COURSE OF TECHNICAL INSTRUCTION

TELEPHONY I

Engineering Training Section, Headquarters, Postmaster-General's Department, Melbourne C.2

THE AUSTRALIAN POST OFFICE

COURSE OF TECHNICAL INSTRUCTION

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TELEPHONY 1.

ISSUED 1959

Contents:—

SOUND WAVES

1. WHAT IS SOUND?

1.1 Human beings have senses of sight, touch, hearing, taste and smell, by which we can detect events taking place about us. Each sense is associated with a particular area of the brain. For example, when light is applied to the eyes, the optical nerves transmit that stimulus to the area associated with the sensation of seeing, or sight. The stimulus which produces the sensation of hearing is called sound. When sound is applied to the ears (or to the bones of the head behind the ears), the auditory nerves transmit that stimulus to the part of the brain associated with the sensation of hearing. Fundamentally, sound is what we hear.

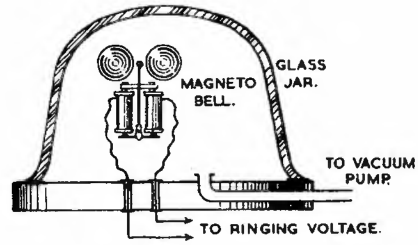
1.2 Musical and speech sounds usually originate from some form of mechanical vibration, which sets up corresponding vibrations in the air and other surrounding objects.

1.3 This paper gives us a general knowledge of the nature of sound, speech and hearing, and helps us understand Telephony, in which the relation between sound and electricity is very important.

2. HOW SOUNDS ARE TRANSMITTED.

2.1 The Transmitting Medium. Sounds are usually carried or transmitted from one point to another through air, but they may be transmitted to varying degrees through any solid, liquid or gas. Unlike light and radiant heat, sounds cannot be transmitted through a vacuum.

For example, Fig. 1 shows a magneto bell in the sealed glass jar connected to a vacuum pump. The sound from the bell is transmitted through the air inside the jar, through the glass walls of the jar, and then through the air outside the jar to our ears. As the air is exhausted from the jar by the operation of the pump, the sound gradually becomes fainter and finally ceases. The bell is still vibrating but there is no longer any air around it to transmit the sound. When the air is gradually admitted again, the sound returns. This experiment also shows that the loudness of the sound depends on the density of the air.



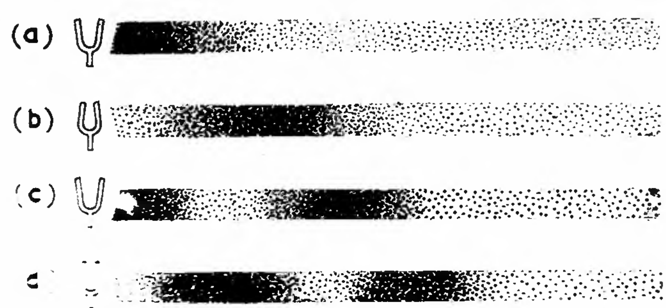
SOUND NEEDS A TRANSMISSION MEDIUM.

FIG. 1.

2.2 The Tuning Fork is a simple example to show how sound is transmitted through air. When the fork is "struck", the prongs vibrate rapidly and vary the air pressure in their immediate vicinity. This sets up, in the adjacent air particles, a series of alternate compressions (pressures greater than normal) and rarefactions (pressures less than normal) which travel outwards in all directions from the source.

For example, in Fig. 2a, the prong of the fork advances swiftly and compresses the air particles immediately in front of it. The energy of the compression is transmitted to neighbouring particles and moves outwards. The prong then recedes (Fig. 2b) and leaves behind it a rarefaction or partial vacuum. While the compression and rarefaction are being transmitted, the prong again advances (Fig. 2c) and compresses the air particles. The prong recedes again (Fig. 2d) and produces a further rarefaction.

In Fig. 2, the denser sections represent compression, and the lighter sections, rarefaction. For simplicity, only a narrow strip section is shown, but it is important to know that all the air around the prongs is similarly affected.



TRANSMISSION OF SOUND.

FIG. 2.

2.3 Movement of particles. Vibrating objects cause the particles of the transmitting medium to move backwards and forwards about their normal or rest positions in line with the direction in which the sound is travelling. In Fig. 2, the air particles at the immediate right-hand side of the right-hand prong move to the right at (a), to the left at (b), to the right at (c), and so on. The greater the movement of the fork prong, the greater the displacement of the individual air particles.

In practice, the distances moved are quite small, ranging from much less than one millionth of an inch for barely audible sounds to about one thousandth of an inch for very loud sounds in air. The distances moved in liquids and solids are much smaller, because their molecules are spaced much closer than those of gases. This means that a molecule of a liquid or a solid does not move as far as that of a gas without colliding with some other molecule, in which collision the energy possessed by the first molecule is transferred to the second molecule.

2.4 Velocity (or speed). Examples of the velocity of sound are seen in everyday life. Thunder always follows lightning although both occur together at the source. The crack of a bat hitting a cricket ball is often heard after the hit is seen. The sound of an explosion takes some time to reach a distant observer.

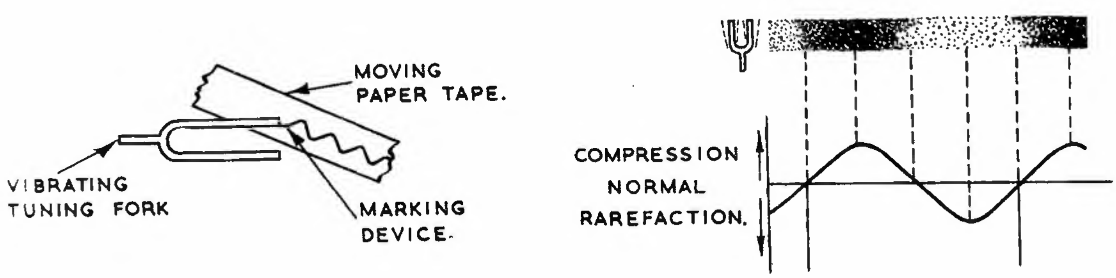
The velocity of sound depends on the nature and temperature of the transmitting medium. For example -

(i) In air, sound travels at about 1,120 feet per second, (765 miles per hour), at 15°C. The velocity increases (or decreases) about 2 feet per second for every 1°C rise (or fall) of temperature. Thus, the velocity is about 1,090 feet per second at 0°C.

(ii) In water, the velocity is about 3,200 miles per hour.

(iii) In most metals, the velocity varies from about 8,000 to 11,000 miles per hour.

2.5 Graphical representation. For convenience, sound vibrations are usually drawn as graphs. For example, if the vibrations of a tuning fork prong are traced on a moving paper tape (Fig. 3a), the trace is a sine curve, that is, the graph of the sine ratio of an angle as it varies from 0° through all angles to 360°. Similarly, the varying degrees of compression or rarefaction of the air particles may be indicated by a graph drawn above or below a reference line which represents the normal air pressure (Fig. 3b).



(a) (b)

GRAPH OF SOUND WAVES.

FIG. 3.

From the shape of these graphs, the term Sound Wave is applied to the successive compressions and rarefactions in the transmitting medium.

2.6 Attenuation. (Fig. 4). As the distance from the source of a sound is increased, the loudness (or amplitude of the sound wave) quickly decreases until the sound is inaudible some distance from the source. This effect is called Attenuation, and the sound is said to be attenuated as it progresses outwards from the source. The attenuation or loss of energy is caused by dispersion of the sound waves and by frictional losses in the transmitting medium.

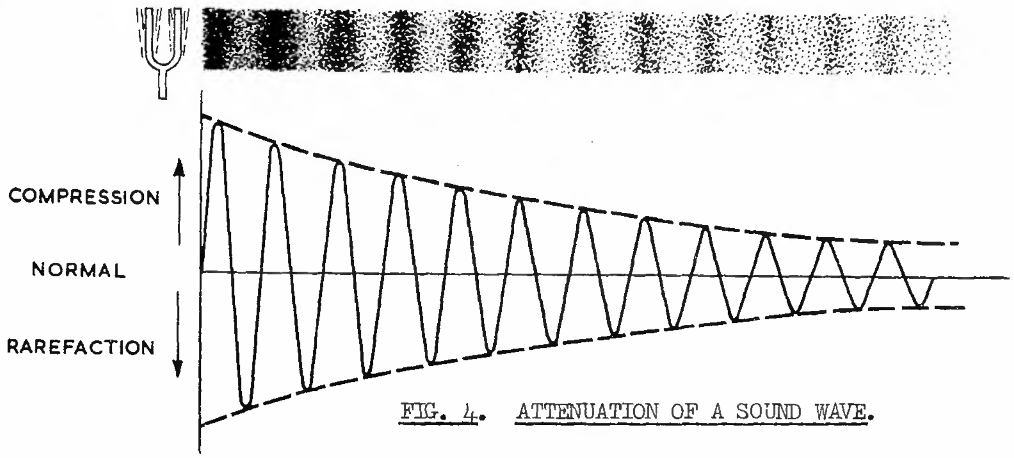


FIG. 4. ATTENUATION OF A SOUND WAVE.

2.7 Reflection and Echoes. When sound waves travelling through air strike any obstruction such as a wall, hill, etc., some of the sound continues to travel through the obstruction, and the remainder is reflected back. Thus, a person may often hear the same sound via the direct path and also the indirect or reflected paths. When heard separately from the direct sound, the reflected sounds are called echoes.

3. VOLUME, PITCH AND TIMBRE.

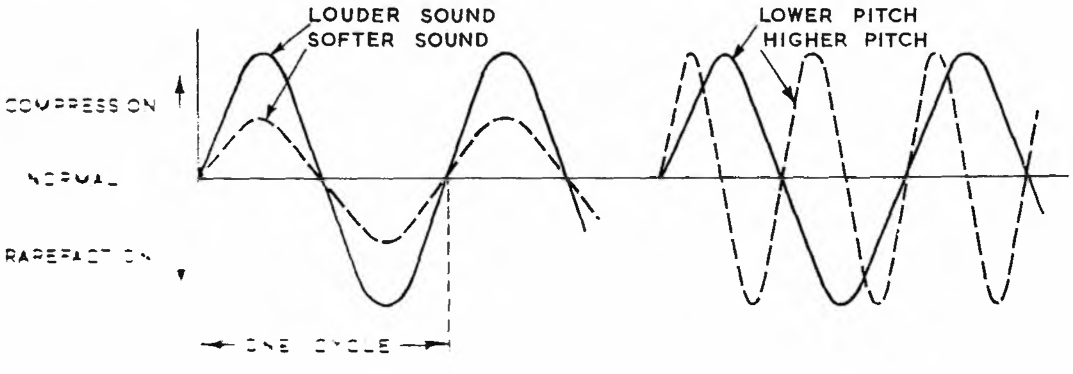
3.1 Sound waves have three important characteristics -

(i) Volume, that is, whether the sound is loud or soft.

(ii) Pitch, that is, whether the sound is high or low.

(iii) Timbre, or the distinctive quality of the sound.

3.2 The volume, loudness or intensity of a sound is determined by the amplitude of the vibrations made by the vibrating body. This affects the distance each particle of the transmitting medium is displaced from normal, or the extent to which the medium is compressed and rarefied above and below its normal value. (Fig. 5a).



(b)

FIG. 5. [illegible] VOLUME AND PITCH.

3.3 The pitch of a sound is determined by the number of vibrations per second made by the vibrating body, and, therefore, by the number of complete waves per second transmitted by that body.

For example, Fig. 5a compares the graphs of sounds of differing volume but the same pitch; and Fig. 5b compares sounds of the same volume but of differing pitch (or frequency).

3.4 Referring to Fig. 5 -

A cycle is the term given to one complete wave of compression and rarefaction.

The frequency of the sound is the number of cycles produced each second (abbreviated to c/s.). Increasing the number of vibrations increases the frequency and raises the pitch. In Fig. 5b, the higher pitch sound is twice the frequency of the lower pitch sound.

The period is the time taken for one cycle. Thus, for a frequency of 1000 c/s -

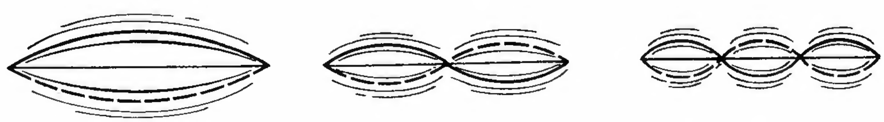
$$\text{the period} = \frac{1}{1000} \text{ second.}$$

The wavelength, usually denoted by the Greek letter λ (Lambda), is the distance occupied by one complete cycle; it can be expressed in any unit of length. Thus, for a frequency of 1,000 c/s, the wavelength in air (at 15°C) -

$$\lambda = \frac{\text{velocity}}{\text{frequency}} = \frac{1120 \text{ feet per second}}{1000 \text{ cycles per second}} = 1.12 \text{ feet.}$$

3.5 Quality or Timbre (a French word meaning "tone colour") is that characteristic which distinguishes sounds of the same pitch and volume.

The reason for differences in quality is seen from a long string or wire which is stretched tight and then plucked with the finger (Fig. 6). When it vibrates as a whole, the wire produces its fundamental note. But when touched in the middle while vibrating, either section vibrates twice as fast and the higher pitched note is called an overtone or harmonic. When the string vibrates in two parts, it produces a second harmonic; in three parts, a third harmonic; and so on.



(a) Fundamental. (b) 2nd Harmonic. (c) 3rd Harmonic.

PRODUCTION OF TONES BY VIBRATING STRINGS.

FIG. 6.

A vibrating object may produce a fundamental note and harmonics simultaneously. The fundamental frequency determines the pitch of the sound, and is the same for different musical instruments playing the same note. The harmonics, when added to the fundamental, vary the quality of the sound. For example, we can distinguish between different musical instruments playing the same fundamental note because the number and the relative strengths of the harmonics produced by each, are different.

4. ANALYSIS OF SOUND WAVEFORMS.

4.1 Sound waves can be divided into two types -

(i) Sine waves, which are the simplest form, and are referred to as a pure sound.
(ii) Non-sinusoidal or complex waves.

Very few sounds have the pure sine wave formation of a tuning fork vibration. Some typical waveforms are shown in Fig. 7. Although the complex waveforms are not sinusoidal, they are regular, that is, each curve is repeated again and again. The difference between a musical note and a noise is that the musical note contains a repetition of a waveform but a noise has no recurring waveform.

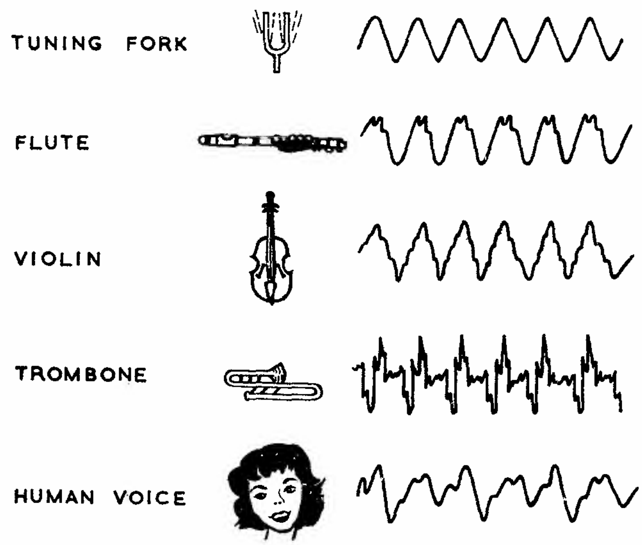


FIG. 7. SOME TYPICAL WAVEFORMS.

4.2 All recurring complex waves are made up of two or more sine waves of different frequencies. The lowest frequency is the fundamental frequency, and this is the frequency of the complex wave. The other sine wave components are harmonic frequencies, because their frequencies are multiples or harmonics of the fundamental. The multiple which is twice the fundamental frequency is called the second harmonic frequency, and so on.

4.3 The shape of any complex wave depends on -

(i) The number of components and their frequencies.
(ii) The relative amplitudes of the components, and
(iii) The phase relationship between the components.

For example, in Fig. 8, the fundamental frequency (and, therefore, the pitch of the sound) is the same in each case, but the resultant waveform (and, therefore, the quality of the sound) is varied by harmonics of different frequency, amplitude, and phase relationship.

For example, Fig. 8a shows a complex wave composed of a fundamental and second harmonic.

Fig. 8b shows the resultant waveform when a third harmonic is added to the same fundamental.

Fig. 8c shows the effect when the amplitude of the harmonic frequency is reduced.

Fig. 8d shows the effect of varying the phase relationship between the components. For example, comparing Fig. 8d with Fig. 8c, the position of the second harmonic has been shifted (or varied in phase) with respect to the fundamental.

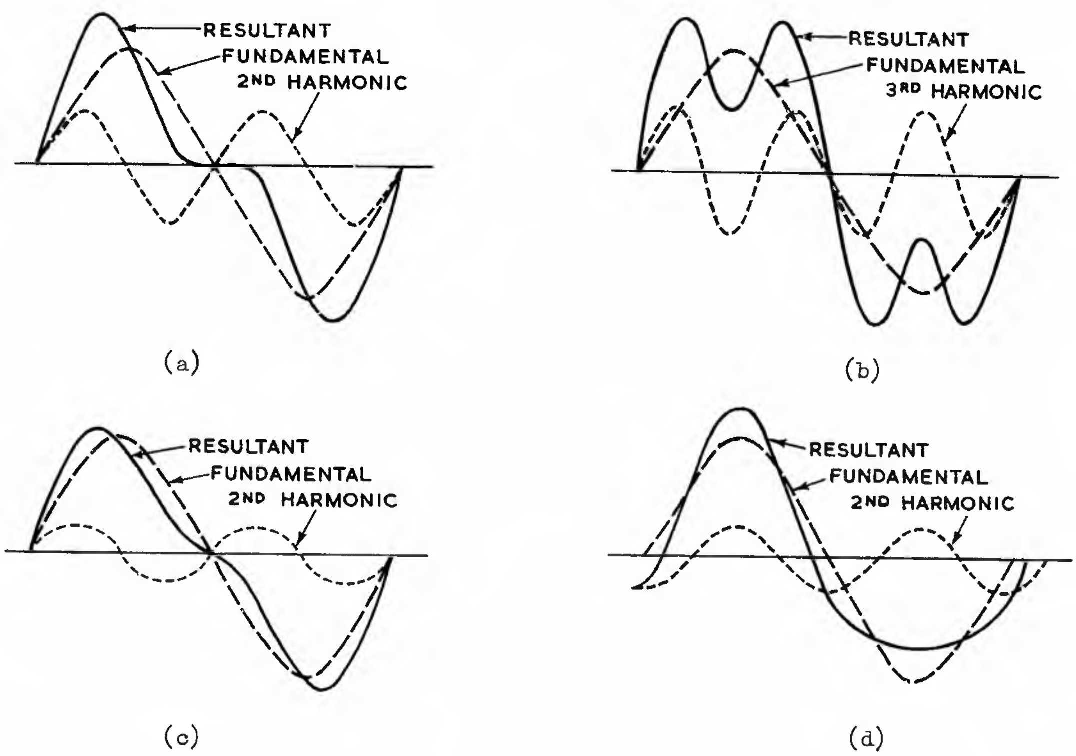


FIG. 8. ANALYSIS OF COMPLEX WAVES.

4.4 Distortion. Any change (other than in overall amplitude due to, perhaps, attenuation) in the shape of the original sound waveform as it passes from one point to another, is called distortion.

Distortion affects the quality of the received sound and may be caused by any alteration in the three factors which affect the waveform. In extreme cases of distortion, the received sound may be quite unintelligible.

4.5 Resonant frequency. When a tuning fork is struck, it immediately vibrates at the particular frequency for which it has been designed. This is called the natural or resonant frequency of the fork.

If the fork prongs are at rest and placed in the path of a sound wave which has the same frequency as the resonant frequency of the fork, the prongs will vibrate at this frequency. The fork will not vibrate at other frequencies except when the amplitude of the sound wave applied to it is very large, and then only slightly, unless perhaps the sound is exactly half or twice the resonant frequency of the fork.

Similarly, all objects, including enclosed volumes of air, have natural or resonant frequencies at which they vibrate most readily. The resonant frequency of such objects as transmitter and receiver diaphragms, etc., must be considered in the operation of telephone apparatus.

When any object continues to vibrate of its own accord for some considerable time after the energising source has been removed, the emitted sound wave is said to be undamped, but when the amplitude of vibration is quickly reduced, generally by mechanical means, the sound wave is damped.

5. SPEECH AND HEARING.

5.1 The human vocal organs (Fig. 9) consist of -

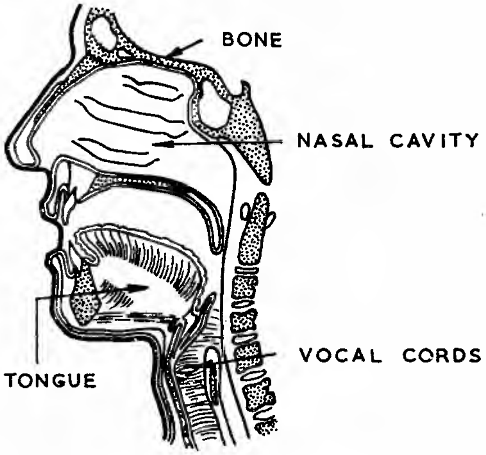


FIG. 9. HUMAN VOICE ORGANS.

(i) the lungs and respiratory muscles, which provide a flow of air;
(ii) the larynx, containing the vocal cords;
(iii) the throat, mouth and nasal cavities.

When a stream of air passes through them from the lungs, the vocal cords vibrate and produce a sound wave. By varying the shape and also the width of the narrow slit they form across the air passage to the throat, the vocal cords are made to vibrate at different frequencies, so varying the fundamental and therefore the pitch of the spoken sound.

The sound waves produced by the vocal cords are rich in harmonics, but their number and amplitude must be varied to produce the different consonant and vowel sounds which make up human speech. This is done by varying the relations between the lips, tongue, teeth and roof of the mouth. This controls the resonant chambers provided by the throat, mouth and nasal cavities. Thus, the sound waves from the vocal cords are given the characteristics of human speech.

5.2 The human ear has three sections (Fig.10). Sounds collected by the external flaps pass along the outer ear passage, which is about 1-1/4" long, and cause the ear drum to vibrate. A chain of tiny bones across the middle ear amplify the pressure variations on the ear drum some 50 or 60 times.

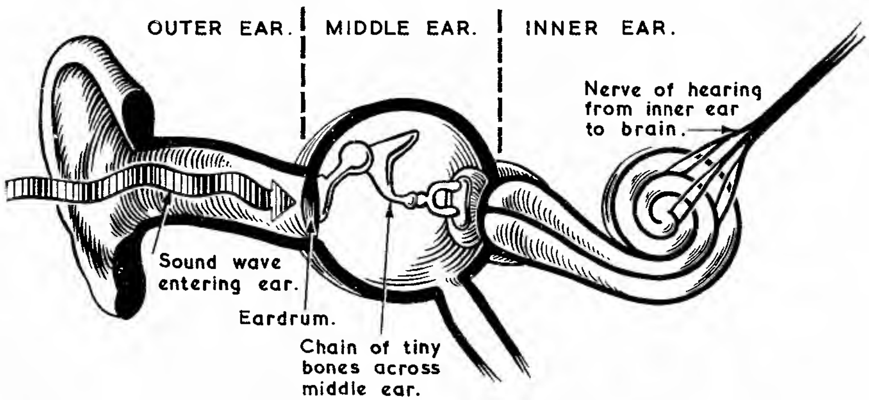


FIG.10. HUMAN EAR.

The inner ear contains a spiral tube filled with a fluid in which are thousands of nerve ends, each of which is resonant to a particular small range of frequencies and is stimulated only when those frequencies are received. The nerve ends send pulses along the auditory nerve to the brain to give the sensation of hearing. The ear is sensitive not only to differences of frequency but also to differences in loudness, which cover a power ratio of more than one million to one.

5.3 Audio Frequency (A.F.) Range. Audio frequencies are those which may be heard by the ear when the energy is in the form of sound waves. The A.F. range is from about 16 to 20,000 c/s. but the limits vary with different persons. Most people can hear from 30 to 15,000 c/s. The sound from an orchestra may cover most of the A.F. range (fundamentals and harmonics) but the range used for speech is very much less. The sensitiveness of the ear varies over the A.F. range. It is a maximum at about 2,000 c/s and decreases as the upper and lower limits of audibility are approached.

6. ELECTRICAL TRANSMISSION OF SOUND.

6.1 Sound is a form of energy sometimes called acoustical energy, from the Greek word akoustikos meaning to hear. Sound waves cannot be transmitted very far because they have comparatively small energy and attenuate rapidly. They must first be changed to another form of energy that does not attenuate so rapidly and can be transmitted more easily from one point to another.

6.2 The subject of Telephony deals with the electrical transmission of sound (speech and music) between points some distance apart. The word is derived from two Greek words - tele meaning far, and phone meaning voice. Telephony is one of the modern forms of communication, and the messages may be sent over either line wires or radio channels.

A telephone is a device which converts the energy of sound waves in speech to electrical energy when transmitting, and electrical energy back into sound when receiving.

A practical telephone must also provide a means of signalling at both ends of the line preparatory to speaking, and a means of receiving such signals. The basic requirements are, therefore, transmitting, receiving and signalling.

6.3 Although many interesting experiments had been done previously, the first practical telephone was developed in 1876-77 when Alexander Graham Bell demonstrated that sound waves in the air could be recreated some distance away by means of alternating currents sent over wires. (Fig.11).

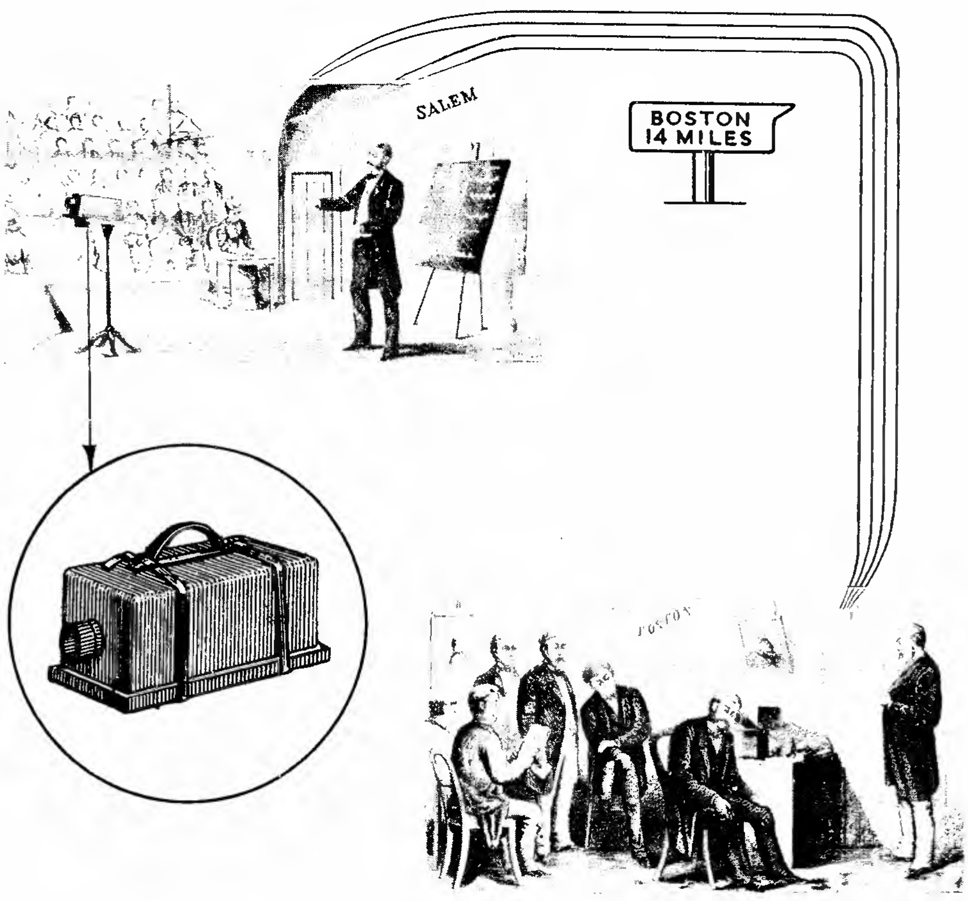


FIG.11. THE TELEPHONE IN 1877.

The telephone was introduced in Australia in 1878. Since then, many different types have been used and, for identification, a numeral code has been adopted. The telephones most commonly used at present are in the 300 and the 400 series.

The original telephones were largely experimental but, as improvements were made, the provision of a comprehensive telephone service within and between communities soon became a practical possibility. A telephone service within a community area, for example a town, suburb, or city, is provided by terminating all the lines from the telephones in that area at a central building called a telephone exchange, where any two lines and their corresponding telephones can be connected together, as required.

The source of the electric energy may be either a local battery at the telephone (Magneto working) or a central battery at the exchange (C.B. working). There are two types of C.B. exchange - manual and automatic - and, therefore, two types of C.B. telephone - manual and automatic - which differ only in the method of signalling from the telephone. By usage, however, the telephones are known as C.B. and automatic respectively, but it should be remembered that both are central battery instruments.

These telephones and the different exchange systems (Magneto, C.B. Manual and Automatic), are described in other papers.

One function of the Engineering Division of the Postmaster-General's Department is to provide and maintain a telephone service in Australia. This refers mainly to telephone exchange equipment and the apparatus owned by the Department and rented to the public, who are called subscribers.

6.4 Frequency range transmitted. When transmitting speech by electrical means, each sine wave component must be transmitted with equal efficiency so that the waveform and, therefore, the intelligibility of the received sound is not changed or distorted. To achieve this, a very wide band of frequencies must be transmitted and any reduction of this band produces some distortion. In general, increasing the lowest frequency transmitted distorts the vowels, and reducing the highest frequency distorts the consonants.

However, the wider the band of frequencies transmitted, especially over long distances, the more expensive the apparatus becomes.

A compromise is made between these two conflicting points by designing the telephone apparatus to transmit a band of frequencies from 200 to about 3,000 c/s, called the speech frequency or voice frequency (V.F.) range. It contains the most essential sine wave components of speech and results in reasonable intelligibility and, at the same time, is narrow enough from an economic point of view, but it is not the complete range of frequencies used in speech.

It is interesting to note that the sibilant sounds, s and f, for example, contain frequencies of the order of 4,000 c/s. The correct transmission of these sounds is not always possible in a telephone system, as these higher frequencies are unlikely to be transmitted.

For good quality music, a range from about 30 to 10,000 c/s is generally transmitted.

NOTES

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7. TEST QUESTIONS.

1. Sounds usually originate from ....
2. Can sounds be transmitted through a vacuum? ....
3. Describe a simple experiment to support your answer in Question 2.
4. Explain how sounds are transmitted through air.
5. The velocity of sound in air is .... at a temperature of ....
   The velocity .... about ..... feet per second for every 1°C rise of temperature.
6. The term "Sound Wave" is applied to ....
7. What is meant by "attenuation," applied to sound waves?
8. How are "echoes" produced?
9. Three important characteristics of a sound wave, are -
   (1) .... (2) .... (3) ....
10. What is meant by the terms - cycle, frequency, period, wavelength?
11. The relationship between velocity, wavelength and frequency of a sound wave is ....
12. A complex wave consists of .... and .... frequencies.
13. The .... frequency determines the pitch of the sound.
14. The .... frequencies vary the quality of the sound.
15. The shape of any complex wave depends on -
    (1) ....
    (2) ....
    (3) ....
16. What is meant by the resonant frequency of an object?
17. What is the main difference in the waveforms of a musical note and noise?
18. The A.F. range extends from about .... to .... c/s.
19. Why is it necessary to convert acoustical energy to electrical energy for transmission over long distances?
20. What is the frequency range usually used for telephone transmission of speech? ....
    This is called the .... range.

TRANSMITTERS AND RECEIVERS

1. INTRODUCTION.

1.1 As stated in the paper "Sound Waves", there is only a small amount of energy available in speech, and in order to transmit sound over long distances, it is necessary to change the acoustical energy into energy of a new form, for example, electrical energy.

1.2 Three basic requirements are necessary for telephony -

(i) The transmitter, a device operated by the sound waves, which changes acoustical energy into electrical energy.

(ii) The receiver, a device which changes the received electrical energy into sound waves.

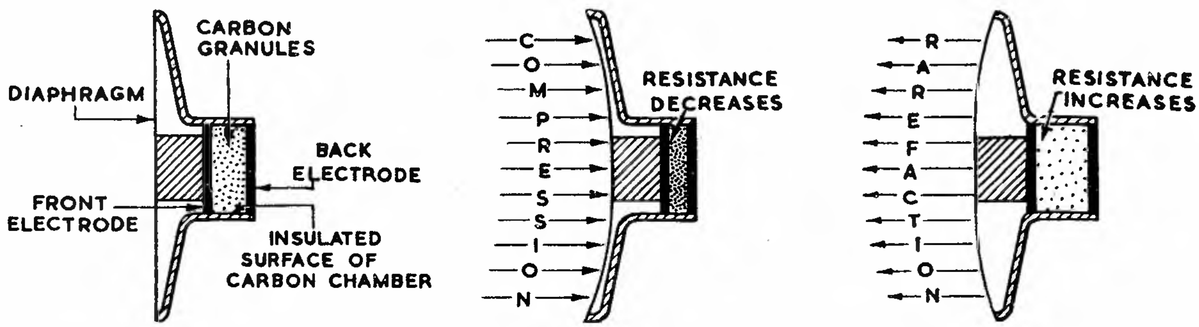
(iii) The telephone line, the medium for conducting the electrical energy from the transmitter to the distant receiver.

1.3 This paper describes the principle of operation and construction of modern telephone transmitters and receivers. The schematic circuit symbols are -

2. CARBON TRANSMITTER.

2.1 The early telephones used a device similar in principle to a modern receiver (see Section 4) for both transmitter and receiver. When used as a transmitter, however, a telephone receiver is not very sensitive, because the amount of energy in the human voice is so small that the sound output from the distant receiver is almost inaudible over even short telephone lines. This is due to the losses which occur in the conversion to electrical energy, losses on the line, and losses in the reconversion to acoustical energy.

2.2 Modern telephones use a more sensitive and efficient type of transmitter called a carbon transmitter (Fig. 1a). This consists, basically, of many grains of carbon called carbon granules, packed between two carbon electrodes mounted in a small chamber which has insulated sides so as not to short-circuit the electrodes. One electrode is fixed to the back of the chamber; the front electrode is attached to the centre of a light, flexible diaphragm. The resistance of the transmitter is the resistance of the carbon granules between front and back electrodes.



(a) Diapnragm Normal. (b) Diaphragm Moves Inwards. (c) Diaphragm Moves Outwards.

OPERATION OF CARBON TRANSMITTER.

FIG. 1.

2.3 Principle of operation. When a sound wave strikes the diaphragm, the varying pressures in the adjacent air particles cause it to vibrate. Acoustical energy is converted into mechanical energy in the vibration of the diaphragm.

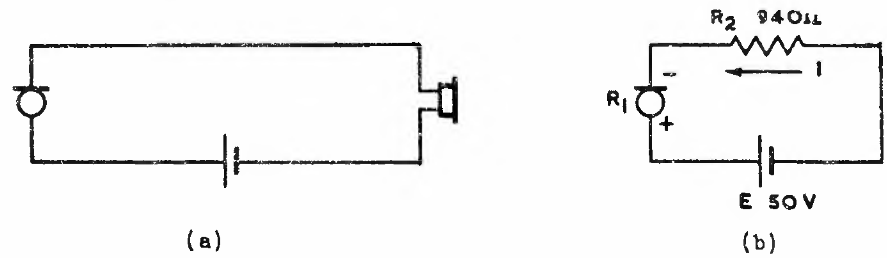
A compression moves the diaphragm and front electrode inwards (Fig. 1b). The increased mechanical pressure "packs" the carbon granules closer together, and this increases the number of granules in contact with each other. Thus, the area of contact is increased and this reduces the contact resistance of the carbon between the electrodes.

Conversely, a rarefaction moves the diaphragm and front electrode outwards (Fig. 1c), and the transmitter resistance increases.

When a battery is connected between the transmitter electrodes in an electric circuit, a D.C. flows through the conducting carbon granules. The variations in transmitter resistance vary or regulate the current in the circuit. Thus, a small value of acoustical energy can vary a comparatively large value of electrical energy supplied by the battery. With an efficient transmitter, this variation may be over 1,000 times greater than the original acoustical energy.

The carbon transmitter, therefore, does not directly convert acoustical energy into electrical energy, but can be considered to be an amplifier as it effectively amplifies or enlarges the acoustical energy supplied to it. An amplifier does not violate the energy conservation law, as this law applies only to energy conversion, and not to one form of energy controlling another form.

