P. R. R.

UTILITY OF WIRES.

PENNSYLVANIA RAILROAD COMPANY.

NORTHERN CENTRAL RAILWAY COMPANY.
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY.
WEST JERSEY & SEASHORE RAILROAD COMPANY.

Telegraph and Telephone Department.

UTILITY OF WIRES.

OFFICE SUPERINTENDENT OF TELEGRAPH.

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PREFACE.

In recent years many ways of utilizing wires for telegraphing and telephoning simultaneously have been perfected, and, while a number of these systems have, at different times, and at more or less length, been described in periodicals, we are not aware that even a majority of them have been fully described in any one book. Believing that such a book would be of value, the attempt has been made, in this work, to supply a comprehensive account of the systems considered of practical use in railroad work. The subject has been treated from a practical standpoint, and the use of technical terms avoided as much as possible. To explain all the electrical laws would require several volumes, and, as there are many electrical books on the market that give these laws in detail, we have intentionally omitted them.

CONTENTS.

INTRODUCTION.

Electricity is used in telegraphy and telephony either as direct currents or alternating currents, often abbreviated as D. C. and A. C.

Direct currents are those that flow always in the same direction. Of these we may have several varieties:

First.—If the strength of the current remains constant, the current is called steady.

Second.—If the current's strength varies, becoming now weaker and now stronger, but at no time absolutely stopping, we have a variable D. C.

Third.—If the current stops and starts again continually, we have a pulsating current. This is sometimes called intermittent in telegraph use.

An alternating current is one which flows alternately in opposite directions. One forward and one backward rush of current taken together are called a cycle, and the number of such cycles in one second is called the frequency of the alternating current.

Resistance and impedance.

If a long, straight wire has sent through it first, a steady current and then an alternating current, both currents will encounter the same resistance; but if the wire be coiled into a helix of many turns and an iron core be placed inside the helix, this is no longer true. While the steady current encounters the same resistance, the alternating current is much more impeded. The reason for this is found in the fact that the alternating current must continually make and destroy the magnetism of the iron core at the expense of its own energy, a burden from which the steady current is free. Such a coil is said to offer resistance to steady currents and impedance to alternating currents. Both quantities are measured in ohms. The impedance includes the resistance as a part of itself. The rest is due to what is called the inductance of the coil, a quantity which depends in a complicated manner on the frequency of the alternating current, the number of turns in the helix, and the amount of iron it contains. A coil wound thus is said to possess inductive resistance, or to be wound inductively.

It is possible to wind a coil so as to offer the same resistance to all kinds of currents. Fig. 1 illustrates this.

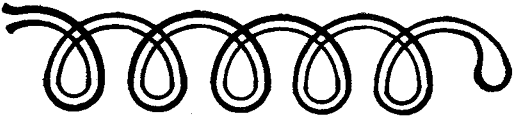

Figure 1.
Non-inductive Winding.

A long wire is doubled at the centre and the coil wound with the doubled wire. A current in such a coil has no magnetizing power. A coil so wound is said to be wound non-inductively, or to possess no inductance.

Induction coil. Let two long, straight wires be stretched side by side, as in Fig. 2, and the ends of wire B be connected to a suitable current detector.

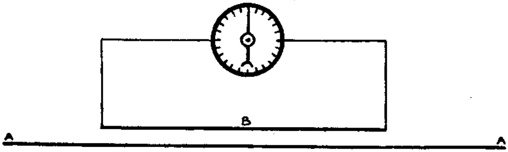

Figure 2.
Production of a Current by Induction.

If, now, either a pulsating, variable or alternating current be sent through A, an alternating current will flow through B and show itself in the detector. This is the simplest example of the production of a current by induction.

The circuit A is called the primary, and the circuit B the secondary. A steady current in the primary will produce no current whatever in the secondary. The inductive effect of A upon B may be much increased by coiling both wires into spirals, placing one within the other and inserting an iron core in the centre as in Fig. 3.

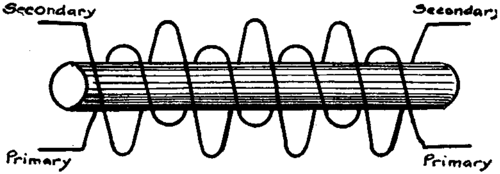

Figure 3.
Induction Coil.

Such an arrangement is called an induction coil. Several varieties of induction coils may be mentioned: The transformer, which has usually a continuous ring-shaped iron core upon which primary and secondary coils are wound, sometimes on opposite sides of the ring. The transformer is used for

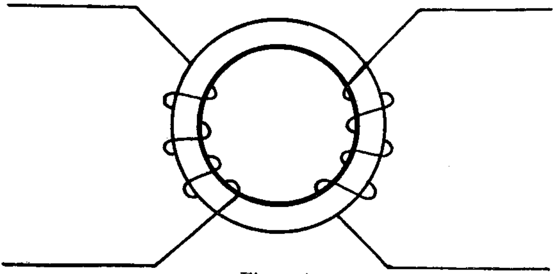

Figure 4.
Transformer.

changing the voltage of an alternating current. An alternating current supplied to the primary coil will induce an alternating current in the secondary coil with a voltage greater or less than that of the inducing current, according as the number of turns of wire in the secondary coil is greater or less than that in the primary coil. When the voltage is increased by the transformer it is called a step-up transformer, and in the reverse case a step-down transformer. The repeating coil used in telephone work is merely a small transformer.

Induction coils with closed or ring-shaped cores have a greater inductive effect than those with open cores or straight cores, but introduce also more impedance into the circuit.

An induction coil or transformer is usually represented in diagrams as in Fig. 5.

