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PW—D20

# Post Office Engineering Department

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## TECHNICAL PAMPHLETS FOR WORKMEN

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*Subject :*  
**Superposed Circuits  
Transformers  
Bridging Coils and Retardation Coils**

ENGINEER-IN-CHIEF'S OFFICE,  
*July, 1934*

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LONDON

PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE

To be purchased directly from H.M. STATIONERY OFFICE at the following addresses:  
Adastral House, Kingsway, London, W.C.2; 50 George Street, Edinburgh 2;  
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21. Call Offices.

[Continued on page iii of Cover.]

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# Post Office Engineering Department

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**PW—D 20**

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## **SUPERPOSED CIRCUITS**

### **TRANSFORMERS**

### **BRIDGING COILS AND RETARDATION COILS**

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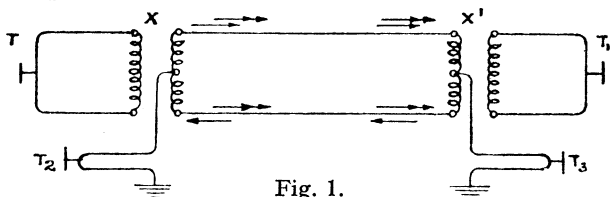
# 1.—SUPERPOSED CIRCUITS

## A.—TELEPHONE PHANTOM CIRCUITS.

When two telephone circuits are twisted together on an aerial line, or in a multiple twin underground cable, it is possible to obtain a third circuit by superposition. This third circuit is known as the **phantom** or **plus** circuit.

The principle of the phantom circuit is shown in Fig. 1.

The currents from telephones T and T1 pass through the transformers X and X1, and circulate around the wires of the line loop in series, as shown by the arrows—→



If the middle points of the line windings of the transformers be connected through telephones T2 and T3 to earth, then currents from these telephones will flow along both lines of the loop in parallel, as shown by the arrows—→→

The currents entering the middle point of the line windings of the transformer will divide equally, so that their effects on the telephone windings cancel out. Consequently telephones T and T1 do not respond to speech currents from T2 and T3 (*see* section on "Transformers").

It is seldom possible in actual practice to form a phantom circuit on one loop, as shown above, on account of the disturbance brought in by the earth connections; but when the phantom is formed from two loops, an earth connection is unnecessary, and the circuit arrangement is as shown in Fig. 2.

It is of importance that the two loops shall be twisted together, and shall be exactly alike in regard to conductor and insulation resistance and capacity. Similarly, the wires of each loop must be alike, otherwise out-of-balance currents will be caused, and interference between the phantom and physical circuits will result.

It is necessary, of course, that the windings of the transformers themselves shall be exactly balanced. The standard transformers for phantom working are:—

Coils, Repeating 4006A for use on ordinary repeating coil racks.

Transformers No. 4 (encased transformers for use on pole test boxes).



Transformers No. 50 for plate mounting.

Transformers No. 16 for plate mounting for use on circuits equipped with 2-wire telephone repeaters.

Transformers No. 27 for plate mounting for use on circuits equipped with 4-wire repeaters.

Transformers No. 16 consist of two transformers specially paired as to their impedance characteristics, one transformer being put in the line circuit and the other in the balance circuit. They are provided with special cores designed to give stable impedance characteristics.

Transformers No. 27 are similar in construction to Transformers No. 16 but are single transformers.

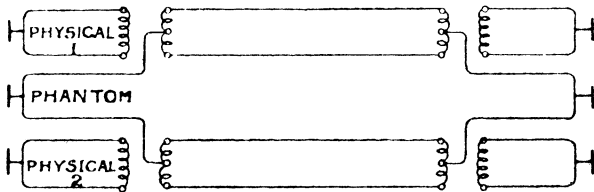


Fig. 2.

The method of joining up Coils, Repeating 4,006A for a phantom circuit is shown in Fig. 3.

On Transformers Nos. 16, 27 and 50, the tags are similarly numbered but are arranged in different order on the transformer.

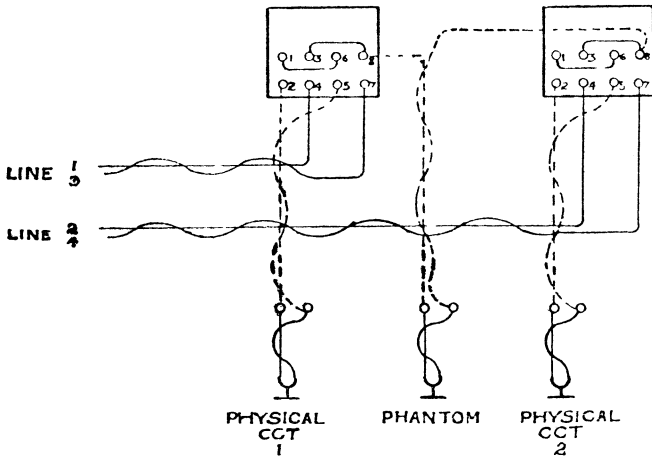


Fig. 3.