2.4 Simple Mathematical Analysis. A simple one-way telephone speaking circuit consists of a carbon transmitter, receiver and telephone line connected in series with a battery. (Fig. 2a.)



BASIC ONE-WAY SPEAKING CIRCUIT.

FIG. 2.

In the equivalent circuit of Fig. 2b, the resistance of the line and receiver is assumed to be 940 ohms and is represented by a single resistor (R_2).

Assuming typical D.C. values, the circuit operation is as follows -

In the rest position, the transmitter resistance (R_1) is 60 ohms, and the circuit resistance (R) is, therefore, 1,000 ohms.

The current in the circuit -

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

$$= \frac{50}{1000} = 0.05 \text{ ampere.}$$

$$= \underline{50 \text{ mA}}$$

The P.D. across the transmitter -

$$E_1 = I \times R_1$$

$$= \frac{50}{1000} \times \frac{60}{1}$$

$$= \underline{3 \text{ volts}}$$

Assume, now, that a person speaks into the transmitter and the resistance varies between limits of 40 ohms (a compression) and 80 ohms (a rarefaction).

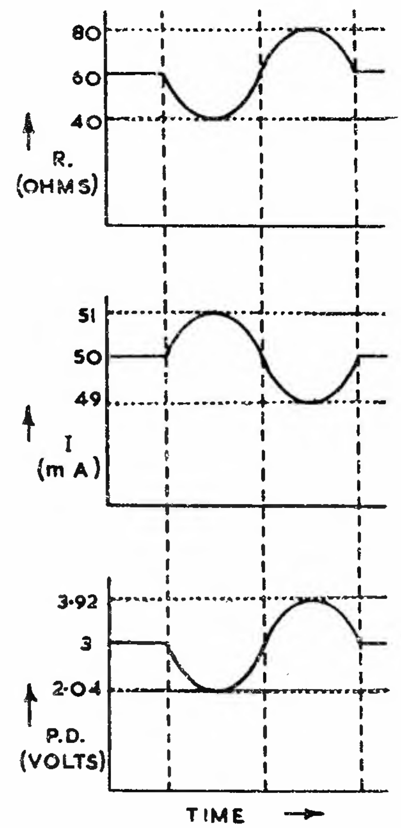
When R_1 falls to 40 ohms, the current rises slightly, but the P.D. across the transmitter decreases. Applying Ohm's Law, the respective values are -

51 mA and 2.04 volts

When R_1 rises to 80 ohms, the current falls slightly, but the P.D. across the transmitter increases. The respective values are -

49 mA and 3.92 volts

These variations are shown graphically in Fig. 3.



TRANSMITTER RESISTANCE, CURRENT AND VOLTAGE VARIATIONS.

FIG. 3.

2.5 Summarising, when a person speaks into the transmitter -

(i) the transmitter resistance varies,
(ii) a varying current flows in the circuit, and
(iii) a varying voltage is produced across the transmitter resistance.

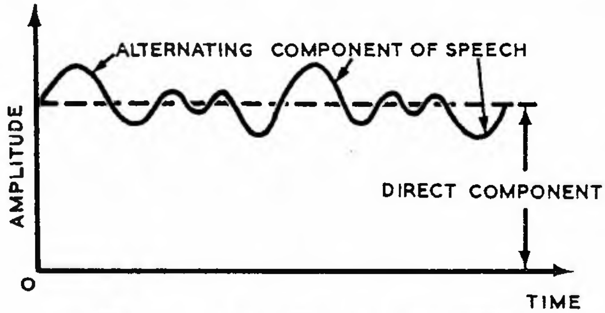


FIG. 4. A.C. AND D.C. COMPONENTS.

Both the varying current and voltage can be considered to consist of a steady direct component on which is superimposed the alternating component of speech (Fig. 4). The latter contains the intelligence as it follows the frequency and amplitude variations of the sound waves which vibrate the transmitter diaphragm; and it consists of fundamental and harmonic sine wave components, as in the original sound waves.

As will be seen in other papers, the speaking circuit of a telephone separates the A.C. components from the steady D.C. component, and permits the A.C. to operate a receiver. Fig. 5 shows how either a transformer or capacitor may be used to separate the A.C. and D.C. components.

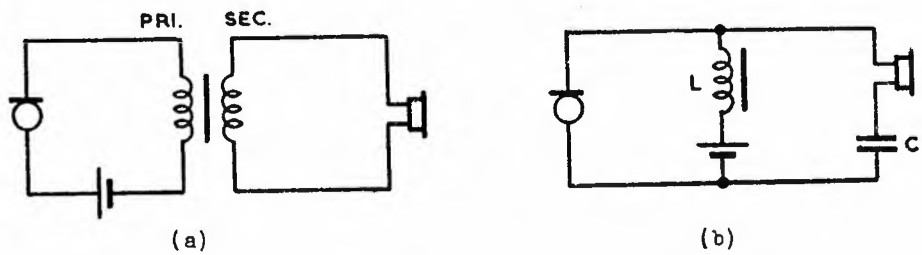


FIG. 5. SEPARATING THE A.C. AND D.C. COMPONENTS.

In Fig. 5a, the varying current in the primary winding of the transformer sets up a varying magnetic field which induces an alternating voltage across the secondary. The A.C. component of speech flows through the receiver. The steady D.C. component is confined to the primary circuit.

In Fig. 5b, the steady D.C. flows through the transmitter and low resistance of the inductor (L). The capacitor (C) "blocks" the D.C. from the receiver. The major portion of the A.C. component of speech, however, flows through the receiver via the transmitter and capacitor. The A.C. through the inductor is negligible because of its high impedance.

2.6 To simplify the understanding of telephone circuit operation, therefore, it is often convenient to assume that the carbon transmitter, during operation, develops a speech signal consisting of alternating voltages and currents at speech frequencies.

The amplitude of this speech signal is directly proportional to -

(i) the value of the D.C. flowing through the transmitter. However, in practice, when the D.C. exceeds a certain value dependent on the size and shape of the carbon granules used, the transmitter produces loud hissing noises in a receiver. This effect is called frying, and is due to arcing across the space between adjacent granules which are not actually touching. To reduce this effect, the D.C. through carbon transmitters must not exceed about 100 mA.

(ii) the resistance variation of the transmitter. Carbon granules are preferred to other materials, because they provide a relatively large resistance variation for a relatively small variation in pressure. Also, carbon does not oxidise or melt, under normal conditions of operation.

3. INSET TRANSMITTER NO. 13.

3.1 Many different types of carbon transmitters have been used, but the most common is the Inset Transmitter No.13. This is the immersed-electrode carbon granule type, and is used in the 300 and 400 series telephones.

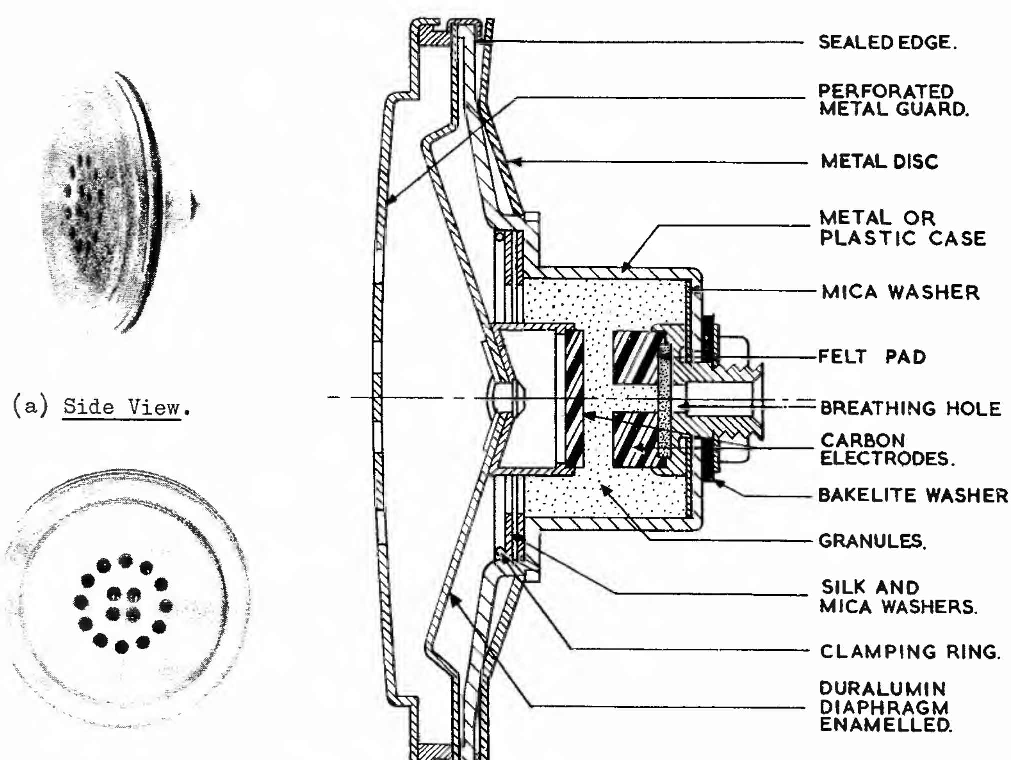
3.2 Construction (Fig. 6). The outer case, of diecast aluminium or zinc, or moulded plastic, is shaped to form a container for the carbon granules. When metal is used, the inner surface is enamelled for insulation. The back electrode is fixed to the back of the container but insulated from it by a mica washer and a bakelite washer. When a plastic case is used, further insulation is unnecessary.

A metal disc clamped over the back of the case provides a metallic connection via the diaphragm to the front electrode.

The duralumin diaphragm is cone-shaped and combines lightness and strength. An aluminium cylinder which carries the front electrode is attached to the centre of the diaphragm. A number of closely fitting silk washers, stiffened by mica washers, prevent the escape of carbon granules. These washers allow the front electrode to move in and out, and are held in place by a clamping ring.

A perforated metal guard protects the diaphragm from mechanical damage, and the diaphragm has a coating of enamel to prevent corrosion by moisture from the atmosphere and the speaker's breath.

The front of the inset is sealed by a spinning operation, the area of contact between the diaphragm and the case being sealed with a special cement to prevent the possibility of corrosion at this point. A small breathing hole in the centre of the back electrode allows slowly varying differences of air pressure on either side of the diaphragm to equalise. A felt pad prevents the escape of carbon granules. Thus, changes in temperature and atmospheric pressure do not cause diaphragm displacement.



(a) Side View.

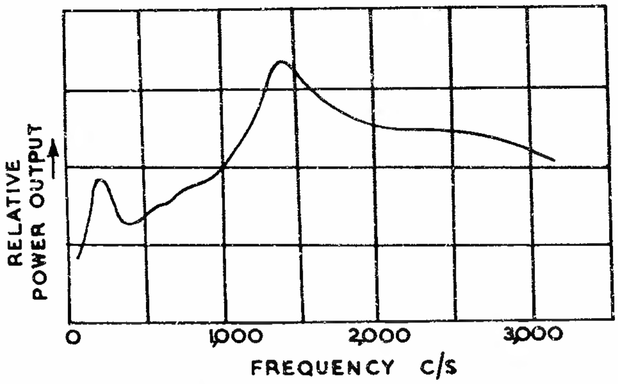
(b) Front View.

(c) Cross-Section.

FIG. 6. CONSTRUCTION OF INSET TRANSMITTER NO. 13.

3.3 The D.C. resistance varies for different samples and also depends on the current through the transmitter. The resistance of a sample transmitter varied from about 100 ohms (with a current of 20 mA) to about 50 ohms (with a current of 100 mA). The decrease in resistance is due to the negative temperature coefficient of carbon. For normal operation, the average rest resistance is taken as 60 ohms. In operation, the resistance must not be too high, or the value of D.C. through the transmitter is reduced, causing faint transmission.

3.4 Frequency response. The natural frequency of the diaphragm is about 1,400 c/s. This means that, if sound wave components of constant amplitude, but of different frequency are applied to the transmitter, the amplitude of vibration of the diaphragm (and thus the resistance variation and electrical output of the transmitter) will be greatest at 1,400 c/s. Fig. 7 shows the relative "response" to different frequencies.



RESPONSE CURVE OF INSET TRANSMITTER NO. 13.
FIG. 7.

3.5 Some advantages of this transmitter, compared with earlier types, are -

(i) Better frequency response and more sensitive, due to the lighter moving system, and larger resistance variation.

(ii) Less tendency to produce "frying," due to the use of a larger quantity of granules and the complete immersion of the electrodes in the granules.

(iii) The transmitter works well in any position because the electrodes are immersed in the granules. Earlier transmitters had the disadvantage that, in certain positions, the granules fell away from the electrodes, resulting in either a disconnection or high resistance in the transmitter circuit.

(iv) Less tendency to produce "packing" of the carbon granules. This is the term used when the granules form an almost compact mass which produces very little resistance variation under the influence of sound waves.

4. MAGNETIC DIAPHRAGM RECEIVER.

4.1 As the speech signals received from a telephone line are extremely small (usually less than 0.1 μW), a telephone receiver must be efficiently designed to convert as much of the electrical energy as possible into acoustical energy.

Also, the speech signals consist of a wide range of frequencies which must be faithfully reproduced by the receiver, so that the speech output will not sound distorted.

A telephone receiver must be designed, therefore, for maximum sensitivity (or volume efficiency) as well as for good quality reception.

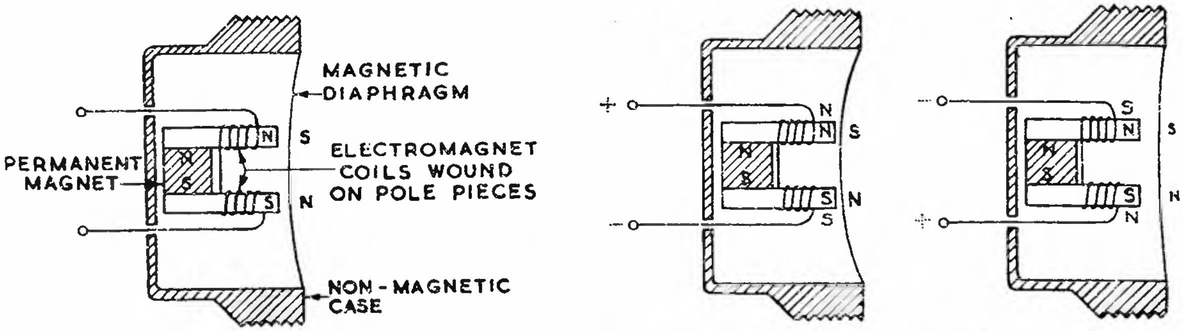
Two different types are at present used -

(i) receivers with a diaphragm of magnetic material, used in the 300 series telephones.

(ii) receivers with a non-magnetic diaphragm, used in the 400 series telephones. (See Section 7.)

4.2 The principle of operation of a receiver with a magnetic diaphragm is shown in Fig. 8. Electromagnet coils are wound on the pole pieces of a permanent magnet (either horse-shoe or bar). The end polarity of the pole pieces is the same as the magnet poles to which they are attached. A flexible magnetic diaphragm which is clamped around the circumference but free to move at its centre, is mounted a short distance from the pole pieces. By magnetic induction, opposite poles are produced in the diaphragm directly opposite the pole pieces and the diaphragm is normally stressed towards the pole pieces. (Fig. 8a.)

The coils are connected in series and produce opposite polarities at the pole tips. When the A.C. component of speech flows through the coils, the electromagnetism alternately aids and opposes the force exerted on the diaphragm by the permanent magnet, as indicated by the letters N and S in Figs. 8b and 8c.



(a) Diaphragm normal. (b) Diaphragm moves inwards. (c) Diaphragm moves outwards.

OPERATION OF RECEIVER.

FIG. 8.

The diaphragm, therefore, moves from its normal stressed position to positions closer to, and further from the pole pieces, producing sounds having the same characteristics as the speech currents applied to the receiver. Thus electrical energy is converted into mechanical energy in the vibration of the diaphragm, which, in turn, radiates acoustical energy. Due to energy conversion losses, the acoustical energy output is less than the electrical energy input to the receiver.

4.3 The Magnetic Circuit. The path for the magnetic flux includes the permanent magnet, pole pieces, air gaps and diaphragm.

The permanent magnet provides a high flux density and has a high coercive force to resist demagnetisation.

The pull on the diaphragm depends on the magnetic flux density in the air gaps, and hence the design must aim for a maximum change of flux for a given change of current in the coils.

The magnetic circuit, therefore, is made as short as possible and the magnetic materials used for the pole pieces and diaphragm have -

(i) high permeability to provide minimum reluctance for the magnetic flux,
(ii) high specific electrical resistance to reduce eddy current losses, and
(iii) low coercive force to reduce hysteresis losses.

Also, the air gap between the pole pieces and diaphragm (and, therefore, the reluctance of the air gap) is reduced to a minimum to just prevent the diaphragm touching the pole pieces during normal operation of the receiver. The tips of the pole pieces are usually lacquered to maintain a small gap in the magnetic circuit, and prevent the diaphragm sticking should it touch the pole pieces during operation.

4.4 The permanent magnet enables the receiver to reproduce sounds with the same frequency as the speech currents applied to it.

For example, in Fig. 8, each cycle of speech current causes the diaphragm to vibrate at the same frequency by merely increasing or decreasing the pull exerted on the diaphragm by the permanent magnet.

In a receiver without a permanent magnet, the diaphragm is attracted to the pole pieces irrespective of the polarity of the electromagnet or the direction of the current in the coils. The diaphragm is attracted twice for each cycle of speech current. This produces a sound with a fundamental frequency twice that of the original sound and also results in the production of harmonic frequencies which were not present in the original sound, giving unnatural speech.

4.5 The permanent magnet also increases the sensitivity of a receiver. This can be shown mathematically as follows -

In a receiver, the pull exerted on the diaphragm at any instant is directly proportional to the square of the flux density in the air gap between pole pieces and diaphragm.

Let B equal the flux density due to the permanent magnet. Then, the force of attraction exerted on the diaphragm by the permanent magnet is proportional to B^2.

Let b equal the maximum value of the alternating flux density due to the speech currents in the electromagnet coils. This flux alternately aids and opposes that produced by the permanent magnet as the current reverses in direction.

Then, the total flux density will vary between $(B + b)$ and $(B - b)$, and the force on the diaphragm from $(B + b)^2$ to $(B - b)^2$. The difference between these is 4Bb, and this is the range of force on the diaphragm.

If there were no permanent magnet, the variation would be between b^2 and zero, which is much less than 4Bb in which the comparatively large value of B is included.

By similar reasoning, the amplitude of vibration, and, therefore, the loudness of the sound produced by the receiver diaphragm for a given current input, increases as the strength of the permanent magnet is increased.

A receiver fitted with a permanent magnet is said to be polarised.

4.6 Receiver diaphragms. Early receivers use a soft iron diaphragm. As soft iron is a good conductor, eddy currents of a large value are induced and circulate in the diaphragm as it vibrates in the magnetic field. When the diaphragm is attracted to the pole pieces, the induced eddy currents produce a flux which, according to Lenz's law, opposes and weakens the flux due to the speech currents, thereby reducing the force of attraction on the diaphragm. Similarly, the extent to which the diaphragm moves away from the pole pieces, is likewise reduced. Therefore, the eddy currents reduce the movement of the soft iron diaphragm.

Later receivers use a thin diaphragm (about 10 mils for greater flexibility) of a magnetic alloy which has good magnetic properties and also a higher specific resistance than soft iron to reduce the eddy current losses. Typical materials are -

(i) Stalloy (Diaphragm No.12), an alloy of iron, silicon and aluminium; used in the Receiver type 1A (also known as the Bell receiver) and the Inset Receiver type 1L.

(ii) Permendur (Diaphragm No.25), an alloy of iron, cobalt, and vanadium; used in the Inset Receiver type 2P.

The diaphragms are generally varnished on both sides to prevent corrosion. When only one side is varnished, this side must be placed towards the ear.

The diaphragms must be removed or replaced by gently sliding sideways over the pole pieces. This prevents any sudden attraction to the pole pieces which may permanently distort the flat surface of the thin diaphragm and affect its operation.

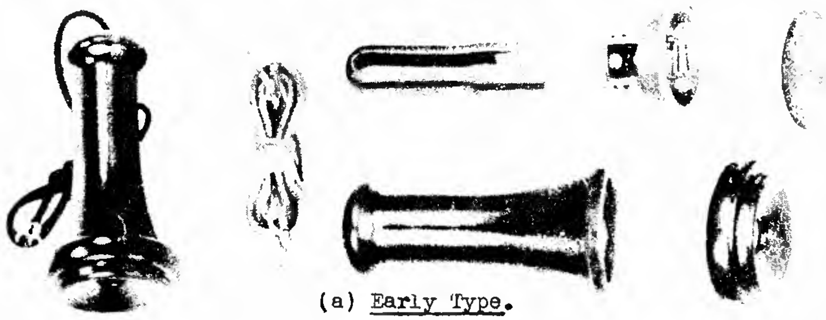
5. RECEIVER TYPE 1A (BELL RECEIVER).

5.1 Construction (Fig. 9). The L-shaped soft-iron pole pieces carry the two electromagnet coils, and are screwed to Bessemer steel pieces, clamped to the inside of a brass cup, by steel screws. These screws also hold the tungsten-steel permanent magnet, which may be either two bar magnets yoked together at the far end, or a single horse-shoe magnet. The ends of the coils connect to terminals fitted between the poles of the permanent magnet at the base of the brass cup. The terminals are provided with screws to connect the receiver cord.

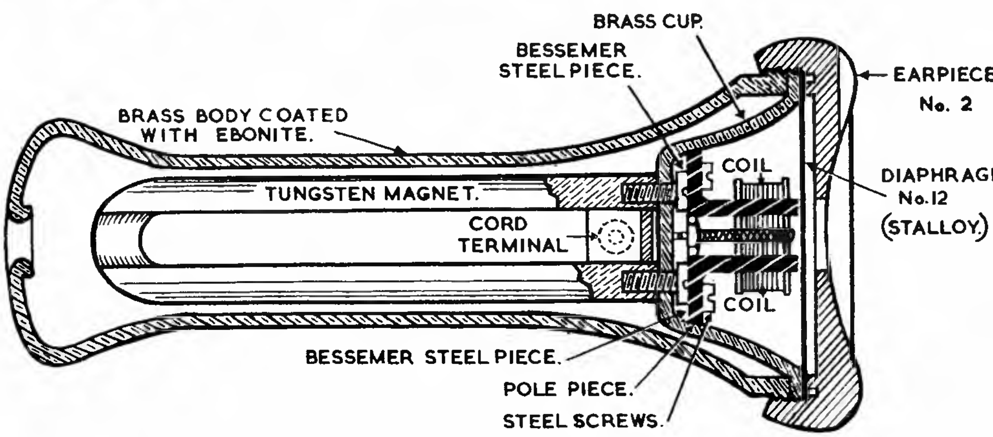
The stalloy diaphragm is seated on the edge of the brass cup. The clearance between the diaphragm and the ends of the pole pieces is 13.5 mils $\pm$ 1 mil tolerance.

The assembly is enclosed in an outer brass case insulated with an ebonite coating. An ebonite earpiece is screwed into position on the outer brass case and holds the diaphragm and assembly in position. A shallow recess in the outer rim of the earpiece allows the "howler" signal from the exchange to be heard if the receiver is left with the earpiece downwards on a flat surface.

The resistance of each coil is 30 ohms, and the D.C. resistance of the receiver is 60 ohms. The impedance varies from about 115 to 450 ohms over the voice frequency range (200-3000 c/s); and is about 250 ohms at 1000 c/s.



(a) Early Type.



(b) Cross-section of Later Type.

BELL RECEIVER.

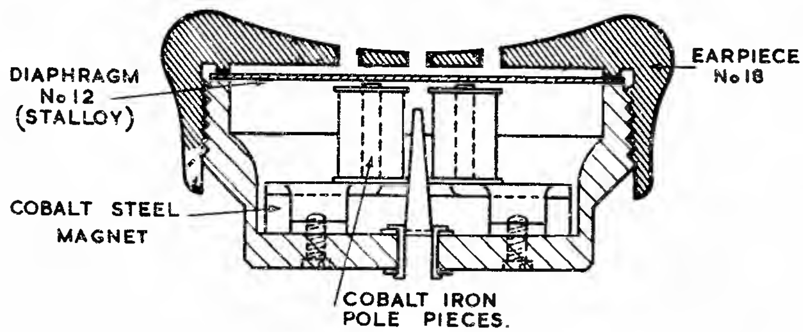
FIG. 9.

5.2 In the magnetic circuit, the Bessemer steel pieces and the intervening air gap provide a shunt path which offers less reluctance than the permanent magnet to the changes in flux due to the speech currents. This improves the sensitivity of the receiver. It also reduces the flux changes through the permanent magnet so that they do not, in time, affect its strength.

6. INSET RECEIVERS, TYPES 1L AND 2P.

6.1 Inset Receiver Type 1L (Fig. 10) uses a short cobalt-steel permanent magnet, which provides a high flux density and has a higher coercive force than the tungsten-steel magnet used in the Bell receiver. The coils are fitted on cobalt-iron pole pieces which are saddle-shaped at one end, so that, when screwed to the receiver case, they fit over and clamp the permanent magnet in position. The case is either aluminium or moulded bakelite, and is threaded so that the bakelite earpiece can be screwed to hold the diaphragm in position. The ends of the coils terminate on lugs, insulated from the case when aluminium is used.

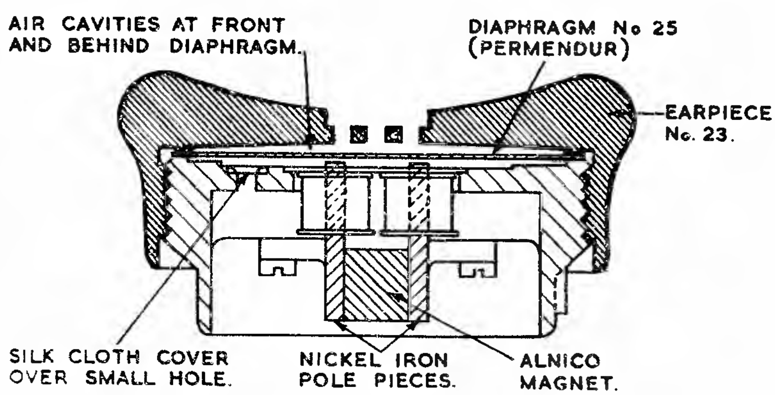
The resistance of each coil is 40 ohms, and the D.C. resistance of the receiver is 80 ohms. The impedance varies from about 110 to 710 ohms over the voice frequency rango, and is about 350 ohms at 1000 c/s.



TYPE 1L RECEIVER.

FIG. 10.

6.2 Inset Receiver Type 2P (Fig. 11) uses a short Alnico permanent magnet composed of aluminium, nickel, iron and cobalt. This alloy provides a higher flux density and has a higher coercive force than cobalt-steel. The coils are fitted on nickel-iron pole pieces.



TYPE 2P RECEIVER.

FIG. 11.

The magnet and pole piece assembly are mounted on either a die-cast aluminium case or a case of moulded phenolic material, which is threaded so that the bakelite earpiece can be screwed to hold the diaphragm in position. The pole pieces project through slots in a moulded insulating plate which is sealed to the case and to the pole pieces to make an airtight joint. A small hole in this plate is covered with a silk cloth of very fine mesh. The ends of the coils terminate on lugs, insulated from the case when aluminium is used.

The D.C. resistance is about 55 ohms. The impedance varies from about 100 to 640 ohms over the voice frequency range, and is about 290 ohms at 1000 c/s.

The type 2P and 1L receivers do not have Bessemer steel pieces as in the Bell receiver. However, the wide pole pieces provide an alternative air path of large cross-section at the base of the coils, which shunts the high reluctance of the permanent magnet for the changes of flux in the magnetic circuit.

6.3 A 1L receiver is fitted with a stalloy diaphragm No.12 and an earpiece No.18 which has seven small holes drilled at its centre (Fig. 12a).

A 2P receiver is fitted with a permendur diaphragm No.25 and an earpiece No.23 which has four small holes drilled in a recessed cavity at its centre (Fig. 12b).

(a) 1L receiver, diaphragm No. 12, earpiece No. 18.

(b) 2P receiver, diaphragm No. 25, earpiece No. 23.

CORRECT COMBINATION FOR INSET RECEIVERS.

FIG. 12.

When the wrong combination is used, the volume efficiency of the receiver is reduced, and the quality of the reproduced speech is impaired.

6.4 Comparison of performance. A telephone receiver has natural resonant frequencies governed by the mechanical properties of mass and stiffness of the diaphragm, and also by the air cavities on either side of the diaphragm.

For maximum volume efficiency, these resonant frequencies are designed to fall within the range of speech frequencies reproduced by the diaphragm.

However, for good quality reception, the resonance effects must not be too pronounced; otherwise, when complex sound waves are being reproduced, the components at or near the resonant frequencies will "mask" or render inaudible the other frequencies, which are produced relatively weakly, causing a loss of intelligibility.

In the Bell receiver and the 1L receiver, the natural frequency of the diaphragm is about 1100 c/s. This means that, if a constant amplitude alternating current is passed through the receiver coils and the frequency varied from zero upwards, the amplitude of vibration of the receiver diaphragm, and, therefore, the loudness of the sound produced, will be greatest at 1,100 c/s. This is shown graphically by the "response curve" in Fig. 13.

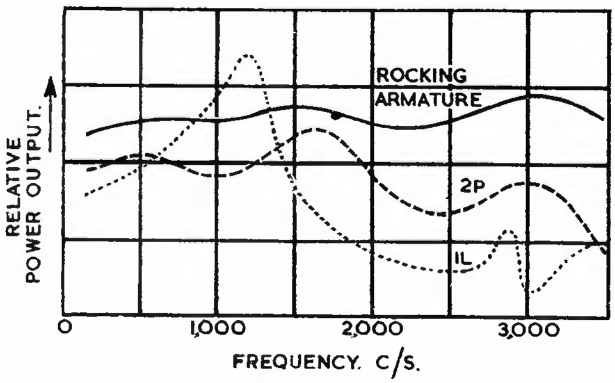


FIG. 13. RESPONSE CURVES OF TELEPHONE RECEIVERS.

In the 2P receiver, three damped resonant frequencies spaced at about 500 c/s, 1700 c/s and 2900 c/s, give a flatter response curve over the V.F. range. The resonances are due to the combined effects of the diaphragm resonance and the air cavities of suitable dimensions on either side of the diaphragm. The small air cavity at the back of the diaphragm connects to a larger air chamber at the back of the receiver through the small hole covered with silk.

The small air cavity between the front of the diaphragm and the earpiece is connected by four small holes in the earpiece to the larger air cavity of the ear when placed against the earpiece. The balanced air loading on either side of the diaphragm and the silk covering over the small hole are designed to provide a damping effect on the diaphragm resonance.

The diaphragm damping improves the quality of the reproduced speech, but tends to reduce the volume efficiency. To compensate for this in the 2P receiver, the efficiency of the magnetic circuit is improved (compared to the 1L receiver) by the use of better quality magnetic materials.

For comparison, Fig. 13 also shows the further improvement in performance obtained with the Rocking Armature Receiver described in Section 7.

7. ROCKING ARMATURE RECEIVER.

7.1 Construction. In the 1L and 2P receivers, the magnetic diaphragm has to perform a dual function in which both its magnetic and acoustical properties are used. Since these conflict in their requirements for best performance of the receiver, a compromise has to be made.

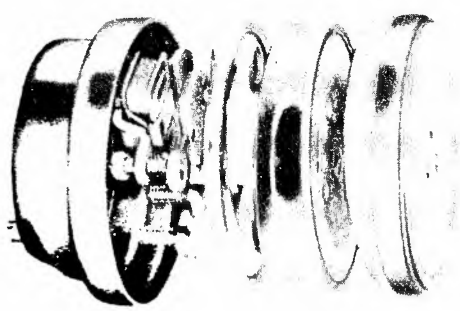


FIG. 14. EXPLODED VIEW OF ROCKING ARMATURE RECEIVER.

In the Rocking Armature receiver (Fig. 14) used in the 400 series telephones, these two functions are separate. The magnetic function is confined to the rocking armature, and the acoustical function to a light non-magnetic diaphragm, each of which can then be designed for best performance.

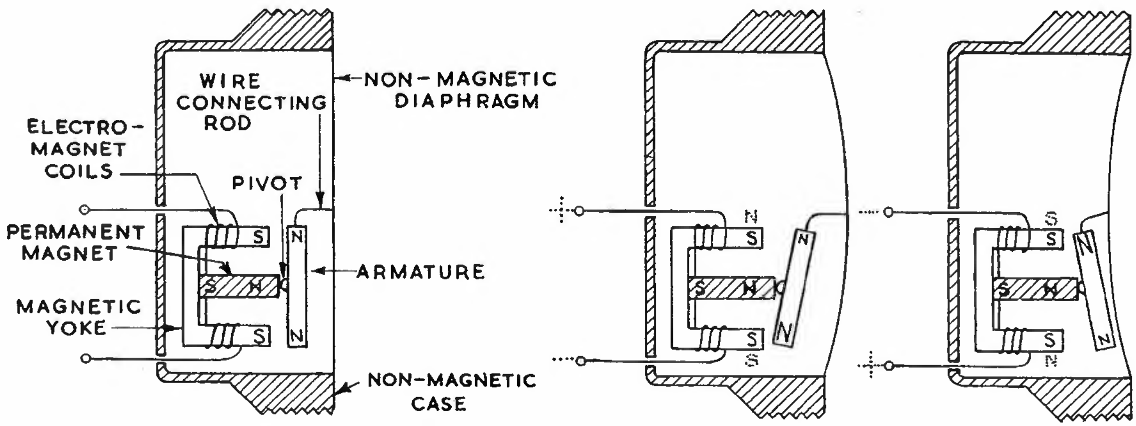
The permanent magnet is a small alcomax bar magnet (an alloy of aluminium, nickel, cobalt, copper and iron), mounted centrally between the limbs of a U-shaped yoke of permalloy (a nickel-iron alloy) which forms the two pole pieces. The permalloy armature rocks or pivots on the magnet, and is mechanically connected by a wire rod to a light flared non-magnetic alloy diaphragm.

The receiver is mounted in a sealed case. The ends of the electromagnet coils connect to terminals mounted on the back of the case.

The D.C. resistance of the receiver is 20 ohms. The impedance varies from about 50 to 200 ohms over the voice frequency range, and is about 150 ohms at 1,000 c/s.

7.2 Principle of operation. In the normal condition (Fig. 15a) with no current in the coils, the two ends of the armature are equidistant from the tips of the pole pieces. The permanent magnet extends south magnetic poles of equal strength to each end of the magnetic yoke. The north poles induced into each end of the armature are, therefore, also of equal strength. As a result, the magnetic forces of attraction on each end of the armature are balanced, and there is no tendency for it to be attracted to either end of the yoke.

When a current flows in the coils, the electromagnetism strengthens one south pole of the magnetic yoke, and weakens the other; and the armature is attracted to the stronger pole. Thus, when alternating speech currents flow, the armature is alternately attracted to either pole of the magnetic yoke and this movement is transmitted to the diaphragm (Figs. 15b and 15c).



(a) Diaphragm normal. (b) Diaphragm moves outwards. (c) Diaphragm moves inwards.

OPERATION OF ROCKING ARMATURE RECEIVER.

FIG. 15.

7.3 The Magnetic Circuit. Under static conditions, the steady flux due to the permanent magnet divides equally between two parallel paths, which have similar magnetic characteristics. The alternating flux due to the electromagnet, however, is confined to the magnetic yoke and the armature, and does not have to overcome the reluctance of the permanent magnet and the air path which shunts the permanent magnet, as in the 1L and 2P receivers. Because of this, and also because the magnetic and acoustic sections of the receiver are separately designed for best performance, the rocking armature receiver is more sensitive and has a flatter response curve than the magnetic diaphragm receivers described earlier.

A typical response curve is included in Fig. 13.

8. HANDSETS.

8.1 In modern telephones, the transmitter and receiver are combined in a moulded bakelite casing called a handset. The shape of the handset is designed so that when the receiver is placed to the ear, the speaker's mouth comes as near as is practicable to the transmitter. The 300 series telephones use either a Handset No.164 or Handset No.184. The 400 series telephones use a Handset 400.

These telephones are sometimes called handset telephones to distinguish them from the non-handset types in which the transmitter and receiver are mounted separately.

8.2 The Handsets No.164 and No.184 (Fig. 16) use an Inset Transmitter No.13 and an Inset Receiver type 1L or 2P.

When the Mouthpiece No.15 is locked into position the metal disc at the back of the transmitter is pushed against springs which thus make electrical contact with the front electrode via the diaphragm. A centre pin in the transmitter cavity connects to the back electrode. To protect the diaphragm from mechanical damage, the holes in the mouthpiece are not in line with those in the metal guard of the transmitter.

