70°, slightly over ⅓ turn
No. 3	66	Back a & c	110°, between ¼ & ⅓ turn
No. 4	16	Front b & d	240°, or just ⅔ turn
No. 4	16	Back a & c	170°, not quite ½ turn.

Be sure that for each vibrator both back contacts "a" and "c", Fig. 523, are adjusted so as to have the same separation, also that both front contacts "b" and "d" have the same separation. As soon as the contacts on the four vibrators are adjusted the fuses Nos. 1, 2, 3 and 4 can be replaced and the current connected to the Converter. If the contact adjustments are made properly, no sparking will exist when the vibrators are operating. However, if any should show, due to a slight inequality in the contact separations, (other parts of the Converter having been previously inspected according to instructions) it can be cleared up by a slight movement (not more than 1-6 of a turn in either direction) of one or the other of the front platinum screws "b" or "d", the adjustment being made with the vibrators in motion. In the latter adjustment, be sure not to move the screws more than 1-6 turn either way as a short circuiting of the contacts may result which will blow the Harmonic Converter fuses and possibly melt the platinum contact surfaces together.

If the Harmonic Converter platinum contacts should become fused together due to an accident short circuiting, they can be separated by a knife blade, driving it between the contacts by a light sharp blow. After separating, clean the surfaces as explained under "Care of Platinum Contacts."

The Harmonic Converter now should be tested for proper frequency, voltage and output as explained under the headings "Frequency Testing and Adjusting" and "Voltage Testing Apparatus."

FREQUENCY TESTING AND ADJUSTING.

The reeds or moving parts of the Harmonic Converter vibrators are made so that they will last indefinitely and vibrate uniformly without a perceptible change in rate of operation. However, a different adjustment in the contact springs or wearing away of the platinum will sometimes alter the speed so that we provide a means for readjusting. Thus, the weights, found at the lower ends of the vibrator armatures, are provided with set screws so as to be raised or lowered. Raising the weights increases the rate of vibration. Lowering the weights decreases the rate.

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Before making a change in the adjustment of the weights, be sure that the Harmonic Converter is operating properly in every other way; that the voltage of the battery and the voltages of the ringing currents are normal; that the vibrators are moving their full amount and that all of the platinum screws are properly adjusted. Also, have some means at hand for testing the frequency of the ringing current so that it will be known when the reeds are vibrating properly.

There are several types of frequency meters on the market which can be used in making this adjustment, but if not available, a set of four accurately tuned harmonic ringers will serve the purpose. These standard ringers should be mounted on a rigid support and wired across a pair of line wires with a 1 M. F. condenser in series with each bell. A 5,000 ohm non-inductive resistance should be placed in series with one of the line wires so that all ringing current to the bells must pass through the same. (See Fig. 524 for proper wiring). This resistance cuts down the ringing current to such an extent that none of the bells will respond unless the ringing currents are exactly in tune with the natural period of vibration of the bells.

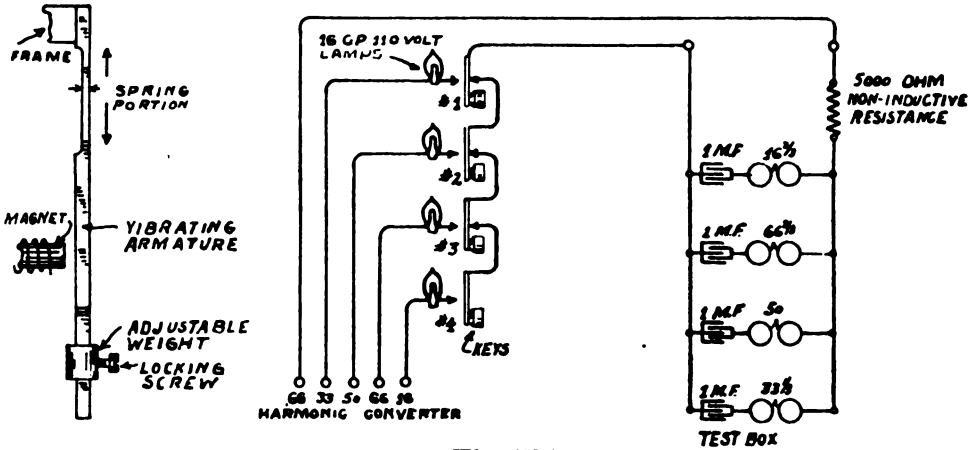


Fig. 524.

If, upon test, it is found that none of the standard bells will respond to its corresponding ringing current, it is evident that the vibrator is not operating at the correct speed.

Now, upon touching the tapper of the standard bell, (when ringing current is applied) it is possible to make it ring, or at least accelerate the movement of its tapper, the vibrator is running too fast to operate the bell. Otherwise, if the bell does not ring, the reverse is true and the vibrator is too slow.

The speed of the vibrator then can be easily increased or decreased, as is necessary to ring the bell, by simply raising or lowering the weight on the end of the armature.

In adjusting the lowest frequency vibrator (No. 4 party, 16 2-3 cycle) always have the weight placed as low as it will go and at the same time operate the standard bell through the 5,000 ohm test resistance.

Before adjusting the armature weight be sure that a mark or scratch is made on the armature projection just below the lower end of the weight.

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This will allow the weight to be replaced to the same position if a better adjustment is not found. A mark of this sort is made after the final adjustment by the factory Testing Department to show the original setting. In changing the weight for adjustment, it is better to do it with small movements, up or down on the armature, rather than by one big movement. This method may take several trials, but the correct position may be ascertained to a certainty and much quicker than by making a big movement of the weight to start with.

It will be found an advantage to mount the standard adjusting bells in a permanent position and wire them through four keys to the Harmonic Converter as illustrated in the accompanying circuit.

VOLTAGE TESTING APPARATUS.

If no high resistance alternating current voltmeter (5,000 ohms at least) is available for testing the ringing current of the Harmonic Converter, very good results can be obtained by using a regular 24 volt switchboard lamp wired in series with the proper non-inductive resistances, as shown in Fig. 525.

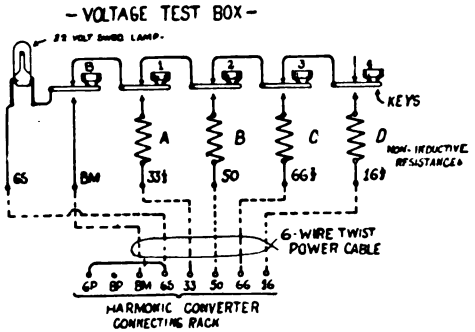


Fig. 525.

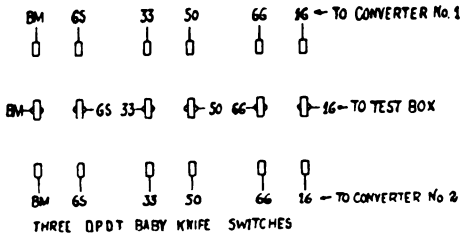


Fig. 526.

It is absolutely essential that these resistances be wound non-inductively and that the entire spool be boiled in paraffine or bees-wax or insulated with armature varnish.

The resistance of the non-inductive windings should be as follows:

For	No. 1	Frequency	33	cycle	use	750	ohms Res.	(A)
"	No. 2	"	50	"	"	1050	" "	(B)
"	No. 3	"	66	"	"	1450	" "	(C)
"	No. 4	"	16	"	"	550	" "	(D)

The lamp should burn at full brilliancy when connected to the proper frequency by pressing the corresponding button. For example, to test the 33 cycle ringing current button No. 1 is pressed, etc. Button marked "B" is for testing the voltage of the battery used in operating the Harmonic Converter. If the lamp does not show full brilliancy when button "B" is depressed, it is an indication of a weak battery and the latter will need immediate attention. It would be well to test the battery in this way before testing the voltage of the ringing currents as it will be impossible to get full strength of the latter if the battery is low in voltage.

The keys, resistance coils and switchboard lamp can be mounted in a small box and located near the Harmonic Converter and wired permanent-

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ly to it. If there are duplicate sets of Harmonic Converters, three double pole double throw baby knife switches can be wired into the circuits extending from the Harmonic Converter to the voltage test box, so that one box will serve for both Harmonic Converters. This wiring is indicated in Fig. 526. We can furnish these voltage test boxes completely wired, also the necessary six wire twist power cable for connecting the same to the Harmonic Converters. These test boxes can be readily made or assembled by the Telephone Company and in this event, we can furnish the separate parts, such as the four resistance spools and switchboard lamp with socket. When ordering the voltage test box or parts of the same, give the serial number of the Harmonic Converter.

CARE OF PLATINUM CONTACTS.

The pole changing and vibrator operating contacts of the Harmonic Converter are made from platinum securely riveted into the contact springs and adjusting screws. With very little attention these contacts will do all of the work required of them and last many years.

To prevent unnecessary waste of platinum and also to give the most efficient operation of the Harmonic Converter, it is essential that the machine be adjusted so that the contacts will not spark. A slight sparking when ringing a large number of bells is sometimes difficult to avoid, but as the sparking then is of short duration, it will not cause trouble.

The continual opening and closing of the circuit at the contacts of the Harmonic Converter will in time cause the positive (+) contact to become blackened and to loose platinum and the negative (—) contact to be whitened and to receive a deposit of the platinum lost from the positive contact. Thus, depressions or pits will be formed in the positive contacts and corresponding tips, or built up portions, in the negative contacts. For example, if the positive and negative poles of the battery are connected to the contacts of the Harmonic Converter as shown in Fig. 527, then the points a, d, 1, 3 and 5 will be eaten away and the corresponding points 2, 4, b, c and e will be built up.

FIG. 527

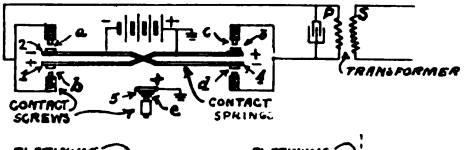




FIG. 528



FIG. 529

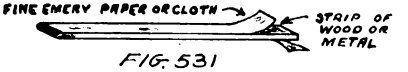


FIG. 531

FIG. 530

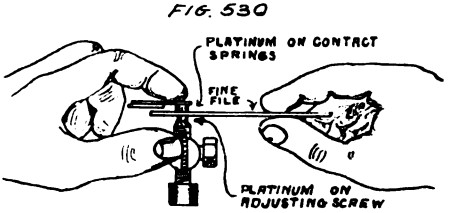




FIG. 532



FIG. 533

By properly wiring the battery so as to allow its connections to the Harmonic Converter to be reversed at least once a week, it will be possible to cause the platinums to deposit in the opposite direction and partially overcome this trouble. (See "Battery Reversing Circuits"). However, a rought pair of contacts will have a tendency to spark and if left in this con-

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dition the pits in the platinum will become very deep and eventually necessitate a complete replacement of parts. Figs. 528 and 529 show enlarged views of a pair of contacts which have been subjected to sparking, the second view showing the result when the sparking is allowed to continue for some time. The contacts should never be allowed to get in either of these conditions.

As soon as the surface of the contacts become roughened, it is time to file or dress them off smooth. This process may be necessary once a week. In dressing off the platinums use a "dead smooth" file with a flat surface. This file should also be thin so as to be readily drawn between contacts as illustrated in Fig. 530.

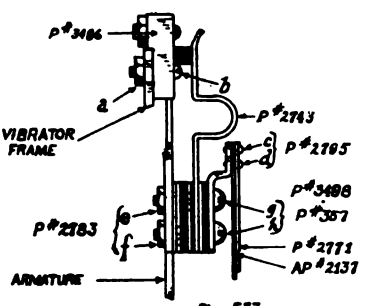
If a file is not available, use emery cloth of the finest grade stretched over a thin, flat piece of wood or metal as illustrated in Fig. 531. Before using this tool, its surface should be rubbed over an iron bar or other hard material so as to render the emery less harsh and prevent roughening the platinum. Always use a file for this work when possible.

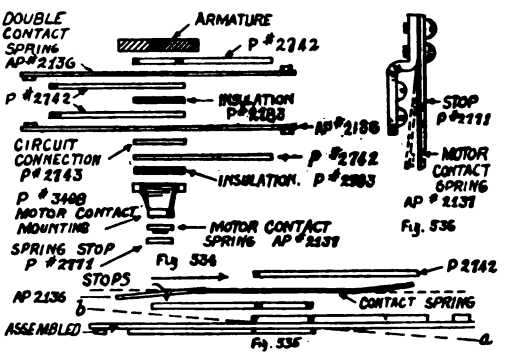
If the contacts are badly pitted, it will be necessary to remove enough of the platinum to reach a smooth surface. This is indicated in the cases shown in Figs. 528 and 529 by the dotted lines.

The file (or emery cloth) should be drawn between the platinum contacts with a light free motion, care being taken to keep the file straight and square with the end surfaces of the platinum. In other words, when the platinums are dressed up smooth, their end surfaces should be parallel as shown in Fig. 532 so as to give the largest possible area of contact between them. If it is difficult to do this properly, then slightly round the end of the platinum in the screw but always keep the platinum in the spring with a flat smooth surface. See Fig. 533.

REPLACING PLATINUM CONTACTS.

When it becomes necessary to replace the platinum contacts of our Harmonic Converter new platinum pointed springs and new platinum pointed screws can be readily substituted for the defective ones.





Figs. 533a, 534, 535, 536.

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The five adjustable contact screws on each vibrator are removed by first loosening the clamping screws in the tops of their respective posts.

The middle or motor contact spring is removed by taking out the screws c and d, Fig. 533a.

The two springs holding the four outside or pole changing contacts are removed by first taking the complete armature off the vibrator frame. This is accomplished by removing the lock nuts marked "a" and screws "b", Fig. 533a. These contact springs are securely held in place by the screws "g" and "h" and lock nuts "e" and "f". When replacing these parts be sure to arrange them in their proper positions as illustrated in Fig. 534 and clamp them securely with the screws "g" and "h". The lock nuts "e", "f" and "a" are used solely to keep the screws from loosening and therefore must be set tight.

All of the contact springs on the Harmonic Converter are provided with stops to limit their movements in one direction. The contact springs should have a slight initial tension against these stops when not in contact with their respective platinum screws. In other words, the springs should normally rest lightly against the stops.

When assembling the contact springs see that their ends are slightly bowed as indicated in the upper view of Fig. 535. Then when the springs are clamped in place between the stops, the proper initial tension against the latter will be had. If this tension is found to be too great, after the springs are clamped in place, it can be reduced by forcing the contact spring back into the position indicated by the dotted lines "a" and "b", Fig. 535.

The middle or motor contact spring, shown in Fig. 536, should have a fairly strong initial tension against its stop, more so than the pole changing springs.

The proper separation between the platinum screws and contact screws is given under the heading "Adjusting Vibrator Contact Screws."

BATTERY REVERSING CIRCUITS.

Under the heading "Care of Platinum Contacts" attention is called to the action of direct current on the platinum contacts of the Harmonic Converter, the material of the surface of one contact gradually eating away and becoming deposited on the surface of the opposite contact. As this action is not uniform for the entire surface of the contacts a roughness will result which has a tendency to cause sparking. We have found that if the battery is reversed periodically this depositing action can be practically neutralized, the platinum deposited on one contact being re-deposited on the opposite contact, etc. In order to be effective this reversing should be done at least once every twenty-four hours, preferably the first thing in the morning.

Battery Reversing Circuits—One Converter—One Storage Battery.—Fig. 537 illustrates the wiring of our Harmonic Converter when operated by one storage or constant current battery. In this case the storage battery is one which is not used for furnishing talking current for the switchboard circuits, and can be eleven small size cells such as "PT Chloride Accumulator." The switches shown in this circuit are as follows:

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Switch No. 1—Four Pole, Single Throw. Lever up—Connects Converter to Switchboard.

Switch No. 2—Double Pole, Single Throw—Fused. Lever up—Starts Converter.

Switch No. 4—Double Pole, Double Throw, Lever down—Battery direct. Lever up—Battery reversed.

Switch No. 5—Single Pole, Double Throw, Lever up—Normal position, 11 cells, Lever down—Charging position—9 cells.

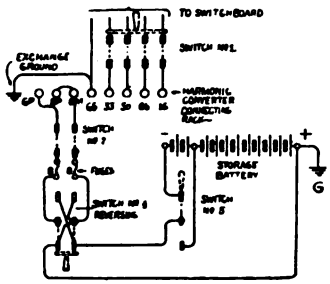


Fig. 537.

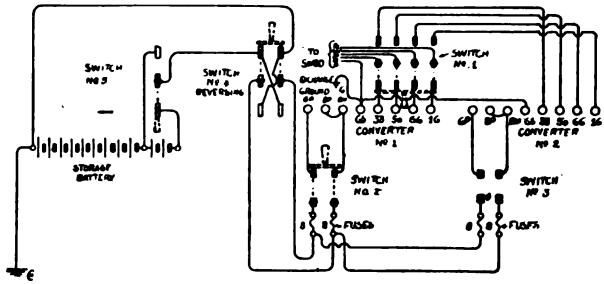


Fig. 538.

Switches Nos. 1 and 2 make it possible to test and adjust the Harmonic Converter without removing the wires from the connecting rack. Switch No. 4 does the reversing of battery as previously described so as to equalize the wear on the contacts. Switch No. 5 is arranged so that the Harmonic Converter can be operated from nine cells when the battery is being charged, thus keeping the voltage practically uniform at all times.

The Harmonic Converter is designed to operate from eleven cells regardless of the charging periods, but it will be found that a higher efficiency can be obtained by keeping the voltage of the current, supplied for its operation, at about 22 volts. This will allow the vibrators to be adjusted for a small range in voltage and not require as close attention as the wider range of adjustment. The use of the end cell switch No. 5 for this purpose will cause no inconvenience as it is always set so as to connect nine cells when charging the storage batteries and immediately when the charging is stopped, it is thrown to the normal or eleven cell position. This operation will give all of the cells practically the same wear, as cells Nos. 10 and 11 receive the same discharge as the remaining nine cells.

Battery Reversing Circuit—Duplicate Converters—One Storage Battery.—Fig. 538 shows a modification of Fig. 537 in that a duplicate set of Harmonic Converters is used. Here it is necessary to make switch No. 1 of double throw construction so that ringing current from only one Harmonic Converter can be connected to the switchboard, the leads to the other Harmonic Converter being automatically cut off when the switch is thrown. Separate starting switches Nos. 2 and 3 can be provided for

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each Harmonic Converter so that the machines can be started and operated independently of each other. This will allow each machine to be inspected and adjusted when the other is furnishing current for the exchange. Switches Nos. 4 and 5 are the same as in Fig. 537. The switches for this complete circuit will be as follows:

Switch No. 1—Four Pole, Double Throw.
Lever up—Connect Converter No. 2 to Switchboard,
Lever down—Connect Converter No. 1 to Switchboard.
Switch No. 2—Double Pole, Single Throw, fused,
Lever up—Starts Converter No. 1.
Switch No. 3—Double Pole, Single Throw, fused,
Lever up—Starts Converter No. 2.
Switch No. 4—Double Pole, Double Throw,
Lever up—Batter direct,
Lever up—Battery reversed.
Switch No. 5—Single Pole, Double Throw,
Lever up—Normal position—11 cells,
Lever down—Charging position, 9 cells.

If a duplicate set of storage batteries are available for operation of this circuit, an additional switch will be necessary and should be wired the same as switch No. 6 in Fig. 540. This switch No. 6 is a double throw and when its lever is in the "up" position it connects exchange battery No. 1, and when in the "reversed" position exchange battery No. 2. The connection of all of the other switches from Nos. 1 to 5 inclusive remain the same as just described.

Battery Reversing Circuits—Duplicate Converters Noise Killer—One or Two Storage Batteries.

When a retardation coil and auxiliary battery are used for preventing noise on the talking circuits of the switchboard as explained under the heading "Talking Battery Noise Killer" a circuit as shown in Fig. 540 should be used. This circuit is for a duplicate set of Harmonic Converters and a duplicate set of storage batteries. The functions of the various switches are the same as explained in Fig. 538 and consist of the following:

Switch No. 1—Four Pole, Double Throw,
Lever up—Connect Converter No. 2 to switchboard,
Lever down—Connect Converter No. 1 to switchboard.
Switch No. 2—Three Pole, Single Throw—Fused,
Lever up—Start Converter No. 1.
Switch No. 3—Three Pole, Single Throw—Fused,
Lever up—Start Converter No. 2.
Switch No. 4—Four Pole, Double Throw,
Lever down—Battery direct,
Lever up—Battery reversed.
Switch No. 5—Single Pole, Double Throw,
Lever up—Normal position—11 cells,
Lever down—Charging position—9 cells.
Switch No. 6—Double Pole, Double Throw,
Lever up—Converter on exchange Battery No. 1,
Lever down—Converter on exchange Battery No. 2.

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If only one exchange battery is used then switch No. 6 can be omitted and the wire from the outside terminal to cell No. 11 connected to the upper contact to switch No. 5 and the wire from the point between cells Nos. 9 and 10 connected to the lower contact of switch No. 5.

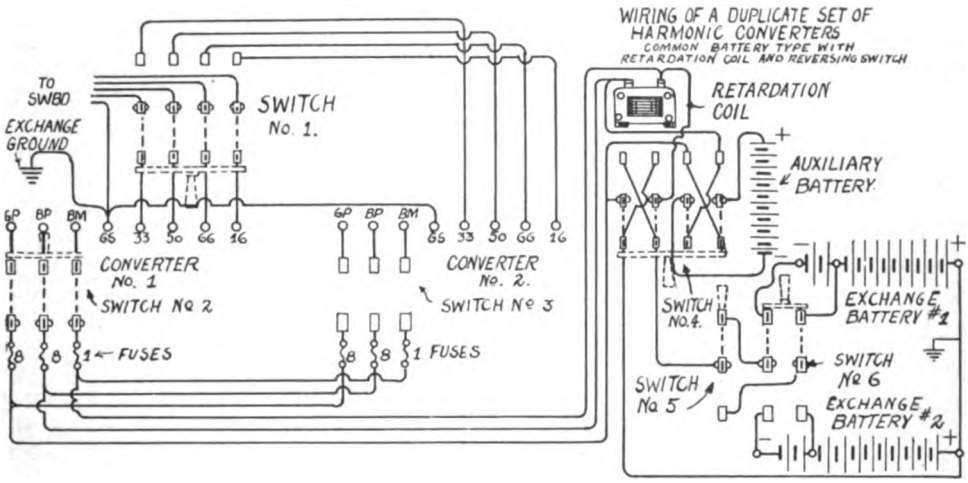


Fig. 540.

Battery Reversing Circuits—Dry Cell Converter.

The reversing of the battery connections to the Harmonic Converter for equalizing the wear on the contacts can be had on the dry cell type by providing a single pole, double throw baby knife switch and wiring the same as illustrated in Fig. 541.

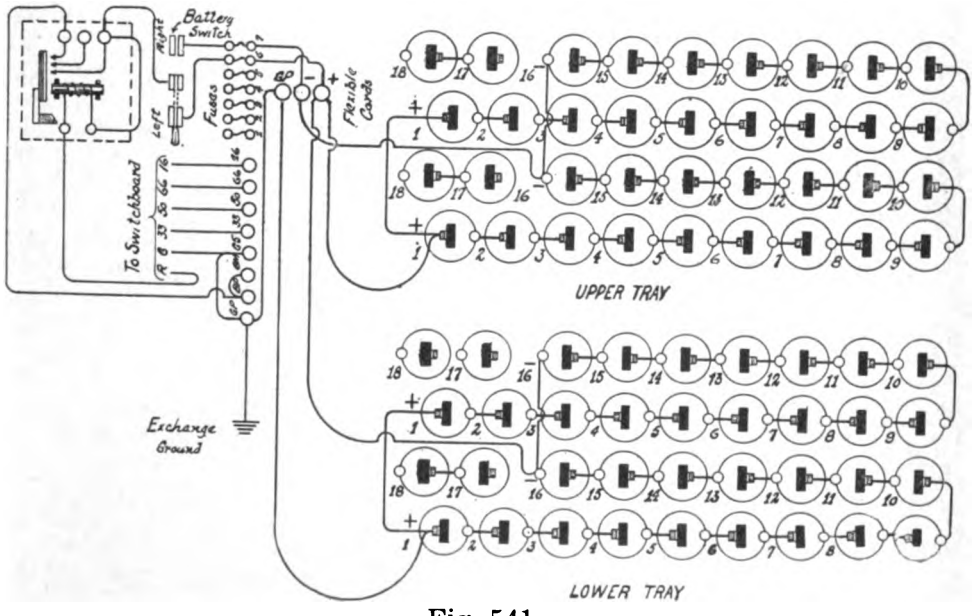


Fig. 541.

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Each of the battery trays should be wired with two sets of sixteen or eighteen dry cells (32 or 36 total cells in each tray) connected in series multiple. The positive (+) terminal of tray No. 1 and the negative (—) terminal of tray No. 2 are both connected to the GP binding posts of the Harmonic Converter, while the negative (—) terminal of tray No. 1 is connected through fuse No. 6 to the left hand contact of the reversing switch and the positive (+) terminal of tray No. 2 through fuse No. 7 to the right hand contact of the same switch. Now when the reversing switch lever is thrown to the right hand position, the upper tray is connected to the Converter circuit furnishing current in one direction and when the reversing switch lever is thrown to the left hand position, the upper tray is disconnected and the lower tray substituted, the operating current then being in a reversed direction.

CARE OF DRY CELLS.

A good dry cell can be made to give excellent results in connection with the Harmonic Converter as the current consumption of the latter is very small when connected to a switchboard in the proper manner. It is absolutely essential, however, that the dry cells be inspected often and all defective ones immediately removed and replaced with fresh cells.

Most dry cells are protected with a pasteboard casing and the latter will absorb moisture if not kept in a dry place. This will cause a quick deterioration of the cell, especially when put in service, as a leakage of current will then exist between adjacent cells.

Battery makers recommend that all surplus stock of dry cells be kept in a cool dry place, but not where they will freeze. The makers also call attention to the fact that a dry cell, when cold, will not show a full reading on a testing ammeter but will give good results when at a normal temperature. This, in itself, is sufficient reason for placing the Harmonic Converter and its dry cells in a room where uniform and normal temperature is maintained.

When installing dry cells in a Harmonic Converter, be sure that each cell is of full rating by testing with a reliable pocket ammeter, or other current indicating device, and also reject all cells which have damp or moist pasteboard coverings. If an ammeter is used, each new No. 6 dry cell should show a discharge of at least 15 amperes when the ammeter connections are made direct with the terminals of the cell as shown in Fig. 543, and not fall below this amount when the discharge is maintained for about five seconds. Continuous discharge of this sort is rather severe on the cell and must not be maintained for any longer period.

In making ammeter tests each cell should be tested separately and the ammeter connected directly across the metal binding posts of the cell. After the cells have been wired in the Harmonic Converter circuit, these tests can be made in the same way and without disconnecting the cells from the circuit. In all current tests have the ammeter firmly connected with the dry cell binding posts as a slight resistance in the contacts will cause a false reading—the needle then indicating a small current flow.

If a voltmeter is used for testing, it will be necessary to discharge the dry cell through a low resistance (about two-hundredths of an ohm), such as can be obtained from a piece of No. 18 B. & S. gauge copper wire, 3 ft. long, and at the same time measure the voltage across the terminals as shown in Fig. 542. In such a test, on new dry cells, the voltmeter

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should give a reading of at least 1¼ volts when the current is discharged continuously through the copper wire for five seconds. An open circuit reading, made across the cell terminals but without any current discharge will give no indication of the condition of the cell. As a matter of fact, a completely worn out cell often will show full voltage reading on the high resistance voltmeter. This same cell will give practically no current and if left in a series of cells will destroy the effect of the whole series.

When no measuring instruments are at hand a rough test for determining the output of a dry cell can be made by observing the heating effect of a piece of wire. For example; a 12 inch piece of about No. 30 B. & S. gauge copper wire held across the terminals of a fresh cell, as shown in Fig. 544, should heat up so as to be almost too warm to hold. If the current discharge maintains the same heat after the wire has been held against the terminals for five seconds, this cell can be considered good. This is an emergency test only and is not recommended for regular use.

While preliminary tests will allow poor cells to be discarded when installing the battery yet these tests must not be considered final. Even in the best makes of dry cells local chemical action often will destroy their efficiency after being in use a few weeks. As has been stated before, one or more bad cells will spoil the complete series, and in the case of a multiple series one bad cell in each series will render the complete installation of dry cells inefficient.

Therefore, we would recommend that the dry cells be inspected at least once a week, and all cells which show a low discharge be replaced with fresh cells of full rating.

Also, all dry cells should be replaced which show wet or moist places in their pasteboard coverings. Such cells will dry out quickly and cut down the effect of the good cells, and in addition will cause a short circuit in adjacent cells and eventually ruin the complete set.

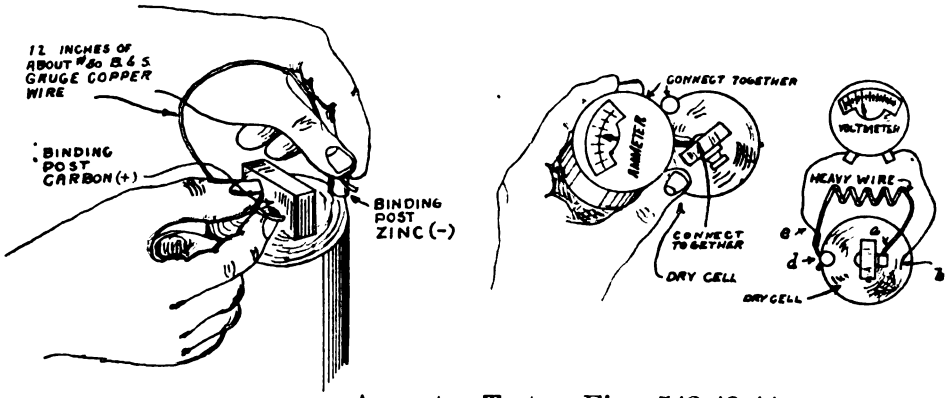
If these instructions are followed carefully the Harmonic Converter will operate always at full efficiency and the cost of the battery renewals will be reduced to a minimum. Thus, it will not be necessary to replace all the cells at one time.

It will be found that the best results are obtained by using dry cells of the same make and size when for a series or series-multiple connection. In wiring the cells into the converter, great care should be exercised to see that the cells are properly connected together and to the converter. Heavily insulated copper wire, at least as large as No. 18 B. & S. gauge should be used for connection between the cells and from the battery to the converter circuit. The ends of these connecting wires should be scraped bright where they are to be held by the binding posts, care being taken not to nick the wire as a slight cut of this sort will be sure to cause break at some future time. Clamp the ends of the wires so as to avoid short circuits between adjacent cell terminals and connecting wires.

New Cells should show an ammeter reading of at least 15 amperes at the end of five seconds, the meter being connected during the entire time.

Old Cells—When in use dry cells will gradually become inefficient and should be discarded when they show an ammeter reading of less than 2 amperes at the end of five seconds, the meter being connected during the entire time.

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Ammeter Tests. Figs. 542-43-44.

In making this test have heavy wire "d" and wire to voltmeter "e" connected together permanently. Then connect "d" to one binding post of dry cell and other end of heavy wire "a" to other binding post of dry cell. After allowing the current to flow through heavy wire for five seconds, remove end "a" and immediately connect wire "b" so as to get reading on voltmeter.

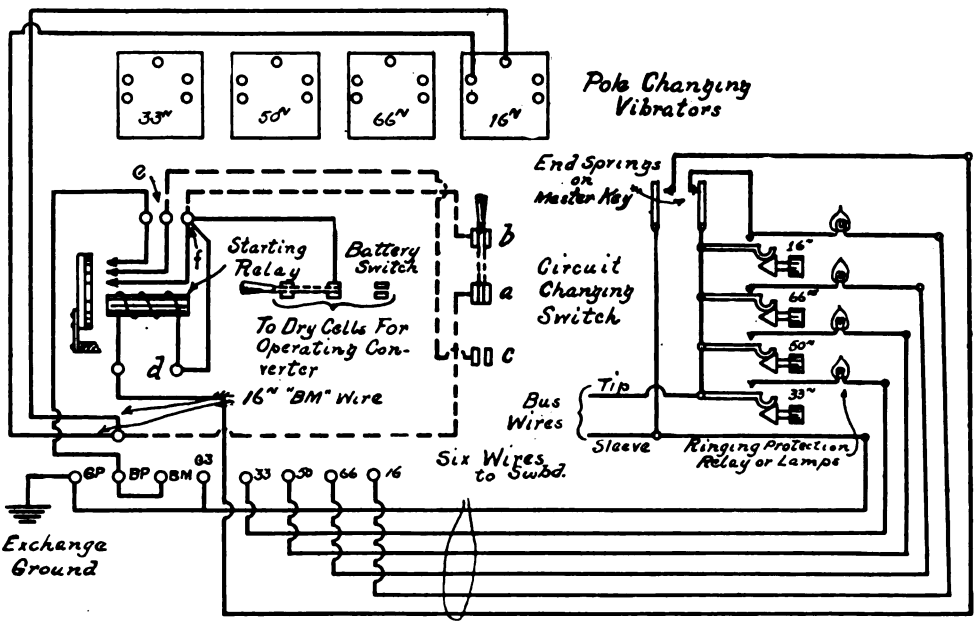


Fig. 545.

CODE SIGNAL RINGING CIRCUIT CONNECTIONS.

It has been found from practical operation in a large number of exchanges that a 33 1-3 cycle alternating ringing current is of too high frequency for the successful signaling on regular bridging or rural lines. Also, any frequency above 20 cycles is too fast to allow the regular bridging ringers to respond properly, especially when the bells are of different makes and the lines heavily loaded or of short length and consequently

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low resistance. This requires that the 16 2-3 cycle ringing current of the Harmonic Converter be used for such service and it has been found to give excellent results. However, the 16 2-3 cycle vibrator is slow in starting, due to the low frequency, so that if a dry cell Converter is used and the same is started with the relay, it will be difficult to ring code signals. If a master key is used and provided with a relay starting contact, the 16 2-3 cycle button can be depressed and held while the ringing of code signals can be done with the regular cord circuit ringing key. In this case the Harmonic Converter will not be running except when actually ringing.

Some operating companies prefer to sacrifice battery current for convenience in signaling bridging lines and keep the 16 cycle portion of the Harmonic Converter operating continuously, at least during the busy part of the day. We show two circuits which will give this kind of service in connection with our standard Harmonic Converter.

WHEN MASTER KEYS ARE USED.

Fig. 545 shows a circuit arranged for use with master keys, the latter being of special construction with an extra set of contacts on the end spring combination. The change in the Harmonic Converter is made by removing the two wires which run from the 16 cycle vibrator to the BP and BM binding posts of the Harmonic Converter connecting rack. The

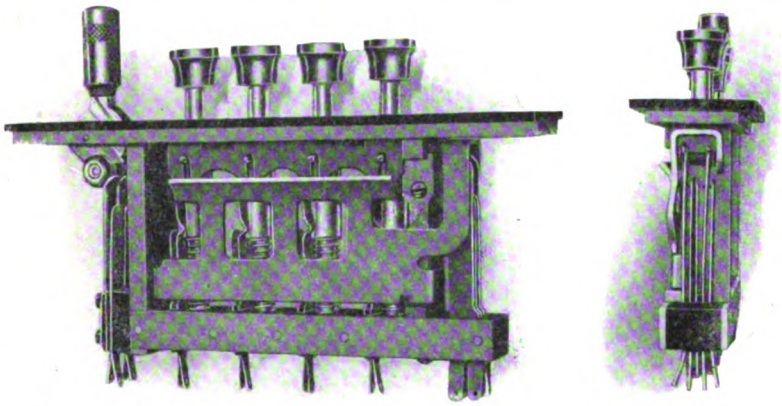


Fig. 545a. End and Side view, Dean Party Line Key.

ends of these wires are connected together and run to the middle point "a" of a single pole double throw baby knife switch. The upper contact "b" and the lower contact "c" of this switch are connected respectively to the upper rear binding post "f" and upper binding post "e" of the starting relay. Now when the switch blade is in the "down" position ("a" connected to "c") the Harmonic Converter will operate in the regular way and the 16 cycle vibrator will be started by means of the relay, thus consuming no battery current except when actually ringing. With the switch blades in the "up" position ("a" connected to "b") and 16 cycle portion of the Converter will operate continuously so that the regular lines can be rung with this frequency without depressing the master key. This circuit changing switch can be located in any convenient position, near the switchboard if thought advisable, so that the operator can have the 16 cycle vibrator operating continuously during rush periods and at

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other times to reverse the connections so that battery current will not be wasted. The special apparatus required for this service are the master keys, as shown in Fig. 545a and the circuit changing switch.

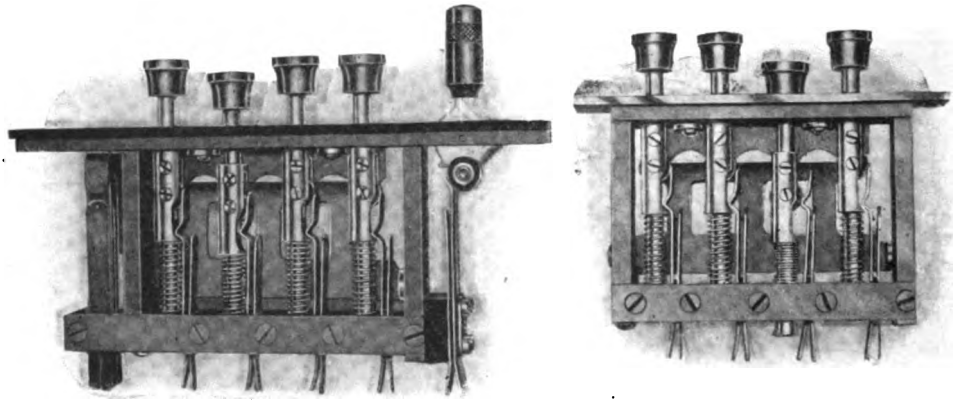


Fig. 545b. Side view of Dean Key, showing Contact Springs.

WHEN INDIVIDUAL KEYS ARE USED.

Fig. 546 shows a modification of the circuit just described, which is designed for use when individual four or eight party ringing keys are provided in the switchboard. The two wires extending from the 16 cycle vibrator to the BP and BM binding posts of the Harmonic Converter con-

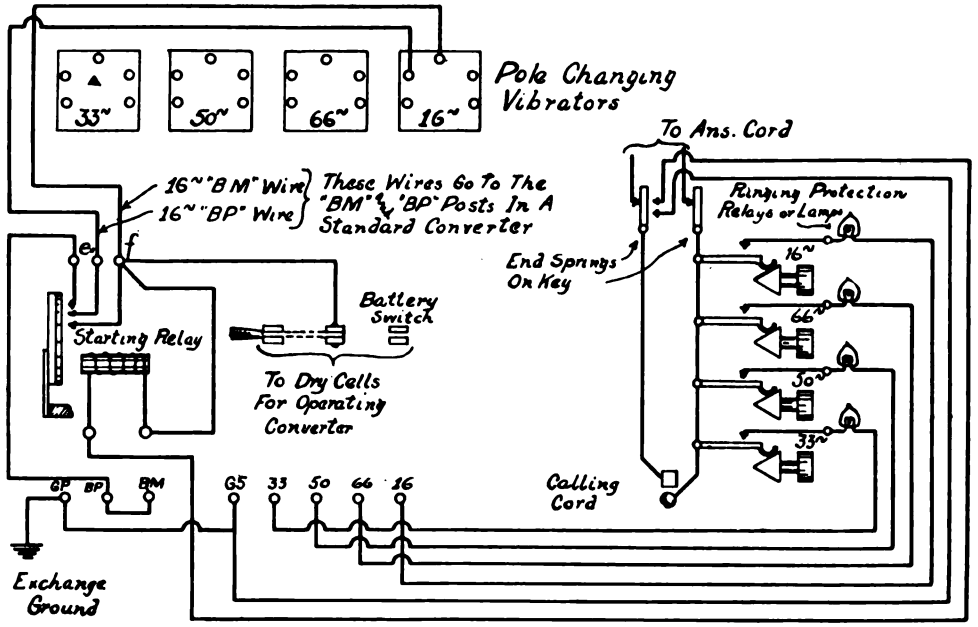


Fig. 546.

necting rack are removed as in the previous case and are connected directly to the upper binding posts "e" and "f" respectively of the starting relay. This change in wiring allows the 16 cycle vibrator to operate con-

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tinuously but without the 16 cycle transformer connected in circuit until a ringing key is depressed. Thus, the advantages of continual operation of the 16 cycle vibrator can be had without unnecessary waste of battery current, as the current required for operating this vibrator alone is almost negligible.

No special apparatus will be necessary to provide for this method of operation.

TO PREVENT SPARK AT MOTOR CONTACT.

The amount of current broken at the motor contact of the Harmonic Converter is of such a small amount that sparking at this point does not occur unless the contact surfaces are in poor condition and improperly adjusted. However, external conditions often influence this portion of the Harmonic Converter so that a slight spark results. This spark is not of a destructive nature as long as the current is periodically reversed (see "Battery Reversing Circuits") and the contacts kept clean (see "Care of Platinum Contacts")

The spark at the motor contacts can be done away with entirely by placing a condenser and a non-inductive resistance in series and across this portion of the vibrator circuit as shown in Fig. 547. A No. 6040 condenser and a No. 6605 resistance coil should be used. The condenser and coil for each vibrator can be placed in the space directly below the slate vibrator base, care being taken to fasten them so as not to jar forward or interfere with the vibrator armature.

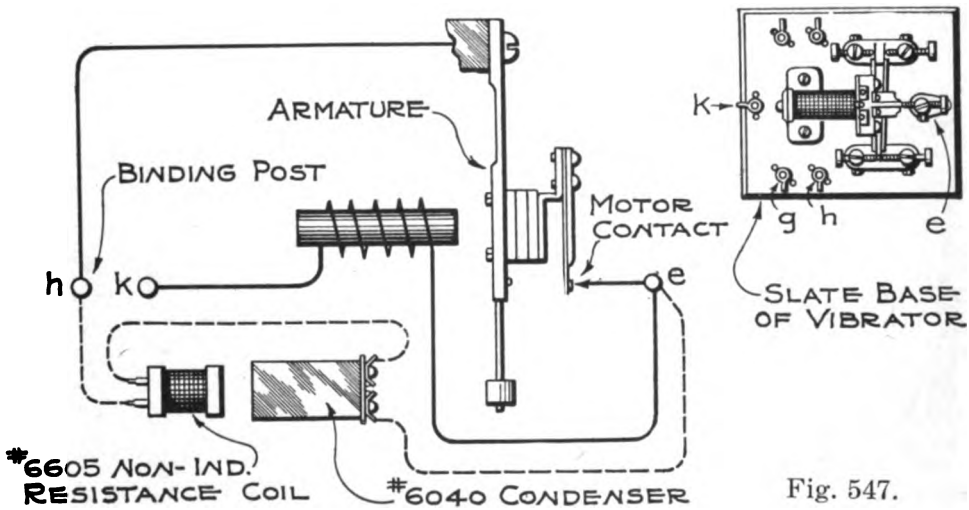


Fig. 547.

TALKING BATTERY NOISE KILLER.

When the Harmonic Converter was designed one of the first problems was the elimination of buzzing noises in the talking circuits of a common battery exchange, when the Harmonic Converter was operated from the same storage battery which furnished current to the switchboard. If the exchange has a duplicate set of storage batteries, switches can be provided so that the Harmonic Converter always can be operated from the battery which is idle, thus doing away with these buzzing noises and without the use of special apparatus. However, as this battery usually receives a charge when not connected to the switchboard, special end cell switches should be provided as illustrated in Figs. 537 and 538 under

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the subject "Battery Reversing Circuits" so as to keep the voltage of the current supplied to the Harmonic Converter, practically uniform, (about 22 volts).

Fig. 548 shows the theoretical arrangement of the "Noise Killer" circuit devised by the Dean Co. It consists of a special retardation coil of low resistance and high impedance and an auxiliary battery, the latter being connected between the coil and the Harmonic Converter. The use of a retardation coil alone will cut down the efficiency of the Harmonic Converter to a greater extent than it will cut down the buzzing noise in the switchboard talking circuits so that the auxiliary battery must be used to supply the momentary impulses of current which the retardation coil chokes out. The drain on the auxiliary battery is so slight that large size dry cells (No. 8) can be used for the auxiliary battery on small exchanges, but for large common battery installations the auxiliary battery should be small storage cells. The latter cells need not be larger than PT size "Chloride Accumulators" for exchanges up to 6,000 lines. With a proper size retardation coil the storage cells will be charged automatically thereby requiring practically no care to keep them in proper shape.

When dry cells are used for the auxiliary battery it will take thirty-four of the No. 6 size connected in series multiple, seventeen in each series, or if No. 8 size cells are used, one set of seventeen in series will do. If small storage cells are employed only ten will be required, one less than the eleven cells of the exchange storage battery used for operating the Harmonic Converter. This will allow the small cells to receive their charge directly from the exchange storage battery through the "Noise Killer" retardation coil.

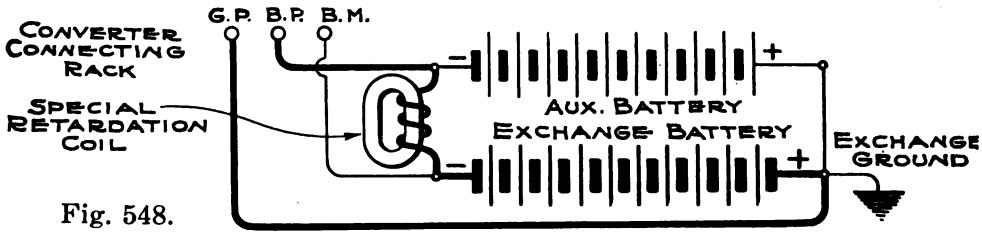


Fig. 548.

In connecting the auxiliary battery of the "Noise Killer" to the Harmonic Converter circuit great care must be taken in having it arranged so as to furnish current in the same direction as the exchange storage battery, otherwise a short circuiting of the cells will result. See the accompanying sketches.

From the fact that the "Noise Killer" is designed to do away with the buzzing noise on the switchboard talking circuits, it is evident that any such noise may indicate trouble in the auxiliary battery. A poor auxiliary battery not only cuts down the operating efficiency of the Harmonic Converter but also causes the pole changing contacts to spark. Thus, a buzzing noise in the talking circuits or inefficient ringing will serve as an automatic indication of worn out dry cells in the "Noise Killer" circuit (if dry cells are used) or trouble in the small storage cells, if the latter are used. See another portion of these instructions for "Care of Dry Cells" or the instructions accompanying the storage battery, if the latter is used.

One of the most important factors in the successful operation of a harmonic system of selective ringing is the keeping of the various currents used at the proper frequencies. Where a motor driven set is used for the source of ringing current the frequency can be found at any time

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by a speed indicator and a watch. However, in a large number of cases the ringing currents are furnished by pole changers.

Since these pole changers have no rotating part, determination of the frequency of the current delivered has been a task of some difficulty. Although the meter here described furnishes a convenient means of measuring the frequency of any alternating current, it was primarly designed to meet the need of a meter to be used with polechangers.

The principle employed is that of counting the alternations which pass through an electromagnet in a given time. To this end a spring-driven wheel is held from rotating by a pallet mounted on an oscillating shaft. Fixed on this shaft is a light polarized armature, which is held by one or the other pole of an electromagnet through which passes the current whose frequency is to be measured. Each alternation, by reversing the polarity of the electromagnet, allows the force of the wheel to detach the armature from one pole and throw it to the other where it is held until the next following alternation. Connected to the escape wheel by suitable reducing gears are hands which move over a dial. The hands are set to zero, current is allowed to pass through the magnet for a given time and, since each alternation permits the hands to advance, the total alternations during the period may be read from the dial.

The highest frequency used in telephone work is 4500 cycles per minute or 75 cycles per second; this requires the escapement to act very rapidly to respond to such a current. The method of obtaining this speed may be explained by reference to Fig. 549.

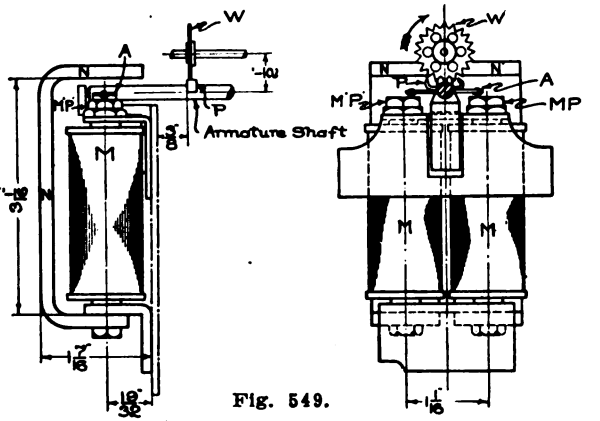


Fig. 549.

A prime-driven wheel W has teeth which engage with the impulse faces of the pallet P mounted on a rock shaft. To this shaft is attached a light armature A with ends similarly polarized by the permanent magnets N and N'. An electromagnet MM has poles MP and M^1 P^1 which act as stops to the motion of the armature and hold the armature in either position against the force of the wheel as transmitted through the pallet. For example, assuming the left-hand armature to be held by $M'P'$, if a current is now sent through MM in a direction to weaken the magnetism of $M'P'$, as soon as this holding force is made less than the force of the wheel tending to throw the armature from the magnet, the armature will rotate to the right, come in contact with the MP, the tooth of the wheel will escape the right-hand point of P and the escapement will come to rest with a tooth of the wheel locked on the left-hand point and tending to rock the shaft to the original position. However, this motion will be pre-

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vented by the attraction of *MP* for *A*. The next reversal will weaken the electromagnet, and the armature will then return to its original position. It is evident that for each cycle of two alternations the wheel *W* will be advanced one tooth, and by connecting hands to *W* by suitable reducing gears the number of cycles passing through *MM* may be read.

This escapement is very sensitive, for all of the work of rocking the pallets with the attached armature is done by the force of the wheel, which, as before stated is driven by a spring. In practice the inventor states that he has had no difficulty in constructing this escapement to respond positively to currents of 165 cycles per second, considerably above the frequencies met in commercial work. If there were any reason for so doing it is probable that the mechanism could be made to respond to frequencies of 300 cycles per second, since it is only a question of the torque on the wheel *W*. In this case, however, one would perhaps have to use a small transformer to step the current up to about 400 volts to overcome the high impedance of the magnet *MM* at that frequency.