Direct current signalling is not practicable in phantom circuit combinations, and all signalling must be done with magneto generators.

The insertion of two Coils, Repeating 4,006A in an aerial loop or loaded cable loop causes a transmission loss of  $1\frac{1}{2}$  decibels. The phantom circuit on two aerial loops is equal in efficiency to the physical circuits.

Phantom circuit working is used in certain exceptional cases, to obtain additional subscribers' circuits when new line plant is not available.

### B.—TELEGRAPHS SUPERPOSED ON TELEPHONES.

The principle of phantom circuit working is applied in superposing telegraph circuits on telephone trunks.

Coils, Repeating 4,006A are suitable for this purpose.

The battery voltage of the telegraph circuit should be kept as low as practicable for reliable working, and a resistance spool

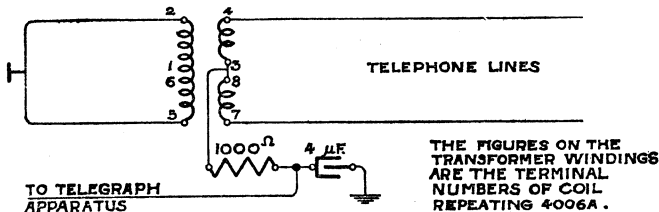


Fig. 4.

of 1,000 Ω should be inserted in the connection between the telegraph apparatus and the telephone circuit. The telegraph apparatus should also be shunted by a 4 microfarad condenser. The theoretical connections are given in Fig. 4.

The effect on the efficiency of a telephone circuit due to superposing a telegraph thereupon is a loss of  $1\frac{1}{2}$  decibels in the transformers and a further loss equal to about 1 decibel from the disturbance caused by the telegraph currents.

In setting up telegraph testing speaker circuits superposed on telephone trunks, it is frequently necessary to introduce an

intermediate telegraph connection. The circuit arrangement for this is as shown in Fig. 5:—

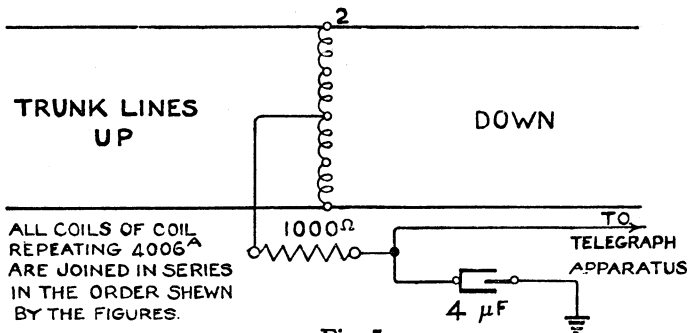


Fig. 5.

The phantom circuits in star quad cables are unsuitable for telephone working, but are used for teleprinter working, as are the double phantom circuits in multiple twin cables. A double phantom circuit is a superposed circuit having two sides, each of which consists of four conductors of the two sides of a phantom circuit in parallel, as shown in Fig. 6.

### C.—PHANTOM CIRCUITS ON LOADED SUBMARINE TELEPHONE CABLES.

The phantom circuits of submarine cables are used when cross-talk is tolerable. Fig. 6 illustrates a case where eight superposed telephone circuits are formed on a 4-quad, paper core, continuously-loaded cable. The line windings of the transformers only are shown.

## 2.—TRANSFORMERS.

A **transformer** consists of two coils of insulated wire so arranged that, when an alternating electric current is sent through one of them, the magnetic field produced acts upon the second coil, so as to set up an induced electro-motive force in the latter.