HANDSET FOR 300 SERIES TELEPHONES.

FIG. 16.

The 1L receiver is secured to the handset by two No. 3BA x 9/16" fixing screws; the 2P receiver uses two No. 3BA x 1-1/16" screws. These screws also make the electrical connections between the ends of the electromagnet coils and wires moulded in the handset, which terminate on the receiver terminals in the transmitter cavity.

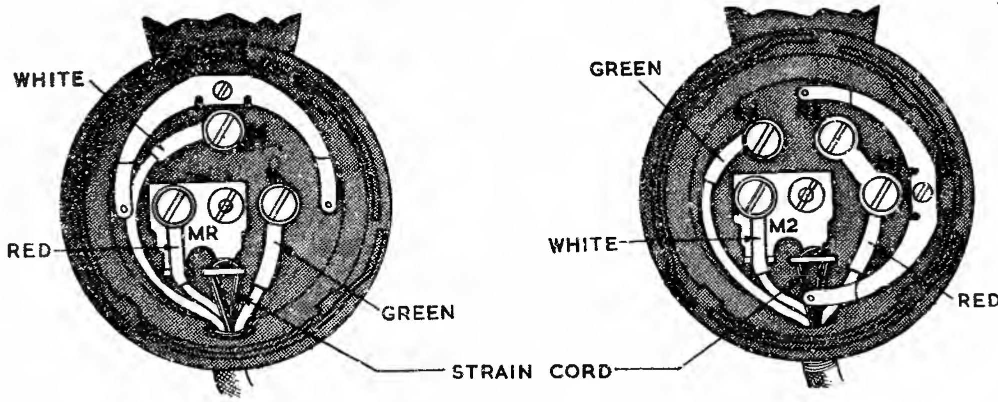
8.3 Instrument Cords are flexible cords which connect the different units of a telephone. For example, they are used to connect the handset (or receiver of non-handset telephones) to the case of the telephone; and, in table telephones, to connect the case to the terminal block on which the exchange line terminates.

An instrument cord consists of a number of insulated conductors covered with a cotton braiding. Each conductor consists of a number of thin copper alloy wires (called tinsel wires) wound around a cotton thread, with an insulation covering of either rubber or P.V.C. (polyvinyl chloride) which is coloured to identify the conductors. A strain cord is bound in, so that the points at which the cord conductors are connected to the terminals, may not be subjected to any appreciable stresses.

Cords are generally designated by a four figure number in which the thousands stands for the number of conductors, the hundreds for the length in feet between bindings, and the tens and units for the number of inches extra to the feet. Thus, 2406 denotes a two conductor cord, 4'6" in length between bindings.

8.4 Handset Cord Connections. The Handset No.164 uses an instrument cord 3306 which passes through a hole in the transmitter end of the handset, to connect to the transmitter and receiver. The conductors are screwed under terminals in the transmitter cavity. A common terminal (MR) connects to the back electrode of the transmitter and one end of the receiver winding. (Fig. 17a.)

The Handset No.184 has four terminals (M1 and M2 for the transmitter, R1 and R2 for the receiver) instead of three. Normally, an instrument cord 3306 is used, and a strap connection is provided between terminals M1 and R2. (Fig. 17b.) The strap is removed and a four conductor cord used when no electrical connection is desired between transmitter and receiver.



(a) Handset No. 164. (b) Handset No. 184.

FIG. 17. HANDSET CORD CONNECTIONS.

3.5 The Handset 400 (Fig. 18) uses an Inset Transmitter No. 13, a Rocking Armature Receiver, and an instrument cord 3306A or 4306.

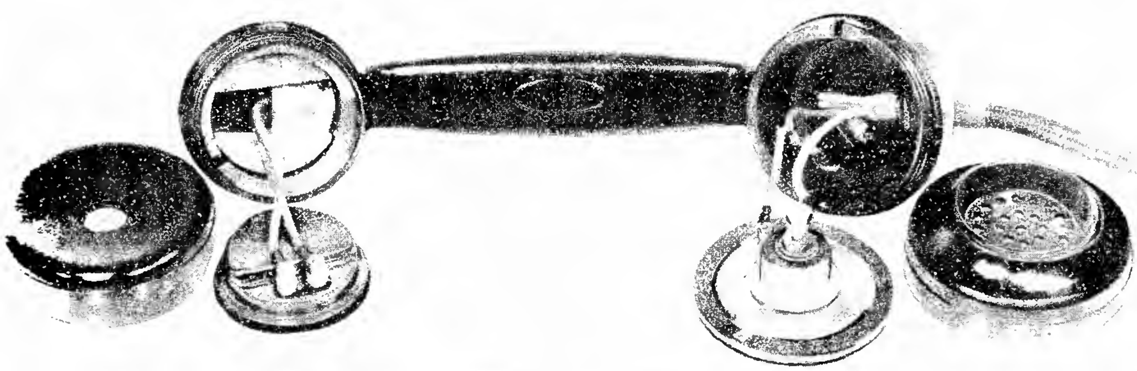


FIG. 18. HANDSET FOR 400 SERIES TELEPHONES.

A rubber sleeve is fastened to the cord to reduce wear, where it passes through the rectangular entry hole in the handset. The sleeve is enlarged within the handset and has a rectangular section so that it cannot be pulled through or twisted in the hole, so protecting the cord conductors from strain. The cord is fitted by passing its telephone end through the hole in the handset from inside the transmitter cavity.

Connection to the front electrode of the transmitter is made by replacing the usual metal disc on the back of the case by one fitted with a terminal post for the connection of one cord conductor. The new metal disc has a small tongue bent down to engage in a slot in the handset moulding, so preventing the transmitter from turning and straining the cord connections as the mouthpiece 400 is screwed on. The receiver cord conductors pass through a "tunnel" (formed when the handset is moulded) and connect directly to terminals on the back of the receiver case. As the earpiece 400 is screwed on, the receiver is clamped firmly against a spring ring.

3.6 It is necessary to switch the telephone transmitter and receiver in or out of circuit as required, and to disconnect the battery for the transmitter operation when the telephone is not in use.

In non-handset telephones, this switching is done by placing the receiver on a hook which operates spring contacts to do the switching and is called a switch-hook. The contacts automatically close on lifting the receiver, and automatically open on replacing the receiver.

In handset telephones, a cradle switch is generally used. When not in use, the handset is placed on the telephone case so as to cause a plunger to move and open-circuit a spring assembly consisting of two pairs of contacts. Further details are given in the paper "Signalling Apparatus".

9. TEST QUESTIONS.

1. What are the three basic requirements for the electrical transmission of speech?
2. The symbol for a telephone transmitter is .... ; and for a telephone receiver is ....
3. Describe with the aid of diagrams, the basic construction and principle of operation of a carbon transmitter.
4. When a compression moves the diaphragm .... , the transmitter resistance ....
5. In a carbon transmitter, the .... energy varies the .... energy supplied by the battery.
6. Describe the operation of two simple telephone speaking circuits which separate the A.C. component of speech from the steady D.C. component flowing through the transmitter.
7. The amplitude of the A.C. output from a carbon transmitter depends on .... and ....
8. Why are carbon granules preferred to other materials?
9. To reduce "frying," the D.C. through a carbon transmitter must not exceed about .... ampere.
10. What are the advantages of the inset transmitter No. 13 compared with earlier types?
11. What is the reason for the small "breathing hole" in the centre of the back electrode?
12. The average rest resistance of an inset transmitter No. 13 is about .... ohms.
13. When the D.C. through a carbon transmitter is increased, the transmitter resistance ...., due to ....
14. Why is a modern telephone receiver unsatisfactory for use as a transmitter?
15. Describe with the aid of diagrams, the basic construction and principle of operation of a receiver using a diaphragm of magnetic material.
16. What are the advantages of using a permanent magnet in a telephone receiver?
17. Why is soft iron not used for a modern receiver diaphragm?
18. Why must a particular combination of diaphragm and earpiece be used with the types 1L and 2P receivers? State the correct combination for each receiver.
19. Why is a shallow recess provided in the outer rim of the earpiece used with a Bell receiver?
20. Describe the basic construction and principle of operation of a rocking armature receiver.
21. An instrument cord 3406 has .... conductors and a length of ....
22. What is the main difference between a handset No. 164 and a handset No. 184?

END OF PAPER.

THE AUSTRALIAN POST OFFICE

COURSE OF TECHNICAL INSTRUCTION

Engineering Training Section, Headquarters, Postmaster-General's Department, Melbourne C.2.

SIGNALLING APPARATUS.

1. INTRODUCTION.

1.1 In all telephone systems, signalling apparatus is provided at the subscriber's premises and at the exchange to operate on incoming calls and to originate outgoing calls.

1.2 Incoming signalling apparatus is divided broadly into two types -

(i) Aural (heard by the ear) signalling.
(ii) Visual (seen by the eye) signalling.

Aural signalling is provided by bells and buzzers; visual signalling by indicators and lamps.

Some of these items are operated by D.C. supplied from dry cells or from the exchange battery. Other items operate from A.C. generally at a frequency of $16\frac{2}{3}$ c/s, often referred to as 17 c/s. As explained in other papers, the A.C. is generally supplied from a power-driven generator (ringing machine) at the telephone exchange.

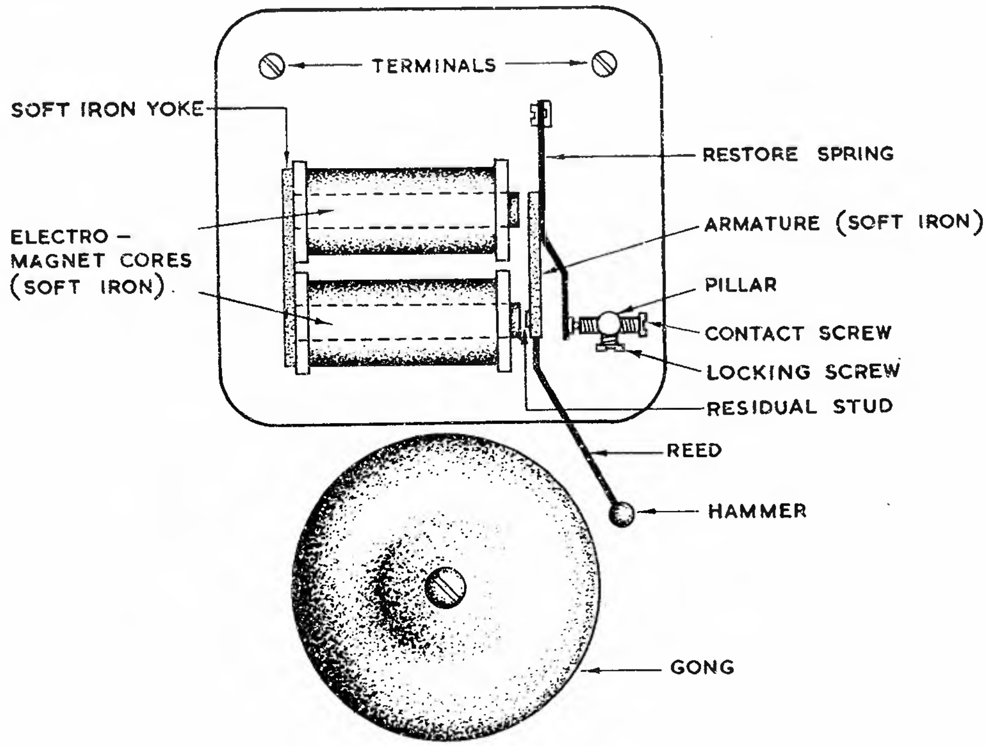
1.3 In magneto telephones, a hand generator is used to signal the exchange. Signalling from C.B. manual telephones is by means of a switch-hook or cradle switch, and automatic telephones are provided with a dial.

1.4 This paper describes the construction and principle of operation of the more common items of signalling apparatus.

2. TREMBLING BELLS AND BUZZERS.

2.1 These are operated by D.C. and are used in magneto and C.B. systems to give the telephonist or subscriber a continuous audible alarm signal on an incoming call. The schematic circuit symbols are -

2.2 The basic construction of a trembling bell is shown in Fig. 1.



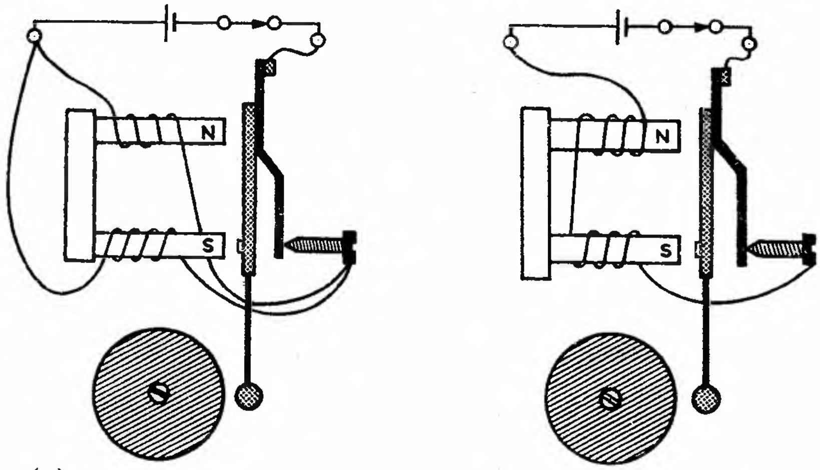
TREMBLING BELL.

FIG. 1.

Two coils wound on soft iron cores are attached to a soft iron yoke and mounted on an insulating base to which a cover is screwed. The coils are connected either in parallel or series, depending on the operating voltage (see paragraph 2.5). A flat spring which is fixed at one end, carries the soft iron armature. The non-magnetic residual stud on the armature prevents the armature "sticking" to the core due to residual magnetism. A pillar mounted on the base carries an adjustable contact screw and locking screw. The contact screw is adjusted to touch a contact on the spring. A reed and hammer are attached to the armature, and a gong is mounted close to the hammer.

2.3 Principle of Operation. In Fig. 2, when the switch is closed, D.C. flows through the spring, contact screw and the two coils. This sets up a magnetic flux in the magnetic circuit consisting of the electromagnet cores, yoke, air gaps and armature, and the armature is attracted to the pole pieces. The movement of the armature causes the hammer to strike the gong and also opens the circuit at the contact points. The coils are de-energised, the armature returns to its normal position under the tension of the spring, and the contacts close the circuit. The coils are again energised and the cycle of operation continues, the hammer striking the gong on each attraction of the armature. The armature vibrates at a rate determined by its weight and the adjustment of the contact screw.

In both the parallel and series connections (Fig. 2), the coils produce opposite magnetic polarities at the end of the pole pieces as indicated by N and S.



(a) Parallel Connection. (b) Series Connection.

OPERATION OF TREMBLING BELL.

FIG. 2.

2.4 A buzzer is similar to a trembling bell, but the gong, hammer and reed are omitted. The moving system is lighter and vibrates at a higher speed emitting a high-pitched note.

2.5 Types in use. The coils of trembling bells and buzzers may be wound to any resistance to suit the operating voltage. In general -

The "lower voltage" trembling bells have two 50 ohm coils connected in parallel, and operate from a local battery of from two to four dry cells in series. The number of cells depends on the gong diameter which can be 2½", 4", 6", 8" or 10". The "lower voltage" buzzer has two 12.5 ohm coils connected in series, and operates from two dry cells.

The "higher voltage" types have two 250 ohm coils connected in series, and operate from 22-46 volts usually supplied from a central battery. The diameter of the trembling bell gong can be 2½", 4" or 6".

2.6 Sparking at contacts. Each time the contact points open, the current through and, therefore, the flux about the coils, fall to zero almost instantly. This induces an e.m.f. of self induction in the windings which produces sparking across the contacts. To prevent rapid deterioration of the contacts due to this sparking, both the contact spring and the contact screw are tipped with a hard metal alloy (for example, platinum-gold-silver) which does not oxidise or melt except at very high temperatures. In some bells and buzzers, the high induced e.m.f. and, therefore, the sparking, are reduced by -

(i) a N.I.R. of 1,000 ohms or higher (often wound on the soft iron cores) connected across the coil windings to provide a path for the induced current; or
(ii) a low value of capacitance connected across the contacts, so that the induced current flows into and charges the capacitor, instead of arcing across the contacts.

2.7 Adjustments. With the armature held against the pole pieces, there should be just clearance between the hammer and the gong. Adjust by turning the gong, which is drilled off centre.

To adjust the frequency of vibration, slacken the locking screw and turn the contact screw in or out. (Some buzzers have an additional adjusting screw at the other end of the armature which effectively varies the tension of the restore spring.)

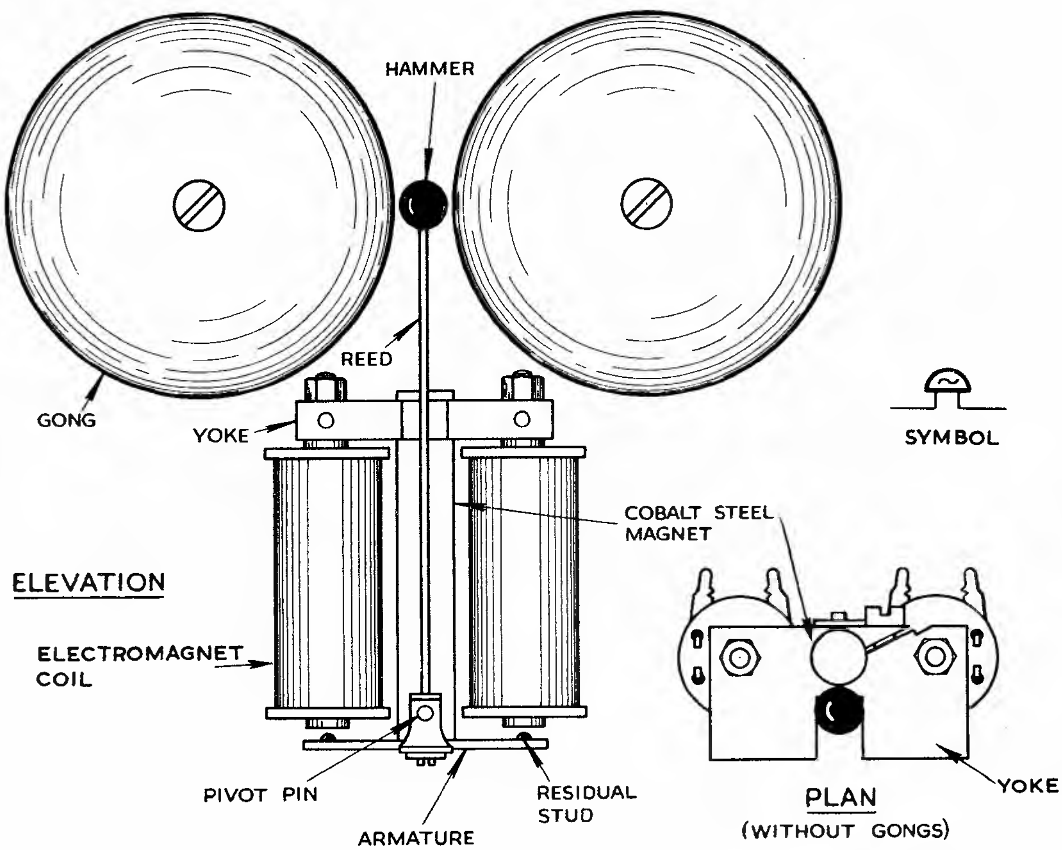
3. MAGNETO BELL.

3.1 The magneto bell is operated by 17 c/s ringing current and is used to provide an intermittent audible signal on an incoming call.

It is used in magneto, C.B. manual and automatic telephones in preference to trembling bells for the following reasons -

(i) It has less fault liability because there are no contacts to become worn or dirty.
(ii) It is more economical and reliable in operation, as it is operated from the ringing current and does not depend on the condition of a dry cell battery.

3.2 The basic construction of a modern magneto bell is shown in Fig. 3.

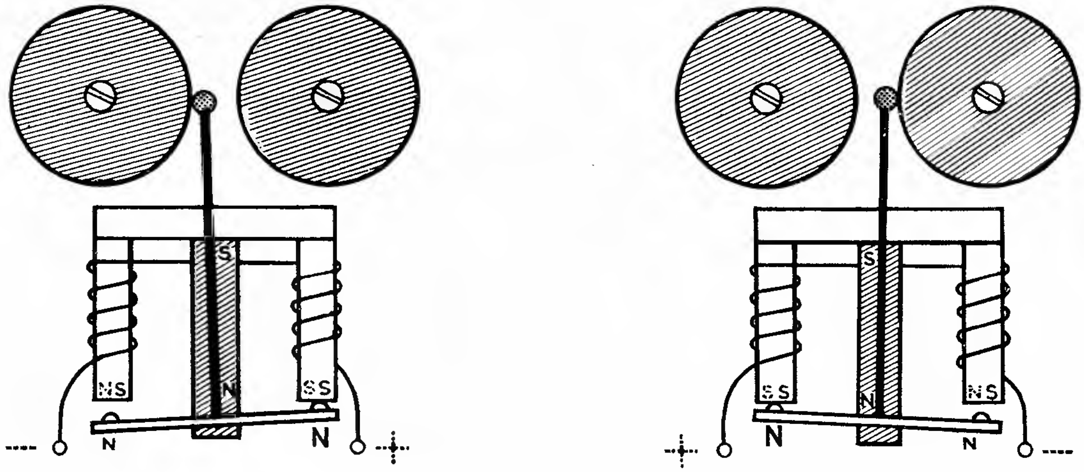


MAGNETO BELL.

FIG. 3.

Two coils, wound on soft iron cores, are attached to a soft iron yoke and connected in series. A permanent magnet fits in a hole in the centre of the yoke and is held by a clamping screw. A soft iron armature is centrally pivoted to the other end of the permanent magnet by a non-magnetic pivot pin. The armature has non-magnetic "residual studs" fitted opposite each electromagnet pole piece, to prevent the armature "sticking" to the pole pieces due to residual magnetism. The reed, which carries a hammer, is fixed centrally to the armature, and brass gongs are mounted on either side of the hammer. The diameter of each gong is usually $2\frac{1}{2}$", but larger gongs are fitted on some bells. Each gong is of different thickness to give different tones resulting in a more pleasant ring.

3.3 Principle of operation (Fig. 4). The flux from the permanent magnet divides between the two parallel paths of the magnetic circuit consisting of the magnet, yoke, electromagnet cores (pole pieces), air gap and armature. The magnet extends south poles via the yoke to the ends of the pole pieces, and north poles to the ends of the armature. In the normal condition, with no current in the coils, the armature is attracted equally to either pole piece and rests on whichever side it is placed.



(a) (b)

OPERATION OF MAGNETO BELL.

FIG. 4.

When a current flows in the coils, opposite poles are produced electromagnetically at the pole tips. This strengthens one of the extended south poles and weakens the other, and the armature is attracted to the stronger pole. Thus, with alternating ringing currents, the armature is alternately attracted to either pole of the magnetic yoke (Figs. 4a and 4b), and the hammer strikes each of the gongs once per cycle. The letters N and S indicate how the polarities due to the electromagnet aid and oppose the permanent magnet.

The operation is basically similar to the action of the rocking armature receiver. As in a telephone receiver, the permanent magnet greatly increases the sensitivity of the bell, because the force of attraction on the armature is then very much greater than that produced by the applied A.C. only.

3.4 Adjustments. With the armature held against one pole piece, the space between the armature and the other pole piece should be 20 mils. Adjust by loosening the clamping screw and moving the magnet in or out of the yoke.

Also, there should be perceptible clearance between the hammer and gong. Preliminary adjustment is made by turning the gong, which is drilled off centre. Repeat for the second gong by holding the armature against the other pole piece.

3.5 The D.C. resistance of the magneto bell used in telephones is 1,000 ohms (each coil is 500 ohms). The impedance at 1000 c/s is about 18,500 ohms.

When a magneto bell is connected across a trunk line, the coils have more turns to increase the sensitivity and improve the ringing on these long lines. This bell also has higher impedance to reduce the shunting effect when several stations are connected across the line. The D.C. resistance of this type of bell is 2,000 ohms and the impedance at 1,000 c/s is about 27,000 ohms.

4. INDICATORS.

4.1 At manual exchanges (where many telephones may be connected), it is not practical to connect a magneto bell across each line to signal the telephonist. The usual method is either by indicators or lamps.

The main types of indicator and the schematic circuit symbols, are -

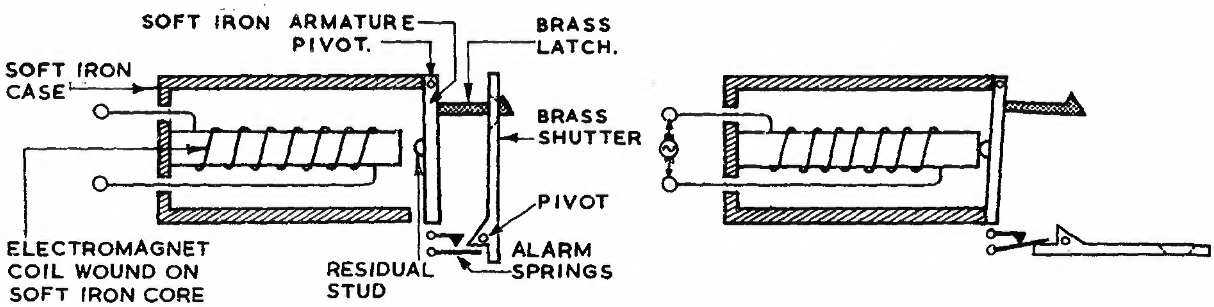
(Note: The figures indicate the resistance value in ohms.)

4.2 The Drop Indicator is usually operated by A.C. It is used in magneto exchanges and some types of magneto and C.B. subscriber's equipment. In magneto exchange systems -

(i) A Line Indicator gives a calling signal to the telephonist when the subscriber turns the hand generator to originate a call.

(ii) A Clearing Indicator gives a clearing (or supervisory) signal to the telephonist when the subscriber turns the hand generator at the finish of a conversation.

Construction. A coil is wound on a soft iron core and enclosed in a soft iron cylindrical case which is open at one end. A soft iron armature is pivoted at the open end. A brass latch is attached to the armature. This latch passes through an opening in a hinged brass shutter, and normally holds the shutter in a vertical position. (Fig. 5a.) A non-magnetic residual stud (or screw) on the armature prevents the armature touching the core during operation. This provides a small gap in the magnetic circuit and prevents the possibility of residual magnetism causing the armature to "stick" in the operated position.



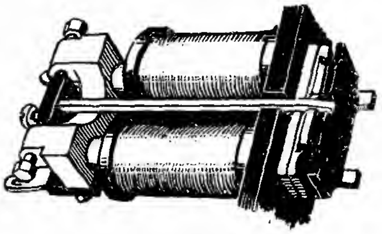
(a) Unoperated. (b) Operated.

OPERATION OF DROP INDICATOR.

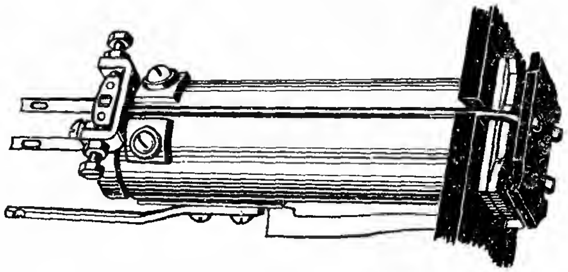
FIG. 5.

Operation. When alternating ringing current flows through the coil, an alternating magnetic flux is set up in the magnetic circuit consisting of the core, air gap, armature and case. The armature is attracted to the core irrespective of the direction of current, and the latch releases the shutter which drops to disclose the designation plate, and gives a visual signal to the telephonist. (Fig. 5b.) When the shutter drops, it causes a moving spring mounted on the indicator to touch a fixed contact on the mounting plate. This closes the circuit for a trembling bell or buzzer to provide an audible alarm, if required. The shutter is restored manually to its normal position by the telephonist.

4.3 Typical Drop Indicators. Fig. 6 shows two early types of line and clearing indicators. The shutter is held in position by the latch which is attached to the armature at the rear of the indicator. The line indicator (Fig. 6a) has two coils wound to a resistance of 50 ohms each and connected in series (total 100 ohms). It does not have a soft iron case and is of relatively low impedance because it is disconnected from the subscriber's line when the telephonist answers a call. The indicator in Fig. 6b has a single coil (D.C. resistance either 100 or 1000 ohms) mounted in a soft iron case.



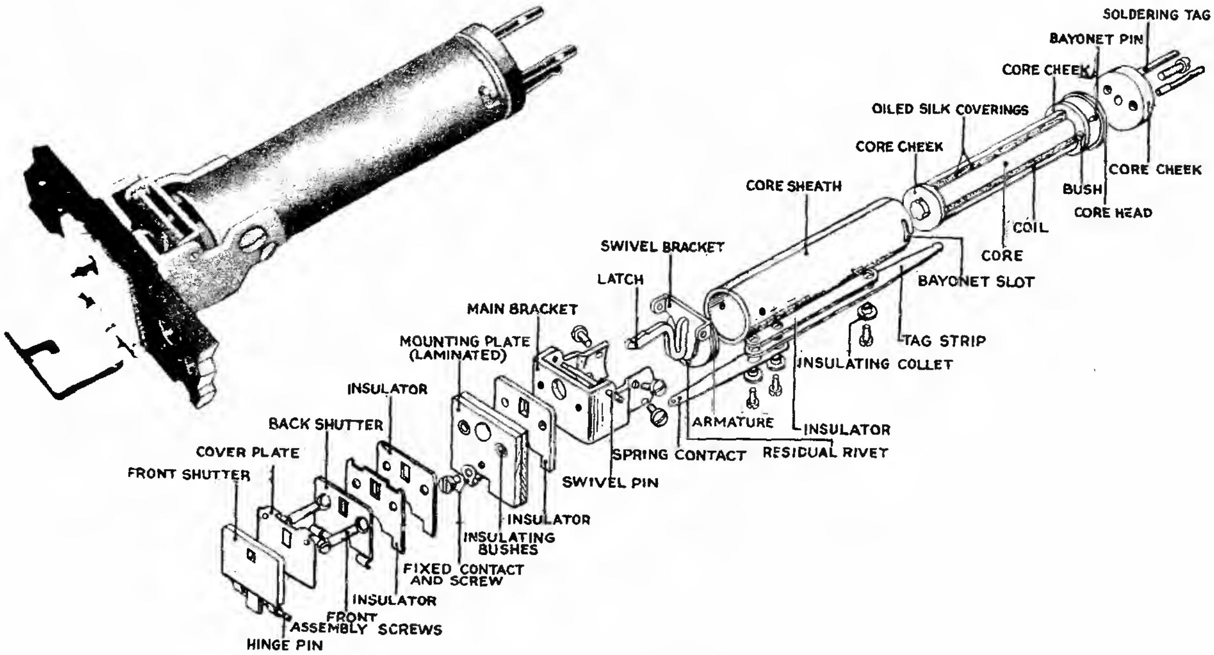
(a)



(b)

FIG. 6. EARLY DROP INDICATORS.

Fig. 7 shows the construction of a modern type drop indicator which is smaller in diameter than the early types and is used as either a line or clearing indicator. The D.C. resistance is 1,000 ohms for use on subscriber's lines, and 2,000 ohms for trunk lines. The ends of the coil connect to tags at the back of the indicator. The core is attached to the sheath by a bayonet socket. This allows a faulty coil to be readily removed and replaced without dismantling the main assembly, or affecting the adjustment of the armature or alarm springs. The armature is at the front of the core instead of at the rear as in earlier types. This permits more reliable adjustment. The indicator operates with an A.C. of 6 mA at 17 c/s.



DROP INDICATOR (MODERN TYPE).

FIG. 7.

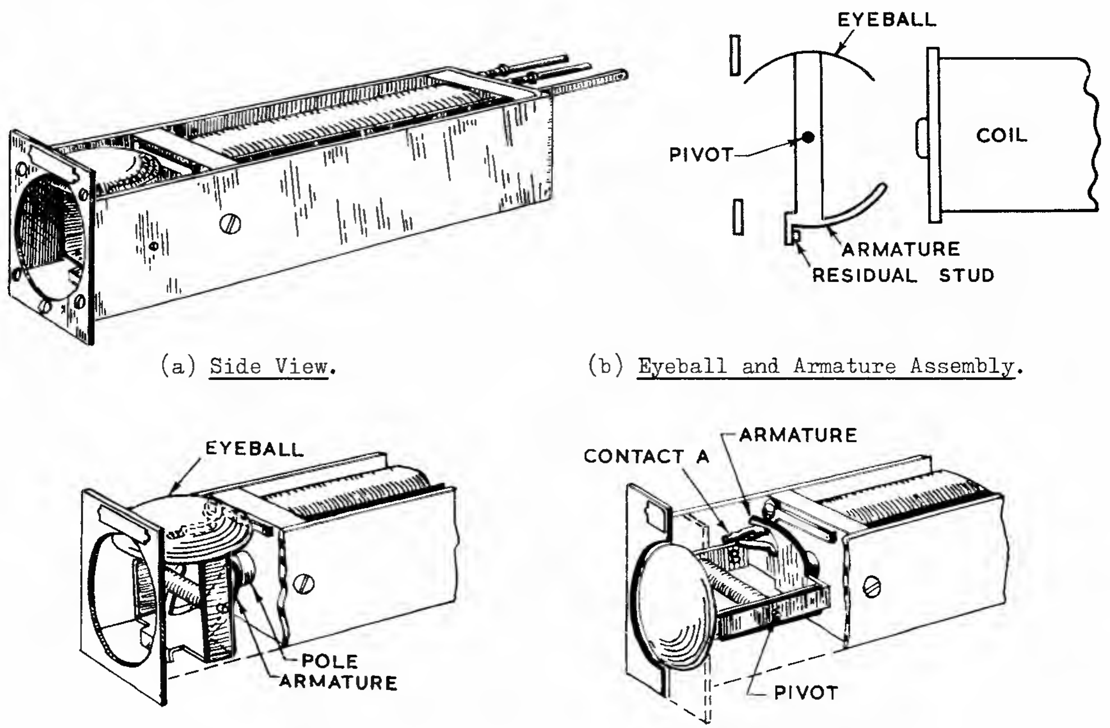
4.4 Magnetic Screening. To improve the magnetic circuit of drop indicators and make them more sensitive in operation, modern types have a soft iron case around the coil.

In magneto exchanges, the indicators are mounted close together, and, during switching, there is one clearing indicator across each connection. When A.C. speaking and signalling currents flow through the indicator, an alternating magnetic flux is produced. The soft iron case magnetically screens each indicator to confine the flux to its local magnetic circuit. This prevents the flux cutting and inducing e.m.f's. in nearby indicators,and thus prevents crosstalk between circuits.

The improved magnetic circuit also increases the inductance and, therefore, the impedance of the indicators,so as to reduce the shunting effect on the speech currents.

4.5 The Eyeball Indicator (Fig. 8a) is operated by D.C. and is commonly used in some C.B. switchboards at subscriber's premises to give both calling and supervisory signals.

A coil with a resistance of 50, 500 or 1,000 ohms is wound on a soft iron core. The ends of the coil connect to tags at the back of the indicator. The moving system (Figs. 8b and 8c) consists of a pivoted carriage which has a white or coloured portion of a hollow aluminium sphere on one side and a curved, tongue-shaped, soft-iron armature on the other side.



(a) Side View. (b) Eyeball and Armature Assembly.

(c) Unoperated. (d) Operated.

FIG. 8. OPERATION OF EYEBALL INDICATOR.

When D.C. flows in the coil, the core is magnetised and attracts the armature. The magnetic circuit consists of the core, the two sides of the soft iron frame in parallel, and is completed at the front by the armature and air gap. The carriage then revolves about its axis so that the "eyeball" is drawn down and exposed in the aperture in front of the indicator (Fig. 8d). A small non-magnetic residual stud on the armature prevents the armature "sticking" to the core due to residual magnetism. An extension (B) of the armature touches an insulated contact spring A to complete a local alarm circuit, if required. When current ceases, gravity automatically restores the eyeball to normal.

5. SWITCHBOARD LAMPS.

5.1 Although indicator signalling is used on small switchboards, lamp signalling is more commonly used wherever the required power supply is available without undue cost.

The advantages are -

(i) A glowing lamp is easily seen.

(ii) The space occupied by a lamp is small.

(iii) Lamps may be automatically extinguished when a call is answered.

(iv) Lamps are easily replaced.

The disadvantages are the necessity to use a relay and the greater operating current required. In large installations, the advantages exceed the disadvantages.