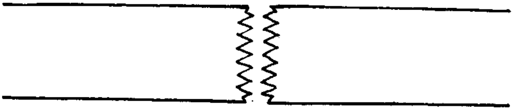

Figure 5.
Theoretical Diagram of Induction Coil or Transformer.

To form a retardation coil, a wire is doubled and wound non-inductively upon an iron core, allowing the doubled end to extend some distance from the winding. Retardation coil.

The doubled end is then cut. We then have the arrangement shown in Fig. 6,

Figure 6.
Retardation Coil.

where A_1 and A_2 are the ends of the same wire.

A_2 is then joined to B_1 at C, and another wire D fastened to the joint, giving the arrangement of Fig. 7.

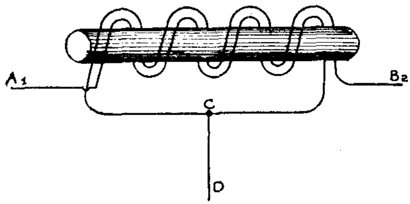

Figure 7.
Retardation Coil with Ends of Wire Joined.

A study of Fig. 7 will reveal the following facts: A current entering by C will divide itself equally and flow in opposite directions, and therefore non-inductively, around the core, leaving in equal strength by A_1 and B_2. Such a current will encounter only the resistance of the coil.

A current entering by A_1 will traverse the helix and reach the point C. Here it would normally divide; but if the resistance of the line D is very great compared with the resistance of the coil, but little current will flow along D, the greater part re-entering the helix and traversing it in the same direction as before, and leaving by B_2. Such a current would have a magnetizing effect on the coil, and if it be alternating will encounter the impedance of the coil.

Resistance of divided circuits.

If a portion of a telegraph wire be cut out and replaced by wire of greater thickness, it is obvious that the total resistance of the line will be decreased. The same effect may be obtained by using, instead of one thick wire, two thinner wires whose cross-sectional areas together make up that of the thick wire. If, now, one of these wires be removed, leaving the other, the current, because it encounters a thinner path, meets a greater resistance. This is equivalent to the statement that the joint resistance of a divided portion of a circuit is less than that of either of the wires composing it. This is analogous to the fact that the exit of an audience from a theatre is made easier by opening several doors instead of one.

We may have a divided circuit of two, three, or any number of branches. When all of the branches are of equal resistance the joint resistance may be found by dividing the resistance of one branch by the number of branches. For instance: In Fig. 8, if we were to replace the two wires of 100 ohms each that join A and B by one wire of 50 ohms, the current in the main line would be unaltered.

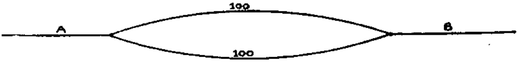

Figure 8.
Resistance of Divided Circuit.

Divided circuits of as many as four equal branches occur in what are called phantom-simplex lines, and by the above rule the joint resistance of the four-fold line will be one-fourth that of the single wire.

Divided circuits, in consequence of their low resistance, require less voltage to maintain and give current in them than is required for a single wire.

A few examples will make this clear. In Fig. 9 let A and B be two telegraph

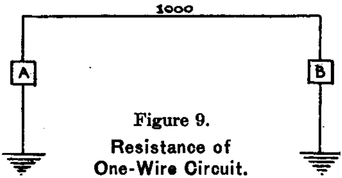

Figure 9.
Resistance of
One-Wire Circuit.

offices separated by a grounded line of 1000 ohms resistance. Suppose that a current of 0.07 of an ampere is required to work the instruments. The necessary voltage may be found by multiplying the current by the resistance, or in symbols

$$E = C \times R$$

In this case $E = 0.07 \times 1000 = 70$ volts.

Suppose, now, that two wires of 1000 ohms each connect the two stations as in Fig. 10, forming (be it carefully noted)

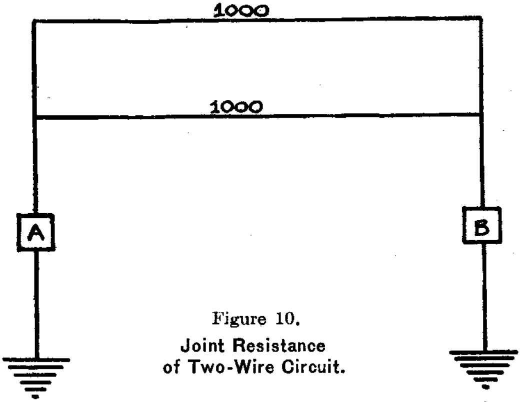

Figure 10.
Joint Resistance of Two-Wire Circuit.

not a metallic circuit, in which each wire would carry a current in the opposite direction, but a divided circuit, where each wire carries a current in the same direction. The joint or equivalent resistance of the double line is, now,

$$\frac{1000}{2} = 500 \text{ ohms}$$

and the necessary voltage to send a current through either instrument 0.07 of an ampere in strength is

$$E = 0.07 \times 500 = 35 \text{ volts.}$$

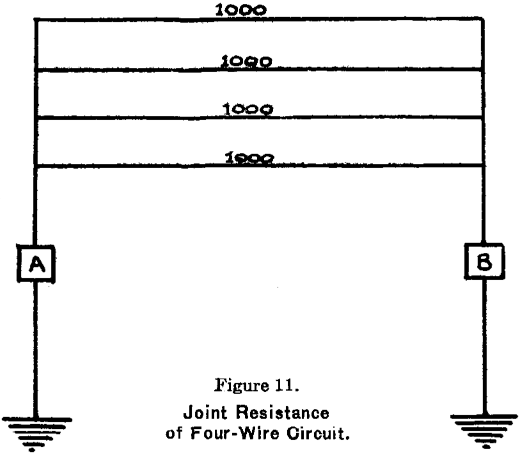

Figure 11.
Joint Resistance
of Four-Wire Circuit.