In Fig. 8 A.B. is a tube of some non-magnetic material filled with soft iron wires forming the "core" of the transformer. One or more layers of insulated copper wire are wound over the tube to form the "primary winding," and over this are wound one or more layers of insulated copper wire to form the "secondary winding." The latter winding has been shown as wound on a tube C.D. for the sake of clearness, but it may be wound over the "primary" winding without the tube. Similarly the

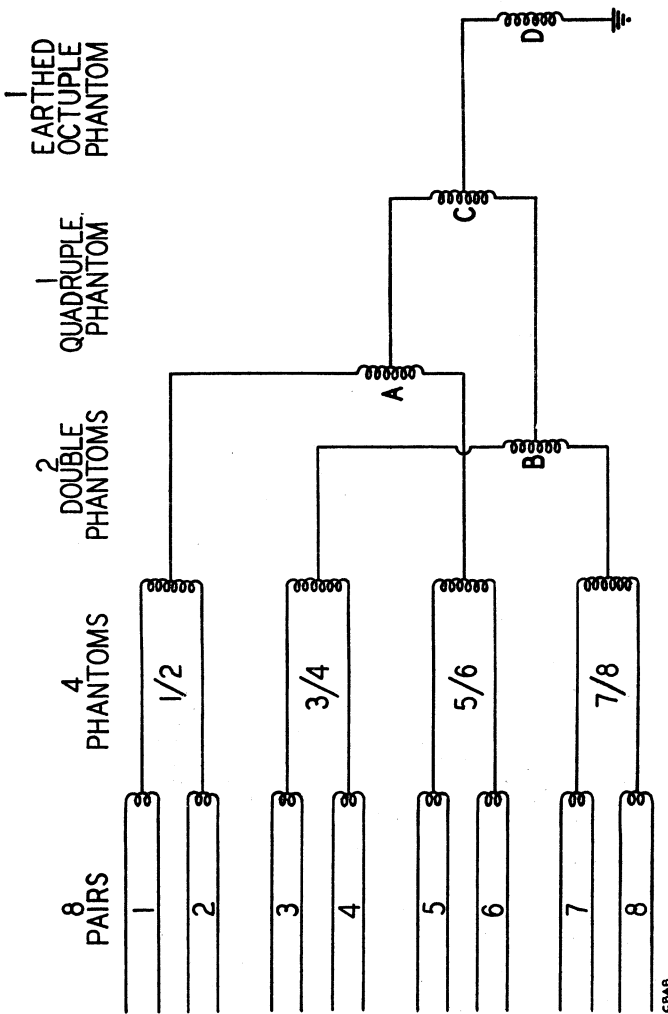


Fig. 6. Telephone Phantom Circuits in 4 Quad, paper core, continuously loaded Submarine cable.

“ primary ” winding may be wound on the bundle of soft iron wires direct, so long as the insulation of the copper wire is protected from injury. It is usual, however, to separate the “ primary ” winding from the iron core.

This piece of apparatus represents an “ open ” core or “ straight ” core transformer—small examples are the induction coils in primary battery and C.B. telephones.

Fig. 9 represents a “ closed ” core transformer of the “ toroidal ” or “ ring ” type. The principle is the same as that of the straight core transformer, but the core forms a closed circuit for the magnetic lines of force set up by a current in the “ primary ” winding. Coil, Repeating 4,006A and Transformers Nos. 16, 27 and 50 are of this type.

There are various other types of closed core transformer, but as the principle of their action is the same, it is not necessary to describe them.

In some cases the core is made up of thin plates of iron stamped into the form of the letter E and fitted one over the other to the required number, with the open ends alternately to left and right thus :—

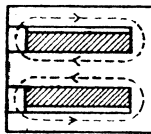


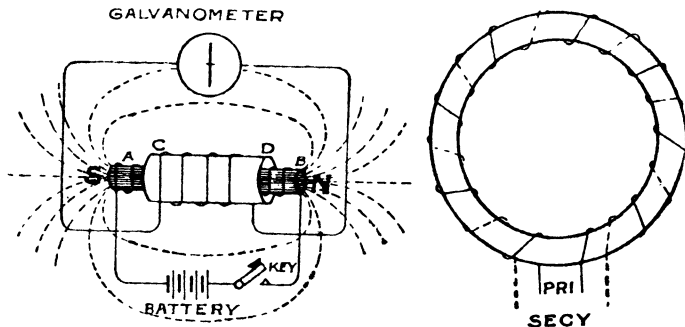
Fig. 7.

the coils being wound on a bobbin and placed in the position shown in a cross section shaded. The stampings are put into the bobbin one at a time, the central limb of the E of the first being pushed in from (say) the right and the next from the left, and so on alternately. The magnetic lines of force have thus a path through the centre of the bobbin and round outside as shown by the dotted lines.