The current required to run this meter is very small, on the order of 0.005 amp; the magnet is made with a resistance of about 1,000 ohms and with this resistance requires for a current of 70 cycles per second a voltage of about 80 across its terminals. For lower frequencies less voltage is of course required.

From the construction of this meter it will be seen that its indications are independent of the wave form of the current measured. In fact, since there is a condenser wired in circuit with the magnet *MM* it will respond to makes and breaks of a unidirectional current. It is not affected by temperature or variations of voltage. Providing that enough current is sent through it to work it, any excess will not change its indications.

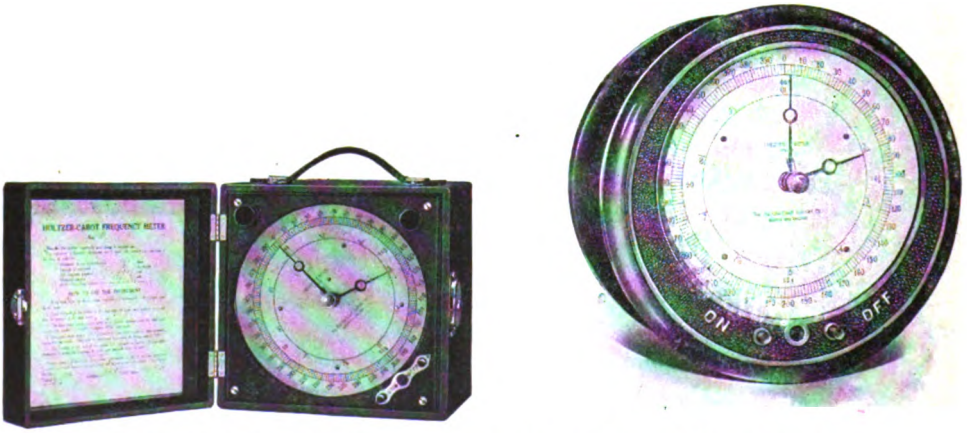


Fig. 550. H. C. Co., Portable type—Switchboard type.

While this meter was designed primarily for work with pole changers, it is very convenient for measuring the frequency of an alternating current of any kind. One does not have to be at the generator, as is the case where a speed indicator is used, but may use the meter in any place where the wires carrying the current are accessible.

In addition to the Dean harmonic ringer previously described, in

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which the period of the vibrating reed is determined by means of clappers of different weights, several other forms of construction are offered.

The Stromberg-Carlson harmonic ringer is shown in Figs. 551 and 552. The weights as shown, are permanently fastened on the end of the armature, to the centre of which is riveted a steel reed. When assembling each ringer, the adjustment is secured by grinding this reed, thereby allowing for inequalities in material or manufacture.

The 16 cycle ringer is wound to a resistance of 2500 ohms and the 33, 50 and 66 cycle ringers to 500 ohms. The only difference between the 16 and 33 cycle ringers is in the size of the armature weights, the 33 cycle being smaller. The reeds are also differently adjusted.

In the 50 and 66 cycle ringers shown in Fig. 552 no armature weights are used the adjustment of the reed being all that is necessary.



Fig. 551.

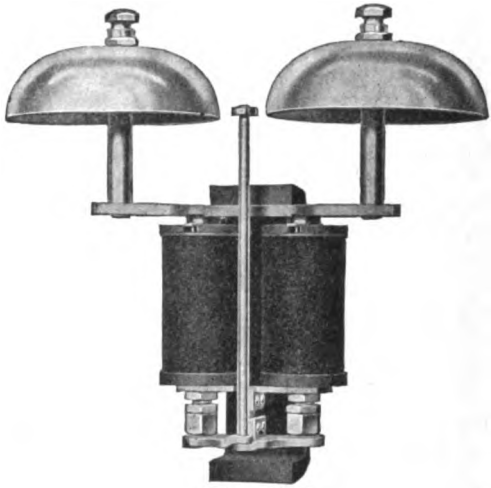
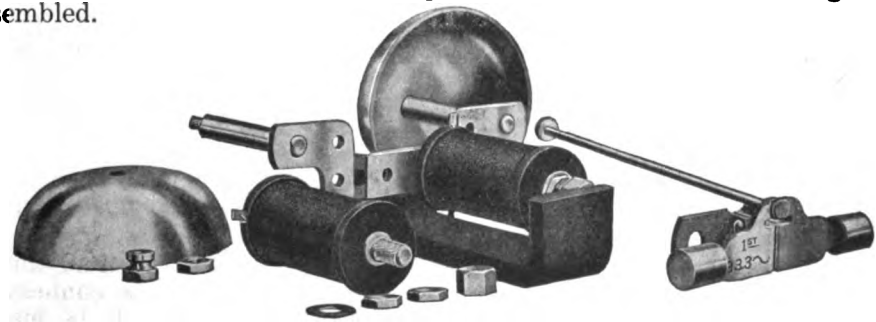


Fig. 552.

The design of the ringer is such that a complete disassembly of all parts may be had by taking out the complete armature and the ringer spools. The distance of the pole pieces from the armature is adjusted by turning the pole pieces up and down and locking same into place by means of lock nuts provided for the purpose. This adjustment is made in the factory and very seldom if ever need be changed by the customer except when the instrument is used on very long or high resistance lines. The lower end of the pole pieces fit into slots in the mounting plate to avoid any possible twisting or working loose of these parts. Fig. 553 shows the ringer disassembled.



Underground Fig. 553. Underground

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The only adjustment necessary when putting up the instrument is to properly adjust the gongs same as in an ordinary ringer. The gong posts are riveted to the mounting plate and the adjustment of the gongs is obtained by having them drilled slightly off centre. Loosen the lock nuts holding gong, and turn with the fingers until the gong is proper distance from the striker ball, this being determined by asking the operator to ring on the line with the proper current. Adjust the gong so that a loud ring is secured. Then ask the operator to ring on the line with the other three currents, in which case the clapper should not tap the gong. If it does, the distance between the clapper and the gong should be adjusted to allow the clapper to vibrate but not hit the gong except when actuated by the proper current. To prevent the gongs from working loose, due to the vigorous vibration of the tapper rod, lock nuts are furnished.

Fig. 555 shows the usual method of wiring magneto phones for harmonic ringing. The generator has a special commutator, designed to give a rapidly pulsating current which does not affect the ringers on the line, when calling central. In series with the harmonic ringer is placed a 1 M. F. condenser.

It will be noticed that these instruments are wired for either 4 or 8-party service. When using the instrument for 4-party service with a single wire grounded line, connect the line wire to either one of the line posts and the ground wire to the remaining line post and the centre post marked G. Then connect clips A and B consisting of the bell terminals, to terminals marked 1 and 2.

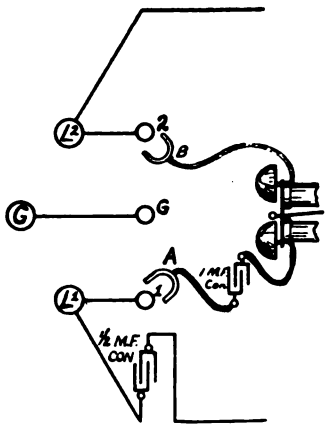


Fig. 554.

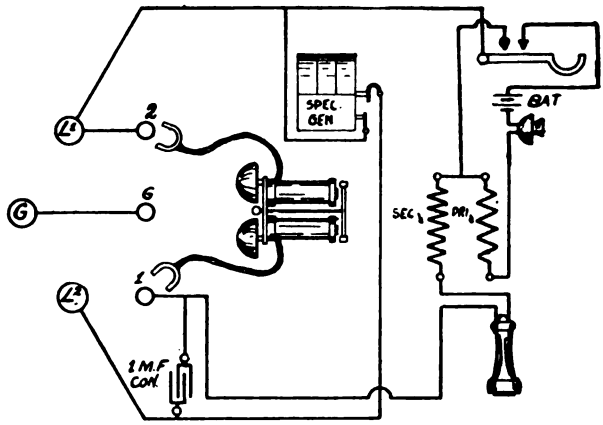


Fig. 555.

On metallic lines connect the line wires to the two line posts marked L1 and L2, and connect the centre post marked G to ground if lightning protection is desired,—if not, do not connect anything to G. Connect bell clips A and B to terminals 1 and 2.

From the above, it will be noticed that no particular method of connecting the instruments is followed, and the instruments need not be put up in rotation. That is, on a line, the fourth party 'phone can be put up first. Then the second, then the first or third.

When used as eight-party instruments, it is necessary to bridge four bells from each side of the metallic line to ground. Talking is at all times metallic. In putting up an instrument, the line wires should be connected to the line posts, and a ground wire to G. This ground should be made

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in the best possible manner to insure satisfactory ringing. After observing these points, ask the operator to throw the proper key for the party it is desired to connect the instrument up for, and it will be found that by connecting B clip on bell to terminal G, and then connecting A clip to terminal 1 or 2 that in one of these positions, the bell will ring. Of course the bell must be adapted to the cycle current being used.

When through connecting the eight instruments in the manner above described, it will be found that four of the bells are bridged from each line to ground, and it will be observed that the method of connecting these instruments and testing out is far simpler than with any system heretofore offered.

In another type of this instrument two condensers are used instead of one, viz., a 1 M. F. condenser in series with the ringer and ½ M. F. condenser in series with the receiver, as shown in Fig. 554. By the use of the low capacity condenser in the receiver circuit, it is possible for one party on a line to call for another party on the same line without having to hang the receiver on the hook, while Central is ringing the wanted party. While the single condenser circuit shown in Fig. 555, accomplishes this to some extent, still better results in some instances are secured when two condensers are used. In exchanges where parties on the same line do not call for each other frequently, it is unnecessary to use the instrument with two condensers.



Fig. 556.

Any standard magneto telephone can be re-equipped for this system by changing the ringer and installing a condenser in the ringer circuit, the condensers usually being mounted on the door of the telephone. It is advisable to install the special generators as above referred to, but in a great many instances the telephones can be very satisfactorily operated without any change in the generator except to remove therefrom one or two of the bars or magnets, thus weakening the generator current. This combined with the use of a low wound drop at the switchboard prevents the generator current from causing any of the party line bells to tap.

The vibrating converter furnished by Holtzer-Cabot Electric Co., is

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shown in Fig. 556. In operation and principle it is similar to those previously described. Fig. 557 shows one of the vibrating units, and Fig. 558 shows one method of connecting this converter to a master key. This machine is furnished complete with a separate switch for each unit, a reversing switch, fuses, etc., mounted on a slate base in the cabinet, which also holds the transformers and batteries. This makes a very convenient set and one in which trouble can be located or adjustments made without loss of time.

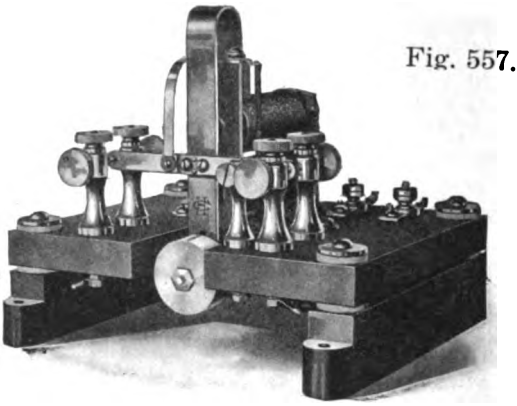


Fig. 557.

Referring to Fig. 558, it will be noted that the 33 cycle vibrator is allowed to run all the time, to supply ringing current for ordinary bells. The 16, 50 and 66 cycle vibrators however, do not start unless a master key button is depressed.

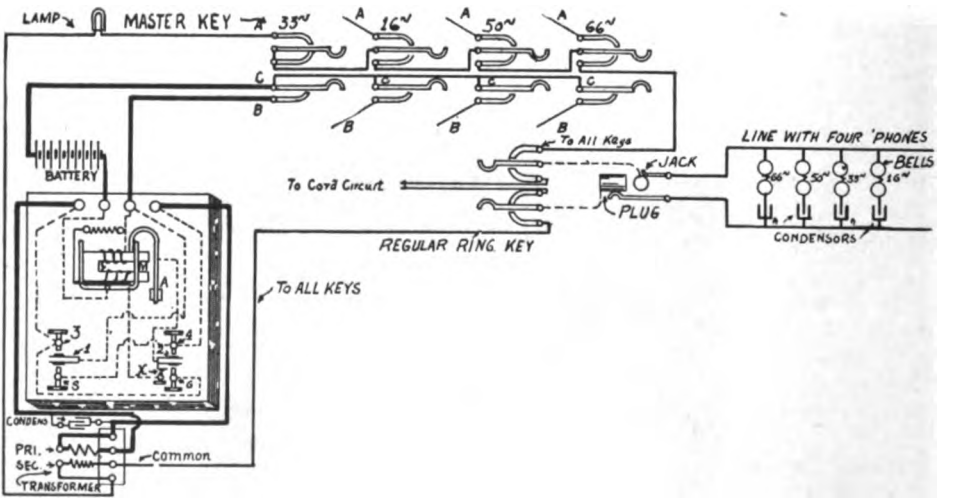


Fig. 558.

When using a master key for starting the vibrating units, care must be taken to allow sufficient time to elapse for the vibrators to reach their proper speed, before operating the cord ringing key, otherwise more than one bell will ring. This is particularly liable to happen with the 16 and 33 cycle units, which take 1½ to 2 seconds to reach their proper speed.

As each exchange often requires a special circuit arrangement, and each switchboard system differs in details, no attempt will be made to show the varied key and circuit combinations used with this harmonic equipment, as sufficient has been said to show that it is capable of arrangement to meet any occasion in magneto or common battery work where an efficient selective signalling system is necessary.

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CHAPTER XIII.

LINE AND CABLE CONSTRUCTION.

One of the most essential elements in first-class telephone service is good outside construction. Poor construction is always getting out of order, and the cost of maintenance in two or three years will far more than exceed what good construction in the beginning would have cost. Poor construction not only proves a source of annoyance to the owner of the individual line which is poorly constructed, but it makes the entire service bad when this line is connected to the switchboard with others. In this respect a telephone exchange is not unlike the human system, as one broken arm or leg effects all the other members, so does one bad line affect all the others.

The following brief specifications will serve as an indication of the usual methods of construction in common use. No attempt is made to completely cover the subject of line construction, as methods and ways are as varied and numerous as the various forms of telephone equipment, and differ in various parts of the country.

Size of Poles.—Poles should be at least 25 feet long, 28 inches around the body 5 feet from the butt, 6 inches in diameter at the top, and reasonably straight. Cedar is the best timber, but chestnut is fairly good. In building country lines it often happens that the route of the wire crosses a hollow necessitating the use of a high pole. As it may be impossible to secure one without a very great deal of expense and loss of time, a writer in the American Telephone Journal suggests the following method of splicing two or three poles together, which makes a very strong pole and, at the same time, is not expensive. Referring to Fig. 559 it will be noticed that the ends to be spliced together are shaped as at c. They are then tightly bound with wire. At the top of the pole a bolt is driven through and to this four steel wires a, are attached which are separated by means of spreaders, as shown at c in the figure. At D is shown the sort of spreader to use. These wires should be brought down to the base of the pole and fastened in a similar manner to that employed at the top. When well done the pole will be as staunch as if it was made of a single piece of wood. On the left side of Fig. 559 is shown the use of three poles to secure one long one. The tension wires should be grounded so as to prevent injury from lightning.

Staking.—The first thing to do is to stake out the line. This should be done with a great deal of care to get the poles in absolute alignment. If the line is crooked every pole will have to be guyed in order to keep the wires from pulling it over, and this makes the line expensive.

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Distance.—Stakes should be set 100 to 150 feet apart (depending upon the number of wires, etc., 160 feet is a good distance) and the holes dug in exact alignment. On uneven ground or in going over hills the poles should be set closer together than on even ground. Set two long stakes as far apart as they can be seen, then fill in between them.

Poles.—Poles should be set in the ground in accordance with following table and the earth well tamped in. It is a good idea to tamp stone around the foot of the poles with plenty of dirt to keep the foot firm. Use short poles in going over hills and long poles in valleys, so that the top of your line will be as level as possible.

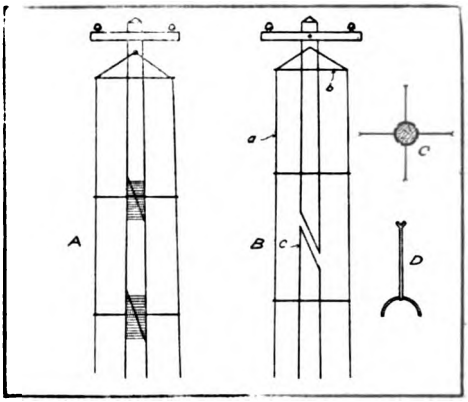


Fig. 559.

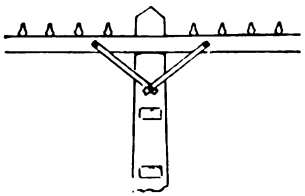


Fig. 560.

Table showing depth to set poles:

Length of Pole.	Depth in Ground.	Depth in Solid Rock.
25 feet or less	5 feet	3 feet.
30 " " "	5½ "	3½ "
35 " " "	6 "	4 "
40 " " "	6 "	4 "
45 " " "	6½ "	4½ "
50 " " "	7 "	4½ "
55 " " "	7½ "	5 "
60 " " "	8 "	5 "
65 " " "	8½ "	5 "
70 " " "	9 "	5½ "

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.

Railroads.—In crossing railroads, wires should be carried 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.

Framing.—Before setting the pole in the ground, the top of the pole, which should never be less than six inches in diameter, should be "roofed." This can best be done with a hand-saw. Five or six inches from the peak of the roof the first gain should be cut. The standard gain is one inch deep by 4¼ inches wide, but gains may be proper size to admit

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the cross-arm. It is also well to cut other gains 18 inches below each other, 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. 560.

Brackets.—If brackets are used instead of cross-arms, the first bracket should be placed so the top will be level with the top of pole; and if two wires are used, the second bracket is placed eighteen inches below the first, on the opposite side of the pole, except on curves and corners, here both brackets must be on the outside of the curve. Use one sixty-penny and one twenty-penny nail to secure each bracket.

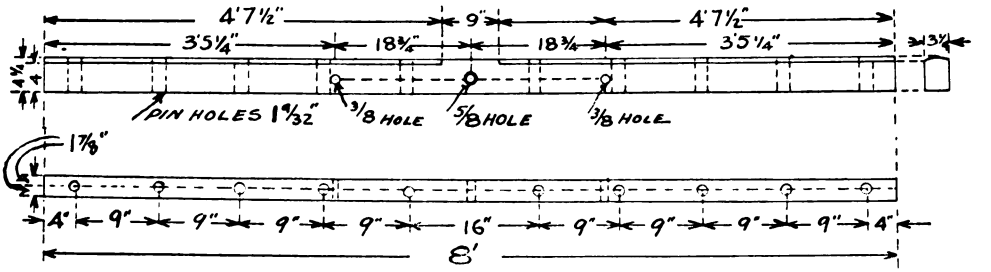


Fig. 561.

Cross Arms.—Before raising a pole a cross arm should be bolted to the top gain with one ⅝ inch bolt with washers beneath head and burr, the dimensions of a 10-pin cross arm are given in Fig. 561. Two iron braces 26 inches long should be bolted on the cross-arm with 4 inch carriage bolts and secured to the pole with a 4 inch lag. bolt. The pole is now ready to raise. Care should be taken in framing the pole to cut the gains opposite belly of the pole or in such a way that when the pole is set the straight side of the pole will come into alignment. This gives the line the appearance of good workmanship. On straight lines, the cross-arms should be put on alternating sides of the pole as shown in Fig. 562.

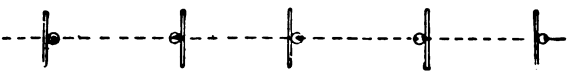


Fig. 562.

Guying.—Before stringing any wires all poles not in perfect alignment must be thoroughly guyed, the guy line having a strength ten times as great as the ordinary strain on the line, See Figs. 563-564. Then the strain of the wires is on the guy instead of the pole. The reason for this is the danger of sleet storms and the natural increase of wires on the line. In turning corners the poles must be guyed as shown.

Anchors.—Where there is no tree or other substantial anchorage it is necessary to set a strong post in the ground or bury a "dead man," as shown in Fig. 565. This latter consists of a log or large stone buried fully five feet deep, to which the guy is attached. The best method is to use an anchor of the type shown in Fig. 565. The anchor is driven into the ground the desired depth with a sledge or maul. The blades are set by twisting to the right three revolutions. The design of the blades, like those of a screw propeller, causes them to spread when the anchor is

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twisted. The pitch is such that they spread to an angle of ninety degrees with the rod in three revolutions. The spread of the blades sinks the anchor about one inch, so that there is absolutely no lost motion in the ground. The pull is on solid earth that has not been disturbed. The

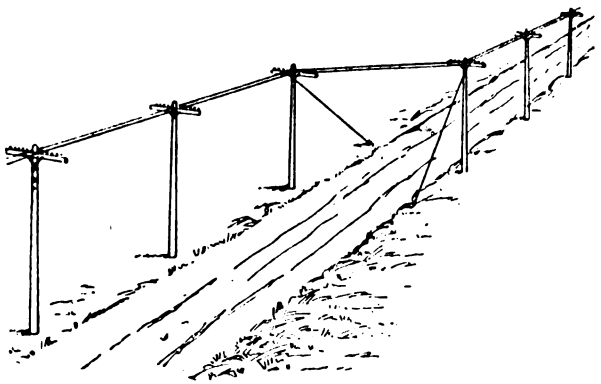


Fig. 563.

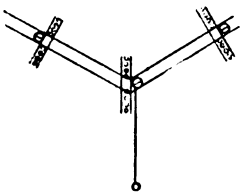


Fig. 564.

anchor can be set by one man in sixty seconds. Heavy poles should be selected for corners, as they have a much greater strain than the others; it is a good idea on corner poles to place a cross-arm on both sides of the pole, bolt through same outside to outside, with a block between the ends also bolted together.

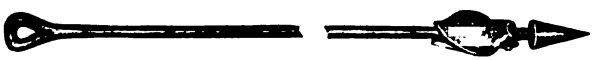


Fig. 565.



Distributing Poles.—Where only two wires are required such, for instance, as connecting a house with the main line, smaller poles may be used and brackets used instead of cross-arms, as shown in Fig. 568.

Tieing.—If the line is not straight, observe method of tieing wires to pins shown in Fig. 566, right hand side.

Bracing.—At the end of each line of wire or in going over a steep hill, the line should be thoroughly braced for two or three poles, as shown in Fig. 567. This takes the strain off the end pole, which otherwise would be apt to break off in a sleet storm, letting the strain come on the next pole, which is also quite sure to break, and in this manner ruin the entire line.

Making Guys.—Guys are made of a number of strands of wire twisted together. Each guy is generally different in some respects from the others, but a little judgment will show the general requirements. For a

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six-wire line, twist three wires into a strand and anchor to a tree near the ground, or as shown in Figs. 568-569. A 12-wire line will require a 7-strand guy. Remember that in building a line this is the most important part of the work and the part generally neglected. The breaking of

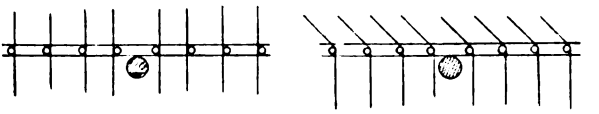


Fig. 566.

a guy wire may not only break the pole, but it will let the entire line sag and the wires swinging together will "short-circuit" and cause constant interruptions to the service. Guy wire can be purchased far cheaper

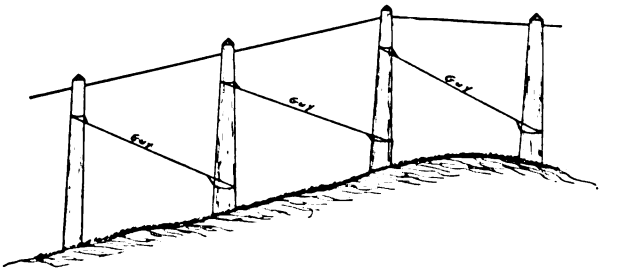
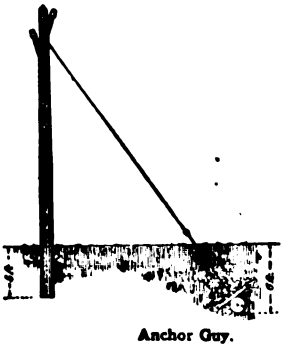


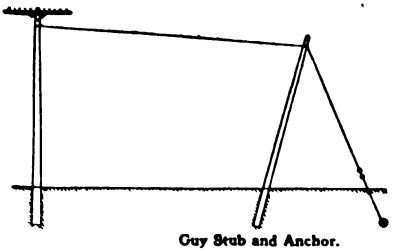
Fig. 567.

than it can be made, but in case of necessity, a good way to make a guy is to cut off the number of wires required all the same length. Fasten one end of the strands to the spokes of a wagon wheel and the other end to some distant object. Raise the axle to free the wheel from the ground and turn until the strands are sufficiently twisted. Only B. B. or soft



Anchor Guy.

Fig. 568.



Guy Stub and Anchor.

Fig. 569.

wire No. 14 gauge, can be used in this manner. Fasten the guy around pole with clamps as shown in Fig. 570.

Stringing Wires.—When the pole line is thoroughly built and guyed, the wires can be strung. This should be done collectively. That is, if there are six wires to string, do them all at once, drawing from six reels at the same time.

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MESSENGER WIRES AND GUY WIRE.

7 Wires No.	Approximate Diam. Inches.	Weight 100 feet.	Tensile Strength Pounds.
8	1-2	52	8320
9	15-32	42	6720
10	7-16	36	5720
11	3-8	28	4640
12	5-16	21	3360
13	9-32	16	2560
14	17-64	12	1920
15	1-4	10	1600
16	7-32	8	1280
17	3-16	6	960
18	11-64	4 3-10	688
19	9-64	3 3-10	528
20	1-8	2 4-10	384
21	3-32	2	320



Fig. 570.



Fig. 571.

Reels.—A wire reel is shown in Fig. 571. Make or purchase as many reels as needed. To make a reel take two pieces of 2x4 scantling, three feet long, halve them together and nail solidly in the form of an X. Fasten a 4x4 block on the center by spiking at the corners. Bore a 1 inch hole in the center, and insert a pin 12 inches long, which will protrude 8 inches. Now halve two more pieces together, nail solidly and bore holes in the centre so as to turn easily on the standard. In the arms of this second piece bore a number of inch holes to allow of adjusting to the size of the coil of wire to be used. Four pins will hold the coil on the reel and allow it to unwind.

When a reel is provided for each coil, set them in a row and attach the end of a wire from each coil to a 2x4 scantling or stick 2 feet long, the wires being about evenly distributed from one end to the other. Now tie the ends of a ten foot rope to the ends of the stick and a long rope in the center of the short rope so it will pull in the form of the letter Y. Throw the long rope over several cross-arms near the poles and hitch a horse to the other end. As the horse passes the poles, let the workmen continue to throw the rope over additional cross-arms until the horse can draw it no further. Fasten the wires to the cross-arms temporarily, bring forward the reels and proceed again as before.

Drawing Up.—When the wire is drawn, first make sure that the head pole, or the end of the line is properly guyed to prevent it from

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being pulled over, screw the glass insulators on the pins, tie the ends of the wires thoroughly by winding them twice around the glass knob and twisting the end around the body of the wire, as shown in Fig. 572. 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. 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, 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, then proceed as before.

In passing through trees, never fasten the wire to the tree direct, for the swaying of the tree will either break the wire or pull something loose. Always fasten as shown in Fig. 573.

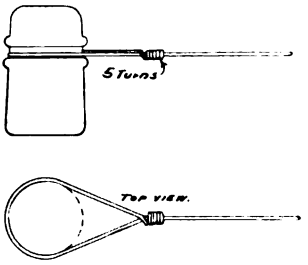


Fig. 572.

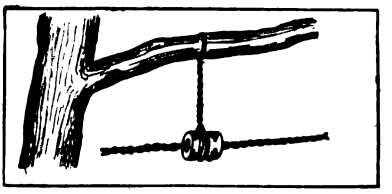


Fig. 573.

In building lines through timber country the ordinary ladder is often of not much use on account of the limbs of trees interfering with the position it would occupy. To overcome this difficulty, a writer in the "Journal" designed the rope ladder which is illustrated in Fig. 574. The design is such that makes it easily carried, and yet of sufficient length to allow reaching the lowest branch of a tree, about 18 or 20 feet. The ladder is supported to the branch by means of a hook fastened to a bow-shaped piece of iron, which holds the side ropes. The rod shown to the left of the ladder is composed of pieces of pipe held by thumbscrews, and is used to hook the ladder over the branches.

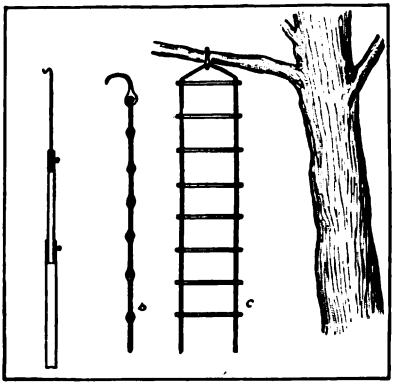


Fig. 574.

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Sagging Wires.—In putting up a lead of wires, be very careful to draw them all to about the same tension, the amount of sag being given in the acccompanying table.

The following shows sag for No. 8 and 12 wire. For No. 14 allow about 2 inches more for same temperature and span:

Temp. Degrees Fahr.	Length of Span In Feet. 75	100	115	130	150	200
	Sag In Inches.					
30	1	2	2½	3½	4½	8
10	1½	2½	3	4	5	9
10	1½	3	3½	4½	6	10½
30	2	3	4	5½	7	12
60	2½	4½	5½	7	9	15½
80	3	5½	7	8½	11½	19
100	4½	7	9	11	14	22½

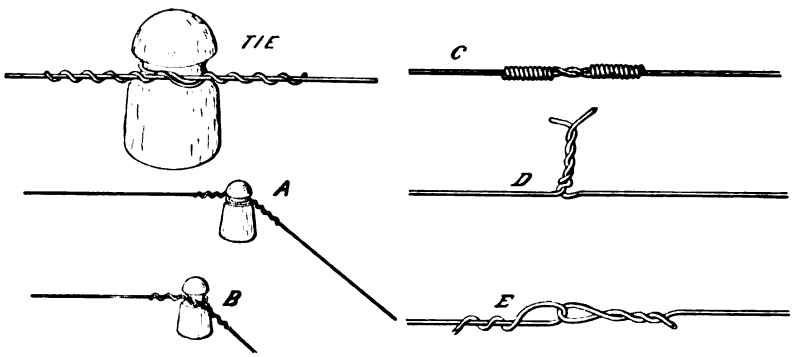


Fig. 575.

Tieing and Splicing.—To make a tie take a piece of wire same size as that used for the line wire and wrap same around insulator, as shown in Fig. 575, then wrap tie around the line wire, NOT in a close spiral but with the turns slightly apart as indicated. This prevents water from lying between the turns and thereby rusting the tie. Do not strain the tie wire around the insulator, as the expansion and contraction of the line wire and glass is not the same the glass will be factured. In turning a corner the line wire should be placed on the outside of the glass, as shown at "A". Do not turn a corner as shown at "B" as in this case the strain is always away from the pin, and the wire will soon pull out. At "C" is shown the proper method of making a plice. Never nick or twist the wire to such an extent that the galvanizing is damaged. The wire should be wrapped tightly but should not be marred or bruised. At "D" and "E" are shown some bad splices, which will cause noise and poor service. A good splice well made does not require any soldering, and it is not good practice to solder iron line wire except where a copper wire joins the iron line. When this is the case the joint may be soldered. When soldering a joint on iron wire, do not apply acid or other flux

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until a moment before the solder is applied, for if the acid is applied some time in advance the acid will discolor the galvanizing and after the joint is made the bare wire will be exposed for an inch or so on each side of the joint which will soon rust out.

Another point to be remembered is that you cannot do anything without a good hot flame and as stated before, it is best to make the joint so that no soldering is necessary. For long trunk lines use No. 8 or No. 10. For long heavily loaded country lines, No. 12. For short town lines, No. 14 may be used. While the EXTRA B. B. is best from an electrical standpoint, for all ordinary purposes, use the B. B. grade. The steel wire will give satisfactory service when the lines are not too long. When very long spans are used such as crossing a river, it is well to use a steel wire on account of its increased strength.

The following table gives the weight in pounds per mile together with the breaking strain and resistance of iron telephone wire:

No.	Diameter in inches	Weight in pounds per mile	Put up in bundles of	Approx. breaking strain in pounds E. B. B.	B. B.	Steel.	Av'ge resistc' in ohms. at 68 degrees F. E. B. B.	B. B.	Steel
6	.192	540	1-3 mile	1,620	1,782	1,998	8.70	10.19	12.04
8	.162	380	1-2 "	1,140	1,254	1,406	12.38	14.47	17.10
9	.148	320	1-2 "	960	1.065	1.184	14.69	17.19	20.31
10	.135	260	1-2 "	780	858	962	18.08	21.15	25.00
11	.120	214	1-2 "	642	706	792	21.96	25.70	30.37
12	.105	165	1-2 "	495	545	611	28.48	33.33	39.39
14	.080	96	1-2 "	288	317	355	48.96	57.29	67.71

Noisy Lines and Their Cure.—When two lines are strung for any distance parallel to each other and current is flowing in either, there is a current induced in the opposite direction in the other, the result of this induced current is cross talk and in the case of grounded lines, there is no way to overcome the trouble.

One grounded line and any number of metallic circuits may be strung on the same pole for any distance without having cross talk, if the metallic lines are transposed.

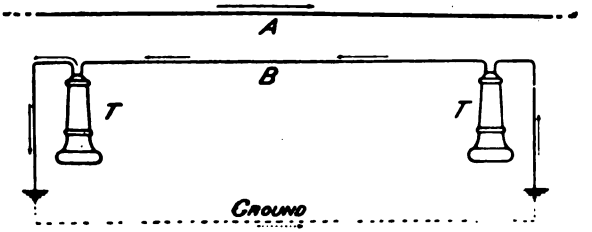


Fig. 576.

In Fig. 576 is shown the effect of having one or more grounded lines on the same poles and cross arms. It will be noticed that as indicated by the arrows, the current in one line is in an opposite direction from that induced in the other.

It will at once be seen that if the wire "A", which we will take to be the disturbing wire, is an electric light or other wire carrying a heavy

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current, that the induced currents in the line "B" will be of such a nature as to seriously interfere with the satisfactory operation of the telephones which are represented by the receivers. Or if the wire "A" is a telephone wire, the noise induced in "B" will be of the variety commonly known as "cross talk."

Transposing will be found to cure this trouble if the lines are made metallic. This is shown in Fig. 577. Here it will be seen that the current in the metallic line is in an opposite direction to that of the disturbing wire "A" and since the transposition of the metallic line causes the induced current to flow in first one direction and then another, these currents will neutralize each other, and as the transpositions are cut at equal distances apart, the pressure of the currents are the same and therefore no current will flow through the receivers at each end of the line and the line will be unaffected by outside influences as long as the balance of the line itself is maintained.

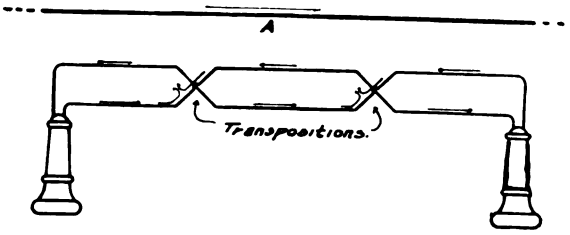


Fig. 577.

In cases where there are more than one metallic line on the same poles, all of them must be transposed but not at the same place, as in this case there would be no difference in the relative position, and the effect would be the same as though they had not been transposed at all. There are several systems of transposition, but they are all only slightly different roads to the same end, and the diagram as shown in Fig. 578 is the method most frequently used and is perhaps the best. The horizontal lines represent the metallic circuits and the poles shown represent every tenth pole beginning with the pole nearest the office and counting it as No. 1, next No. 2, and so on. Begin with the tenth pole in the following order: A. B. C. B. A. B. C. B. keeping this system up all the way to the other end of the line disregarding any branches that may tap the line, and when the marking is done, the transposing is to be done as indicated. It will be seen that each line is transposed at either just one-half or twice the distance of the next circuit to it.

It is necesssary to use what is known as transposition insulators when doing this work. These are the same as the ordinary insulator except that they have two grooves for the wire instead of one and are shown in Fig. 579* The method of crossing over or transposing the wire is clearly shown in small sketch of lower corner of diagram. This work should be carefully done and will be found to cure immediately the very common and annoying trouble known as "cross talk." It will also cure inductive noises caused by lines paralleling power or telegraph wires.

We will suppose that the metallic trunk lines in an exchange have been carefully transposed, and that all the local lines are grounded, or

*Standard transposition insulators are different from cut, which shows a double groove insulator, sometimes used for this work.—Ed.

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vice versa. As soon as one of the ground lines is connected to the metallic line through a cord circuit in the switchboard, an unbalance results, which immediately makes both the metallic and grounded lines noisy, although either one of them by itself is perfectly quiet. This immediately renders useless all the transpositions which have been so carefully made, and some method of maintaining an equal balance between lines must be devised. This is accomplished by using a repeating coil which is described in connection with switchboard equipment.

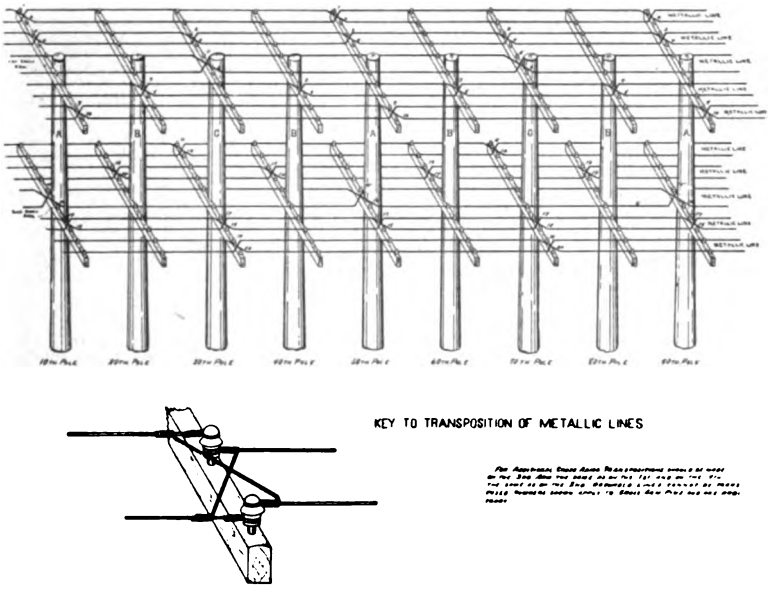


Fig. 578.



Fig. 579.

If the line is for the purpose of connecting several 'phones together, connect the instruments to the outside line or lines as shown in Fig. 580 using twisted rubber covered and braided wire to connect from the main line to each phone when the lines are metallic and single rubber or plain weatherproof covered wire when single wire or grounded lines are used.

If it is desired to bring the bare line wires directly to the building, use brackets or knobs and leave sufficient slack between the last pole and the house to prevent the humming sound present when the wires are tightly drawn.

*"When running wires to a building in a conspicuous place, it is desirable that they present a neater appearance than the ordinary method of nailing on wooden brackets can give. Iron brackets can be bought from the supply companies, but their cost may be prohibitive, or possibly there are none on hand. Following the idea here presented almost any type of an iron fixture can be quickly and cheaply made."

"A piece of strap iron is bent into the desired shape, as shown in Fig. 581, screw holes drilled, and its end placed in an insulator. Around

*American Telephone Journal.

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the iron, Plaster of Paris is poured, mixed with water to the consistency of cream. When the plaster sets the fixture is ready for use."

"The type shown is only one of the many which may be made. By cutting in half at the middle screw hole a single bracket would be formed. By properly bending the strap iron a double bracket with its two insulators in a horizontal line could be shaped. Special fixtures to be placed on building corners or bolted to steel work can easily be arranged."

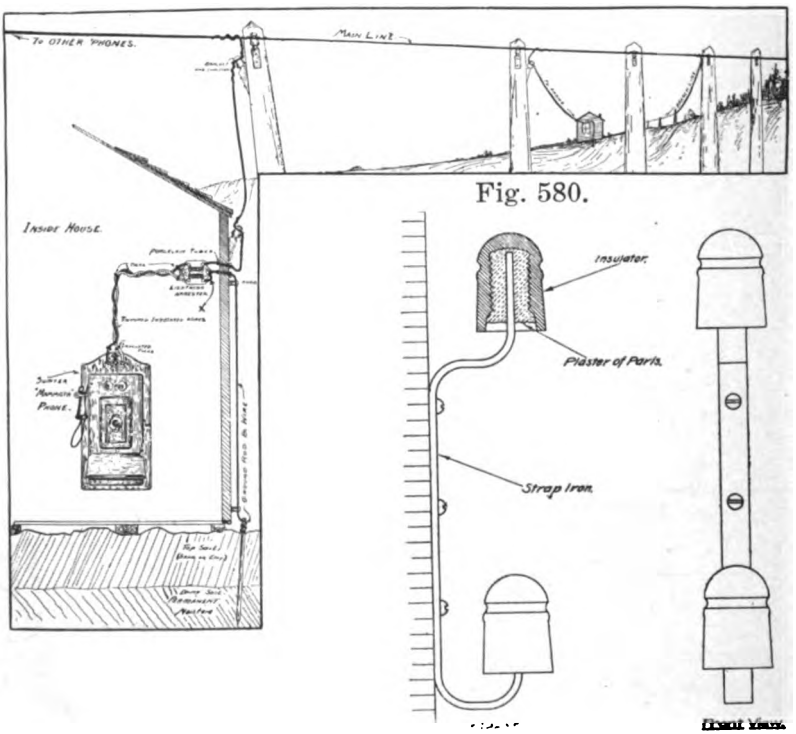


Fig. 580.

Fig. 581.

"Strap iron is best used if a forge is not available, as it can be bent while cold by using a vise and hammer. The screw holes may be drilled with a breast drill. Any size of strap iron that will enter the hole in the insulator will do, provided it is stiff enough. Judgment must be exercised, as in no two cases will the strain on the brackets be the same. Round iron is better than strap, as it is stiffer, but for most sizes it would be necessary to heat it before bending. If round iron is used it should be flattened at the points where the screw holes are drilled. This may be done with a hammer when hot. The whole length of iron below the first screw hole may be flattened so that the fixture will lie closely to its support."

"Screw holes are best placed directly in the line along which the strain is to be. If this is done there will be no bending action at the point where the screw hole is drilled, where the iron is weakest. This is illustrated in figure. The bottom screw hole being placed directly back of the groove in the insulator, thus, when a strain is brought on the insulator, there will be a tendency to pull the screw from the wood, but there will

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be no tendency to bend. In the bracket shown it would be impossible without altering its construction, to so place the upper screw hole that it would fulfill the above conditions."

"When a screw comes directly behind an insulator some trouble may be experienced in turning it into place, the insulator being in the way of the screw driver. This can be avoided by first turning the screws into the wood as far as they will be required to go, before the bracket is in place, using it as a templet to determine their positions. The screws can now be removed, the brackets replaced, the screws reinserted and turned until tight."

The inside wiring is greatly neglected especially by those doing the work in small exchanges. There are many reasons why inside wiring should be properly done. Aside from the question of good looks, the inside wires should be properly installed, so that the trouble resulting from loose and broken wires is eliminated to as great an extent as possible.

Where the outside lines run for any distance, it is necessary to have a lightning arrester, a standard form of which is shown in Fig. 130, page 98 this being of the choke coil variety. A standard carbon and fuse arrester is shown in Fig. 582, this being installed as a unit, where the lines enter the building, or where the ground connection is nearer the instrument than the line entrance, the fuses may be mounted on a separate block, shown in Fig. 583, while the carbon arrester is mounted separately as shown in Fig. 584.

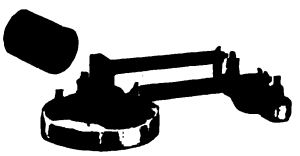


Fig. 582

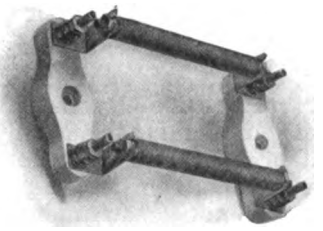


Fig. 583



Fig. 584

After deciding where it is necessary to bring the outside lines into the building, suitable holes should be bored, and porcelain tubes should be placed in the holes. It is supposed that the wire entering the building is of the twisted pair, rubber covered variety, and is joined to the bare wire lines at the first pole nearest the house. In this case the twisted pair comes through one tube into the house, and is connected directly to the lightning arrester, which should be placed as close as possible to the point where the wire enters. This is shown in Fig. 580.

The line wire should connect directly to the post of the lightning arrester. Where the wires enter the porcelain tube a short loop should be made on the outside to keep rain from running in on the wire.

The next operation is to connect the ground wire to the lightning arrester. The ground wire should be suppported by small porcelain knobs like those shown in Fig. 580, which also shows how the ground wire is tied to the knob. The wire should be fastened to the knob as

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shown, great care being taken not to make any sharp bends, twists or curls; the wire should be as short and straight as possible. Use No. 14. Methods of making the ground connection, ground clamps, running the ground wire etc., are described on pages 100 to 101.

In case no lightning arrester is used except the one usually furnished on the telephone instrument, the ground wire should connect to the ground post on telephone, usually the centre one.

After fastening the telephone in place upon the wall, the line wire can be run from the arrester to the telephone. The best wire for this purpose is rubber covered and braided twin wire. This can be secured at a slight additional cost over the ordinary annunciator wire sometimes used, which is not at all satisfactory for this purpose.

The wire can be held in place by small wooden cleats, porcelain knobs or insulated staples. In using staples or tacks, it should always be borne in mind that only one wire should be brought under the staple; never put both wires under the same tack as trouble will result. The wire should be tightly stretched so as to make a neat job. In a great many cases the wire can be run back of picture moulding or around the edges of window frames, and thus kept out of view.

The line wires entering the telephone and lightning arrester posts can be curled into small spirals. Do not treat the ground wire in this manner however. The ends of the wire should then be carefully bared, doubled back and formed up into a tip so that the wire will not be cut off, if screw binding posts are used. This lends strength to the wire, and prevents the screws cutting it off when the wire is placed in the hole on the binding post. All connections should be tight. If not, a rattling, scraping noise will occur.

Particular attention should be paid to suitably locating the telephone. It is very bad practice to mount a telephone on a damp wall or in any place where it is liable to be damaged in any way. Telephones should not be located on lathed or plastered partitions of buildings, as such a location will cause a ringing sound in the telephone if there is much noise around. When putting a telephone instrument on a solid brick wall, it is well to hold the telephone in position and mark the screw holes by driving a nail through them. Then remove the telephone and drill the holes by means of a chisel. Wooden plugs can then be driven into the holes, and the telephone held in place securely by screws inserted through the plugs. In any event the instrument should be solidly mounted.

With some types of telephones, the batteries are located in a closet, or some other suitable place. In this case it will be apparent that the wires connecting the telephone with the batteries should not be long enough to offer any serious resistance, and if the batteries used are of the wet cell type, great care should be taken to place them where they will not freeze or become over-heated. This is especially the case when batteries are placed in cellars, as they are often put on shelves near heater pipes, which soon renders the batteries worthless.

When a switchboard is to be connected up it is best to end all the wires of the exchange on a pole directly outside of the exchange building. A suitable cable box can be located on the pole and a weather-proof cable connected from the cable box directly to the lightning arrester distributing frame or other device in the "Central Office" to which the cable from the switchboard is connected. Fig. 585 represents a cable

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box of the usual pattern. This should be firmly attached to the pole by taking two short cross-arms and bolting them fast to the pole. The cable box can then be attached to the cross-arms by means of lag screws.

The cable box should be located slightly below the cross-arms carrying the lines, and a small deck or platform should be erected below the cable box so that the work can be conveniently done in the box.

The cable box is provided inside with strips of terminals, fuses, or carbons and ground plates, and the pairs of wires should be connected to these terminals by means of twisted weather-proof wires. Bear in mind that the twisted pair used for inside work cannot be used on a pole as it is exposed to the weather and when it becomes wet will cause cross talk and leaks. Rubber insulated or braided weather-proof wire is recommended for wiring the poles.

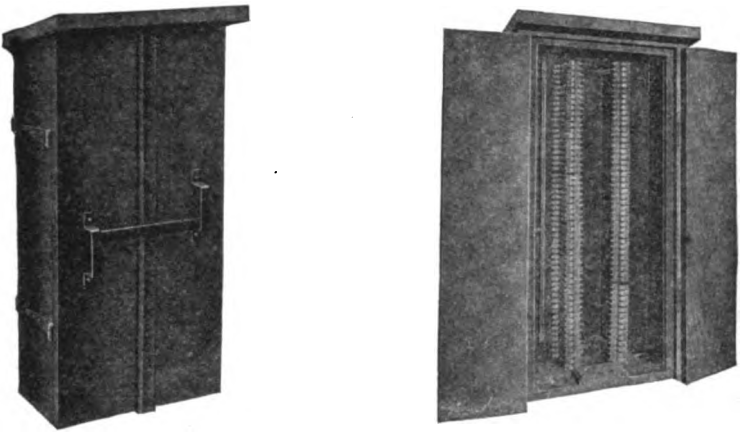


Fig. 585.

The following method of connecting up a small exchange will be found of interest:

Metallic Lines.—Carefully solder a twisted pair of wires to each line, then run the twisted pair through insulated iron or leather rings placed on the pole at convenient intervals until the wire reaches the cable box. Then connect it to a pair of terminals in the box, as shown on the right hand side of Fig. 586.