For four wires, as in Fig. 11, the joint resistance will be

$$\frac{1000}{4} = 250 \text{ ohms}$$

and the necessary voltage to maintain a current of 0.07 of an ampere will be

$$E = 0.07 \times 250 = 17.5 \text{ volts.}$$

These rules will not apply to divided circuits when the resistance of the different branches are unequal.

When two telephone circuits are stretched side by side on the poles there may be induction between them, resulting in cross talk, which means that a message in the first circuit may be heard by induction in the second one. This induction will disappear if the two wires constituting a circuit be twisted into a cable. As it is not always convenient to do this, the same effect may be approximately obtained by transposing the wires on the poles as in Fig. 12. **Transposition.**

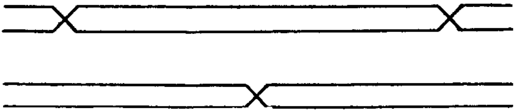

Figure 12.
Transposition.

A condenser consists essentially of two conducting sheets separated by a non-conducting layer. In practice these are usually sheets of tin foil separated by paraffined paper or mica. Many such layers are combined to give a greater surface, the alternate layers of tin foil being electrically connected as in Fig. 13. **Condenser.**

Figure 13.
Condenser.

The condenser is often represented in diagrams as in Fig. 14.

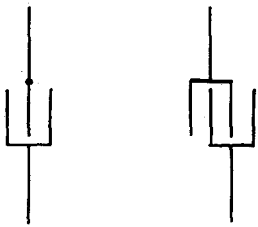

Figure 14.
Theoretical Diagram of Condenser.

A steady current will not pass through a condenser on account of the insulating layer. If, however, one side, A in Fig. 13, be connected to one pole of an alternating current generator, and the other side B to the other pole, the alternating current will flow fairly well through the condenser. This is due to what is called electrostatic induction, taking place between the two sides of the condenser.

The action of the condenser may be best understood by considering a water analogy. Suppose we have a water pipe with an India-rubber diaphragm stretched across it (Fig. 15).

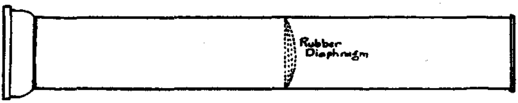

Figure 15.
Water Analogy illustrating Action of Condenser.

No steady flow of water is possible; but if a series of impulses be given the water on one side from a pump of some kind, the diaphragm will bulge and contract in time with the impulses and transmit these impulses to the water on the other side.

The insulating layer in a condenser acts as the diaphragm in a water pipe, permitting no steady flow but transmitting alternations of electrical pressure. The ease with which the insulating layer allows this passage to take place depends upon the extent of surface and the nature and thickness of the insulating layer, and is measured by what is called the capacity of the condenser. A condenser with many sheets of tin foil and very thin insulating layers is of great capacity, and readily transmits small changes of pressure, such as a very thin diaphragm would do in the water pipe.

DESCRIPTION OF DIFFERENT SYSTEMS.

Telephone circuits.

Telephone circuits are either grounded lines or metallic circuits. The latter are much more satisfactory and are exclusively used for long distance work. A grounded line, however, is considerably cheaper to install and can be used with fair results for short distances.

The arrangement of circuits used by the commercial telephone companies is very complex. We shall illustrate a few of the simpler forms only, such as are used in connection with railroad lines.

The local battery grounded line is arranged as follows (Fig. 16):

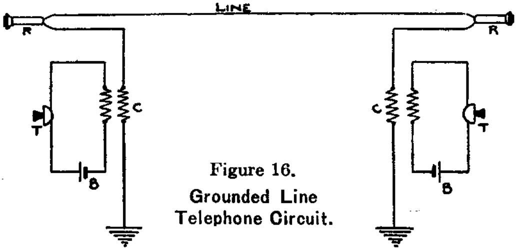

Figure 16.
Grounded Line
Telephone Circuit.

The current from the local battery B flows through the transmitter T, which renders the current variable. This variable current passes through the primary of the induction coil C and back to the local battery, inducing an alternating current of high frequency in the secondary and the line. The secondary of C is connected on one side to earth and on the other through the receiver R to the line. A similar arrangement obtains at the other end.

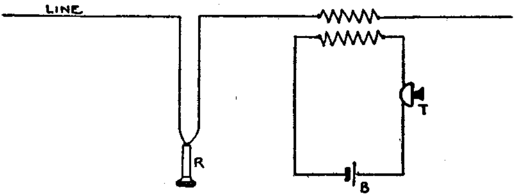

Figure 17.
Series Connection for Intermediate Station on Grounded Line Circuit.

Intermediate stations may be introduced either in series (Fig. 17) or by bridging (Fig. 18), also called multiple.

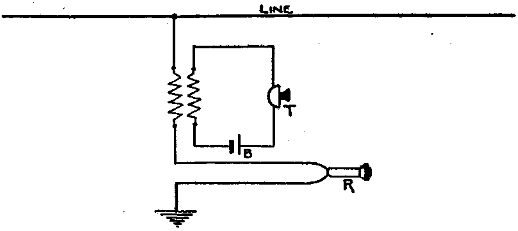

Figure 18.
Bridging or Multiple Connection for Intermediate Station on Grounded Line Circuit.

Signaling is effected by means of an alternating current furnished by a small hand magneto, which for grounded lines will furnish from 70 to 75 volts, operating upon a bell with a polarized armature at each station.

Each station is called by a certain number of rings, and each station, whether series or bridging, hears all the rings for the other stations.

On grounded lines the bells should have about 80 ohms resistance for the series arrangement, and in bridging from 1000 to 2500 ohms.