The action of the transformer may be briefly explained as follows :—

If a current of electricity is caused to flow through the primary coil, a magnetic field will be set up, the lines of force flowing along the inside of the coil and returning outside, as shown in Fig. 8. As the secondary coil is wound over the primary coil, these lines of force also flow through the secondary coil and return outside it. Now, whenever magnetic lines of force are set up through a coil of wire in this way, an electromotive force is induced in the coil while the lines of force are

being established, and it ceases when the magnetic field has reached its full strength. An electromotive force is also set up in the coil, but in the opposite direction when, owing to the cessation of the current in the primary coil, the magnetic field disappears. The electromotive force is also reversed in direction, if the primary current is reversed.



Figs. 8 and 9.

The strength of the induced electromotive force depends upon—

- (a) The number of lines of force generated in the core per second ;
- (b) The number of turns of wire in the secondary coil.

Thus, if there are 1,000 turns in the secondary coil, and the number of lines of force increases or decreases at the rate of 100,000 per second, an E.M.F. of one volt will be generated in the secondary coil.

The number of lines of force set up in the core at any instant depends on—

- (a) The strength of the primary current at that instant from
- (b) The number of turns of wire in the primary coil
- (c) The length, cross-section, and material of the core
- (d) The shape of the core (whether straight or ring).

The number of lines of force set up per second depends upon the rate at which the current strength varies.

The reason for using an iron core is given in the section on Bridging Coils and Retardation Coils.

It will be easily understood from this that the shorter the path for the lines of force and the greater the cross-section of the path, the more lines will be forced through by a given current flowing through a given number of turns of wire.

The magnetizing force of the primary coil is proportional to the strength of the current multiplied by the number of turns of wire. This product, current (in ampères), multiplied by the number of turns, is usually referred to as the "ampère turns." The number of lines of force, or the magnetic field set up by the primary coil, may therefore be said to be proportional to the ampère turns.

It should be clearly understood that an E.M.F. is generated in the secondary coil only so long as the strength of magnetic field in the core is changing, and ceases immediately the latter becomes steady. Also that a direct current passing through the primary coil, if varied in strength (say) by the action of a telephone transmitter which is being spoken into, will set up an alternating E.M.F. in the secondary, the E.M.F. acting in one direction, while the current is increasing, and in the opposite direction when the current is decreasing.

It has been stated that the E.M.F. generated in the secondary coil depends upon the number of lines of force generated per second in the core, and that the number of lines of force is proportional to the "ampère turns" in the primary coil. A current of 10 ampères flowing through 100 turns ( $10 \times 100 = 1,000$  ampère turns) would therefore produce the same number of lines of force as a current of 1 ampère flowing through 1,000 turns ( $1,000 \times 1 = 1,000$  ampère turns), or as 1 milliampère ( $1/1,000$ th of an ampère) through 1,000,000 turns ( $1,000,000 \times 1/1,000 = 1,000$  ampère turns).

In addition to the E.M.F. set up in the secondary coil, an E.M.F. is also set up in the primary coil, due to the magnetic lines of force generated by the current flowing through it. This E.M.F. opposes that of the battery applied to the primary coil on closing the circuit, and acts in the same direction as the battery on opening the circuit. It thus tends to oppose the variation of the primary current, and is therefore called a "counter E.M.F.," or a "back E.M.F." Its strength also depends on the number of lines of force generated per second by the change in the primary current, and also on the number of turns in the primary coil. The primary winding thus offers an "impedance" to the variations in the primary current (see the Section on Bridging Coils, etc., for further details regarding impedance).

The impedance of the primary circuit is less when a current is allowed to flow in the secondary circuit, due to the induced E.M.F., than when the secondary circuit is left open, because the secondary current flows in such a direction as to oppose the effect of the primary current on the core, and this consequently reduces the counter E.M.F. in the primary circuit, and allows a stronger alternating current to flow or, in the case of a telephone induction coil, allows greater variation in the primary current.

These facts are taken into account in designing the telephone induction coil for primary battery work.

The number of turns in the primary coil is kept low not only to keep the resistance of the transmitter circuit low, but also to keep the back E.M.F. in the primary coil low, so that it shall oppose as little as possible the changes in the strength of the primary current—that is to say, the “impedance” is made low. Greater variation in the number of lines of force flowing through the core, and therefore through the secondary coil, is thus obtained, and consequently a greater E.M.F. is generated in the secondary coil. In the latter, more turns are used so as to increase the E.M.F., to enable the line resistance to be overcome.

In the case of repeating coils, the number of turns in the primary and secondary coils are generally equal. For example, in a C.B. cord circuit, this apparatus is used to enable current to be fed to the subscribers’ telephones from the exchange battery without the alternating speech currents being short-circuited by the battery (*see* Fig. 10).