"Grounded" or Single Wire Lines.—One single weather-proof wire should be soldered to each line wire. This should run through the rings and join the top terminal of each pair in the cable box, as shown on the left hand side of Fig. 586, which also shows that the bottom terminal of each pair in the cable coming from switchboard, is *securely connected to the ground in the cable box* as shown in Fig. 586 by the strap wire X. It will be observed from the above that the exchange will always be wired full metallic completely from the switchboard to the cable box, and that when grounded or single line wires are used, one side of the metallic pair coming out from the switchboard will go to the ground in the cable box. This method of grounding in the cable box will prevent a great deal of cross talk. While more wires from switchboard to cable box are necessary when using this method, greater satisfaction is gained as it is not good practice to run the single lines into the switchboard and then con-

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nect one side of the switchboard jacks together and run same to the ground, as this brings all the grounded lines in close proximity to each other where they pass through cable from the terminal pole to the switchboard which causes a great deal of cross talk.

Where the number of lines exceed five, it is best to use weather-proof cable to connect from the box on pole to Central Office lightning arrester; rubber insulated weather-proof cable is made up of twisted pairs of wires. Each twisted pair should be connected to a pair of line terminals in the cable box. This end of the cable should be formed up for connecting to terminals in cable box, as shown in Fig. 586.

Take a board as shown in Fig. 587, of proper size and drive nails in it at points corresponding to terminals on lightning arrester, fan out and lace up the cable wires by means of twine so that each pair of wires is in a proper position to reach the terminals in cable box without having a great tangle of wires in the box. In the figure C C C shows the nails, spaced same as the terminals in box. The distance A is the length that should be allowed so that wires will join terminals without having too much slack. Line S shows where wires should be skinned.

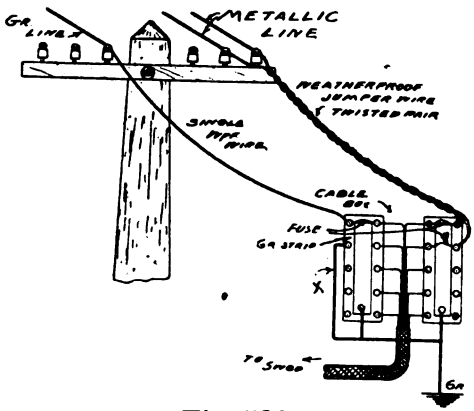


Fig. 586.

The four upper figures show method of forming a "butt," or end for the outer braiding of the cable.

Figs. 588 and 589 show how to open and lace the cable. The cable should be supported by means of a leather strap wrapped around the cable and fastened to the pole. The other end of cable should be opened up and formed out in the same manner. It will be necessary in this case to test out each set of wires to find out how the wires should be distributed. This can be accomplished with a bell and two batteries, as shown in Fig. 590.

From this it will be seen that the end of the cable which connects in the cable box can be distributed without any regard to testing out each pair of wires, but that the end going into the lightning arrester in the office should be tested out and the pairs numbered 0, 1, 2, 3 and 4, etc., to correspond with the end in the cable box as shown in Fig. 590. The wire from the battery is first connected to one wire in the cable and then the wire connected to the bell is touched to the bared ends of each one of the wires on the other end of the cable until the bell rings. This will denote the correct pair and it can be distributed as described.

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The office end of the cable should be connected to the carbon and fuse lightning arrester so that the circuit passes through the fuses first, and then to the carbon side of the arrester, and to the switchboard.

Another, and perhaps the most vital point to be observed in connecting up this cable, is the following, which is particularly important when grounded or single wire lines are used:

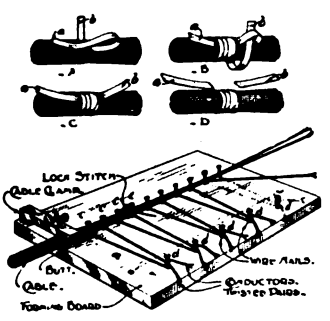


Fig. 587.

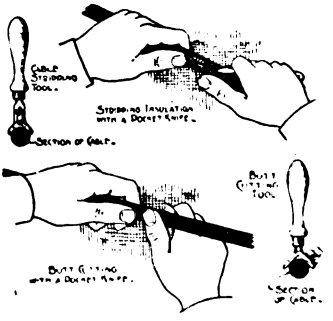


Fig. 588.

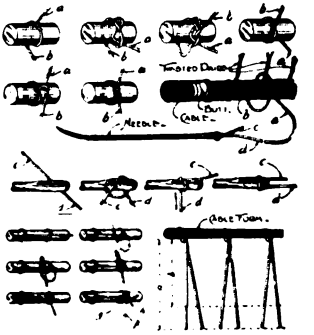


Fig. 589.

The wires in the weather-proof cable which connect with the lower terminal of each pair in the pole box and which in the case of ground or single wire lines are connected to the ground strip, are run into the lightning arrester and connected to the lower carbon and fuse of each

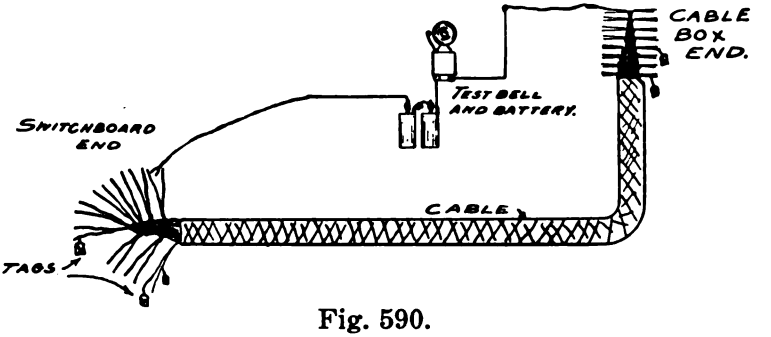


Fig. 590.

pair. A diagram of this condition is illustrated in Fig. 591 which shows a pair of wires extending from the carbon and fuse lightning arrester out of the cable box strip, one of them being connected to the ground in cable box and the other continuing out as a single wire or grounded line.

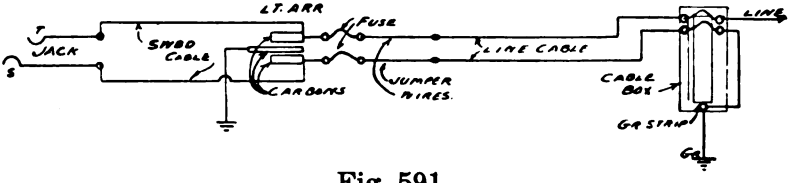


Fig. 591.

In case of metallic lines, this point is not of such vital importance, but in the case of grounded lines, it is vitally important that all the bot-

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tom terminals of each pair on the lightning arrester should be connected to the wire in cable which connects to the ground in the cable box.

Fig. 592 shows the next operation which consists of connecting the lightning arrester to the switchboard cable. It will be seen that the switchboard cable terminates in a board or panel which is provided with terminal clips. This board is known as a "Route Board," "Distributing Board," "Distributing Rack," and various other names, and in the case of small exchanges it is always the board which is attached to the end of the cable coming out of the switchboard. This board is fastened to the opposite side of the lightning arrester frame from the strips of carbons and fuses, and each set of terminals on the board should be connected to a pair of lightning arrester terminals comprising a line, by means of a short piece of twisted pair wire, commonly known as "jumper wire," which consists of different colored wires twisted together to form a pair.

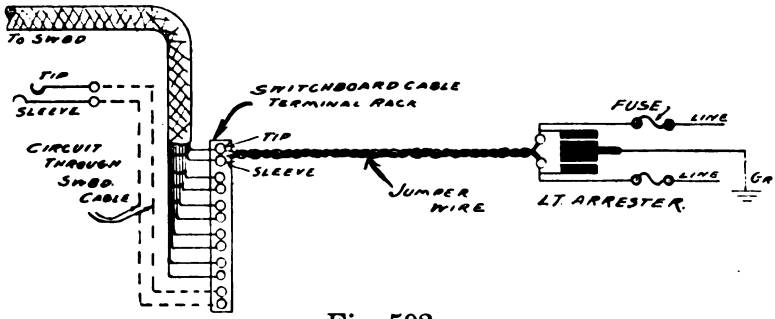


Fig. 592.

The bottom terminal of each pair on the lightning arrester should be connected to the bottom terminal of each pair on cable board. This can easily be done by connecting a certain colored wire of each pair to the bottom terminal on lightning arrester and connecting the same wire to the bottom terminal on each pair on the switchboard. The resulting circuit is as shown in Fig. 592.

It will now be seen that all the tips or short springs of the jacks are connected to the line wires in the case of ground or single wire lines, and that all the sleeve springs of the jacks or the long springs which make contact with the sleeves of the plugs when same are inserted in the jacks, are connected to the wires which go to the ground in the cable box.

The reason for so much caution in keeping this circuit straight will readily be noted by reference to page 137 and reading the matter relating to reversed lines.

The metal frame of the office lightning arrester, and the ground strip in the cable box should be connected to the ground. It is only necessary when installing a Central office to have one good ground. It is not necessary to have a separate ground wire for each line. The reason for grounding the metal frame of the lightning arrester is to provide a path for the ready escape of the lightning.

The arrester equipment so far described is suitable protection against lightning currents, or heavy currents of considerable quantity. It is also necessary to protect the switchboard from so called "sneak" currents, which are currents of such small quantity that they will not operate the ½ or 1 ampere fuse commonly used, but will heat and destroy

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any ringer or drop coil that may be in the circuit. Many devices for this purpose have been offered, nearly all of them depending upon the heating effect of the sneak current on a small coil of wire commonly known as a "heat coil" to open the line.

Typical of the highest development of this class of apparatus, is the Cook protector. These are arranged in banks of 20 or more pairs, and are adapted for mounting on the regular iron frame furnished by Frank B. Cook. The No. 10 protector is shown in Fig. 593, the banks of protectors being mounted vertically, as shown in cut of complete frame, Fig. 594.

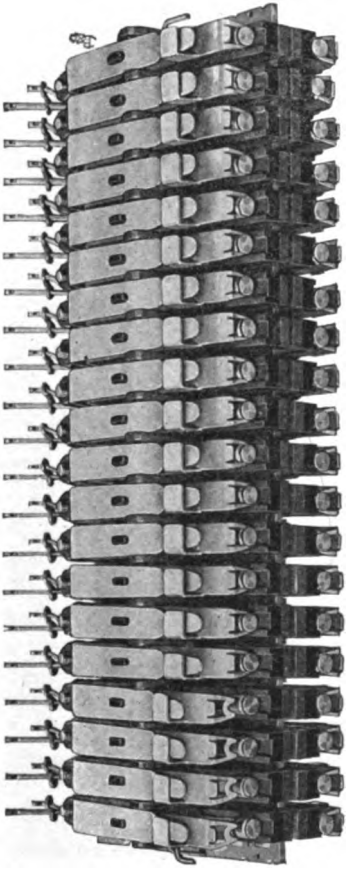


Fig. 593.

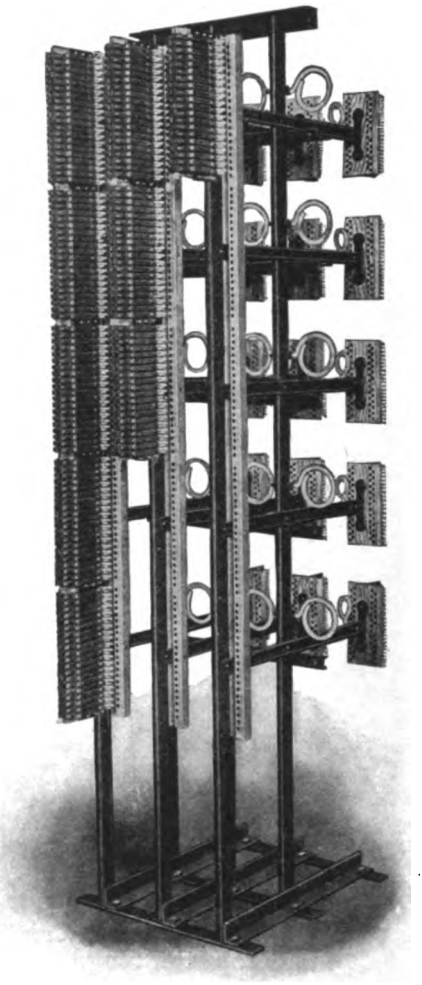


Fig. 594.

The circuit and operation of the device will be understood by reference to Fig. 595, which shows one pair of protector springs and heat coils, one for each wire. The top of the figure shows the coil in circuit in the normal condition, while at the bottom is shown a coil operated. Refer-

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ring to the figure the line wires connect to A and A¹. Considering the sneak current as entering over line A, it would pass to spring B via the contact between A and B and then pass through heat coil C to spring D. If the voltage was sufficiently great, as is the case with lightning, a path is provided to ground via carbon block F, which is connected to spring D, and which is separated from ground carbon G by a thin piece of mica or celluloid. In the event that the current does not jump this gap, but continues to flow through D to E and through the instrument and out over the other side of the protector, the heat coil immediately becomes warm, the solder holding B to C melts, and B is released, thereby opening the circuit and stopping the current flow.

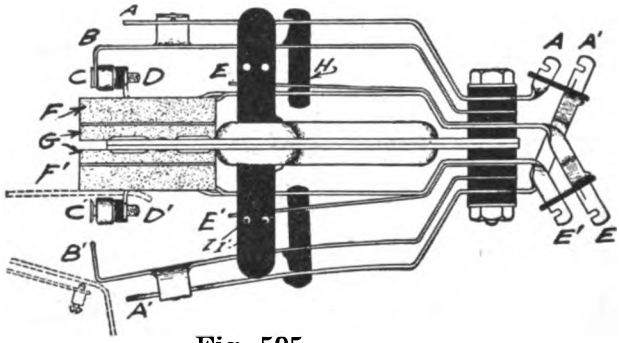


Fig. 595.

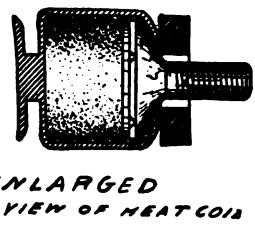


Fig. 597.

When B is released, it carries with it the hard rubber strip H which pulls spring E against the alarm contact I I¹, thus causing a bell connected in this circuit to ring, thereby notifying the wire chief of an open line. Only the ends of the alarm wires I, I¹, can be seen in the illustration, but these run vertically through all the banks of protectors in each section of the frame.

Cook's No. 10 Protector is a re-soldering but not a self-soldering protector. The protective apparatus is automatically reset by the use of a resetting plug, which is shown in Fig. 596. This plug closes a battery circuit through the heat coil. The battery current heats the coil and melts the solder. The plug presses the operating spring back against the heat coil, holding it there until it re-solders in position to operate again. The battery current is then automatically cut off, allowing the coil and the solder to cool. The plug holds the operating spring to its position in the coil until the solder has hardened. As soon as the plug is inserted the line is put in operative condition, the plug in no wise interfering with the subscriber's use of the line. The dotted lines, Fig. 596 show the spring of the resetting plug engaging the spring on protector. It requires about 1 ampere to operate the plug.

One of the novel points about the protector is that in resetting a coil which has operated, a test of the protector is made. Should the coil be defective, the operation of resetting indicates automatically that the coil is imperfect and it simply cannot be reset. If a self-soldering protector is not carefully tested after each operation, it might contain a defective coil which could cause a great deal of damage. This is impossible with Cook's No. 10, as a heating current is closed through the heat coil after it

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has operated, to reheat the coil and automatically restore the protector to operative condition. This reheating current tests the coil.

Cook's No. 10 has no loose contacts (or pressure contacts) at the heat coils. The heat coils are screwed to their mounting springs (and may be soldered as an additional precaution), and the operating springs are soldered to the other end of the heat coils when the apparatus is set for operation.

When the protector operates, it grounds the line circuit and closes an alarm circuit. This automatic alarm is reliable.

The coil itself (Fig. 597), consists of a metal casing or shell, in which is enclosed a graphite composition, insulated from the metal casing, except on one end. The coil is so constructed that the heat is confined to one end, where it is utilized to soften the solder, allowing the apparatus to operate. The graphite takes the place of the wire in a wound coil, providing the heating element in this protector.

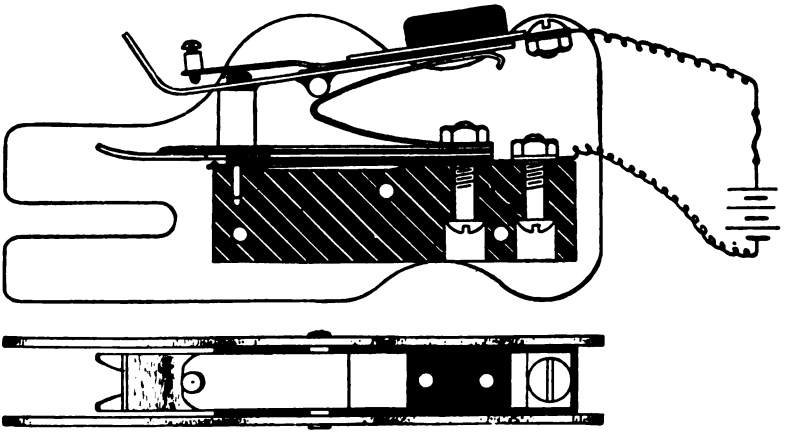


Fig. 596.

Each pair of protectors is separated from the adjacent pairs by hard rubber strips which extend through the ground plate. These strips keep all the springs in alignment and provide a very substantial and durable construction. Adjacent pairs of springs absolutely cannot be forced into contact with each other.

The No. 10 is so designed that by the use of a test plug (Fig. 598), it is possible to test every circuit or combination by simply inserting the plug.

The springs are all mounted on a plate of formed sheet metal, which is unusually strong and so light that it greatly reduces the weight on the frame and mounting bar.

The No. 10 protector is equipped with the improved form of carbon arresters, using either perforated or U shaped celluloid dielectrics .005 of an inch thick. In the perforated celluloid dielectric the perforations are so small and so numerous, that the discharge is greatly broken up, and is forced to pass through the arrester at many points. This prevents particles of carbon from breaking off and short circuiting the arrester. The celluloids do not vary in thickness, and are consequently uniform and reliable in their operation. If an arc continues through the arrester, due

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to a cross with a high voltage circuit, the celluloid will melt and allow the springs to press the carbon blocks together and form a dead ground through the arrester. This stops the arc, after which, if the circuit increases sufficiently, the fuses at the outer end of the line will blow and entirely cut out the switchboard from the circuit. The exposed surface of one carbon is insulated with an enamel which prevents a short circuit from occurring at the exterior surface of the arrester.

A combined distributing and protector frame consists of an angle iron frame built in vertical sections of 100 to 200 pairs. New vertical frame sections can be added at any time. The protectors can be readily attached to the frame as needed.

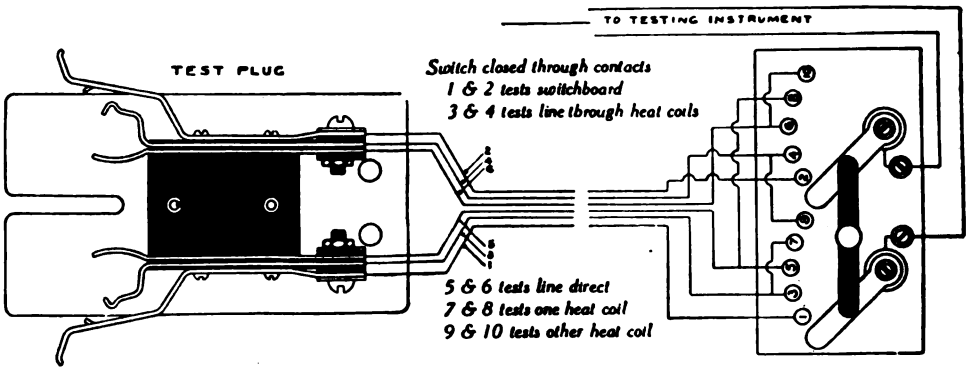


Fig. 598.

The uprights are of angle iron and are securely bolted to an angle iron base, making a rigid and substantial frame work. To the uprights are secured horizontal bars of channel iron, extending from front to back. To the front ends of these bars are fastened vertical mounting bars to which the protectors are secured.

Directly back of the protectors are mounted maple fanning strips extending the full length of the rack. Each strip is drilled and numbered to correspond to the protector pairs directly in front of it.

At the back end of the horizontal bars, directly opposite the protectors, are the cable terminal blocks, mounted vertically in strips of twenty or twenty-five pairs each.

For distributing the cross-connecting wires, a small insulated ring is placed directly back of each cable block and larger ones are secured to the vertical angle irons.

A set of horizontal channel irons extending lengthwise of the sections provides ready means of joining additional sections.

This frame is suitable for any size exchange, and is the standard type for 100 or more lines up to any capacity. Protectors can be added in banks of 20 pairs at any time.

A good ground connection must be provided for the frame. Use a No. 6 copper wire.

Cook's Intermediate Distributing Frame should be used in multiple-system exchanges having a few hundred lines or more, as it is very advantageous in distributing the amount of work equally between the various operators on the board. In appearance this is the same as the main

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frame, except in place of protectors are mounted groups of terminals. By the aid of an Intermediate Distributing Frame, certain operators will not be overworked while others have a lack of work, as is usually the case in exchanges of any size where an Intermediate Distributing Frame is not used.

In a Multiple Switchboard the answering jacks and line signals generally branch off from the main line circuits which include the multiple jacks. By using an Intermediate Distributing Frame these branches to the answering jacks and line signals, may be interchanged between the lines, so that any line may be answered at any position on the switchboard. In this manner the total number of very busy lines may be distributed between the various operators so as to divide the work equally between them.

Cook's Intermediate Distributing Frame having distributing blocks on one side, preferably on the answering jack side, is very advantageous in making the cross connections from one side of the frame to the other. There is a considerable space between the distributing blocks so that a person's arm may be inserted into the frame and then moved either vertically or horizonally throughout the entire extent of the frame.

The uprights of the frames are of angle iron and are securely bolted to an angle iron base, making a rigid and substantial frame work. To the uprights are secured horizontal strips of channel iron extending from front to back. These horizontal channel irons support the distributing blocks and strips.

The vertical distributing strips on the multiple jack side of the frame hold the parts of the frame together rigidly and provide a very substantial construction.

The main vertical angle irons of the frame are provided with insulated distributing rings, which, in connection with the rings directly back of the distributing blocks, keep the jumper wires in the frame away from any of the iron portions.

Iron racks or runways are provided to carry the cables from the board to the frames. A 100-line outfit is shown in Fig. 599. The usual method of connecting the equipment, is such that the incoming line wires connect directly to the protector terminals, and then connect by means of jumper wires with the terminals of the switchboard cable.

In some systems the protectors are located on the switchboard side of the frame, the line side being equipped with plain terminals. This method affords the same protection to the switchboard and apparatus, except that the jumpers are not protected except by such fuses as may be placed in the boxes outside.

One of the largest manufacturers furnishes the following information regarding forming up the switchboard cables, as it is sometimes necessary to form these to connect to the arrester or intermediate frames.

Switchboard Cabling.—After the cables from the swtichboard are laid in their permanent positions the free ends should be lined up parallel to the arrester strips to which they are to be attached. Each pair of conductors in these cables are provided with distinguishing colors arranged in a definite code so that the switchboard drops and arrester terminals can be readily wired together and the same uniformity kept throughout.

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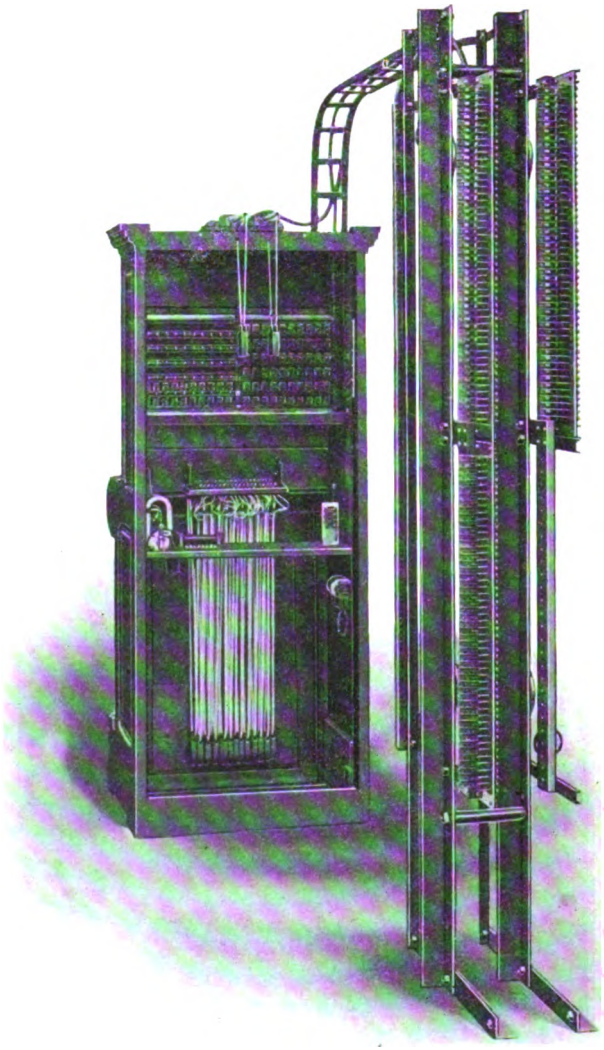


Fig. 599.

A color code used by The Dean Electric Co., is as follows: each wire from 1 to 20 inclusive, being twisted with a white mate, 21 to 40 a red mate, and 41 to 50 a black mate.

1—Blue	9—Blue-brown	17—Green-slate
2—Orange	10—Blue-slate	18—Brown-white
3—Green	11—Orange-white	19—Brown-slate
4—Brown	12—Orange-green	20—Slate-white
5—Slate	13—Orange-brown	21—Blue
6—Blue-white	14—Orange-slate	22—Orange
7—Blue-orange	15—Green-white	23—Green
8—Blue-green	16—Green-brown	24—Brown

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25—Slate
26—Blue-white
27—Blue-orange
28—Blue-green
29—Blue-brown
30—Blue-slate
31—Orange-white
32—Orange-green
33—Orange-brown
34—Orange-slate
35—Green-white
36—Green-brown
37—Green-slate
38—Brown-white
39—Brown-slate
40—Slate-white
41—Blue
42—Orange
43—Green
44—Brown
45—Slate
46—Blue-white
47—Blue-orange
48—Blue-green
49—Blue-brown
50—Blue-slate
51—Blue-orange-white
52—Blue-orange-white

(The last two pairs are spares with a white and red mate respectively which can be used in case any of the regular pairs should become defective.)

We wire pair No. 1 of a cable to the terminals of Drop No. 1 of the switchboard, the plain colored conductor (white in this case) going to the tip spring of the jack, while the wire having the distinguishing color is connected to the sleeve of the jack. The wiring remains uniform in our switchboard regardless of any special numbering of the drops and jacks. In this way, one cable will include the drops No. 1 to No. 50 inclusive, while No. 51 to No. 100 inclusive will be wired with the second cable, drops No. 101 to No. 150 inclusive will be wired to a third cable, etc. The color code for distinguishing the pairs is the same in each cable, and it is an easy matter when installing to determine the group of drops included by a particular cable by tracing the run to the switchboard.

As soon as the cables are properly arranged along side the arrester terminals and each marked at the point where the first pair of wires is to leave for its corresponding terminal clips, the outer braidings and paper coverings can be removed so as to expose the twisted pairs of wires. In marking these points it is best to arrange to remove about one inch more of the covering than is actually necessary to allow the first wire to clear, thus giving room for a binding called a "butt." The latter is made as illustrated in Fig. 587 by binding a stout linen tape, one quarter of an inch in width, tightly around the exposed edge of the braiding. The free end "b" of this tape should be inserted in the loop first formed and pulled under the binding by drawing on the end "a", after which both ends are cut away so as to produce a finished job.

The exposed wires of the cables should now be boiled in beeswax or a combination of beeswax and paraffine, up to the butt and including it, until all bubbles in the liquid disappear. The wax serves a double purpose, as a moisture repellant and a means of preventing the insulations 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 the latter from the boiling liquid. A temporary forming board, made from a wide piece of soft wood, should now be provided and marked off with the distance between the clips on the arrester or terminal frame to which the cable is to be fastened. A distance equal to the space which the cable is to set back from these clips should also be marked on this forming board. The former distances are shown as "CC" in Fig. 587 and should be laid off uniformly, while the latter distance is shown at "A". Drive nails "d", "d", "d", etc., into the board at the points just marked so that the cable wires can be bent around the same in making the form. The cables

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should now be clamped as shown in the illustration and the wires brought around the nails following the color code, and bringing the No. 1 pair around the nail "d" nearest the butt of the cable and anchoring it to the nail by making one complete turn around the latter, etc.

The loose wires are bound together with a single length of bees-waxed linen twine by what is called a lock stitch lacing formed as shown in Fig. 589. This lacing, when properly made, requires that the free end of the twine be drawn under the loop thereby locking each lace and preventing it from loosening. In starting the stitch a knot is first taken next to the butt of the cable as shown in Fig. 589 and after the last stitch is taken the lacing should be securely fastened at the end of the form. After lacing up the form, the projecting pairs of wires should be cut off even, leaving a sufficient length "*a*" to properly fasten to the terminals, allowing an inch for skinning.

Care should be exercised in doing this skinning operation as a small nick in a wire is sufficient to cause a break as soon as the wires are handled or subjected to vibration.

The wires and cables should now be permanently fastened in place on the frame, either by small leather straps bound around the cable and secured by screws or by binding with waxed lined twine.

In making the subsequent connections to the arrester strips, the wires with the colored insulation should always be connected to the uppermost clip of a pair of terminals as it comes from the tip spring of the line jack and goes to the tip side of the line circuit. The mate should go to the next clip, etc.

The bare ends of the wires are threaded through the holes in the clips up to their insulated covering and bent back, or, if notched clips are used, the wire should be wrapped once around the notched portion of the clip. Be sure to have the hole or notch free of the insulation of the wire, also that the wire be bright and a good connection made.

Acid must not be used under any consideration in soldering as it forms a good conductor for the voice and generator currents and will result in cross talk and generator noise by leaking from one line to another. Resin core solder is the safest material for soldering as the resin flux is fed in the right quantity for good work and the latter is non-corrosive and an insulator. After soldering, the free ends of the wires should be cut off close to the clips and each joint inspected to discover any imperfect work.

If cross connecting strips are provided on the arrester frame, they will be a great convenience in connecting any switchboard drop to the line without disarranging the cables or terminal wiring of the exchange. The connecting wires between the terminals are called jumper wires and can be changed from time to time as different lines are terminated on different drops or subscribers' telephones are moved to different locations.

These jumper wires come in twisted pairs, one of the conductors of a pair having a white insulation, and the other a red insulation, the former always being used for connecting together the tips of the circuits and the latter the sleeves.

Extreme care should be used in running these jumper wires that the colors be connected straight through, never connecting a red wire of a jumper pair to a tip wire on the cross connecting strip as this would reverse the tip and sleeve line conductors with respect to the switchboard.

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The arrester frames are provided with jumper strips and jumper rings, the latter for holding the jumper wire when making a cross connection.

In common battery systems a relay rack is nearly always used, and this requires an additional set of cables. The wiring varies with each system but in general conforms to the examples previously given. A view of a terminal room equipped with Western Electric Co.'s apparatus is shown in Fig. 600 which shows the relay rack, intermediate and main frames and cabling. The actual arrangement varies with each installation.

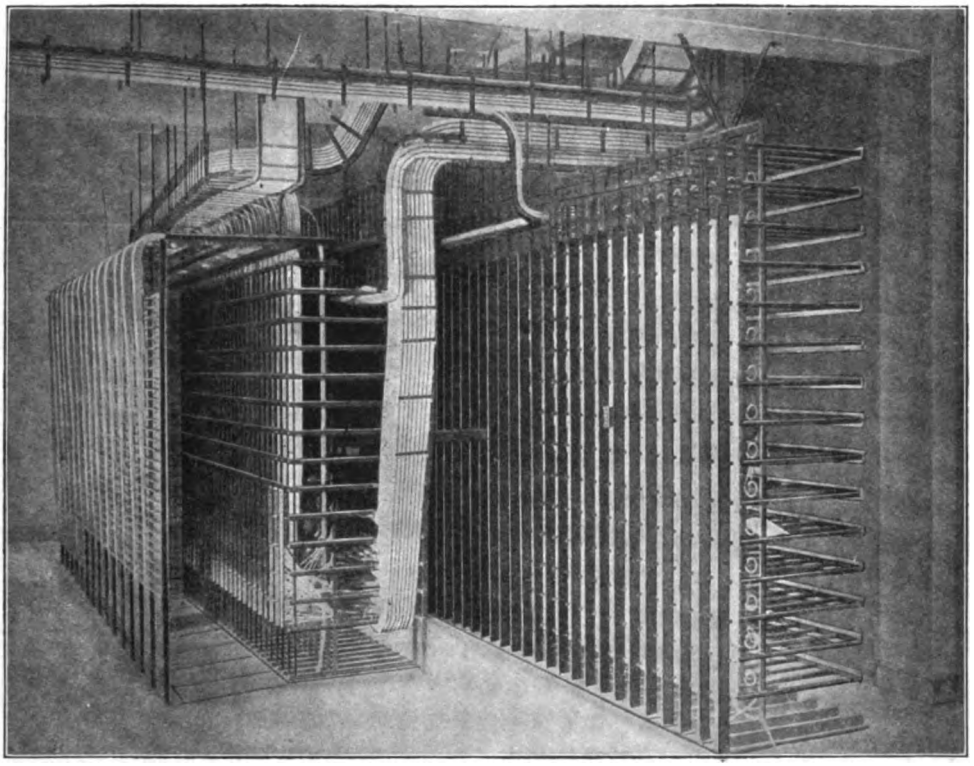


Fig. 600.

The growing tendency is to use as much cable as possible in outside construction. Although the first cost is greater than that of the open wire plant, still the decrease in cost of maintenance will in a few years more than counter-balance the first outlay.

*"The arguments in favor of cable conductors are too well known to require more than the briefest mention: perhaps the strongest, from the point of view of the electrical companies is the great unreliability of the overhead conductors, subject, as they are to all changes of the weather,

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and at times entirely disabled by wind, snow or sleet, causing the entire suspension of business for hours at a time, and costing hundreds of thousands of dollars annually for repairs. Considered from the point of view of the public, overhead wires are also objectionable, disfiguring the streets, obstructing firemen in their duties, and constantly menacing life and limb. The contrast in the appearance of the same street with overhead wires and with under-ground cables, is graphically shown in the illustration in Fig. 601 which represents Broadway, N. Y., as it appeared in 1887, while an illustration of Broadway as it is today is shown in Fig. 602."

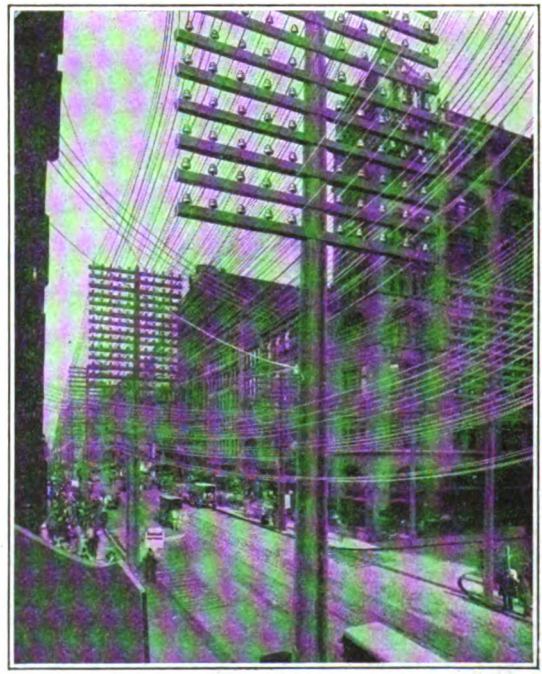


Fig. 601.

While a complete system of underground cable is the best guarantee of the practical control of the telephone business, the use of aerial cable also affords immunity from wind, snow and sleet, and it may be safely asserted that in any case where the extent of the line exceeds six ten pin crossarms it is much better and cheaper to use cable.

By improved methods the cost of cable has been gradually decreased, with the result that today it is cheaper to lay underground or use aerial cable than to use open wire circuits, when the cost of maintaining the aerial circuits for three or four years is considered.

Where the number of conductors is great, as is the case in exchanges of considerable size the relative saving between cable and open wire construction is enormous.

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There are several large companies today making cable suitable for telephone work. The information, method of construction and data given in this chapter illustrates the product of The Standard Underground Cable Co., which is one of the oldest and most reliable of these concerns. Their product has been developed over a period of more than twenty years, and some of the largest systems in operation are furnished with their equipment.

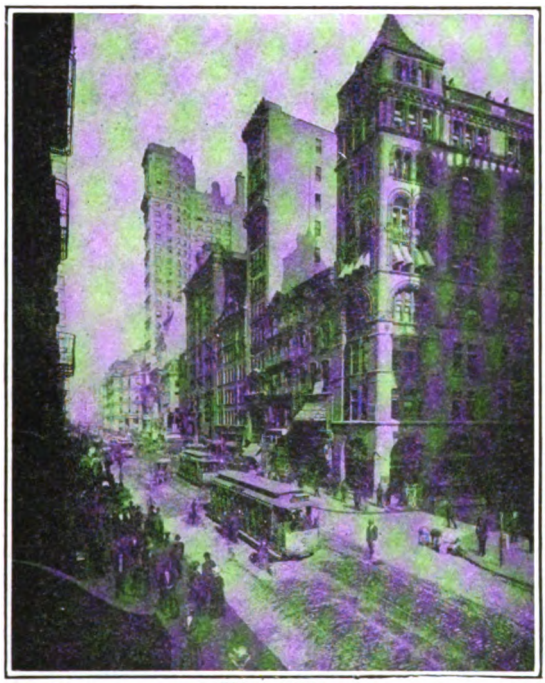


Fig. 602.

"Aerial telephone cable is usually furnished in No. 19, No. 20 or No. 22 B. & S., guage. No. 19 is commonly used for undergound work, while No. 20 and No. 22 is used for aerial. In cables of this description each conductor is insulated with one or two wraps of paper. Paper is used as the insulating covering because it lowers the capacity of the cable, which is highly desirable in telephone work. For this reason it is desirable to apply the paper so as to include as much air as possible, consistent with the prescribed size of the cable. Therefore the bunch or core of wires is preferably left "dry core," i. e. not saturated or filled with insulating compound."

"In some cases the cables which branch or distribute from "dry core" cables are made with saturated core so that there may be no danger of moisture gaining access to and destroying the insulation of the dry core mains. It is apparent that injury to the sheath of the saturated core cable will destroy but a small portion of it, whereas a dry core cable under the same conditions would in the majority of cases become a total

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loss, for the substance entering the sheath would quickly spread through the cable, and it would be necessary to cut out or replace a great many feet each side of the break."

"The form of construction now universally used in telephone cable is that known as "Twisted Pairs," the individual conductors, after receiving their proper covering of paper, being twisted together in twos. After the wires are so paired, they are assembled into a bunch or core: the core is wound with paper tape and then thoroughly baked in specially designed apparatus, and finally it is provided with a lead cover."

"Each twisted pair constitutes a "metallic circuit" from the exchange switchboard to the subscriber's telephone, and as each leg of the circuit is subjected to the same influences from the adjacent conductors, occupying the same position relative thereto, a complete neutralization or balance of inductive interference is secured. If the twist is short, say one in three or four inches, there is no cross talk whatever. In order to facilitate identification of the individual wires of a pair, and to avoid crossing the pairs in splicing, they are covered with paper of different colors: for example, one wire may be covered with red paper, and another with blue paper."

"Dry core cables are especially susceptible to moisture, and the ends must always be sealed with solder. Where they terminate in actual service the ends must be protected by pot heads, or other suitable terminals, as described later."

"The highest class of telephone cable, and that generally used for telephone work by the large Bell and Independent telephone companies, is represented by the following condensed specifications:

"Copper conductors No. B. & S. G., 98 per cent conductivity: insulation to consist of one or two paper tapes: conductors to be twisted in pairs (one or two pairs to have colored paper) the length of the twist not to exceed 3": pairs to be formed into a core arranged in reversed layers: the core to be dry (unsaturated) except for two feet at each end: the sheath to be free from defects, to be of lead alloyed with 2½ to 3½ per cent tin, and a uniform radial thickness of 1-12" for 1 to 49 pair, 3-32" for 50 to 99 pairs, and 1-8" for 100 to 150 pairs: insulation resistance at least 100 megohms per mile when laid, spliced, connected to terminals, ready for use; mutual electrostatic capacity (any conductor measured against its mate with the remaining wires grounded to the sheath) .054 average and .060 maximum. The mutual capacities stated are equal respectively to .08 and .085 mfs. per mile regular capacity (each conductor against all others grounded to the sheath.)"

"Specifications for aerial cable may be so modified as to permit of the use of No. 22 B. & S. G. conductors with an electrostatic capacity of .069 average and .078 maximum mutual, the thickness of lead being slightly reduced throughout. The decreased efficiency of the talking qualities is comparatively immaterial, where short lengths of cable are used."

"The following will be of interest to telephone cable users in comparing the relative values of telephone cable in terms of cost and terms of relative "talking value," and may give them a better appreciation of the factors to be considered and the care to be observed in order to insure a

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correct decision as to such relative values. The specifications should be exact and definite on all points, and particularly as to electrostatic capacity."

"A given standard of efficiency in transmission of sound is more economically obtained by the use of No. 19 B. & S. G. conductor than with any smaller size. As between No. 20 and No. 22 whether for overhead or underground use, it should be remembered that No. 20 insures a greater immunity from service interruptions resulting from mechanical injury to the conductors."

"The following figures from the American Telepone & Telegraph Co.'s (Bell Long Distance) specifications show conductor resistance allowed per mile for conductors of various sizes, and the figures take into consideration and make proper allowance for the increased length of the conductors due to twisting in pairs and laying up into cable form:

22 B. & S. G., 95 Ohms; 20 B. & S. G., 60 Ohms; 19 B. & S. G., 47 Ohms.

Two wrappings of paper applied spirally in opposite directions add somewhat to the cost of the cable, but are mechanically superior to one wrapping. Costly experience has demonstrated this many times."

"There are two methods for testing for electrostatic capacity. First, the regular or old trade standard method of testing to ground with the connections made in the same manner as in a test for insulation resistance, namely, One wire measured against the remaining wires grounded to the sheath."

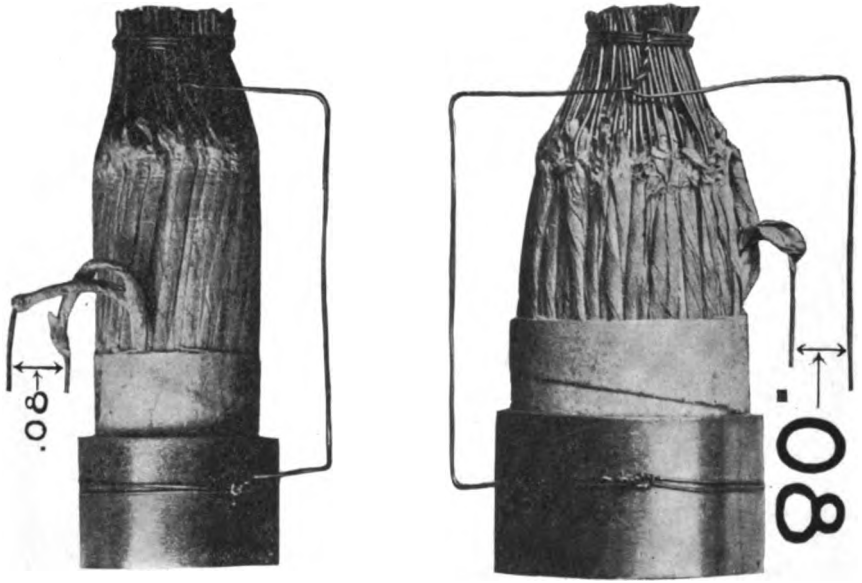


Fig. 603.

"Second: an entirely different test, for mutual electrostatic capacity, in which one wire is measured against its mate, the remaining wires being grounded to the sheath. Fig. 603 shows graphically the relative

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sizes of two cables alike in other respects, and which tested by the different methods (as also graphically illustrated) show '.08 capacity': but which when both are tested by the regular method with one conductor against the remaining wires grounded to the sheath, show .08 microfarad per mile for the larger cable and .12 microfarad per mile for the smaller."

"If these two methods of testing were applied to identical cables, the average relation between the two methods would be shown as follows:

Average Regular Capacity (to ground).		Average Mutual Capacity (to mate).
.08	equals	.054
.10	"	.066
.12	"	.08
.14	"	.093
.16	"	.107
.18	"	.12

"This is a feature of telephone cable specifications which is of immense importance to all buyers and users of telephone cable, especially those who operate moderate or long lengths of cable, yet its full significance is seldom grasped by cable purchasers."

"For the purpose of obtaining relative efficiencies of telephonic transmission through cables of different conductor resistances and electrostatic capacities, Sir Wm. Preece's "KR" law stands today re-affirmed and may be expressed thus:

$$\text{Capacity} \times \text{Resistance} = \text{C}.$$

"In which the various values obtained for C (from cables of like length but different electrostatic capacities and conductor resistances) may be used to compare the relative talking values of such cables."

"This law is based upon the fact that as the resistance of the conductor increases, it becomes a poorer talking circuit. Similarly when the electrostatic capacity increases, the talking circuit is poorer and speech is transmitted less perfectly, and when it decreases, the reverse is true. Now since the value of a talking circuit in a cable (for speech transmission) depends upon both electrostatic capacity and conductor resistance, the relative values of talking circuits in different cables may be observed by comparing the product of electrostatic capacity and resistance in the one cable, with the product of electrostatic capacity and resistance in the other. All combinations—of electrostatic capacity multiplied by resistance—which give the same product (or value for C) would have the same telephonic transmitting value. Any combination which has a smaller product will have a better transmitting value, and any combination which has a greater product will have a poorer transmitting value."

"Thus, if we take a specific case of ten miles of cable No. 19 B. & S. G. conductor having conductor resistance of 47 ohms per mile, and an electrostatic capacity of .08 microfarads per mile, the application of the formula would show the following results."

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"The total electrostatic capacity of the circuit would be .08 × 10 equals .8 microfarads: and the total resistance, 47 × 10 equals 470 ohms, and when these are substituted in the formula we have .8 × 470 equals 376."

"As any other cable whose electrostatic capacity multiplied by its conductor resistance equals 376, has the same value for telephonic transmission, it will be observed that not more than 5¾ miles of No. 22 B. & S. G. cable, .12 microfarads per mile, could be used if the service is to be of the standard given by 10 miles No. 19 B. & S. G., .08 cable: and this is shown by the following application of the formula."

"The total electrostatic capacity of the circuit would be .12 × 5.75 equals .69 microfarads: and the total conductor resistance, 95 × 5.75 equals 545 ohms, and when these are substituted in the formula, we have .69 × 545 equals 376. It should be remembered that doubling the length of the cables in the above example, would change the relation in "talking values" since the length enters into the calculation as squares and not as simple fractions."

"The following table shows in convenient form the relative values of electrostatic capacity multiplied by the resistance, for 10 miles of cable with various conductors and electrostatic capacities in general use:

VALUES OF C FOR TEN MILES OF CABLE.

B. & S. G.	Ohms per Mile.	Electrostatic Capacity per Mile.		
		.08	.10	.12
19	47	376	470	564
20	60	480	600	720
22	95	760	950	1140

"The following table shows the various combinations of length, capacity and resistance of telephone cables required to produce the same arbitrary talking value. In other words, it will be observed from this table that a telephone cable 2,656 feet long, made up of No. 19 B. & S. G. wires having a capacity of .08 mfs. per mile, will have the same talking value as 877 feet of telephone cable made up of No. 22 B. & S. G. wires having a capacity of .12 mfs. per mile."

LENGTHS OF VARIOUS CABLES FOR SAME TALKING VALUE.

B. & S. G.	Ohms per Mile.	Electrostatic Capacity per Mile.		
		.08	.10	.12
19	47	2656 ft.	2128 ft.	1773 ft.
20	60	2083 ft.	1667 ft.	1389 ft.
22	95	1310 ft.	1053 ft.	877 ft.

"Lead covered aerial cables used generally for telephone distribution, require some supporting medium between the poles, as the cables themselves do not possess sufficient mechanical strength to stand the strain. The necessary support is provided by galvanized steel wire, from one quarter inch in size up to one half inch, depending on the weight of the cable, length of span, etc."

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"A fairly good factor of safety should be used in the suspension of aerial cables, especially in long span work in cities or towns where loss of life or injury to passers-by may be occasioned by the failure of the suspension strand."

"The following sizes of strand are recommended for suspending cable, when it is desired to have 2 as the factor of safety.

RECOMMENDED SIZES OF STRAND.

Weight of Cable Lbs. per foot.	100 foot Span. 1% Sag.	120 foot Span. 1.2% Sag.	140 foot Span. 1.4% Sag.	160 foot Span. 1.6% Sag.	180 foot Span. 1.8% Sag.	200 foot Span. 2% Sag.
.75	9-32	9-32	9-32	9-32	9-32	9-32
1.00	5-16	5-16	5-16	5-16	5-16	5-16
1.25	11-32	11-32	11-32	11-32	11-32	11-32
1.50	3-8	3-8	3-8	3-8	3-8	3-8
1.75	13-32	13-32	13-32	13-32	13-32	13-32
2.00	7-16	7-16	7-16	7-16	7-16	7-16
2.25	15-32	15-32	15-32	15-32	15-32	15-32
2.50	1-2	1-2	1-2	1-2	1-2	1-2

"The suspension wire is fastened to the sides of the poles or to the bottoms of the cross-arms by suitable clips and pulled taut in place. There should be no splices between poles, and the ends should be securely fastened to prevent the possibility of slipping when the weight of the cable is added."

"The cable itself is suspended from the supporting wire, called a "Messenger" by means of hangers of various forms which clasp the cable firmly, and are provided with a hook which rests upon the messenger wire, the hangers being placed from two to three feet apart. When installing aerial cables, a Leading up" wire is stretched from the bottom of one pole to the messenger wire on the starting pole. A rope is fastened to the end of the cable and carried along the messenger to the point where the cable is to reach, and is run through a snatch hook down the terminal pole to a second block at the bottom and thence to a capstan or winch. Temporary rollers are provided on the poles over which the rope runs or it may be held in place by wire hooks on the poles, or by wire hooks or loops on the messenger."

"Draw the cable slowly up the inclined wire and along the messenger, attaching hangers to the cable as it pays out, and hooking every third or fourth hanger onto the messenger to carry the weight of the cable."

