THE AUSTRALIAN POST OFFICE

COURSE OF TECHNICAL INSTRUCTION

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MAGNETO TELEPHONES

INTRODUCTION.

1.1 How to study telephone circuits. A telephone circuit consists of -

(i) a speaking circuit containing a transmitter and receiver, by which you speak to and hear the person at the distant telephone, and

(ii) a signalling circuit by which you are called to the telephone and also obtain access to other telephones via the exchange.

Some circuits look complicated because they perform a number of functions, but the circuit operation is simplified when these functions are studied separately. When studying telephone circuits, therefore, it is convenient to separate the speaking and signalling circuits. In the speaking circuit, the transmitting and receiving conditions may be considered separately. In the signalling circuit, the incoming and outgoing signalling conditions may also be considered separately.

1.2 Although to Technicians, the circuit and its performance are important in the operation of a telephone and must be thoroughly understood, the form of the instrument is important to the subscriber. Two forms have been designed for general requirements - table telephones and wall telephones.

Although many modern telephones use the one type of case for magneto, C.B. manual and automatic table telephones, and another type of case for the magneto, C.B. manual and automatic wall telephones, the circuit and the operation of the corresponding table and wall models are similar.

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EARLY MAGNETO TELEPHONES.

1.3 Many different types of magneto telephones (sometimes called local battery telephones) have been used and some early types are shown on page 2. The types commonly used at present are in the 300 and the 400 series, and these are available in table and wall models.

1.4 Magneto telephones are identified by the code letters -

(i) MT for a Magneto Table Telephone,
(ii) MW for a Magneto Wall Telephone.

1.5 This paper describes the principle of operation of the early magneto telephones and also the modern handset magneto telephones which use the anti-sidetone induction coil.

2. BASIC SPEAKING CIRCUIT.

2.1 Simple one-way circuit. Fig. 1 shows a simple magneto telephone speaking circuit. The transmitter and battery are connected to the primary winding of the induction coil; the secondary connects to the line and distant receiver.

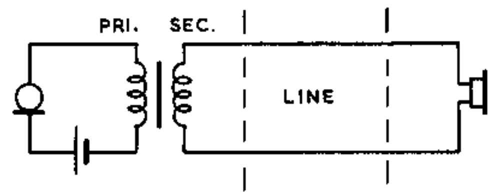


FIG. 1. MATCHED ONE-WAY SPEAKING CIRCUIT.

The functions of the induction coil in a magneto telephone are -

(i) To enable the transmitter to operate in a low resistance circuit. This reduces the battery voltage and, therefore, the number of cells required to supply the minimum D.C. (about 50 mA) for satisfactory transmitter operation. If the transmitter were connected directly to line, the resistance of the circuit would be very high (particularly on long lines) and too many cells would be required. In practice, the resistance of the primary winding is 1 ohm; the battery voltage is usually 3 volts, provided by two No. 6 dry cells in series.
(ii) To prevent D.C. flowing through the receiver coils. The D.C. would tend either to oppose and weaken the permanent magnet in the receiver or to saturate the magnetic circuit, depending on the direction of current. In either case, the efficiency of the receiver would be reduced.
(iii) To match approximately the transmitter impedance (about 60 ohms) to that of the line and distant receiver (about 600 ohms) for better transmitting efficiency.

2.2 The Induction Coil No. 12 (I.C.12) is a typical open magnetic circuit transformer used in early magneto telephones. It consists of two insulated windings -

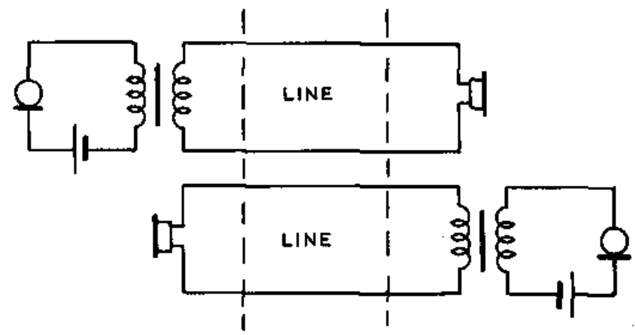
(i) A 1 ohm winding of 430 turns.
(ii) A 25 ohm winding of 1,350 turns.

This gives a transmitting primary to secondary turns ratio of about 1 : 3.

The core comprises a bundle of soft iron wires insulated from each other to reduce eddy current losses. Due to the open core, all the flux produced by the primary current does not cut or link the secondary winding. The efficiency of the induction coil is about 80%.

The open core, however, prevents saturation of the magnetic circuit due to the transmitter current in the 1 ohm winding. If magnetic saturation were to occur, variations in magnetising force (caused by the varying D.C. in the primary circuit) would not cause similar variations in the flux density. The alternating voltage induced across the secondary would not then follow the primary current variations, the induction coil would be very inefficient, and distortion would occur.

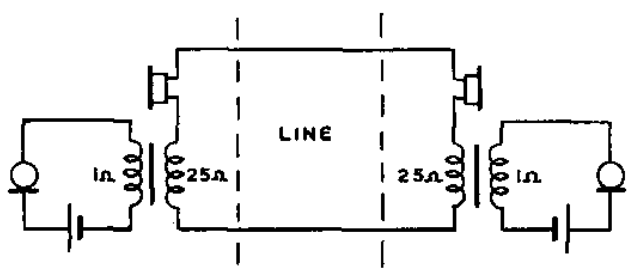
2.3 Two-way circuits. Telephone circuits must be two-way. This may be achieved by the circuit shown in Fig. 2. This is called a "four-wire circuit" because four wires or two pairs are used, one pair for each direction of transmission.