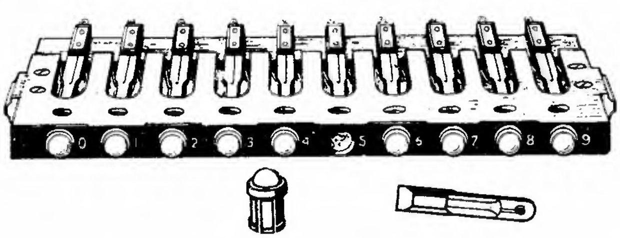
5.2 Switchboard lamps depend for their operation on the heating effect of an electric current through a thin conducting "filament" mounted in an evacuated glass bulb. The temperature of the filament is raised to white heat to give light.

5.3 The Switchboard Lamp No. 2 with a voltage rating of 6 volts is the lamp most commonly used. It has a tungsten filament and is sometimes called a metal filament lamp to distinguish it from earlier lamps which used a carbon filament. The filament is connected to two tinned brass plates on either side of the glass bulb. The current consumption is about 40 mA, and it operates from either D.C. or A.C.

The schematic circuit symbol is

Note : 2/6V denotes No. 2 type lamp with 6 volt rating.

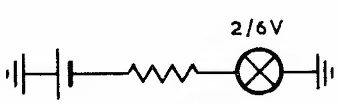
5.4 Lamps are inserted into strips of lamp sockets or jacks (Fig. 9) and each is covered by a coloured lamp cap or lens of frosted glass to diffuse the light and make the signal easily visible. The brass body of the lamp cap is split for security of fixing. Individual lamp jacks are also used.



LAMP, CAP AND LAMP JACK STRIP.

FIG. 9.

5.5 When operated from a voltage greater than 6 volts, a suitable dropping resistance is wired in series. In a telephone exchange, where the positive terminal of the battery is earthed, the negative terminal is wired to the resistor (Fig. 10) and not direct to the lamp. This protects the lamp or battery should an accidental earth connection be applied to either side of the lamp.



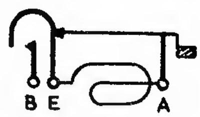
CONNECTION OF SWITCHBOARD LAMPS.

FIG. 10.

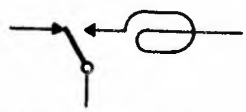
6. HAND GENERATORS.

6.1 Hand Generators (also called Magneto Generators) are hand-operated A.C. generators used in magneto telephones and some types of C.B. subscriber's equipment.

The schematic circuit symbols for some of the types in common use are -



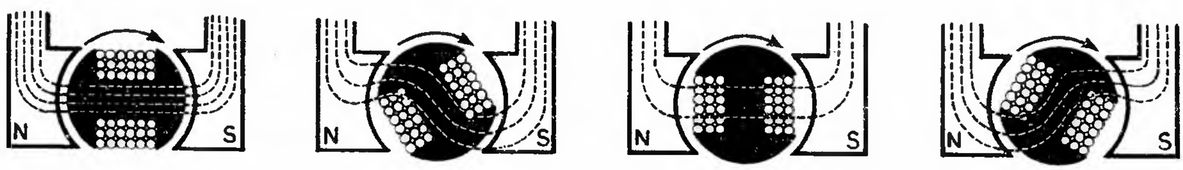
GENERATOR No. 1



GENERATORS No. 4C
TYPE C, & A.P.O. TYPE

6.2 Principle of Operation. Hand generators use the principle of electromagnetic induction. The armature,consisting of many turns of insulated wire wound on a soft iron core, is mechanically rotated in the magnetic field produced by a permanent magnet. As the coil rotates, it cuts the magnetic field and an alternating voltage is induced across the coil. When the coil is connected to a closed circuit, current flows. The voltage of the induced e.m.f. is proportional to the strength of the magnetic field, the speed of cutting, and the number of turns in the coil. The frequency depends on the speed of rotation.

6.3 Generator Voltage Waveform. When a straight conductor or loop rotates in a uniform magnetic field, the induced e.m.f. follows a sine curve. This does not apply in the hand generator, however, since the distribution of flux between the magnet poles is neither uniform nor constant. This is because the coil is wound on an H-shaped soft iron former which, as it turns, varies the reluctance and, therefore, the flux between the poles (Fig. 11).



(a) (b) (c) (d)

FIG. 11. CHANGES OF FLUX DISTRIBUTION.

The resultant voltage wave is generally peaked as shown in Fig. 12. This is because, when the armature moves from (b) to (d) in Fig. 11, not only do the conductors cut the field substantially at right angles,but the field itself rapidly cuts across the conductors from top to bottom. The broken curve indicates the sine wave voltage if the flux distribution were uniform and constant.

A hand generator operates indicators and bells which at the normal low frequencies of ringing, will respond to the peak voltage applied to them. The large peak voltage of a hand generator is, therefore, an advantage in that it may drop an indicator or produce an audible ring,when a generator of similar power output but producing a sine wave voltage, might fail.

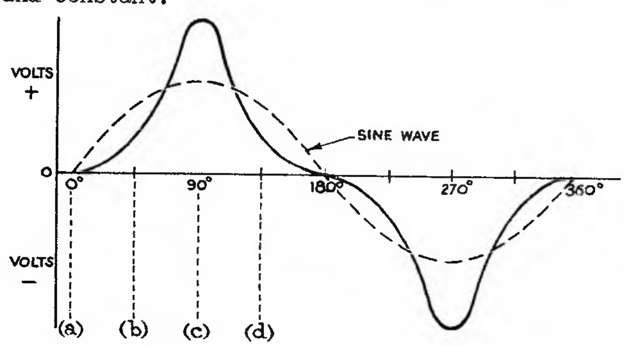


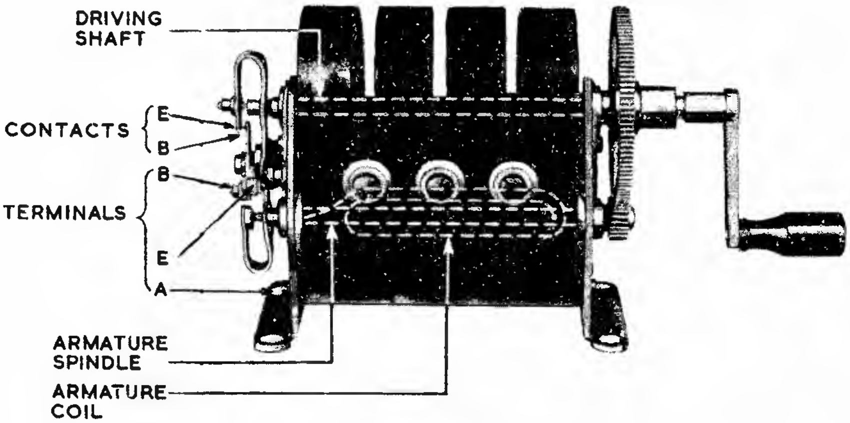
FIG. 12. WAVEFORM OF A HAND GENERATOR.

6.4 Generator Springset. A change-over springset assembly which operates mechanically when the handle is turned and restores to normal when the handle is released, is fitted at one end of the hand generator. This springset performs switching functions in the signalling circuit; these are explained in the paper "Magneto Telephones".

6.5 The Hand Generator No. 1 (Fig. 13) has four horseshoe tungsten steel permanent magnets fitted over a pair of soft iron pole pieces which are held together by non-magnetic rivets. The magnets are assembled with like poles together. The end pieces carrying the bearings, are screwed to the pole pieces.

One end of the coil winding connects to the armature spindle (which passes through the armature coil) and thus to the frame (terminal A) of the generator. The other end of the winding connects to an insulated pin which protrudes from the end of the spindle, and thus to terminal E. In the normal position, the armature is short circuited by the generator frame, driving shaft and spring E.

A small wheel on the spindle meshes with a larger driving wheel to give a gear ratio of about 5 to 1. The driving shaft has a pin riding in a V-shaped slot in the boss of the driving wheel. When the handle is turned, the shaft moves away from spring E to remove the short circuit from the armature, and contacts E and B close. Spring B is insulated from both spring E and the frame.



HAND GENERATOR NO. 1.

FIG. 13.

The D.C. resistance of the armature coil is 500 ohms. At normal hand speeds (200 r.p.m. of the handle), the e.m.f. is about 75 volts at a frequency of 17 c/s. The electrical output is 4 watts when connected to a 1,200 ohm N.I.R. load.

6.6 The Hand Generator No. 4C (Fig. 14) is similar to, but smaller than the Generator No. 1, and has three horse-shoe tungsten-steel permanent magnets. The spring-set assembly also is different.

The D.C. resistance of the armature coil is 400 ohms. At normal hand speeds, the e.m.f. is about 66 volts. The electrical output is about 1.4 watts when connected to a 1,200 ohm N.I.R. load.

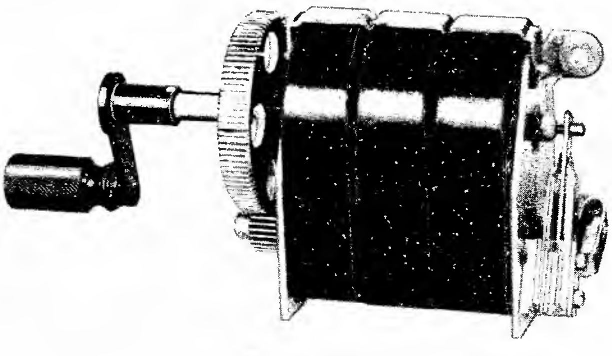


FIG. 14. HAND GENERATOR NO. 4C.

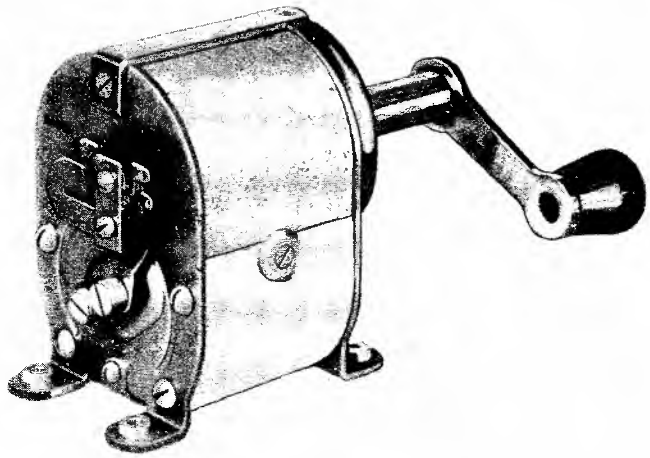
6.7 The Hand Generator Type C (Fig. 15) was originally developed for mounting in magneto table handset telephones. The generator handle projects through the space occupied by the dial on the equivalent automatic telephone.

The generator has a single alnico (an alloy of aluminium, nickel, cobalt and iron) permanent magnet, which produces a relatively greater field than the tungsten-steel magnets used in earlier generators. The alnico magnet will tend to demagnetise to a degree if it is removed from the generator. All moving parts of the generator, other than the handle and the spring-set assembly, are totally enclosed.

The D.C. resistance of the armature winding is 500 ohms. At normal operating speeds, the e.m.f. is about 112 volts, and the electrical output is 4 watts when connected to a 1,200 ohm N.I.R. load.

An output of 4 watts is required for some types of service, for example, a party line service. When used on a "straight line" service, the generator output is reduced to about 1.7 watts by a magnetic shunt which is a 16 gauge iron plate fitted between the pole pieces.

When used without the magnetic shunt, a high starting force may be necessary to turn the generator handle, particularly when ringing over short lines of low resistance. This is due to the high magnetic flux and small air gap between the armature and pole pieces. This force may move the table telephone unless it is held firmly while ringing.

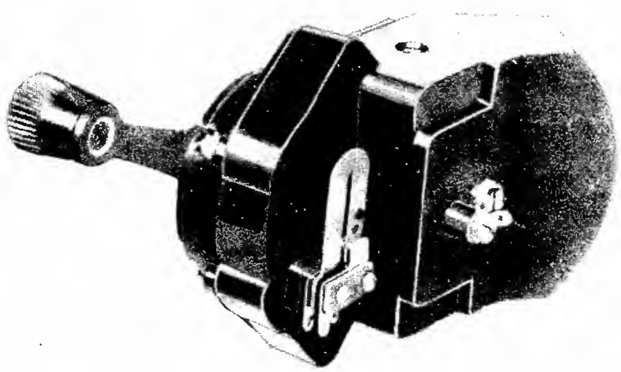


HAND GENERATOR TYPE C.

FIG. 15.

6.8 The A.P.O. Generator (Fig. 16) developed by the Australian Post Office, is designed to fit into the dial space of the type 300 magneto table and wall handset telephones.

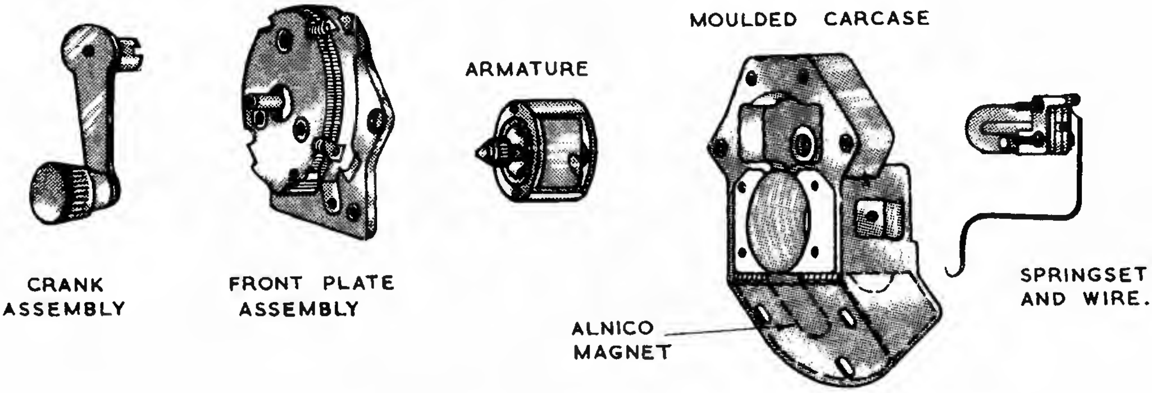
The generator consists essentially of five parts (Fig. 17). The H-shaped armature has a moulded core, in which magnetic iron laminations are suspended in moulding powder. The resistance of the armature winding is 750 ohms. The moulded carcase includes the pole pieces, which are made of malleable cast iron, and a cast alnico magnet of horseshoe shape. The alnico magnet is shown by dotted lines in the moulded carcase portion of Fig. 17.



A.P.O. TYPE MAGNETO GENERATOR.

FIG. 16.

The spring assembly is of the change-over type. The generator delivers approximately 2 watts at normal speeds.



EXPLODED VIEW OF HAND GENERATOR (A.P.O. TYPE).

FIG. 17.

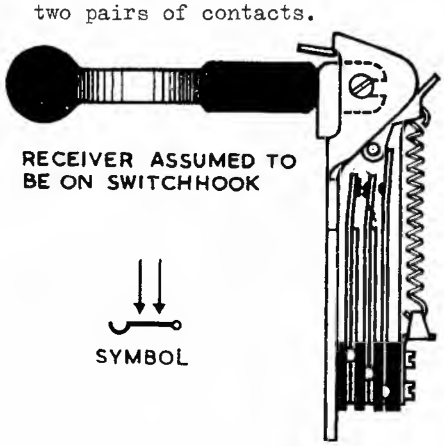
6.9 A modern type of hand generator called the rotating magnet generator has been developed by overseas manufacturers. This type has a fixed coil which eliminates the need for slip rings and collecting brushes. As the magnet rotates, the magnetic field alternately cuts the coil in opposite directions, and this induces an alternating e.m.f. in the coil.

7. SWITCH-HOOK.

7.1 Signalling from C.B. manual telephones is by means of the switch-hook (or cradle switch) contacts which make by spring tension when the receiver (or handset) is lifted, allowing current to flow through the telephone transmitter from the exchange battery. This current also operates exchange apparatus, and a lamp glows on the switchboard.

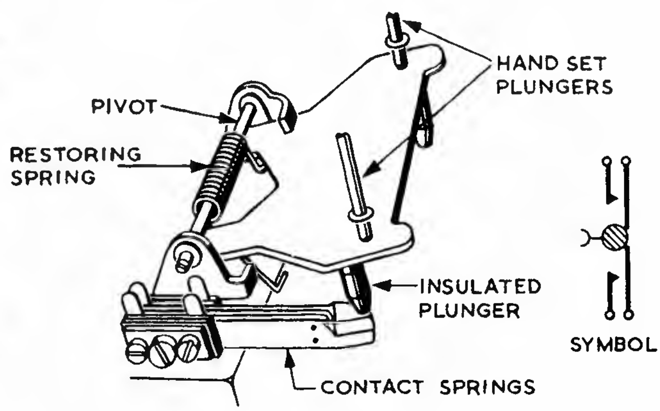
7.2 An early type of switch-hook is shown in Fig. 18. A slot is cut on the underside of the hook, which is detachable, and this is engaged by the front part of the pivot rocker. A strong spiral spring raises the hook when the receiver is lifted, and an insulated arm allows the three springs to make contact.

In handset telephones, the cradle switch (Fig. 19) consists of a pair of handset plungers which rest against a metal plate under spring tension. An insulated plunger attached to this metal plate operates a spring-set assembly consisting of two pairs of contacts.



SWITCH-HOOK.

FIG. 18.



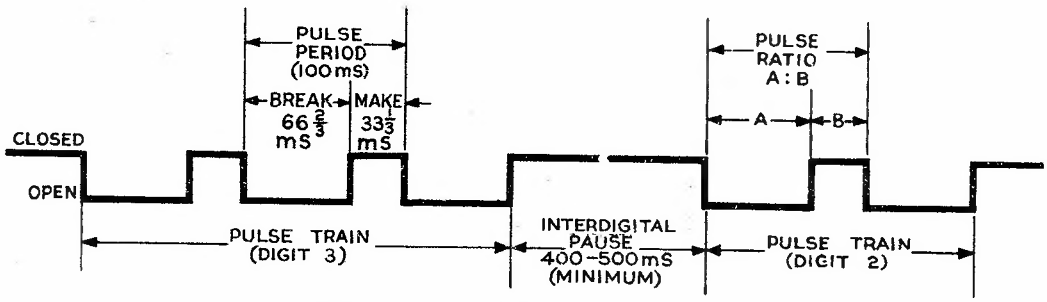
CRADLE SWITCH.

FIG. 19.

8. AUTOMATIC DIALS.

8.1 Automatic Signalling. Signalling from automatic telephones after the receiver or handset is lifted and the switch contacts close, is by means of a dial which interrupts the D.C. in the loop circuit to operate the automatic exchange equipment. Each interruption is called a pulse (or impulse), and the sequence of interruptions is a pulse train. This process is called pulsing or dialling.

Two dial pulsing springs are connected in series with the line circuit. When the dial is operated, contacts on these springs open and close the circuit a number of times corresponding to the digit dialled. Fig. 20 shows how the pulsing contacts operate during a pulse train, the open (break) period being followed by a short closed (make) period.



ILLUSTRATING TERMS USED IN DIALLING.

FIG. 20.

To ensure satisfactory operation of the exchange equipment, the break period should be $66\frac{2}{3}$ milliseconds (mS), and the make period $33\frac{1}{3}$ mS. The combined break and make period, called the pulse period, should be 100 mS.

The standard pulse speed or frequency is, therefore, 10 pulses per second (p/s).

The standard pulse ratio is the ratio of break period to make period, that is, $66\frac{2}{3} : 33\frac{1}{3}$ or 2 : 1.

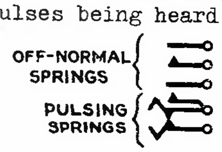
As will be seen in other papers, the automatic exchange equipment performs certain functions, such as searching for a free outlet on a bank level and switching the subscriber through to the following selector, both before the first train of pulses is received and between each successive pulse train. These operations require a minimum time, called the interdigital pause, of about 400-500 mS between pulse trains. About half of this time is taken up by the subscriber in turning the dial, and the dial pulsing mechanism is mechanically arranged to introduce a delay, sometimes called the lost motion period, of about 200 mS before each train of pulses.

8.2 The functions of an automatic dial, are -

(i) To operate the exchange apparatus by transmitting a number of pulses corresponding to the digit dialled, at a speed of 10 p/s, and a ratio of 2 : 1 break to make.

(ii) To provide the minimum time between pulse trains, required by the automatic exchange apparatus.

(iii) To automatically effect circuit changes in the telephone during dialling, so as to give the best pulsing conditions and prevent the pulses being heard as annoying clicks in the receiver. (This is the function of the off-normal springs and is explained more fully in the paper "C.B. and Auto Telephones".



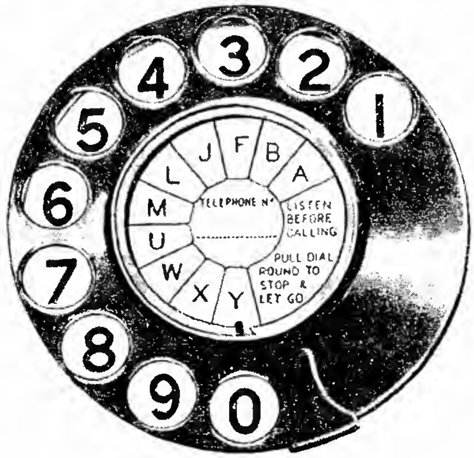
DIAL SYMBOL

The Dial No. 10 and the Dial No. 12 (also known as the Trigger Dial) are the types most commonly used in automatic telephones.

8.3 Dial No. 10. (Fig. 21). Through the holes in the finger plate are seen the numbers enamelled on a number-ring fixed to a brass case assembly by a wire spring. A fixed finger-stop is bent over the finger-plate in a position next to the digit 0. An instruction label and celluloid protection disc in the centre of the finger-plate are held in position by a securing ring.

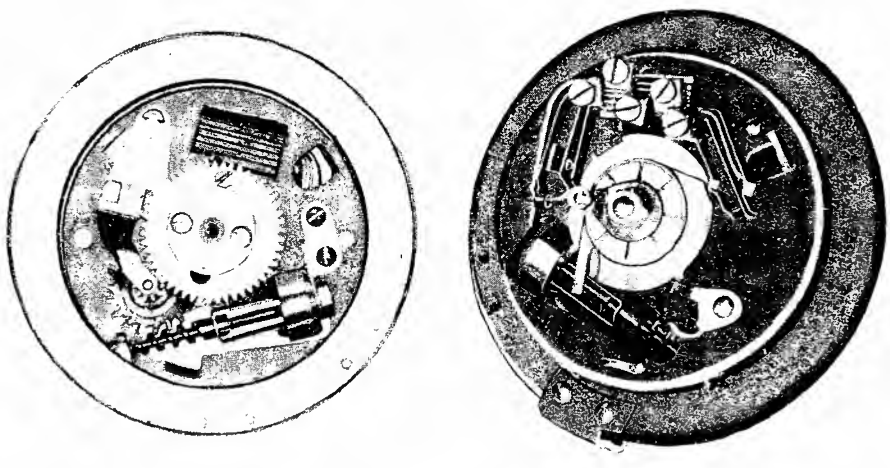
Construction. Fig. 22a shows a front view with the finger-stop, finger-plate and number-ring removed.

The finger-plate is fixed to a main spindle which rotates in a bearing in the centre of the case. When the spindle is rotated under the control of the finger-plate and then released, a spring returns it to normal. The spring (not shown in Fig. 22), which is similar to the main spring of a watch, is assembled in a case, and mounted at the back of the dial. One end of the spring keys into the boss of the main spindle bearing; the other end is fastened to the spring case, which in turn is keyed to the main spindle. A stop screw keeps the spring in a partially wound condition and also limits the rotation of the finger-plate and dial mechanism.



DIAL NO. 10.

FIG. 21.



(a) Driving Mechanism. (Front View). (b) Pulsing Mechanism. (Rear View).

CONSTRUCTION OF DIAL NO. 10.

FIG. 22.

The main gear wheel is fixed to the main spindle, and drives the governor gear mechanism which controls the pulse speed. A small coiled spring in the governor gear assembly forms the coupling between the small gear-wheel and the worm-wheel. This spring introduces a slipping clutch action so that, although the governor may turn when the finger-plate is rotated to the finger-stop, it only acts as a governor on the return motion. The governor consists of two wings, each with a small brass weight at the free end. The weights rub over the inner surface of the governor-cup when they move outwards under the influence of the centrifugal force set up by rotation.

The friction controls the speed of the governor, and consequently the speed at which the dial mechanism returns to normal. The speed of rotation depends on the adjustment of the governor wings (see paragraph 8.7).

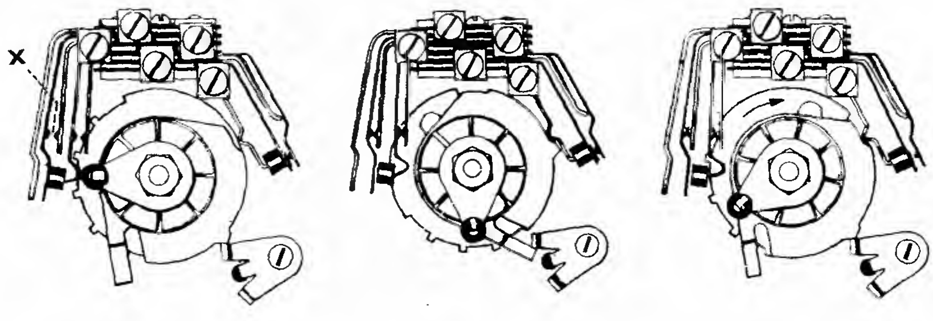
Fig. 22b shows the rear view. The pulse-wheel is fixed to the main spindle and revolves with it when the finger-plate is turned. The outside of the wheel has 10 evenly spaced slots. The switching lever is fixed to the main spindle and, between it and the pulse-wheel a slipping cam and assembly of washers are loosely fixed on the spindle. The spring-set assembly consists of two groups of contact springs - off normal springs (normally open) and pulsing springs (normally closed) - which connect to screw terminals.

The dial is secured to the telephone by three mounting lugs, one of which is provided with a fixing screw.

Pulsing operation. Fig. 23a shows the normal position of the switching lever, pulse-wheel, slipping cam, and off-normal and pulsing springs.

During the forward motion of the finger-plate, the switching lever moves away from the off-normal springs, which close. The outer springs (X) are adjusted to make before the inner pair to prevent loud clicks in the telephone receiver when the dial is pulled off-normal. Also, the pulse-wheel and slipping cam move together until the latter is arrested by the forked stop. The pulse-wheel then continues to move, and when the forward motion of the finger-plate is completed, a number of slots corresponding to the digit dialled are exposed by rotation past the pulsing recess in the cam. The slipping cam masks the pulse-lever from the slots in the pulse-wheel, so that no pulses are produced during the above operation. Fig. 23b shows the conditions just prior to removing the finger after dialling 1.

When the finger-plate is released, the dial returns to normal under control of the main spring and the slipping cam moves with the pulse-wheel until again arrested by the forked stop. During this movement, the slipping cam masks two slots of the pulse-wheel to provide a lost motion period of about 200 mS. The pulse-wheel is then unmasked, and during the remaining portion of the return motion, the pulse-lever falls into the slots which have been exposed on the pulse-wheel. Thus, the pulsing contacts break and make a number of time corresponding to the digit dialled. Fig. 23c shows the conditions during the break period of the pulsing contacts.



(a) Normal Position. (b) One Pulse Prepared. (c) Pulsing Position.

ACTION OF PULSING MECHANISM.

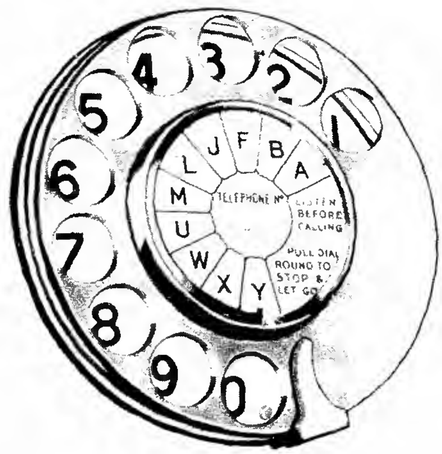
FIG. 23.

After the pulsing contacts close at the end of the last break period, the switching lever opens the off-normal springs as the finger-plate comes to rest against the stop screw.

8.4 Dial No. 12 (Trigger Dial). The slipping cam of the Dial No. 10 sometimes causes wrong numbers. Too much lubricant between the pulse-wheel and the slipping cam or inadequate pressure, causes the cam to slip before it is stopped by the forked stop. Also, the oil tends to congeal at low temperatures, which slows down the return motion of the dial mechanism.

The Trigger Dial (Fig. 24) is a modern dial which does not use a slipping cam. It is interchangeable with the Dial No. 10, but has fewer parts and is more silent and reliable in operation. The front appearance is similar to the Dial No. 10, except that the finger-stop is narrower.

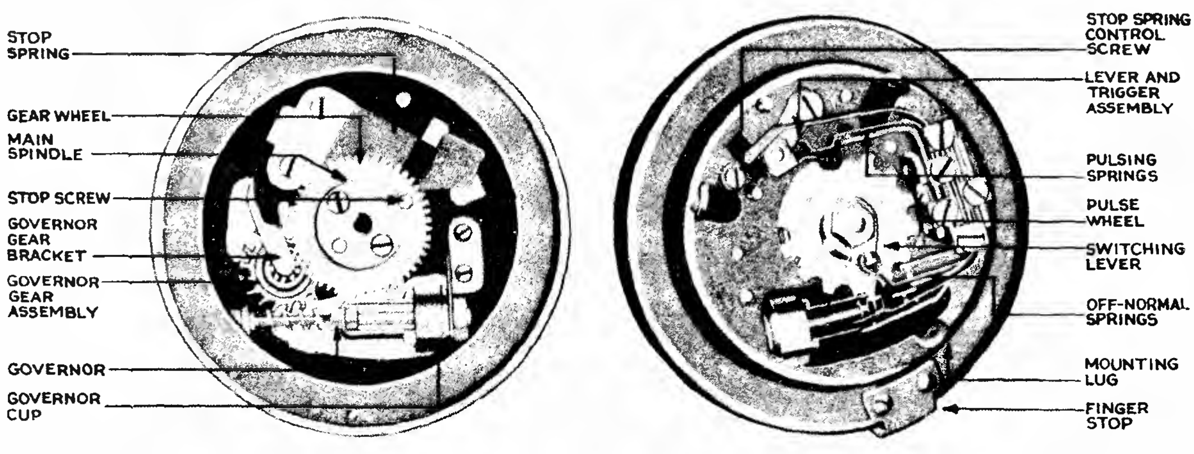
A simple "trigger" assembly to replace the slipping cam, can be fitted on the Dial No. 10 to give the improved performance of trigger dial operation.



TRIGGER DIAL

FIG. 24.

Construction (Fig. 25). The driving mechanism and governor action is similar in principle to that of the Dial No. 10. The noise generated by the drive has been reduced by using a bakelite worm-wheel, and by including a rubber damping ring under the number-plate. This type of worm-wheel also reduces wear on the governor and the possibility of sticking. The stop spring, which keeps the main spring in a partially wound condition, is adjusted from the rear of the dial.



(a) Driving Mechanism (Front View). (b) Pulsing Mechanism (Rear View).

CONSTRUCTION OF TRIGGER DIAL.

FIG. 25.

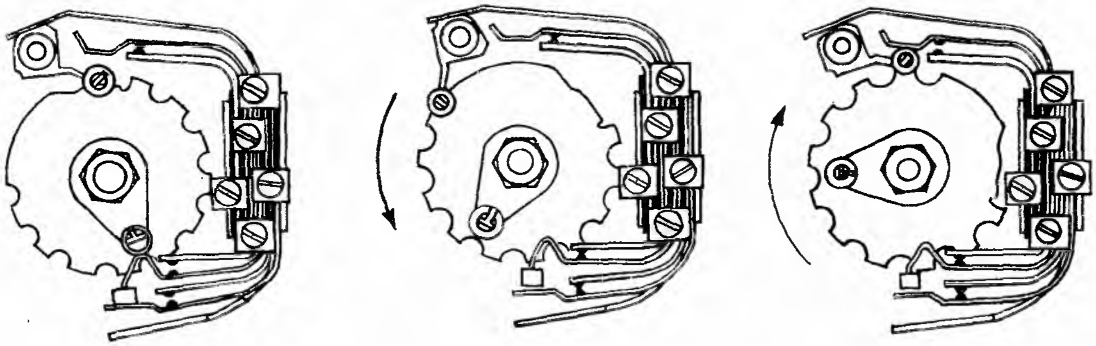
The pulsing mechanism differs from the Dial No. 10. The pulse-wheel and switching lever are fixed to the main spindle, and revolve with it when the finger-plate is turned. The spring-set assembly consists of two groups of contact springs - pulsing springs (normally closed) and off-normal springs (normally open) - which connect to screw terminals. The terminals are spaced further apart than those in the Dial No. 10, reducing the possibility of accidental short circuits. The shaft of the pulse-lever and trigger assembly is lubricated by two felt pads placed around an exposed section of the shaft. The teeth of the pulse wheel are also lubricated by a felt pad to reduce noise caused by the lever falling into the spaces between the teeth.

Pulsing operation (Fig. 26). In the normal position (Fig. 26a), the trigger lies underneath the pulse springs.

During the forward motion of the finger-plate, the pulse-wheel rotates and transfers the trigger to the articulated position (Fig. 26b). Also, the switching lever moves away from the off-normal springs which close.

When the finger-plate is released, the pulse-wheel rotates in a clockwise direction (Fig. 26c) and picks up the trigger transferring it to the pulsing position. The time taken for the trigger to move from the articulated position before the first pulse is given, provides a lost-motion period of about 230 mS. The trigger then rides over the teeth of the pulse-wheel and interrupts the pulsing contacts.

When the dial returns to normal at the end of each pulse period, the switching lever opens the off-normal springs.



(a) Normal Position. (b) Articulated Position. (c) Pulsing Position.

ACTION OF PULSING MECHANISM.

FIG. 26.

8.5 Precautions when dialling. To avoid wrong numbers, it is essential to dial correctly. Turn the finger-plate round until the finger firmly touches the finger-stop. Then remove the finger and let the dial return unaided.

A clipped first pulse may occur with the Dial No. 10 should the hole in the finger-plate by careless operation, fail to reach the finger-stop. Also, if the finger-plate "overshoots" the finger-stop, an additional short pulse may be produced. Overshooting may occur if a pencil is used instead of the forefinger to turn the finger-plate.

The trigger dial does not give a clipped or an additional short pulse. If the finger-plate is moved too far or too little in relation to the finger-stop, the trigger rides on the upper edge of the following or preceding tooth of the pulse-wheel. On the release of the dial, the trigger falls back into the groove corresponding to the digit dialled.

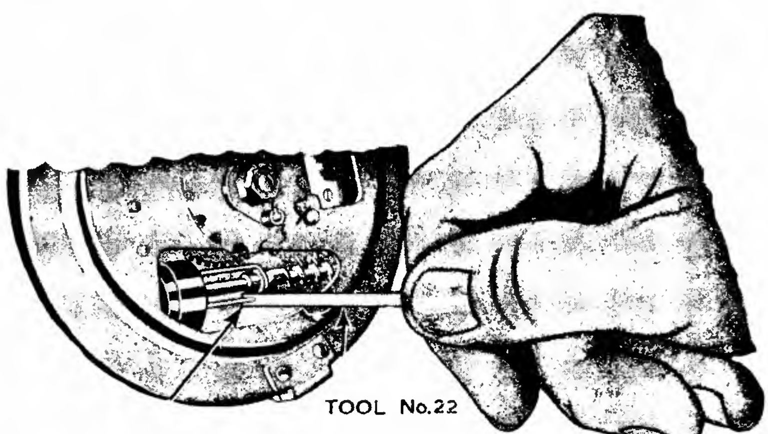
8.6 Special Types. Some public telephone circuits used with the prepayment type of coin collecting boxes, are designed so that the caller cannot operate the exchange apparatus without prepayment, except when making calls to an operator at a parent exchange or special services. To enable a caller to gain access to an exchange operator without prepayment, a special dial (Dial No. 11) is fitted to the telephone. This dial is similar to the Dial No. 10 but has an auxiliary cam and spring-set assembly which operates when a particular digit is dialled (usually 0).

Other special types of dials used in some party-line telephones in rural automatic exchange areas, are similar to the Dial No. 10 and Trigger Dial, but modified to include an auxiliary cam and a make-before-break spring-set.

8.7 Adjustments. The critical performance limits and the intricate nature of the dial mechanism, make it inadvisable to do other than very simple maintenance such as speed adjustment, on dials in working equipment. In general, faulty dials are changed by technicians and repairs are done at a central depot.