"Linemen must be stationed at each pole to remove the hangers from the messenger, pass them by the messenger clamp, and replace them on the messenger. When the end of the cable arrives at the last span, the linemen put every hanger, as it passes the clamp at their respective poles, on the messenger so that when the cable is drawn over the last span all the hangers will be in place. The strain on the hangers which carry the weight of the cable while it is being drawn along, is such that they may loosen and tend to slip along the cable: it is therefore better to pull the

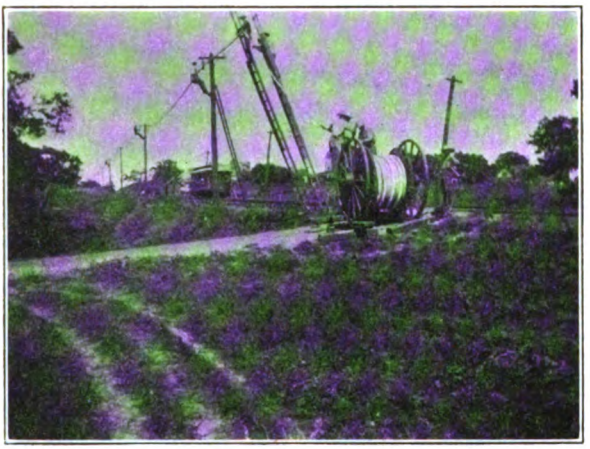
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cable in place while supporting it by "Carriers", the wheel of the carrier running on the messenger, and the cable hanging in the stirrup. If carriers are not available, wire hooks may be used. The permanent hangers are hooked on to the messenger, as already described, but not before the last span is reached. They are put in place by linemen riding along the messenger wire in a "carriage" after the cable is drawn up. In this latter method the loosening and slipping of the hangers is avoided and they remain evenly spaced on the cable."

"Measurements of aerial cable should always be so made that the joints will be at poles and not in the middle of sections between poles."

"Platforms or steps should be provided on all poles where terminals are located, so as to facilitate the work and the regular inspection of the apparatus."



B Erecting Aerial Cable.

Making Joints, Loops, Etc.—Caution. Lead covered cables are only as strong as the weakest spot in their entire length, and the weak spot often is in the joints. This is not necessarily the case, for joints properly made are fully as reliable as the cable itself, but the greatest care must be exercised to secure perfect results.

In view of the importance of the joints—the most important part of the cable installation—employ only experienced and careful workmen. Have every splice inspected by the foreman, (who should be thoroughly competent to detect defective workmanship) and consider no joint complete which has not received his approval.

"An expert lineman may sometimes be used to make and insulate the wire joints but never allow the solder wipe-joint to be made by any one who is not thoroughly experienced in such work. If a cable splicer is not available, a first class plumber will answer, provided extra careful inspection is given to his work. Scrupulous cleanliness is an essential to good results, and the workman's hands should be as free from perspiration as possible. A little moisture from the hands may result in poor insulation resistance, especially in the case of dry core telephone cables.

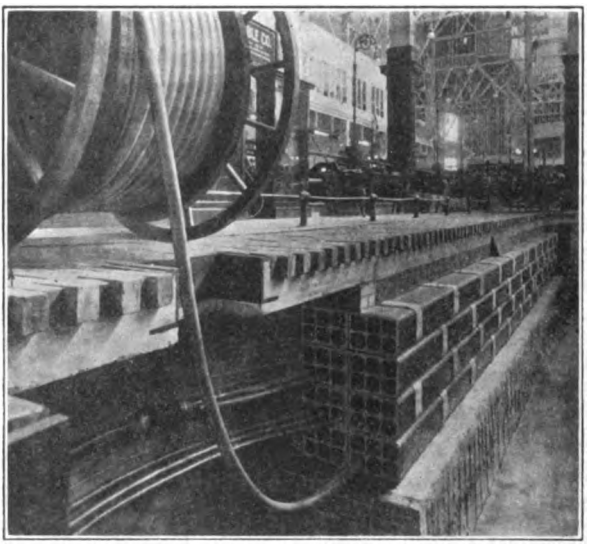
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"Wherever possible, each section of multiple conductor cable should be tested for continuity and grounds before making the joint, and again after the joint is finished.

"General Directions for Making Joints on Lead Covered Cables.—The directions here given apply to any cable locations but more particularly to cables in underground conduits and manholes.

"The cables are usually left by the pulling-in gang without very much reference to final arrangement, and it should be the jointers' first duty to inspect the cable thoroughly, from the edge of the duct to the sealed end, in order to discover any mechanical injury or intrusion of moisture. Where there are several cables to be jointed in one hole, care must be exercised that the corresponding incoming and outgoing sections are spliced together. Absurd as it may seem, mistakes are sometimes made on this point. After placing protectors in the mouth of the ducts,



A Drawing in Underground Cables.

the cables should be neatly bent and stored around the sides of the manhole, and the ends brought into position for jointing at the designated point, which should always be such that the joint, when finished, will lie between two supports or hangers so that there will be no strain on the joint itself when completed and stowed away. In single conductor cables where a "butt" joint is used, the cables should overlap very slightly if any; but in multiple conductor cables where the wire joints must be "staggered" (i. e. not all opposite each other) the cables should overlap sufficiently to allow for the proper distribution of the wire splices.

Removing Moisture.—When the ends of cables have been allowed to lie for any length of time in manholes where there is water, a very slight imperfection in the soldered end will admit more or less moisture to the

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insulation. A careful examination should always be made, and, if any moisture is evident, the cable should be cut back a little at a time until all evidence of moisture disappears, care being taken not to cut back so far as to render it too short to make the joint. When no more cable can be cut off, and moisture is still present, as shown by bubbles when the cable is dipped into hot insulating compound, apply heat to the lead cover of the cable, beginning at the point nearest the duct and very slowly approaching the end of the cable, the object being to drive all moisture to the open end. Wherever it is allowable, a furnace or gasoline torch may be used for this purpose, and if the cable is covered with saturated fibre, a metal screen should be interposed between the flame and the cable to prevent ignition of the fibre. If the use of a furnace or torch is forbidden, or is unsafe on account of the presence of gas, the heating should be effected by pouring very hot insulating compound over the cable, catching it in a vessel held underneath. Where there is still any doubt as to freedom from moisture, it is best to make a careful insulation test before the joint is made. This test may indicate the necessity of replacing the cable section.

"Never cut off the end of one section until sure that there is no moisture in the other section.—You will thus have an opportunity to change the location of the splice in case the other end must be cut back for moisture.



C Feeding Cable through Manhole.



D Underground ducts in trench.

"Scoring the Lead.—When the cables are placed in position and ready for the jointing, the ends should be marked at the point to which the lead is to be removed, and scored or cut entirely around. This cutting is easily and accurately accomplished by means of a special tool which works on the principle of an ordinary pipe cutter.

"Most jointers accomplish the same result by means of a plumber's chipping knife and hammer, marking the lead but being careful not to cut entirely through to the insulation which might thereby be damaged.

"Removing the Lead.—The lead sheath is then cut lengthwise of the

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cable from the circular score to the end, by the chipping knife, and the piece of lead is removed with a pair of pliers. In making the longitudinal cut which goes entirely through the lead, great care must be exercised not to injure the insulation. The knife should be held at such an angle that it will go through the lead, tangent to the insulation, (i. e., so that the knife will pass between the insulation and the lead and not cut the insulation), or a special tool furnished by the manufacturer may be used.

"After the lead has been removed, the parts where the lead was scored should be carefully examined and all sharp edges or projections, which might tend to penetrate the insulation of the cable, should be removed by a knife, or the lead should be slightly bellied out by some blunt instrument such as the end of the pliers.

"*The Lead Sleeve.*—When the lead covers of the two cable sections have been thus treated a lead sleeve, which will later be used in jointing, is slipped over the more convenient end and pushed back out of the way. The lead of this sleeve should be at least as thick as the lead of the cable itself, and, in view of its exposed position, may (in the case of thin lead on the cable) be made somewhat heavier to give greater mechanical strength.



Fig. 604.

"Before slipping it on the cable, each end of the sleeve is thoroughly scraped with a shave-hook or knife, for a length of about two inches, and the cleaned portion thoroughly smeared with some convenient flux, (usually a tallow candle,) which, by preventing the formation of the usual film of lead salts, insures a close union of the lead and the wiping metal which is used to make the joint between sleeve and cable sheath. The internal diameter of the sleeve should exceed the diameter over the lead of the cable by 1″ to 1½″. The operation of wiping the joint is shown in Fig. 604.

"The following table is somewhat more liberal in allowances for clearance between inside of sleeve and outside of cable, but it is fairly representative of average practice in this respect as well as in the sleeve lengths.

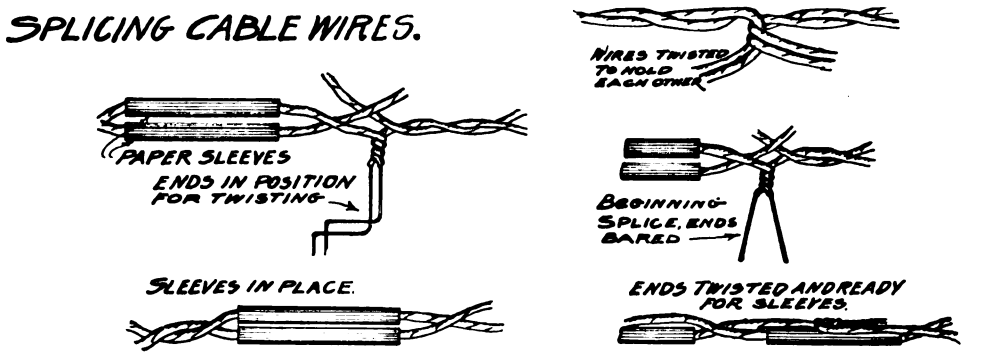
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"Approximate data as to lead sleeves, weights of solder and splicing compound for straight joints (two-way.)

	Outside Diam. of cable in Mile.	Inside Diam. Sleeve	Length of Sleeve	Gals. Ozite per Joint.	Wiping Solder per Joint.
	Up to 800	1½"	14"	.15	1.5 lbs.
	801 — 1200	2	16"	.25	2.5 lbs.
Telephone	1201 — 1600	2½"	18"	.40	3.7 lbs.
and	1601 — 2000	3"	20"	.7	5.0 lbs.
Telegraph	2001 — 2400	3½"	22"	.9	6.3 lbs.
Cable.	2401 — 2800	4"	24"	1.3	7.6 lbs
	2801 — 3200	4½"	26"	1.8	8.3 lbs.

Note: Ozite is not used in paper insulated telephone cable splices.



"Joints on Bunched Cables.—"Bunched Cables" so called, are used for telegraph, telephone and signal circuits, and contain, in the case of telegraph cables, any desired number of conductors up to two hundred, usually of No. 14 B. & S. G. copper, each wire insulated to a diameter (over the insulation) of 5-32" or 6-32"; the insulated wires are arranged in layers with a spiral twist, each layer being twisted in a direction opposite to the next adjoining. In telephone and signal cables the wires are



Fig. 605.

smaller, No. 22, No. 20, No. 19 or No. 18 B. & S. G., each wire being insulated (but with different colored paper) are twisted upon each other once in every 2½ to 3" so as to form a "Pair". The twisted pairs are then formed into a "Core" containing any desired number of pairs, usually in multiples of five, up to a miximum of six hundred.

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"Arrange the cables in position for jointing, allowing the ends to overlap from twelve to twenty-four inches, according to the number of wires or pairs in the cable. In case the insulation is dry paper, the mass of wires must be thoroughly saturated with hot paraffine, before separation, to prevent the paper from untwisting, but more particularly to prevent the absorption of moisture by the paper. Slip the lead sleeve over one end of the cable, strip off the lead and bend the wires back, layer by layer, until the innermost wire or layer is reached. Choose a wire or pair from one of the ends, and its mate from the other, and slip a small paper sleeve, three inches long, (See upper part Fig. 605), on the more convenient end. Having determined the location of the wire splice, cut off the surplus after allowing an overlap of 3″ for twisting the wires together; draw the two ends snug (not too tight), strip off the surplus insulation, twist the bare wires together and tighten with a pair of pliers; cut off the surplus wire, bend the ends down on the main wire and slip the insulating sleeve over the splice, all as shown in lower part Fig. 605.

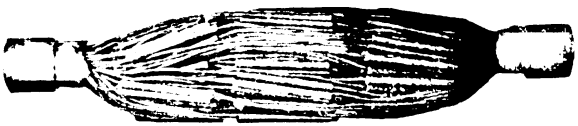


Fig. 606.

"The term "mate" as above used, needs further explanation: In twisted pair telephone cable, it may be any pair in a corresponding layer, care being taken to splice red to red, and blue to blue, so as not to cross the colors, for such crossing may lead to confusion when testing out; equal care must be used not to split the pairs, i. e., not to connect the wires of one pair with the wires of several pairs in the opposite section, for that too will cause trouble in testing out and destroys the anti-induction qualities of both circuits. In a telegraph cable, "mate" means any wire in a corresponding layer, unless each layer has an identifying wire or marker, in which case the identifying wire must be first connected and the first adjoining wire on one side with the corresponding wire on the other side, (passing around to right or left) in each layer, so as to preserve the continuity of identification and the same relative position of all other wires in each layer, throughout the whole length of the cable.

"While paper sleeves are used in joints of telephone cables, cotton tubing is often used in the case of telegraph cables.

"In order to make the finished joint as small as possible, it is necessary to distribute the wire splices evenly along the entire length of the cable joint, no two adjacent wires having joints opposite one another. (See Fig. 606.)

"When all the wires are joined and insulated, the entire splice should be thoroughly boiled out with paraffine, and wrapped with muslin cut in strips about 3″ wide. This serving enables the workman to draw the joint down to the smallest practicable size consistent with the size of the

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lead sleeve. The cotton serving should be thoroughly boiled out, and the lead sleeve wiped to the cable sheath, in a manner already described.

"We do not recommend filling the joints on dry paper telephone cables.

"The wires to be tapped or branched are picked out at the splice, usually by electrical tests, and the two main wires together with the branch wire are joined under the same insulating sleeve, the lead joint being made in the shape of a Y.

"In working on dry paper insulated bunched cables, observe the following precautions:

"Never leave the ends exposed to the atmosphere, or open in manholes, if possible to avoid it; and when this is unavoidable in the process of work, soak the exposed paper carefully with hot paraffine.

"Start at one end of a cable (not at intermediate sections) and put on a "Test-Cap" before making any joints. A test-cap is made by stripping all of the insulation from the end of each wire for a distance of six inches, bunching all of the wires together, carefully insulating the bunch, and protecting it from the weather by a lead cap, soldered or taped to the lead sheath of the cable.

"When starting to splice at the first break in the cable, a test with a telephone receiver in series with a few cells of dry battery, between any wire and the lead sheath of the cable, will at once show if a "ground" exists on any wire in the cable.

"Connecting one side of the battery to one wire of the cable and the other side of the battery to one side of the receiver and touching the other wires, in succession, with the free wire of the receiver, a decided click is heard if the wire under test is continuous to the test cap. If no sound is heard in the receiver, or only a very faint click, it is good evidence that the wire is open or broken.

"In making joints in manholes or elsewhere, these tests should always be made to the test cap, and ahead through the next section, which has been provided, at the next joint, with a temporary test cap. Grounded wires, which are very rare, should be identified at the test cap and separated from the bunch so that the remaining wires will show clear.

"Defective wires or pairs in one section should be joined to defective wires or pairs in the next section. If this is not done and the wires are connected at random, without test, the cable when entirely completed, may be found with many defective pairs or wires whereas proper attention to this detail might in many cases save every wire or pair except one.

"All cable manufacturers provide extra wires in bunched cables, over and above the number ordered by the customer, in order to provide for possible breaks in the wires of the cable. If care is exercised in the splicing and tests referred to above, the extra wires will always suffice for such cases of open or grounded wires as arise in ordinary manufacture and installation.

"These simple tests do not locate crossed wires, but crosses in cables are very infrequent and can be readily located after the work is otherwise completed." (See Chapter 9.)

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It is more economical to install large main leads of telephone cable, with branches of smaller cable extending to various points of distribution, than it would be to extend separate cables from the exchange to each distributing point. This plan of cable distribution, however, requires cable splices at each junction, and many exchanges have no one at their command capable of forming a cable splice or wiping a joint, and to obtain skilled cable splicers adds materially to the cost of installing cable.

A simplified method of forming a splice or of making a joint, which would not require labor particularly skilled, is not only a great convenience, but reduces the cost of installing cable and the time taken to do the work. The character of a lead sleeve splice depends almost entirely upon the skill of the workman, and may or may not prove to be a reliable joint. Defects in the cable joints are sometimes due to accident. Apparatus which would eliminate or even reduce the opportunity for defects in the cable joint should be a marked improvement.

Description.—Fig. 607 shows a junction and splicing box manufactured by the Moon Manufacturing Company, which is made of one solid iron casting, with cast iron cover and self-soldering nozzles. The cover is firmly secured to the box by heavy machine screws which do not extend through to the inner side of the box. The joint is made by a one-piece rubber gasket, between two perfect, turned surfaces, in the same manner as the joint at the cylinder head of a steam engine.

The Self-Soldering Nozzles are sealed to the cable sheaths by simply heating them with a blow torch, when the solder which they contain melts and runs to a lower level, uniting with the tinned surfaces of the nozzle and the cable sheath, casting a perfect, solid joint. No particular skill is required to perform this work, and the same result is obtained with each nozzle. The lower portion of the junction box may contain a small quantity of compound or paraffine which surrounds the cable wires and covers the ends of the cable sheaths, and prevents moisture from penetrating into the cable when the box is opened at any time. The cable wires extend above the compound, where they may be inspected or tested.

Drying out the Box.—A screw plug at the top of the box affords a place for ventilation, while the air in the box is being dried out, which is performed by warming the box, either with a blow torch or with the hot paraffine. When the screw plug is replaced (before the box cools) the junction box is sealed up like a fruit jar.

The Cables are not Exposed.—It must be understood that to open the box, by removing the cover, does not mean that the cable has been opened or exposed, for this is distinctly not the case. The compound covers the cable sheaths, and the cables are thus practically pot headed. Only the wire splices are exposed. With ordinary sleeve splices, where the joint is opened for any reason, the cable ends are exposed and no protection is afforded.

Providing for Extensions of Cable.—The junction box may be provided with extra openings for additional cable, in contemplation of future extensions. These openings are sealed temporarily by a screw plug, which may be removed at any time and self-soldering nozzles inserted to receive the additional cable, and provides a simple method of making a splice, and a cable joint easy to form without skilled labor, practically eliminating the danger of forming a leaky joint, the joint being less liable to injury from accident and also provides means for extensions of cable lines or changes in cable distribution, besides establishing permanent

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places of opening along cable lines, where each cable may be tested and each wire splice inspected.

The Combination of Terminal Head and Junction Box. (Fig. 608) affords means for distributing a portion of the cable conductors to the line wires with fuse and carbon protection. The balance of the cable conductors may be continued in cables of smaller size to other points of distribution, making the necessary cable splices on the inside of the terminal head. Ample room is afforded for splicing the cable wires. By this means a main lead of cable may extend from the exchange, branching to various points of distribution. The plan of distribution may be either direct or in multiple, as is indicated on the accompanying diagram (Fig. 609).

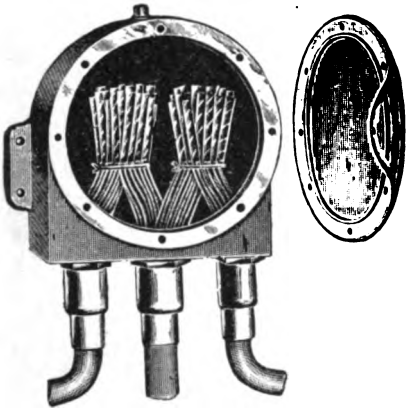


Fig. 607.

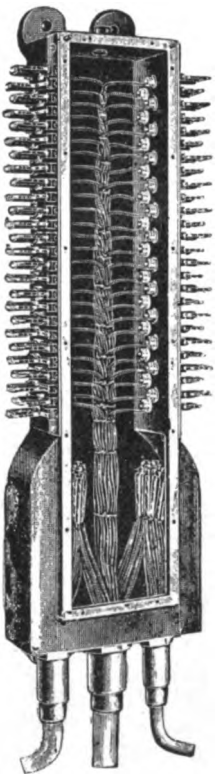


Fig. 608.

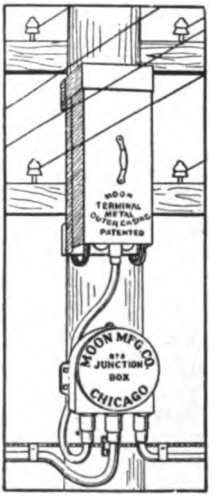


Fig. 614.

The combination terminal heads are made in sizes to distribute any number of cable conductors to line wires, from five pair to one hundred pair. The combination head is intended to be mounted in a metal outer case or pole box, to protect it from the weather. In the accompanying drawing (Fig. 610) no attempt is made to show this outer case or the detail of the head, but it is the intention to show the manner of connecting up the cable wires and the convenient manner of forming the splice inside of the head. The covers are removed to show the wire splices.

Reference to the suggested plan of cable distribution indicated in the diagram (Fig. 609), shows the greatest economy in the use of cables, as

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each cable contains exactly the number of wires required, leading to the various points of distribution, without waste or dead wires. The heads are designed to contain a small quantity of sealing compound, covering the ends of the cable sheaths, as in the junction box. This, with the cover and rubber gasket, forms a double seal. This plan of cable distribution and use of the apparatus designed to eliminate sleeve splices and wipe joints has been in practical use for several years, and the firm manufacturing it states that fully one-half of its extensive orders for pole terminal apparatus for the past year have been for terminals of the combination type.

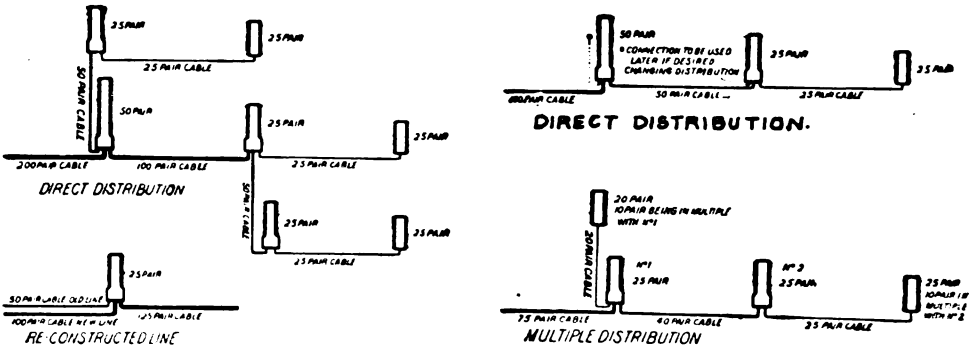


Fig. 609.

The combination head is mounted in the Moon Metal Outer Case or pole box, and as the cover slides either above or below the head in opening, it can be placed just below a circular distributing frame, or below cross-arms.

Multiple Cable Distribution.—It is the aim in modern telephone construction, to build permanently, providing as far as possible for increasing the capacity without abandoning or destroying work previously performed. Multiple cable distribution affords a certain amount of expansion by enabling one line to be used at two or more distributing points. As its name implies, the multiple method of cable distribution requires that the same pairs appear at two or more terminals. Since it is not always desirable or practical to complete the cable installation at its initial stage of construction, a method that will allow extra cables to be installed, without additional cost for terminals or changing present conditions is herewith described.

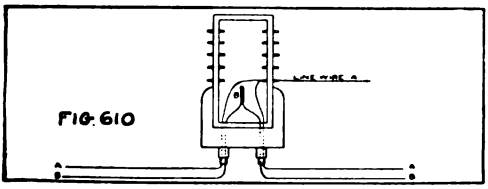
Fig. 610 shows cable conductor, A, not only connected to line wire A, through the terminal head, but it extends from the terminal connection, through conductor A in the continuing cable, to the next terminal head.

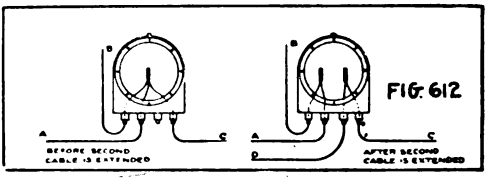
The cut also shows conductor B spliced inside of the terminal head to the conductor, B, of the continuing cable, passing direct to the next distributing point.

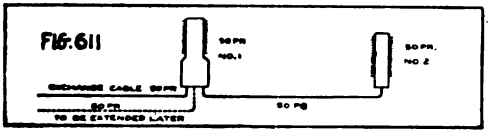
In this same manner, in Fig. 611, terminals 1 and 2 are connected in multiple, and to the exchange, by a fifty-pair cable. When desired, a new cable can be run from the exchange to terminal No. 1, and the circuits at that point rearranged, giving full capacity to both terminals.

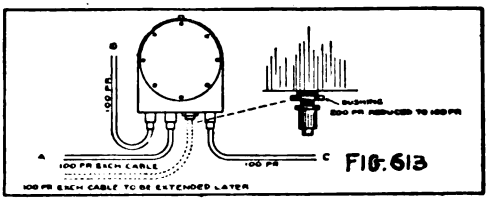
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A junction box can be used to great advantage when temporary multiple distribution is desired, as shown in Fig. 612. The exchange cable, A is at first connected in multiple with the two cables B and C, the circuits of which being distributed at various points to subscribers' stations, through permanent terminals. When the full capacity of cable B or C is required, an additional cable, D, may be extended from the exchange to the junction box, entering through an opening previously provided, or a 200-pair cable may take the place of cable A (See Fig. 613). If a 200-pair cable is contemplated, a suitable opening in the junction box should be provided. These openings should be standard pipe tap, and then bushings can be used. The splices in the junction boxes are arranged as shown in Fig. 607. The obvious advantage of first extending the cables in multiple, and later increasing the capacity by using junction boxes, is apparent, as none of the original terminal work need be disturbed. The cable, B, shown vertical in Figs. 612 and 613, can, of course, be extended in any direction; it is so drawn in the illustration to clearly indicate its purpose.


FIG. 610


FIG. 612


FIG. 611


FIG. 613

Tapping out wires from a junction box may be easily done at any time, if an opening for an additional nozzle is provided. A short piece of cable extends from the nozzle of the junction box to the nozzle of a terminal head, which may be located on the same pole (See Fig. 614.)

The cable may terminate or dead end in the junction box, but the box should be provided with one or more additional openings for nozzles of proper size.

Directions for making the cable joint with the Moon Self-Soldering Nozzle.

The terminal head or junction box is first fastened in place upon the pole. It is necessary to have the nozzle in a vertical position when the cable joint is formed.

Before passing the cable end into the nozzle, remove a portion of the lead casing of the cable, leaving the cable wires free on the inside of the terminal head or junction box, so that they may be connected to the terminal connections on the inside of the head, or may be spliced onto other cable wires entering the head or box. Bind these wires with cord to prevent spreading.

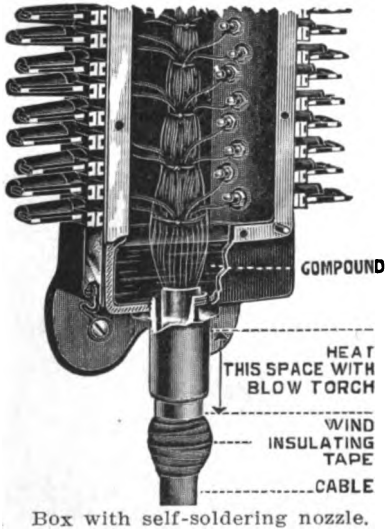
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Mark off on the lead sheath of the cable the place that would come inside of the nozzle where the joint is to be made.

Scrape the lead sheath at that point until it is bright and clean, then rub the bright or clean space with a tallow candle, soldering paste, or non-corrosive flux, which will cause the solder to unite with the sheath of the cable very readily when the solder is heated. The inner surface at the lower end of the nozzle is properly tinned before it leaves the factory.

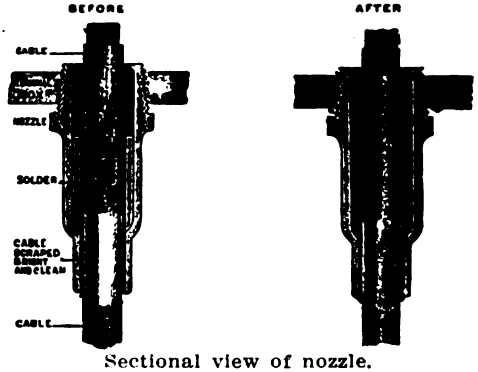
When the work of preparing the cable has been performed, pass the end of the cable up through the nozzle into the box. The lead sheath of the cables should extend into the box about one-half inch.

Take ordinary insulating or adhesive tape and make a few turns around the lower end of the nozzle, lapping down onto the cable sheath, as is shown in the adjoining cut. This tape prevents the solder from running out of the nozzle when the solder melts.



Box with self-soldering nozzle.

Fig. 615.



Sectional view of nozzle.

Fig. 615a.

A litttle pulverized rosin sprinkled into the opening between the sheath of the cable and the nozzle after the cable is in place, will aid in the union of the metals.

Then apply the blow torch to the nozzle below the terminal head or box, and heat the nozzle uniformly to a degree which will cause the sleeve of solder in the nozzle to melt and run down to a lower level, forming a union with the cable sheath and with the inside of the nozzle.

To ascertain the proper heat, occasionally touch the outside of the nozzle with a piece of slender solder, similar to string solder, and when the nozzle is warm enough to melt the solder on the outside, it is evident that the solder contained in the nozzle has melted and has formed the joint.

Continue the heat on the nozzle for one half minute or so, to give the solder ample time to form a thorough union. Then cool the nozzle with a wet piece of waste or rag, and remove the tape, and it will be found that a perfect cable joint has been made.

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After connecting up the cable wires, or making the splices in the manner indicated in the accompanying cuts, pour a quantity of paraffine or cable compound into the pocket or cavity at the lower end of the box. This compound will surround the cable wires, cover the end of the cable sheath and will fill the cavity in the nozzle above the solder, forming an additional seal, and prevent injury to the cable when the box is opened for any purpose.

To close the terminal head or junction box after all connections are made, first see that the rubber gasket forming the cover joint, is in proper place. Then screw on the cover, setting screws in snugly. Remove screw plug at top of box, and with the blow torch slightly warm the cover of box. This will evaporate all the moisture from the air in the box, allowing it to discharge through the opening at the top of the box.

While the cover is still warm, again set up the screws of cover snugly. Then replace the screw plug at top of box. This partially forms a vacuum in the box, which is perfectly free from mositure.

If the box is ever opened, repeat process.

Where the junction box is intended for use in a manhole it should be specified in ordering, as they differ in some particulars from those used on poles.

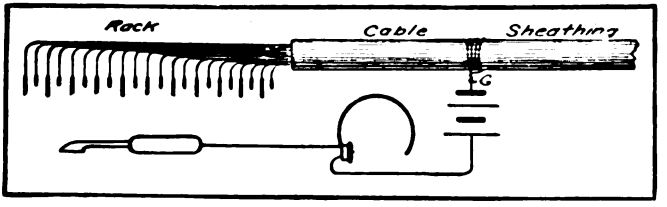


Fig. 616.

*"In offices where one man has to do everything without the assistance of another the duties sometimes include the picking of pairs in a new cable. The writer suggests a method that has been used by many under the circumstances, but which, however, may be new to some of our readers."

"First, fan out the office end of the cable and connect it to the rack at random, being sure that the red and white components of a pair are in regular order on the rack. Open the other end of the cable—but only when the air is free of moisture—and test for "bad" pairs at the office end."

"This can be done by using the contrivance shown in Fig. 616, which consists of a receiver, two cells of battery and a "pick". A convenient "pick" can be made from a large needle, such as is used in sewing burlap sacks."

"To test for "grounded" pairs, connect the receiver to the sheathing, as at *G*, and run over the terminal, or rack, connections with the pick. In case any conductors are "grounded" on the sheathing, a "click" will be heard in the receiver, due to current flowing from the battery, through

*American Telephone Journal.

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the pick and faulty wire to the sheathing, and back to the receiver. Any "bad" pairs thus located should be set aside and tagged as such. Fig. 617 shows method of connecting to locate grounded pairs, or conductors. "Open" conductors or "crosses" cannot be located in this way, though crosses may be by using a second pick in place of *G* and testing each pair separately, and each pair with every other pair."

"Assuming the new cable tests clear, as it should, connect the "red" side of pair one, as in Fig. 617, in the office to *G* on the cable sheathing, through a battery. Then connect the white side of the same pair—pair one—to the "red" side pair two, and so on down the rack. Always connect the "white" side of a pair to the "red" side of the succeeding pair, in regular order, so that the "white" side of the last pair has nothing to be connected to."

"Now go out on the terminal, with your locating contrivance (Fig. 616) and attach the battery to the cable sheathing. Touch each of the exposed "red" conductors with your pick till you get "battery", or a click in the head-receiver. As there is only one conductor in the cable that has "battery" on it, and that is the "red" side of pair one, you can safely tag the "red" wire and its "white" component as "pair one."

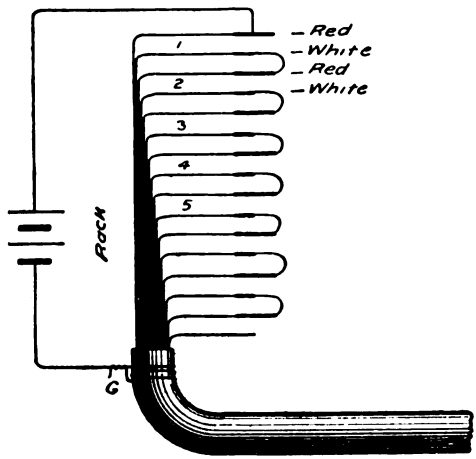


Fig. 617.

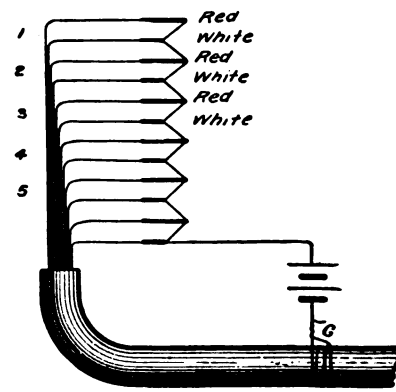


Fig. 618.

"Now attach the "white" wire of pair one to the "red" (battery) wire of the same pair, and pick over the "red" conductors again. When you get "battery" again, you know you have found the "red" side of pair two, for the battery current from the "red" side of pair one flowing back to the central office rack over the "white" side of pair one, and comes out to you again on the "red" side of pair two. You have the "white" side of pair two twisted with the "red" side, so no further identification is necessary. Tag this "pair two." "

"Now disconnect the "white" side of pair one from its "red" mate—the battery wire—and attach the "white" of pair two to the "red" battery wire of pair one. Go over the untagged pairs until you get "battery" again, which will, of course, be on the "red" side of pair three. Tag it as such, attach its "white" mate to the "battery wire" of pair one and locate

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pair four. And so on. When you locate the "red" side of the last pair you have its "white" mate without need of further identification."

"In case you have a fifty-pair cable, and wish to take out pairs one to twenty-five at one terminal—as a top—and pairs twenty-six to fifty at another box, the following idea may prove available:

"Connect every "red" and "white" wire together, from one to twenty-five, as a solid conductor, Fig. 618. From the "white" side of pair twenty-five run the connecting wire to *G* on the cable sheath through a battery as shown."

"Then go to the point on the cable where it is desired to tap these twenty-five pairs, and lay open the sheathing. Touch each conductor with your pick—it will go through the paper covering—and tag every wire on which you get "battery." That will locate the first twenty-five pairs. Then go to the other point, where the pairs twenty-six to fifty are desired, and tag every pair upon which you *do not* get "battery". The number of each pair can be ascertained later by the method described. Multiple taps can be made in the same method, by putting "battery" on such pairs as you wish to appear at certain points. Ordinary dry cells will give results in all these cases, but "tone test" is better. It is a noise that *will* work through almost any resistance, and cannot be mistaken when heard. An apparatus for giving "tone test" can be arranged very easily as follows:"

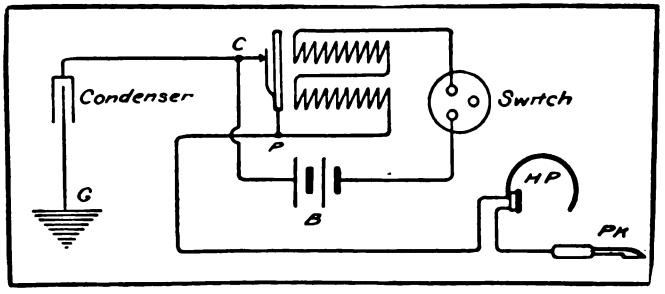


Fig. 619.

"An ordinary "buzzer" or electric bell with the gong removed is connected to a couple of cells of battery (Fig. 619). Connect a wire to the make-and-break screw, *C*, and another to the armature spring, *P*, or the frame of the bell. (One side of the battery will do as well, providing you get right side.) Ground the wire from *C* through an ordinary condenser, as at *G*. The other wire take to the head-phone and out to the pick. When the pick strikes a grounded wire, or completes the circuit to *G* in any way, a peculiar buzzing noise is manifest in the receiver or head-phone. It can never be mistaken when once heard, and is particularly serviceable when there are "working wires" in a cable, that is, subscriber's circuits. The condenser prevents any signals being thrown on the board, and seems to take the "rough edges" off the noise itself."

"The loudness of the "tone" can be regulated by the tension of the armature spring."

"It can be used to take the place of the ordinary battery "click" in

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the location and selection methods described in this article, and will find favor at once."

"Buzzer, battery and condenser can be mounted together as one piece of apparatus, and one-point switch included to start the buzzer. With two cells of ordinary dry battery it will run for hours without attention, the writer having had one running twenty hours continuously without exhausting the batteries to any extent."

"In making the test for pairs the two batteries should be in series. Otherwise the click might be too faint to test with; or else the battery of the test set should be disconnected from the circuit."

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CHAPTER XIV.

THE AUTOMATIC TELEPHONE SYSTEM.

BY far the best known and most widely used of the various automatic systems is that manufactured by the Automatic Electric Company, Chicago, and known as the Strowger Automatic, or more commonly as the "Automatic."

The first patents on this system were issued in 1890 to Almon B. Strowger. In 1892 Mr. Alexander E. Keith, at present General Superintendent and Chief Engineer of the Automatic Electric Company, assumed charge of the work of development and under his direction the first exchange was manufactured and installed at La Porte, Indiana.

It is principally due to the untiring efforts of Mr. Keith that the system has reached its present high state of perfection.

The La Porte exchange was necessarily crude in form, and required four wires between the subscriber's station and the exchange, besides a common return, but it demonstrated that the automatic system was possible.

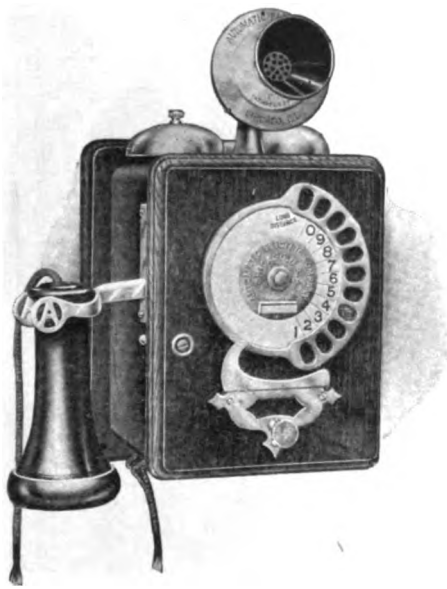


Fig. 620. Common Battery Automatic wall Telephone.



Fig. 621. Automatic Desk Telephone.

In 1894 Messrs. Chas. J. and John Erickson, two inventors of unusual ability became associated with the Strowger Company and in the fall of the same year a new switchboard of one hundred (100) line capacity was

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installed at La Porte, Indiana, replacing the older one, and reducing the number of lines per subscriber to two and a common.

In 1895 the vertical and rotary type of switch was developed and a number of installations of 200 lines capacity were made.

The trunking feature was first used in 1897 when an exchange of one thousand lines capacity was installed at Augusta, Georgia. Two years later, in 1899, the automatic trunking system was perfected and an exchange of 10,000 lines capacity was installed at New Bedford, Mass. This exchange is still in operation. The automatic selection of trunks solved the problem of the capacity of the automatic switchboard and since its introduction, the growth and development of the system has been very rapid. Several exchanges of 100,000 lines capacity are now in operation and in certain instances of trunking between exchanges the 1,000,000 system is employed.

A description of the types of apparatus used during the different stages of development of the system would be of interest to the student of telephony, but as it is not possible to treat the subject fully within the limits of this article, we shall confine ourselves to the exposition of the exchange equipment as manufactured and operated today.

In the automatic system the subscriber's station is connected to the exchange by two line wires designated respectively "vertical" and "rotary." By operating the dial of the telephone, the vertical line is grounded a number of times, corresponding to the figure from which the dial is rotated. The rotary line is automatically grounded once after each series of vertical impulses. Thus, in calling 7256 for example, current impulses are transmitted to the exchange as follows: Seven vertical, one rotary; two vertical, one rotary; five vertical, one rotary; six vertical, one rotary. In addition, a preliminary impulse is made automatically on the rotary line as the dial is being pulled down for the first digit.

When the call is completed and the ringing button depressed the vertical line is again grounded. When the switch hook is pulled down, as in hanging up the receiver after making a call, both vertical and rotary lines are grounded momentarily at the same time.

At the exchange the line terminates in a line switch and also in a pair of contacts which are multiplied throughout the banks of a group of ten connectors. 100 pairs of contacts comprise a connector line bank, being arranged in ten parallel rows of ten pairs of contacts each. By operating a connector shaft five steps vertically and then rotating it six steps, for instance, a connection is established through the contact arms or wipers of the connector with contact number 56 in the bank, which is line number 56. If the number to which the connector be rotated is busy, the switch will be automatically released and the busy signal thrown on the calling line. The automatic release from a busy contact is effected through the busy or private bank which comprises single contacts multiplied throughout the ten connectors in the same manner as the line banks.

If a line be connected directly to a connector, the connector is operated by the ground impulses at the telephone. Since in actual practice it rarely occurs that more than ten lines in any group of one hundred in an exchange are being called at the same time, the 10 connectors are sufficient to establish all connections to 100 subscribers, but it is necessary to provide means for enabling the calling line to secure anyone of these ten connectors.

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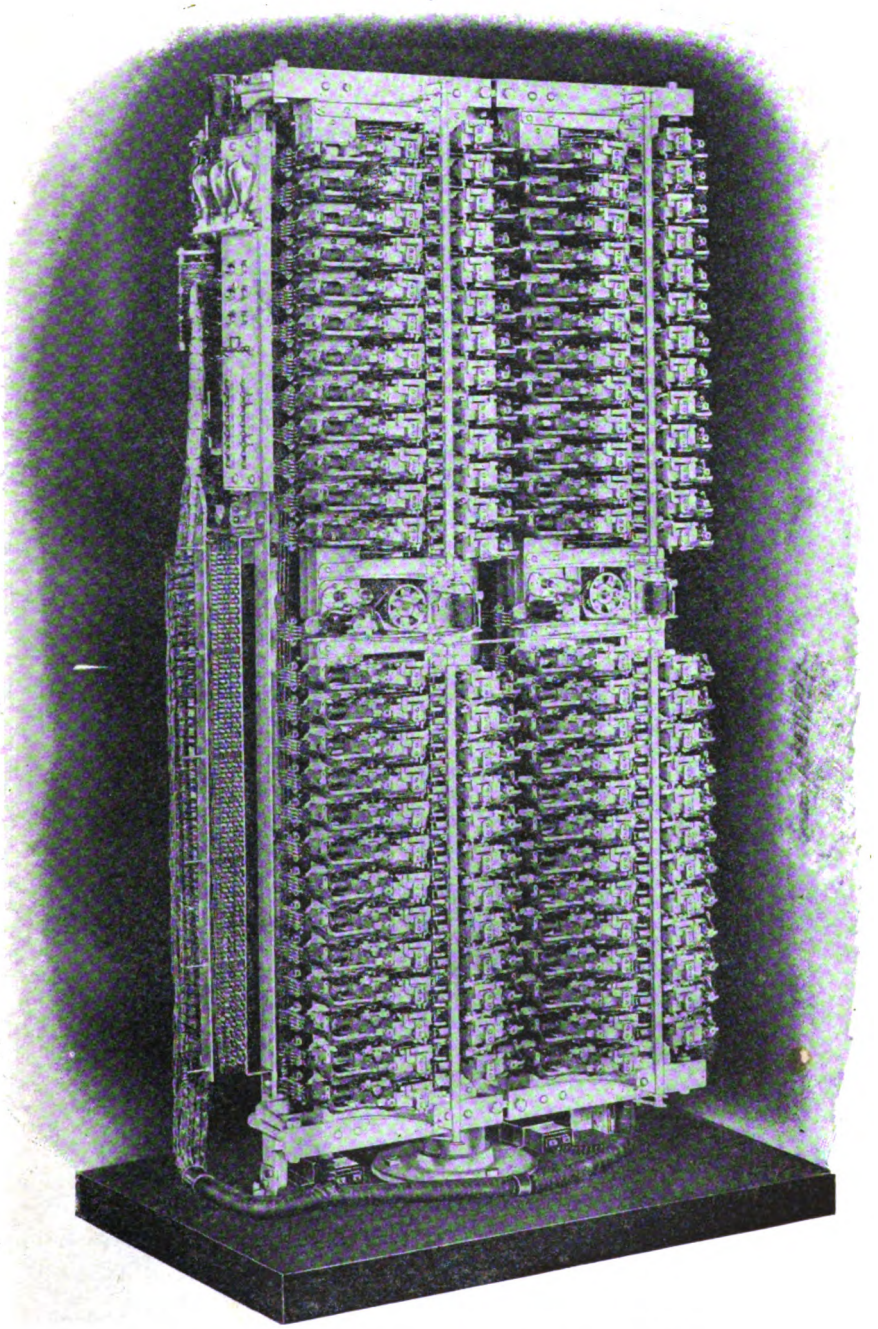


Fig. 622. Line Switch Unit. (Front view.)

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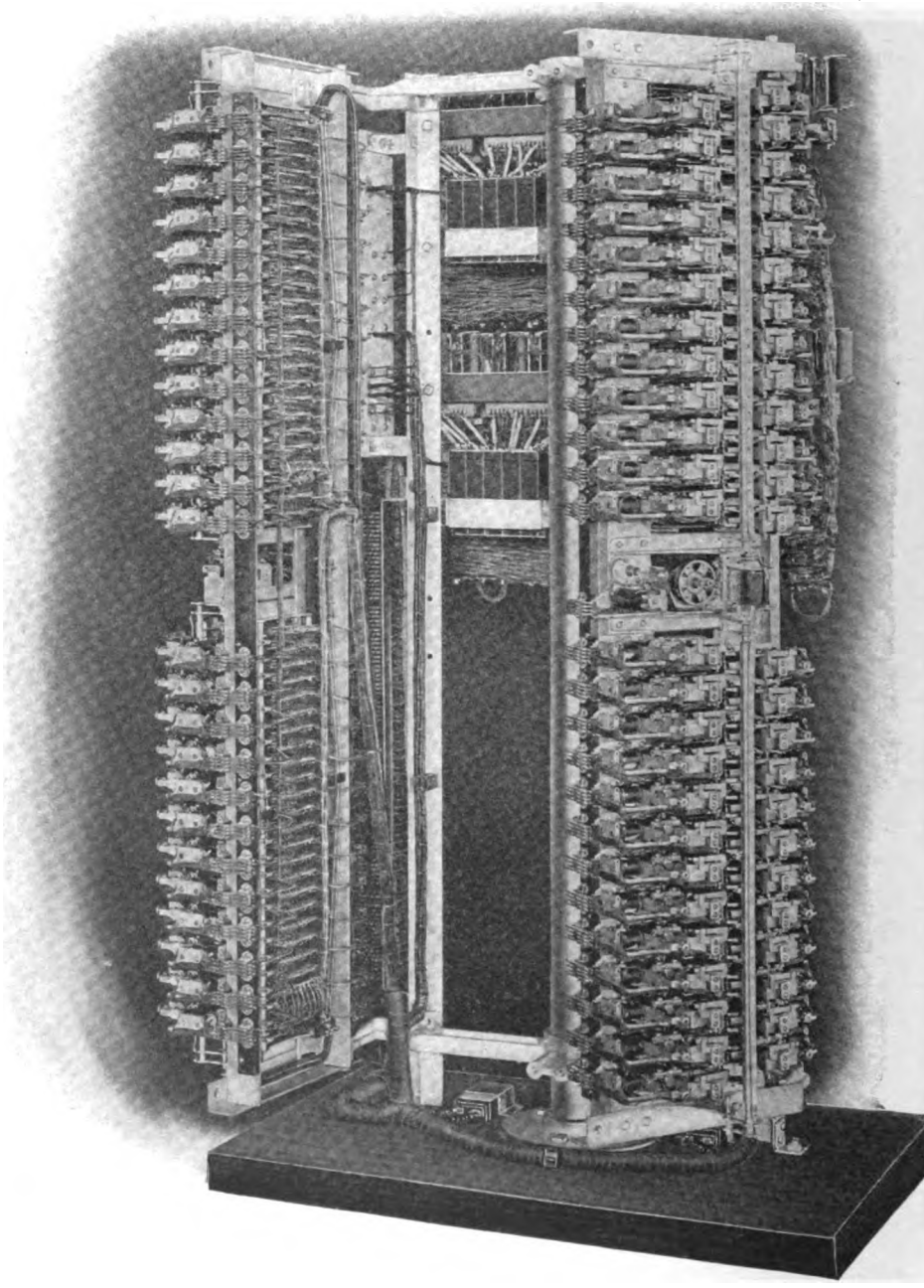


Fig. 623. Line Switch Unit. (Front view, open.)