TWO-WAY SPEAKING CIRCUIT.

FIG. 2.

Four-wire circuits are costly as regards provision of lines, and a compromise is made between economy and efficiency by connecting the receivers in the secondary circuit to produce a two-wire circuit (Fig. 3).



BASIC MAGNETO SPEAKING CIRCUIT.

FIG. 3.

2.4 The circuit operation of Fig. 3 for either direction of transmission is as follows.

D.C. from the battery flows through the 1 ohm winding and the transmitter. When a person speaks into the transmitter, the transmitter resistance and, therefore, the D.C. in the primary circuit follows the frequency and amplitude variations of the sound waves.

The A.C. component of speech induced in the 25 ohm winding flows in a series circuit consisting of the local receiver, line conductors, and the receiver and 25 ohm winding at the distant telephone.

Speech signals are heard, therefore, in both the local receiver and the distant receiver.

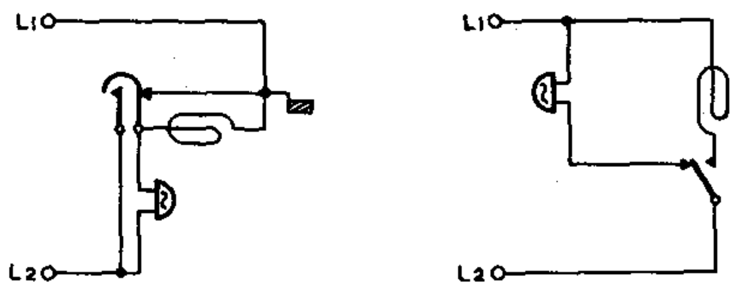
3. BASIC SIGNALLING CIRCUIT.

3.1 In the magneto telephone signalling circuit -

(i) the magneto bell provides an audible signal when the exchange rings the subscriber, and

(ii) the hand generator provides a calling signal to the exchange, when the subscriber wants to make a call, and a clearing signal when the subscriber has finished a conversation. The differentiation between the calling and clearing signals is provided by suitable connection of the apparatus at the exchange.

3.2 Two types of signalling circuit are used in magneto telephones (Fig. 4).



(a) Short-circuit type. (b) Open-circuit type.

MAGNETO SIGNALLING CIRCUITS.

FIG. 4.

Fig. 4a shows the arrangement in early type magneto telephones using the Generator No. 1. In the normal position, incoming A.C. ringing current energises the bell via the generator frame, shaft and contact assembly which short circuits the generator armature. When the generator handle is turned, the spring-set operates to short circuit the bell and the short-circuit is removed from the armature. The generator voltage is applied to line via the short-circuit on the bell.

Fig. 4b shows the arrangement in later type telephones. In the normal position, the bell is connected to the line and the generator armature is disconnected. When the handle is turned, the change-over spring operates to open the bell circuit and apply the generator voltage to line.

3.3 Reasons for Generator Spring-set. The hand generator "switching" or "cut-out" springs have two functions -

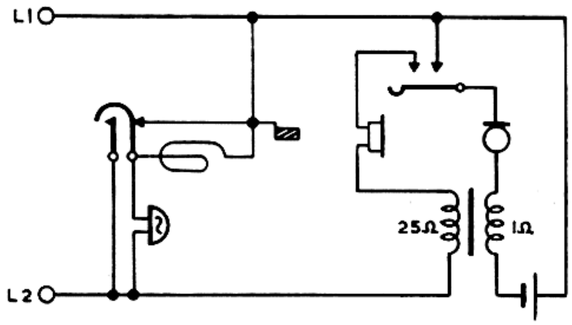
(i) When the telephone is not in use, they switch the generator armature out of circuit and connect the bell across the line. Thus, the impedance of the generator does not reduce the ringing current through the bell.

(ii) When the generator handle is turned, they switch the bell out of circuit and connect the armature across the line. Thus, the impedance of the bell does not reduce the ringing current sent to the exchange. This also prevents the local bell from ringing on outgoing calls and possibly annoying the calling subscriber.