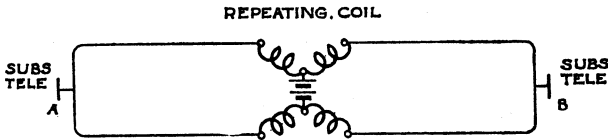


Fig. 10.

Variations in the direct current flowing through one winding of the Repeating Coil, due to the operation of the transmitter at B, do not affect the **direct** current flowing to A, but the variations of the current in the right-hand coil cause variations of the magnetic field in the core of the repeating coil, which sets up an alternating E.M.F. in the left-hand coil, which causes an alternating current to be superposed on the steady current flowing to A, and this, acting through the induction coil at A, operates the receiver.

Repeating coils are also used for superposing (*see* the Section on “Superposing”).

The method of joining up a Coil, Repeating No. 4,006A, together with a diagram of the internal connections, is given in Fig. 11.

In the section on Bridging Coils, the subject of differential winding is dealt with. In the case of the Coil, Repeating 4,006A the primary and the secondary windings each consist of two wires twisted together in the same manner as twin jumper wire, so that each wire of the pair shall affect the core equally when equal currents flow through them. The secondary winding is wound all round the core, and over this is wound the primary.



In the diagram the windings have been shown on a portion of the core only for the sake of clearness.

The two wires of the primary winding are carefully balanced so as to make them as nearly perfectly differential as possible, and this winding should therefore always be connected to the line and the secondary to the apparatus side. Terminals 1 and

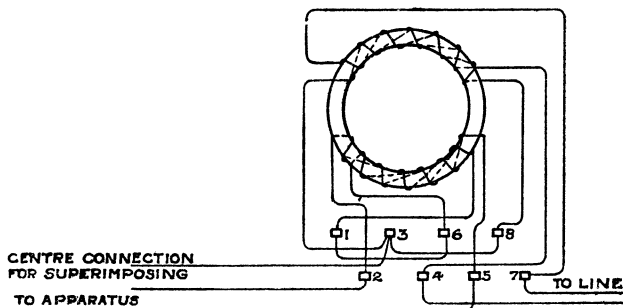


Fig. 11.

6 and 3 and 8 should be connected together, terminals 2 and 5 being connected to apparatus and 4 and 7 to the line.

For superposing, the centre point of the line winding is the junction of terminals 3 and 8. If a current is sent in at this point and out to line at terminals 4 and 7, it will traverse the two wires in opposite directions round the core as indicated by the arrows, and will therefore produce no magnetic effect if the line itself is sufficiently well balanced to allow equal portions of the current to flow through each half of the primary winding. For details as to superposing, *see* the section on that subject.

Transformers are used in electric lighting installations, to enable alternating current supplied to a building at high pressure to be fed to lamps, etc., at a lower pressure.

Thus, if the supply is at 1,000 volts and we wish to use the current at a pressure of 100 volts, we make the number of turns in the winding connected to the leads to the lamps one-tenth of the number of turns in the winding connected to the supply mains. The supply current will now generate a certain alternating magnetic field in the core of the transformer. If the number of turns on both secondary and primary coils were equal, this alternating magnetic field would generate an E.M.F. in the lamp leads very nearly equal to the supply voltage, namely, 1,000 volts. As, however, the number of turns on the lamp leads side of the transformer is only one-tenth of those on the

supply mains side, the voltage is also only one-tenth, viz., 100 volts. Now the energy we put into any electric circuit per second is measured by the current in ampères multiplied by the voltage. The unit is one watt: thus 1 ampère  $\times$  1 volt = 1 watt.

$$10 \text{ ampères} \times 100 \text{ volts} = 1,000 \text{ watts.}$$

If this quantity is multiplied by the number of hours during which the 10 amps. is flowing, we get the number of Board of Trade Units. Thus 1,000 watts  $\times$  1 hour = 1 Board of Trade unit. This is the unit used by Electric Lighting and Power undertakings in selling electric energy.

Neglecting losses in the transformer, we can take out as much energy from the secondary as we put into the primary, but we have the advantage that we can supply current to the transformer at high pressure and take a greater current out but at a lower pressure. Thus:

Supplied to transformer 10 amps. at 1,000 volts = 10,000 watts.  
Taken from secondary 100 amps. at 100 volts = 10,000 watts.

Now suppose the transformer connected to the supply mains with the secondary disconnected. There will now be no secondary current, and the transformer will simply act as a bridging coil of high impedance, owing to its high inductance, and a very small current only will flow.