Grounded lines are usually very noisy, partly on account of stray earth currents finding their way into the lines, and partly on account of the induction from neighboring telephone, telegraph or power circuits. Some of this noise can be eliminated by placing a condenser in series in the line, but complete quiet can be obtained only on metallic circuits.

In the metallic circuit the grounded return for the current is replaced by a second wire. The local battery metallic circuit is illustrated in Fig. 19.

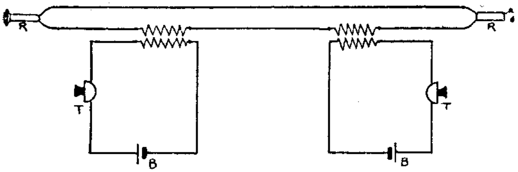

Figure 19.
Metallic Telephone Circuit.

In this type of circuit it is customary to insert intermediate stations by bridging only, as in Fig. 20.

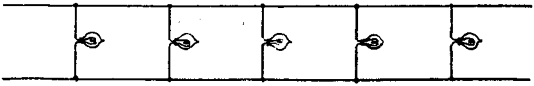

Figure 20.
Bridging or Multiple Connections.

It is absolutely necessary for the proper working of the metallic circuit that the line be balanced in resistance, capacity, leakage and inductance. This applies to phantom circuits as well as to metallic circuits. In case the two lines of the metallic circuit are of different gauge or material, thus rendering them of different resistance, proper balancing may be effected by suitable transposition or transferring.

To eliminate inductive noise and cross talk from a metallic circuit, transposition is resorted to. When a number of such circuits are parallel to each other all circuits should not be transposed on the same pole.

For further information as to how the transposition scheme should be carried out, consult blue print and specification issued by the Superintendent of Telegraph under date of November 20, 1908.

The current supplied to the transmitters is obtained either from a primary battery or from a secondary or storage battery. In telephone exchange work it is a common practice to supply many transmitters from the same storage battery. In this case cross talk may occur from the battery being overworked or from the solution getting too low in specific gravity.

Connecting grounded lines to metallic circuits.

It is sometimes desirable to extend a metallic circuit by making use of a single wire, or vice versa. This may be done by connecting the ends of the metallic circuit to one side of a repeating coil and connecting the end of the single wire through the other side of the coil to earth, as in Fig. 21.

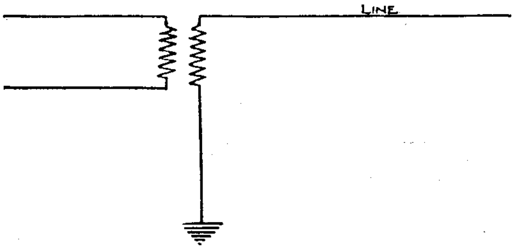

Figure 21.
Connecting Grounded Lines to Metallic Circuits.

It is obvious that the arrangement is a reversible one, that is, a message can be transmitted either way, and thus a line of considerable length can be pieced together from single and double portions.

Tying telephone lines to telegraph wires.

Sometimes a grounded telephone line parallels a long telegraph wire for a short distance. In this case it is possible to use the telegraph line as the second telephone wire, thus making the telephone circuit metallic without interfering with the working of either circuit. This may be done in three ways:

In Fig. 22 let A–B be the telegraph wire and C, D two telephone stations. C and D are directly connected to the telegraph wire. Comparatively little of the telegraph current will flow around the branch C, D, because the resistance of the telephone instruments is much greater than the resistance of that portion of the telegraph wire used with the telephone circuit.

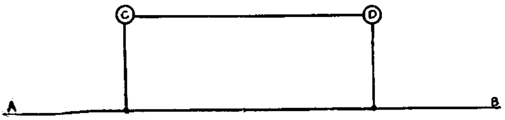

Figure 22.

Tying Telephone Lines to Telegraph Wires, the Telephone Wire being Directly Connected to the Telegraph Wire.

Fig. 23 (similarly lettered) illustrates the second way. C and D are connected to the telegraph wire through condensers E and F, which allow the alternating telephone current to pass but hinder the passage of the telegraph current. This procedure may be resorted to when the first arrangement will not give a telephone line free from the clicking of the telegraph current.

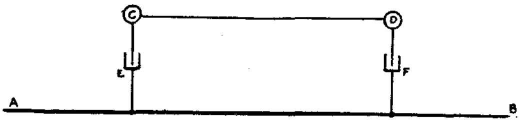

Figure 23.
Tying Telephone Lines to Telegraph Wires, the Telephone Wire being Connected to the Telegraph Wire through Condensers.

A third method is to use two retardation coils. (See Fig. 24.) A telegraph wire is cut opposite the telephone stations C and D. The ends of its middle segment are connected to the terminals of the coils and the other free ends of the telegraph wire to the middle of the coils. The other terminals of the coils are connected to the ends of the telephone wire, and the telephone stations are bridged in as shown in the figure. The action of this arrangement is as follows: A telegraph current coming from A will divide equally when it encounters the coil, traverse the non-inductive resistance which the coil offers to it, and pass along the two wires between which the telephone stations are inserted without entering the telephone instruments. The telephone current from Station C or D will traverse the circuit C–E–F–D–G–H without entering the retardation coils. The reason of this is that the coil opposes an inductive resistance to the current entering by either terminal, and the telephone current being a high frequency alternating current would encounter a great impedance in the coil.

A metallic circuit constructed in either of these three ways should be transposed like any ordinary metallic circuit and for the same reason.

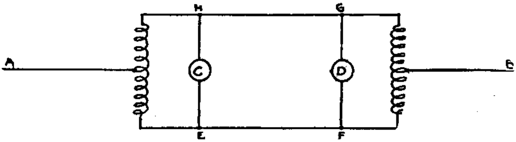

Figure 24.
Tying Telephone Lines to Telegraph Wires using Two Retardation Coils.