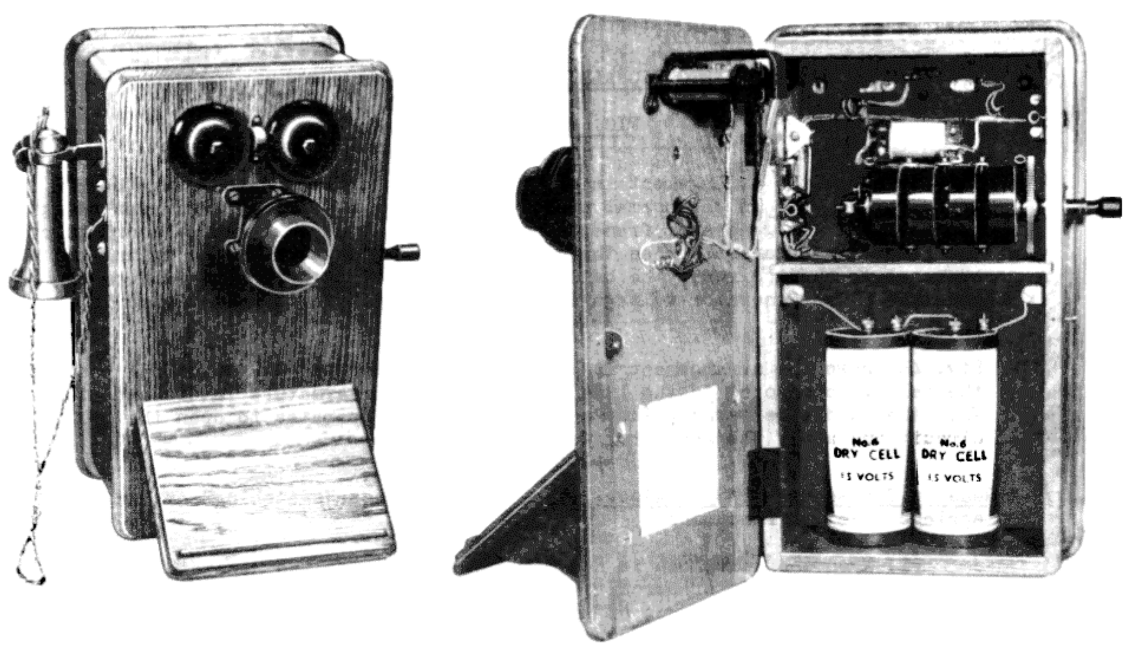
4. BASIC MAGNETO TELEPHONE.

4.1 For economy, the speaking and signalling circuits are combined so that their separate currents are transmitted to the exchange and distant telephone over the same pair of wires.

Fig. 5a shows the basic circuit used in the type 135 MW telephone (Fig. 5b) which is typical of the early type magneto telephones. The dry cells for the transmitter operation are mounted inside the telephone.



(a) Schematic Circuit.



(b) Telephone 135 MW.

BASIC MAGNETO TELEPHONE.

FIG. 5.

In Fig. 5a, the signalling circuit is connected permanently across the line but the speaking circuit is switched out of circuit by placing the receiver on the switch hook when the telephone is not in use or during signalling.

The switch hook operates a spring-set (the switch hook contacts) which performs two functions -

(i) Opens the transmitter circuit to prevent unnecessary current drain from the battery when the telephone is not in use.

(ii) Opens the receiver circuit to remove the shunt on the bell or generator during signalling.

The common electrical connection between the primary and secondary of the speaking circuit simplifies the wiring as it enables three switch hook contacts to be used instead of four.

4.2 Speaking circuit. During a conversation, the receiver is off the hook and the switch hook contacts close to complete the circuit for the transmitter and connect the receiver circuit to the line.

The bell is connected across the speaking circuit. Because of the high impedance of the bell (about 18,500 ohms at 1,000 c/s), it has no noticeable effect on the speaking circuit during either transmitting or receiving.

The speaking circuit operation is similar to that described for Fig. 3 (see paragraph 2.4) in which the primary and secondary circuits are separate.

4.3 Signalling circuit. To receive an incoming ring from the exchange, the switch hook contacts must be open to disconnect the low impedance of the receiver and 25 ohm induction coil winding from across the bell. Similarly, when signalling the exchange, the switch hook contacts must be open to disconnect the low impedance of the receiver and 25 ohm induction coil winding from across the generator armature.

The signalling circuit operation is similar to that described for Fig. 4a (see paragraph 3.2).

4.4 Testing. The basic magneto telephone circuit may be tested before installation by the following simple tests -

Generator Test.

(i) Turn the generator handle - it should turn freely.

(ii) Place a short-circuit on the line terminals - the generator handle should be hard to turn.

Bell Test. Open the generator cut-out make spring and with a short circuit on the line terminals, turn the generator - the bell should ring.

Speaking Test. Place a short circuit on the line terminals, lift receiver to your ear and blow or speak into the transmitter - sound should be heard in the receiver. If this test fails, the next test will prove the receiver circuit.

Receiver Test. Remove the short circuit from the line terminals, lift the receiver to your ear and turn the generator handle. Generator output should be heard in the receiver.

5. ANTI-SIDETONE INDUCTION COIL.

5.1 When sounds picked up by a telephone transmitter are reproduced by the local receiver, the effect is called sidetone. In the speaking circuit used in early magneto telephones, all the transmitted speech passes through and is heard as sidetone in the local receiver.

Excessive sidetone has two disadvantages -

(i) When a speaker hears his own voice too loudly in the local receiver, he tends to lower his voice. This decreases the amplitude of the sound in both the local receiver and the distant receiver, and is equivalent to reducing the transmitting efficiency.
(ii) Loud room or background noises tend to "mask" the received speech, making it difficult to hear and understand the person at the distant telephone. This is equivalent to reducing the receiving efficiency.

The elimination or reduction of sidetone is, therefore, equivalent to raising the transmitting and receiving efficiencies. In practice, it is not desirable to eliminate sidetone completely but merely to reduce it, because many people gauge the efficiency of a telephone by the presence of sidetone.

The early transmitters and receivers were relatively inefficient and did not produce excessive sidetone. However, improvements in transmitters and receivers caused a corresponding increase in sidetone, and anti-sidetone circuits were developed to reduce this effect. All modern telephones use an anti-sidetone induction coil, abbreviated to A.S.T.I.C.