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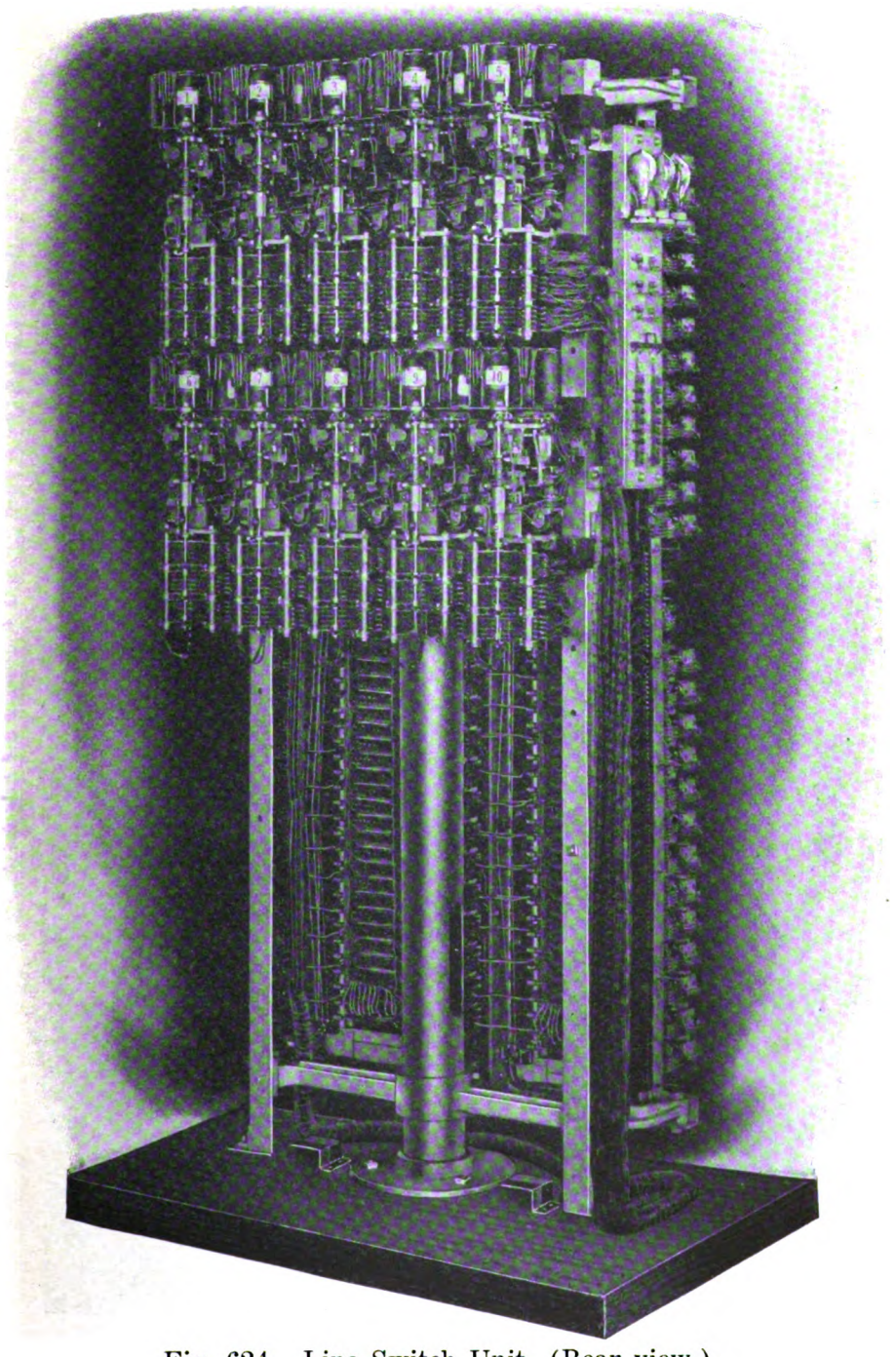


Fig. 624. Line Switch Unit. (Rear view.)

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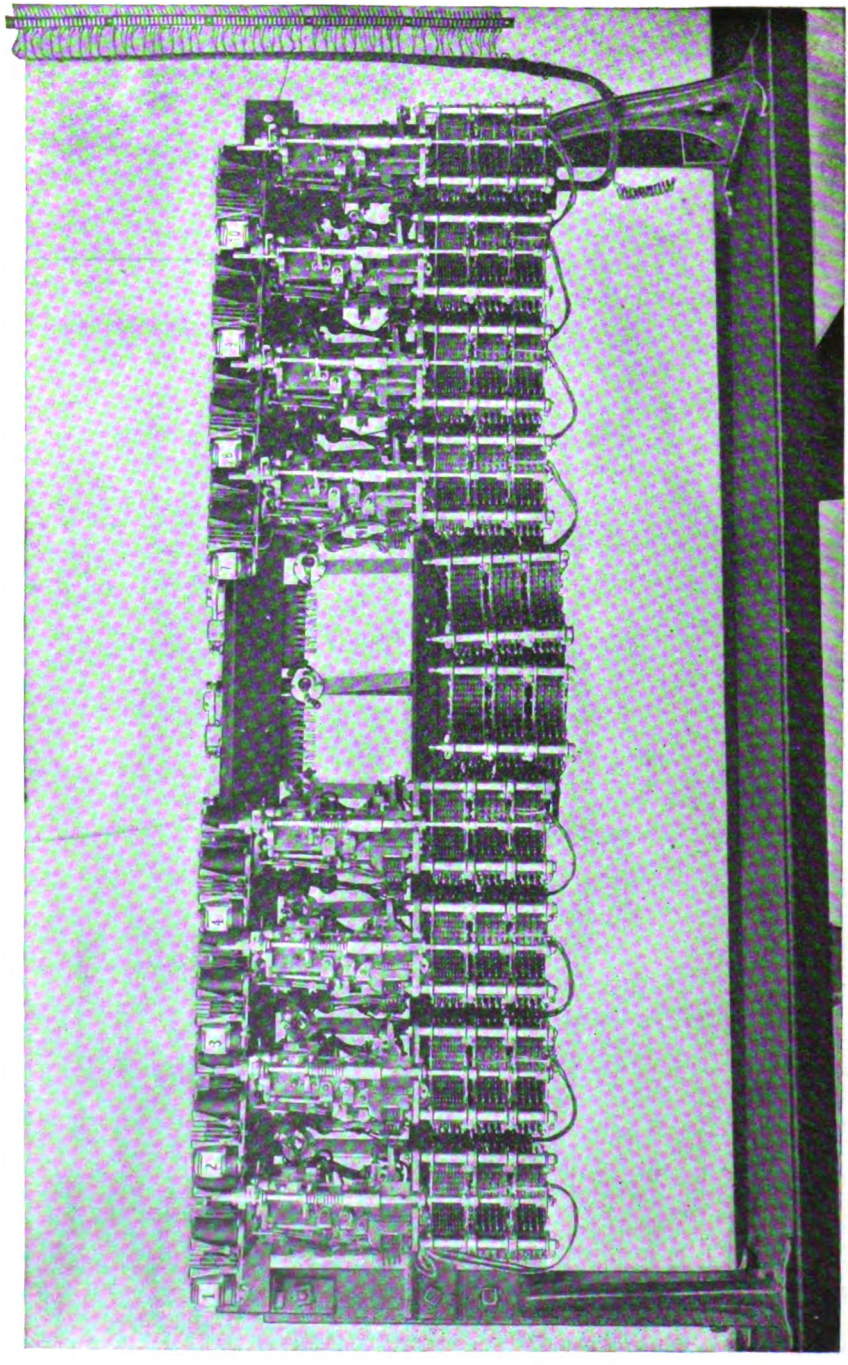


Fig. 625. Shelf of Selectors.

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In the 100 system or two-figure system, the function of the line switch, to which each line is directly connected, is to automatically switch the line of the calling subscriber to an idle connector. This is accomplished through the banks of the line switch which comprise ten pairs of contacts or jacks multipled throughout the entire 100 line switches and wired directly to the connectors. These connecting lines are called trunks.

The ten pairs of bank contacts in any line switch are paralleled by two common strips of contacts or jack springs connected to the line itself. The line switch has a plunger or a plug which effects the connection from the line to a trunk by closing these contacts, the action being analagous to inserting a plug in a jack in the manual switchboard.

The plungers of all the 100 line switches in the group normally engage with a common shaft and are pivoted in such a manner that when the shaft is rotated, the plungers are carried from one to another of the ten trunks but without making contact, the plungers being simply poised in front of the contacts. The common shaft is rotated by a simple mechanism called a master switch. If, while the plungers are all held by the shaft directly in front of contact or trunk No. 1, a subscriber begins a call, his line switch plunger, by the preliminary impulse, will be automatically "tripped" in on this trunk, disengaging from the shaft. Besides closing the calling line through to connector No. 1, the plunger also closes a local circuit which actuates the common master switch, rotating the shaft one step, thus moving the remaining 99 plungers to trunk No. 2. Another subscriber beginning a call will now occupy trunk No. 2, moving the remaining plungers to trunk No. 3, etc. When all ten trunks have been occupied in succession, the shaft rotates back to trunk No. 9, then to trunk No. 8, etc, until finally the plungers are again in front of trunk No. 1 and the cycle is repeated. The rotation never proceeds more than one step unless the trunk to which the plungers are directed is occupied, in which case the shaft is automatically rotated another step, etc. If all ten trunks are occupied, the shaft will continue to rotate until a trunk is freed.

The 1,000 or three-figure system comprises ten groups, or units, each consisting of 100 line switches and ten connectors as described. In order that the different groups may be intercommunicating, another series of switches, called selectors, is introduced, and the trunks from the line switch banks instead of leading to connector switches, are brought to these selectors. The function of the line switch is now to connect the calling subscriber's line with an idle selector, and the function of the selector is to further connect the line with an idle connector in the hundred group into which it is desired to call.

The banks of the selectors comprise one hundred pairs of contacts, arranged in ten rows the same as the connector banks, and multipled throughout the entire one hundred selector switches, the first row or level of contacts being continued to the ten connectors in the "100" group the second row to the ten connectors to the "200" group, etc.

In calling number 256, for example the line switch plunger of the calling subscriber is automatically tripped in on a trunk to a selector. The two impulses on the vertical line step the selector shaft up to the second row or level of contacts, the single rotary impulse starting it rotating over the contacts. It will rotate one step, stopping the wipers on the first contacts, which is the first connector in the 200 group, provided none of the other 99 selectors are occupying that contact, in which case the shaft automatically rotates to the second contact, etc., not stopping in its rotation until

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it has found a contact—that is a connection—which is not in use. The line of the calling subscriber now being connected through to a connector in the group desired, the two remaining digits of the number operate the connector shaft vertically, and then rotate it to contact 56. The automatic selection of an idle contact or trunk line by the selector is controlled by the private bank which comprises single contacts multipled in the same manner as the line banks.

The 10,000 of four-figure system comprises ten 1,000 systems or groups as described. To effect the interconnection among the different thousands, another series of selectors is introduced, and the trunks from the line switch banks are brought to these switches, which are called first selectors to distinguish them from the selectors of the thousand groups which are now called 2nd selectors. The function of the line switch, as in the 1,000 system is to connect the calling subscriber's line with a first selector. The first selector further connects the line with a 2nd selector in the thousand group desired, and the 2nd selector still further connects the line to a connector in the particular hundred group into which it is desired to call. The bank contacts of the first selectors in each of the ten groups are multipled throughout the 100 1st selector switches, and are continued to second selectors, the first row or level of contacts being connected to ten second selector switches in the 1,000 group, the second to the 2,000 group, etc. This arrangement provides 1,000 second selectors through which calls may be made or 100 for each thousand group.

In calling 7256 for example, the line switch plunger is automatically tripped in on a trunk to a first selector. The seven vertical impulses step the first selector shaft up to the seventh level of contacts, the single rotary impulse starting the rotation by which the first free contact in the row is automatically selected. The calling line is now connected to a second selector in the seventh thousand group, and when the next digit, 2, is called, a connector in the "200" group of this thousand is automatically selected as described in the 1,000 system, the last two digits being made on the connector.

The 100,000 or five figure system comprises ten 10,000 systems or groups. To effect the inter-connections among these ten groups, another series of switches called 3rd selectors is introduced, the selection of trunks and the operation of the switches being substantially as described for the 10,000 system.

The automatic is strictly a trunking system and the automatic selection of trunks makes it possible to construct exchanges of any capacity, or to subdivide an exchange in almost any manner desired without affecting the operation. The 1,000 system may be used in combination with the 10,000, the 10,000 with the 100,000, etc. Whatever system or combination of systems be employed, the object is the same, viz: the ultimate selection, through trunks, of a connector, the banks of which contain the line contacts of the desired subscriber.

While it has been convenient to describe the system as having 10 per cent. trunking capacity and while this is ordinarily sufficient, it should not be inferred that the system is limited to any particular percentage. In some instances of busy sections as high as 20 per cent. is employed. Any desired percentage may be provided by the proper arrangement of the interconnecting switchboard wiring, without changing switches or banks in any particular.

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Thus, the 100 line switches belonging to a particular group are divided into two sections each controlled by a separate master switch. Ordinarily the trunks from both sections are multipled together at the terminal strip, but if these trunks be brought separately to first selectors, the outgoing trunk capacity will be thereby increased to 20 per cent.

To provide increased incoming trunking capacity into any particular hundred group it is only necessary to open the selector bank multiples at the proper terminal strip and wire each section separately to connectors. For this purpose each hundred group or unit is provided with space for additional connectors. Increased trunking capacity between the different thousand groups, or between different exchanges is accomplished in the same general manner, there being practically no limit to the different trunking arrangements which may be made.

Since any automatic exchange consists of a number of groups of units with interconnecting trunks, it will readily be seen that the sub-division of a plant into a number of branches presents no problems. The exchange is already sub-divided. It is only necessary to fix the location of the branches or units which compose it.

If we consider two exchanges, A and B, of 1000 lines each, the lines in exchange A for instance, will be numbered from 1000 to 1999 and the lines in exchange B from 2000 to 2999. In A exchange, the trunks from the second row or level of multiplied bank contacts of the first selectors are continued to second selectors in exchange B, so that any subscriber calling 2 for the first figure will step a first selector up to the second level of contacts and automatically select an idle trunk terminating in a second selector in exchange B, where the call is completed. In exchange B, the first row or level of the first selector bank contacts is continued to second selectors in exchange A, and any subscriber calling 1 for the first figure similarly secures a second selector in exchange A.

For convenience, the dials of the telephones are sometimes lettered as well as numbered and a certain line in exchange B may be designated, for instance, as B-756 instead of 2756, the two being, of course, identical.

Ten such exchanges may be interconnected, each being designated by a different figure or letter, and the selection and operation proceeding exactly as when the switches are all in the same exchange.

The exchanges are not limited as to capacity. Each may have 10,000 instead of 1,000 lines, and any or all of the component exchanges may be further sub-divided into two or more branches, if desired.

Fig. 626 shows a plan of the six interconnecting automatic exchanges serving the city of Los Angeles, Cal., three of these being further sub-divided, making eight exchanges in all, the two farthest being over 13 miles apart.

The automatic system is peculiarly adapted for sub-divided exchanges, because a call is made as quickly and as accurately through two or more exchanges as through a single exchange, and because the cost of operation and maintenance is not materially increased by reason of the sub-division. It possesses an added advantage of great importance, in that the number of interconnecting trunks required is considerably less than in case of a manual system as shown by actual statistics. The reason for this is apparent when it is considered that in an automatic exchange of 100,000 capacity, the average time elapsing from the instant of beginning a call until the called subscriber answers is 18 seconds, while in the largest and

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best equipped manual exchange, this time is 30.39 seconds for a connection in the same office, and 35.89 seconds for a trunked connection through two offices. If the disconnect be included, the operating time is increased to 18.50 seconds for the automatic and 38.99 for the manual. The difference, 20.47 seconds, represents the saving in time effected by the automatic. If the average time of conversation one minute and twenty seconds in each case be included, it will be seen that the saving in time during which a trunk is occupied per connection is approximately 17 per cent.

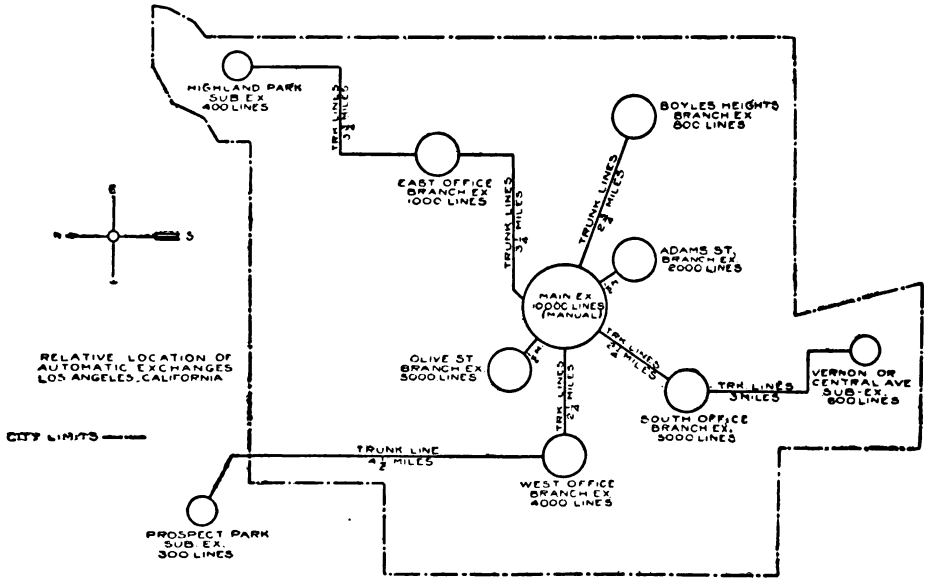


Fig. 626. Plan, Los Angeles Plant.

The distinguishing feature of the automatic telephone is the impulse sending mechanism, or calling device consisting of the dial and its accompanying mechanism.

All other parts, transmitter, receiver, induction coil, ringers, condenser and switchhook are of the usual type and require no description.

The dial is on the front of the instrument, in the most convenient position for operating, and is secured directly to the shaft of the calling device which is inside of the telephone box or case. It consists of a revolving wheel or disc about four inches in diameter provided with ten finger holes arranged on its periphery and numbered from 1 to 0, beginning at the bottom. The finger holes are on the right side of the dial and occupy less than half of its circumference. In calling 256, for example, the subscriber removes the receiver from the hook, places his finger in the number 2 hole and pulls down the dial, rotating it until his finger comes in contact with a stop. Upon removing the finger, the dial immediately rotates back to its normal position. The subscriber then pulls down the 5, and then the 6, completing the connection with the called party, and signals by pressing the ringing button.

The essential part of the calling mechanism is the impulse wheel which is attached to the dial shaft and which rotates with it. This impulse wheel has ten teeth which correspond to the 10 finger holes in the

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dial, and which engage with the vertical impulse spring upon the return movement of the dial. An extra single tooth also engages with the rotary impulse spring. The dial is brought back to normal position after each

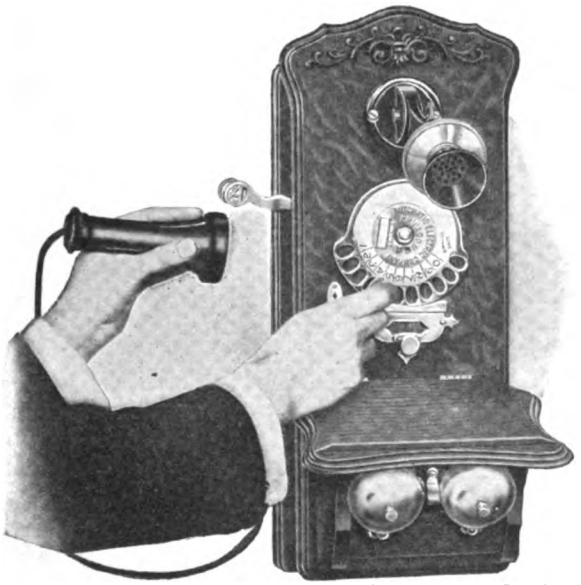


Fig. 627. Wall phone and hand showing method of operation.

rotation by a strong clock spring which is attached to the dial shaft. A small centrifugal governor geared to the shaft by a one to twenty gear, regulates the rate of speed of the impulse wheel.

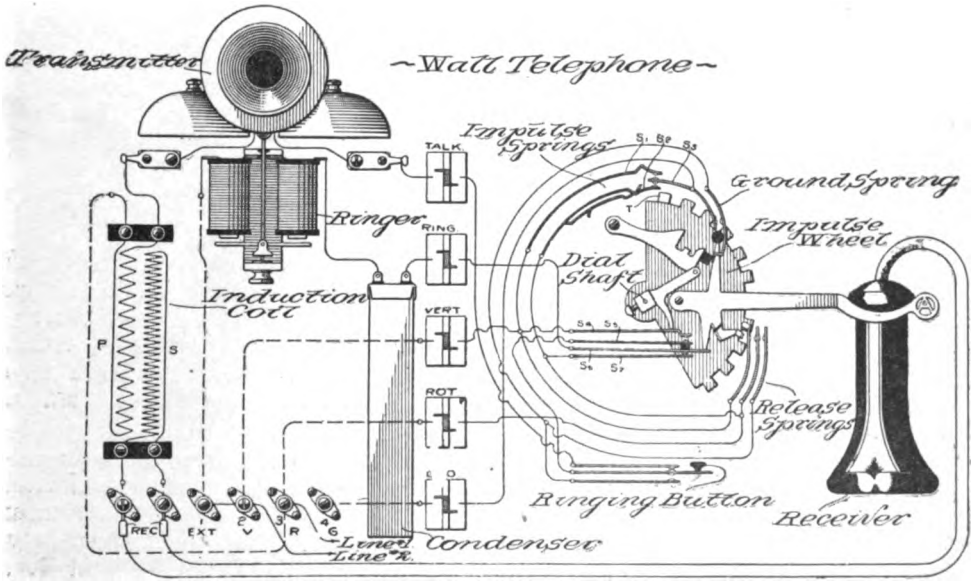


Fig. 628. Circuit Common Battery Wall Phone.

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Fig. 628 shows the circuit and mechanism of the telephone. When the receiver is on the hook the ringers and condenser are bridged across the line, and the dial locked in position. Upon removing the receiver the telephone is in the talking position with transmitter and primary of the induction coil across the line, the receiver being included in circuit with the secondary of the induction coil.

When the dial is pulled down, the ground spring is closed and the connection between the two lines through the transmitter is broken. In this position, the lines end in the impulse springs and as the dial returns to normal, the teeth of the impulse wheel slide over the vertical spring in such a manner as to press it against the ground contact a number of times corresponding to the figure which has been pulled down. Following these vertical impulses the extra impulse tooth slides over the rotary spring pressing it against the ground spring once.

The talking circuit is broken each time the dial is pulled down and closed as soon as it has returned to normal. When the subscriber pushes his ringing button, the talking circuit is again opened and the vertical line grounded as long as the button is pressed.

When the receiver is restored to the switch hook or when the hook is pulled down, the three release springs are pressed together momentarily grounding both vertical and rotary lines at the same time, which action always releases the switches in the exchange. Should the hook be moved up and down before rotating the dial, however, no release action takes place as the ground spring is not closed.

The dial may be pulled down as fast or as slowly as desired, since the governor engages the shaft only on the return movement. The switches in the exchange will operate successfully at any desired speed up to about 18 impulses per second, the governor usually being adjusted so that the vertical line is grounded at the rate of 12 to 15 times per second.

The time required to make a call depends, of course, on the size of the number and the speed of the operator, the average for a four-finger number being 3 to 7 seconds.

In describing the operation of the switches, it is not the purpose to enter into detailed description of mechanical construction further than is required for a clear understanding of the essential features. The common battery system only will be described, as this represents the latest in automatic practice.

The line switch, selector and connector will be described in the inverse order of their operation.

Fig. 630 represents a common battery connector in combination with its electrical circuits. The switch is operated by ground impulses imparted at the telephone of the subscriber and directed to the two relay electromagnets VR and RR, called respectively vertical and rotary relays, which are bridged across the line at the exchange. These relays operate two springs, S1 and S2, which take up the ground impulses and direct them to different parts of the switch.

The only mechanism which undergoes translation and rotation is the shaft A situated in front of the switch. The middle of the shaft contains a hub, H, the upper half of which is milled to form ten horizontal circular teeth, and the lower half longitudinal teeth. These are engaged respectively by the pawls P1 and P2 on the vertical and rotary armatures VA and RA, when these are acted upon by the vertical and rotary magnets V and R,

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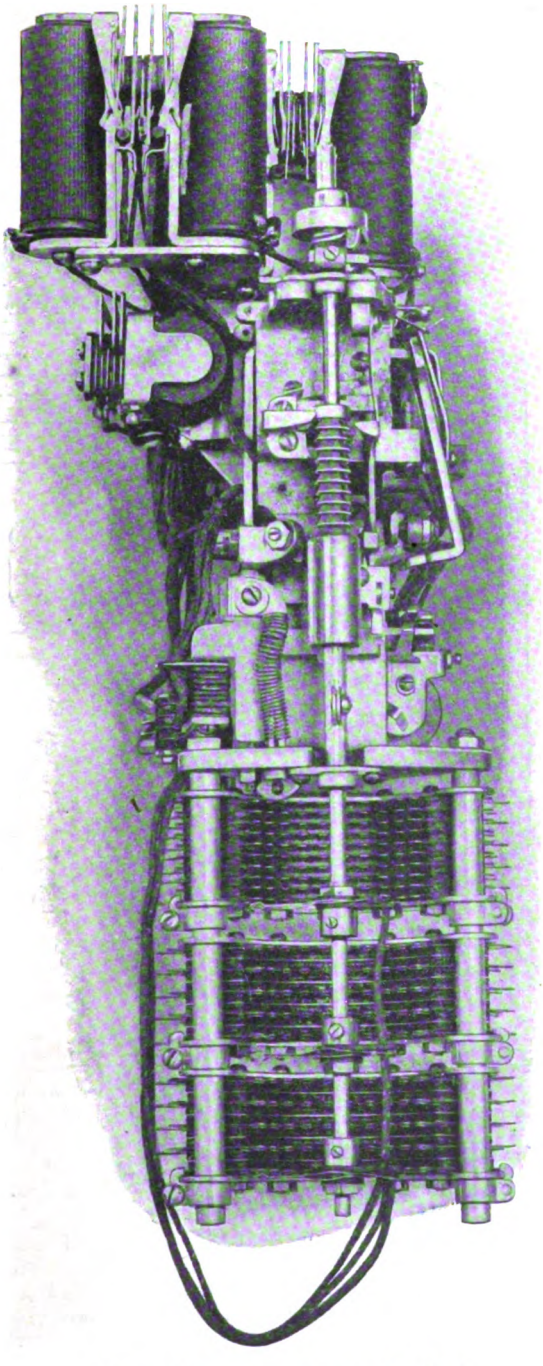


Fig. 629. Connector Switch.

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enabling the shaft to be raised and rotated. Each impulse energizing the vertical magnet raises the shaft one step, each step corresponding to a

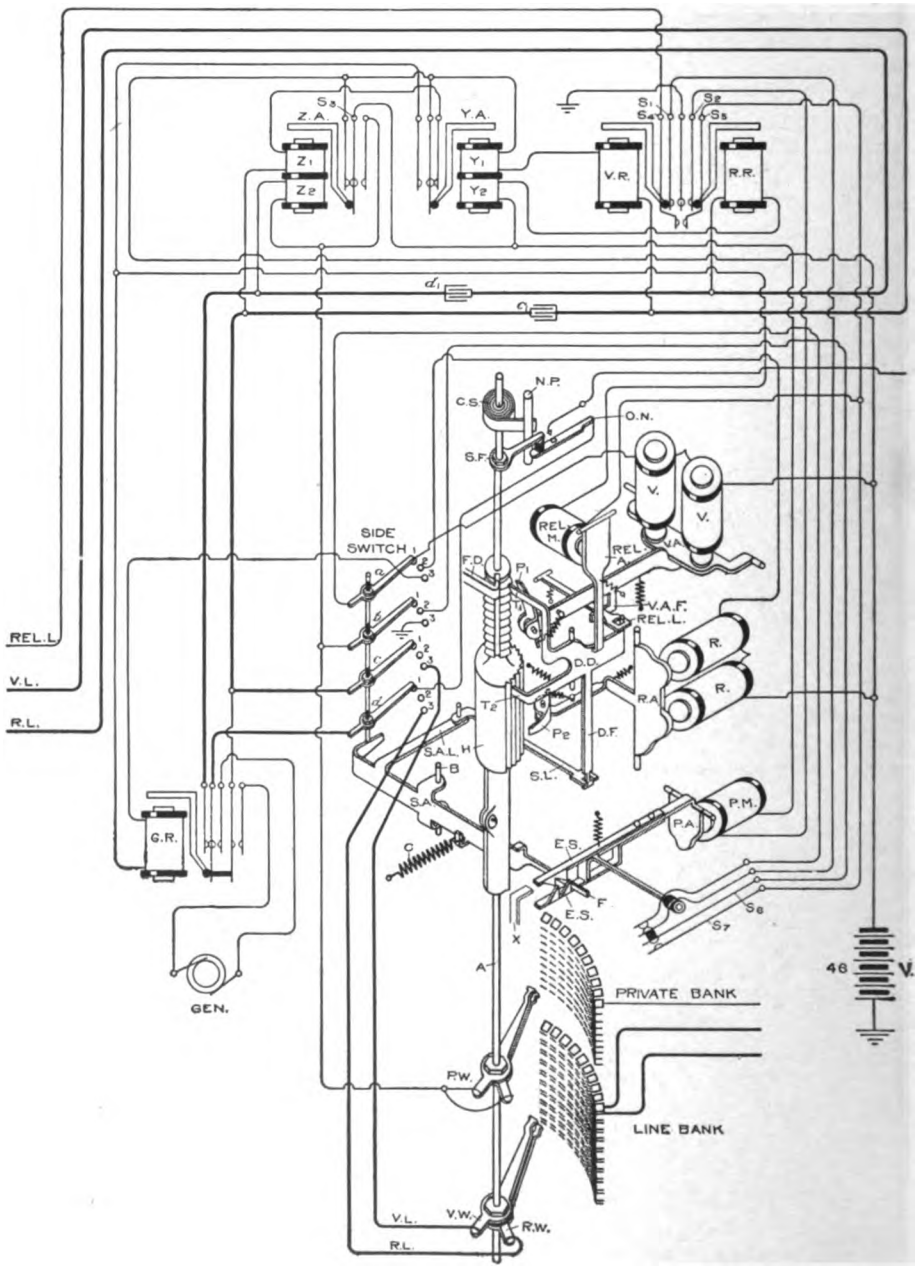


Fig. 630. Circuit and mechanism of Connector Switch.

certain level or row of bank contacts. Each impulse through the rotary magnet rotates the shaft one step, each step corresponding to one of the

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ten contacts in the bank row. After each vertical impulse the shaft is retained in position by the upper tooth T1, of the double dog DD the lower tooth of which T2, performs the same office for the shaft after rotation. This rotation may occur at any one of the ten vertical positions the shaft being supported by the fixed dog F D. The lower part of the shaft holds the line and private wipers, the top, or private wiper P W, operating on the private banks, forming the release trunk, while the lower or line wipers V W and R W connect the vertical and rotary lines with the corresponding contacts on the line banks. These wipers which are rigidly attached to the shaft, form the jaws of a knife switch which engage the bank contacts.

The impulses, repeated by the vertical and rotary relays, are directed to various parts of the switch by the action of the side-switch. The side-switch in this case consists of four knife switches, a, b, c and d insulated from one another and mounted upon a shaft rigidly attached to the end of the spider arm S A pivoted at B and operated by a spring at C. The action of the spider arm is controlled by a finger F engaged by two escapement springs E S fastened to an arm of the private armature P A. In the normal position of the switch the finger F of SA is in the position shown. An impulse through the private magnet P M pulls down the private armature, allowing F to fall against the upper tooth of E S. Upon cessation of the impulse, the armature assumes the normal position and F passes into the second place of the lower escapement spring, the spider arm carrying the side switch into the second of three positions 1, 2 and 3. Upon the next impulse through the private magnet, F is carried out against the stop X, and the side-switch takes the third position.

Battery is thrown upon the vertical line V L through the vertical relay V R in series with an additional coil Y1. Similarly, the rotary line R L receives battery through the relay R R in series with the coil Y2. The two coils Y1, Y2 one above the other, are differentially wound on the same core and an impulse over either line will actuate the armature Y A.

The two line relay armatures when attracted by the relay magnets V R and R R, throw ground respectively on springs S 1 and S 2. Spring S 1 when closed, forms part of a circuit passing through the spring contact of the private relay arm P A, and the side switch (a), and the coils of the vertical magnet V to battery. Spring S 2 closes the circuit through the private magnet P M and springs S 3 to battery.

By the construction of the telephone, every series of impulses over the vertical line is followed by one impulse over the rotary line without a special act of the subscriber. A series of impulses over the vertical line is transformed into an equal number of vertical steps imparted to the shaft by the attraction of the vertical armature V A to the vertical magnet V. The succeeding impulse over the rotary line allows the side switch (a) to pass into position 2.

The next series of impulses over the vertical line will be transformed into an equal number of steps imparted to the rotary shaft by the action of the rotary armature R A. Again the impulse over the rotary line, operating the private magnet, allows the side switch (a) to occupy position 3. It will now be seen that the vertical and rotary lines are connected through the side switches (c) and (d) to the wipers M W and R W and that the private wiper P W is connected to ground through side switch (b). An impulse over the vertical line will now throw ground through position 3 of side switch (a) upon the ringer relay G R, which acting upon a pair of

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springs throws an alternating current from the generator upon the called lines.

When the called subscriber takes his receiver from the hook, a circuit is closed through the transmitter over the vertical line to main battery through coil Z1, and to ground over the rotary line through coil Z2, thus supplying current for talking to the called line. Coils Z1 and Z2 mounted in a like manner as Y1 and Y2, but with their magnetic forces acting in the same direction attract armature Z A thereby throwing the rotary line of the calling subscriber by the action of spring S 3 from battery to ground. Since the receiver of the calling subscriber is removed from the hook, a circuit is then completed from the ground at side switch (b) through coils Y2 and R R, over the calling line, back through coils V R and Y 1, to main battery, thus supplying current to the other half of the line. Relays V R and R R may or may not be operated by this current, but coils Y1 and Y2, now in series, have their magnetic forces opposed so that armature Y A is not attracted. Connections between the calling and called line is made through condensers C1 and D1, of two microfarads capacity each.

Upon completing the conversation, the switch is released and restored to normal in the following manner: A ground impulse imparted simultaneously to the vertical and rotary lines, upon hanging up the receiver, actuates the differential relay by shunting out the circuit of coil Y2. This relay throws main battery on one side of the release magnet Rel M, at the same time opening the circuit of the relay Z, which in falling back restores the rotary line of the calling subscriber to main battery. Both V R and R R are operated by the release impulse at the telephone, thus closing the front release springs S4 and S5. Spring S4 is grounded through a half ohm coil of a selector over the release trunk Rel T. and spring S5 is connected directly to the release magnet which attracting its armature causes the double dog to release its clutch on the shaft. A release link Rel L, dropping over a finger of D D retains it until the switch is again used. The shaft on being released by D D, is rotated back by the tension of a coiled spring C S until it is stopped by the finger S F striking the normal post N O, when it is dropped to its original position. The same motion which withdraws the double dog also restores the arm S A by means of the finger D F acting through a link S L upon the lever S A L. When the switch is next used the first vertical impulse raises the release link by means of the finger V A F on the vertical armature, allowing the double dog to be acted upon by a spring which returns it to the shaft. The switch can thus be released from any position.

Connection with a busy line is prevented by an automatic release of the connector, as follows: The private wiper of the connector throws ground on the private contact corresponding to the line contacts of the called subscriber, from side switch (b) in position 3. The last impulse over the vertical line of one subscriber who is making the same call as another, causes the private wiper of his connector to engage a multiple of the private bank contact occupied by the other subscriber while the side switch of the former is still in position 2. Consequently, the wiper P W receives ground from the side switch (b) of the latter connector through the private bank.

The impulse over the rotary line which follows every series of vertical impulses, as noted before, energizes private magnet P M, which in attracting armature P A closes springs S 6 and S 7, throwing main battery on the grounded private wiper through the release magnet, affecting the "busy"

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release. The subscriber, not yet knowing that his connector has been released, grounds the vertical line in order to ring. The connector responds by raising the vertical shaft. The off normal springs O N which are held open by the finger S F when the switch is at normal now close, connecting the rotary side of the line with the generator, which by an inductive effect, produces the common "busy" signal.

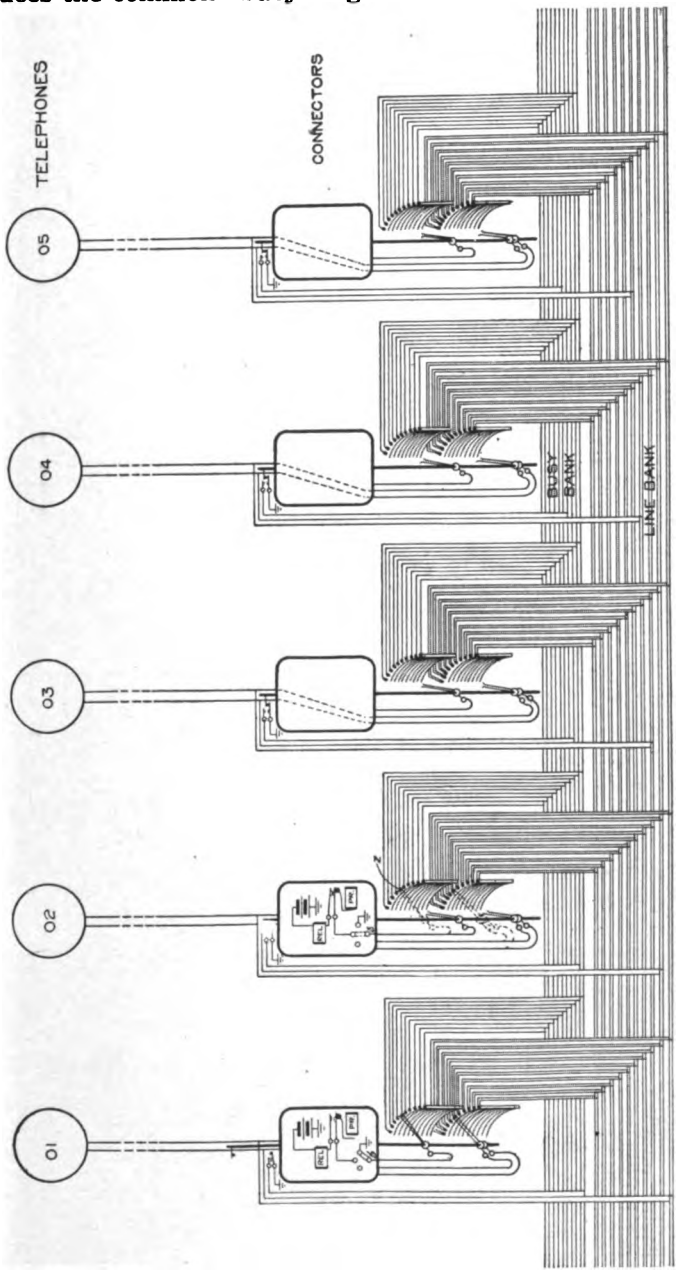


Fig. 631. Diagrammic circuit of busy release.

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Fig. 631 shows diagrammatically how this release is effected. O1 is here represented as having called O5 whose normal leads are connected

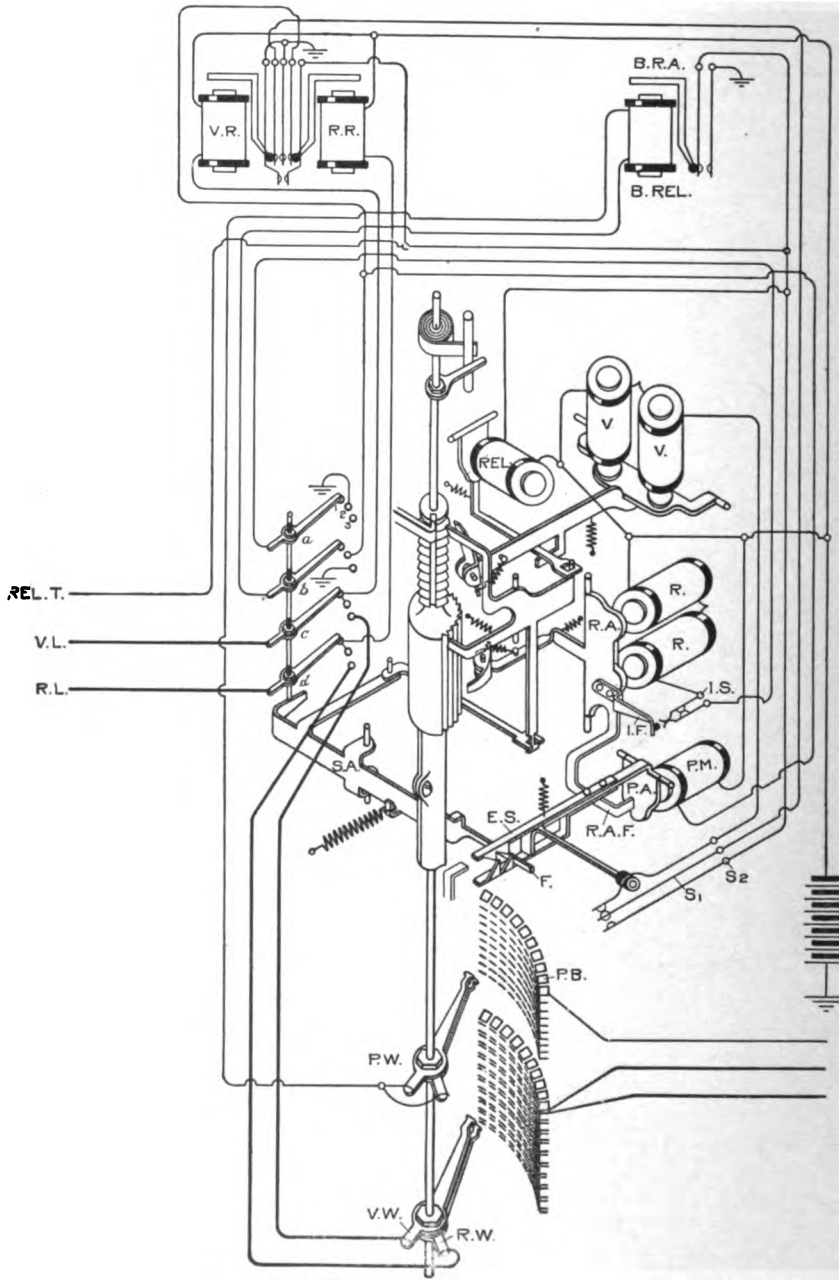


Fig. 632. Circuit and Mechanism of Selector Switch.

with the fifth contact of the tenth bank level. O2 attempts to call O5 and engages a multiple at Z of the contact still occupied by O1, with his last

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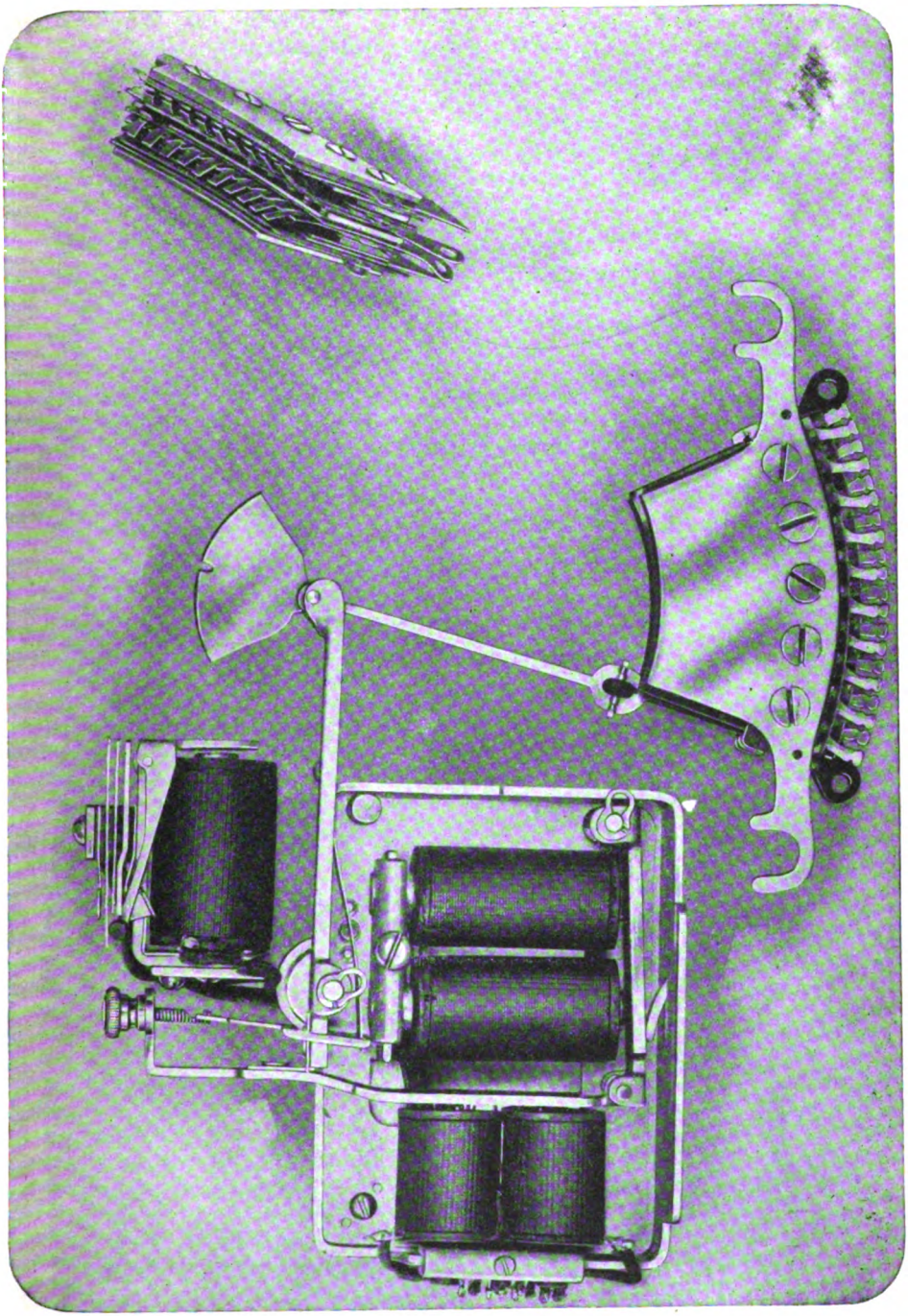


Fig. 633. Individual Line Switch and Bank.

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impulse over the vertical line while his side switch (b) is in the second position. The succeeding impulse over the rotary line causes the private armature to close two springs which complete the circuit through the release magnet to battery. If instead of O5, O2 attempts to call O1, the release is similiarly accomplished. The normals of switch O1 are connected to the first contact of the tenth bank level, and the shaft being off normal, the off normal springs are closed, throwing ground over the private normal upon this contact. O2 upon engaging a multiple of the same contact has his connector released as before.

Fig. 632 graphically represents the parts of a first selector with circuits. The purpose of a selector being to select a trunk line only, it is more simple than the connector, and coils Y1 and Y2, Z1 and Z2 and G R do not appear. An additional coil B REL called the back release relay, and the interrupter springs 1 S, constitute the chief mechanical addition.

The step by step rotary movement of the first selector is automatic and not operated by the subscriber. After the first series of impulses over the vertical line has raised the wipers to the desired level, the following impulse over the rotary line operates, as before, the private magnet P M. This magnet, attracting the private armature P A allows the finger of S A to pass directly from position 1 to position 3 in the following manner:

When F, together with the side switch, passes into position 2 a circuit from ground at side switch (a) passes through springs L S and the rotary magnets R to battery. The rotary armature R A in pulling up presses down mechanically the private armature by means of the rotary armature finger R A F, allowing F to fall against the upper tooth of the escapement spring E S. At the same time the circuit through R is broken by means of the rotary armature finger L F which is interposed between the two interrupter springs. The circuit being broken, the rotary armature is pulled back by the action of a spring and the private armature rising, allows F to pass to position 3. The wipers are thus left by the one rotary impulse upon the first bank contact of the row to which they were carried by the vertical impulses. The two lines V L and R L are thereby connected directly with the first connector of the group, further operation of the first selector being prevented when the side switches C and D passed into position 3. The private wiper P W of this selector, now throws ground upon the private bank contact through the half-ohm coil B Rel, mentioned before as being connected with the front release spring S 4 of the connector over the release trunk Rel T.

Another subscriber calling into the same group will obtain a second connector in the manner described herewith. At the first impulse over the rotary line the side switch B will pass into position 2 and the private wiper will engage the multiple of the contact previously grounded. The interrupter finger 1F breaking the circuit through the rotary magnets allows the rotary armature to fall back. The private armature, however, remains held down due to the ground receiver by the private magnet through the wiper P W. The interrupter springs again closing the circuit, the shaft is rotated another step. The private wiper now resting on a contact not grounded, the private armature is released and the finger F passing into position 3 leaves the lines connected with connector 2. As long as the private wiper continues to engage a grounded contact, it will rotate automatically, the side switch being unable to pass out of position 2 until the private armature is released.

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Owing to the fact that the first selector is entirely eliminated from the line circuit after the side switch reaches position 3, its release is effected by the connector over the release trunk Rel T. Rel T. of Fig 9 is connected with one of the 100 contacts of the first selector private banks P B, and from there with a ground through the back release coil B rel when the private wiper engages the contact. When the front release springs of the connector are closed during the release, the coil B rel, energized, attracts its armature and throws ground on the release magnet, thereby releasing the first selector.