In either of these three ways intermediate telephone stations may be inserted by bridging, but in none of them is it practicable to introduce intermediate telegraph stations.

The telephone wire should have the same resistance as the portion of the telegraph wire used with it. Should this not be the case, resistance should be inserted in the side containing the wire of the smallest gauge.

The simplex. The simplex circuit is an arrangement for telegraphing over a metallic telephone circuit without interfering with the working of the telephone. It is represented in Fig. 25.

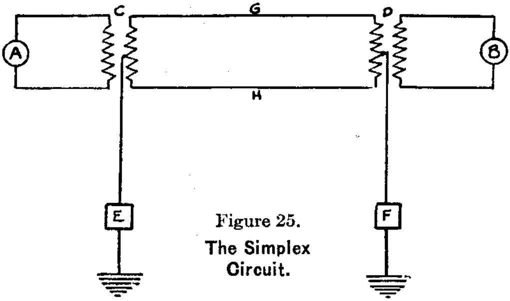

Figure 25.
The Simplex Circuit.

A and B are two telephone stations connected by a metallic circuit. Into this circuit are inserted two repeating coils, C and D. Wires lead from the middle of one side of each coil, as shown in the figure, through two telegraph offices E and F to earth. The wires G and H carry the telephone current in opposite directions, but carry the telegraph current in the same direction in both wires, forming, as far as the telegraph current is concerned, a divided circuit of two branches, completed by a ground return. The telegraph current flows in opposite directions in the two halves of the coils, and thus each portion neutralizes the inductive effect of the other, and no clicks are heard in the telephone.

For the proper working of the simplex the telephone circuit must be perfectly balanced. The divided circuit of which the telegraph line consists makes this line much lower in resistance than is usual for a single grounded line, and consequently earth currents will enter it more easily. To overcome this trouble, enough resistance should be inserted to cut down the earth currents to a harmless value. Of course, this resistance should not be inserted in the divided portion of the line. If much resistance has to be introduced it may also be necessary to increase the voltage of the line.

Much of the success of the simplex depends on the proper choice of repeating coils to fit the conditions of the line.

Intermediate telephone stations may be inserted along the line by bridging in the usual way.

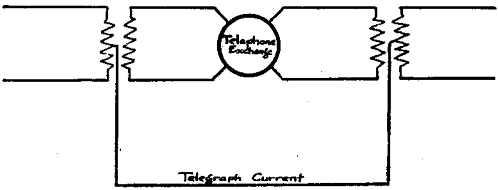

Figure 26.
Intermediate Telephone Stations on Simplex Circuit.

If it is desired to run the line through an intermediate telephone exchange the arrangement of Fig. 26 is used.

Repeating coils are inserted in the metallic circuit on each side of the exchange and the telegraph current taken off by a single wire from the middle of each coil and carried around the exchange.

The inserting of intermediate telegraph offices on the simplex requires a specially wound coil. It consists of two retardation coils of the usual pattern wound in opposite directions on the same core (Fig. 27).

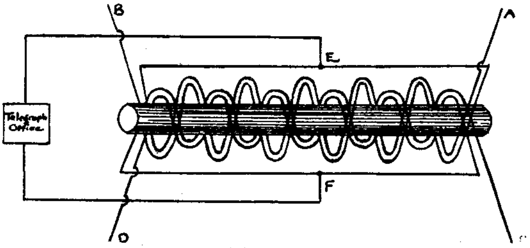

Figure 27.
Specially Wound Retardation Coil for use at Intermediate Telegraph Offices on Simplex Circuit.

The telephone current entering by A and leaving by B will encounter an inductive resistance, and to this current the coil will act like an ordinary induction coil, of which the secondary terminals are C and D. The telephone message will therefore pass through the coil and on.

The telegraph current entering both at A and B encounters a non-inductive resistance, producing, therefore, no effect in the secondary coil, but passes out by the wire at E through the telegraph office and re-enters the secondary coil at F. Here it again encounters a non-inductive resistance and divides equally, and flows out by C and D.

None of the telephone current will escape at E or enter at F, because, as far as the telephone current is concerned, these are points of equal potential.

The phantom. The phantom is an arrangement by which two metallic telephone circuits can be made to do the work of three. The two metallic circuits are called the physical circuits, and the third circuit, resulting from their combination, is called the phantom circuit. Fig. 28 illustrates the connections.

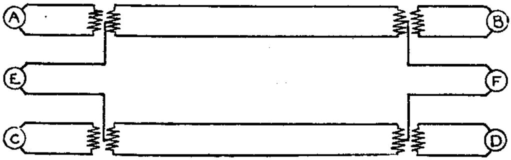

Figure 28.
Theoretical Diagram of the Phantom Circuit.

A and B are two telephone stations connected by a metallic circuit. C and D are another pair similarly connected. Two repeating coils are inserted in each circuit and wires led off from the middle point of these coils to the telephone stations E and F. It will be seen by the figure that the circuit containing the stations E and F is metallic, and consists mainly of two divided circuits, each of two branches. On account of this, its resistance is much less than that of either physical circuit.

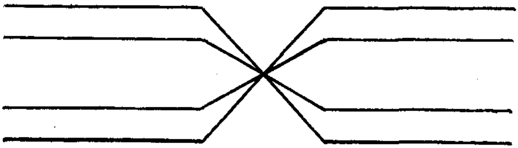

Figure 29.
Phantom Transposition.