The pulse speed will vary as the main spring loses tension or as the friction of the governor alters with use. Although most automatic switches will work with speeds of from 7 to 14 p/s, the dial speed should be kept as near as possible to 10 p/s to allow a working margin. The speed is corrected by bending the governor wings from the root only, using a Tool No. 22. (Fig. 27). The wings must be evenly positioned and free from kinks or bows.

To increase the speed, bend the wings inwards.
To decrease the speed, bend the wings outwards.



ADJUSTING SPEED OF DIAL.

FIG. 27.

During adjustment, the identification of a particular governor wing can be made by the relationship of its position to the end of the worm thread. Alternatively, a spot may be painted on one of the wings.

The buffer spring between the pulsing springs provides a means of adjusting the pulse ratio. The ratio is adjusted before installation of the dial, however, and is not altered on a subscriber's premises.

For additional information on adjustments and replacement of dial parts, refer to E.Is. TELEPHONE Exchanges Automatic AD 1103 (Dial No. 10), and Substation AD 101C (Trigger Dial).

9. TEST QUESTIONS.

1. What is the difference between a trembling bell and a buzzer?
2. The symbol for a trembling bell is ....
3. The symbol for a buzzer is ....
4. Describe with the aid of diagrams, the basic construction and principle of operation of a trembling bell.
5. What causes sparking at the contacts of a buzzer? How is this sparking reduced?
6. Why are magneto bells used in preference to trembling bells in telephones?
7. Describe, with diagrams, the basic construction and principle of operation of a magneto bell.
8. The symbol for a magneto bell is ....
9. Why is a magneto bell unsuitable for operation from D.C.?
10. The D.C. resistance of the magneto bell used in telephones is usually ....
11. What is the reason for the residual studs in a magneto bell?
12. The symbol for a drop indicator is ....
13. The function of a line indicator is ....
14. The function of a clearing indicator is ....
15. Describe, with diagrams, the basic construction and principle of operation of a drop indicator
16. What is the reason for the residual stud in a drop indicator?
17. Why must a clearing indicator have high impedance?
18. How is crosstalk prevented between clearing indicators?
19. The symbol for an eyeball indicator is ....
20. Describe, with diagrams, the basic construction and principle of operation of an eyeball indicator.
21. The symbol for a 6 volt switchboard lamp No. 2 is ....
22. The current consumption of a 6 volt switchboard lamp is about ....
23. Briefly explain the principle of operation of a hand generator.
24. The frequency of the generator output voltage depends on ....
25. The voltage of the e.m.f. induced in the generator armature is proportional to -

    (i) .... (ii) .... (iii) ....
26. The symbol for a hand generator with a change-over spring assembly is ....
27. Why is a magnetic shunt used with a hand generator type C?
28. The symbol for a dial is ....
29. What are the functions of the dial pulsing and off-normal springs?
30. The standard break period of the pulsing contacts is ....; the make period is ....
31. The standard pulse speed is ....
32. The standard pulse ratio is ....
33. What is meant by the terms - (i) interdigital pause; (ii) lost-motion period?
34. Compare the pulsing operation of a Dial No. 10 and a Trigger Dial.
35. Describe how the lost-motion period is provided in a Dial No. 10 and a Trigger Dial.
36. How is the speed of a dial adjusted?

END OF PAPER.

THE AUSTRALIAN POST OFFICE

COURSE OF TECHNICAL INSTRUCTION

SWITCHING APPARATUS.

---

1. INTRODUCTION.

1.1 In magneto and C.B. manual telephone systems, apparatus is provided for the telephonist to connect or "switch" together any two lines terminating at the exchange.

On the larger (cord type) manual switchboards the lines terminate on special spring assemblies called jacks, and switching is done by plugs and flexible cords. To answer a call or to monitor the progress of a call between two subscribers, the telephonist connects her telephone circuit to a particular cord by means of a key.

Some small switchboards (cordless type) have no cords and all the interconnecting and monitoring is done by either plugs and jacks or keys only.

1.2 In general, switching in automatic exchanges is done by automatic selectors and associated relays. Relays are also used in some manual switchboards.

1.3 This paper describes the construction and principle of operation of the more common items of switching apparatus.

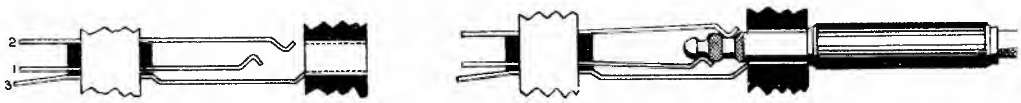
2. JACKS, PLUGS AND CORDS.

2.1 Switchboard jacks (Fig. 1) have two or more nickel-silver springs and a brass socket (sleeve), separated by strips of insulating material. They are two-, three-, four-point, etc., according to the number of tag connections.

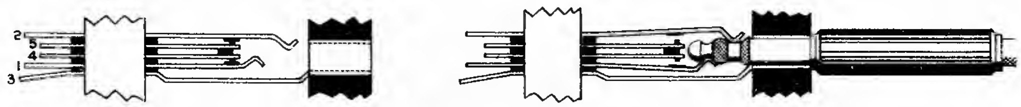
When a plug is inserted in a jack (Fig. 1a), the tip and ring sections of the plug connect to the line (tip and ring) springs of the jack. The sleeve of the plug bears against the jack socket. The tip, ring and sleeve connections are numbered 1, 2 and 3 respectively.

In Fig. 1b, silver contacts on the inner springs (4 and 5) normally make connection with the line springs. These contacts break when a plug is inserted.

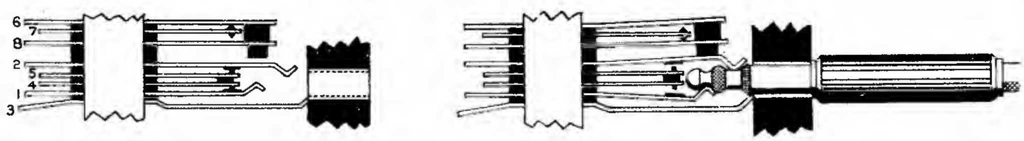
In Fig. 1c, auxiliary springs (6, 7 and 8) are fitted, which are operated by the movement of a line spring when a plug is inserted.



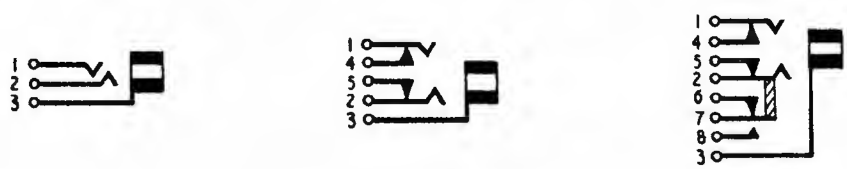
(a) 3-point jack.



(b) 5-point jack.



(c) 8-point jack.



SYMBOLS.

FIG. 1. TYPICAL SWITCHBOARD JACKS.

On switchboards, jacks may be fitted individually or in strips of either 10 or 20. (Fig. 2.)

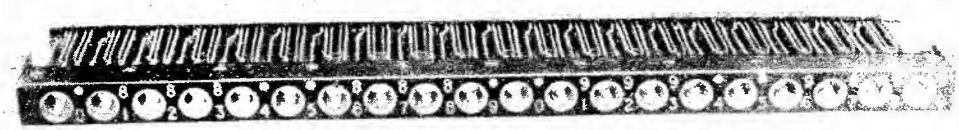


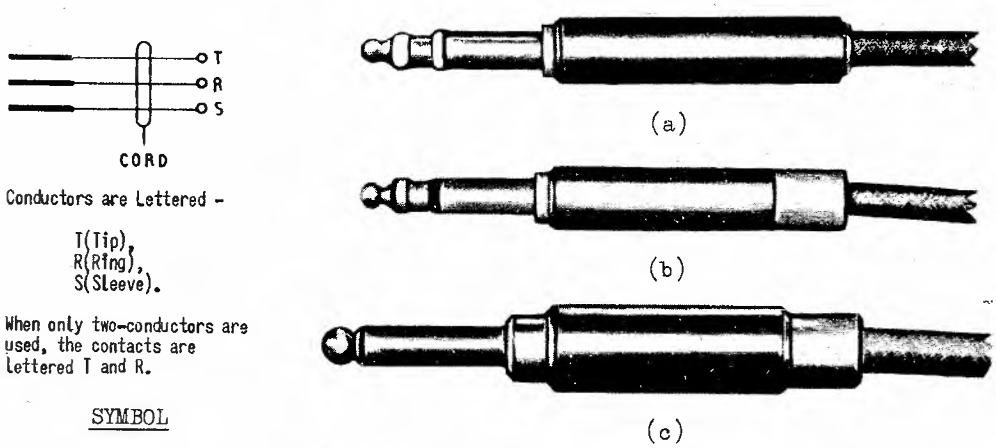
FIG. 2. TYPICAL JACK STRIP.

2.2 Switchboard plugs and cords (three-conductor) are used in C.B. manual switchboards. The connections are tip, ring and sleeve.

Fig. 3a shows a modern three-conductor plug with moulded insulation. The tip, ring and sleeve connections are brass, and a thick insulating collar between tip and ring prevents short circuits while the plug is being inserted in a jack. An insulating cover secured by a small screw, completely insulates the brass body of the plug to prevent the telephonist receiving electric shocks from the sleeve circuit, during switching.

In some plugs (Fig. 3b), an insulated brass collar is fitted between tip and ring, and the cover does not completely insulate the body of the plug.

Two conductor plugs (Fig. 3c) and cords are used in some early magneto switchboards. The connections are tip and sleeve, although these are generally referred to as tip and ring.



TYPICAL SWITCHBOARD PLUGS.

FIG. 3.

Switchboard plugs are tested with gauges to ensure that the diameters of the tip, ring and sleeve are within the specified tolerances. The inside diameters of jack sockets are similarly tested. Worn plugs and jacks must be replaced because if they do not fit correctly, they cause noisy connections.

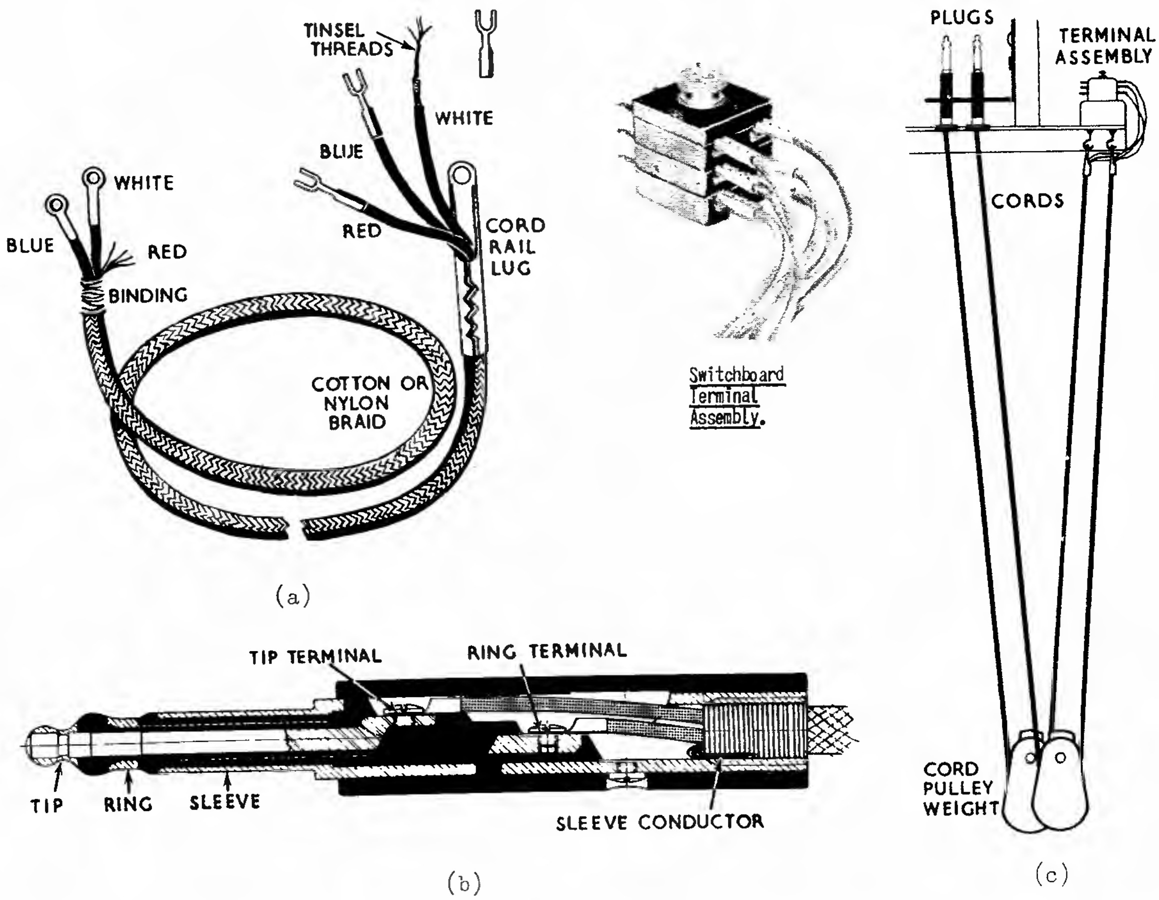
2.3 Switchboard cords are flexible cords designed to withstand continual twisting and bending. In practice, faults often develop where the cord is screwed into the plug.

In a typical three-conductor cord (Fig. 4), each conductor consists of a number of thin copper alloy wires (called tinsel threads) wound around cotton threads, with an insulation covering of cotton braid, rubber or P.V.C., coloured white, blue or red to indicate the tip, ring or sleeve respectively. These are spiralled together and made up to circular cross-section with three soft-cotton wrappings. The cord is enclosed in a cotton or nylon braiding, usually coloured either light grey (neutral) or red.

Small loop or side entry tags are clamped to the tip and ring conductors (white and blue) and screwed to the plug terminals. The side entry tag may be removed from the plug by loosening the screw. The sleeve conductor (red) is not tagged, but the bared tinsel is turned back over a linen thread binding wound over the outer braiding, which is screwed into the end of the plug. (Fig. 4b.) It is not practicable to solder the tinsel wires to the tags because the cotton threads would char under the heat of a soldering iron.

Forked tags are clamped to the tinsel wires at the other end of the cord. A metal lug clamped over the outer braiding is attached to the cord rail in the switchboard, so that the tag terminations are not strained where they connect to the switchboard terminals. (Fig. 4c.) In early cords, a strain cord is used instead of the cord-rail lug. Each cord is threaded through a brass pulley weighted with lead. This restores the plug, when not in use, to its normal position in the plug shelf.

The switchboard terminal assembly is a moulded block into which the tags for two cords are inserted. Tightening or loosening is done by the knurled thumb screw. In early switchboards, screw terminals are used for each tag.



TYPICAL SWITCHBOARD CORD. (3 CONDUCTOR.)

FIG. 4.

The early two-conductor cord is similar, except that one of the conductors is omitted. The white conductor is the tip, and the ring (which is not tagged at the plug end) is either blue or red.

2.4 Plug seat switches are fitted on some early type C.B. switchboards. They consist of a brass tube (or barrel) on which is mounted three nickel-silver springs with silver contacts. A switchboard cord normally passes through the barrel. When a plug rests in the top of the barrel, it pushes against a hinged bracket and a plunger moves to open the spring contacts. When the telephonist lifts the plug, during switching, the spring contacts make to complete a supervisory circuit.

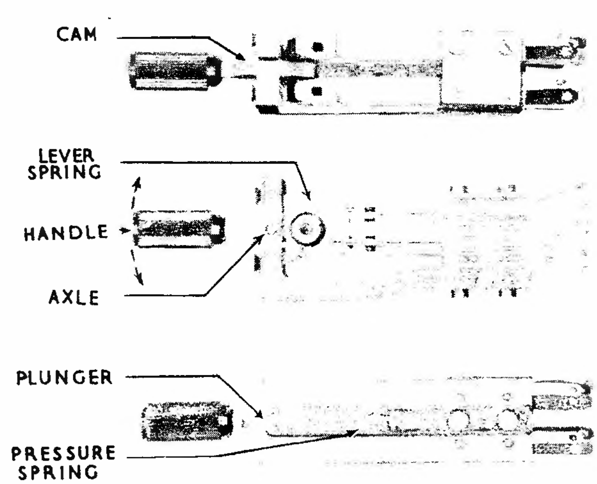
3. LEVER AND PLUNGER KEYS.

3.1 A telephone key is a hand operated assembly of contact springs used to open and close electrical circuits. The main types are lever keys and plunger keys.

3.2 A typical lever key (Fig. 5) has a number of nickel-silver springs with silver contacts. The springs are separated by strips of insulating material, and mounted on an L-shaped brass frame. When the key handle is moved to either side of the centre (normal) position, insulating rollers on the cam move against the main lever springs and the contacts operate.

The main lever spring of a change-over contact unit carries a small L-shaped projection which, when the main spring moves, carries the corresponding short spring away from the break spring. This ensures a satisfactory contact pressure without critical adjustment of the moving spring.

The long limb of the frame carries a steel spring which presses against a small metal plunger and forces a steel ball against the edge of the cam. In the normal position, the ball enters a recess in the edge of the cam, and locates the key in its central position. This prevents momentary over-riding when the key is restored to normal.



TYPICAL LEVER KEY (3-POSITION).

FIG. 5.

3.3 Lever keys are either

- three-position, with one "off" (normal) and two "on" (operated) positions, or
- two-position, with one "off" and one "on" position. This type has a pin inserted through a hole in the cam to prevent movement into the unused position.

The operated positions are either

- locking, which means they remain operated without being held, or
- non-locking, which means they restore to the normal position due to spring tension when released by the hand. This type has two studs on the frame, which limit the travel of the rollers, and prevent locking. Also the ends of the main lever spring are set at a sharper angle.

Some three-position keys have both a locking and a non-locking operated position.

3.4 Contact Units. A contact unit is a combination of a lever spring and the springs electrically associated with it.

In any contact unit

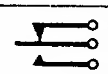
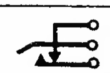
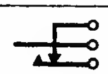
- the lever spring is the spring by which the unit is operated,
- the make spring makes connection with the lever spring when operated,
- the break spring breaks connection with the lever spring when operated.

Keys are made up of various contact units, as required (Fig. 6a). Note that the terms "make" and "break" refer to the operated condition of the contacts, and not to the unoperated condition. The difference between the change-over and the make-before-break is that, in the latter, the "make" contacts close before the "break" contacts open. Present practice is to use C or K contact units when a single make or break action is required, leaving the spare spring for possible future use.

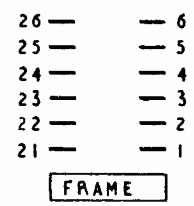
Viewed from the tag end, the springs are numbered from the frame (Fig. 6b).

In schematic circuits, contact units are often shown detached. The key designations comprising the code letters over a figure denoting the total number of contacts units in the spring-set are then shown in an inset diagram on the drawings (Figs. 6c and 6d).

Spare contact units are shown adjacent to the inset, coded and numbered.

CONTACT UNIT	DRAWING SYMBOL		LETTER SYMBOL
	LOCKING	NON-LOCKING	
MAKE			M
BREAK			B
CHANGE-OVER			C
MAKE-BEFORE-BREAK CHANGE-OVER			K

(a) Contact Units.



(b) Spring Numbering.
(Viewed from tag end.)

SPEAK (KS) / 4 + RING (KR) / 2

(c) Three Position Key.

RING CHANGE-OVER (KRC) / 2

(d) Two Position Key.

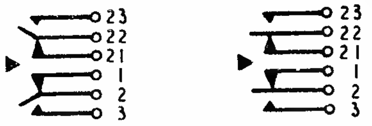
FIG. 6. LEVER KEY CONTACT UNITS.

3.5 A typical plunger key (Fig. 7) has a number of nickel-silver springs with silver contacts. The springs are insulated from each other and mounted on a brass frame. When the key handle is pushed inwards, an ebonite plunger moves against two rollers at the ends of the lever springs, and the contact units operate. The operated position may be either locking or non-locking.

In the locking key, the ebonite plunger is shaped so that when the lever spring rollers ride over the upper edge of the V-shaped portion, the return of the plunger to normal is prevented. The springs are restored to normal by pulling the key handle outwards.

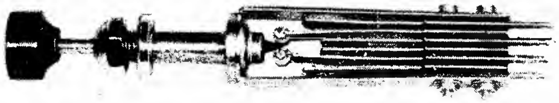
In the non-locking key, the V-shaped portion of the plunger is longer, so that the lever spring rollers do not ride over the upper edge, and when released, the springs and plunger restore to normal due to spring tension.

As with lever keys, the contact units may be M, B, C and K. Viewed from the tag end, the springs are numbered outwards from each side of the plunger.



LOCKING NON LOCKING

SYMBOL



(a) Unoperated.

(b) Operated.

FIG. 7. PLUNGER KEYS.

4. TUMBLER SWITCHES.

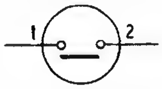
4.1 Shock-proof tumbler switches (Fig. 8) have metallic terminals mounted on an insulating base, and protected by an insulating cover. When the switch is operated by a lever-handle pivoted on the front of the switch, a conducting link moves between the terminals to open or close a circuit, as desired.

4.2 A single-pole (S.P.) switch makes or break a circuit on one conducting path only.

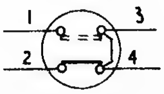
A double-pole (D.P.) switch makes or breaks two conducting paths simultaneously.

A one-way switch provides a single path for current.

A two-way switch provides two alternative paths for current.



S.P. ONE-WAY
(WITH OFF POSITION)

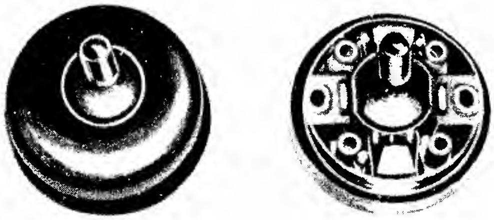


S.P. TWO-WAY
(WITH INTERNAL STRAP)

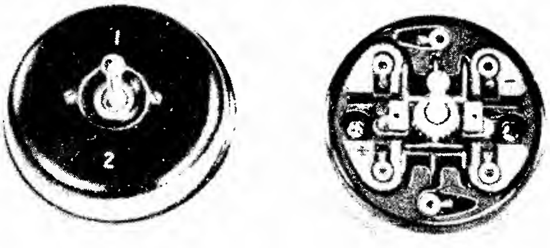
D.P. TWO-WAY

The broken lines show connections for other position of switch.

SYMBOLS.



(a) S.P. two-way switch



(b) D.P. two-way (change-over) switch

FIG. 8. TYPICAL TUMBLER SWITCHES.

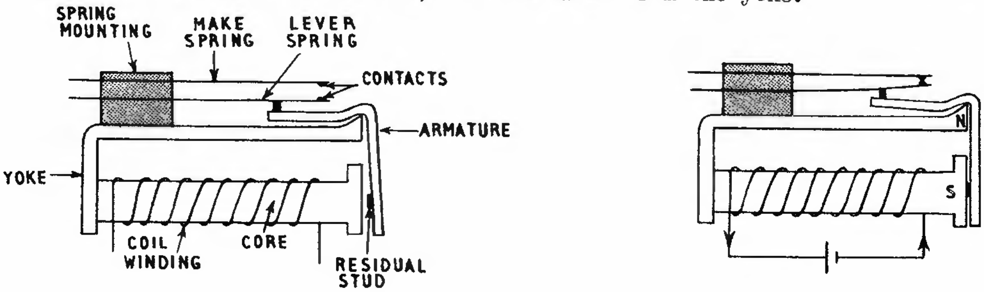
5. TELEPHONE RELAYS.

5.1 A telephone relay is an electromagnetic device used to open and close electrical circuits. Most telecom circuits depend on one or more relays for their correct operation. They are important because, in a single call between two automatic telephones, up to 200 relays may be brought into use. There are many thousands of relays in a large automatic exchange.

The relays most commonly used in modern equipment are the 3000 and 600 types.

5.2 Basic construction and operation. A coil of insulated copper wire is wound on a soft iron core, which is secured at one end to an L-shaped soft iron yoke. A soft iron armature pivots on the front end of the yoke. A non-magnetic residual stud or screw prevents the armature from touching and sticking to the core due to residual magnetism. (Fig. 9a.)

When D.C. flows through the coil (Fig. 9b), a flux is set up in the magnetic circuit (core, yoke, armature and air-gap) and the armature and core face are magnetised with opposite polarities. The armature is attracted and an extension operates the spring-set which is mounted on, but insulated from the yoke.



(a) Unoperated. (b) Operated.

FIG. 9. OPERATION OF TELEPHONE RELAY.

When the coil current is switched off, the magnetic flux collapses and the attractive force between armature and core is reduced. The tension of the springs moved directly by the armature (lever springs) restores the armature and spring-set to normal.

5.3 Contact Units (Fig. 10.) As with lever keys, the contact units which make up the spring-set are make, break, change-over and make-before-break.

Note that the terms "make" and "break" refer to the operated (not the unoperated) condition of the contacts.

In the change-over unit, the make contacts close after the break contacts open.

In the make-before-break unit, the make contacts close before the break contacts open.

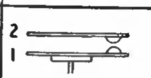
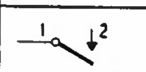
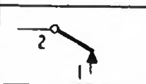
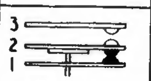
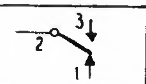
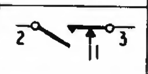
NAME	PICTURE OF SPRING SET	DRAWING SYMBOL	LETTER SYMBOL
MAKE			M
BREAK			B
CHANGE-OVER			C
MAKE-BEFORE-BREAK CHANGE OVER			K

FIG. 10. CONTACT UNITS.

5.4 Flux in magnetic circuit.

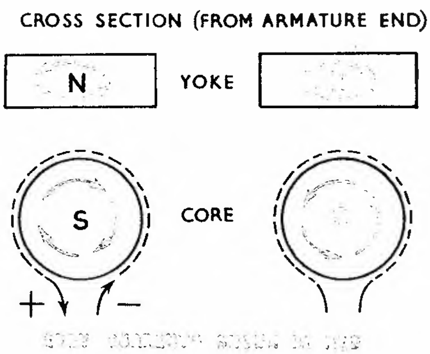
Effect of inductance. When the relay coil circuit is closed, the current does not rise immediately to its Ohm's Law value. As the current commences to rise, the flux in the magnetic circuit rises and links the turns of the coil, inducing an e.m.f. of self-induction which, by Lenz's Law, opposes the applied e.m.f., so limiting the current. The induced e.m.f. depends on the rate of change of current and decreases at a progressively lower rate as the current rises. The current and, therefore, the flux (which is proportioned to the ampere-turns) takes a certain time to rise from zero to the final steady value.

When the relay circuit is opened, the coil current falls to zero practically instantly.

Effect of eddy currents. When the current rises (or falls) in the coil, the rising (or collapsing) flux cuts the solid metal parts of the magnetic circuit (core, yoke and armature). This induces an e.m.f. with resultant eddy currents, the magnetic effects of which, by Lenz's Law, oppose the change of flux producing them.

The magnetising force of these eddy currents, therefore,

- opposes the rise of flux in the magnetic circuit when the coil circuit is closed (Fig. 11a), causing the flux to rise even more slowly and to take longer to reach a particular value;
- opposes the decay of flux when the coil circuit is opened (Fig. 11b), prolonging the collapse of flux.



(a) Current in coil. Flux rising. (b) No current in coil. Flux collapsing.

FIG. 11. EFFECT OF EDDY CURRENTS ON COIL FLUX.

The combined effects of inductance and eddy currents are shown in Fig. 12.

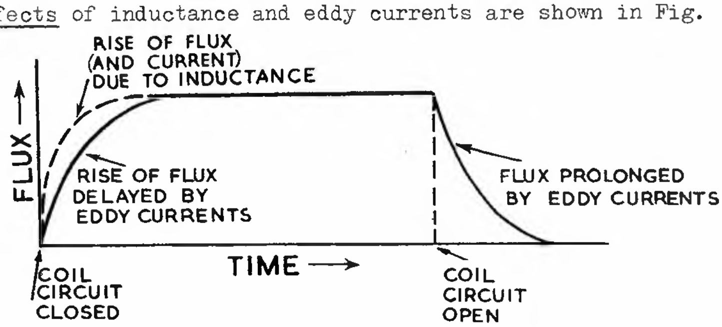


FIG. 12. FLUX IN MAGNETIC CIRCUIT OF RELAY.

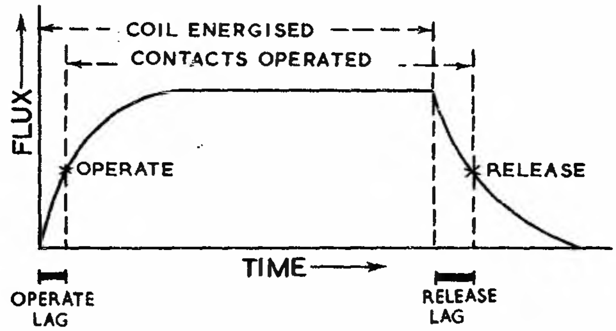
As the flux rises gradually, a gradually increasing attractive force is built up between the armature and core. At some particular value of flux, the attractive force is sufficient to overcome the tension of the lever springs, the armature is attracted and the spring-set operates.

Similarly, when the flux decays to a value low enough to allow the spring tension to overcome the attraction between armature and core face, the armature releases and the spring-set restores to normal.

6. OPERATE AND RELEASE LAGS.

6.1 A relay does not operate immediately its circuit is closed. The delay in operation, or time interval between the application of an e.m.f. to the coil and the rise of flux to the operate value, is the operate lag or operate time.

Similarly, a relay does not release immediately its circuit is opened. The delay in release, or time interval between the opening of the coil circuit and the fall of flux to the release value, is the release lag or release time.



OPERATE AND RELEASE LAGS.

FIG. 13.

6.2 Factors affecting operate and release lags.

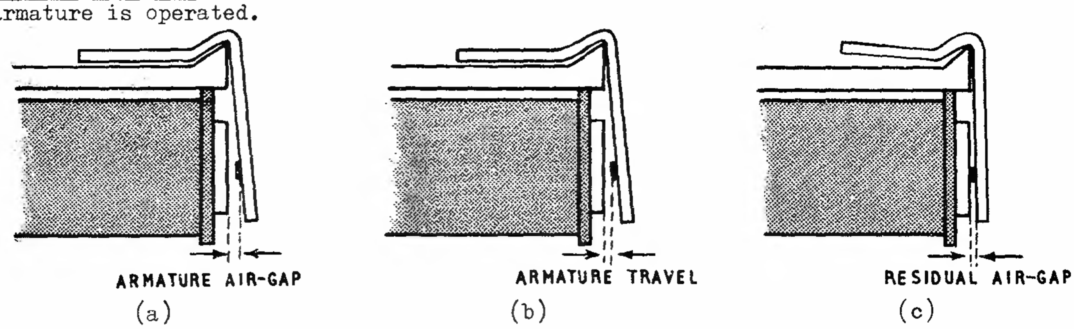
Design factors	-	inductance of winding,
	-	eddy currents.
Adjustments	-	spring tension or armature load,
	-	armature air-gap or armature travel,
	-	residual air-gap.

Spring tension is the force exerted by a spring, usually a lever spring, which tends to hold the armature in the unoperated position. The combined force exerted by the springs on the armature, is the armature load.

Armature air-gap is the distance between armature and core, when the armature is unoperated.

Armature travel (stroke) is the distance through which the armature moves from the unoperated to the operated position. It is equal to the distance between residual stud (or screw) and the core, when the armature is unoperated.

Residual air-gap (residual) is the distance between armature and core, when the armature is operated.



TERMS USED IN RELAY ADJUSTMENTS.

FIG. 14.

6.3 Effect of varying inductance. Increasing the inductance (for example, by improving the magnetic circuit or increasing the number of turns) increases the effect of the induced voltage, and the current and flux rise to the steady value still more gradually. This increases the operate lag.

Increasing the inductance may also increase the release lag. The inductance of a relay is largely a measure of its flux producing properties - a high inductance relay generally produces more flux than a low inductance relay, other factors being kept the same. When the circuit to each relay is opened, the currents fall to zero practically instantly but, because of the higher flux in the high inductance relay, the eddy currents are greater and the flux takes longer to decay to the release value.

Conversely, decreasing the inductance reduces the operate and release lags.

6.4 Effect of varying eddy currents. Increasing the eddy currents (for example, by fitting a copper cylinder over the armature end of the core),

- increases the operate lag by further delaying the rise of flux when the relay is operating, and

- increases the release lag by further prolonging the flux on release.

Conversely, decreasing the eddy currents (for example, by using a nickel-iron core which has higher resistivity than soft iron) reduces the operate and release lags.

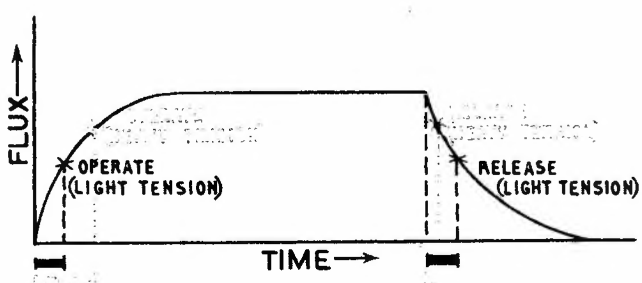
6.5 Adjustment of spring tension, particularly the lever springs.

When the spring tension or armature load is increased,

- a greater operate flux is required to produce the extra attractive force between armature and core to overcome this extra tension, and

- the heavier spring tension forces the armature away from the core at a higher value of release flux.

This increases the operate lag and decreases the release lag. (Fig. 15.)



EFFECT OF SPRING TENSION ADJUSTMENT.

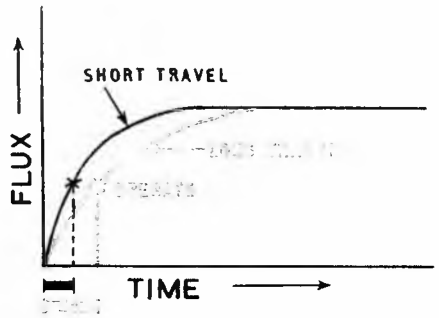
FIG. 15.

Conversely, a lighter spring tension decreases the operate lag and increases the release lag.

6.6 Adjustment of armature air-gap (or armature travel). Increasing the armature air-gap (long travel) increases the reluctance of the magnetic circuit and the same current produces less flux than with a small air-gap. Thus a higher current is necessary to produce the required value of operate flux, and the operate lag is increased (Fig. 16). Conversely, a short armature travel decreases the operate lag.

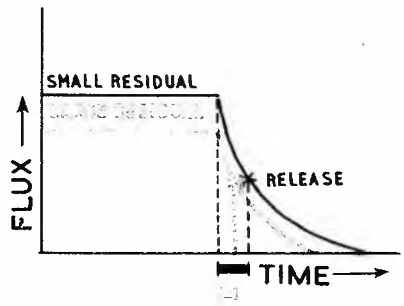
Also the longer the armature travel, the further the lever springs move from the normal position. A slight increase of armature load results, which reduces the release lag slightly.

6.7 Adjustment of residual air-gap. Increasing the residual increases the reluctance of the magnetic circuit. This reduces the steady flux when the relay is operated. When the current is disconnected, the falling flux reaches the armature release value sooner and the release lag is decreased. (Fig. 17.) Conversely, a small (fine) residual air-gap increases the release lag.



EFFECT OF ARMATURE TRAVEL ADJUSTMENT.

FIG. 16.



EFFECT OF RESIDUAL AIR-GAP ADJUSTMENT.

FIG. 17.

6.8 Table 1 summarises the effects of increasing the above factors.

Factor Increased	Operate lag	Release lag
Inductance	Increased	Increased
Eddy currents	Increased	Increased
Spring tension	Increased	Decreased
Armature travel	Increased	Decreased
Residual	Increased (see note).	Decreased

Note: If residual air-gap is increased and armature travel restored to standard, operate lag is increased as armature air-gap is increased.

TABLE 1.

6.9 To satisfy the circuit requirements, relays are designed and adjusted to be :

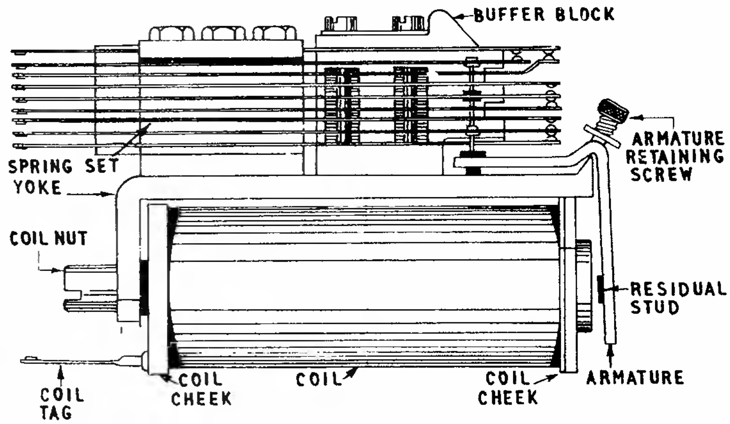
- normal relay; used for general purposes. No special features are used to affect the normal operate and release lags which may be up to 10 - 20 mS.
- fast acting; faster operate and release than normal;
- slow acting; slower operate and release than normal;
- slow releasing; normal operate and slower release.