5.2 The principle of operation of the magneto telephone A.S.T.I.C. circuit is explained from Figs. 6 and 7, which show the conditions at a particular instant. For the other half cycle of speech, the conditions reverse.

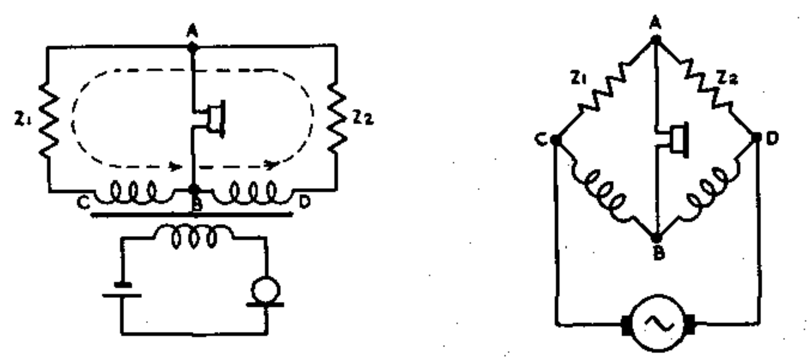
The A.S.T.I.C. circuit is similar to the basic speaking circuit with the addition of an extra winding on the induction coil and a balance network.

For simplicity of explanation, it is assumed that -

(i) the CB and BD windings connected in series, have equal turns and resistance, and
(ii) the impedance (Z_1) of the line and distant telephone equals the impedance (Z_2) of the balance network fitted in the telephone (600 ohms).

Transmitting (Fig. 6a). When a person speaks into the transmitter, the A.C. component of speech induced in the CD winding flows through the balance network (Z_2) and over the line and distant telephone (Z_1).

The turns ratio of the induction coil windings helps to match the transmitter to the load which consists of Z_1 and Z_2 in series.



(a) (b)

OPERATION OF A.S.T.I.C. (TRANSMITTING).

FIG. 6.

Sidetone Suppression. Fig. 6b is an equivalent simplified "bridge" circuit of Fig. 6a. The alternating voltage induced across the CD winding when the transmitter is operated by sound waves, exists also across the load.

As point B is the mid-point of the CD winding and point A is the mid-point of the load impedance, points A and B, at all times, have the same potential. As the receiver is connected between these points, no sidetone is heard.

Receiving (Fig. 7). Alternating speech currents from line flow through the receiver and CB winding.

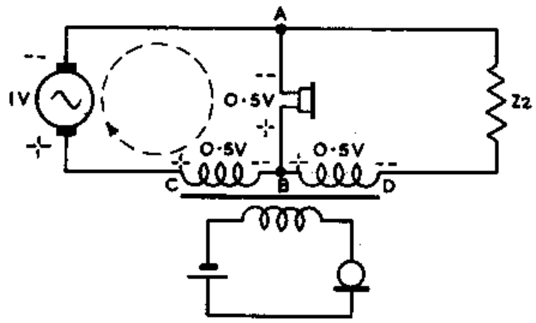


FIG. 7. OPERATION OF A.S.T.I.C. (RECEIVING).

Although it would appear that a large portion of the speech current flows through the balance network, this is not so. The alternating magnetic flux produced by the CB winding sets up an e.m.f. of mutual induction across the BD winding, the polarity of which tends to oppose any current through the network.

Under certain conditions (for example, when the receiver impedance equals the impedance offered by the CB winding, the CB and BD windings have equal turns and the induction coil is 100% efficient), the voltage across the CB winding and, therefore, the e.m.f. induced in the BD winding equals the P.D. across the receiver. Fig. 7 shows the polarities at a particular instant for an applied e.m.f. of 1 volt.

The balance network is then connected to points A and D which, at all times, have the same potential. Thus, no incoming speech currents flow through the network and all pass through the receiver.

Compared with the basic speaking circuit, therefore, this basic anti-sidetone circuit eliminates sidetone when transmitting but does not reduce the receiving efficiency.

It is interesting to note that when the circuit to the balance network is open, the transmitting and receiving efficiencies are not appreciably altered but there is no reduction in sidetone.

5.3 In modern magneto telephones, the A.S.T.I.C. is designed for satisfactory transmitting and receiving efficiencies and sidetone suppression.

In practice, the optimum ratio of turns of the three windings and the impedance provided by each, differ for each function; for example, if the A.S.T.I.C. is designed for maximum transmitting efficiency, it may not necessarily give satisfactory receiving efficiency or sidetone suppression. Also, the line impedances to which the telephone may be connected vary considerably depending on the primary constants, lengths and types of lines; also both the line and receiver impedances vary over the V.F. range.

In the practical design of A.S.T.I.C's, therefore, it is necessary to adopt a compromise which gives satisfactory performance for each condition of operation. As a result, a number of different A.S.T.I.C's have been used, each development giving some degree of improved performance compared with the earlier types, but they are all basically similar in operation to the arrangement described in paragraph 5.2.

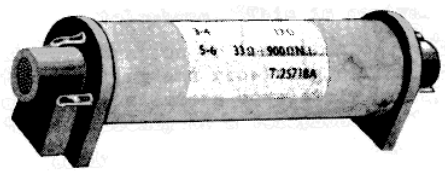
A typical coil is the A.S.T.I.C. No. 21A used in 300 series telephones.