The telephone current from either E or F entering or leaving at the middle of the repeating coils produces no inductive effect in the coils, because it travels in opposite directions in the two halves of the coil. Therefore the message from the stations E or F is not heard at either A, B, C or D, just as the telegraph current in the simplex is not heard in the telephone.

Each physical circuit must, of course, be transposed for the usual reason, and, in addition, the phantom circuit requires transposition also. This is effected as shown in Fig. 29.

The presence of intermediate stations on a telephone line does not prevent using the line as part of a phantom circuit, for when so used the phantom message travels along both wires in the same direction and therefore will not enter the intermediate stations. Such stations will, therefore, not hear the phantom message.

Intermediate stations on the phantom circuit may be installed as shown in Fig. 30. Retardation coils A and B are placed in the physical circuits, and wires leave from the centre of these coils to the intermediate telephone station C.

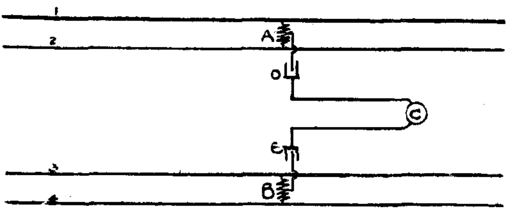

Figure 30.
Connections for Intermediate Telephone Stations on Phantom Circuit.

The phantom telephone current going in the same direction in wires 1 and 2 will enter the retardation coil A by both terminals simultaneously, encounter, therefore, a non-inductive resistance, and leave by its central wire, passing through C to the coil B and the return wires 3 and 4.

The telephone current in the physical circuit composed of wires 1 and 2 will not enter the retardation coil to any appreciable extent, as the coil opposes to a current entering by one terminal and leaving by the other an inductive resistance, and the telephone current being of high frequency would therefore be greatly impeded.

Condensers are sometimes inserted at D and E. These are convenient when it is desired to make measurements on one of the physical circuits, as they insulate the two physical circuits from each other. They are also of value in case one of the physical circuits becomes grounded, in preventing the other physical circuit from being disabled also.

In phantom lines, cables should be avoided as far as possible on account of their capacity. If cables are necessary, the variety known as "double-twisted pair" should be used.

The choice of a coil properly suited to the conditions of the line is as important in phantom lines as in simplex lines.

The phantom simplex.

The phantom simplex is a simplex applied, not to a physical metallic circuit, but to a phantom circuit. The arrangement is shown in Fig. 31.

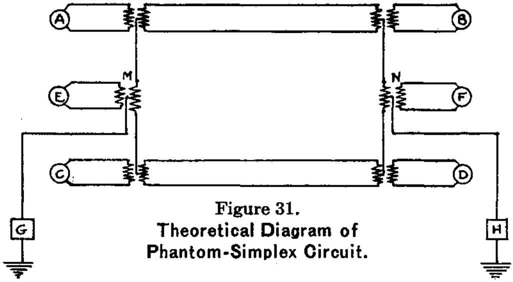

Figure 31.
Theoretical Diagram of
Phantom-Simplex Circuit.

A and B are telephone stations connected by a metallic circuit. C and D are another similarly arranged pair. E and F are two telephone stations on the phantom circuit, composed of the two physical circuits just mentioned. Repeating coils are inserted into the phantom circuit at M and N, and the ordinary simplex construction applied to these coils. This allows the introduction of telegraph stations at G and H, the circuit of which is completed by an earth return.

It will be noticed that the wire of this telegraph circuit is a four-fold divided circuit for the greater portion of its length, and is correspondingly low in resistance. Much more trouble is therefore likely to occur from earth currents than in the simplex, but it may be overcome in the same manner.

The presence of intermediate telephone stations on either physical circuit does not interfere with the workings of the phantom simplex. Intermediate telephone stations on the phantom circuit may be introduced just as in the ordinary phantom, but condensers should always be used in this case. (See Fig. 30.)

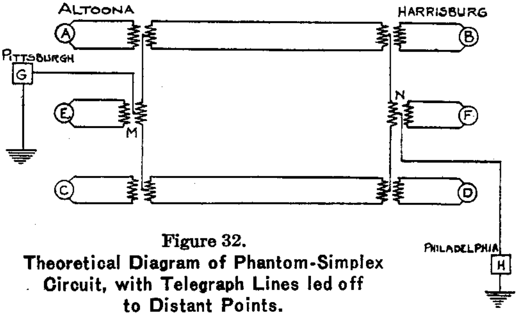

Figure 32.
Theoretical Diagram of Phantom-Simplex Circuit, with Telegraph Lines led off to Distant Points.

The telegraph offices G and H may be widely distant from the telephone stations on the phantom circuit. For instance (Fig. 32), the phantom circuit may extend only from Altoona to Harrisburg, while the telegraph lines led off from it may extend from Altoona to Pittsburgh and Harrisburg to Philadelphia. It is, however, not practicable to insert telegraph offices between the telephone stations.

It must be noted that a four-fold line will produce four times as much leakage in damp weather as a single line, and extra care must be given to the insulation on this account.

If trouble is experienced in ringing, the resistance of the ringing circuit should, if possible, be diminished. If a power generator is used this can usually be done by replacing the lamp ordinarily included in such a circuit by a lamp of lower resistance. With a hand generator the trouble is not so easily cured. Either the generator must be more highly geared, or else replaced by one producing a higher voltage.

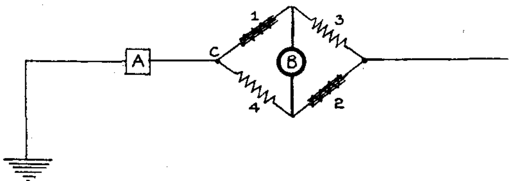

Figure 33.
Theoretical Diagram of Grounded Line Composite Circuit.

The grounded line composite.