(The last three: Used for special circuit requirements.)

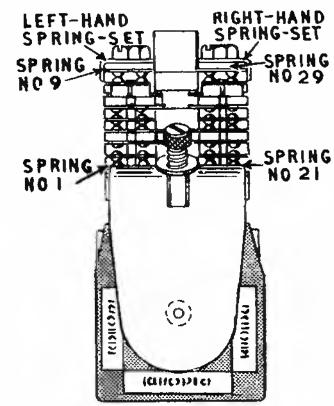
The construction and principle of operation of relays used for special circuit requirements, are described in Telephony 2.

7. 3000 TYPE RELAYS.

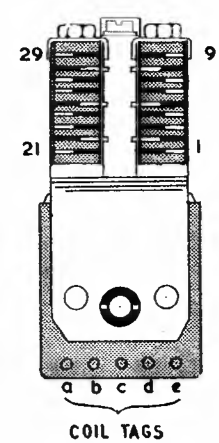
7.1 These comprise a range of fast and slow-acting relays with various spring-sets and coil resistances. Fig. 18 shows details of a relay used for normal circuit requirements.



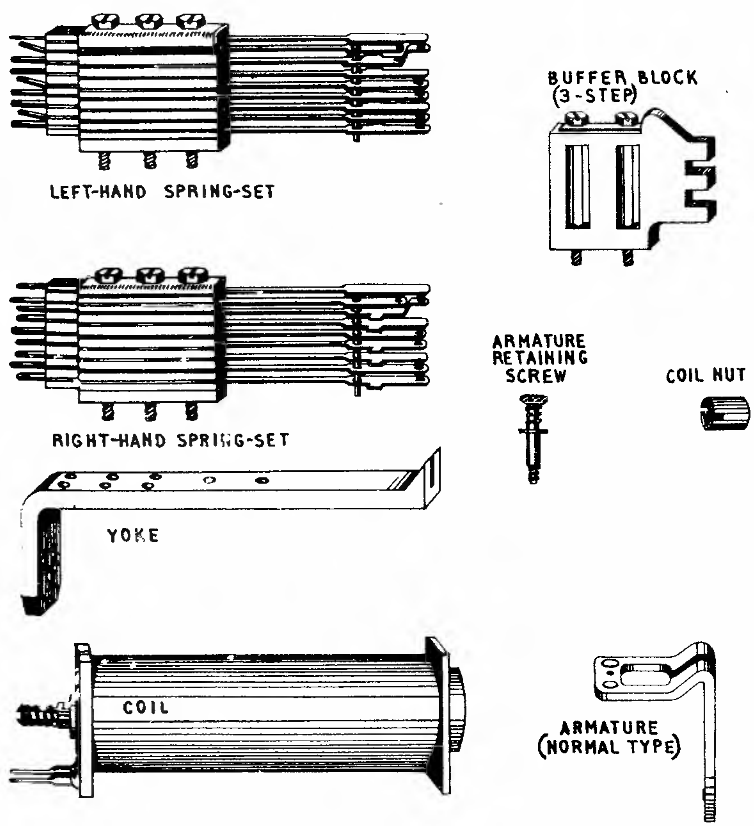
(a) Side View.



(b) Front View.



(c) Rear View.



(d) Component Parts.

FIG. 18. 3,000 TYPE RELAY.

7.2 Coil Assembly. Up to four windings (including non-inductive) are wound on the core, and terminated on coil tags fitted to the rear coil cheek. The windings are anti-clockwise starting from the inner end and viewed from the rear (tag) end. A red enamel marking on a tag denotes the inner end of a winding, and this is connected to the earth (+) side of the circuit.

The tags are designated a, b, c, d, e, commencing from the left-hand tag when the relay is viewed from the rear with the springs uppermost. When the centre tags are omitted, the outer tags are still "a" and "e".

There are many variations in terminating the windings, but in general

- a single winding connects to tags a and e,
- with two windings, the inner winding connects to tags a and b, and the outer winding to tags d and e.

A coil code label which gives the resistance and tag connections of each winding is fixed under the outer layer of the coil wrapping. A relay code label is pasted on the front coil cheek (see paragraph 7.10).

The coil assembly is withdrawn from the yoke by removing the armature and unscrewing the coil-fixing nut.

7.3 Types of coils.

Plain; used for general purpose relays. This has a soft iron core between S.R.B.P. (synthetic resin-bonded paper) cheeks. An enlarged pole face is fitted to the armature end of the core to reduce the reluctance of the air gap. Some early types used a copper front coil cheek.

Nickel Iron Core; used in fast-acting relays instead of a soft iron core to reduce the effects of eddy currents and decrease the operate and release times to about 5 mS or less. The core has no enlarged core face.

Slugged. A copper cylinder (slug) at the armature end of the soft iron core increases the effects of eddy currents and makes the relay slow acting. A copper slug at the other end (heel end) of the core makes the relay slow releasing. Three lengths of slugs are used (½", 1" and 1½") according to the spring load and the required time lag.

Nickel Iron Sleeve. Three cylindrical nickel iron split sleeves over the soft iron core, increase the impedance of the relay winding to speech currents; used when relays are connected across speech circuits or when they are used for the C.B. transmission bridge. These cores have "3N" marked on the top of the front coil cheek.

7.4 Types of armatures.

Ordinary. This is made in four patterns. Three have a phosphor bronze residual stud riveted to the armature to give a fixed residual air-gap of 4, 12 or 20 mils, of which the 12 mil is most commonly used. The other pattern has a brass residual screw and locknut to provide an adjustable residual air-gap on relays requiring more accurate release times.

Isthmus. This type has two slots cut in the armature and is used on relays which respond to dial pulses. A residual screw and locknut are generally fitted.

The armature pivots on a knife edge on the front end of the yoke. An armature retaining screw fitted with a spring loaded washer screws into the yoke to hold the armature in position and prevent side movement. A phosphor bronze stud (armature back stop) on the underside of the armature normally rests on the yoke to prevent the armature from touching and sticking to the yoke due to residual magnetism. Studs on either side of the armature back stop serve as bases for the spring lifting pins and insulate the springs from the armature. (Fig. 18.)

7.5 Spring-sets. The usual thickness of the nickel silver springs is 14 mils; but 12 mil springs or, in special cases, thicker springs may be used.

The front end of a spring is split, and the two portions (tongues) each carry one of a pair of twin dome contacts which function independently to reduce contact dust troubles and provide more reliable operation. The contacts are fixed to the springs either by spot welding or riveting a shank formed on the back of the contact.

The springs are insulated from one another and clamped between plates as complete assemblies (spring-sets) which are screwed to the yoke on either side of the buffer block. Spring-sets are designed with the lugs on the buffered springs protruding for either left or right-hand mounting. Lifting springs and studs attached to the lever springs transmit the armature movement to the spring-set.

Note that, when referring to spring-sets, the terms "left" and "right" refer to the relay viewed from the armature end with the springs uppermost.

The maximum number of springs fitted is 18 (9 on either side of the buffer block) which may consist of M, B, C and K contact units. When one contact unit is fitted, it is mounted on the left of the block. Two or more units are divided into two sets with approximately equal loads. When the loads are unequal, the heavier is on the left.

The springs are numbered from the coil. Springs 1 to 9 are on the left-hand side and 21 to 29 on the right-hand side.

Wires are soldered to tags at the rear ends of the springs. The tags are staggered to facilitate wiring, the lever spring tags being innermost and the buffered spring tags outermost.

7.6 Contact materials.

Silver is normally used to carry and break currents up to 300 mA, with 50 volt working.

Platinum is used from 0.3A up to 1.25A. These contacts are identified by a "V" notch in the end of the spring.

P.G.S. alloy (platinum, gold, silver) was used in some early types of relays.

7.7 The buffer block screwed to the yoke, positions the springs correctly and ensures that, provided the springs are straight, satisfactory contact clearances (not less than 10 mils) are obtained.

The block is moulded from a white porcelain or synthetic insulating material and has a number of projections (steps) which engage on small lugs on the sides of the buffered make or break springs, so limiting their travel.

The make and break springs are adjusted to bear against their buffer block step with a certain pressure, so that when the armature is operated or unoperated and the spring is lifted clear of the block, the required contact pressure is automatically obtained. This ensures a definite standard of contact pressure, which reduces fault liability. The upper surface of the buffer block is curved to guide a relay set cover safely over the contact springs.

The usual types used are

- a 1-step block for assemblies containing one or two units,
- a 2-step block for three or four units,
- a 3-step block for five or six units,
- a 3/4-step block for seven units, and
- a 4-step block for eight units.

7.8 "x" and "y" contact action. Some relays have a make or break set of contacts, called x contacts, which operate before any other contact unit.

Make or break contacts which operate after all other contact units, are called y contacts.

Only one x or y unit is fitted on a relay, on the right-hand side. The x unit is fitted nearest to the armature, and the y unit furthest away from the armature.

7.9 Adjustments. Details of 3000 type relay adjustments are in E.I. TELEPHONE Relays AD 1001.

The main adjustments are -

(i) Adjust residual screw or check residual stud using feeler gauges.

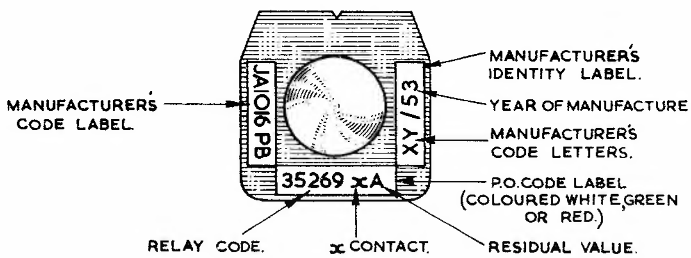
(ii) Check and adjust armature travel using the armature bending tool.

(iii) Straighten springs and align the twin contact points to make or break simultaneously, using a spring tongue adjusting tool.

(iv) Adjust the tension of the buffer springs against the buffer block steps, using a spring adjuster and tension gauge.

(v) Adjust each lever spring in turn using the spring adjuster and tension gauge.

7.10 Relay label. Information regarding adjustments is given on the label on the front coil cheek. (Fig. 19.)



LABELLING SYSTEM (3000 TYPE RELAY).

FIG. 19.

Figures on the left and right refer to the manufacturer's code and year of manufacture.

The colour of the bottom label refers to the spring thickness and the nature of the adjustments, as follows -

White label	:	14 mil springs, standard adjustments.
Green label	:	12 mil springs, spring tension reduced.
Red label	:	These relays require special adjustment and usually have a separate adjustment chart.

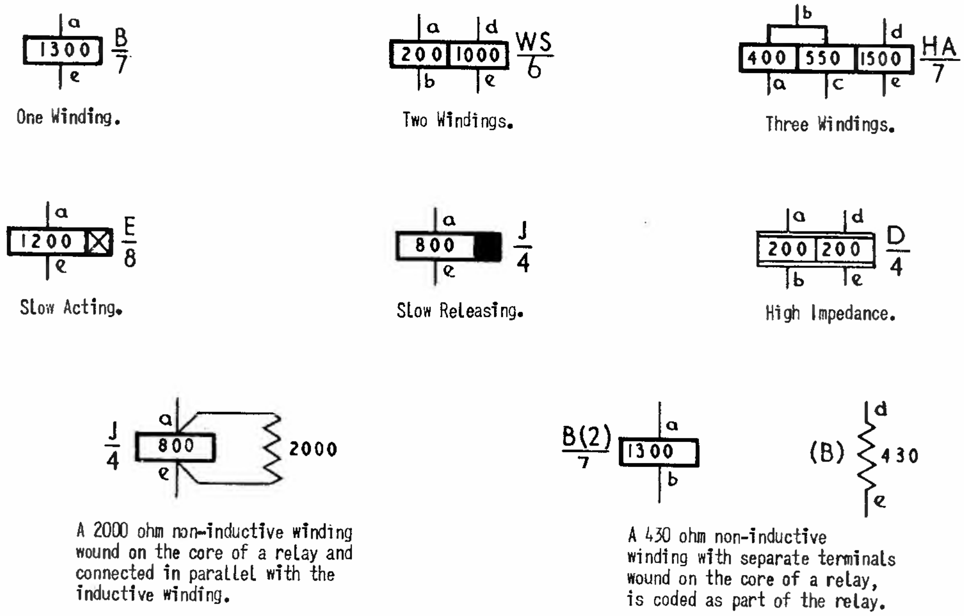
Figures on the bottom label indicate the provision of an x or y contact, and residual adjustment. With fixed residual studs, the letters A, B, or C signify 4, 12 or 20 mils respectively. A residual value in brackets indicates restricted tolerance.

7.11 Retardation coils (high impedance, low resistance coils) of the 3000 type are provided for association with 3000 type relays and consist of yoke, armature and coil of the standard pattern, but spring-sets are omitted. Adjustment of residual, and other maintenance operations are the same as for 3000 type relays.

3. RELAY SYMBOLS.

3.1 Windings. Fig. 20 shows the drawing symbols for typical 3000 type relays as used in schematic circuits. The figure in the symbol indicates the resistance in ohms of each coil winding, this value depending on the circuit requirements. The coil tag connections are also shown.

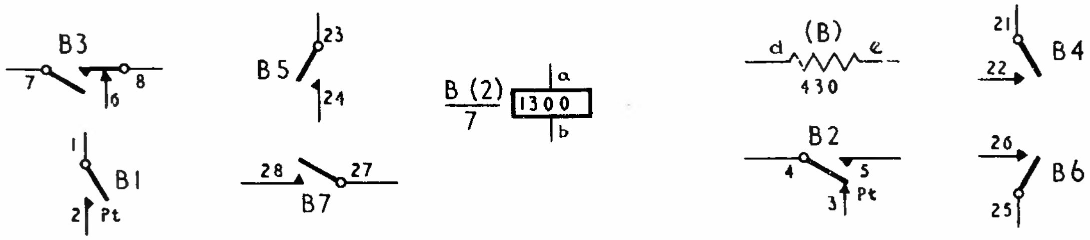
Each relay in a circuit is identified by a different code letter or letters over a figure denoting the total number of contact units mounted on the relay.



RELAY WINDING SYMBOLS.

FIG. 20.

3.2 Contact Units. In a circuit which uses many relays, it is not convenient to show a relay with all its contact units close to it. The contacts are identified by standard symbols and are detached from the relay and each other, so that the circuit is easier to "read". For example, in Fig. 21, relay B has 7 contact units (B1, B2, etc.) which may be anywhere in the drawing identified as shown. The contact spring numbers are also shown.



DETACHED CONTACT UNITS.

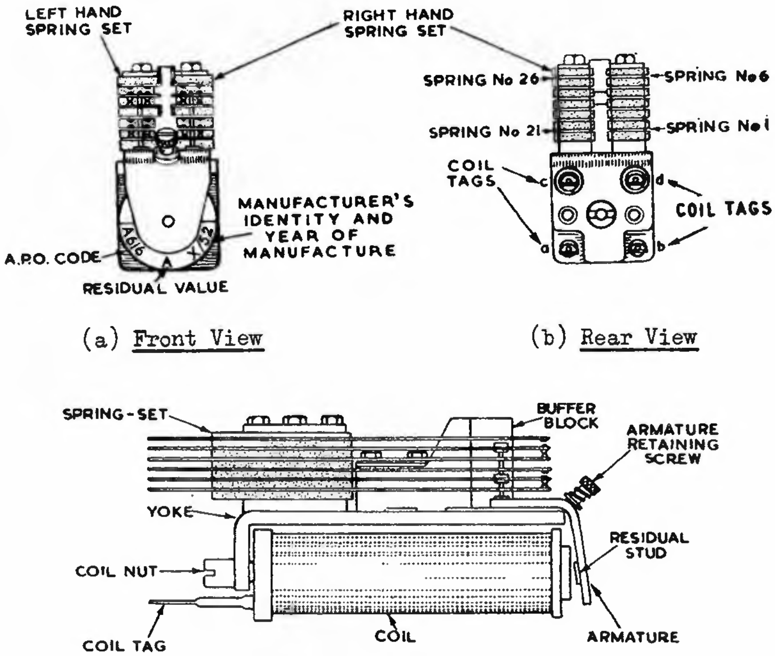
FIG. 21.

The letters Pt adjacent to a contact unit signify platinum contacts. Other contacts are silver. The letters x or y signify "x" or "y" contact action.

In make or break contact units, the moving spring is usually connected to the earth (+) side of the circuit.

9. 600 TYPE RELAYS.

9.1 These relays (Fig. 22) are designed to perform comparatively simple functions only and are used where a large number of similar relays are required, for example, as L and K relays in subscribers' line circuits in C.B. manual and automatic exchanges. They incorporate the main features of the 3000 type relays.



(a) Front View (b) Rear View

(c) Side View

600 TYPE RELAY.

FIG. 22.

Compared with the 3000 type, they are smaller and, therefore, space saving. The construction and adjustments are simpler, and the relays are efficient and reliable in operation, requiring less power to operate them.

9.2 Coil Assembly. The coils are wound on a soft-iron core. Nickel-iron sleeves and cores are not used, but an armature end slug ($1\frac{3}{8}$" long) is fitted on some relays. The end of the yoke on which the armature pivots has no projection as in the 3000 type. The front edge of the yoke is sheered at an angle and the armature is shaped to make a bearing on this edge.

The small dimensions of the coil assembly usually restrict the number of windings to two, one of which may be non-inductive. The rear coil cheek has either two or four tags. Coils are wound anti-clockwise, viewed from the rear. A single winding connects to tags a and b. With two windings, the second connects to tags c and d.

Tags a and c are the inner ends of the windings and are connected to the earth (+) side of the circuit. In some relays, these tags are painted red.

The relay code label is fixed to the front cheek and the coil code label is fixed to the core under the outer layer of the wrapping.

The coil assembly (core, windings and coil tags) is removed from the yoke, by detaching the wiring from the coil tags, removing the armature and unscrewing the coil nut.

9.3 Armatures. A phosphor bronze stud riveted to the soft iron armature gives a fixed residual air-gap of 4, 8 or 12 mils. Adjustable residual screws and isthmus type armatures are not used.

9.4 Springsets. The maximum number of springs fitted is 12 (6 on either side) which may consist of M, B, C and K contact units, but no "x" or "y" operation.

The springs are numbered as in 3000 type relays. Springs 1 to 6 are on the left-hand side and 21 to 26 on the right-hand side.

The thickness of springs is 14 mils.

Twin contacts are fitted on each spring, silver contacts for low currents, platinum contacts for higher currents.

9.5 Buffer blocks. An early type consists of a cylindrical flanged pillar supported by a bracket. Modern relays use a moulded block similar to the 3000 type,

- a 1-step block for assemblies containing one or two units,
- a 2-step block for three or four units, and
- 2/3-step block for five units.

9.6 Adjustments. 600 type relays have simplified mechanical adjustments, 25 mils armature travel, a residual of either 4, 8 and 12 mils and 14 mils springs with standard tensions. The list of "white label" adjustments for 3000 type relay springs applies to the 600 type.

Complete details of adjustments are in E.I. TELEPHONE Relays AD 2001.

10. TEST QUESTIONS.

1. Describe the construction of a five-point switchboard jack.
2. The symbol for a five-point jack is ....
3. Describe the construction of a modern three-conductor switchboard plug.
4. The symbol for a three-conductor plug is ....
5. Describe the construction of a three-conductor switchboard cord.
6. What is a plug seat switch?
7. Describe the construction of a three-position locking type lever key.
8. How does a two-position lever key differ in construction from a three-position key?
9. How does the non-locking lever key differ from the locking type?
10. The types of contact units used on lever keys, are

    (i) .... (ii) .... (iii) .... (iv) ....
11. Draw the symbols for these contact units, both locking and non-locking.
12. How are the springs numbered on lever keys?
13. Describe the construction of a locking type plunger key.
14. How does the non-locking plunger key differ from the locking type?
15. The symbols for plunger keys are (i) locking .... (ii) non-locking ....
16. Describe the basic construction and principle of operation of a simple telephone relay.
17. What is the reason for the residual stud in a relay?
18. What is meant by the terms - operate lag, release lag?

19. Explain why the armature does not operate and release immediately the relay circuit is closed and opened.

20. What is meant by the relay terms -

(i) spring tension, (ii) armature air-gap, (iii) armature travel, (iv) residual air-gap?

21. Explain the effect on the operate and release lags when -

(i) the spring tension is decreased,
(ii) the armature travel is increased,
(iii) the residual air-gap is increased and armature travel restored to standard.

22. What is meant by the relay terms -

(i) fast acting, (ii) slow acting, (iii) slow releasing?

23. Briefly describe the construction of a normal 3000 type relay.

24. How is the coil assembly removed from the yoke?

25. How are the tags designated in 3000 and 600 type relays?

26. How is the armature movement transmitted to the spring-set?

27. What does the red marking indicate on a relay tag?

28. What information is obtained from the labels on the relay?

29. Why are the following sometimes used -

(i) a nickel iron core,
(ii) nickel iron sleeves,
(iii) copper slugs,
(iv) an isthmus armature,
(v) an adjustable residual screw?

30. Why is a buffer block used?

31. The symbols for contact units used on relays, are -

(i) .... (ii) .... (iii) .... (iv) ....

32. Why are twin contacts used on relay springs?

33. The material normally used for relay contacts, is ....

34. Why are platinum contacts sometimes used?

35. How are platinum contacts indicated on schematic circuits?

36. What are "x" and "y" contacts?

37. How are relay springs numbered?

38. Complete the following for (a) 3000 type (b) 600 type relays -

(i) Sizes of fixed residual studs .... (a) .... (b) ....

(ii) Maximum number of springs .... (a) .... (b) ....

(iii) Thickness of springs .... (a) .... (b) ....

(iv) A single winding connects to tags .... (a) .... (b) ....

39. What are the main adjustments for a 3000 type relay?

40. Draw the symbols for the following relays -

(i) slow acting ....
(ii) slow releasing ....
(iii) normal relay...........................
(iv) high impedance ....

41. How are detached contact units coded in schematic circuits?

END OF PAPER.

TIE

COURSE OF TECHNICAL INSTRUCTION

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TELEPHONE LINES

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1. INTRODUCTION.

1.1 A telephone is designed so that, when the transmitter is operated by speech, the variations in transmitter resistance produce a signal consisting of alternating voltages and currents at speech frequencies. Similarly, a telephone receiver is designed to produce a sufficiently loud sound when these speech signals are applied to it.

1.2 The satisfactory transmission of speech depends not only on properly designed transmitters and receivers, but also on the ability of a telephone line to carry the speech signals from the transmitting to the receiving end.

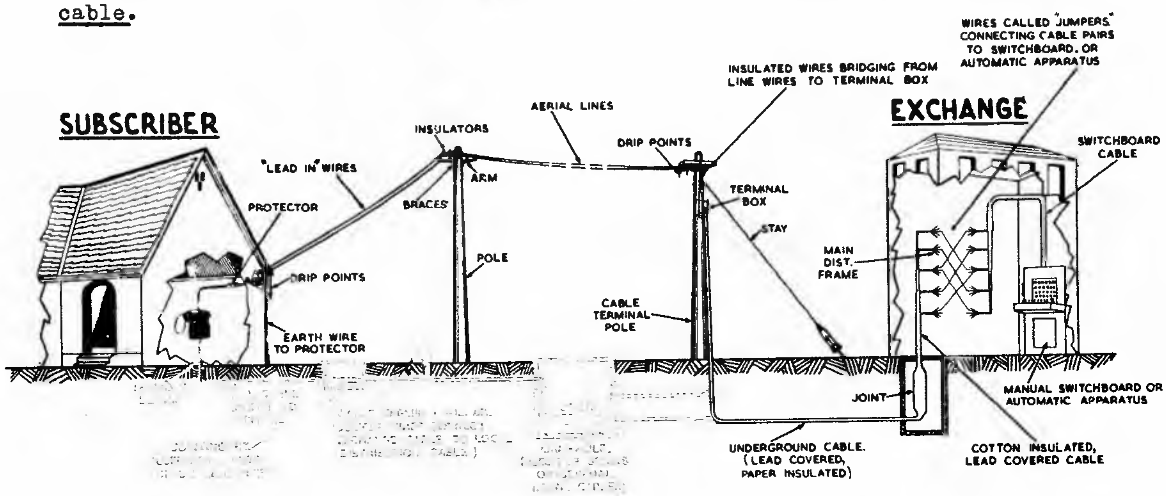
1.3 So that we can more fully understand the operation of modern telephone circuits, this paper gives some idea of the way a telephone line affects the speech signals sent over it.

2. TYPES OF TELEPHONE LINES.

2.1 Telephone Lines (Fig. 1) are wires in the air or under the ground that connect telephones to exchanges.

Aerial or open wire telephone lines are tied to porcelain or glass insulators fitted on wooden arms which are supported by wooden or steel poles.

Other lines use paper, plastic or cotton insulated wires inside a lead or plastic sheath to give mechanical protection and to prevent moisture from reaching the insulation. One or more pairs of wires form a cable, which may be either buried in the ground as an underground cable or supported between poles as an aerial cable.



DETAILS OF A TELEPHONE LINE

FIG. 1.

2.2 A telephone line generally uses two wires, and this is called a metallic or two-wire circuit. When the earth (or the lead sheath of the underground cable, which is connected to earth) is used instead of one of the wires, the circuit is then an earth return or single-wire circuit. Earth return circuits may be used for some telegraph or signalling circuits, but are rarely used for telephone circuits, because they provide a noisy, inferior type of circuit.

2.3 For identification, the two conductors of telephone circuits are designated in various ways. They are, respectively -

Line 1 and Line 2, A and B, Positive(+) and Negative(-), or Tip and Ring.

2.4 A subscribers line connects the subscriber's telephone to the local exchange.

A line between two exchanges within the same unit fee area, is called a junction line.

A line between two exchanges not within the same unit fee area, is called a trunk line.

Combinations of these lines may be used to set up a telephone connection between two subscribers.

2.5 Conductors used for Telephone Lines. In general, copper or copper alloy wires are used because copper has low resistivity, sufficient strength to withstand the effects of wind and weather variations, and is comparatively cheap.

Copper wires are used for all cable lines.

The wires most commonly used for aerial lines are -

(i) Hard Drawn Copper (H.D.C.) wire, made by drawing refined copper through steel dies. To obtain the maximum strength for the wire, the copper is drawn in the cold state.

(ii) Cadmium Copper (C.C.) wire, composed of copper alloyed with 0.8% cadmium. This wire is stronger but costs more than copper wire.

In some country districts, Galvanised Iron (G.I.) aerial wires may be used on minor aerial line routes. G.I. wires are cheaper but, for equal weights, the resistance per mile is about six times that of copper. These wires, therefore, are generally of large cross-sectional area.

In some areas, aluminium aerial wires may be used. Although the resistivity of aluminium is higher, the resistance per mile of this wire, for equal weights, is less than that of copper wire.

2.6 Telephone line wires are classified in terms of the weight in pounds per mile of single wire. For example, the term "70 lb. cadmium copper" indicates that a mile of this wire weighs 70 lb. Wires having the same weight per mile have different diameters according to the density of the materials from which they are made.

2.7 Details of the wires most commonly used, are given in Tables 1 and 2.

Type of wire.	Approx. R per single wire mile.	General use.
4 lb. copper	220 ohms.	Subs. lines (short distance)
6-1/2 lb. copper	135 ohms.	Subs. and Junction lines.
10 lb. "	88 ohms.	Subs. and Junction lines.
20 lb. "	44 ohms.	Trunk lines.
40 lb. "	22 ohms.	Trunk lines.

TABLE 1. CABLE TELEPHONE WIRES.

Type of wire.	Approx. R per single wire mile.	General use.
40 lb. C.C.	26.0 ohms.	Subs. lines (short distance)
70 lb. C.C.	15.0 ohms.	Subs. and Junction lines.
118 lb. C.C.	9.0 ohms.	Trunk lines.
237 lb. C.C.	4.5 ohms.	Trunk lines.
100 lb. H.D.C.	8.8 ohms.	Trunk lines.
200 lb. H.D.C.	4.4 ohms.	Trunk lines.
200 lb. G.I.	26.6 ohms.	Minor routes in country areas.
400 lb. G.I.	13.3 ohms.	Minor routes in country areas.

TABLE 2. OPEN WIRE TELEPHONE WIRES.

3. LINE AND LOOP RESISTANCE.

3.1 In C.B. manual and automatic telephone operation, the D.C. for the telephone transmitter is fed from the exchange battery over the subscriber's line. The conductor resistance and, therefore, the length of the line must not exceed specified limits otherwise the current will be too low and the transmitter will not operate satisfactorily.

The two wires of the line are in series as far as the current flow is concerned. Thus, the line resistance (sometimes called the loop resistance of the line) is twice the single wire resistance. It is measured from the exchange end with a short circuit across the line at the distant end.

The resistance per loop mile is the resistance of a line which is one mile long; that is, the total length of wire is two miles.

The complete loop resistance of a telephone line and distant telephone is measured from the exchange end with the receiver off the switch-hook at the distant telephone.

3.2 Ohm Mile Constant. When the resistance in ohms per mile of a single wire (see Tables 1 and 2 for typical values) is multiplied by its weight in pounds per mile, the result is constant for a given material and is called the ohm mile constant of the wire. For example, the Ohm Mile Constant of copper or H.D.C. is about 880.

A knowledge of this constant helps us remember the resistance per single wire mile (or per loop mile) of copper or H.D.C. wire. For example -

$$\text{Resistance (ohms) per single wire mile} = \frac{880}{\text{Weight (lbs. per mile)}}$$

The resistance per loop mile is twice the resistance per single wire mile.

3.3 To calculate the conductor resistance of any type of telephone line, multiply the resistance per loop mile by the length in miles (because resistance is proportional to length).

For example, to find the resistance of a 10 lb. cable line, 1-3/4 miles long -

$$\text{Line Resistance} = \text{Resistance (ohms) per loop mile} \times \text{Length (miles)}$$
$$= \frac{176 \times 7}{4} = 308 \text{ ohms.}$$

When the telephone line consists of two or more sections of different types of wires, calculate the line resistance of each section and add these values to find the total line resistance.

3.4 A simple formula to calculate quickly the line resistance in ohms when copper or H.D.C. wire is used, is -

$$\text{Line Resistance} = \frac{\text{Length of line (yards).}}{\text{Weight (lbs. per mile).}}$$

For example, the resistance of a 4 lb. cable line, 1120 yards long, is 280 ohms.

NOTE: This formula does not apply to C.C., G.I., or aluminium wire.

It is also interesting to note that the weight (in lb.) per mile of single copper or H.D.C. wire equals the length of line (in yards) which has a resistance of one ohm. Thus -

4 lb. cable	:	4 loop yards per ohm.
10 lb. cable	:	10 loop yards per ohm.
100 lb. H.D.C.	:	100 loop yards per ohm.

4. INSULATION RESISTANCE.

4.1 The two wires of a telephone line are insulated from each other and the earth. The resistance of the insulation (air, paper, plastic, porcelain, etc.) is called the insulation resistance (I.R.). Because there is no perfect insulator, there is always some leakage of current from one wire to the other and earth. The quality of the insulation is indicated by its actual resistance value in megohms, the higher the value the better the insulation.

The I.R. of a telephone line is measured from the exchange end with an open circuit at the distant end.

4.2 The longer the line, the lower the I.R. becomes. The I.R. between wires and from each wire to earth must not be too low or the telephone service will not operate satisfactorily. This fault condition is called low insulation resistance, abbreviated to L.I.R.

4.3 The I.R. of open wire lines generally decreases during wet or foggy weather, due mainly to the lower resistance leakage path offered by the moisture and dust on the surface of the insulators. Although the loss may be small on any one insulator, it is considerable over a long line. L.I.R. faults can often be traced to cracked or dirty insulators.

For example, the I.R. between the wires at each pair of insulators of a telephone line, may be 500 megohms. If the line were fixed to 100 pair of insulators, the total I.R. of the line would be 5 megohms. If, owing to rain, the I.R. between the wires at each pair of insulators is reduced to 50 megohms, the total I.R. would fall to 0.5 megohm.

4.4 The I.R. of cable lines is normally high and does not vary with changing weather conditions. However, the cable insulation may fail due to -

(i) A break in the insulation, due to excessive vibration or bending, which allows the wires to come into contact.
(ii) Dampness. When moisture enters the cable through cracks or holes in the sheath, it may be absorbed by the insulation, to provide a L.I.R. path for the current between the wires or from the wires to earth.
(iii) Dust. Over a period of time a layer of dust covers the wire, insulation and sheath of indoor cable terminations. The dust, when dry, has usually no effect on the insulation but in damp situations, the dust gathers moisture and provides an L.I.R. path.

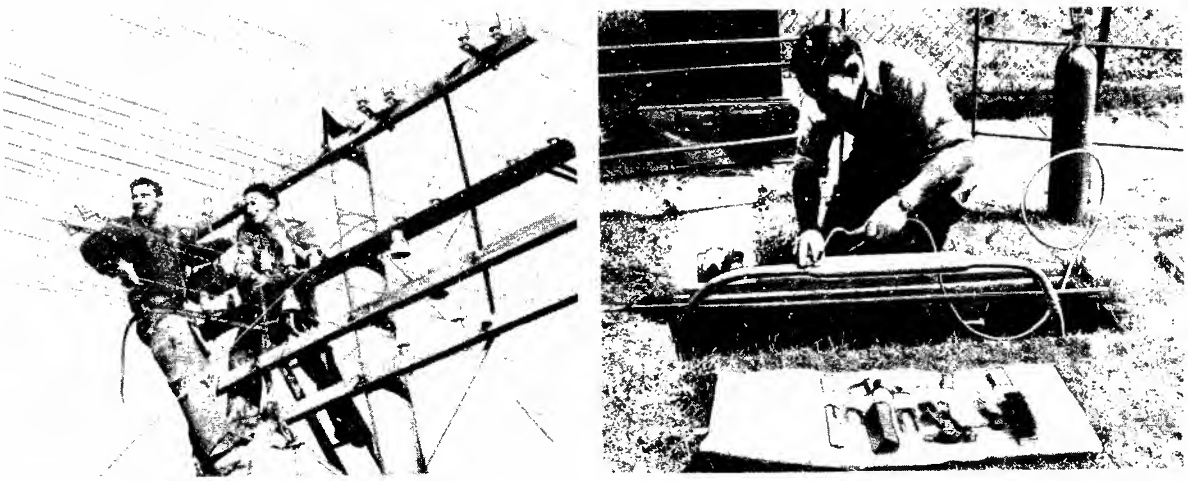


FIG. 2. LOOKING AFTER THE LINES OF TELECOMMUNICATION.

5. PRIMARY CONSTANTS.

5.1 Any telephone line, whether aerial or underground, has four electrical properties which determine how the line will affect the speech signals sent over it. They are -

(i) Series Resistance (R) which is the loop resistance of the line; measured in ohms.

(ii) Series Inductance (L) which causes opposing e.m.f.'s to be induced in the line wires when speech currents flow; measured in henries.

(iii) Shunt Capacitance (C). The two wires behave as the plates of a capacitor, the line insulation being the dielectric; measured in farads.

(iv) Shunt Conductance (G) which is the conductance of the line insulation; measured in mhos.

These properties are evenly distributed along the line and their values increase with length of line. The values differ for the various types of lines.

5.2 When expressed in terms of a one mile length of line, the values of R, L, C and G are termed the Primary Constants of the line.

Typical values at voice frequencies (200-3000 c/s) are -

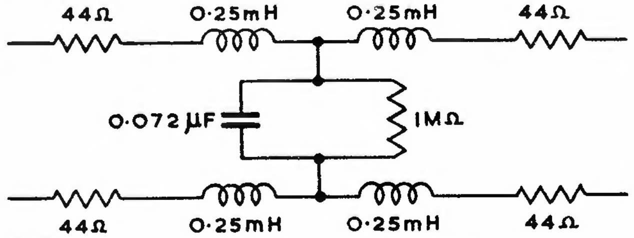
(i) The series resistance is the resistance per loop mile. (See Section 3.)

(ii) The series inductance of open wire lines is about 3 to 4 mH per loop mile; and for cable, about 1 mH per loop mile.

(iii) The shunt capacitance of open wire lines is about 0.008 to 0.01 μF per mile; and for cable, about 0.072 μF per mile.