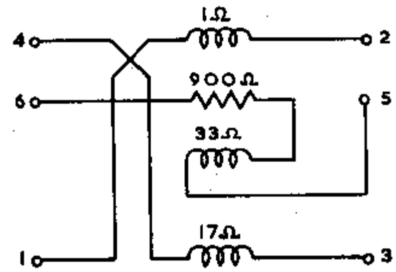
5.4 The A.S.T.I.C. No. 21A (Fig. 8) has four windings -

(i) A 1 ohm "transmitter" winding of 400 turns.
(ii) A 17 ohm "line" winding of 1,000 turns.
(iii) A 33 ohm "balance" winding of 1,500 turns.
(iv) A 900 ohm non-inductive resistance.

The core comprises a bundle of soft iron wires insulated from each other to reduce eddy current losses.

The open core prevents saturation of the magnetic circuit due to the transmitter current in the 1 ohm winding.

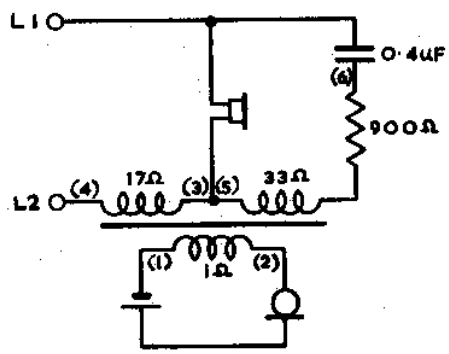




A.S.T.I.C. No. 21A.

FIG. 8.

5.5 The speaking circuit operation is similar to that described in paragraph 5.2 and can be developed from Fig. 9 which shows the basic connections.



ANTI-SIDETONE SPEAKING CIRCUIT.

FIG. 9.

One important difference is that the A.S.T.I.C. No. 21A has more turns on the "balance" than on the "line" winding. The reason for this is as follows -

Due to the open magnetic circuit, all the flux produced by the 17 ohm "line" winding by incoming speech currents does not cut all the turns of the 33 ohm "balance" winding. Thus, for equal turns, the e.m.f. induced in the 33 ohm winding would be less than the P.D. across the receiver. The balance network would not be connected to points of equal potential and it would shunt some incoming speech current from the receiver thus lowering the receiving efficiency. The increase of turns raises the induced e.m.f. in the 33 ohm winding to equal, approximately, the P.D. across the receiver.

The increased turns would unbalance the circuit and produce excessive sidetone when transmitting, and to compensate for this, the impedance of the balance network is similarly increased, compared with the impedance of the line and distant telephone.

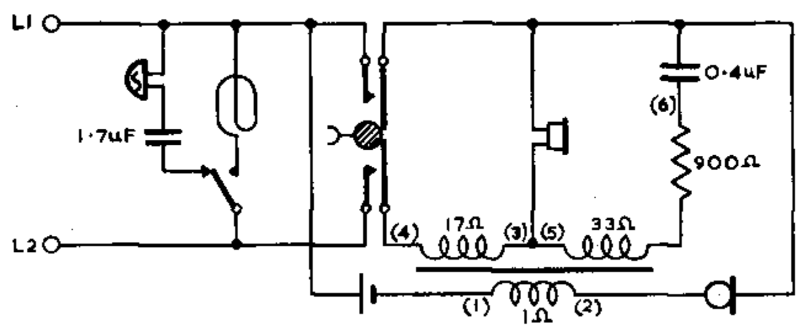
To keep sidetone to a minimum over the V.F. range, the impedance of the balance network must vary with frequency in the same manner as the impedance of the line and distant telephone. In an attempt to simulate the variation in line impedance, which decreases as the frequency rises, a capacitor is connected in the balance network.

The balance network consists of the 900 ohm N.I.R. in series with an 0.4 μF capacitor.

In practice, this anti-sidetone circuit does not entirely eliminate sidetone because it is impossible to maintain a perfect impedance balance between the balance network and the different types of telephone lines used, over the V.F. range. However, compared with the earlier circuits, it greatly reduces the sidetone, without any noticeable effect on the efficiency of the speaking circuit.

5.6 To produce a practical telephone circuit (Fig. 10), a magneto bell, hand generator and cradle switch contacts are added to the anti-sidetone speaking circuit.

The signalling circuit operation is similar to that described for Fig. 4b (see paragraph 3.2).



SIMPLIFIED CIRCUIT OF 300 SERIES MAGNETO TELEPHONES.

FIG. 10.

5.7 The 1.7 μF capacitor in series with the bell allows the ringing current to pass through and operate the bell, but ensures that a D.C. circuit is not provided when the telephone is not in use. Under certain conditions (for example, a call from a subscriber connected to an automatic exchange to a subscriber connected to a magneto exchange within the same unit fee area), this D.C. circuit is used to provide for the metering of the call against the calling subscriber (automatic) when the called subscriber (magneto) removes the handset from the cradle switch to answer the call.

6. 300 SERIES TELEPHONES.

6.1 Some of the telephones in this series are -

(i) The types 334 MT and 338 MT, developed in England.
(ii) The types 300 MT and 300 MW, developed by the Australian Post Office.

The general appearance of the table telephones is similar, and the main difference is in the construction and layout of the component parts. For example, the type 334 telephone uses a type C hand generator mounted on the chassis, but the type 300 telephones use the A.P.O. generator mounted on the case. (Fig. 11.) The schematic circuit and the operation of the table and wall telephones are similar.