The grounded line composite is a device for inserting telephones on a grounded telegraph line. The telephones may be inserted either in series or in multiple. Various forms of composite telephone apparatus are on the market. One method of introducing the telephones in series is the device known as the Telegraphone (Fig. 33).

In this figure, A represents a telegraph station and B a telephone station. Four coils of wire surround B as indicated, forming a Wheatstone Bridge arrangement. Of these four coils, 1 and 2 are wound inductively and 3 and 4 non-inductively. The resistance of all four coils must be equal, and may be about 30 ohms each. The telephone current in the line on reaching the point C does not divide equally between coils 1 and 4, as it is an A. C. of high frequency, and therefore greatly impeded by the inductively wound coil 1. It therefore passes through coil 4. For the same reason it will not enter coil 2, but passes through the telephone apparatus B, and through coil 3 to the line.

The telegraph current in the line will, on the other hand, divide itself equally at C and traverse both branches of the rectangle, passing the telephone apparatus without entering, and uniting again in the main line.

Not more than five or six telephones should be inserted in this manner in a single line, and it is not practicable to have more than four or five telegraph offices in the line. With only two or three sets of telephones thus inserted, a line up to 200 miles in length may be worked satisfactorily, provided, however, there are no intermediate telegraph offices between the telephone stations.

Signaling is effected by a howler instead of a bell. This is merely a telephone receiver provided with a horn to intensify the sound emitted by its diaphragm, and actuated by a rapidly intermittent current, producing a harsh musical note.

The inserting of telephones by bridging may be carried out as shown in Fig. 34.

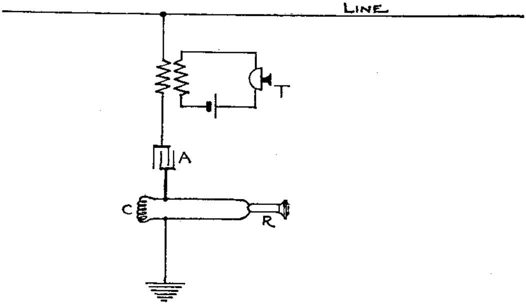

Figure 34.
Intermediate Telephone Station on Grounded Line Composite Circuit.

A condenser is inserted at A to prevent the telegraph current in the line from passing to earth. The high frequency alternating telephone current will readily pass this condenser. T is the transmitter and R the receiver, connected in the usual way, except that as a shunt to the receiver we have a retardation coil, C, made without a leading wire from its centre, and provided with an iron core that may be pulled in and out

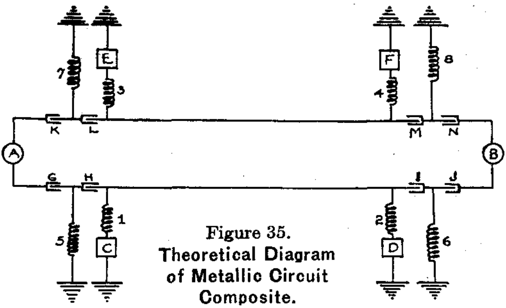

Figure 35.
Theoretical Diagram
of Metallic Circuit
Composite.

to vary the inductance. This coil is inserted to reduce the noise in the telephone. Of course it reduces the telephone current also, but as the noise is usually the feebler of the two, it may be eliminated without seriously interfering with the telephone transmission. Moreover, an extra strong transmitting current may be used, if necessary, to make up for the sound lost in the coil C.

It is not practicable to continue a grounded telegraph line by means of a metallic circuit if the latter runs through a telephone exchange.

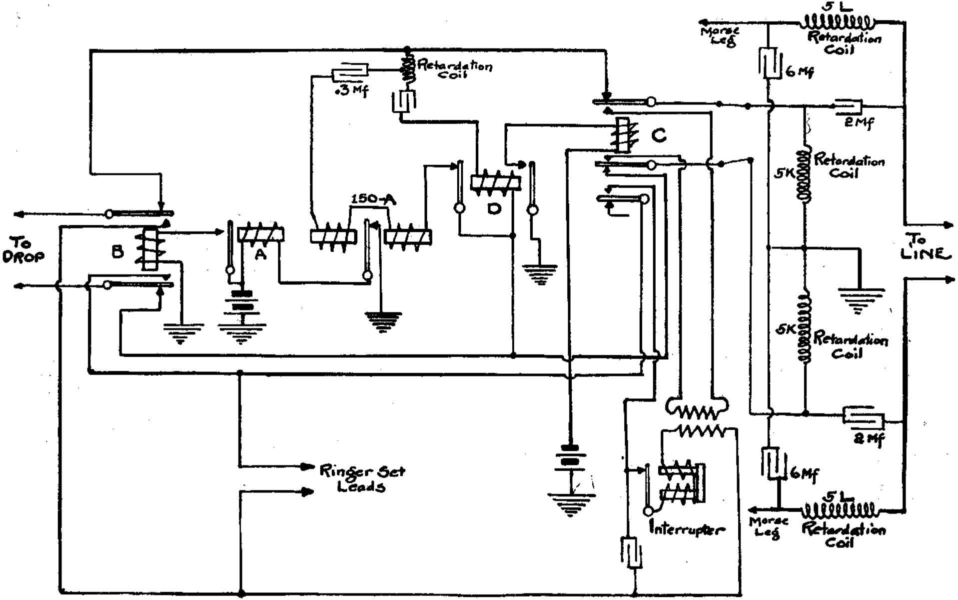

Figure 36.
Wiring Diagram of Metallic Circuit Composite.

Metallic circuit composite. The metallic circuit composite is a device by which a metallic telephone circuit may be used also for two simultaneous telegraph messages. The principle is shown in Fig. 35. A and B are two telephone stations connected by a metallic circuit. C and D are two telegraph stations in connection with each other, and E and F another such pair.