Now suppose we begin to draw current from the secondary, the magnetization of the core will be reduced, which reduces the counter E.M.F. in the primary winding, and so allows more current to flow from the mains; as more current is taken from the secondary, the counter E.M.F. is further reduced and more current flows from the mains. The transformer thus adjusts the supply current to meet the requirements of the secondary circuit.

### 3.—BRIDGING COILS AND RETARDATION COILS.

In telephone circuits, it is often necessary to arrange a path which shall offer a relatively small resistance to a steady, direct current, but shall oppose any variation either in the strength or direction of the current. In other words, the path must allow a direct current to pass readily, but an alternating current must be opposed. For example, in a trunk circuit, the permanent current is fed to the line as shown in Fig. 12.

The bridging coils are used to choke back the generator calling currents which would otherwise pass through the battery, instead of through the higher impedance path of the relay or indicator.

In C.B. Exchange working, it is sometimes required to connect a "holding coil" across the exchange line at a subscriber's main instrument—for example, when a Magneto Private Branch Exchange is connected to a C.B. Exchange. In the latter case, the steady current from the main exchange is prevented by the insertion of condensers in the exchange line from passing through the Private Branch Exchange, and a holding coil is arranged to be connected across the exchange line when a call

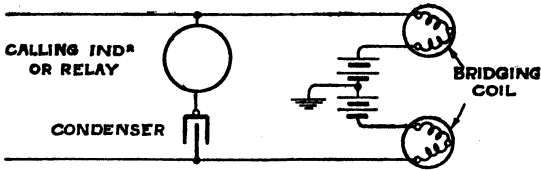


Fig. 12.

is put through, so that a permanent clear may not be given. This coil is required to pass the direct current, but to choke back the speech currents (Fig. 13),

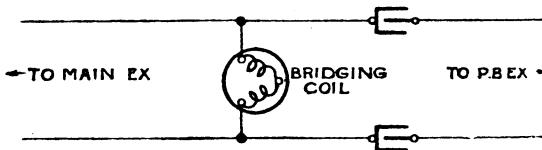


Fig. 13.

Again, where at a C.B. Private Branch Exchange the current is supplied to the cord circuits in the manner shown in Fig. 14,

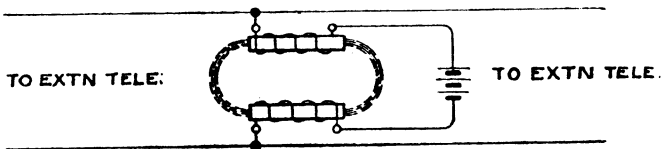


Fig. 14.

the steady currents pass through a double-wound retardation coil to each line, and the speech currents pass between the two telephones at the extension stations through the lines, and do not pass through the retardation coils owing to their opposing the passage of the alternating speech currents.

There are many other instances, but the general principle is that, in all bridging coils or retardation coils, steady currents pass readily and varying or alternating currents with difficulty.

The construction of these coils is based on the following facts. If we take a bundle of soft iron wires to form a core and wind round it one or more layers of insulated copper wire, as in Fig. 15, and pass a current of electricity through the coil,

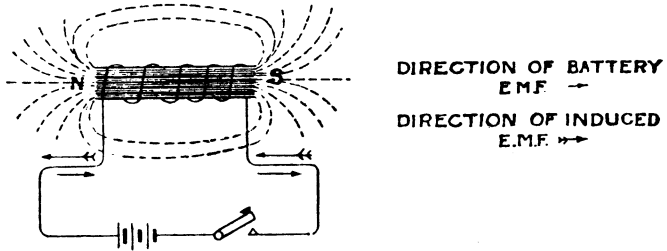


Fig. 15.

as indicated in the figure, a magnetic field will be set up, the lines of force of which will flow through the iron from S. to N. and return from N. to S. through the air. The number of lines of force will depend upon the number of turns of wire in the coil and the strength of the current. Now in any such circuit, setting up lines of force through it induces a momentary E.M.F. in the windings, which acts in a direction opposing the E.M.F. of the battery. Again, if we arrange by a key to cut off the battery and join the circuit through as shown in Fig. 16, the magnetic field will now disappear, and while this is taking place

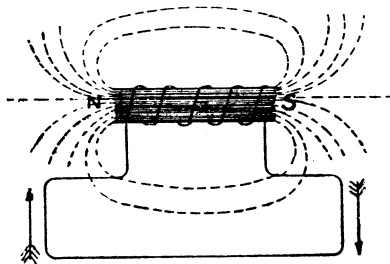


Fig. 16.

an E.M.F. will be induced in the coil in the same direction as the battery E.M.F., thus causing a momentary continuation of the current after the battery is cut off.