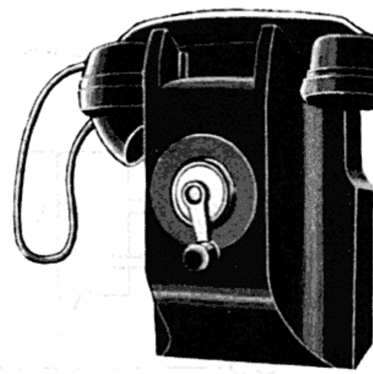
6.2 Both table and wall instruments are made up of two units -

(i) A moulded case containing a 1,000 ohm bell, A.S.T.I.C. No. 21A, 1.7 µF and 0.4 µF capacitors (in the one metal can), cradle switch contacts and hand generator.

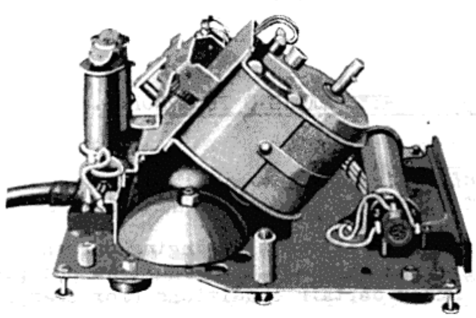
(ii) A handset No. 164 or No. 184 containing the transmitter No. 13, and either a type 1L or 2P receiver. A cord 3306 connects the handset to the case.

In the table models, the exchange line and the connections to the dry cell battery (mounted in a battery box) terminate on a terminal block No. 20/4 which is connected to the case by a cord 3406. In the wall telephone, the exchange line and the local battery connect directly to terminals inside the case.

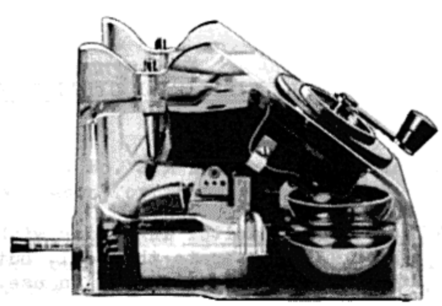
(a) Magneto Table Telephone.



(b) Magneto Wall Telephone.



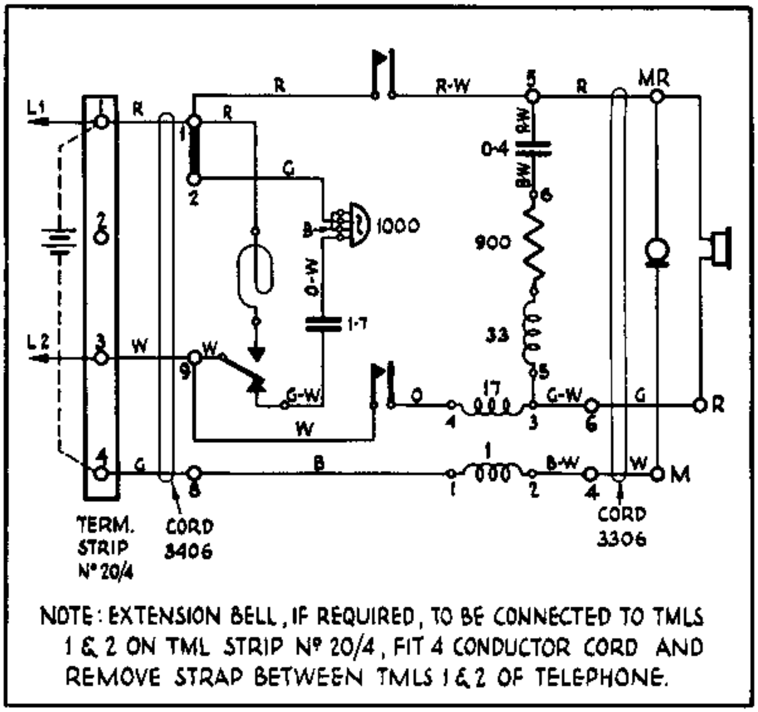
(c) Internal View of 334 MT.



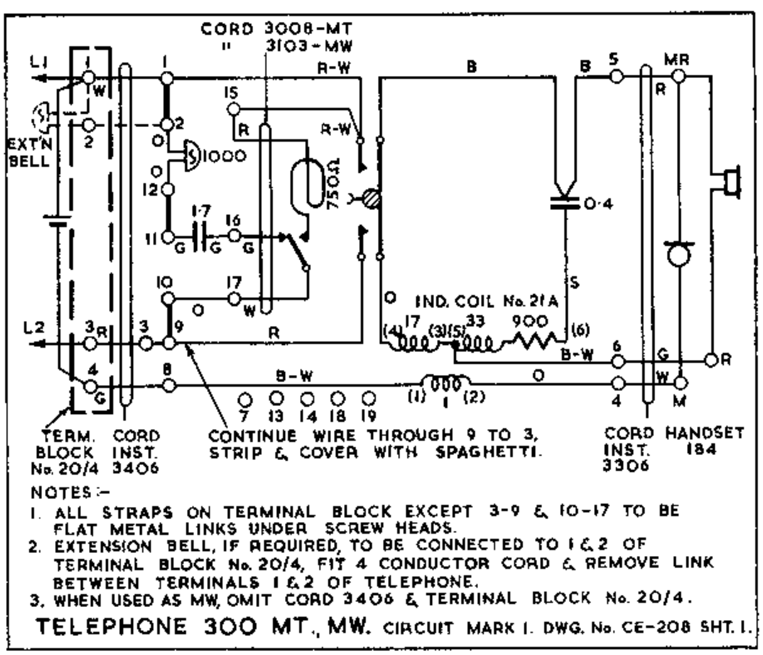
(d) Internal View of 300 MT.