(iv) The shunt conductance varies over a wide range with different types of construction, and also, in the case of open wire lines, with changing weather conditions. Typical values range between 1 to 6 μmhos per mile for open wire, and from 1 to 4 μmhos per mile for cable.

5.3 Equivalent circuit of telephone line. From a knowledge of the primary constants, a network can be made up to represent any length of line. Fig. 3 shows the equivalent circuit of a 10 lb. cable pair one mile long with the following primary constants -



EQUIVALENT CIRCUIT OF ONE MILE OF 10 LB. CABLE.

FIG. 3.

R = 176 ohms.
L = 1 mH.
C = 0.072 μF.
G = 1 μmho. (Shown as 1 MΩ resistance in Fig.3.)

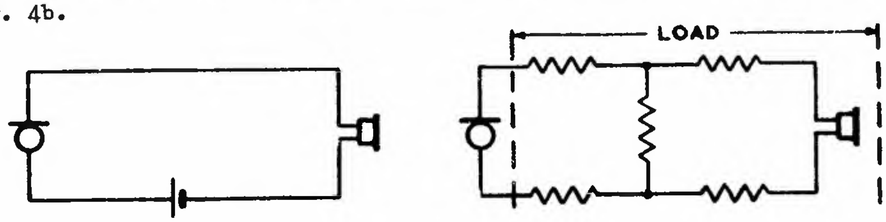
Two such networks connected together would represent a 10 lb. cable pair, two miles long; three sections for three miles, and so on.

Equivalent circuits of this type help to explain the behaviour of a line having the same primary constants. However, it must be remembered that, in practice, these constants are not "lumped" together as in Fig. 3, but are evenly distributed along the line.

It is sometimes convenient to represent the series and shunt components of the line by a network of resistances (as in Fig. 4b) the values of which, at a particular frequency, equal the impedance of the components which they replace. This simplification is not strictly correct, but it does help us understand how the line behaves without using advanced mathematics which more accurate results would require.

6. LINE IMPEDANCE.

6.1 Fig. 4a shows a simple telephone speaking circuit consisting of a carbon transmitter, telephone line and receiver connected in series with a battery. The equivalent circuit as far as the speech signals are concerned is shown in Fig. 4b.



(a) (b)

LINE IMPEDANCE AFFECTS SPEECH SIGNALS.

FIG. 4.

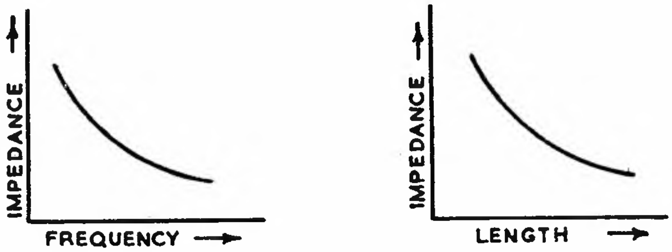
When a person speaks into the transmitter, the A.C. component of speech developed by the transmitter causes an alternating speech current to flow through the line and receiver (or distant telephone). Maximum speech energy is transferred from the transmitter to the load when the transmitter impedance equals or "matches" the combined impedance of the line and distant telephone. The line impedance is, therefore, one of the factors which must be considered when speech signals are sent over it.

The presence of resistance, inductance and capacitance indicates that a line offers impedance or opposition to the flow of A.C. This impedance is quite distinct from and must not be confused with the D.C. resistance of the line.

6.2 How line impedance varies. The value of impedance depends on the primary constants and the length of line; and it varies for different types of lines, because the values of the primary constants are different.

For any line, the effect of the primary constants (particularly the series L and the shunt C) varies with the frequency of the speech signals. The effect of the shunt C is greater than that of the series L. Because the shunt capacitive reactance is inversely proportional to frequency, the impedance, therefore, decreases as the frequency rises. (Fig. 5a.)

Similarly, at any one frequency, the impedance decreases as the length of line is increased. (Fig. 5b.)



(a) (b)

IMPEDANCE VARIATIONS OF TELEPHONE LINES.

FIG. 5.

The impedances to which a telephone may be connected, therefore, vary over a wide range due to variation in the primary constants, lengths and types of lines.

For example, when an open wire line is connected to a distant telephone, the impedance may vary between 1,200 ohms and 550 ohms over the voice frequency range; and cable lines may vary between 1,300 ohms and 200 ohms.

6.3 Use of induction coil for impedance matching. As the impedance of telephone lines varies considerably, it is not practicable to manufacture each telephone individually to suit the particular line impedance to which it is to be connected. This would not permit flexibility and would be very costly. The best that can be done in practice is to assume an "average" value of impedance for all types of lines at about the middle frequency of the v.f. range. A value of 600 ohms is generally used.

Now, the telephone transmitter is designed to develop a maximum alternating voltage when operated by sound waves and its impedance (about 60 ohms) is fixed by this consideration rather than considerations of impedance matching.

Since it is not practicable to match these impedances by direct design, a transformer arrangement called an induction coil is used.

Assuming 100% efficiency, the turns ratio of the primary to secondary windings to match 60 ohms to 600 ohms, would be -

$$1 : \sqrt{\frac{600}{60}}, \text{ that is } 1 : 3.16.$$

In magneto telephones, the induction coil has separate primary and secondary windings and the current for the transmitter operation is supplied from a battery in the primary circuit. (Fig. 6a.)

In C.B. manual and automatic telephones, an auto-transformer connection is used so that the current for the transmitter operation can be supplied over the line from the exchange battery. (Fig. 6b.)

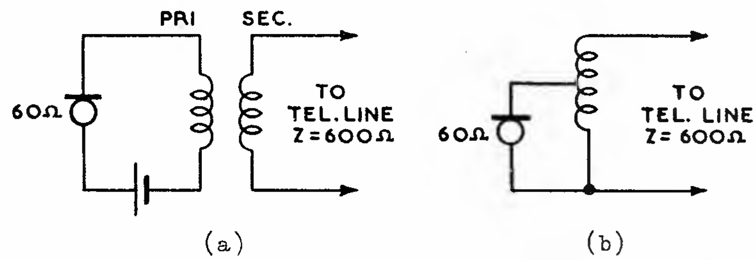


FIG. 6. USE OF INDUCTION COIL FOR IMPEDANCE MATCHING.

In modern telephones, as described in later Papers, the induction coil is also used to match the line and receiver impedances for transfer of speech energy from the line to the receiver. Because the line and receiver impedances vary greatly over the v.f. range, the optimum turns ratio also varies. However, assuming average values at about the middle frequency, to match a receiver with an impedance of 300 ohms to a line with an impedance of 600 ohms, the turns ratio would be -

$$1 : \sqrt{\frac{600}{300}}, \text{ that is } 1 : 1.41.$$

Thus, the optimum turns ratio differs with frequency for each direction of operation and, in practice, must be a compromise to give satisfactory combined transmitting and receiving efficiencies. Any attempt to improve the transmitting efficiency reduces the receiving efficiency, and vice versa.

Although the inclusion of the induction coil does not produce maximum speech energy transfer in each direction of transmission, it does provide some degree of impedance matching over the v.f. range and, therefore, better transmitting and receiving efficiencies are obtained.

6.4 Balance Network. The modern type of induction coil uses a network called a balance network, which approximately equals or "balances" the line impedance for the range of voice frequencies transmitted over the line.

A simple balance network consists of a resistance and capacitance in series. (Fig. 7.) Because the capacitive reactance is inversely proportional to frequency, the capacitance has the effect of reducing the impedance of the network as the frequency rises, and this helps to compensate for the variation in line impedance. By suitable choice of values, the impedance variation may be made to follow fairly closely that of the line. This type of balance network is used in the 300 series telephones; but where a more accurate balance is required, as in the 400 series telephones, a more complicated network of resistances and capacitances is used.

SIMPLE BALANCE NETWORK.

FIG. 7.

7. ATTENUATION.

7.1 As the speech signals pass along a telephone line, the alternating voltage is progressively "dropped" over the series components and the alternating current is progressively "drained away" through the shunt components. Thus, the received speech voltages and currents are less than those transmitted to the line.

The gradual reduction in the amplitudes of the voltage and current along a line is called Attenuation.

The attenuation of telephone lines must not be too great or the received signals will be too low in value to operate the telephone receiver or other apparatus.

7.2 How attenuation varies. The degree of attenuation depends on the primary constants and the length of line; and it varies for different types of lines, because the values of the primary constants are different.

For any line, the effect of the primary constants (particularly the series L and the shunt C) varies with the frequency of the speech signals. The series inductive reactance increases and more voltage is dropped as the frequency rises. The shunt capacitive reactance decreases and more current is drained away as the frequency rises. Thus, the attenuation increases as the frequency rises. (Fig. 8a.)

Similarly, at any one frequency, the attenuation increases as the length of line is increased. (Fig. 8b.)

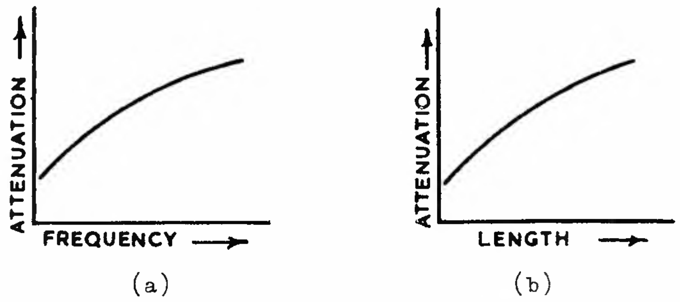


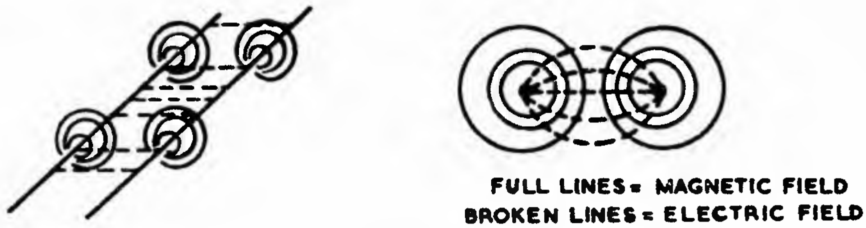
FIG. 8. ATTENUATION VARIATIONS OF TELEPHONE LINES.

Mainly because of the higher shunt capacitance, the attenuation of cable lines is greater than that of open wire lines.

The attenuation of open wire lines increases during wet weather conditions mainly because of the reduced I.R. which causes a higher shunt conductance. Similarly, the attenuation of cable lines increases when dampness or dust reduces the I.R.

8. NOISE AND CROSSTALK.

8.1 Magnetic and Electric Fields. When alternating currents flow in a telephone line, magnetic fields surround the conducting wires. The P.D. between the conductors sets up an electric field. Electrical energy is stored in these fields. The lines of force of the two fields are at right angles to each other, and each field is at right angles to the conductors. (Fig. 9.) These fields exist along the entire length of telephone line, and may affect other telephone lines in the vicinity.



(a) Top view. (b) End view.

FIG. 9. FIELDS PRODUCED ABOUT LINE CONDUCTORS.

Similarly, the alternating fields around other types of circuits, such as A.C. power lines, may affect telephone lines which run parallel to the power line somewhere along the route.

8.2 For example, Fig. 10 shows the A and B sides of a telephone line which is parallel to a single wire interfering circuit.

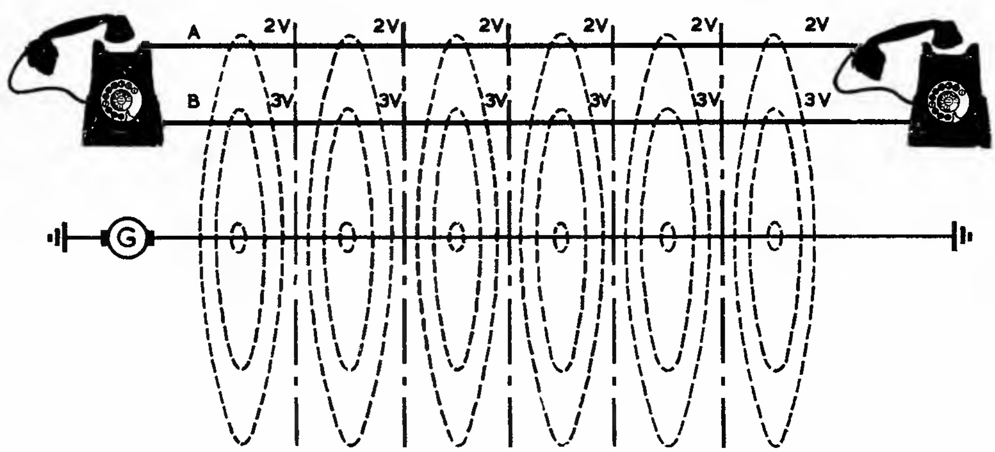


FIG. 10. INTERFERENCE DUE TO MAGNETIC FIELD.

As the B side is closer than the A side to the interfering line, more magnetic lines of force cut B, and the induced e.m.f. is greater than in A. Suppose that for each section of B and A shown, the induced e.m.f.'s are 3 volts and 2 volts respectively, at some instant. Therefore, over the whole line, an induced e.m.f. of 18 volts exists on B, and 12 volts on A. These e.m.f.'s oppose, but the resultant e.m.f. causes a current in the circuit which is heard in the telephone receivers.

Similarly, the induced charge on B due to the electric field, is greater than that on A, and a current flows through the telephones to equalise the charges.

The operation is similar when the interfering circuit is two-wire.

When the interfering circuit is a power line or power circuit, the interference in the telephone circuit is called noise; when it is a circuit carrying a telephone conversation, the interference is called crosstalk.

8.3 Noise and crosstalk on open wire telephone lines are reduced by changing the positions of the two wires at intervals along the route. These change-overs are called transpositions.

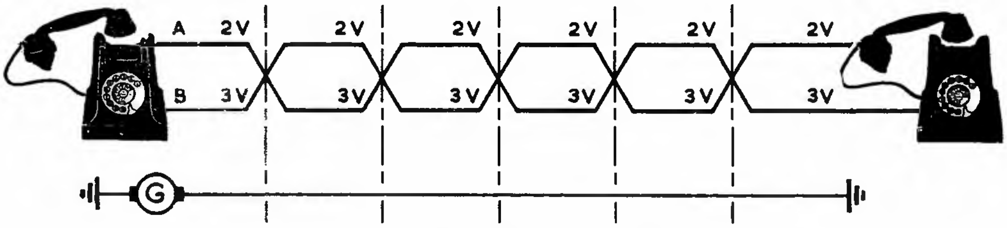


FIG. 11. REDUCING INTERFERENCE BY TRANSPOSITIONS.

For example, in Fig. 11, the induced e.m.f. on B due to the magnetic field, will be 15 volts which is equal and opposite to that induced on A; and no interfering current flows through the telephones.

Similarly, the induced charges on A and B due to the electric field are equal and opposite.

8.4 To reduce interference between lines in some telephone cables, the two wires of any pair are twisted or "twinned"; thus the name Twin Cable. This has the same effect as transpositions on open wire lines.

In other cables, the wires are "quadded" to still further reduce interference; thus the name Quad Cable. In this cable, the wires are arranged in groups of four and twisted spirally to form a quad. The four wires of a quad are formed around a fibre core centre which gives increased insulation between pairs by forming an air gap. In a quad, the directly opposite wires form a pair. (Fig. 12.) With this arrangement, either wire of any one pair is equidistant from the wires of the other pair. Thus, the effect of the fields from either wire is the same at both wires of the other pair, and there are no resultant voltages to produce interference.

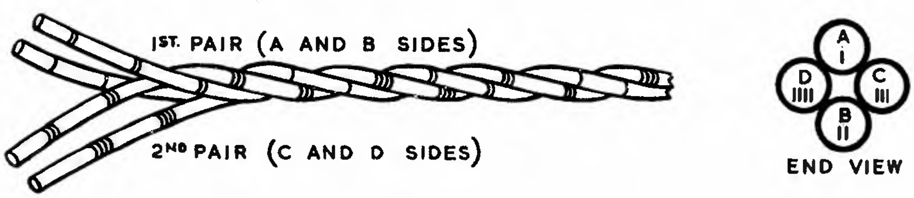


FIG. 12. QUAD WIRES.

8.5 Crosstalk caused by "split" pairs. When one wire of a pair is incorrectly used with one wire of another pair to form a telephone line, the pairs are said to be split, and crosstalk will result.

8.6 Crosstalk due to "cross" or "contact". When one wire of a pair touches a wire of another pair, crosstalk will result. On aerial lines, this may be caused by too much sag in one of the wires; on cable lines, it may be due to faulty insulation.

8.7 Interference caused by radio signals. When an open wire telephone line is in the vicinity of strong radio signals, it acts as a radio receiving aerial and large e.m.f.'s are induced in it due to the magnetic and electric fields sent out from the radio transmitting aerial. Radio frequency currents flow through the telephones but the frequency is beyond the audible range and, normally, they are not heard in the telephone receivers.

Sometimes, however, the carbon granules in the telephone transmitter may act like the crystal of a "crystal set" to convert the radio frequency signals into audio frequencies and the radio programmes are heard. This fault condition is overcome by connecting a capacitor of suitable value in parallel with the transmitter to by-pass the radio frequency currents around the transmitter.

9. TEST QUESTIONS.

1. What is (i) an open wire line.
   (ii) an underground cable line?

2. What is the difference between a metallic line and a single-wire line?

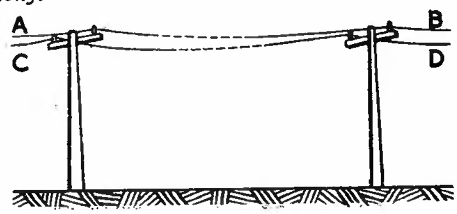
3. What metal is generally used for telephone lines?

4. What is meant by the terms -
   (i) 100 lb. H.D.C.
   (ii) 40 lb. C.C.?

5. What is meant by "Ohm mile constant"?

6. What is the loop resistance of a 6-1/2 lb. cable line, 1430 yards long?

7. The resistance of the wires AB and CD are each 1,000 ohms. Find -



   (i) The loop resistance of the line when a short circuit is applied at one end.

   (ii) The resistance when the two wires are connected in parallel to an earth return circuit of negligible resistance.

8. The I.R. of a telephone line .... as the length of line is increased.

9. The I.R. of open wire lines generally .... during wet weather, due mainly to ....

10. State the primary constants of a telephone line. Draw a simple equivalent circuit of a telephone line in terms of the primary constants.

11. The impedance of a telephone line .... as the frequency rises, and .... as the length of line is increased.

12. What is the average value of impedance of a telephone line, when connected to a distant telephone?

13. Why should the impedance of a transmitter be matched to that of a telephone line?

14. What is a "balance network"?

15. What is meant by "Attenuation"?

16. The attenuation of a telephone line .... as the length of line is increased; and .... as the frequency rises.

17. The attenuation of open wire lines is .... than that of cable lines.

18. What is the difference between "noise" and "crosstalk"?

19. Explain how interference is caused between telephone lines.

20. Interference between open wire lines is reduced by ....

21. Interference between cable pairs is reduced by (1) .... (2) ....

22. What is meant by a "split" pair, applied to telephone lines?

23. Explain briefly why radio signals are sometimes heard as interference in a telephone receiver.

END OF PAPER.

MAGNETO TELEPHONES

1. INTRODUCTION.

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

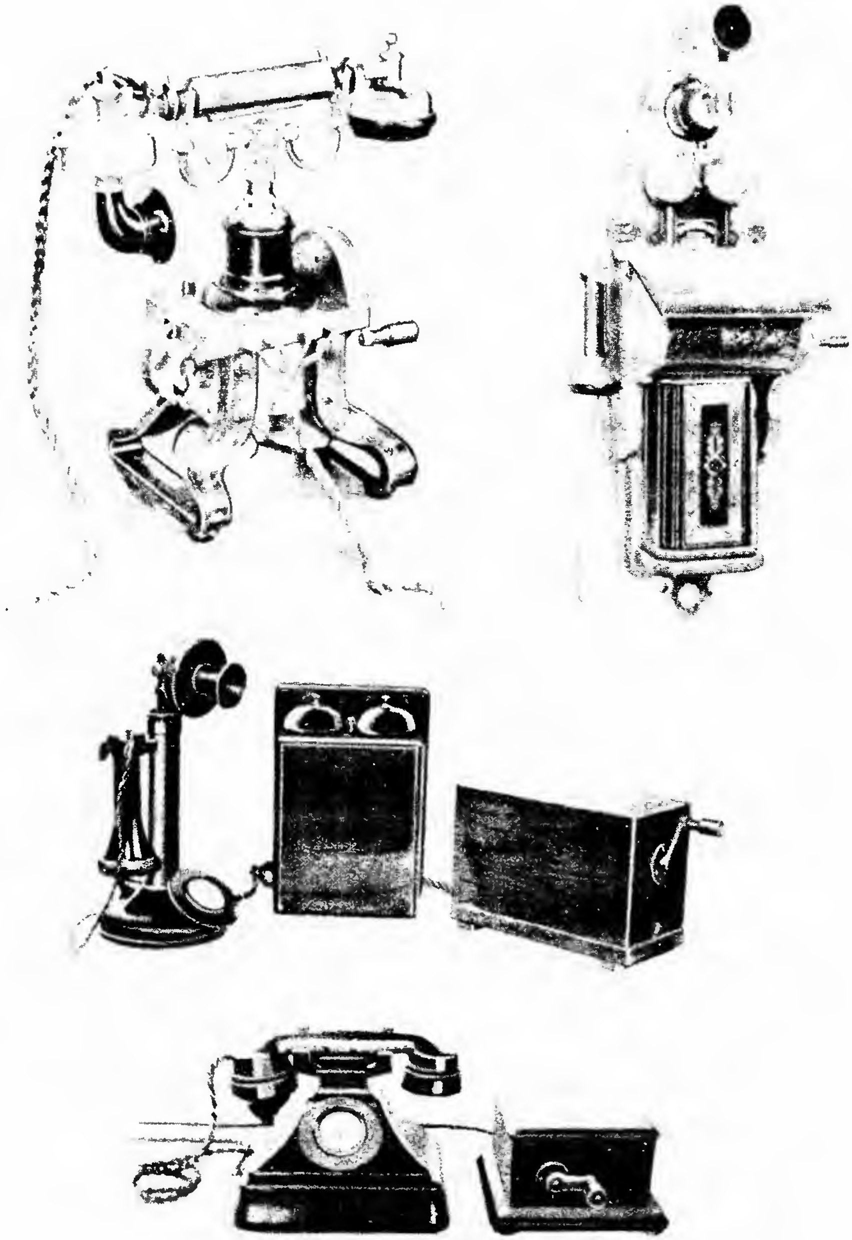
(i) a speaking circuit containing a transmitter and receiver, by which you speak to and hear the person at the distant telephone, and

(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.



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.

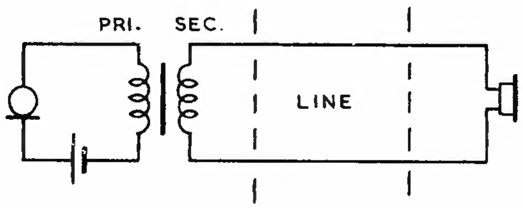


FIG. 1. MATCHED ONE-WAY SPEAKING CIRCUIT.

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 -

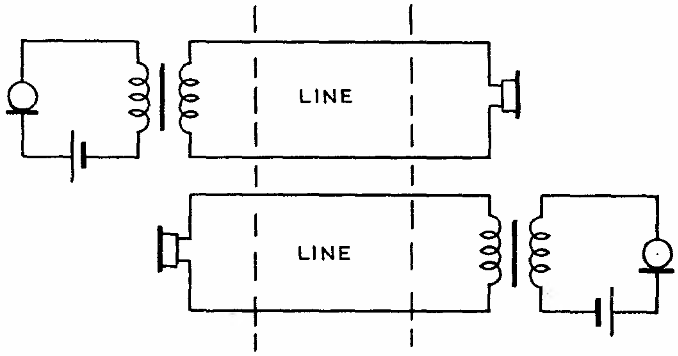
(i) A 1 ohm winding of 430 turns.
(ii) A 25 ohm winding of 1,350 turns.

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.

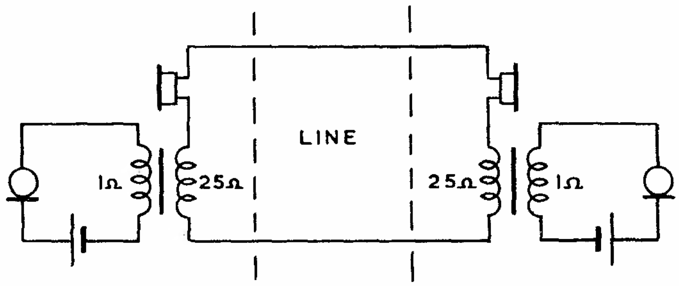
2.3 Two-way circuits. Telephone circuits must be two-way. This may be achieved by the circuit shown in Fig. 2. This is called a "four-wire circuit" because four wires or two pairs are used, one pair for each direction of transmission.



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.

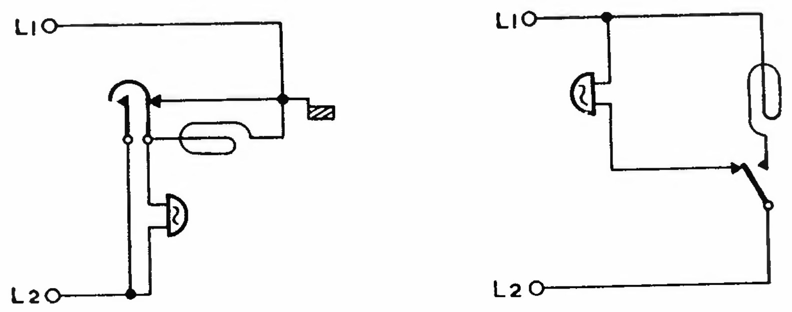
3. BASIC SIGNALLING CIRCUIT.

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 -

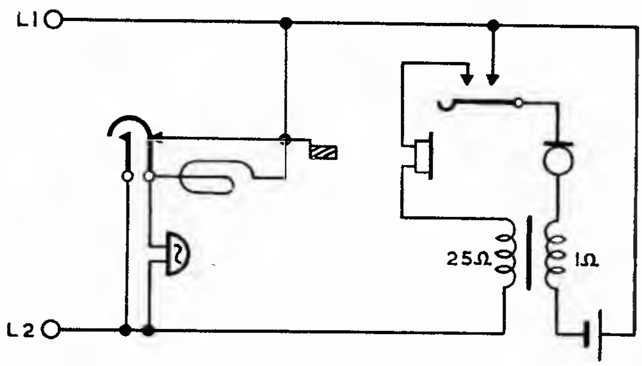
(i) When the telephone is not in use, they switch the generator armature out of circuit and connect the bell across the line. Thus, the impedance of the generator does not reduce the ringing current through the bell.

(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.

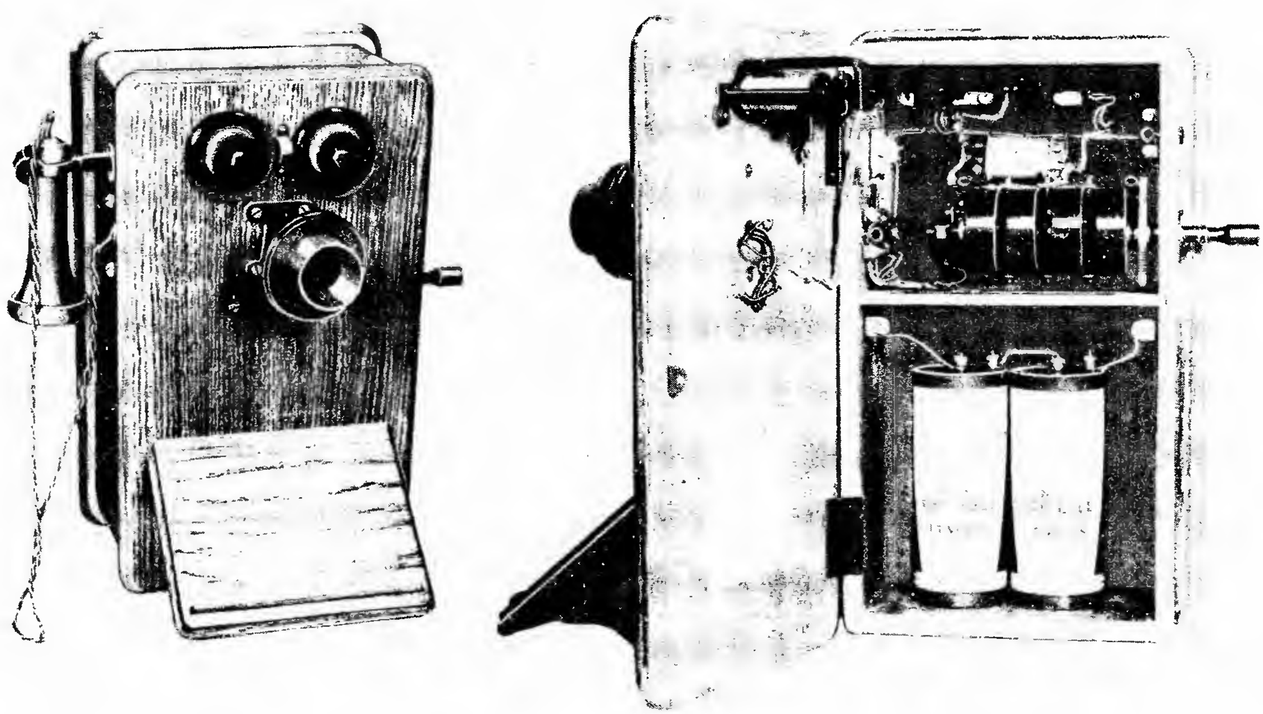
4. BASIC MAGNETO TELEPHONE.

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.

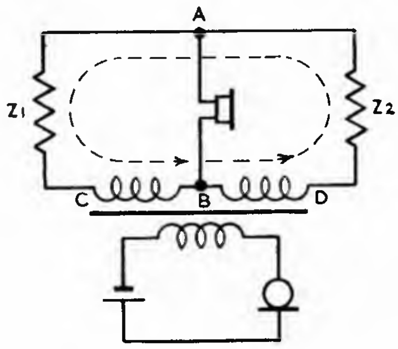
The A.S.T.I.C. circuit is similar to the basic speaking circuit with the addition of an extra winding on the induction coil and a balance network.

For simplicity of explanation, it is assumed that -

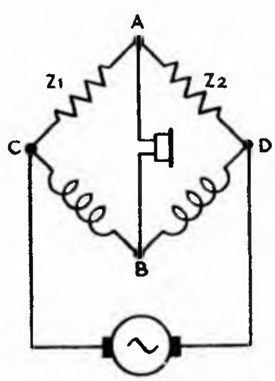
(i) the CB and BD windings connected in series, have equal turns and resistance, and
(ii) the impedance (Z_1) of the line and distant telephone equals the impedance (Z_2) of the balance network fitted in the telephone (600 ohms).

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.

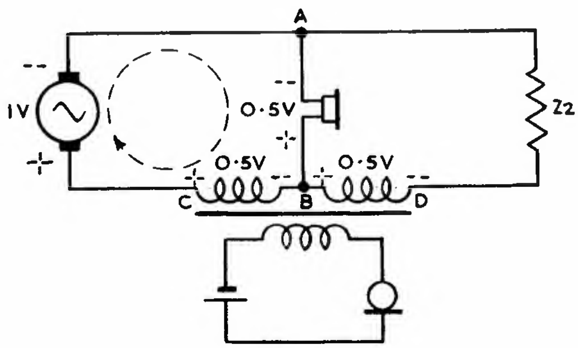


FIG. 7. OPERATION OF A.S.T.I.C. (RECEIVING).

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.

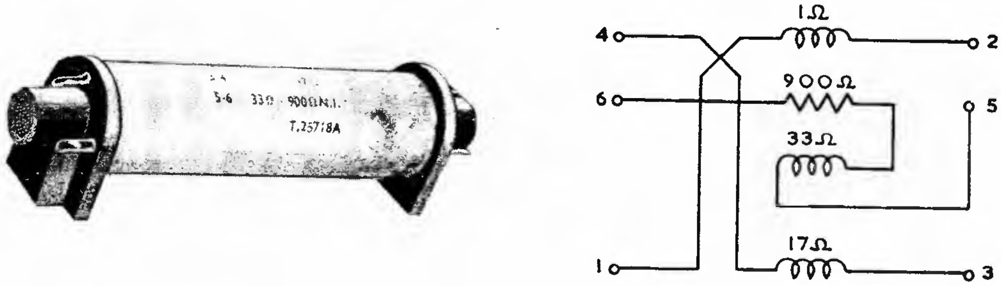
A typical coil is the A.S.T.I.C. No. 21A used in 300 series telephones.

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.

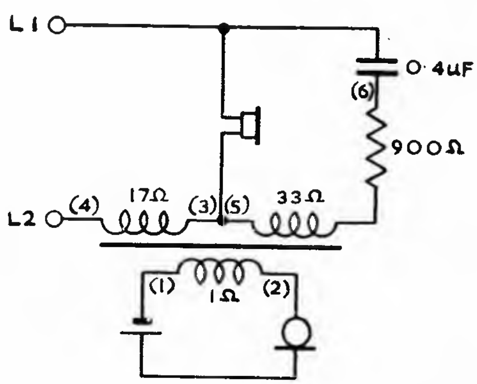
The open core prevents saturation of the magnetic circuit due to the transmitter current in the 1 ohm winding.



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.

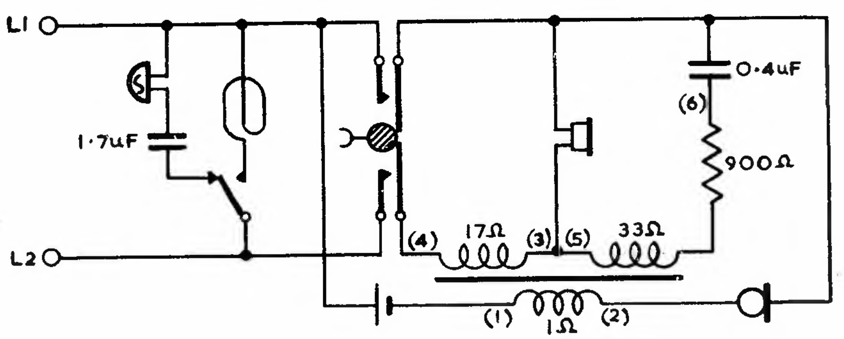
To keep sidetone to a minimum over the V.F. range, the impedance of the balance network must vary with frequency in the same manner as the impedance of the line and distant telephone. In an attempt to simulate the variation in line impedance, which decreases as the frequency rises, a capacitor is connected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

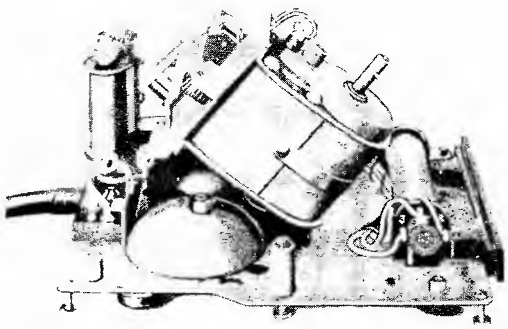
(i) A moulded case containing a 1,000 ohm bell, A.S.T.I.C. No. 21A, 1.7 µF and 0.4 µF capacitors (in the one metal can), cradle switch contacts and hand generator.

(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.

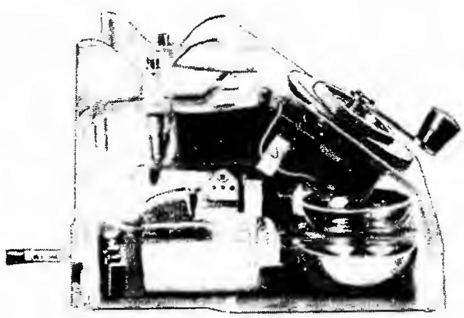
In the table models, the exchange line and the connections to the dry cell battery (mounted in a battery box) terminate on a terminal block No. 20/4 which is connected to the case by a cord 3406. In the wall telephone, the exchange line and the local battery connect directly to terminals inside the case.

(a) Magneto Table Telephone.

(b) Magneto Wall Telephone.