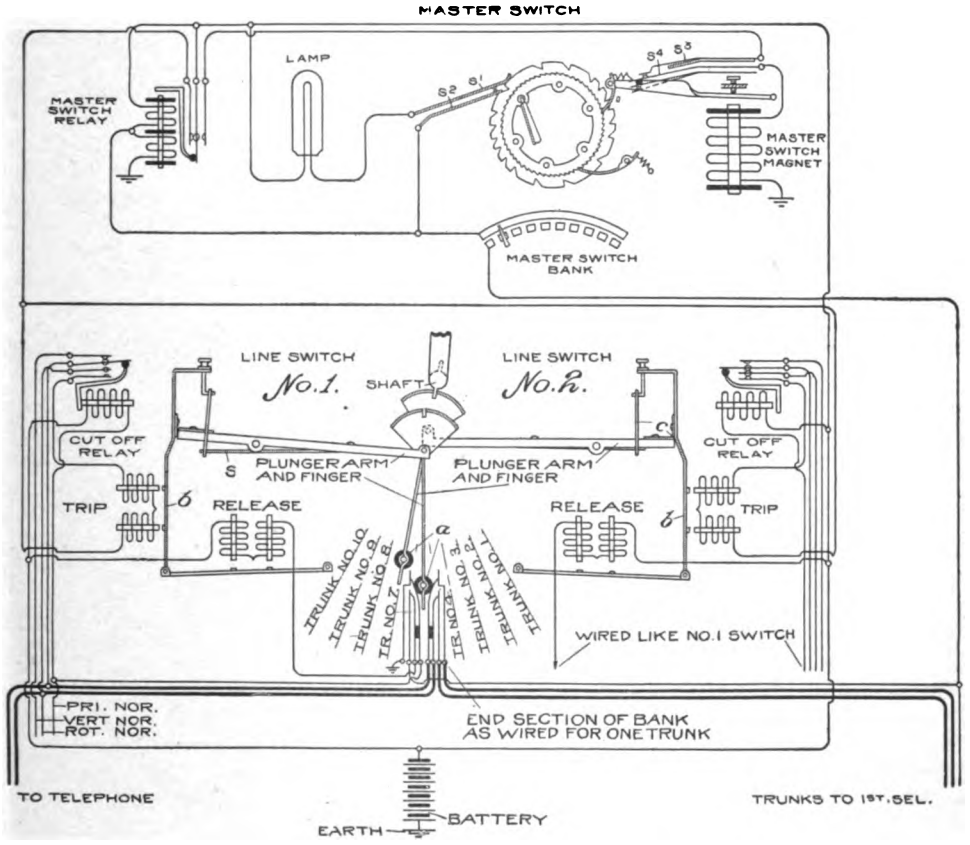


Fig. 634. Circuit of Line and Master Switch.

Should the subscriber for any reason wish to release his first selector before obtaining his connector, he accomplishes this by grounding both the vertical and rotary lines. The rotary line energizing the private magnet causes spring S2 connected with release magnet Rel 1, to make contact with S1, now receiving ground from S which is grounded by the impulse over the vertical line through coil V R.

The operation of the line switch has already been partially described. The circuits and mechanism are extremely simple, since the only movement required is to drop the plunger a distance of three-eighths of an inch into the bank jacks or contacts at the beginning of a call, and to restore it again at the end of the call.

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Fig. 634 represents (with circuits) two adjacent line switches in the relative positions which they occupy when mounted, together with a graphical representation of the master switch, of which two are assigned to each line switchboard unit. Switch No 1 is shown with plunger released from shaft and engaging trunk No. 6, while the plunger of switch No. 2 is in a position to take trunk No. 7 upon the next call.

These plungers are directed to the proper contacts by the operation of the master switch upon the two shafts located centrally in front of their respective panels. The two shafts are operated by one master switch (the second master switch being a reserve only) sufficiently at each call to direct all the plungers not released to the next multiple bank contacts.

The wheel of the master switch has a forward movement only and operates the shaft mechanically by an arm reaching from the rim of the wheel to the point where its axis of rotation intersects at right angles the axis of rotation of the shaft. The displacement of the projection of this arm along the diameter of the wheel corresponds to the translation of the plungers along the bank contacts. Since the displacement of a projected point along the diameter corresponding to a constant displacement along the circumference varies, it is necessary that the arm should rotate further near the extremes than when its projection is passing through the center. This is accomplished by a fibre wheel having its circumference divided into segments corresponding to equal displacements along the diameter.

The construction of the line switch bank is indicated in Fig. 633. To each switch is assigned a single row of line bank contacts corresponding to the 10 first selectors belonging to a particular hundred. Corresponding contacts in each bank of the hundred line switches are multipled together and terminate in these 10 first selectors.

The lines are multipled to two spring contacts occurring in each of the 10 positions of the bank row. Paralleling these and adjusted so as to connect with them readily are the trunk lines of the 10 first selectors. Forming the other half of the contacts belonging to each division of the bank row are two springs connected with the release and cut off coils, in position to engage, respectively, the stationary contacts connected with the release trunk and with ground. The contacts of these banks are made to come together by means of the plunger arm finger. This finger has a small fibre wheel (a) on the end engaging the bank, the other end terminating in a fan-shaped metal plate notched at its center, so as to engage the master switch shaft.

When a call is made, the line switch plunger of the calling line is released from the shaft and driven into the bank, all the remaining plungers being carried to the next position. The switches which have been operated previously and released remain with plungers directed to the contact which they occupied, and should they again be used before the shaft has reached the same position returning, they will reoccupy the same trunk. The shaft, as it passes from one position to another picks up, as it comes to them, all the plungers which have been released from the banks and places them again in position to engage an unoccupied trunk.

Referring to circuit of Fig. 634 an initial impulse over the rotary line passes through the springs of the cut-off coil, and the trip magnet, energized, attracts its armature (b) and releases the plunger arm at (c), allowing the spring (s) to drive it into the bank and close the spring contacts of the bank, as here shown.

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The lines from the telephone are now connected with a first selector over one of the 10 trunk lines. A circuit to ground through the cut-off relay opens the cut-off springs, leaving the rotary and vertical lines clear to the trunks. Any impulse now sent over the lines in no way affects any part of the line or master switch.

Immediately following the operation of the trip magnet, the rotation of the shaft is accomplished by the master switch. When the plunger closes the bank contacts, main battery through the release magnet is thrown upon that contact of the master switch bank which corresponds to the trunk occupied, and upon which is resting the wiper arm of the master switch. This bank consists of 10 pairs of insulated contacts. The upper row of 10 is multipled with the corresponding release trunks, while the lower contacts are all connected to ground through the relay coil of

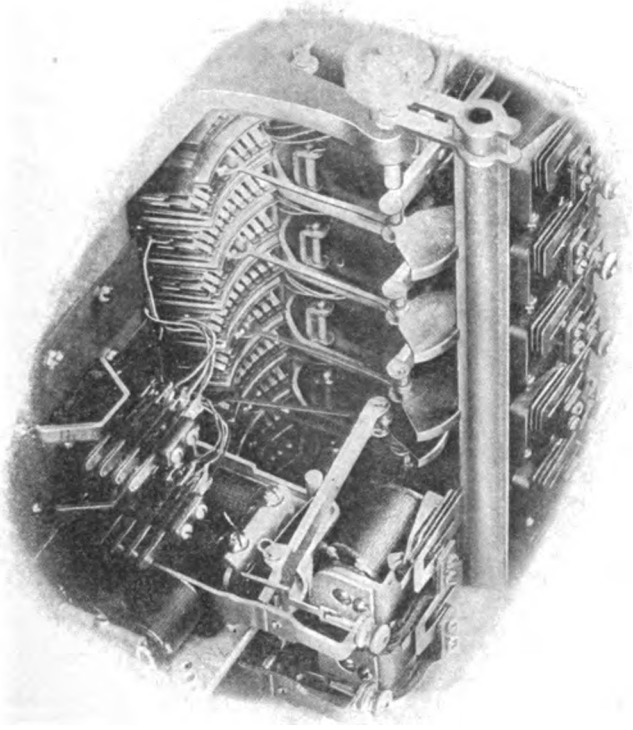


Fig. 635. Details of Line Switch Plungers and Banks.

the master switch. This relay is a double coil of 3,000 ohms resistance, constantly energized, but wound so that the direction of the magnetic force of one winding is opposed by the other. The wiper arm merely connects the ground contact with the release trunk.

When the plunger of the line switch throws battery on this contact, through the release magnet, the circuit is closed through one winding of the differential relay to ground, while the other winding is shunted out. This allows the relay armature to pull down and throw main battery upon the circuit leading to the master switch magnet. This magnet,

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through its armature, causes the pawl to engage the shaft wheel. As this armature pulls down, the circuit through the magnet coil is broken at springs (S3) and (S4), allowing the armature then to fall back. The springs (S1) and (S2), however, have been closed by the movement of the fibre wheel, and this retains the conditions at the differential coil unchanged, even though the wiper arm has passed from its bank contact. Consequently the armature of the differential coil remains down.

When the armature of the master switch magnet falls back therefore, the coil again receives battery through the springs operated by it and again pulls up and drives forward the shaft wheel. This continues until spring (S2) reaches a depression in the fibre wheel and separates from (S1). This point then corresponds to a position of the shaft which holds the plungers directly over a bank contact and the wiper arm upon a contact free of battery. Since the trip magnet receives its battery through the springs of the master switch coil, no switch can trip in while the master switch is operating.

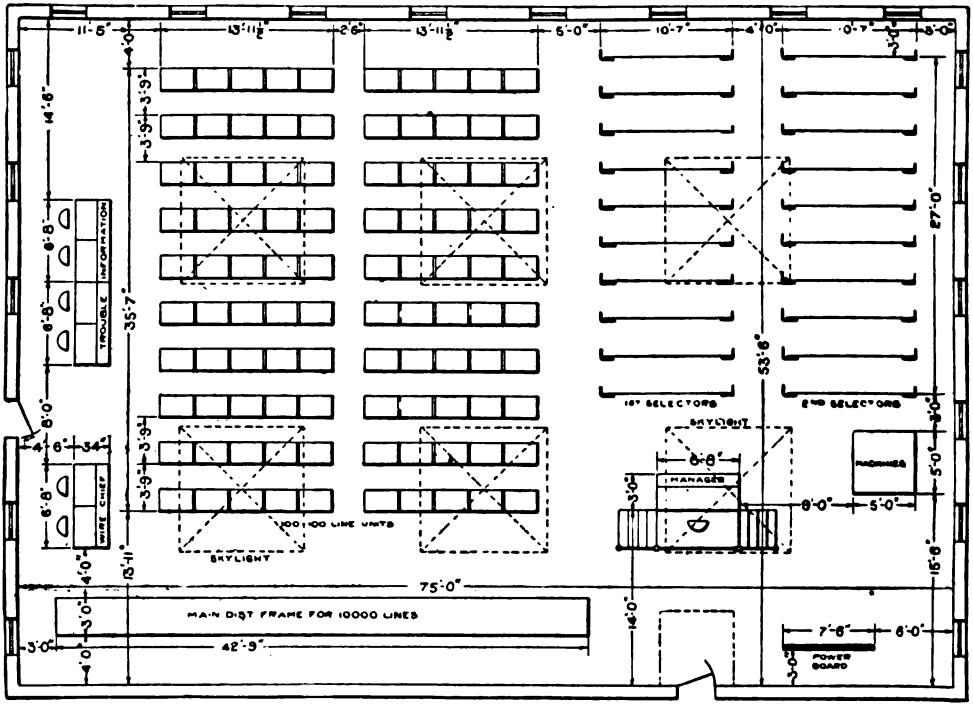


Fig. 637. Floor plan 10,000 line Automatic Exchange.

The line switch is released from the first selector over the release trunk in a manner similar to that in which the first selector is released from the connector. The release armature, in pulling up, catches the plunger arm (C) and, as it falls back after the impulse, withdraws the plunger from the banks.

A completed connection between two telephones in a ten thousand system with diagrammatic circuits of all the switches used in establishing the connection is shown in Fig. 636. (See Frontispiece.)

The talking circuit is substantially the same as used in nearly all manual systems of today.

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It will be noted that with the exception of the connector, each switch used in making the connection is cut out of circuit as soon as it has been operated, and that the connector relays are the only ones remaining on the line when the connection is completed.

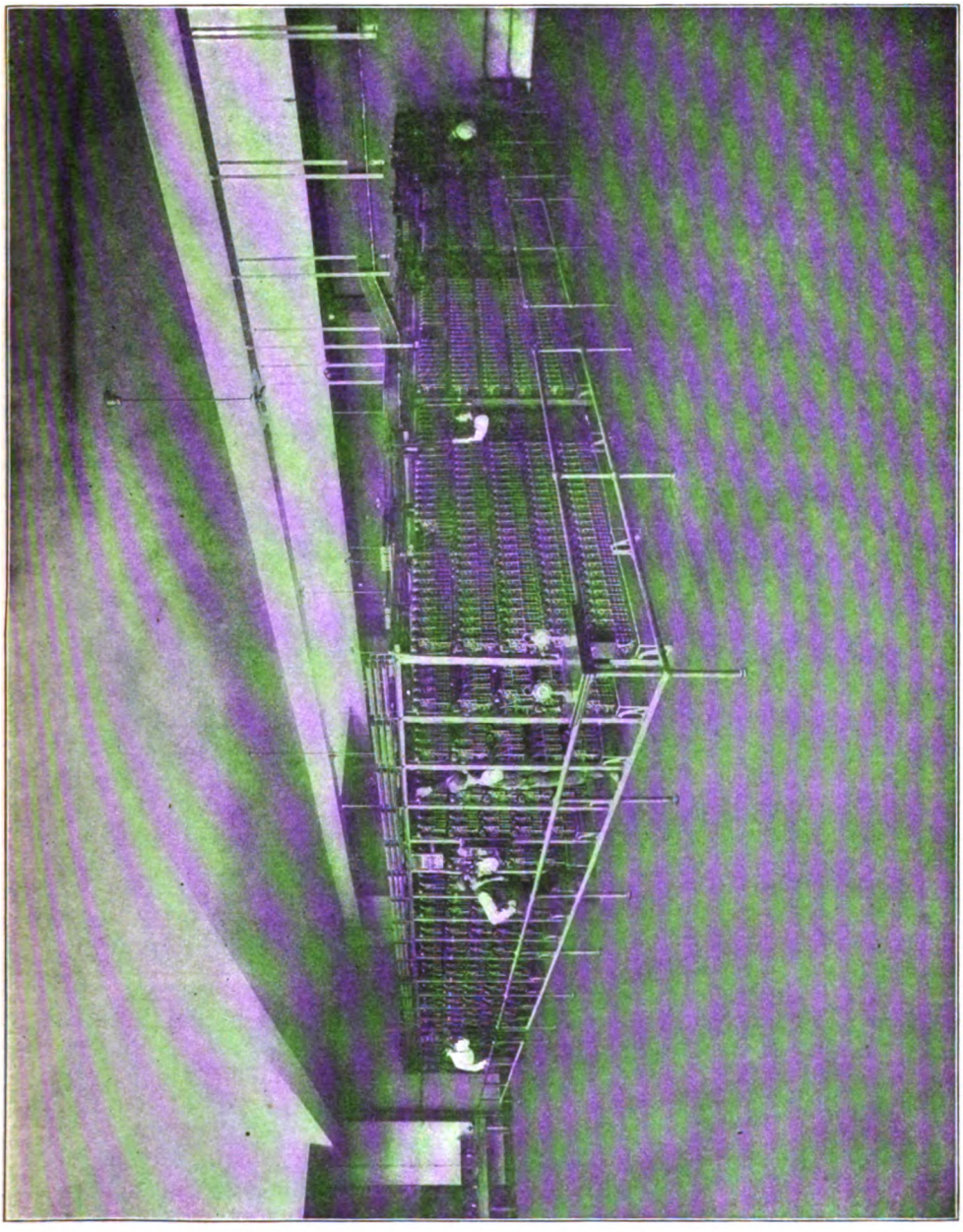


Fig. 638. Columbus, Ohio, Switchboard Room.

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In tracing the operation of a switch from the circuit diagram, it is well to remember that the three-position side switches all move simultaneously, and that in the diagram they are all shown in the third or "through" position.

The exchange battery is maintained at about 46 volts, the same set of batteries being used for operating the switches and for supplying talking current to the transmitters.

The vertical and rotary line relays of the selectors and connectors are wound to a resistance of about 300 ohms each, so that the current flowing over the line when operating is about fifteen hundredths of an ampere. The operating magnets of the switch, i. e., the vertical, rotary and release magnets have about 60 ohms resistance each, and the private magnets 350 ohms each. The relays are adjusted to operate over a resistance varying from 0 to 750 ohms per line. In trunking between widely separated exchanges, where the distance is too great for satisfactory transmission, the trunks are provided with "repeaters" which relay the impulses and also the talking current, the calling subscriber receiving common battery for his transmitter from his own exchange instead of from the connector in the exchange of a called party.

To facilitate toll connections, the "0" hole of every calling dial is marked "Long Distance". When the subscriber pulls down the "0", his first selector is stepped up to the 10th or "0" row of contacts. These contacts are multipled as usual, but the trunks, instead of terminating in second selectors, are wired directly into the toll board, terminating in jacks (or keys). The first selector rotating automatically, selects the first one of these trunk lines which is not in use, and when the subscriber pushes his ringing button a signal lamp is lighted in front of the operator, who completes the connection in the usual way.

From the toll board, there are also a number of trunks to line switches in the automatic switchboard, and the toll operator is provided with a calling dial for calling automatic subscribers.

In some large exchanges where the toll traffic is very heavy, all the subscribers' lines are brought to jacks in a "switching section", where connections with automatic subscribers may be made direct without the use of a calling dial.

All toll connections are controlled by double supervisory lamp signals as in ordinary manual practice.

Where it is desired to operate an automatic in connection with a manual switchboard, an arrangement similar to that used in toll work is made, the manual board being designated by a single digit. An automatic subscriber wishing connection to a manual subscriber rotates his dial from hole No. 1, for instance, (which may be marked "Main") and pushes his ringing button, thereby lighting a lamp signal in front of the operator in the manual trunking section.

Any first selector level, or row of contacts, not in use may be wired to a special board or desk; so that by a single movement of the dial any subscriber may signal an operator or clerk.

This feature is made use of for calling Fire Alarm, Police Alarm, Trouble and Information, Rural lines, or for any purpose where especially quick service is desired.

Private branch exchanges are arranged to be operated entirely automatic or semi-automatic, as desired, the flexibility of the system permitting of almost any desired combination.

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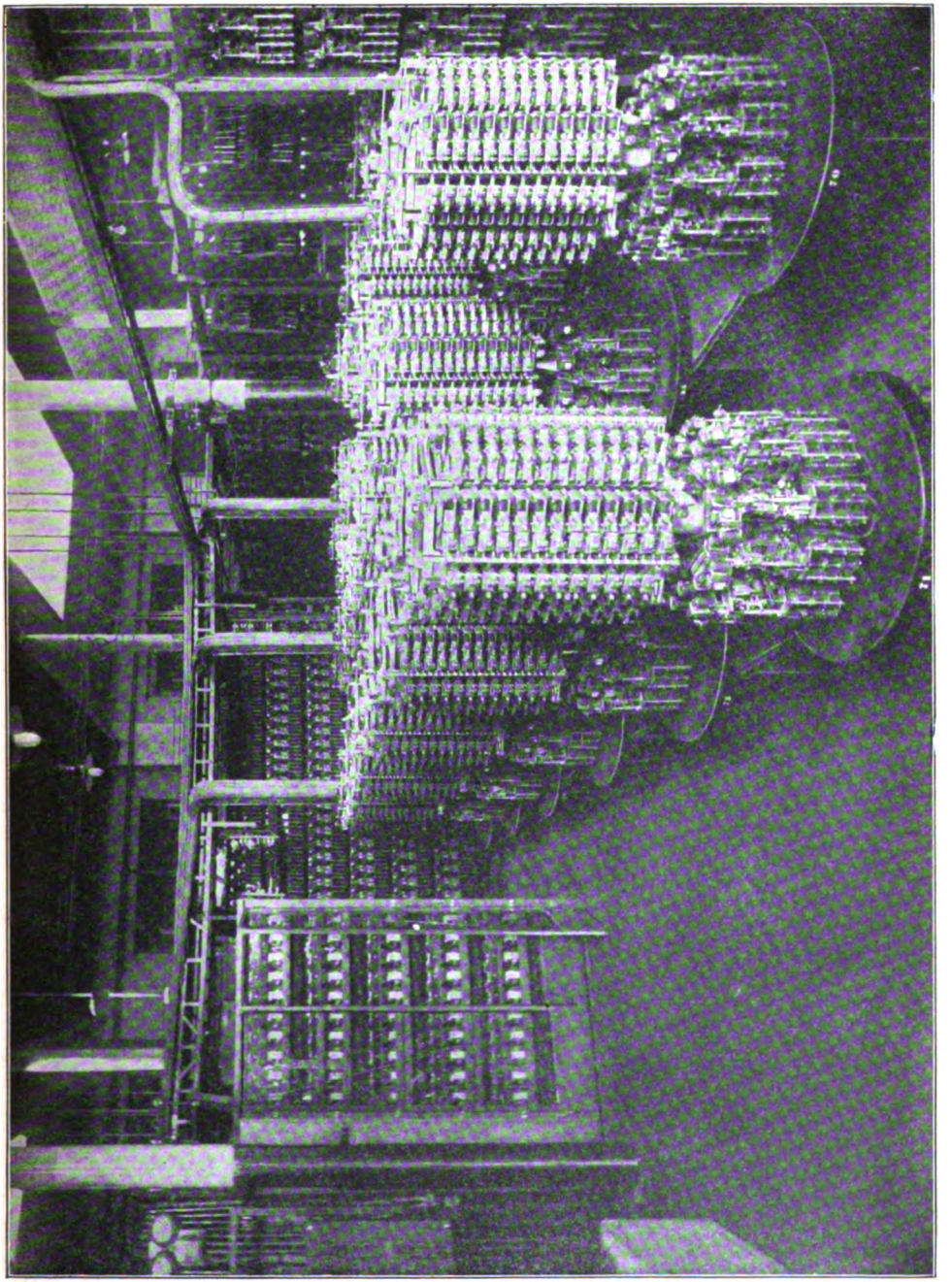


Fig. 639. Grand Rapids, Mich., Switchboard Room, Line Switch Addition.

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A private branch exchange having several trunks, will have one number for all, the connectors in this particular hundred group being arranged to rotate automatically, selecting the first one of the trunks not in use.

The four-party selective ringing system is arranged for in a simple manner by having the party line contacts in the connector banks multipled through four different groups of connectors, the groups being supplied with ringing current of different frequencies. The four subscribers, although on the same line, have different hundred numbers, as for instance, 7256, 7356, 7456, 7556, and the ringers being of the harmonic type respond only to ringing current of the proper frequency.

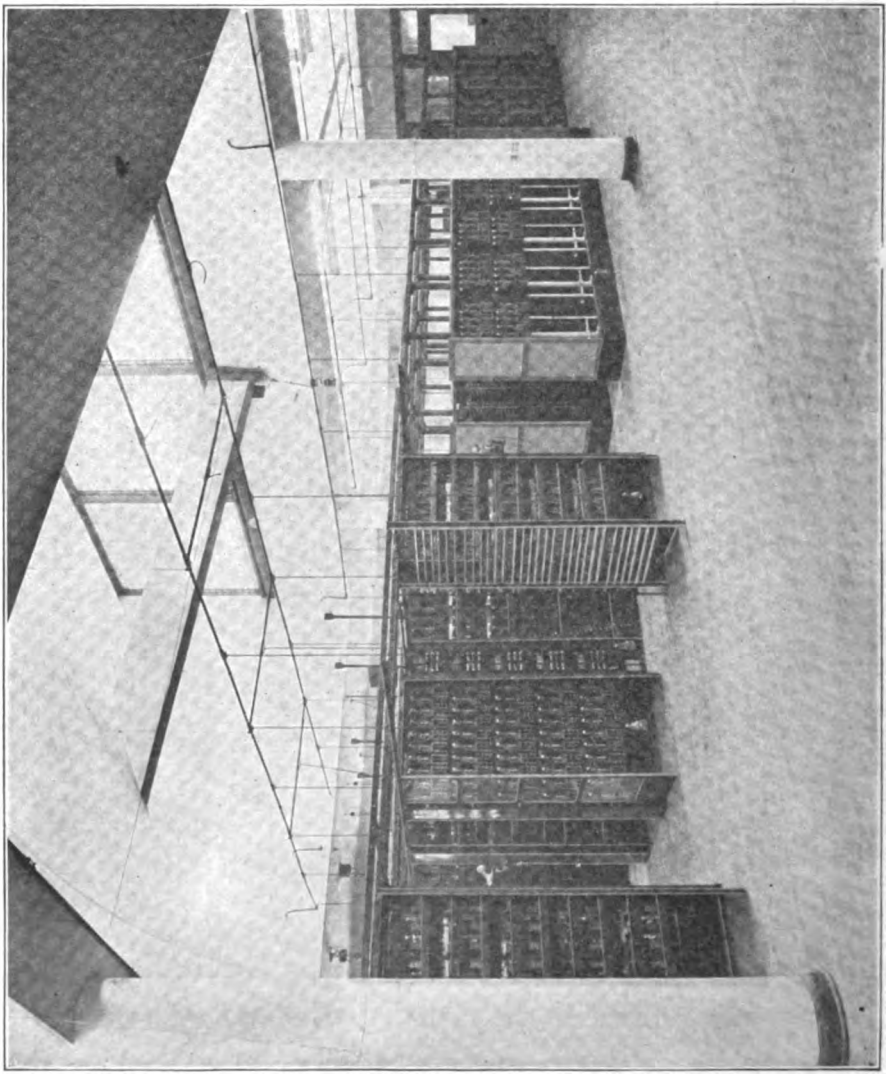


Fig. 640. General View Switchboard Room, Omaha, Neb.

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Perhaps the most important development in automatic telephony in recent years is the installation and operation of the district station or as it is sometimes called the sub-station. The district station consists simply of one (or more) 100 line units, such as have been described, its location being changed from the central office to the center of distribution of a suburb or any section of the city. The subscribers' lines are brought to this station and from the district station to the main exchange incoming and outgoing trunks are provided sufficient to take care of the maximum traffic.

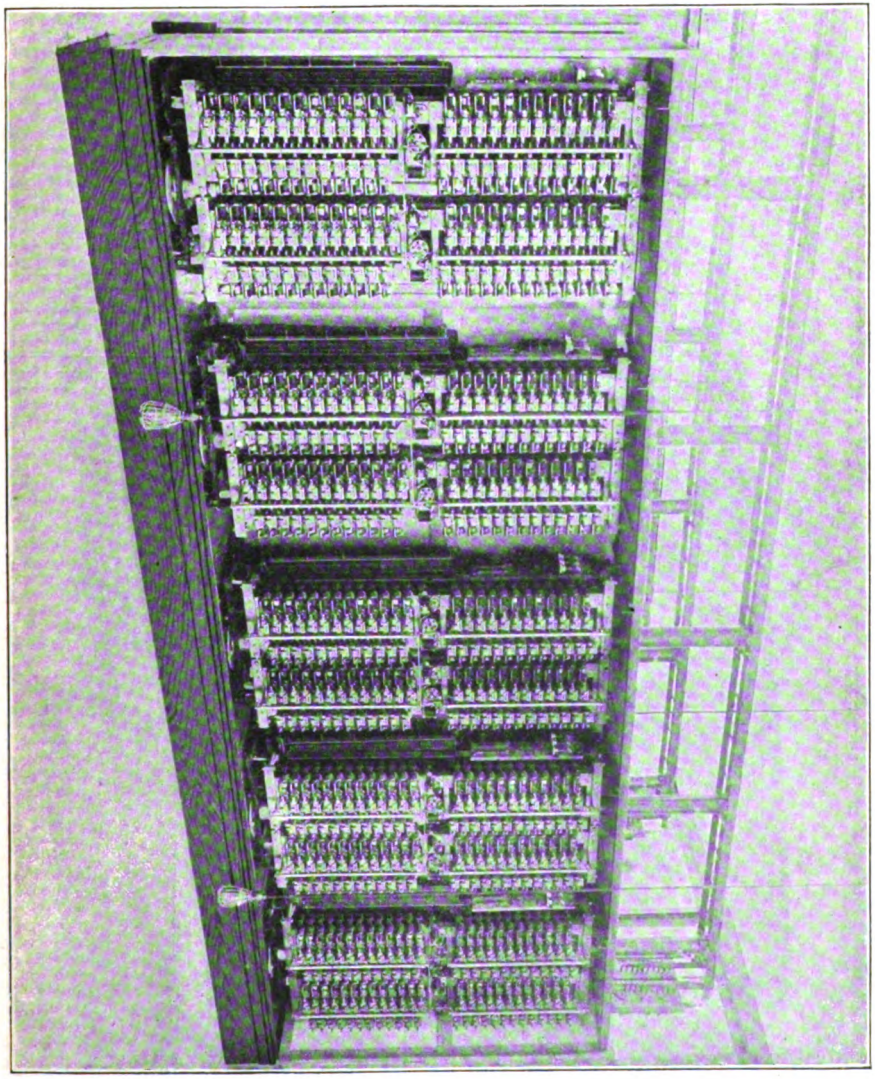


Fig. 641. A 500-line section of exchange, Omaha, Neb.

The 100 unit being only 20 X 33 inches by 5 ft. high, may be placed in small quarters. It is usually located in a small room of an office or

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store building, or in a small frame or cement building constructed for it. A comprehensive system of signals indicate in the Main exchange any trouble which may occur in the district station and every subscriber's line, as well as every trunk line may be tested direct from the Wire Chief's desk in the main exchange. The line switch being comparatively simple in construction, requires little attention and an occasional inspection suffices to keep the switchboard in good working order.

A number of these district stations have been in operation for a considerable time with entirely satisfactory results.

The tremendous saving in construction, etc., which is effected by their use is apparent when it is considered that 15 to 20 trunks are ordinarily sufficient to serve 100 district station subscribers.

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CHAPTER XV.

COMPOSITE SYSTEMS.

*The telephone within recent years has become extremely useful and important in railway work, as an adjunct to the telegraph in relieving overloaded telegraph lines. The enforcement of more rapid and frequent train service has compelled many railway companies to provide more adequate means of communication between the old stations, and to bring in touch with these stations, new ones in which there are no attendants. To accomplish this, requires either an enlargement of the existing telegraph system, the installation of a separate telephone system, or the equipment of the existing telegraph lines with telephonic apparatus—in other words, installing a composite telephone and telegraph system.

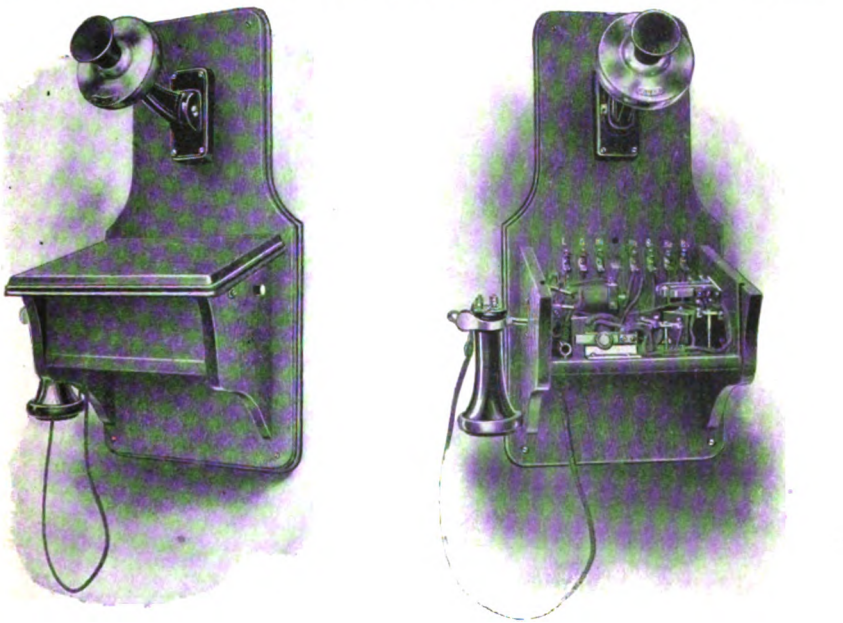


Fig. 641a.

Of these three methods for increasing the communicating facilities of a railway installation, the composite system possesses marked advantages in first cost, operating cost and maintenance. Its installation requires no additional line construction, its operation necessitates no increase in the operating staff, and the absence of outside construction simplifies the maintenance problem. Communication by telephone is, moreover, quicker than by telegraph, and the signaling of the distant party more effectual.

*Railway composite data by Western Electric Co.

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The Western Electric railway composite telephone and telegraph system has been devised for the purpose of enabling telephone and telegraph messages to be transmitted simultaneously over grounded telegraph lines. It is adapted to simple Morse circuits where interruptions in the telegraphic current are of comparatively low frequency and where the change in potential of the current due to the operation of the telegraphic apparatus, is not excessive. Except under favorable conditions, it is not suitable for use on duplex or quadruplex lines, or where machine sending is employed.

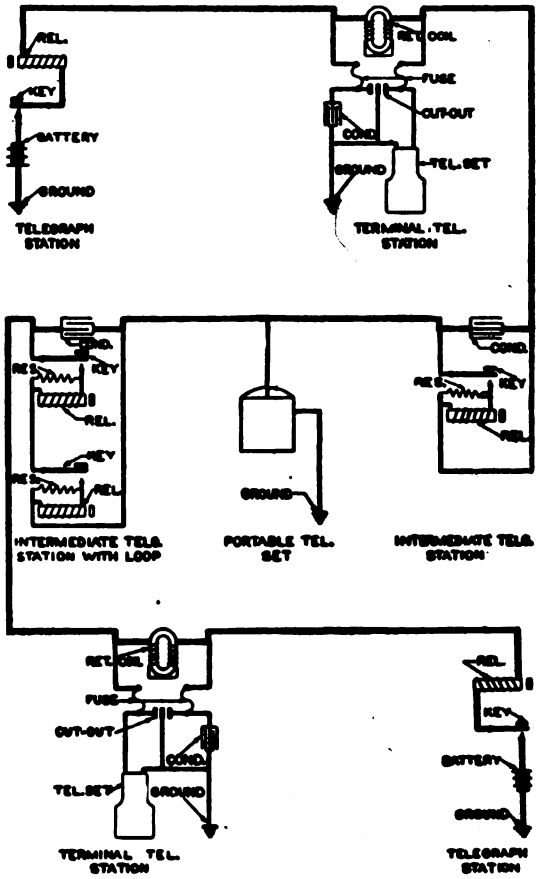


Fig. 642.

The arrangement of grounded line telegraph system equipped with telephonic apparatus is shown in Figs. 642 to 647, Fig. 642 representing the general plan of a whole or part of a telegraph system thus equipped, and Figs. 643 to 647 inclusive, the station wiring.

From these illustrations it will be noted that on the composited portion of a line there may be three kinds of telephone stations: terminal stations, located at each end of that part of the telegraph line used for telephonic purposes; intermediate stations, located between the terminal stations; and portable stations, intended to be carried on a train for emergency use between the terminal stations while the train is at a standstill.

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To adapt a telegraph system to telephone operation requires no change in the telegraphic apparatus or in its operation. All that is necessary is to bridge the apparatus at each telegraph station with a condenser and a resistance, and at the telephone stations to connect the

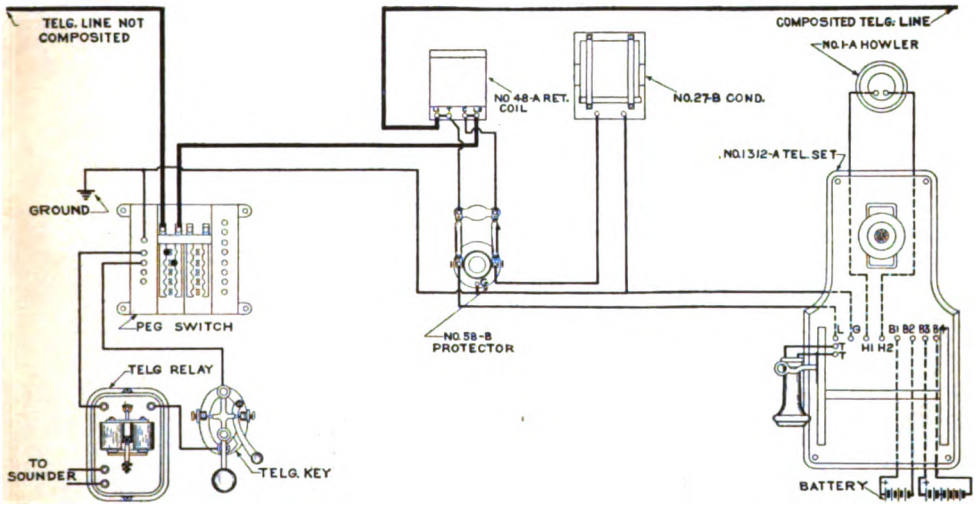


Fig. 643.

telephonic apparatus between the line and ground. A condenser in each telephone set prevents the telegraphic current from passing through the apparatus to ground.

Telephone signaling is accomplished by pressing a button which places high frequency current on the line by means of an interrupter

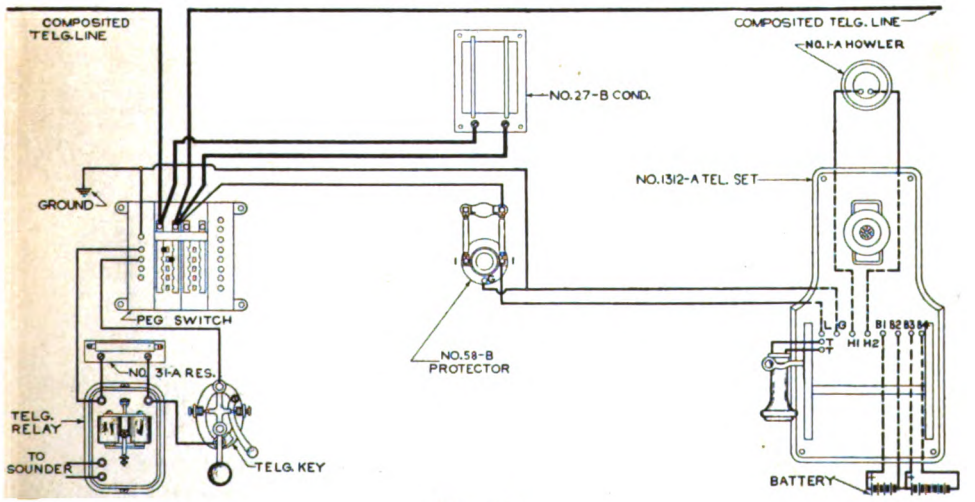


Fig. 644.

and induction coil, as shown at C, Fig. 648. This current at the signaled station passes through a condenser and howler to ground as at A, Fig. 648, causing the howler to produce a sufficiently loud sound to be readily heard in the station. The talking circuits are shown at B, Fig. 648. Regular

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local battery talking is used, and a condenser is joined in series with the receiver, which itself is shunted by a retardation coil.

Telegraph Stations: Each telegraph station on the composited portion of the line is, as already stated, provided with a 1 M. F. condenser and

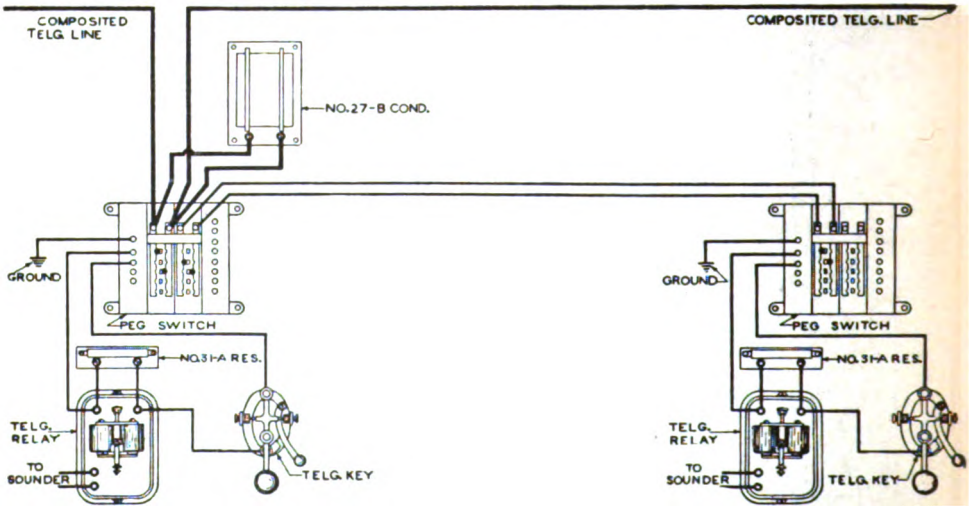


Fig. 645.

a coil having a non-inductive resistance of 1200 ohms. The former is bridged across the telegraph station apparatus outside of the peg switch, Figs. 644, 645 and 646, thus providing a by-path for the telephonic talking and signaling currents, which otherwise would be seriously reduced by the impedance of the relays and interrupted by the operation of the keys.

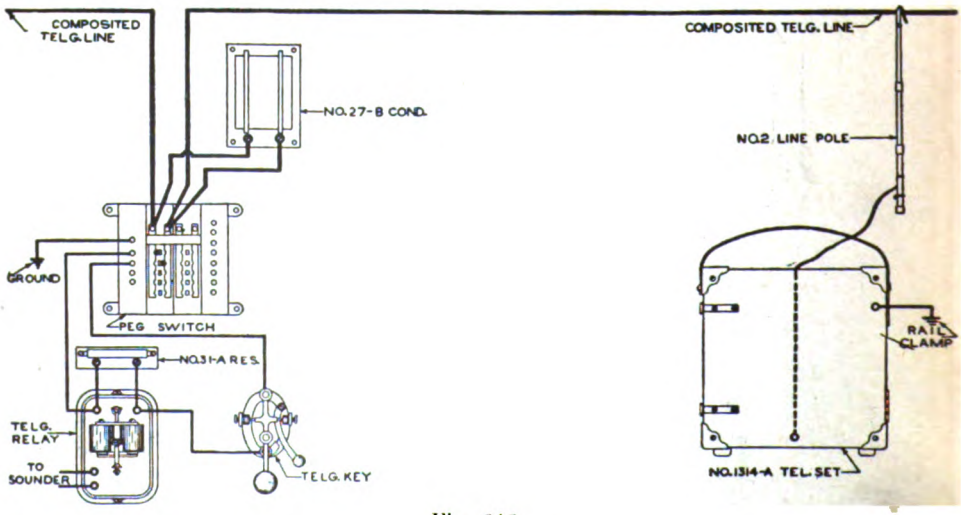


Fig. 646.

The latter, a coil of high non-inductive resistance, is bridged across the telegraph relay so that when telephonic signaling current is applied to the line, any of this current flowing around the condenser will pass through the resistance and so prevent a chattering of the relay.

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Telephone Stations: At each terminal telephone station is located a telephone set, wired as in Fig. 649, a protector, a combined retardation coil of 50 ohms resistance, and a one-microfarad condenser designed to stand a potential of 1000 volts, connected as shown in Figs. 643 and 647.* The

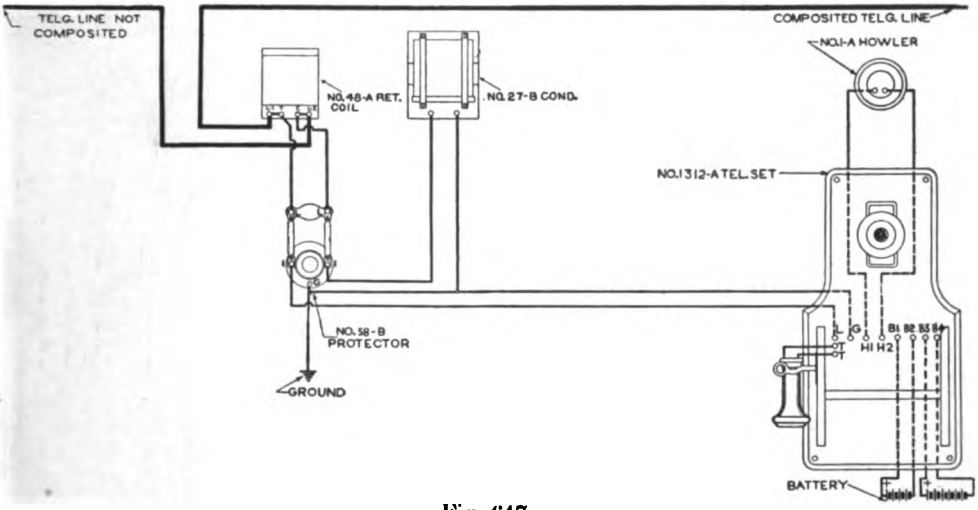


Fig. 647.

retardation coil is joined in series with the line, and the condenser is bridged to ground from that portion of the telegraph line which is not composited. The retardation coil prevents the telephonic currents from

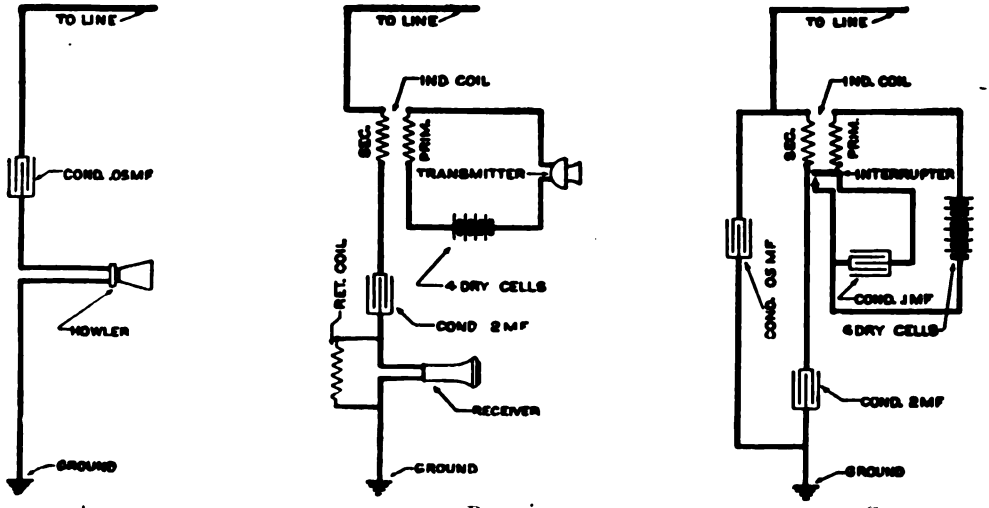


Fig. 648.

passing to ground over the telegraph line beyond the telephone station, but does not impede the telegraphic currents because these are of much lower frequency than those generated by the telephones. This coil and condenser combined prevent the impulses of the telegraphic current from

*The present arrangement is to use a separate coil and condenser. The circuit is the same.—Ed.

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producing annoying disturbances in the telephonic instruments. The condenser also aids in the dissipation of any disturbing currents that may reach the telegraph lines from inductive or other causes.

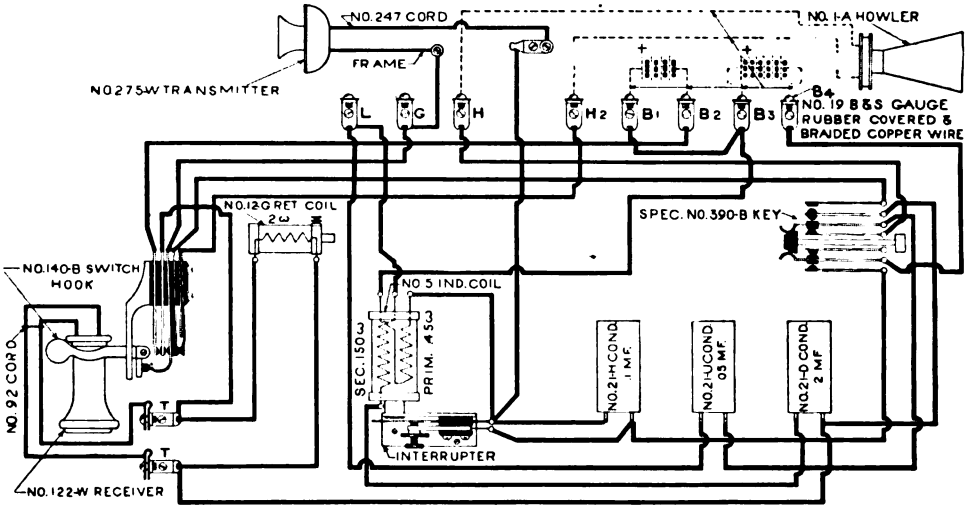


Fig. 649.

Each intermediate telephone station requires a telephone set, and a protector. A portable telephone set, which is a form of intermediate station, is wired as in Fig. 650.

Batteries are installed in all the telephone stations for providing signaling and talking current.

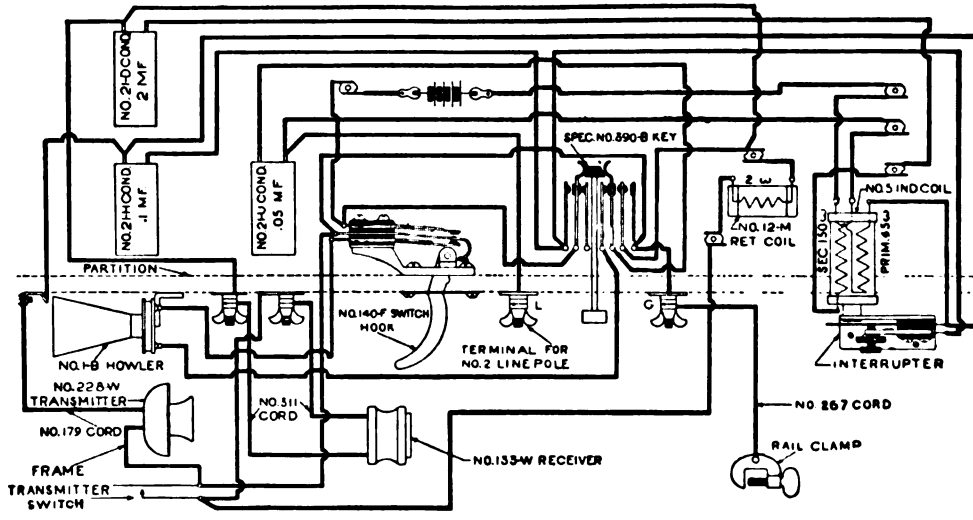


Fig. 650.

Protection of the Apparatus: The protective devices installed at each telephone station, not only protect the telephonic apparatus from lightning and abnormal currents, but owing to the fuses, prevent a permanent ground at the cut-outs from interfering with the telegraph service. The

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protector should be connected in circuit as shown in Figs. 643, 644 and 647, with the fuses next to the line. At intermediate telephone stations, only one side of the protector is used, as there is only one wire connecting the telephone to the line. The protector has copper blocks instead of the carbon usually used.