FIG. 11. TYPICAL 300 SERIES HANDSET TELEPHONES.

6.3 Fig. 12 shows typical schematic circuits for the types 334 and 300 telephones. These circuits are similar in operation to the anti-sidetone magneto telephone circuit developed in Section 5.



(a) 334 MT Telephone.



(b) 300 MT and 300 MW Telephones.

FIG. 12. SCHEMATIC CIRCUITS OF 300 SERIES TELEPHONES.

7. 400 SERIES TELEPHONES.

7.1 The 400 series telephone will in future, be the standard telephone used by the Australian Post Office. This telephone uses a rocking armature receiver which is superior, both in volume efficiency and frequency response, to receivers previously used. It also uses a more efficient A.S.T.I.C., designed to raise the transmitting efficiency of the circuit at the expense of some of the increased receiving efficiency.

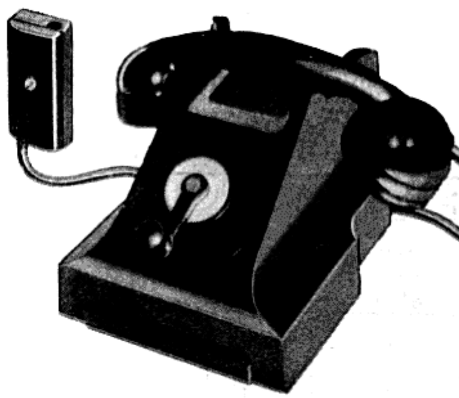
Because of the increased transmitting and receiving efficiencies, these telephones will give a better performance with existing lines than the equivalent 300 series telephones. Alternatively, for similar performance, they can be used on longer lines or smaller gauge wires.

7.2 A typical telephone in this series is the 400 MT (Fig. 13), which is made up of two units -

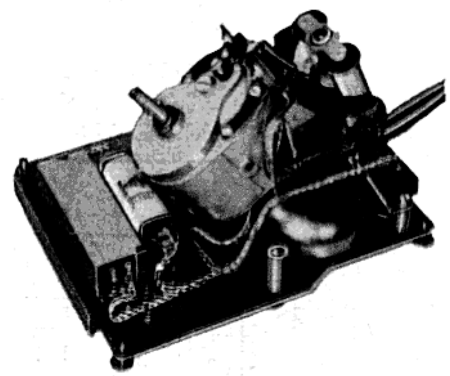
(i) A moulded case containing a 1,000 ohm bell, A.S.T.I.C., 1.7 μF and 0.3 μF capacitors (in the one metal can), cradle switch contacts and hand generator.

(ii) A handset No. 400 containing the transmitter No. 13 and rocking armature receiver.

The exchange line and the connections to the dry cell battery (mounted in a battery box) terminate on a terminal block No. 20/4 which is connected to the case by a cord 4406; and a cord 3306A connects the handset to the case.



(a)



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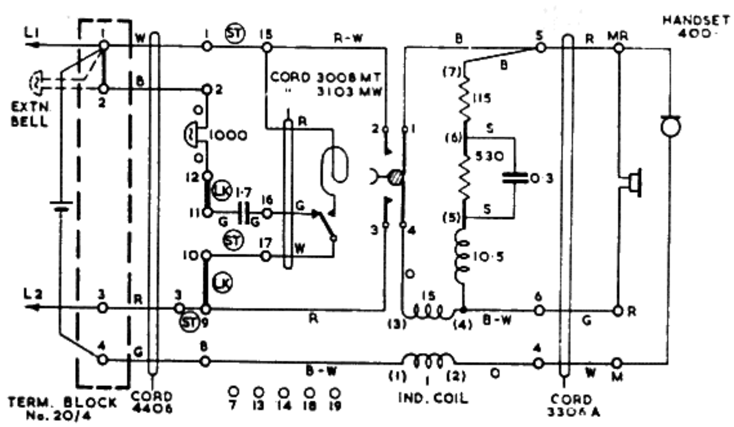
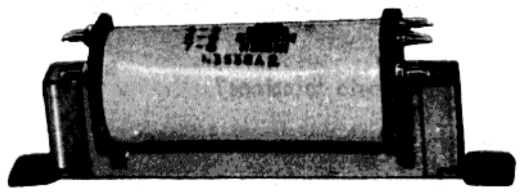


(c) Routed Schematic Circuit.

FIG. 13. TYPICAL 400 SERIES HANDSET TELEPHONE.

7.3 The A.S.T.I.C. has five windings (Fig. 14) -

(i) A 1 ohm "transmitter" winding of 250 turns.
(ii) A 15 ohm "line" winding of 800 turns.
(iii) A 10.5 ohm "balance" winding of 463 turns.
(iv) A 530 ohm non-inductive resistance.
(v) A 115 ohm non-inductive resistance.