Condensers at H, I, L and M hinder the telegraph current from entering the telephone stations. Retardation coils at 1, 2, 3 and 4 prevent the telephone current from entering the telegraph instruments.

It sometimes happens that a small amount of the telegraph current will leak through the condensers H, I, L, M, which are supposed to stop it. To prevent this entering the telephone instruments the retardation coils 5, 6, 7 and 8 are introduced, and also the condensers G, J, K and N. The telegraph leak finds an easier path to ground through the retardation coils than through the condensers, and is thus diverted from the telephone instruments.

The method of signaling is rather complicated. The alternating current from the signaling apparatus, usually a hand magneto, actuates a relay which cuts out the talking apparatus and cuts in another alternating current from a different source, which may be a power generator. This latter alternating current before being sent out over the line is broken up by a vibrating interrupter so as greatly to increase its frequency, and is also raised in voltage by a step-up transformer. On reaching the other end of the line this current actuates another relay which cuts in a 16 cycle alternating current (locally generated) to do the actual ringing. Details of the connection are shown in Fig. 36.

Intermediate telephone stations are not practicable on account of the high voltage signaling current, which would have to be transformed down and up again at each such station.

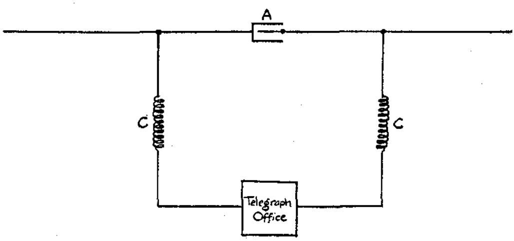

Figure 37.
Intermediate Telegraph Office on One Wire of Metallic Circuit Composite.

Intermediate telegraph offices may be inserted as shown in Fig. 37.

A condenser at A in the line sends the telegraph current around through two retardation coils, B and C, and the telegraph instruments, while the retardation coils keep the telephone current to the main line where it passes the condenser.

Intermediate telephone exchanges are impracticable for the same reason that a single telephone station is impracticable.

Just as in the simplex, the telegraph lines may be extended any distance and in any direction beyond the composite zone before going to ground.

Metallic circuit telephone lines on either side of the composite zone may be extended through the composite intermediate segment by regular switchboard connections.

Cables. The ordering of cable to suit the conditions of any particular line is a matter that requires considerable care. The Superintendent of Telegraph is ready to supply specifications for cables upon information as to the conditions to be met on the line and the uses to which the cable is to be applied.

Electrolysis. Cable sheaths are apt to suffer from electrolytic corrosion unless carefully looked after. This is caused by stray earth currents, usually from trolley lines, using the cable sheath instead of the ground as part of the return path. Although the cables are usually laid in non-conducting conduits, yet the inner surfaces of these conduits may be damp, and thus conduct the current to or from the cable.

Whenever a direct current passes through water the latter is decomposed into its two gaseous constituents, hydrogen and oxygen, which make their appearance respectively where the current leaves and enters the water. Thus, when a current traverses damp earth it is carried by the water in the ground, and if it passes from this damp conductor to a cable sheath, hydrogen is evolved; and if it again leaves the sheath for the ground, oxygen is evolved. Hydrogen is harmless to the metal sheath, and in fact prevents rusting, but oxygen rapidly corrodes the metal. Thus in Fig. 38 we have corrosion of the cable at B and of the rails at A.

In consequence of the principles just set forth, as long as the cable sheath is negative to neighboring conductors there is no danger of corrosion. Frequent readings should be taken at the manholes to ascertain this, especially where the cable runs close to an electric railway. Where there are more cables than one, it is advisable to connect them together at frequent intervals to prevent currents passing from one sheath to another by other than metallic connections.

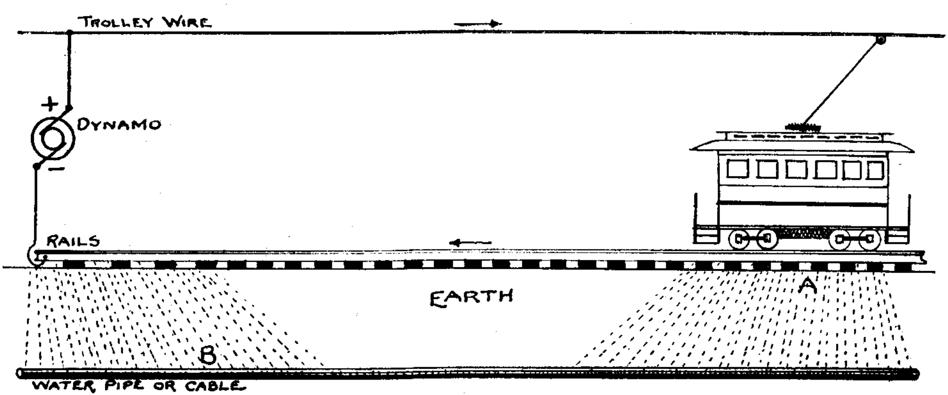

Figure 38.

Electrolysis. Showing Path of Stray Currents from Trolley Lines.

To keep the cable sheaths negative they are sometimes connected to the negative bus bar on the switchboard at the power house where the disturbing current is generated. The life of a cable may sometimes be prolonged at the expense of large ground plates connected by feeders to the cable sheath and inserted at points along its route.

Where a cable is found positive to neighboring car rails the cable is sometimes connected directly to the rails, although this is not always the best thing to do.

No set rules for the preservation of the cable sheath from electrolysis can be given. The Superintendent of Telegraph will be ready to give assistance in this line when called upon.