Limitations of the Composite System: The length of telegraph line and the number of stations with which this composite system can be successfully employed, depend largely upon the character of the telegraph line. On a short line, service will be better and more stations can be operated than on a long line; the length, gage, material of the line wire, and the amount of wire in cable are the more important features which govern the perfect operation of the system.

In arranging a line for composite service it must be remembered that iron wire is much inferior to copper wire of the same size when used for telephonic transmission, and also that conductors in cable are much less efficient than open wires. Furthermore, paper insulated wires in

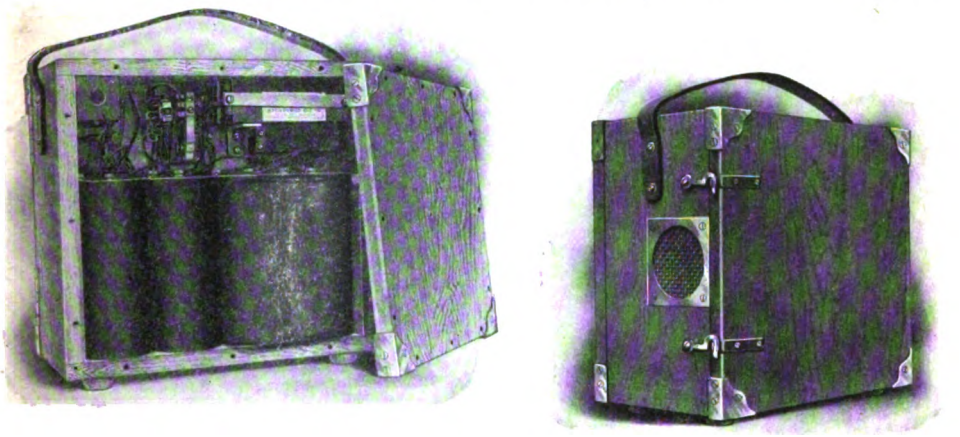


Fig. 651.

cables are much more efficient than wires of the same size in rubber insulated cables, on account of the high electrostatic capacity of the latter.

Owing to the many different conditions governing the use of railway composite apparatus, and the variation in these conditions for each particular line, it is impossible to give inflexible rules applicable to every case regarding the length of line over which service can be successfully obtained, or regarding the number of stations which can be successfully operated on a single line. Each particular telegraph line must be considered separately before a definite statement can be made regarding its adaptability for telephone service.

As a general indication of the possibilities of the system, however, it may be stated that successful operation should be practicable over ordinary telegraph lines up to 100 miles in length, and with as many as five intermediate telegraph stations.

A Western Electric portable set is shown in Fig. 651. It is entirely self contained, the necessary dry cells being inside the case, together with all the talking and signaling apparatus. The box is of substantial hardwood construction with metal corners, and is divided in two parts by a partition, the dry cells, retardation coil, induction coil, hand switch springs, key springs and condensers being located in the rear, while the

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transmitter, receiver, howler, interrupter, hand switch lever, signaling key button and rail clamp are in front. Access to the apparatus in the rear is obtained by taking out the screws in the back of the case, and removing the back board, as shown in Fig. 651.

A line pole is also a part of this portable equipment. It consists of three 6-foot sections, so arranged that either two or three sections may be used. A 104-foot insulated flexible wire cord is furnished with this pole, soldered to the metal joint on the butt section. The joints on the other two sections have permanent wire connections, from one end to the other, the wire on the end section connecting with a metal hook so that

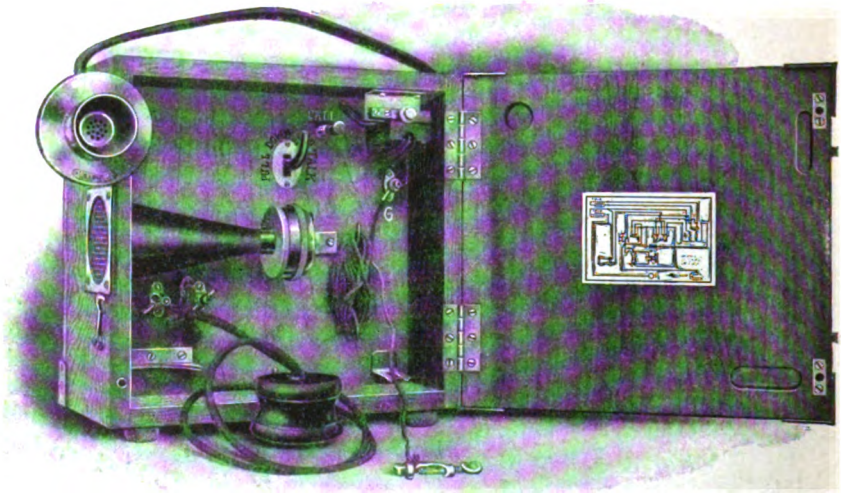


Fig. 651a.

when the pole is jointed together and the hook hung on a bare telegraph wire, the circuit between the line and telephone set is completed. The connection between the set and ground is by means of a rail clamp, made adjustable so as to fit flanges of different sized rails, and connected to the set by a flexible wire cord.

Howlers: The howler consists of a special form of telephone receiver equipped with resonating horn. The diaphragm is operated by the high frequency signaling currents produced by the interrupter and induction coil.

The howler is mounted in the set if same is portable, or is separate for regular stations so that it can be located in any convenient place where it will attract attention when in operation.

Installing Telephones: The instruments should be installed according to the usual methods, taking care to securely fasten the instrument to the wall, avoiding partitions if possible.

Howler: The howler used in connection with the wall telephone set may be located in any convenient place where its operation will attract attention. It is advisable, however, to mount it at a sufficient distance from the set so that it will not be handled by persons telephoning, and its adjustment thereby altered.

Condensers: The condensers and coils should be located as near to the telegraph line or the peg switch as possible, care being taken to avoid

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damp locations and places where they would be exposed to mechanical injury.

Resistance Coil: The resistance for shunting the telegraph should be mounted at some convenient point near the telegraphic apparatus, such as beside the telegraph relay on the table, under the table, or on the wall.

Protector: The protector should be mounted upon the inner wall of the building as near as possible to the point where connection is made with the telegraph line. An asbestos mat should be placed beneath it.

Battery: Six dry cells are usually employed with the station telephone set, four cells being used for talking and the entire set for signalling. Only four cells are used with the portable telephone, these furnishing current for both talking and signalling.

The battery should be placed near the set in some out-of-the-way place, unexposed to mechanical injury and dampness, but accessible for inspection and renewals. The cells should be connected in series,

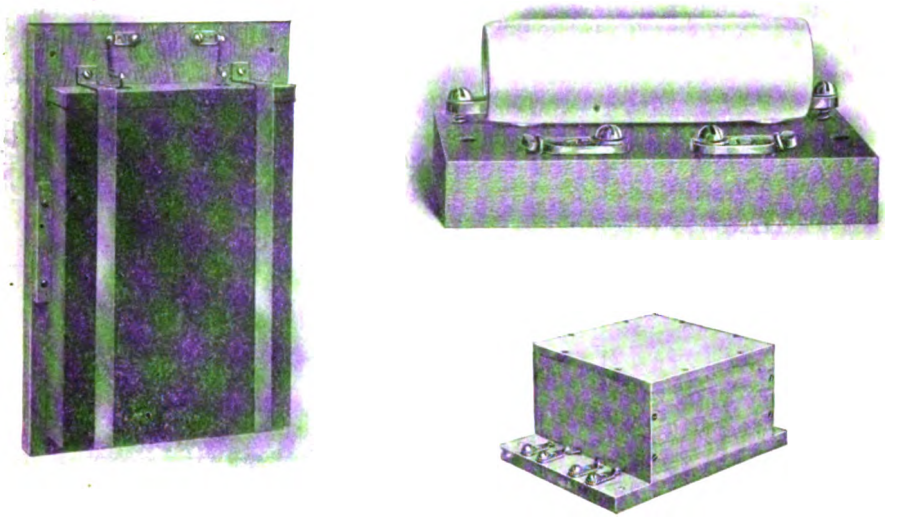


Fig. 651b.

that is, the carbon of one cell should be connected to the zinc of the next throughout the battery, flexible cords being used for this purpose. Care should be taken to connect the terminal leads from the battery to the proper binding posts of the telephone set as shown in Figs. 643, 644 and 647. A diagram of this part of the wiring will also be found in each telephone, so no trouble should be experienced in making the proper connections.

Size of Wire: With the exception of the ground wire from the protector, all interior wires from the telegraph line or the peg switch to the telephonic apparatus, should be of rubber covered and braided copper, not smaller than No. 19 B. & S. gage. The ground wire from the protector should be of copper not smaller than No. 18 B. & S. gage, and should be rubber covered and braided; if exposed to mechanical injury, it should be of No. 14 B. & S. gage, rubber covered and braided.

Ground Connections: Where a telegraph equipment is already installed in an office, the ground wire of that equipment may be used for the telephone set and protector, connection with it being usually made at the

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peg switch. Where no telegraph equipment is installed, it will be necessary to run a ground wire.

Locating Trouble: When the system is not working properly, the trouble may be due to the line being out of order, to a defect in the apparatus or wiring in the telegraph stations; or to a defect in the apparatus or wiring in the telephone stations.

Line trouble is cleared by the usual methods employed in all telegraph systems.

Trouble at telegraph stations equipped with telephone apparatus, must be either in the telegraph apparatus, the No. 27-B condenser, or in the No. 31-A resistance. Trouble in the telegraph apparatus should be cleared in the usual way. If the condenser is short-circuited, no telegraph messages can be sent from that station; if the condenser is open, there will be poor telephonic transmission beyond the break. In case the No. 31-A resistance is open, the telephone signaling currents may cause a chattering of the relay.

Trouble at telephone stations may be traced to a ground across the protector blocks, to a loose or open connection between the telephone set

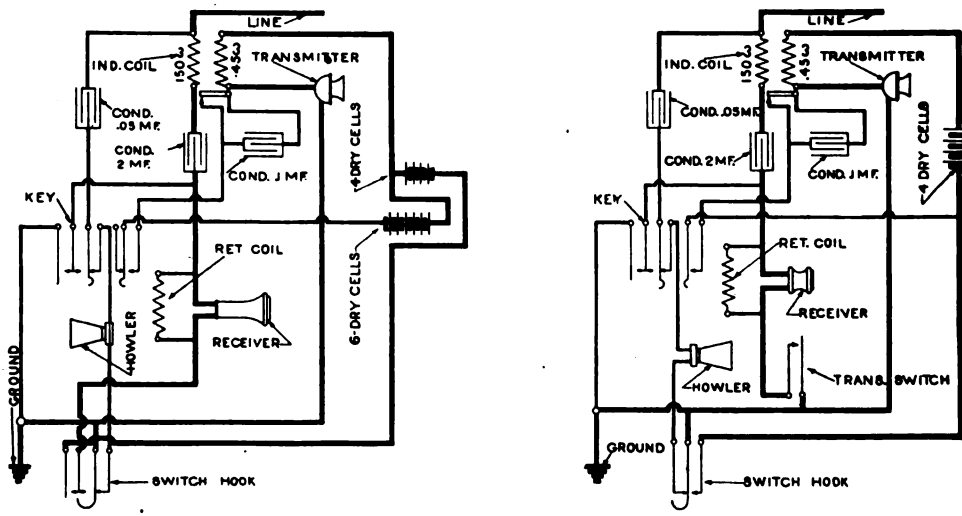


Fig. 652.

and telegraph line, such as an open fuse; to defects in the apparatus or wiring of the signaling circuit in the set (represented by the light lines in Fig. 652) to defects in the apparatus or wiring of the talking circuit in the set (represented by the heavy lines in Fig. 652); or to an open ground connection. Such troubles will not ordinarily interfere with the continued operation of the telegraph apparatus, but in any case, the following tests and remedies should quickly locate and remedy the defects and place the system in operation.

Signaling Trouble: When able to talk satisfactorily over a line but unable to signal other stations, it is well to first ascertain whether the interrupter operates when the signaling key is depressed. If it does not, test the battery, and if that is all right, try a different adjustment of the contact screw on the interrupter.

If the interrupter operates satisfactorily and it is impossible to signal other stations, ascertain whether signaling current is delivered to the

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line when the key is depressed. This may be determined by replacing the receiver on the hook and disconnecting the line wire from terminal "L," Fig. 649, short-circuiting the terminals "L" and "H," and then pressing the signaling key, which should operate the howler at the home station.

If the local howler does not then operate, it indicates that the trouble is in the telephone set at this station, and that the contacts of the switch hook and of the signaling key should be examined to see that they make good contact with each other. If this does not clear the trouble, it is advisable to look for an exhausted battery, loose connections, broken wires, or an open in the No. 21-D condenser.

An exhausted battery can be detected by bridging a low-reading voltmeter or battery gage across each of the six signaling cells of the No. 1312-A telephone set or across each of the four signaling cells in the No. 1314-A telephone set, while the switch hook is in the proper position for talking and after the signaling key has been closed for one minute. If

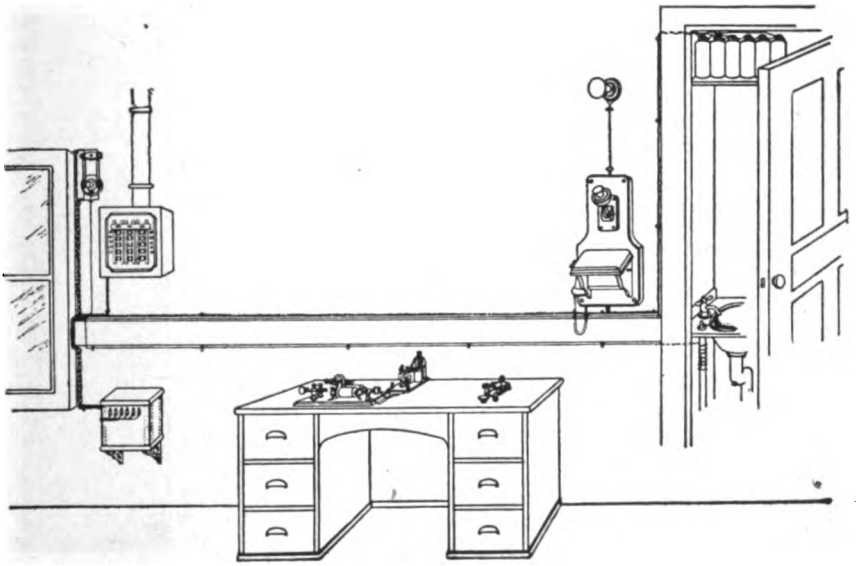


Fig. 653.

the cells are not exhausted, the total pressure under normal working conditions should be at least 0.7 volt per cell. Loose connections or broken wires can readily be found by inspection. To test for an open in the condenser, short-circuit its terminals; if the howler then operates it indicates a defective condenser.

If the howler at the signal station operates satisfactorily after disconnecting the line wire and short-circuiting terminals "L" and "H," it indicates that the trouble is not in the telephone set. It may, however, be due to arcing at the open space cut-outs in the signaling station, or to trouble at the receiving station where the howler may be out of adjustment or open, the No. 21-U condenser defective, or to an open circuit in the wiring. The removal of the copper blocks in the open space cut-outs at the signaling station will therefore, determine at this stage in the tests whether the trouble is in the distant station.

At the receiving station, the method of procedure would be as follows: The terminal "L," Fig. 649, should be connected to "H 1." If the howler then operates, it indicates an open in the No. 21-U condenser.

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If however, the howler does not operate, the next step would be to test the howler separately. This is done by connecting it directly to one battery cell and listening for a click at the instant the circuit thus formed is closed. If no click is heard, the trouble is in the howler; otherwise, it must be an open circuit in the wiring.

Adjustment of the Howlers: The sound emitted by the howler can be varied by moving the diaphragm nearer to or further away from the magnets. One method of adjusting the howler is to have the most distant station keep signaling current on the line until the shell containing the diaphragm has been adjusted to give the desired tone; the locking ring may then be used to fix the shell firmly in place. As the locking of the metal shell in place tends to move the shell slightly away from the magnet, due allowance should be made in adjusting the howler to guard against this action throwing the howler out of adjustment.

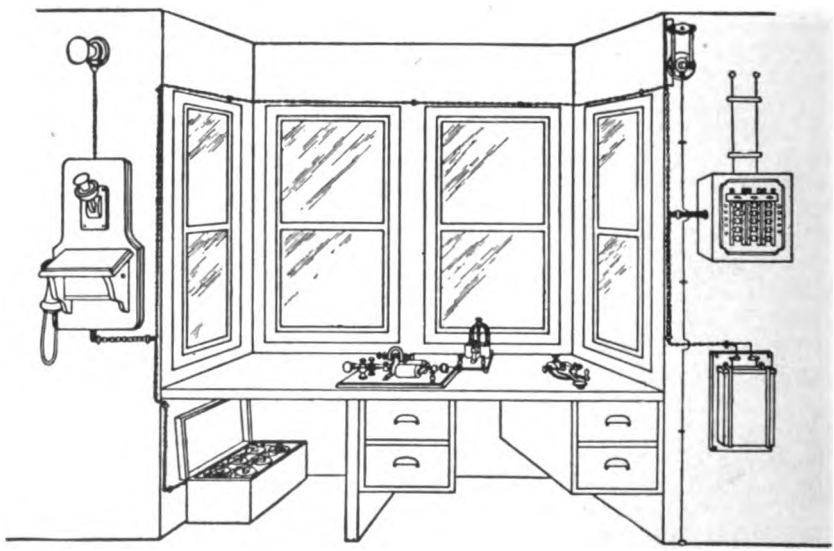


Fig. 654.

It sometimes happens that the magnets in the howler become demagnetized or weakened after being in service for a long time. In this case, the howler should be replaced by a new one and the defective howler returned for repairs.

Transmitting Trouble: If the transmission is poor, that is, if there is trouble in receiving messages at a distant station while messages are clearly received at the home station, the speaker should talk clearly, with his lips close to the mouthpiece of the transmitter. If the transmission is still unsatisfactory, the trouble may be an open in a condenser at an intermediate telegraph station (see Fig. 642); in the primary or secondary of the talking circuit in the sending station (see B, Fig. 648, and heavy line circuit in Fig. 652); or in the secondary (receiving) circuit of the receiving station (see B, Fig. 648, and heavy line circuit in Fig. 652).

If in the condenser at an intermediate telegraph station, the trouble is undoubtedly an open, which although interfering with the transmission of the voice beyond the break, will not interfere with its reaching a station on the same side of the break as the sending station. If in the primary or the secondary of the talking circuit in the sending station, the re-

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ceiving station will have no trouble in hearing messages transmitted to it from other stations on the line. On the other hand, if the trouble is in the secondary (receiving) circuit of the receiving station, the sending station will have no trouble in transmitting to other stations.

To test for trouble in the talking circuit of the sending station, place the receiver to the ear, and if the secondary circuit is not open and there be no defective apparatus in it, the usual low sounds characteristic of aerial lines, will be heard. These sounds vary in intensity according to the length of the line and its exposure to other electric circuits, but they are seldom of sufficient intensity to interfere with telephonic transmission. If the secondary circuit is thus found to be all right, the primary circuit is then tested by listening in the receiver while speaking into the transmitter or tapping it gently. These sounds will be distinctly heard in the receiver if the primary circuit is in good working order, or a click will be heard in the receiver when the switch hook is operated. If such sounds are not heard, the apparatus and wiring in the secondary circuit should be examined, and the battery inspected for an open circuit.

A battery test with an ammeter is here recommended. This test is made by connecting the ammeter in the primary circuit, and after the receiver has been off the switch hook for one minute, noting the current in the ammeter. If the battery is working perfectly, it should give a current of more than 0.14 ampere after it has been thus connected for one minute. This corresponds to a voltage of approximately 2.8 across the terminals of the talking battery while the latter is under load, that is, furnishing current to the primary circuit.

If the condensers on the line are not defective, and there be no trouble in the talking circuit, it is in all probability in the receiving circuit at the distant station.

Receiving Trouble: If unable to hear distinctly, and there is no difficulty in transmitting messages, either in the local or the distant station, it indicates trouble in the secondary circuit of the telephone set. This circuit, as shown at B, Fig. 648, consists of the secondary of the induction coil, the No. 21-D condenser, receiver in multiple with the No. 12-G retardation coil, the switch hook and ground. A thorough inspection should be made of all parts of this circuit for poor connections, and if none be found, an examination should be made of the apparatus in the secondary circuit for defects and poor adjustments.

Adjustment of the Retardation Coil: The No. 12-G retardation coil in the regular telephone set has an iron core which can be moved in or out and secured in any position to vary the impedance and regulate the amount of current shunted around the receiver. If disturbing noises become troublesome in the receiver, the iron core should be moved out of the retardation coil to reduce the impedance of the coil and permit more current to pass around the receiver. On the other hand, to maintain the volume of the sounds received, the amount of current diverted from the receiver should be as small as consistent with the necessary freedom from the disturbing noises. The core should therefore be withdrawn from the coil no further than is necessary to obtain the desired result.

In the portable telephone set the iron core is permanently adjusted in the No. 12-M retardation coil there used, because the disturbing noises vary at different points along the telegraph line, and owing to the temporary use of the set, do not warrant readjusting the core every time the set is put in service at a different point.

Receiver Defects: In case the trouble cannot be remedied by means of the retardation coil, it may be found in the receiver itself. Trouble in

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receivers may be caused by dust or dirt settling upon the pole faces of the magnet and damping the vibrations of the diaphragm. To clear this trouble, the receiver cap should be unscrewed and the pole faces of the magnet wiped perfectly clean. All regular tests for receivers also apply.

Tests and Remedies for Grounds: Ground troubles may be due to foreign matter between the copper blocks of the No. 58-B protector, to a defective No. 21-D or No. 21-U condenser in the telephones, to a defective No. 28-B condenser, or to a cross between the primary and secondary parts of the talking circuit. To determine if the trouble is in the protector, remove the metal cap and pull out both of the copper protector blocks. If this clears the ground, they should be cleaned and replaced, and if necessary, new No. 10 micas should be used in place of the old ones. Under no circumstances should cardboard or paper be substituted for the mica.

If the trouble is not in the protector, and the separation of the line wire from the protector or telephone set clears the ground, the condensers and wiring in the telephone set should next be tested. If the trouble is noticeable only when the receiver is on the hook, the No. 21-U condenser should be investigated. If however, the ground occurs only when the receiver is off the hook, the No. 21-D condenser is probably causing the trouble, and should be remedied.

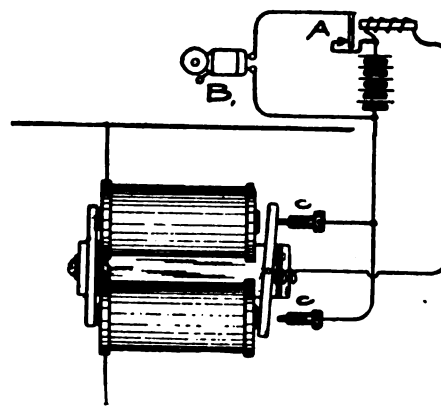


Fig. 655.

In case either the No. 21-D or the No. 21-U condenser be found defective, any available condenser which will clear the trouble temporarily may be inserted between the telegraph line and the telephone set until the defective condenser is replaced. If no suitable condenser is at hand, disconnect the telephone from the line until repairs can be made.

In a terminal station, a ground may occur at the No. 28-B condenser equipment, due to a short circuit in the condenser. To determine whether this is the trouble, remove the ground wire from that equipment; if the trouble then ceases, it indicates that the condenser is defective. To clear the trouble temporarily, the ground connection may be left off the condenser. In doing this, however, the ground connection of the telephone set, which is usually made at this point, must not be disturbed, as this would leave the telephone out of service.

The foregoing system is typical of modern practice, and the method of signalling, and receiving the signal by means of a howler seems to represent the most satisfactory method. It is evident, however, that any

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means that will permit of sending a signal over the telegraph line for calling the telephones, without interfering with the telegraph service will accomplish the result. One method used extensively before the howler system was perfected, makes use of a polarized relay bridged from line to ground, similar to the ordinary telephone ringer, equipped with two contact points *C C* Fig. 655. In either position of the armature, it makes contact on one of the studs, so that the high resistance, slow acting relay A holds its contact open, and the battery bell B is not operated. Ordinary telegraph currents move the armature of the polarized relay so slowly that same is always in contact with one or the other of the contact points,

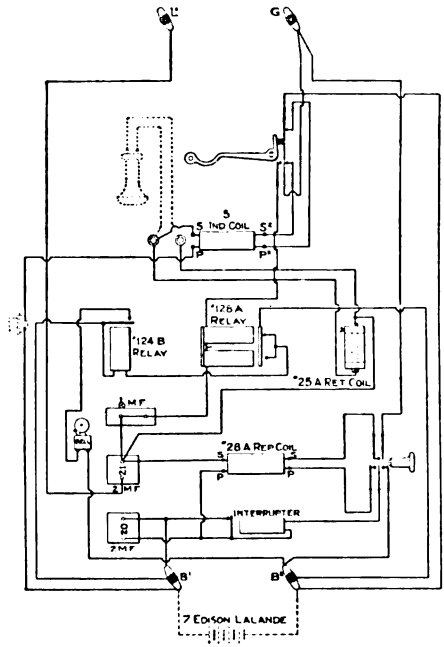


Fig. 656.

therefore, while the armature moves in unison with the telegraph impulses, the circuit through A remains closed, and the bell is not rung.

When a high frequency current, such as used for telephonic signalling, of the character described in connection with the howler system passes through the polarized relay, the armature buzzes at a high rate of speed, and the armature is out of contact with the point *C C* long enough to allow the slow acting relay A to close its contact to ring the bell. The high frequency generating apparatus is of the character shown in Fig. 649, consisting of a suitable interrupter and induction coil.

The circuit of a complete instrument arranged for this system is shown in Fig. 656. The No. 128a relay is the polarized relay shown in Fig. 655. The slow acting relay controlling the bell is No. 124B in the figure. In this set a separate interrupter is used, not combined with the telephone induction coil but having a separate repeating coil (No. 28A) for stepping up the high frequency current. The condensers and other parts perform practically the same functions as in the howler system, and the same condensers and impedance coils are used at each end of the line with a non-inductive resistance and condenser at each intermediate telegraph station.

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The adjustment of the polarized relay is such that the armature has a slight bias in the direction in which the heaviest impulses tend to throw it. A position of the armature will be found in which the telephone calls are received well, without the telegraph impulses ringing the bell.

The slow acting relay should be so adjusted that a momentary opening of its circuit will not cause it to release its armature. It is equipped with a retractile spring for this purpose and this should have only sufficient tension to pull back the armature when the circuit is broken.

It will be noted that closed circuit batteries are necessary, as the slow acting relay winding is in circuit all the time except when a signal is received. Edison Lalande cells are usually used.

If false signals are received the polarized relay is out of adjustment. Should this not be the case, weaken the retractile spring of the slow acting relay. This latter also applies if the bell rings continuously, and it is well to shorten the swing of the armature by screwing in the back contact screw.

If unable to signal other stations, ascertain if the vibrator acts when button is pushed. Disconnect set from line and feel for shock by touching line and ground posts while button is pressed. If no shock is felt, clean contacts in button and hook switch, or look for broken wires.

If the telegraph line tests grounded, the trouble may be an arrester ground, or due to bad condensers. First disconnect the ground wire from arrester. If this clears the trouble, arrester needs cleaning. If the trouble is not in arrester disconnect line from telephone set and if this clears the trouble it may be traced to the No. 22 condenser, which must be replaced. If the ground only occurs when the receiver is removed from the hook, then the No. 29 condenser is defective. Any available condenser may be used in place of the regular ones, temporarily.

If transmission is poor look for a telegraph relay on the line which is not properly shunted by a condenser. Examine the batteries. See that persons using the instrument talk in a firm tone of voice, with the lips close to the mouth piece.

While this system gave excellent results, the howler method of signalling is rapidly supplanting it, as with the latter, there are no relays to adjust, and the closed circuit battery is unnecessary, no current being used except when the set is actually in use.

The foregoing systems are typical of those where a *telegraph* line is also used for telephone purposes, the latter being a secondary consideration, the line being primarily designed for *telegraph* work.

The next arrangement is where existing telephone lines are used for telegraph circuits, or where additional telephone, or so-called "phantom" lines are superimposed on the physical lines. For this work special repeating coils are necessary, and it is well to review the matter in Chapter 5 relating to the design of coils. For phantom work a coil of high efficiency, absolutely balanced as to resistance, number of turns, etc., must be used. When combined telephone and telegraph service is attempted the coil must, in addition to these features, be of comparatively low resistance as the windings are often in series with the relays and batteries of the telegraph, and the less resistance in this circuit, the better.

The Dean Electric Company's No. 1620 coil is especially adapted to Phantom circuits and Simplex telegraph lines. It is enclosed in a seamless iron tube 5¾ in. long and 2½ in. in diameter, with a maple base 7 in. long and 2½ in. wide. The coils are cross talk proof and may be mounted side by side. This coil is shown in Fig. 657.

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Phantom circuits should be treated in the same manner as ordinary lines in order to obtain the best results.

Grounded and metallic lines, without transpositions, can be used only when there are no other lines that will produce a disturbing influence. In the case of a metallic line, when cross-talk or inductive noises are en-

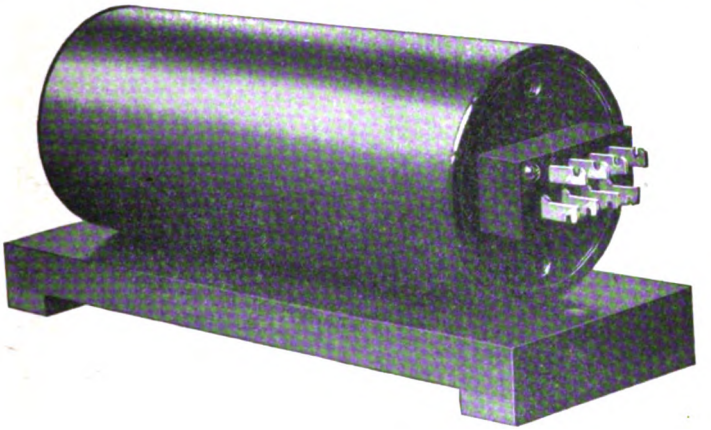
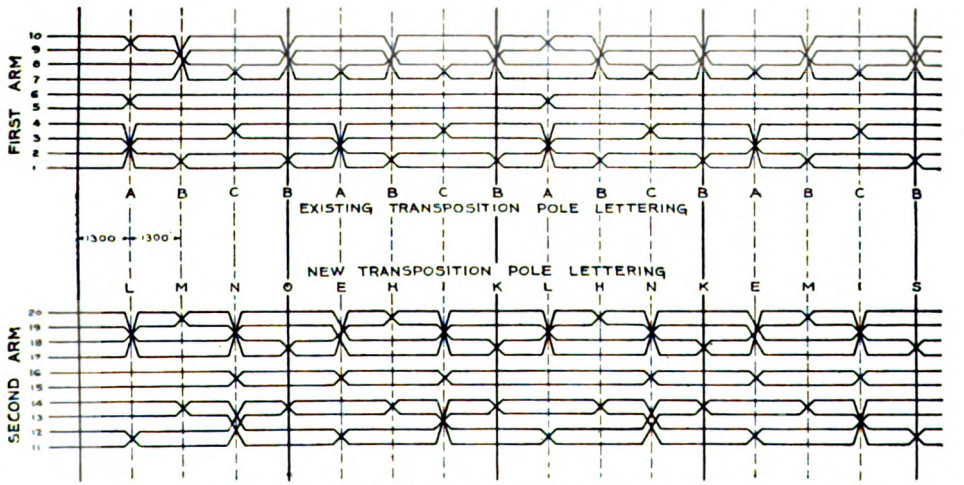


Fig. 657.

countered, the first remedy to be applied is to cut transpositions into the line. Grounded lines must be treated in the same manner in order to overcome disturbances. As it is impossible to transpose a single wire, the line must be made metallic when this kind of trouble appears.



DEAN Transposition Circuit No. 9

Fig. 658.

Phantom circuits are identical with non-transposed physical lines and are not subject to any more troubles. The remedies are the same.

Transposition diagrams for Phantom circuits are simple and easily followed, but are more readily shown than described. Fig. 658 is a greatly reduced drawing of one of the many possible arrangements.

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Fig. 659 shows a Phantom telephone circuit. The arrangement is so obvious that no detailed description is necessary. It is also obvious that a grounded Phantom line could be produced by connecting the wires from the sleeve side of the jacks of the Phantom line, to the ground

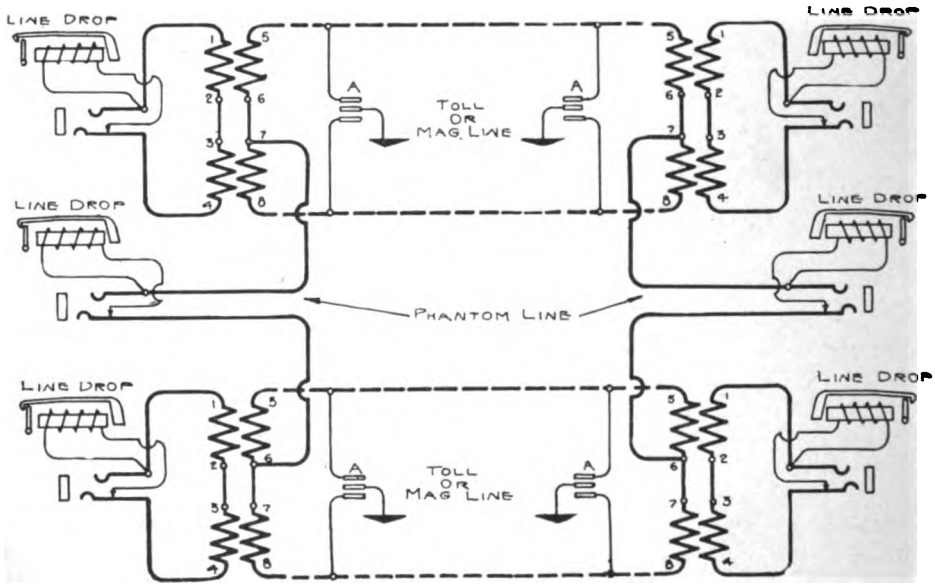


Fig. 659.

instead of to the junction of terminals 6 and 7 of the repeating coils of the lower toll line in the figure. As this line is used for telephonic purposes only, good ring through repeating coils such as the Dean No. 1620 type can be used, having windings of comparatively high resistance.

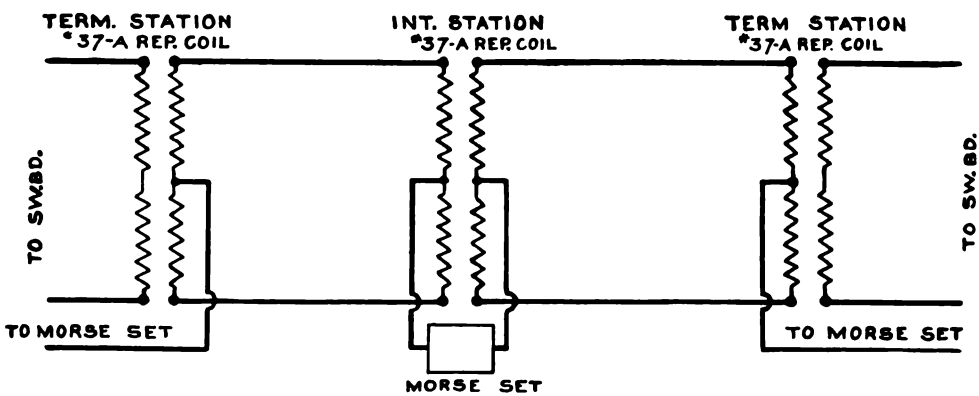


Fig. 660.

Fig. 660 shows a simplex telegraph circuit. For this work special repeating coils having low resistance windings, but of the highest efficiency are desirable. Few of the manufacturers have developed coils of this type, the Western Electric and Dean Company's being the only ones to the writer's knowledge that have offered coils for commercial work.

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The Western Electric Company No. 37A coil is extensively used and especially well adapted for this purpose. Some idea of the construction of this and similar coils may be gained from the following data, obtained from unwinding one of them.

The core is circular and rectangular in cross section, 3 in. inside diameter, 6 in. outside, 2½ in. thick. It is apparently wound from one piece of No. 25 bright iron wire. The core is then wrapped with two layers of cotton tape, well shellacked.

The terminal wires are of No. 24 wire and extend 24 in. from coil, passing once around coil and being securely lashed to coil with thread.

Each layer of winding is separated by a sheet of muslin wide enough to extend across face and sides and turn down ¼ in. in center.

The primary windings are of No. 25 single silk covered wire.

1st	layer,	blue	terminal,	212	turns	half	way	around core.
2nd	"	green	"	418	"	once	"	"
3rd	"	splice to	1st layer,	425	"	"	"	"
4th	"	"	" 2nd "	436	"	"	"	"
5th	"	"	" 3rd "	421	"	"	"	"
6th	"	"	" 4th "	350	"	"	"	"

with a green white terminal making a total of 1204 turns. The 7th layer splices to the 5th, and makes 156 turns half way around core making a total of 1214 turns composing one primary winding, the outer end having a blue white terminal.

The length of the winding having blue—blue white terminals is approximately 845 feet, and the green—green white 843 feet.

The secondary windings are of No. 25 single silk covered wire.

1st	layer,	red	terminal,	176	turns	half	way	around core.
2nd	"	white	"	334	"	once	"	"
3rd	"	splice to	1st layer,	321	"	"	"	"
4th	"	"	" 2nd "	330	"	"	"	"
5th	"	"	" 3rd "	313	"	"	"	"
6th	"	"	" 4th "	288	"	"	"	"
7th	"	"	" 5th "	260	"	"	"	"
8th	"	"	" 6th "	215	"	"	"	"

to a red blue terminal, total 1167 turns. The 9th layer splices to the 7th, and makes 75 turns half way around core to a red blue terminal making 1145 turns.

Two layers of tape are placed between the primary and secondary windings, and over the finished coil, which is then placed in a heavy iron case which is filled with rosin, after being mounted upon a base, 11 x 8⅝ in., carrying the eight terminals. Each winding measures about 35 ohms. Evidently the makers have some means of accurately balancing the windings against each other, as the coil is accurately balanced as a whole, each winding seeming to possess the same impedance, in spite of the fact that the number of turns may be slightly different. The method of winding, while exceedingly difficult, certainly results in a well balanced coil. Fig. 660 shows this coil as applied to a telephone line also used for telegraph circuits, while only one intermediate instrument is shown, it is evident that others may be inserted in the lines in a similar manner.

The coil made for this work by the Dean Electric Co. is shown in Fig. 661. The core is made up of fine iron wires, varnished to reduce the

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electrical losses to a minimum. The windings measure about 30 ohms each, and are treated to render them waterproof. This coil, known as No. 7315 is perhaps the latest development of this type, and is said to be remarkably efficient, and is especially adapted for use with the following circuits. The

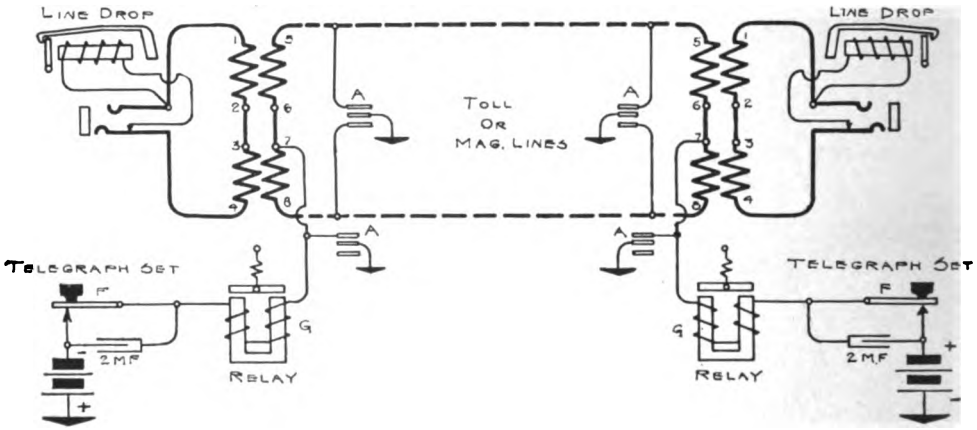


Fig. 660a.

winding is treated to make it waterproof and the coil throughout is designed to stand up indefinitely under all conditions.

Fig. 660-A shows a simplex telegraph circuit in detail. The 2 M. F. condenser is placed across the telegraph keys as shown, to prevent excessive



Fig. 661.

sparking at the contact. The telegraph relays and batteries are of the usual type.

Adequate lightning protection must be used, as the coils cannot be readily repaired, and as a direct path to ground is afforded from the tele-

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phone line to the ground, through the telegraph instruments, too much care cannot be exercised to prevent damage.

The next step is to place two telegraph circuits on one telephone circuit, making three circuits over one pair of wires. Fig 662 shows a scheme often used by the Bell Companies to accomplish this. An arrangement of

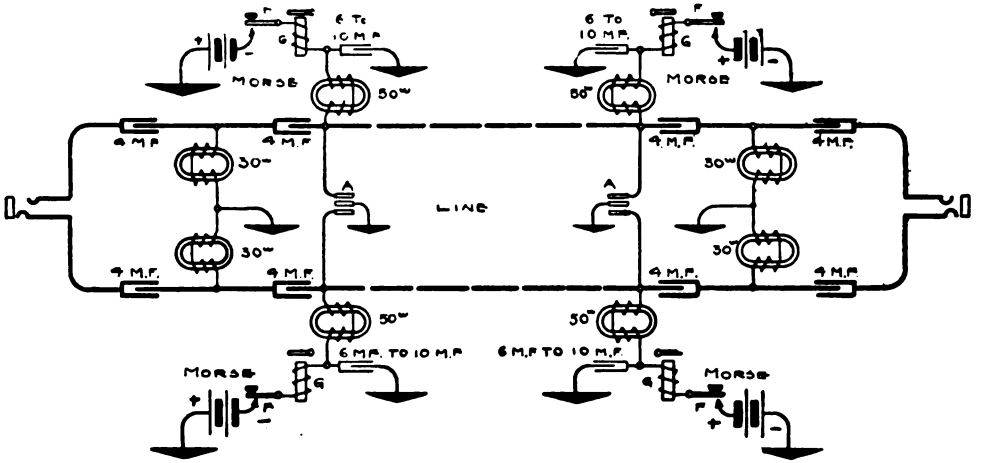


Fig. 662.

condensers and retardation coils serve to provide separate paths for the telephone and telegraph currents.

Referring to the upper telegraph circuit, this is confined to the upper line wire because of the 4 M. F. condensers at each end of the line, the lower telegraph circuit being confined to the lower line in the same manner.

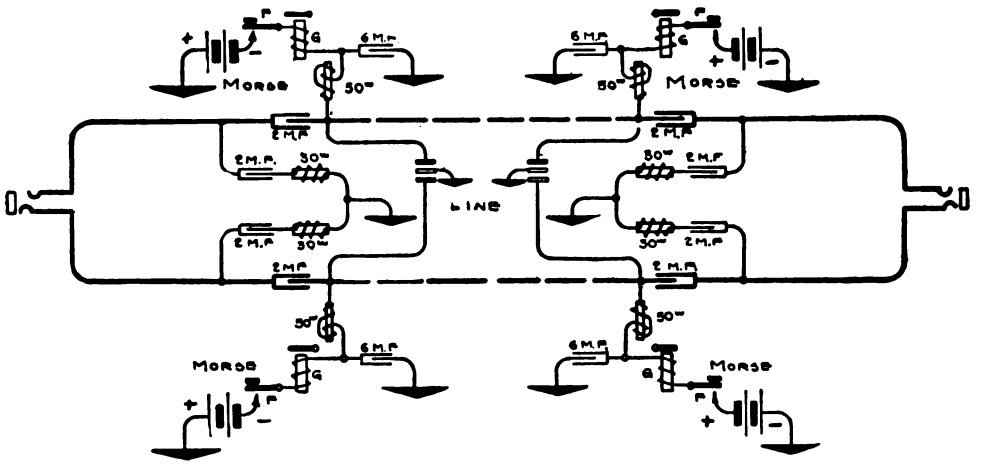


Fig. 663.

The telephone circuit passes from one jack to the other through eight 4 M. F. condensers as shown. The voice currents are prevented from leaking out into the telegraph circuits by the impedance of the 50 ohm retardation coils, while the two 30 ohm coils, with the junction between them grounded, serve to balance the telephone line and remove the noise due to the operation of the telegraph circuits. The 6 or 10 M. F. condenser

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between the 50 ohm coil and the telegraph sounders marked *G* in the figure, helps to eliminate sparking at the keys, and also provides a path to ground for the noise due to the telegraph pulsations.

Fig. 663 shows a later type of Composite circuit. The principal difference consists of placing the 2 M. F. condensers in the taps between each 30 ohm retardation coil and the line. This eliminates the necessity of ringing through so many condensers, which is necessary when the circuit shown in Fig. 662 is used.

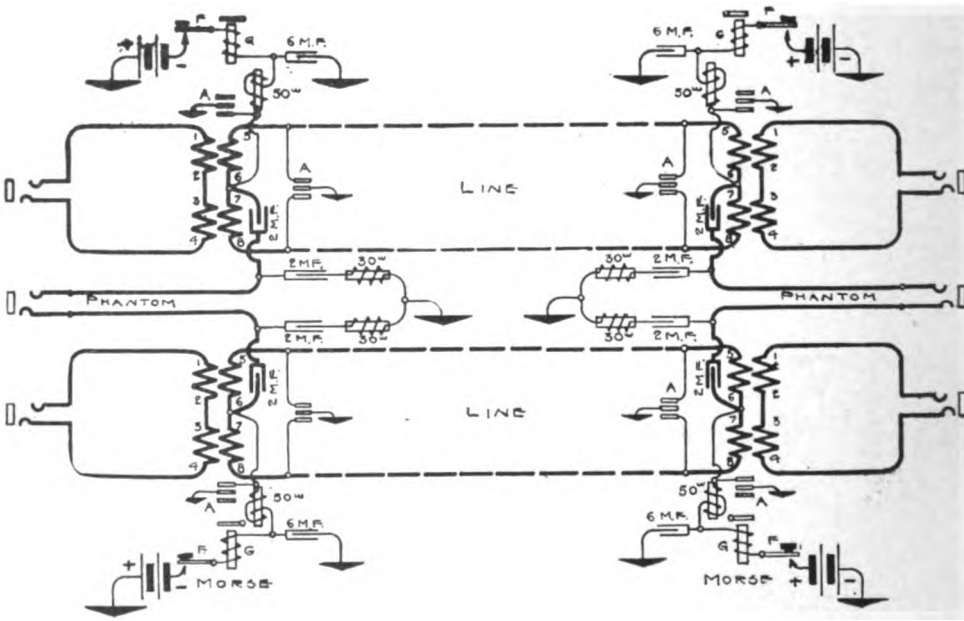


Fig. 664.

The retardation coils are made up of two spools mounted on a wood base about 9 in. square. The spool heads are 4½ in. square, the core about 1¼ in. diameter. The winding space of each spool is about 5½ in., and each spool is wound to exactly one-half the resistance marked, that is, 25 ohms in the case of the 50 ohm coil, and 15 in the case of the 30 ohm coil. These coils are connected in various ways according to the service for which they are used.

The circuit shown in Fig. 663 may be said to represent the latest practice in composite work, using both sides of the telephone line for separate telegraph circuits.

Fig. 664 shows a method of phantoming two simplex circuits. In this arrangement the telegraph current traverses both sides of the respective telephone circuits, but cannot pass from one circuit to the other because of the condensers in the phantom.

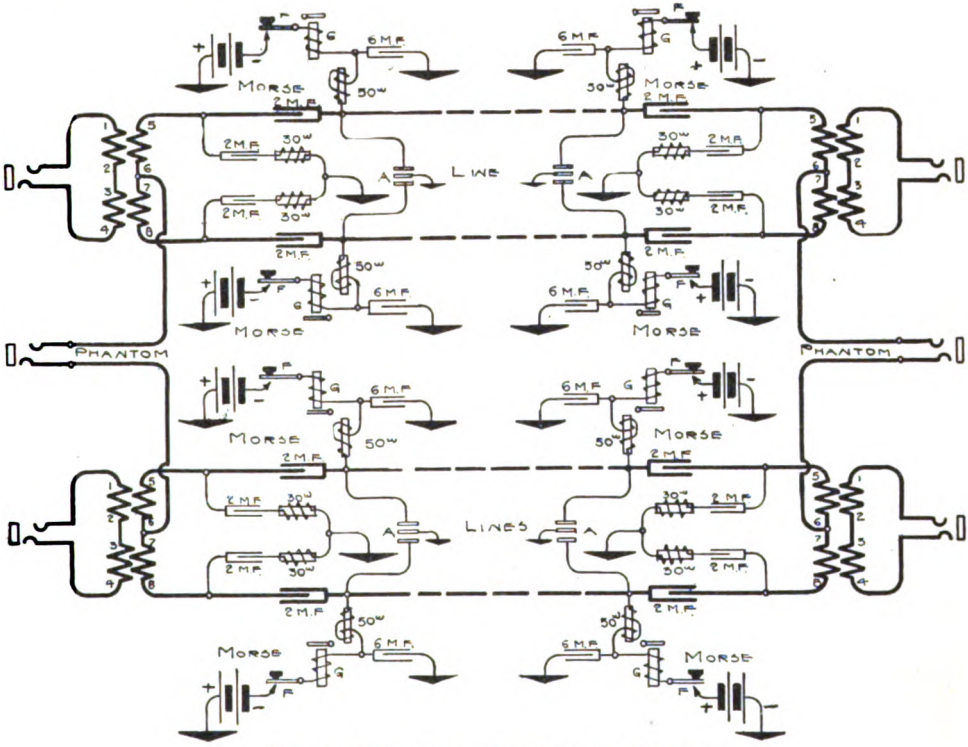
Fig. 665 is practically the same as the foregoing, except each telephone circuit carries two telegraph circuits and the phantom.

Fig. 666 shows a late type of composite circuit using a repeating coil at each end. The condensers inserted between the center terminals on the line side of the coils are of comparatively great capacity to afford a good path for ringing current. The 30 ohm retardation coils in series with each telegraph instrument add impedance to the circuit, and serve

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to smooth out the telegraph pulsations and keep them from affecting the telephone transmission.