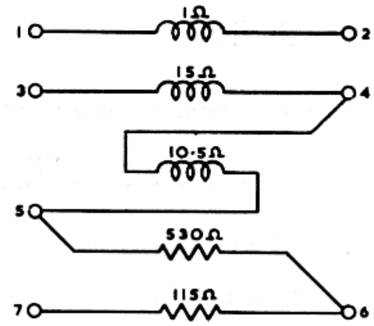


FIG. 14. A.S.T.I.C. USED IN 400 SERIES MAGNETO TELEPHONES.

The silicon iron core is built up in two sections, each L-shaped and laminated to reduce eddy current loss. A spacer provides a small gap in the magnetic circuit to avoid saturation by the transmitter current. The higher permeability of the core material and lower reluctance of the almost closed magnetic circuit enables the use of fewer turns on each winding than are required when the magnetic circuit includes a large air path, as in the A.S.T.I.C. No. 21A. Thus, the higher overall efficiency of the A.S.T.I.C. is the result of reduced magnetic and copper losses.

7.4 The speaking circuit operation is similar to that described in paragraph 5.2 and can be developed from Fig. 15 which shows the basic connections to the A.S.T.I.C.

Owing to the improved efficiency of the speaking circuit compared with the 300 series telephones, the balance network (comprising the 530 ohm and 115 ohm N.I.R's. wound on the A.S.T.I.C., and the 0.3 µF capacitor) is designed to balance more accurately the line impedance variation to ensure satisfactory sidetone suppression over the V.F. range.

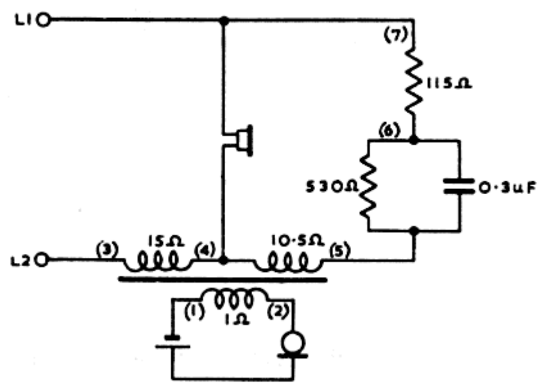


FIG. 15. ANTI-SIDETONE SPEAKING CIRCUIT.

7.5 To produce a practical telephone circuit, a magneto bell, hand generator and cradle switch contacts are added to the anti-sidetone speaking circuit as in Fig. 16. The signalling circuit operation is similar to that described for Fig. 4b (see paragraph 3.2).

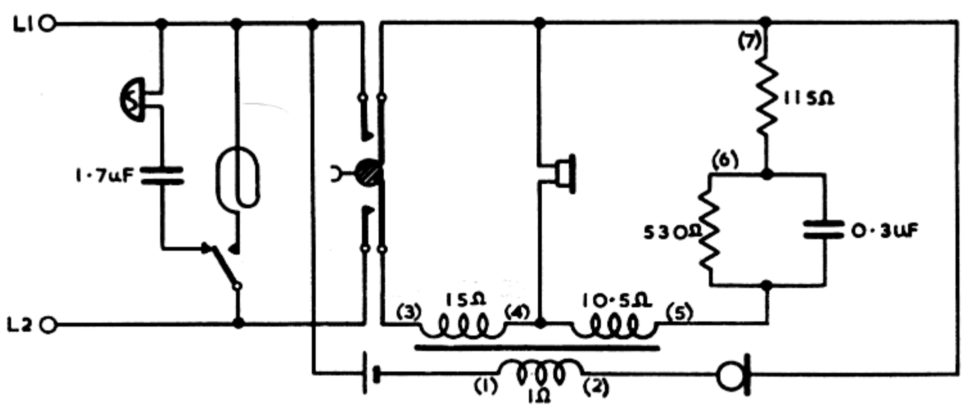


FIG. 16. SIMPLIFIED CIRCUIT OF 400 SERIES MAGNETO TELEPHONES.

8. TEST QUESTIONS.

1. What is meant by the code letters MT, MW, when applied to telephones?
2. Draw a simple two-wire magneto speaking circuit using a two-winding induction coil, and explain the circuit operation during transmitting and receiving.
3. What are the functions of the induction coil in a magneto telephone?
4. What are the functions of the hand generator spring-set?
5. Draw the basic magneto telephone circuit and explain the speaking and signalling circuit operation.
6. Why are switch hook (or cradle switch) contacts necessary in a magneto telephone?
7. What is sidetone? State the advantages to be gained by its reduction in a telephone circuit.
8. Explain how a simple three-winding induction coil can be used to reduce sidetone.
9. What is a necessary requirement of the balance network for satisfactory reduction of sidetone?
10. Draw the schematic circuit of a magneto telephone in which an A.S.T.I.C. is used, and explain its operation for each of the following conditions -

    (i) transmitting speech,

    (ii) sidetone suppression,

    (iii) receiving incoming speech,

    (iv) receiving an incoming ring,

    (v) ringing the exchange.
11. What are the functions of the 1.7µF and 0.4µF capacitors in a 300 series magneto telephone?
12. What are the main differences in construction between the A.S.T.I.C. No. 21A and the A.S.T.I.C. used in the 400 series telephones.
13. Why is the speaking circuit of the 400 series telephones more efficient than that of the 300 series telephones?

END OF PAPER.