If we try to pass an alternating current through the coil, the induced E.M.F. will always be in opposition to the applied E.M.F., and will consequently reduce the strength of the current which can be sent through the coil by any given applied alternating E.M.F. The property of the coil by virtue of which the induced E.M.F. is set up is called inductance, the unit of inductance being the henry. A circuit is said to have one henry inductance if, when a current is sent through it, which varies at the rate of one ampère per second, an induced E.M.F. of one volt is set up in the circuit.

The inductance is usually denoted by the symbol " L "

The value of the inductance depends upon :—

- (a) The kind of iron used for the core
- (b) The area of the cross-section of the core
- (c) The length of the core
- (d) The shape of the core—*i.e.*, whether straight or ring-shaped
- (e) The number of turns of insulated wire in the coil

The use of soft wrought-iron, instead of air or a non-magnetic material inside the coil, increases the strength of the

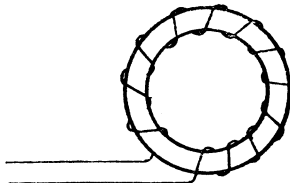


Fig. 17.

magnetic field about 2,000 times in the case of a closed ring core, thus (Fig. 17) :—the lines of force passing round the ring, and not through the air at all.

In a straight core, such as that shown in Fig. 15, the increase would not be so great, as the path for the lines of force is largely through the air and only partly through the iron. This property of conducting lines of force is called " permeability," and iron is said to have a greater permeability than air, because the lines of force pass more readily through iron. The permeability of all kinds of iron is not the same, and consequently, the inductance of a coil depends on the kind of iron used. It will be greatest with the iron of greatest permeability.

Now, the inductance of a coil **increases** with :—

- (a) an increase in the permeability of the core
- (b) an increase in the area of the cross section of the core
- (c) an increase in the number of turns in the coil and
- (d) it increases the more nearly the core approaches to a closed ring

The inductance **decreases** when the length of the path for the lines of force is **increased**, assuming that the material of the core remains the same. A longer path through iron might, however, be better than a very much shorter one through air.

The increase in inductance is proportional to the **square** of the number of turns of wire in the coil. That is, if we increase the number of turns to **twice** the original value, the inductance will be **four** times as great. If the number of turns is raised to **three** times, the inductance will be made **nine** times as great. This is because with a current varying at the rate of, say, one ampère per second, if we double the number of turns of wire in the coil, we shall double the number of lines of force flowing through the core at any given instant, but this increased number of lines of force will also have to pass through twice as many turns, consequently the induced E.M.F. will be multiplied by 2, owing to the doubling of the magnetic lines of force, and again by 2, owing to the doubling of the number of turns through which the magnetic lines pass.

The strength of the induced E.M.F. is proportional to the inductance L of the coil and to the rate at which the current supplied to the coil varies. Hence, the greater the frequency of the alternations of the current supplied to the coil, the greater will be the induced E.M.F. This induced E.M.F., being always in opposition to the E.M.F. of the source of the alternating current, impedes the flow of current through the coil, that is, it offers an "impedance" to the flow of current, this impedance being greater for currents of high frequencies than for those of low frequencies, as explained above.

The impedance of a coil of negligible ohmic resistance, *i.e.*, having a very small resistance for direct currents, is equal to  $2 \times \pi \times f \times L$  where

f = the frequency of alternation of the current, *i.e.*, the number of alternations per second

L = the inductance of the coil in henries

"f" for ordinary ringing currents .. = 17 per second,

for speech currents the representative

testing frequency .. .. = 800 ..

A coil having an inductance of one henry would therefore offer an impedance to ringing currents of

$$2 \times \pi \times 17 \times 1 = 107 \Omega$$

at a frequency of 800 p.p.s. (periods per second)

$$2 \times \pi \times 700 \times 1 = 5030 \Omega.$$

If the coil offers considerable resistance to direct currents, this must be taken into account in estimating the impedance, and the formula becomes

$$\text{Impedance} = \sqrt{R^2 + \omega^2 L^2} \text{ where } \omega = 2 \times \pi \times f.$$

Owing to various causes, which cannot be discussed now, the resistance of a coil to alternating currents is generally greater than that to direct currents apart from the effect of inductance. This resistance to alternating currents is called the effective resistance. R in the above formula is this effective resistance. One or two examples are given.