No special composite ringing set is required with this system as the circuit is adapted to transmit the ordinary frequency generator current



PHANTOMING TWO COMPOSITE CIRCUITS

Fig. 665.

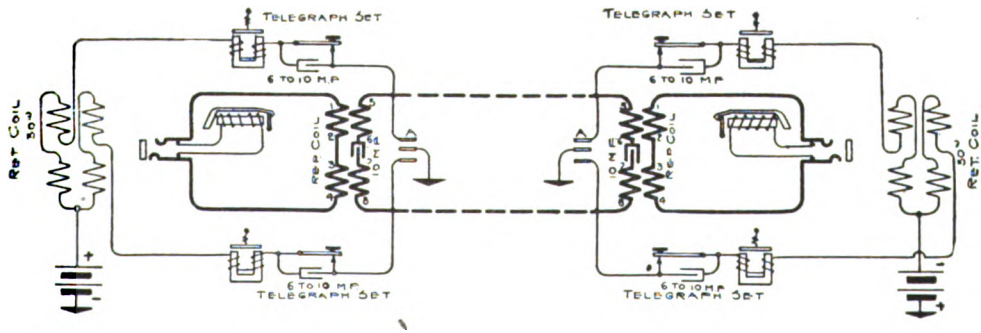


Fig. 666.

and throw the drop at the distant station without disturbing the telegraph apparatus. The telegraph circuits, instead of being tapped directly on the line wire, may be tapped between the condenser and one winding of the repeating coil, and, when so arranged, are not quite so susceptible to generator current.

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Fig. 667 shows the application of this composite circuit into a phantom simplex arrangement, thereby obtaining two telegraph and three telephone circuits from two pairs of line wires. The greatest objection to these cir-

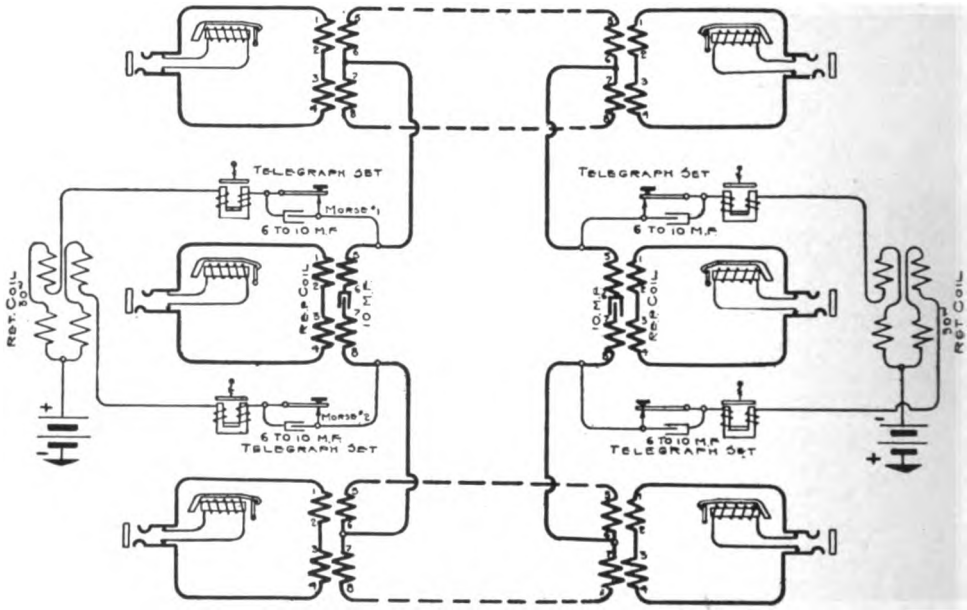


Fig. 667.

cuits, is the loss of efficiency in the telephone transmission through the repeating coils, but when some efficient coil, such as the Dean 7315 is used, excellent results are obtained.

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CHAPTER XVI.

WIRELESS TELEPHONY.

Several methods exist for transmitting speech electrically without wires, from one point to another. The longest distance over which this has been accomplished in the United States is about 80 miles. (1909)

Among the methods which have been investigated, may be mentioned the so-called "inductivity" system, utilizing the principles of electro-magnetic and electro-static induction. As this is a very simple system, requiring no very special apparatus, and as it serves to demonstrate the fact that telephoning can be done without wires, a brief description of the method of assembling a set of these instruments will be given.

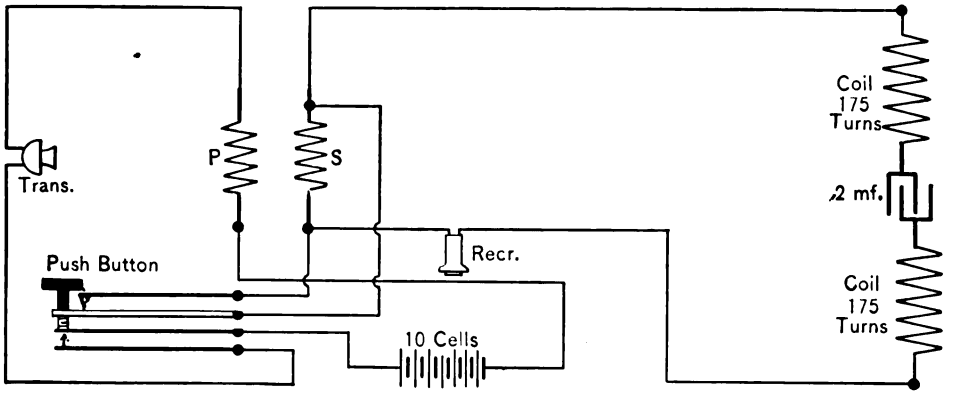


Fig. 668.

Fig. 668 shows a complete sending and receiving equipment, one of these being required for each end of the "line." Ordinary local battery transmitters and receivers are used. The induction coil may be any commercial type as used in magneto telephones, although a coil with a high wound secondary gives better results.

The hoop consists of an ordinary wooden bicycle rim. This is wound with 175 turns of No. 24 B. and S. gauge silk covered wire, a loop brought out and 175 more turns wound on. The ends of the loop are connected to an ordinary telephone condenser of one or two M. F. capacity, and the other ends of the coil to the circuit as shown. The push button is so arranged that normally the secondary winding of the coil is short circuited, the winding on the hoop being directly in series with the receiver. This is the normal or listening position of the instrument.

To talk, two of the instruments are placed from 10 to 25 feet apart. They may be in different rooms as walls or other physical obstructions have no effect on the operation. The button on one of the sets is pushed, thereby closing the battery through the transmitter and primary of the coil. This also opens the shunt around the secondary, and the current flowing in the primary induces a current in the secondary in the usual manner.

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This current flows through the hoop winding and the hoop radiates lines of force lines, which encounter the hoop winding on the receiving station. Immediately a current is induced in this winding, which affects the receiver connected thereto in the usual manner. This station may now answer back, and conversation held both ways, remembering to only press the buttons when speaking.

Larger hoops may be used to advantage, using larger wire and giving a greater range. The telephone induction coil can be omitted and the transmitter, battery, and hoop winding be connected in series. When this is done, a separate hoop with the terminals connected directly to the receiver is used for receiving, and the condenser is omitted. The former method, however, seems to be the best.

To insure satisfactory results the hoops, regardless of their distance apart, should be in a line; that is, same as if one was laid against the other and then removed without turning. They must be parallel, not at right angles. When one hoop is exactly at right angles to the other speech will be impossible, as the lines of force from the sending hoop will not cut across the receiving hoop winding.

The use of a low wound double head receiver also increases the sensibility, and various arrangements of condensers, etc., may be tried. Nothing very practical may be expected of this method, however, as it has been known and under investigation for a long time, its limitations being well known. It is, in fact, nothing more than a good method of producing "cross-talk," such as occurs on wire lines, and depends for its operation on exactly the same principles.

Another method operates by conduction, relying upon two separate grounds at each station. The stations may be placed somewhat farther apart than with the inductive system, but the range of practical operation is small.

The usual method of setting up two stations on this plan is to select a river or canal, placing the instruments on opposite sides. Each instrument is connected to two copper, or one copper and one zinc plate, which are buried in the water at the edge of the river or canal, about 25 or 30 feet apart. When the conditions are favorable conversation may be carried on, even with ordinary telephone instruments, over considerable distances. Of course the distance apart of the plates from each other, the distance apart of the instruments, the character of the soil and water, and other elements, determine the limit of distance in each case.

A peculiar variation of this system came to the writer's attention a short time ago. Two pipes were driven into the ground over two miles apart. The depth was 28 feet. Ordinary telephones were used, one wire being insulated and carried down inside the pipe and fastened. The pipes were then withdrawn, leaving the insulated wires buried in the earth, and connected to earth a distance of 28 feet from the surface. The remaining wire from each telephone was attached to a copper plate, buried in moist surface soil. It was not only possible to talk, but also to ring the telephone bells, except in very wet weather. Upon investigation it was found that the wires buried in the earth connected to a strata of soil that was insulated from the top soil by a strata of sand and clay, so this was practically a wire line, the lower strata forming one side of the circuit, and the top soil the other. In some locations this might be taken advantage of, and would prove satisfactory for short line work of an experimental character. Nothing commercial has been produced of the conductivity type.

No methods of signalling have been described for these systems, as no special methods have been developed, the usual methods employed in

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wireless telegraphy being employed. A filing coherer, adapted to close a local relay circuit and ring an ordinary battery bell, may be used with the inductivity set just described. The feature of selectivity has not been solved as yet, at least no practical system has been disclosed to the public, and, from the nature of the voice currents, even if selective signalling is accomplished, selective telephonic communication will be hard to accomplish, owing to the inherent difficulties of dealing with voice currents of many frequencies, which eliminates most of the methods now used in wireless telegraphy.

The only systems that have received serious consideration as being of practical use, are those depending for their operation upon sustained electric oscillations. The system invented by A. Frederic Collins, is perhaps the best known, and may be said to represent the most advanced state of the art. The following data descriptive of the development of this system to its present state will be of interest as outlining the methods and equipment which may some day supplant the wire telephone.

"Up to the present time every known wireless telegraph system has been utilizing damped electric oscillations. It was not until lately that some of our greatest scientists and inventors have expressed their belief that by such means the greatest drawback that we have to contend with, that is, imperfect tuning, will never be eliminated and perfect tuning will only be possible by using undamped or persistent electric oscillations."

"Since the possibility of the wireless telephone depends entirely upon the production of such oscillations and suitable means for varying them, we may predict that in the near future the wireless telephone will not only progress far ahead of the wireless telegraph, but take its place. For it can be used either for wireless telegraphy or wireless telephony. It also does away with the spark."

"There are a number of different ways of producing electric oscillations, the best known being an induction coil or transformer, and the one that is about the least known being an ordinary arc lamp, energized by a direct current. The difference between the two being that in the former they are damped and in the latter they are undamped or continuous."

"Undamped or persistent oscillations are high frequency alternating currents, just as are the alternating currents used for electric lighting and the transmission of power, the only difference being that the frequency of one is anywhere from 1,000 to 100,000 times greater than the other."

"There are several methods used for producing such currents. One is by the use of the high frequency alternator, the invention of which dates back to 1899, when arc lighting by alternating currents became popular, the sound of which they tried to eliminate by increasing the frequency."

"Nikola Tesla constructed a machine which consisted of a fixed ring-shaped field magnet with polar projections inwards, and a rotating armature in the form of a fly wheel. The magnet had 400 radial poles in the circumference and 400 coils on the armature. When driven at a speed of 3,000 revolutions per minute or 50 per second, it produced an alternating current of 10,000 cycles. The output of this was limited to a small amount of energy, probably not more than ½ kilowatt. It was dangerous, however, to run such a machine."

"The Westinghouse Co. has built for Mr. G. B. Famme an alternator having a 2-kilowatt capacity at a frequency of 10,000. It is of an induction type and has 200 polar projections."

"In all these machines it is customary to make the field magnet the revolving part, the armature being stationary."

"Duddell succeeded in building a machine of the induction type which,

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at a speed of 30,000 revolutions per minute, gave a current of one ampere and a frequency of 15,000 per second at 40 volts."

"There is claimed to be built a machine possible to create an alternating current having a frequency of 100,000, when the disc is driven at a speed of 600 revolutions per second, the output being only 0.1 of an ampere at 2 volts."

"R. A. Fessenden claims to have constructed a machine with a frequency of 60,000, with an output of not more than 200 watts, at a speed of 10,000 revolutions per minute. Although this machine was sufficient for experimental purposes, it was far from being practical for wireless, the output being too small and the machine being too dangerous to run."

"It is said, on one occasion, while one of these machines was going at its normal speed that a magnet flew from the field clear through a two-foot brick wall and 250 feet out into the field. The efficiency being very low, the machine dangerous, and the output small, tend to make the high frequency alternator very impractical and useless at its present stage."

"From the experience so far received by the scientific world, we may conclude: First, that an attempt to run alternators at high speeds, say above 5,000 revolutions per minute, involves the loss of considerable energy due to air friction and churning, hence it cannot have a high efficiency; second, that the size of the armature and its peripheral velocity has its practical limitations; third, in using an induction type of motor, it labors under the disadvantage that an attempt to take a current out of the machine generally results in a large drop in the terminal potential difference. It is, therefore, exceedingly hard to combine in one alternator the properties of high frequency, high power and a large power output. Such machines are not as yet commercial articles, hence the alternating method of producing undamped oscillations has up to the present only come into limited use, although there is a possibility of its being improved."

"The Arc Method of Producing Undamped Oscillations: Up to the time Duddell described his singing arc, many inventors struggled to combine an arc lamp with a capacity and inductance for producing oscillations, but met with little success. As early as 1840 Grove describes an arc lamp burning in hydrogen and its effects. In 1875 de La Rue and Hugo Miller used an arc in hydrogen in experimenting on some vacuum tubes, and in 1892 Elihu Thompson patented the following method for transforming an alternating current in an alternator:"

"In Fig. 671, G is a direct current generator in the same circuit with a very high inductance R, a spark gap, and two metal balls S. These balls are connected in another circuit, consisting of a condenser C and an inductance L in series. When the spark balls are brought in contact, a current is drawn through the inductance L. If the balls are separated, the condenser will become charged by the difference of potential created, and when fully charged it discharges across the gap. With this apparatus Thompson was able to produce periodic oscillations having a frequency of 30,000 per second. It has been claimed that these oscillations were continuous, but Messrs. Collins, Kennelley and Bell have shown conclusively by photographing the spark in a rotating mirror that these oscillations were strongly damped and periodic."

"About the same time Firth and Rodgers gave out the statement that the current through an arc was oscillating and that they had succeeded in converting 3 per cent. of the continuous current into an oscillating one. This was the first recorded production of continuous oscillations."

"It was not until Duddell made his discovery in 1900 that the matter was seriously thought of. He described some of his observations made

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before the London Institute of Electric Engineers on the solid carbon arc lamp, having a capacity and inductance shunted across it, showing its oscillating nature. In his circuit he used a direct current generator of 3.5 amperes and a potential difference of 42 volts. Around the arc he shunted a capacity of about 3 microfarads in series with an inductance of 5 millihenries. Under such conditions the arc gave out a musical tone, the pitch of which depended upon the capacity and inductance. An important factor must be taken into consideration in the Duddell arc. The inductance in the direct current circuit must have a high resistance and inductance as compared with the resistance or inductance in the oscillating circuit. If we draw the characteristic curve of a D. C. arc, we will find that it does not quite agree with Ohm's law; that is, it is not a straight line as the case would be with a metallic conducting circuit."

"If we take observations with a voltmeter and ammeter on a solid carbon direct current arc, for various constants of the arc, using the potential difference in volts as the ordinate, and the current in amperes as abscissa, we will find a curve that is concave upward and as the current increases it slopes downward; it is therefore a curve that slopes in the

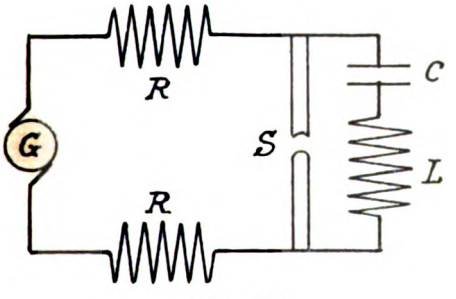


Fig. 669.

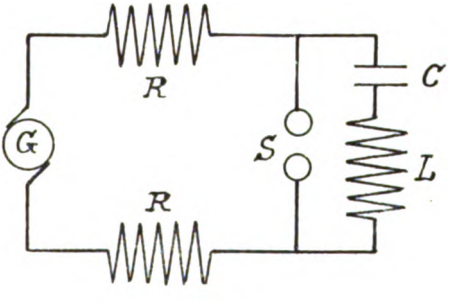


Fig. 671.

opposite direction to the curves that obey Ohm's law. All this phenomena has been investigated by Messrs. Ayrton, Upson, Collins and others, and the conclusion is that in all cases, whether between carbon and carbon, or carbon and metal, or these with gases, the curves slope downward, showing that as we increase the current through the arc the potential difference decreases."

"The action of the capacity and inductance on the arc may be as follows:"

"In shunting the capacity C and inductance L across an arc (see Fig. 669) that is burning steadily, the capacity instantly takes upon itself a charge and the current through the arcs is at the same time diminished; the potential difference therefore increases across the arc and this tends further to charge the condenser. The condenser reacts on the arc and still further increases its current, which in turn lowers the potential difference."

"Since it discharges through an inductance L, it not only fully discharges but becomes charged in the opposite direction, just as a pendulum, when pulled to one side and let go, will not only go back to its original position, but go far beyond it in the opposite direction."

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"When in this condition, it is ready to repeat the operation with more vigor than before, and so persistent and undamped oscillations are set up by the condenser charging and discharging."

"Suppose in swinging the pendulum, we apply enough force on each swing to make up for the friction and other losses and make it come back to the same position every time. This can be accomplished only when we apply the force just about the time it starts to swing in the opposite direction, since it has its own time period of oscillation, depending upon the length. Now, if we should strike it before it starts to swing back, we will have two forces in the opposite direction applied to the same points and they will have a tendency to neutralize each other."

"The same applies to the oscillating circuit. If the capacity and inductance, each having its own natural time period of oscillation (into which part of the direct current is converted), are not in resonance, that is, if the capacity does not fit the inductance, we will have very weak oscillations, one counteracting the other."

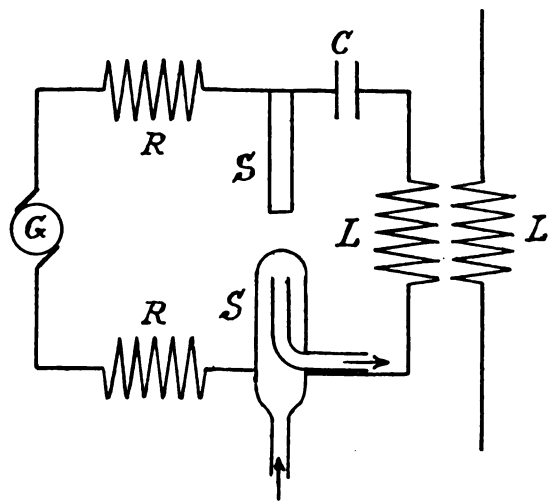


Fig. 670.

"*Poulson's Improvements:* In 1903 the Danish physicist, Poulson, formed an arc between a water cooled metallic electrode S and a solid carbon Sl (Fig. 670), the chief improvement being, however, the fact that he burned his arc in hydrogen as Grove did in 1840. He employed Grove's scheme of burning the arc in hydrogen. With this arrangement he succeeded in obtaining much more forceful oscillations than were heretofore known. The frequency varied from 500,000 to 1,000,000 cycles. When the machine was operated, a great amount of heat was evolved, and although the water cooled the copper rod to some extent, one may readily understand how inconvenient such an arrangement is. However, the advantages gained by the fact that undamped oscillations were obtained, which, as stated in the beginning makes tuning possible, induced him to proceed at once and apply his machine to the practice of wireless telegraphy."

"Now in summing up the work done with the arc, H. Simon and Fleming came to the conclusion that in order to obtain strong undamped oscillations one must have an artificially cooled electrode, and this, I think,

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as been solved by A. Frederick Collins. Since 1900 he has been working n the combination of an arc lamp and transmitter for wireless telephonic ork, thus being practically ahead of all other physicists."

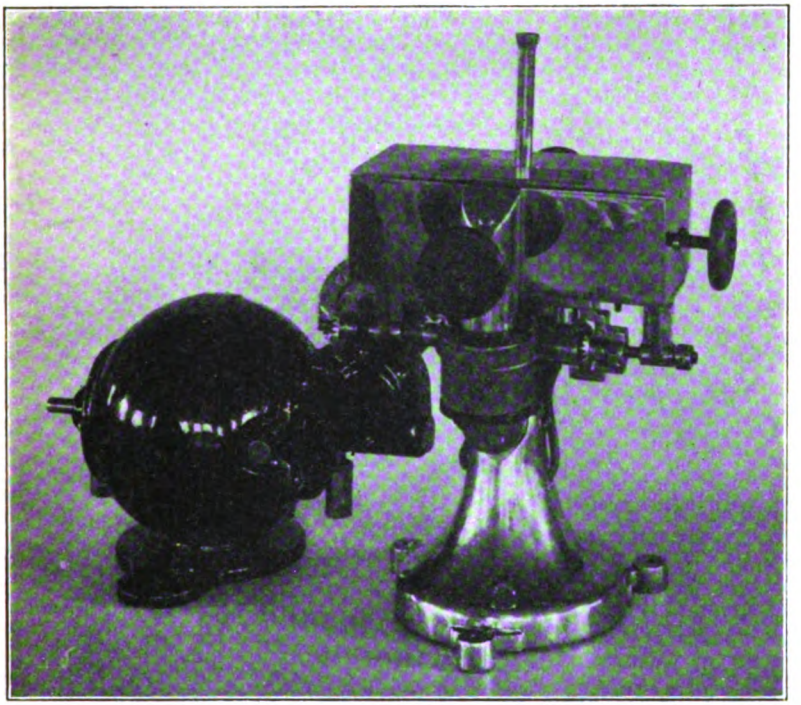


Fig. 672.

"At the time Duddell conceived of the musical arc(he had no idea of ts being used in connection with a transmitter for wireless telephony. A escription of this was given in the Scientific American, 1902, showing hat he was the first scientist to apply an arc lamp for wireless telephony.

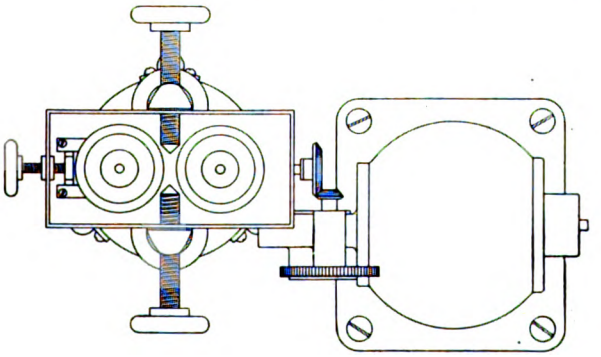


Fig. 673.

he publication of Poulson's experiments, showing that the cooling of the rc lamp electrodes was the cause of powerful oscillations, led Mr. Collins o deeply investigate and evolve a system of wireless telephony."

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"In the Poulson method of producing oscillations, if the arc was l
burning for some time, the machine and its parts would gradually heat u
and the water in the tank would become warm. It is not safe to conn
the water cooled electrode to a water pipe, since this would ground t
machine and interfere with its operation. The question of cooling w
therefore an important one, as pointed out before. Mr. Collins then pr
duced his revolving arc lamp, in which the electrodes were revolved
a small motor or clockwork. This at once eliminated all troubles due
heating, also to getting rid of a large amount of energy dissipated
heat."

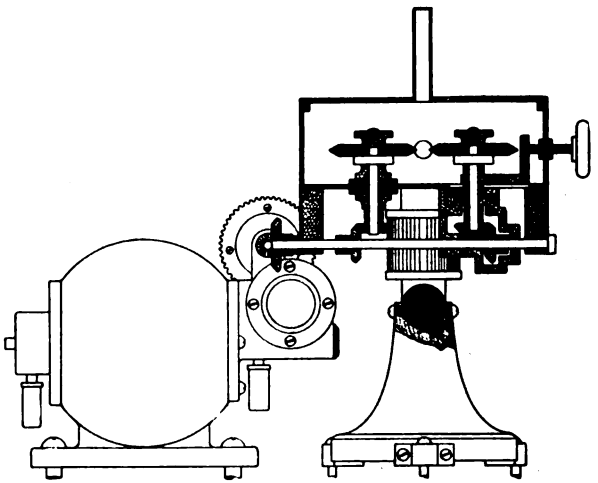


Fig. 674.

"The first application of the direct current arc to wireless telephon
was made by Collins in 1902, and since that time he has devised many
form of arc lamp for the production of sustained oscillations, one of whic
is shown photographically in Fig. 672, top view Fig. 673, and in cro
section in Fig. 674."

"Collins has ascertained that a greater percentage of direct current
converted into high frequency oscillations, providing carbons are used, an
one or both are kept at a low temperature. In order to accomplish this i
practice, he employs a pair of carbon or graphite disks as the anode an
the cathode. These disks are mounted on parallel spindles so that the
are in the same plane and are connected by means of beveled gears to a
insulated shaft."

"The disks are insulated from each other by fiber bushings inserte
in the gearings, the casing forming one of the connections, while the in
sulated bearing in the bottom of the casing forms the other. The gearin
is so arranged that carbon disks are rotated in opposite directions, th
power being furnished by a ⅛ horse-power motor. One of the bearings i
the shaft is mounted in a keyed sleeve which permits the spindle carryin
one of the disks to be moved toward or away from the opposite disk so tha
the length of the arc can be varied while the lamp is in operation. Th
carbon electrodes are placed in a metal casing while the rotatin
mechanism is attached to the bottom casing."

"The casing is supported between the poles of an electro-magnet an
through the ends of the poles and at right angles to them, are polar roc
of soft iron which are threaded. These are screwed through the extrem

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ties of the magnet and at right angles to the arc. The ends terminating in the casing are pointed, while those projecting outside have disks of hard rubber so that they may be adjusted in positions to the arc. The magnet coils are placed in each of the leads of the supply circuit, and serve as well to choke back the oscillations from reaching the generator. The casing is supported between the poles of the magnet, and the magnet in turn is held in position by an iron base."

"The magnets provide a strong magnetic field in which the arc burns and so increases the resistance between the carbons and hence raises the voltage. The adjustable poles of the magnet are used primarily to blow

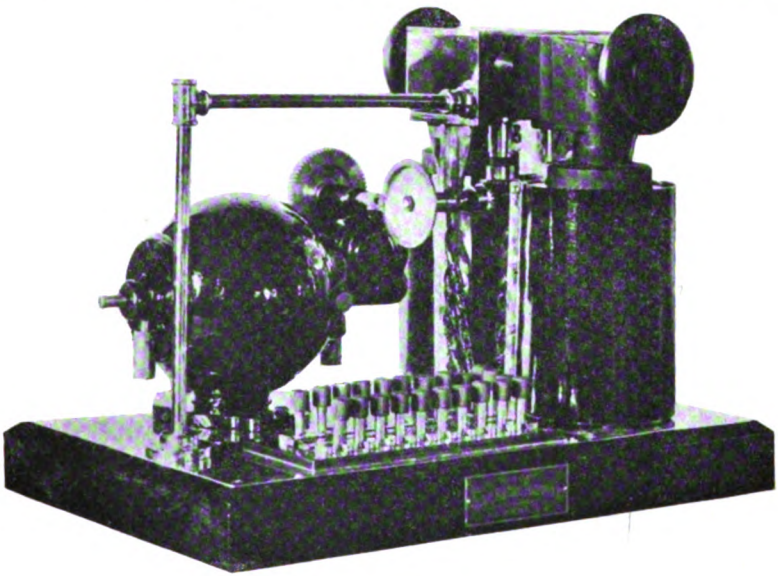


Fig. 675.

back and keep the arc between the carbons where the distance is shortest. Were this not done, the arc would follow the revolving carbons until broken. The arc has been burned in different gases, under pressure and in vacuum. An improved form of this type lamp is shown in Fig. 675."

"The complete apparatus for producing continuous undamped oscillations, shown at the Seattle World's Fair and which took the highest award, gold medal, for wireless 'phones, was the most powerful yet constructed, and it comprised a Collins revolving oscillation arc, photographically shown in Fig. 675, a specially designed high frequency and high potential variable inductance tuning transformer, Fig. 676, an adjustable inductance tuning auto transformer, Fig. 677, and a revolving variable condenser, Fig. 678.

"The oscillation arc lamp is an improved form of the type described. Among the more salient features were extremely powerful electromagnets, the strength of which can be adjusted by means of a plug cut-out system, and this permits the highest initial voltages to be used. These magnet coils also used as a portion of the primary circuit of the transmitter when they served the admirable purpose of choke coils for preventing the oscillations from backing into the high tension direct current generator."

"A small ⅛ horse-power motor geared down to the proper speed is used to rotate the disk electrodes in the magnetic field, thus making it

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possible to obtain much stronger oscillations than has heretofore been possible."

"The chief improvement in the combination tuning inductance transformer was that a new and novel means of contact was introduced by which any degree of variation can be had and in telephony this is a vital point. The contact was made by a ring provided with three small grooved pulleys and which fitted to and pressed against the wire of the primary."

"Having a spiral form, this coil caused the ring, when it was rotated, to travel back and forth from end to end. A small track under the coil served to guide a small carriage which in turn made contact with the ring. With this arrangement the inductance can be varied, thus making

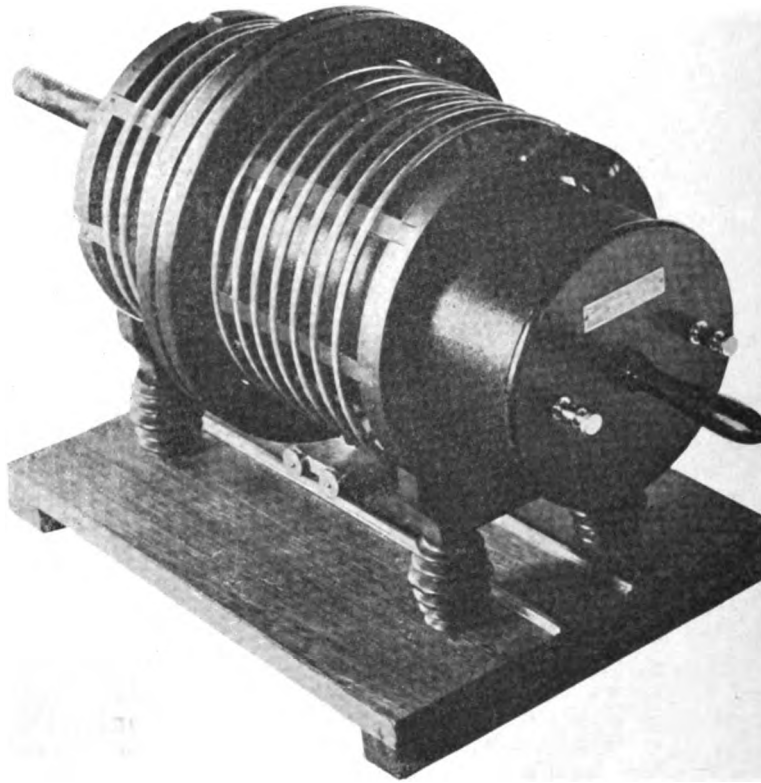


Fig. 676.

it easy to put the closed oscillating circuit in resonance with the open radiating circuit. The secondary was arranged to slide in or out of the primary and making a loose coupling, which is another essential in the production of high frequency undamped oscillations."

"The adjustable inductance tuning auto transformer designed to be used in series with the aerial is of the most perfect construction and more or less inductance may be had by turning the wheel which causes the contact spring to travel back or forth."

"The variable condenser consisted of a number of semi-circular fixed plates of metal and built up in a cylinder of insulating oil while a second series of movable plates secured to a spindle meshed with the first set but was insulated from it. A handle attached to the rod permitted any varia-

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tion of capacity within the limits of the condenser to be obtained. A scale divided into fractions of a microfarad and a pointer indicates the value of capacity at any point."

"The condenser joined in series with the primary of the tuning inductance transformer and the rotating arc constitutes a closed oscillating circuit and when the transmitter is set in operation by properly adjusting

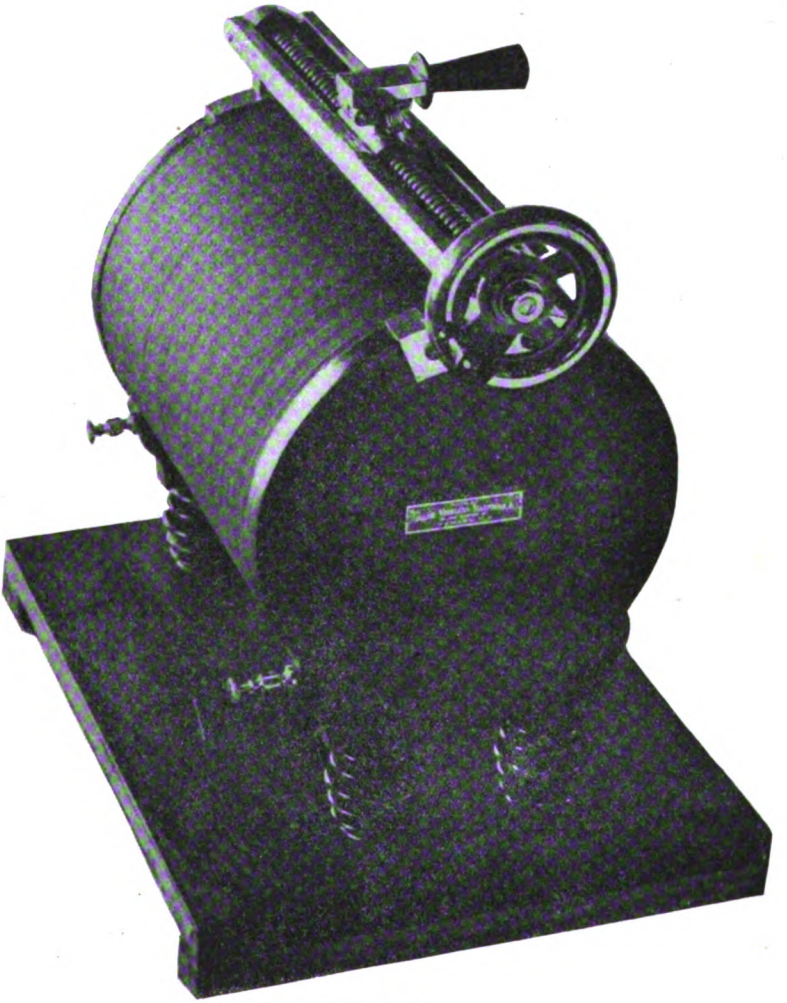


Fig. 677.

the valves of inductance, capacity, and resistance, a high frequency current can be run up to 12 or even 15 amperes, and from 100,000 to 1,000,000 cycles can be had."

"In experimenting with this arc with different gases, Collins has discovered that certain conditions existed in the arc chamber heretofore unknown, one being that certain gases under certain conditions do not burn continuously but explode with a very great rapidity. It was on one occasion when using this gas in connection with the arc that undamped

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oscillations were obtained in the aerial system which indicated two times as much current on a hot wire ammeter than was previously obtained."

"The rotating oscillation arc eliminates the disadvantageous features of the stationary arc in that a constantly fresh and cool surface is presented to the arc, and in that it prevents the burning away of the electrodes which gives rise to untoward variations in the frequency of the oscillations, and finally in that the optumum length of the arc, namely, at the length when the frequency of the oscillations is the greatest, may be maintained for long periods of time, which is quite impossible when the carbons are stationary."

"Across this arc is connected an oscillation circuit having a variable condenser (see Fig. 678) consisting of metal plates placed above one another in a large tank of insulating white paraffin oil. One set of plates

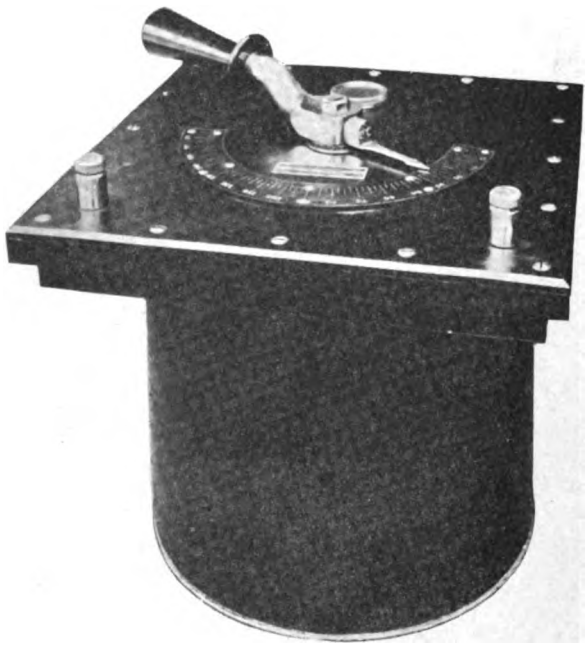


Fig. 678.

is fixed on a shaft so that it can be revolved and brought between the other set, so that any variation of capacity can be obtained. It is upon this condenser that free oscillations of considerable force, so to speak, depend. The variable inductance included in this circuit is a single helix of bare wire, which can also be varied so that any combination of inductance and capacity can be obtained. There is, however, one important point to bear in mind, and that is the capacity must be of a small value as compared with the inductance and adjusted so that a frequency may be obtained anywhere from 100,000 to 1,000,000 cycles per second."

"In one test made by Mr. Collins between Newark and Philadelphia, a distance of ninety miles, described in the Scientific American of 1908, a revolving arc lamp energized by a current of 8 amperes at 500 volts was set in operation in connection with a resonance tube used for tuning. This consists of an exhausted glass tube 13 inches in length and 1¾ inches in diameter. Sealed in the ends are platinum wires 1/16 inch in diameter, and these extend longitudinally through the center of the tube until the

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ends almost touch each other. The outside terminals are connected in shunt with the induction coil. Now, when the first feeble oscillations begin to surge in the closed circuit, one or the other will glow, or both of the free ends of the enclosed wires will glow, depending upon the oscillatory nature of the current. As the current strength of the oscillations increases, the glow light extends farther and farther toward the ends of the tube, always keeping close to the oppositely disposed wires."

"The length of the glow on the wires is proportioned to the current strength, and thus the tube may also be used as a measuring apparatus instead of the milliammeter usually employed. The characteristics of the oscillations can also be easily observed; for if they are positive the light

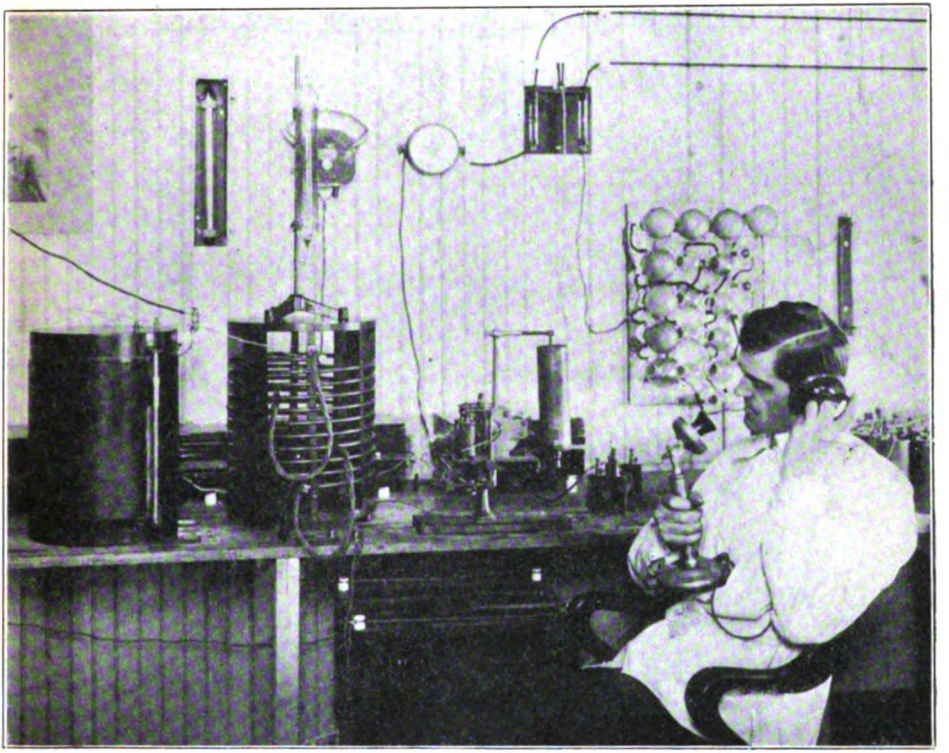


Fig. 679.

will appear almost entirely on the end of one of the wires, and if the current is reversed, on the opposite end; while if the current is oscillating with equal electromotive forces, the light will have the same degree of intensity on both wires. By means of a revolving mirror the oscillations may be segregated, and it is then easy to see whether they are periodic or continuous, and if the latter, to analyze the wave form of the spoken words."

"Upon the Land Title Building, Philadelphia, Pa., were raised three kites in tandem to which the aerial was connected. The aerial at Newark consisted of 1,500 feet of phosphor bronze wire. By means of a reel at Philadelphia, about the same length of aluminum wire was let out, which made the tuning of both instruments quite easy. Fig. 679 shows Mr.

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Collins at the time talking to Philadelphia, where the speech was received quite audibly and clearly."

"Although very good results were obtained by him a short time previous between his Newark laboratory and the Singer Building, New York, a distance of 9 miles, and between Newark and Rockland Lake, a distance of about 40 miles, the Philadelphia test was the greatest distance ever made on this side of the Atlantic Ocean. Fig. 680 shows a wiring diagram of the apparatus."

"Controlling the Waves by Means of a Telephone Transmitter: Many different combinations and arrangements have been tried in connecting

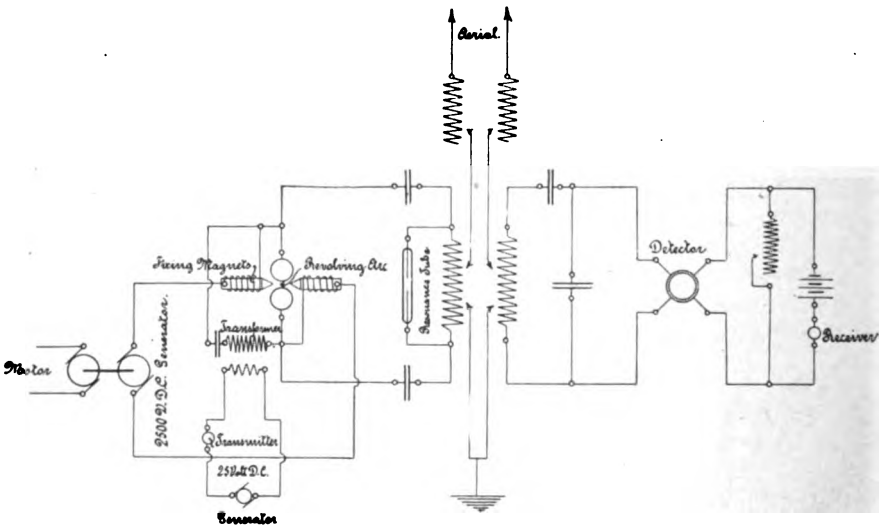


Fig. 680.

up the transmitter with the oscillating circuit, but in all the experiments with the wireless telephone, it has been found most practical, in fact, the only possible way to get good results, to work the transmitter on an independent circuit of its own and connect that inductively to the arc, or superimpose it upon the direct current supplied to the arc."

"Many experimenters claim results with the transmitter connected to the ground circuit. Upon experiment, this will be found to be almost impossible, as the high frequency oscillations of three or four amperes would arc the carbon and burn it out."

"In the last distance tests made, the terminals of a small transformer coil were shunted across the arc, but a condenser of a large capacity is interposed to check the high voltage direct current from flowing through it. The primary of the transformer was connected in series with a 25-volt generator and a telephone transmitter, as shown in the wiring diagram. Now, when the arc is set in operation, a slight change in its resistance would vary the oscillating circuit and hence change the amplitude of the waves sent out. Upon speaking into the transmitter, the current through the primary of the transformer produces an alternating current at the ends of the secondary circuit on the direct current of the arc, and changes its resistance, which in turn varies the oscillating circuit."

"The amplitude of the electric waves changes in the same manner, and is proportional to the change of air pressure against the diaphragm

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and the current through the transmitter. The transmitter may also be inductively connected to the inductance or to some plates of the condenser."

"*Marjorana's Liquid Transmitter:* Marjorana has been using the intermittent discharge of a condenser by increasing its rapidity and he has produced discharges at the rate of 10,000 per second; these discharges in turn consist of a train of oscillations. This he has done by the use of

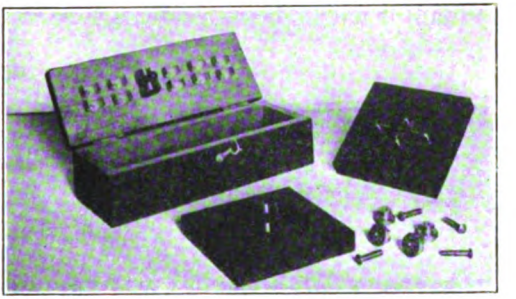


Fig. 681.

a very short spark gap, a high inductance in series with the electromotive force and large impressed voltage. In his transmitter he utilizes the action of a liquid flowing from a tube, which is sensitive to sound vibrations."

"A fine stream of liquid flows out at one end, and, when there is no sound, a straight and unbroken column of water passes between two conductors to which the instruments are connected. When a sound is made, the water column is found to contract in certain places which forms a

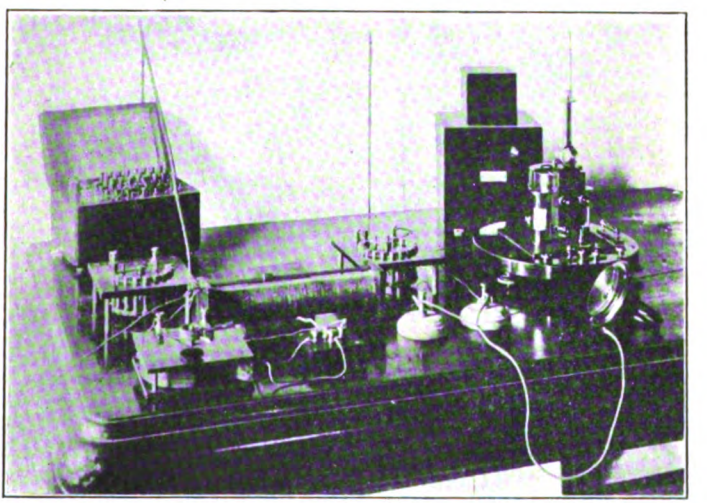


Fig. 682.

wavy column. Contact is made by the liquid between the two terminals and when the liquid flows unevenly, we have a varying resistance between the two terminals."

"*Receiving Instruments:* The receiving instruments used for wireless telephony contain certain forms of detectors, as all wireless telegraph receivers are not suitable for wireless telephony. For example, detectors

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of the coherer or imperfect contact type will only detect oscillations, but do not indicate changes in their amplitude."

"Three forms of detectors have been used with much success, viz.: The thermo-electric, electrolytic, and the ionized gas detector. Of these the first seemed to work about the best, as a form has been devised by Mr. Collins which eliminates all troubles of adjusting after once placed in position. It is different from all other detectors previously invented, and the principle upon which it works is as follows: Two exceedingly fine wires of different metals, crossing at right angles, are made into a thermo-couple and so constructed that the conduction losses are far greater than the radiation losses. Another wire made of a very high special resistance material, and which is heated by the received oscillation surging in it, is mounted on a movable block just underneath the couple and its distance from it can be regulated (see Fig. 681). When the received oscillations pass through this wire of a very high specific resistance, it heats up, which in turn acts upon the thermo-couple, the resulting electromotive force effecting a very sensitive receiver and producing the voice."

"An improvement upon this detector was recently made by making use of the wire which is heated up by oscillations, as one of the metals of the thermo-couple. This detector is shown in a photograph of the receiving set used by Mr. Collins in telephoning 81 miles between Newark and Philadelphia. Fig. 682 is a photograph of the complete receiving outfit.

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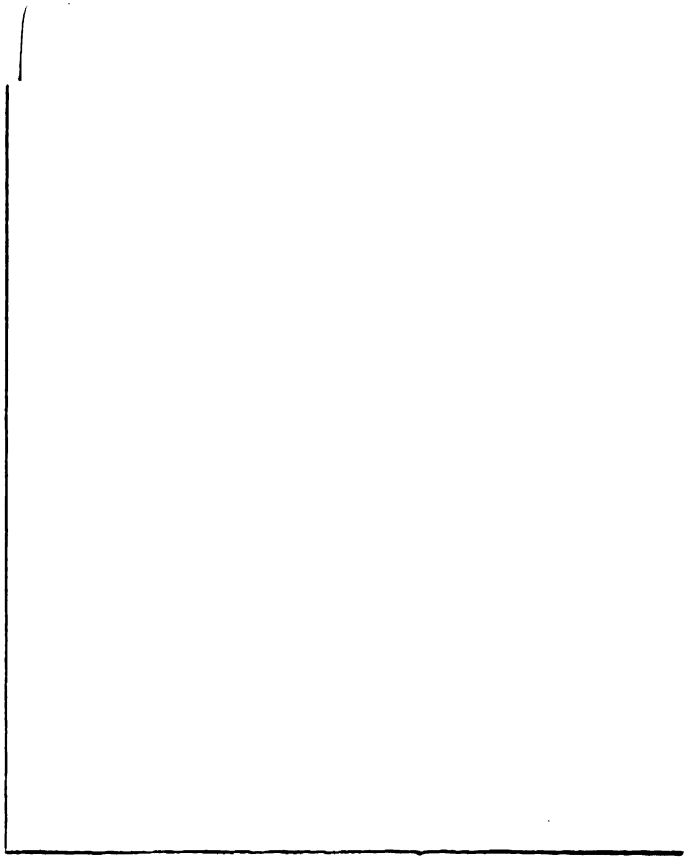
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