Apparatus.	Effective Resistance (ohms).	Inductance (henries).	Impedance (ohms).
Bell magneto 100 $\Omega$ .. ..	7580 ..	1.305 ..	11140
Receiver (double pole) 60 $\Omega$ ..	134 ..	.018 ..	175
Retardation coils (tubular) 600 $\Omega$	5906 ..	.890 ..	8132
Retardation coil 75 + 75 $\Omega$ ..	1827 ..	1.367 ..	8770

These values are for a frequency of 1,000 periods per second.

The value of making a piece of apparatus, such as a bridging coil or a magneto bell, highly inductive by giving it a large number of turns when such apparatus has to be kept across a telephone circuit while speech is passing, will therefore be clear, the inductive coil preventing much of the speech current leaking through it.

From the details given above, we may work out the impedance of a receiver.

$$R = 134 \Omega. \quad R^2 = 134 \times 134 = 17956.$$

$$L = .018 \text{ henry. } f = 1000 \text{ p.p.s.}$$

$$\omega = 2 \times \pi \times 1000 = 6300.$$

$$\omega L = 6300 \times .018 = 113.$$

$$\omega^2 L^2 = 113 \times 113 = 12769.$$

$$\therefore R^2 + \omega^2 L^2 = 17956 + 12769 = 30725.$$

$$\therefore \text{Impedance} = \sqrt{R^2 + \omega^2 L^2} = \sqrt{30725} = 175 \Omega.$$

If we know the E.M.F. of the alternating current supplied to a piece of apparatus and we know its impedance we can calculate the alternating current which will flow simply by dividing the E.M.F. by the impedance, as in the case of direct current, substituting impedance for resistance.

The magnitude of the impedance alone has been considered here. For further information the usual text books may be consulted.

It is sometimes required to use a bridging coil or a retardation coil differentially as shown in Fig. 18:—that is, we wish to pass a current (either alternating or direct) through the bridging coil in such a way that the latter will act for this current just like a simple resistance, but to alternating currents circulating round the loop, we want the bridging coil to offer a high impedance.

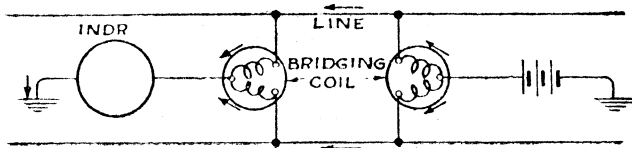


Fig. 18.

To effect this, the coil, whether with a straight core or a ring-shaped core, is wound with two wires side by side, so that they shall each have the same magnetic effect on the core, and they are then connected so that, if equal currents are sent through both coils at the same time, the core will not be magnetized. In this case, there will be no induced E.M.F., and the coil will have no inductance.

In Fig. 19, a core is shown with two windings, AB and CD. If a current is sent round AB in the direction of the arrow head,



Fig. 19.

*i.e.*, from A to B, the end X of the core would become a N. pole, and the end Y a S. pole, the lines of force running in the core from Y to X. Now suppose an equal current sent through the winding CD in the opposite direction, *i.e.*, from D to C. This current alone would make the Y end a N. pole and the end X a S. pole, *i.e.*, the lines of force would be in the opposite direction. Thus the two currents flowing together would try to produce equal magnetic fields in opposition to each other, and as a



consequence, the core would not be magnetized. An alternating current passed through the windings as in Fig. 20, would not encounter an induced E.M.F., and only the resistance of the wire itself would have to be overcome.

For a current flowing across from the A line to the B line, the path would be round the coil from terminal A to B across to terminal C and round the coil to D. That is, the current would now act in both coils in the same direction, and a magnetic field would be set up. An alternating current would thus meet an induced E.M.F. acting against it. That is to say, the coil in

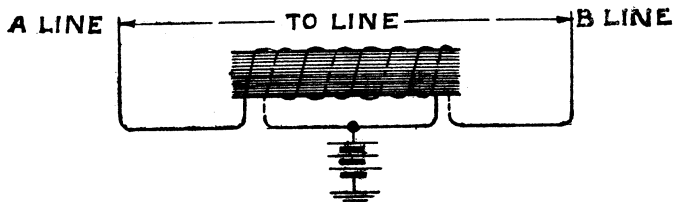


Fig. 20.

this case is inductive, and offers an impedance to the flow of the alternating current.

This is the principle of all differential windings. In the case of a relay, the non-production of a magnetic field in the core would mean that the relay would not be operated. It would be operated only when the current flowed through the coils in such a direction that the inductive properties of the coils became effective.

# LIST OF Technical Pamphlets for Workmen

(Continued)

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