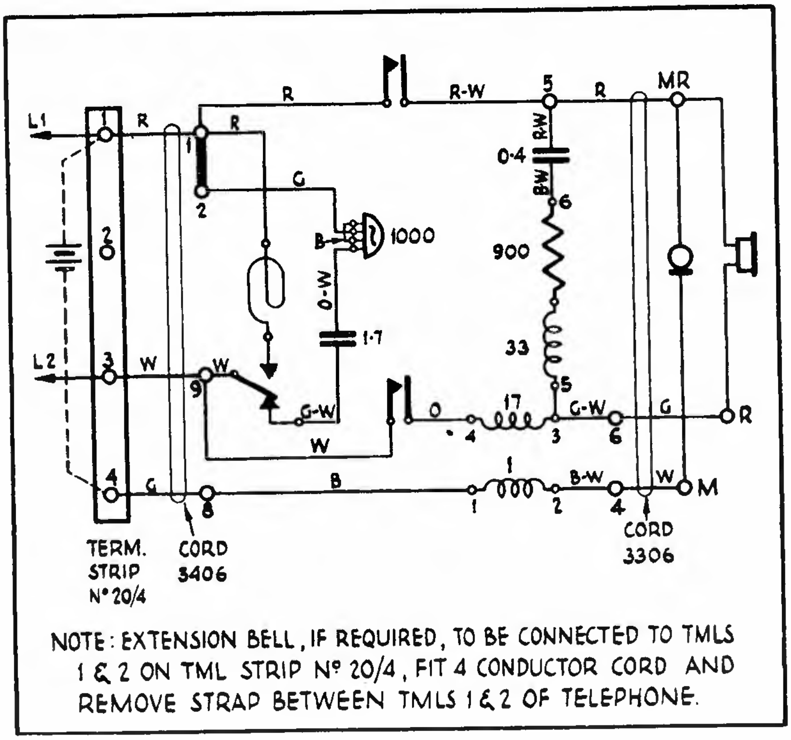
(c) Internal View of 334 MT.



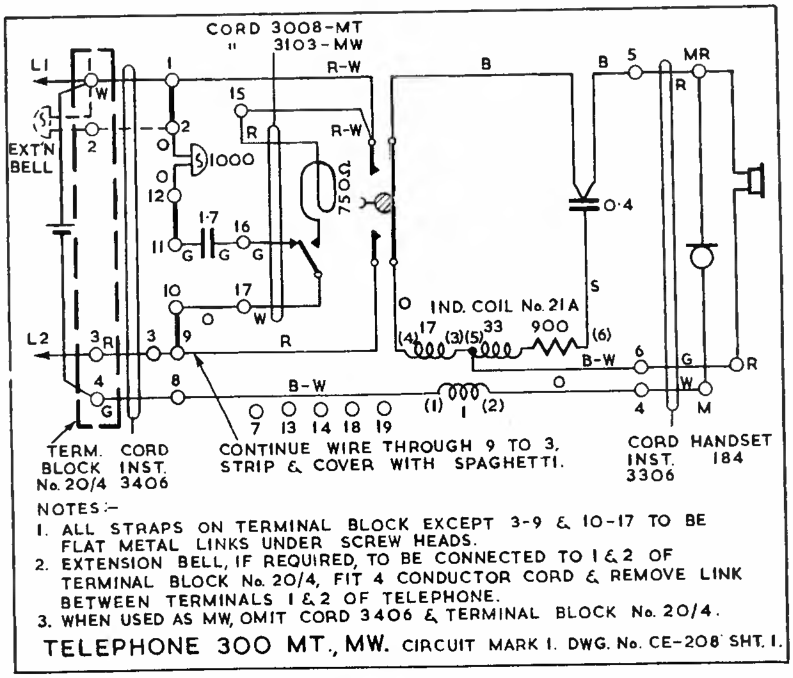
(d) Internal View of 300 MT.

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.

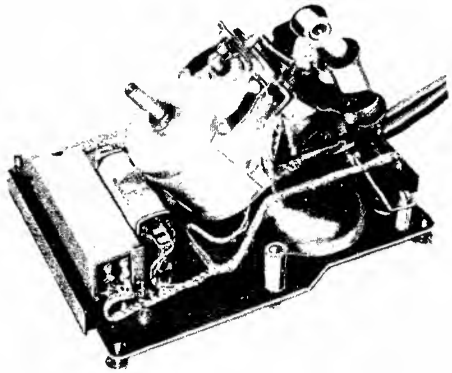
7.2 A typical telephone in this series is the 400 MT (Fig. 13), which is made up of two units -

(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.

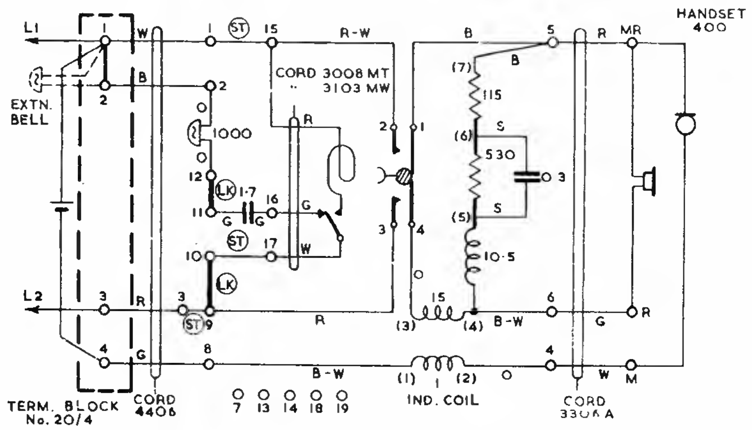
(ii) A handset No. 400 containing the transmitter No. 13 and rocking armature receiver.

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)



(b)

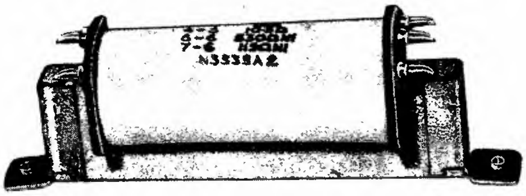


(c) Routed Schematic Circuit.

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.



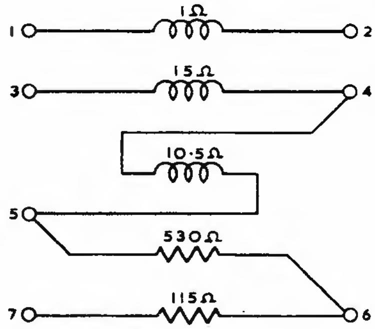


FIG. 14. A.S.T.I.C. USED IN 400 SERIES MAGNETO TELEPHONES.

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.

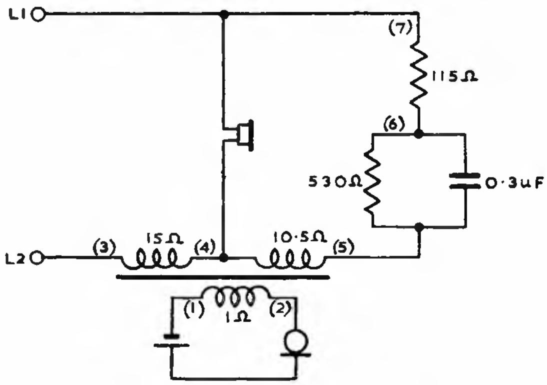


FIG. 15. ANTI-SIDETONE SPEAKING CIRCUIT.

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).

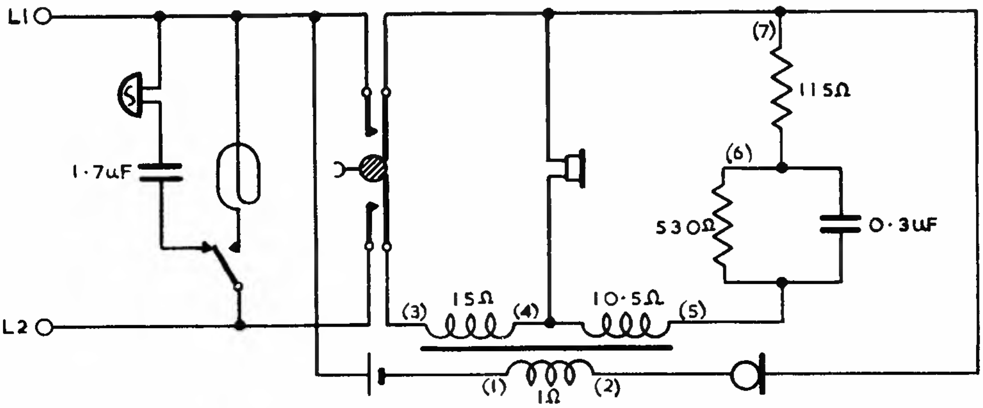


FIG. 16. SIMPLIFIED CIRCUIT OF 400 SERIES MAGNETO TELEPHONES.

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.

C.B. AND AUTOMATIC TELEPHONES.

---

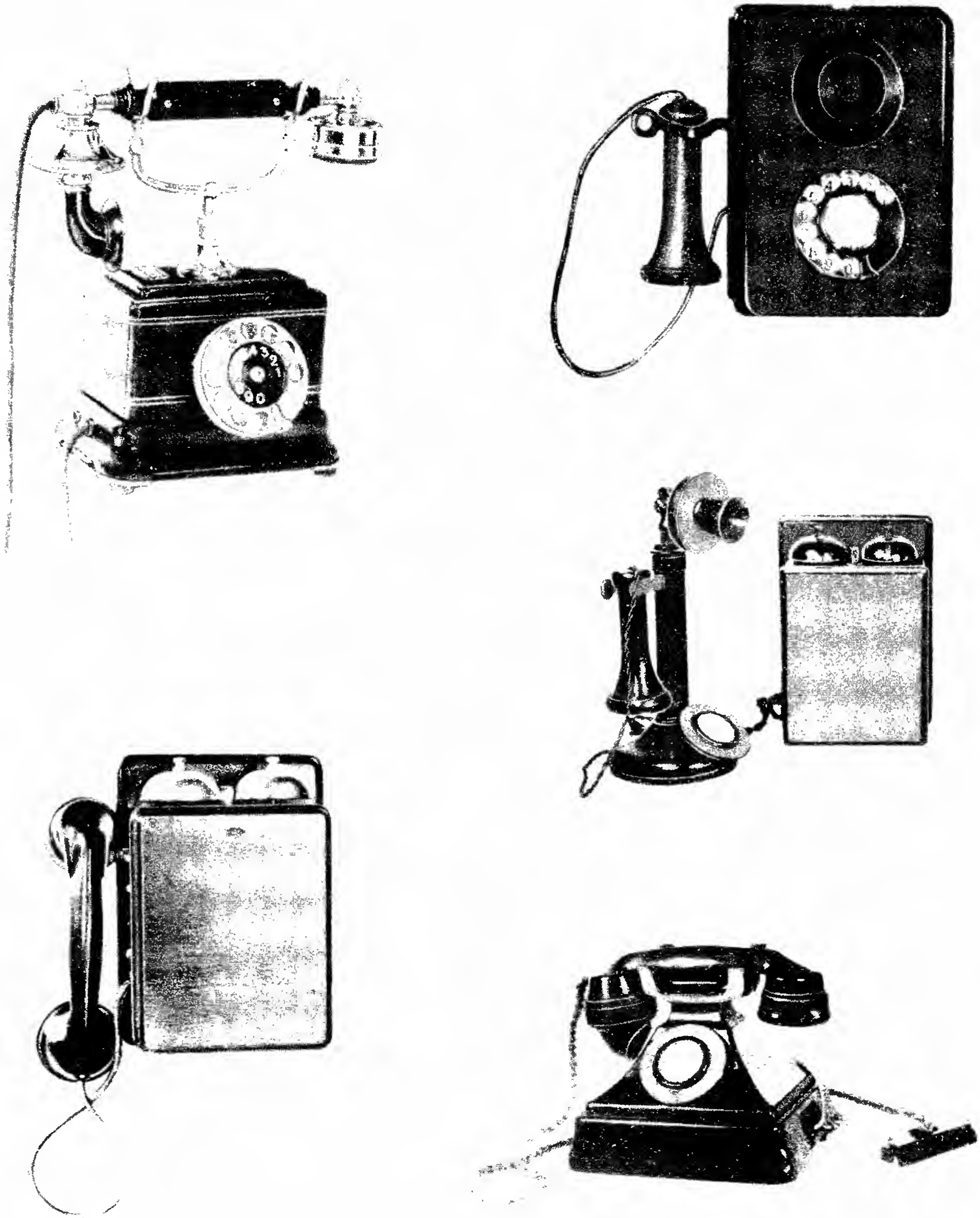
1. INTRODUCTION.

1.1 Many different types of C.B. manual and automatic telephones have been used and some early types are shown on page 2. The types most commonly used at present are in the 300 and the 400 series, and these are available in table and wall models.

1.2 C.B. manual and automatic telephones in the different series are identified by the code letters

- CBT for a C.B. Manual Table Telephone,
- CBW for a C.B. Manual Wall Telephone,
- AT for an Automatic Table Telephone,
- AW for an Automatic Wall Telephone.

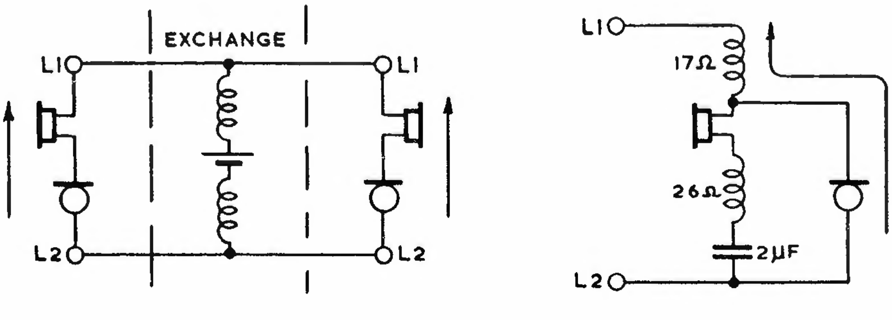
1.3 This Paper describes the principle of operation of the early type telephones, and the modern handset C.B. manual and automatic telephones, which use the anti-sidetone induction coil.



EARLY C.B. MANUAL AND AUTOMATIC TELEPHONES.

2. BASIC C.B. MANUAL TELEPHONE.

2.1 The modern C.B. telephones have been developed from the early circuits. In the first C.B. telephone, a transmitter and receiver were connected in series at each end of the telephone line to provide a two-way speaking circuit (Fig. 1a).



(a) (b)

C.B. SPEAKING CIRCUITS.

FIG. 1.

This circuit has two main defects -

(i) There is no provision for matching the transmitter to the line or the line to the receiver for maximum power transfer.

(ii) The D.C. from the exchange battery for the transmitter operation also flows through the receiver coils, and tends either to oppose and weaken the permanent magnet in the receiver or to saturate the magnetic circuit, depending on the direction of current flow. In either case, the efficiency of the receiver is reduced.

2.2 These defects are overcome by adding a two-winding induction coil and a 2 μF capacitor (Fig. 1b). As the transmitting and receiving efficiencies are essentially a compromise, the number of turns of each winding is designed to provide some degree of impedance matching for each direction of transmission. The Induction Coil No.14 (I.C. 14) is a typical two-winding open core induction coil and consists of -

(i) a 17 ohm winding of 1700 turns,

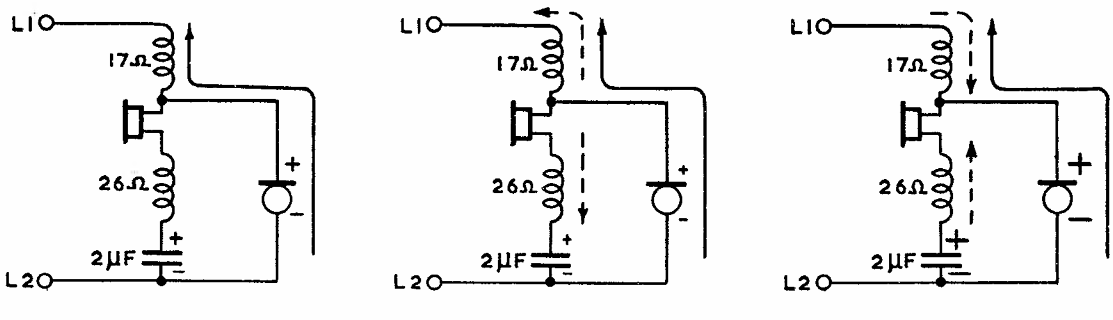
(ii) a 26 ohm winding of 1400 turns.

The open prevents magnetic saturation due to the transmitter current flowing through the 17 ohm winding.

The 2 μF "blocks" the D.C. from flowing through the receiver, and also prevents the receiver and the 26 ohm winding from shunting some of the D.C. from the transmitter.

2.3 The transmitting circuit (Fig. 2). During transmitting conditions, the 26 ohm winding can be considered as the primary of an auto-transformer of which the 17 ohm and 26 ohm windings in series, form the secondary. The transmitter is connected to the primary, and the turns ratio of the windings is designed so that the transmitter is approximately matched to the impedance of the line and distant telephone.

D.C. from the exchange battery flows through the transmitter and the 17 ohm winding. The P.D. across the transmitter also exists across the plates of the capacitor. The polarities are shown in Fig. 2a.



(a) Transmitter at rest. (b) Resistance decreases. (c) Resistance increases.

OPERATION OF TRANSMITTING CIRCUIT.

FIG. 2.

When a person speaks into the transmitter, the transmitter resistance alternately decreases and increases as explained in the paper"Transmitters and Receivers".

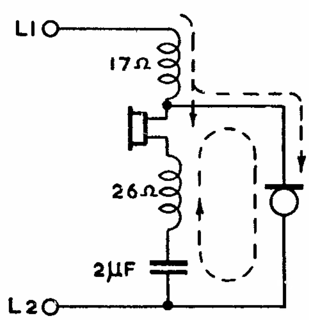
When the resistance decreases (Fig. 2b), the current increases slightly through the 17 ohm winding and the line, and the P.D. across the transmitter decreases. The capacitor discharges so that its P.D. equals that across the transmitter. The discharge current flows through the 26 ohm winding and induces a current in the 17 ohm winding which further increases the line current.

Conversely, when the resistance increases (Fig. 2c), the line current decreases slightly, and the P.D. across the transmitter (and capacitor) increases. The capacitor charging current flows through the 26 ohm winding in the opposite direction and the induced current in the 17 ohm winding further decreases the line current.

Summarising, in terms of the auto-transformer action, the A.C. component of speech developed by the transmitter causes an alternating speech current to flow through the 26 ohm winding. This induces an e.m.f. of mutual induction across the 17 ohm winding, so that the speech voltage applied to line is the sum of the speech voltage across the transmitter and that induced in the 17 ohm winding.

The induction coil, by its impedance matching action, provides a more efficient transfer of speech energy from the transmitter to line than in the case of the transmitter connected directly to line.

2.4 The receiving circuit (Fig. 3). During receiving conditions, the 17 ohm winding can be considered as the primary and the 26 ohm winding as the secondary of a transformer. The line is connected to the primary and the receiver to the secondary; and the turns ratio is designed to match approximately the impedance of the line to that of the receiver.



OPERATION OF RECEIVING CIRCUIT.

FIG. 3.

Speech currents from the line flow through the 17 ohm winding and low resistance of the transmitter. This induces an e.m.f.

of mutual induction across the 26 ohm winding and speech currents flow in the local circuit consisting of the receiver, transmitter and 2 μF capacitor. Fig. 3 shows the conditions at a particular instant during speech.

The speech currents from the line through the receiver, 26 ohm winding and 2 μF capacitor tend to oppose the induced current through the receiver; but their value is small as this shunt path offers a much greater opposition to A.C. than the transmitter.

The induction coil, by its impedance matching action, provides a more efficient transfer of speech energy from the line to the receiver than in the case of the receiver connected directly to line.

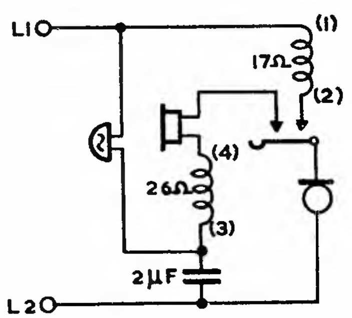
2.5 The Signalling Circuit. A bell and switch-hook contacts are added to the speaking circuit, for signalling and switching purposes. Fig. 4a shows the basic circuit used in the type 137 CBW telephone (Fig. 4b) which is representative of the early type C.B. manual telephones.

Incoming Ring. When receiving an incoming ring from the exchange, the receiver is on the hook and the switch contacts are, therefore, open. Thus, the lower impedance of the speaking circuit does not shunt the bell. The ringing current passes through the bell and 2 μF capacitor in series.

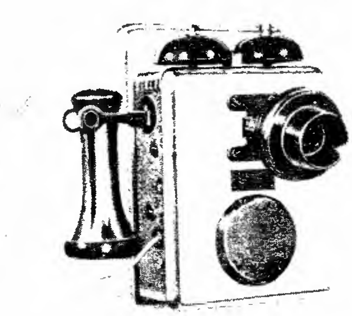
Effect on speaking circuit. During a conversation, the receiver is removed from the hook and the switch contacts close to connect the speaking circuit to the line. The bell is connected across the speaking circuit; but because of the high impedance of the bell (about 18,500 ohms at 1 kc/s), it has no noticeable effect on the speaking circuit during either transmitting or receiving.

To signal the C.B. Manual exchange, the receiver is lifted from the hook and the switch contacts close. The D.C. flowing through the transmitter and 17 ohm winding also flows through and operates signalling apparatus at the exchange (as described in the paper "C.B. Exchange Principles") to indicate to the telephonist that the subscriber wishes to make a call.

The 2 μF capacitor (in series with the bell) and the switch-hook contacts ensure that a D.C. circuit or loop is not provided when the receiver is on the hook.



(a) Schematic Circuit.



(b) Telephone 137 CBW.

BASIC C.B. MANUAL TELEPHONE.

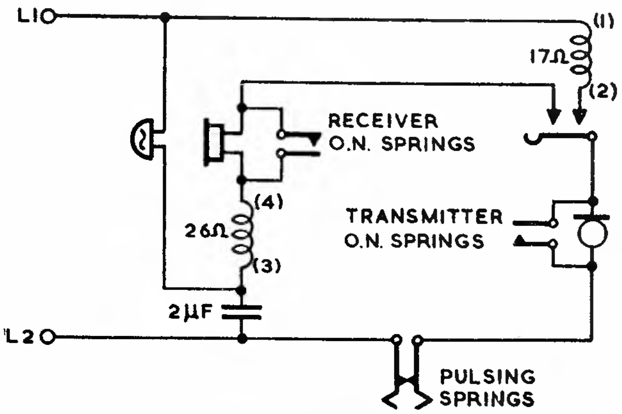
FIG. 4.

3. BASIC AUTOMATIC TELEPHONE.

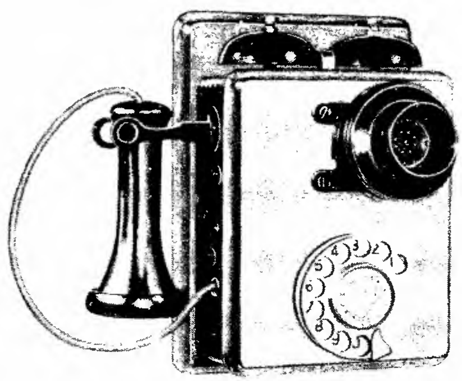
3.1 How Subscribers Signal the Automatic Exchange. When a telephone is connected to an automatic exchange, a telephone dial is provided, so that the calling subscriber can automatically operate the exchange equipment to set up the desired connection.

In its simplest form, the dial consists of a pair of spring contacts, normally closed, but which, under the control of the subscriber, can be made to open and close any number of times from one to ten. These contacts, called pulsing springs, are connected so as to interrupt the D.C. through the telephone and exchange apparatus, when the switch contacts close and the dial is operated.

Fig. 5a shows the basic circuit used in the type 137 AW telephone (Fig. 5b) which is typical of the early type automatic telephones.



(a) Schematic Circuit.



(b) Telephone 137 AW.

FIG. 5. BASIC AUTOMATIC TELEPHONE.

3.2 As shown in Fig. 5a, additional spring contacts provided on the dial are connected across the transmitter and receiver. These contacts are normally open so as not to affect the operation of the speaking circuit. They are called off-normal springs as they operate when the dial is turned off-normal preparatory to dialling, and they remain closed during dialling.

During dialling conditions, the off-normal (O.N.) springs -

(i) Short-circuit the transmitter resistance so that it will not reduce the current in the dialling circuit. Also, if the transmitter were left in circuit, any variation in transmitter resistance during dialling would cause distortion of the dial pulses.

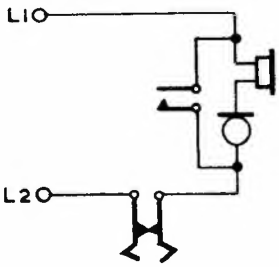
(ii) Short-circuit the receiver to prevent undesirable clicks being heard, due to the capacitor charge and discharge currents. For example, when the dial pulsing springs open, the 2 μF capacitor charges to the exchange battery voltage through the 17 ohm and 26 ohm windings; and when the pulsing springs close, the capacitor discharges through the 26 ohm winding.

(iii) Connect the lower impedance of the induction coil windings across the bell, to prevent tinkling of the bell.

(iv) Connect the 26 ohm induction coil winding in series with the 2 μF capacitor across the pulsing springs to form a spark quench circuit. (See paragraph 3.4.)

To prevent loud clicks in the receiver at the instant the dial is pulled off-normal, the receiver O.N. springs are adjusted to make before the transmitter O.N. springs.

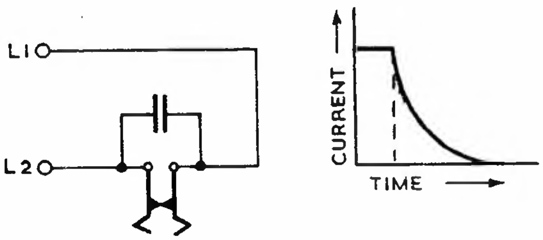
3.3 Development of Dialling Circuit. In the first automatic telephone circuit, the dial pulsing springs were connected in series with the transmitter and receiver (Fig. 6).



EARLY AUTOMATIC TELEPHONE DIALLING CIRCUIT.
FIG. 6.

During dialling, the off-normal springs short-circuit the transmitter and receiver to connect the pulsing springs direct to the telephone line and exchange apparatus. When the pulsing springs open, the current through and, therefore, the flux about the inductive windings of the exchange apparatus, fall to zero almost instantly. This induces an e.m.f. of self-induction across the windings, which is about 700-900 volts for average length lines. This voltage unduly strains the insulation of the lines and equipment and is a hazard to staff working on the equipment. It also produces excessive sparking and deterioration of the pulsing contacts.

The e.m.f. of self-induction can be reduced by connecting a capacitor across the pulsing contacts during dialling conditions (Fig. 7a).



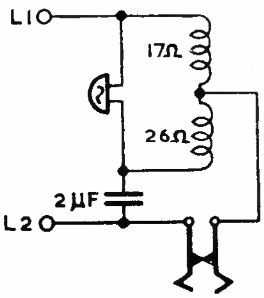
(a) (b)

CAPACITOR ACROSS PULSING CONTACTS.

FIG. 7.

Whilst the contacts are closed, they short-circuit the capacitor, which is, therefore, uncharged. When the contacts open, the capacitor charges to the exchange battery voltage via the windings of the exchange apparatus. Now, a capacitor charging current is a gradually decaying current, being initially high and gradually falling to zero with time (Fig. 7b). The current through the exchange equipment, therefore, does not fall to zero instantly but decays more gradually so that the e.m.f. of self induction is reduced, in practice, to a value of about 150 volts.

A disadvantage of Fig. 7a is that each time the contacts close, the short-circuited capacitor discharges through them. In time, the heavy discharge currents would cause these contacts to deteriorate. To prevent this, a resistance is connected in series with the capacitor to reduce the discharge current.



SIMPLIFIED EARLY DIALLING CIRCUIT.
FIG. 8.

3.4 In early dialling circuits, the operation of the off-normal springs connected the resistance of the 26 ohm induction coil winding in series with the 2 μF capacitor during dialling (Fig. 8); but in the later handset telephones, non-inductive resistances are also used to reduce the discharge current.

The capacitance and resistance in series form a spark quench circuit.

4. ANTI-SIDETONE INDUCTION COILS.

4.1 In the speaking circuit used in early C.B. telephones, sounds picked up by the transmitter are heard as sidetone in the local receiver. The disadvantages of sidetone are explained in the paper "Magneto Telephones".

To reduce sidetone, all modern telephones use an anti-sidetone induction coil (A.S.T.I.C.).

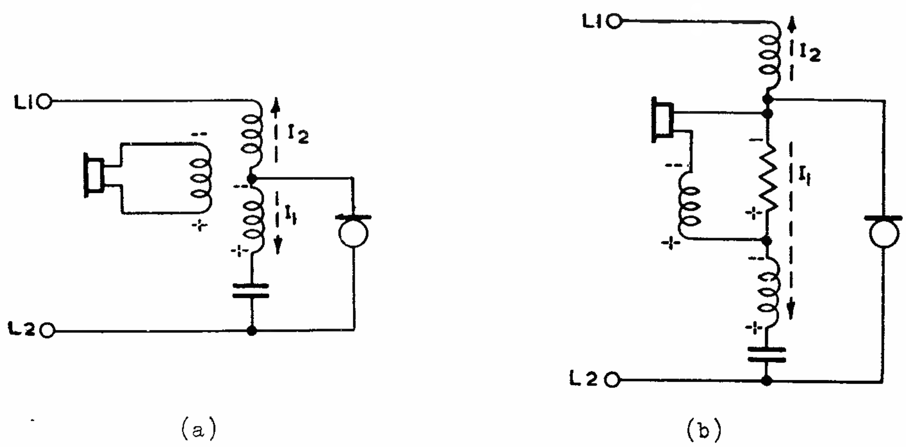
4.2 The principle of operation of the A.S.T.I.C. circuit is explained from Figs. 9 and 10, which show the conditions at a particular instant during speech. As in the earlier speaking circuit, an auto-transformer connection is used to match approximately the transmitter to the line impedance. The receiver is connected to the additional winding, which is adjusted to match approximately the receiver to the line impedance.

Transmitting. In the A.S.T.I.C. circuit, speech signals are transmitted to line in the same manner as described for the earlier speaking circuit in paragraph 2.3.

Sidetone Suppression. In the basic arrangement of Fig. 9a, when a person speaks into the transmitter, the A.C. components of speech, I_1 and I_2, flow through the two windings in opposite directions, and the magnetic effects produced by the windings tend to cancel. The resulting flux, however, induces an e.m.f. in the receiver winding, which produces some degree of sidetone current in the receiver.

One way to reduce this sidetone current would be to make the ampere-turns of each winding equal; but this would destroy the auto-transformer matching effect.

In Fig. 9b, to retain the auto-transformer effect, and at the same time, further reduce the sidetone, the receiver circuit is connected across a non-inductive resistance, the value of which is chosen to give minimum sidetone under average line conditions. The P.D. across this resistance (due to I_1 flowing through it), is approximately equal to the e.m.f. induced in the receiver winding. The receiver is connected between points of approximately the same potential and the sidetone is greatly reduced.

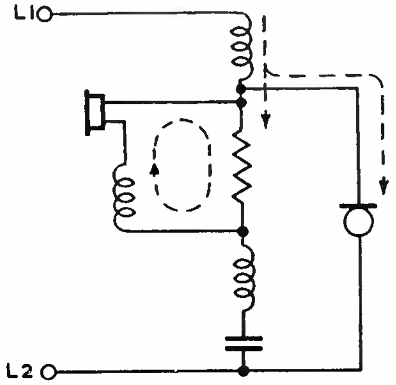


OPERATION OF A.S.T.I.C. (TRANSMITTING).

FIG. 9.

To keep sidetone to a minimum at all frequencies transmitted by the telephone, the impedance of the path through which I_1 flows must vary with frequency in the same manner as the impedance of the line and distant telephone through which I_2 flows. In an attempt to simulate the variation in line impedance, therefore, the path for I_1 contains a balance network made up of the capacitor connected in series with the resistance of the A.S.T.I.C. winding and the N.I.R.

Receiving (Fig. 10). The major portion of the incoming speech current from line passes through one winding and the low resistance of the transmitter. Speech currents are induced in the receiver winding and flow in a local circuit through the receiver and the N.I.R.



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

FIG. 10.

The induced effect from any small speech current from line which flows through the high impedance path shunting the transmitter, tends to assist the current in the local receiver circuit.

4.3 In "anti-sidetone" telephones, the A.S.T.I.C. must be 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.

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 types of A.S.T.I.C.'s have been used in different telephones over the years, 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 4.2.

Some of the open core types are -

(i) the A.S.T.I.C. No. 14A used in the type 237 telephones.
(ii) the A.S.T.I.C. No. 20 used in the type 232 telephones.
(iii) the A.S.T.I.C. No. 22 used in the early type 332 telephones.
(iv) the A.S.T.I.C. No. 27 used in the 300 series telephones.

For convenience, non-inductive resistances are also wound on these A.S.T.I.C.'s.

The 300 series telephones are the most commonly used of the above telephones.

5. 300 SERIES TELEPHONES.

5.1 Some of the telephones in this series are -

(i) The types 332 CBT and 332 AT, developed in England. These were originally supplied in black, ivory, green and red.

(ii) The types 300 CBT, 300 AT, 300 CBW and 300 AW, developed by the Australian Post Office. (Fig. 11.)

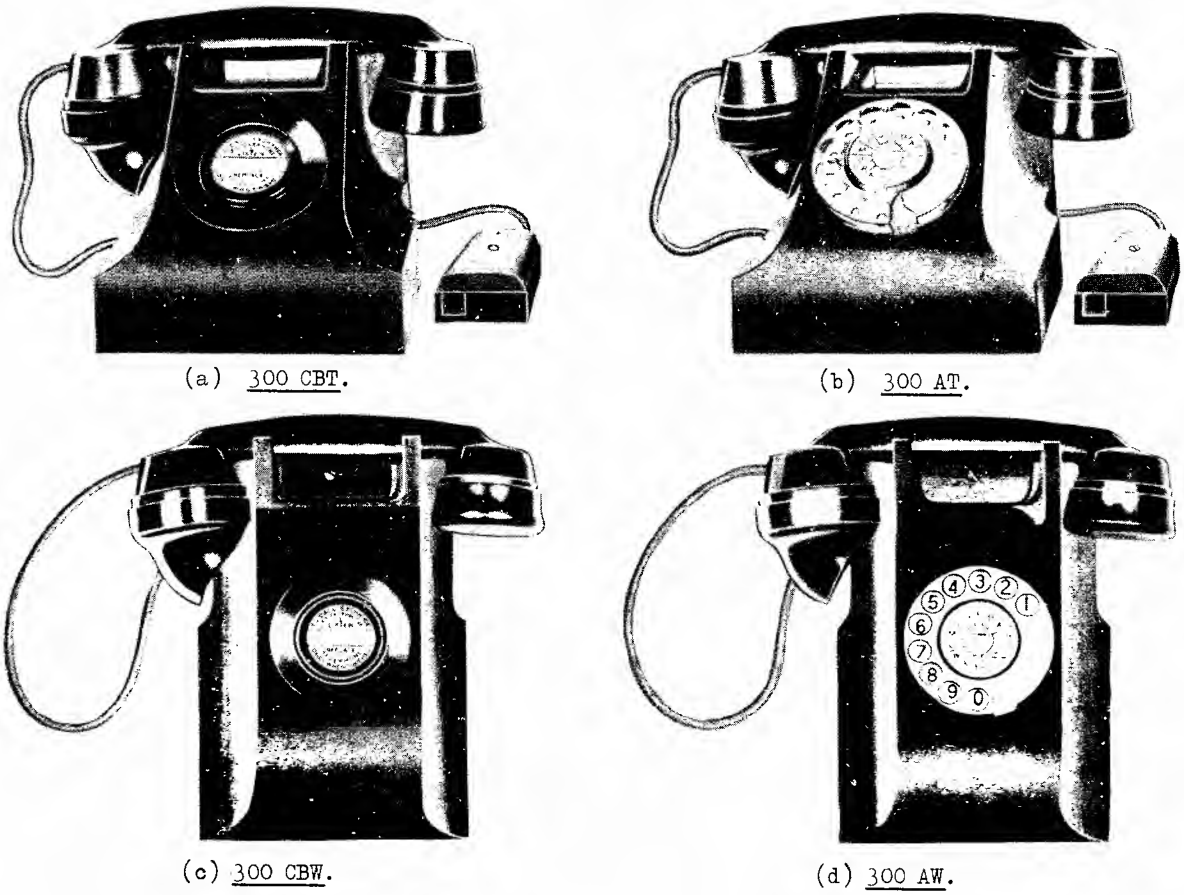
The general appearance of the corresponding table telephones is similar, and the main difference is in the construction and layout of the component parts. The schematic circuit and the operation of the table and wall telephones are similar.

5.2 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. 27, 2 μF and 0.1 μF capacitors (in the one metal can), cradle switch contacts, and either a dummy dial or automatic dial.

(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 terminates on a terminal block No. 20/4. In the wall models, the exchange line connects directly to terminals inside the case.

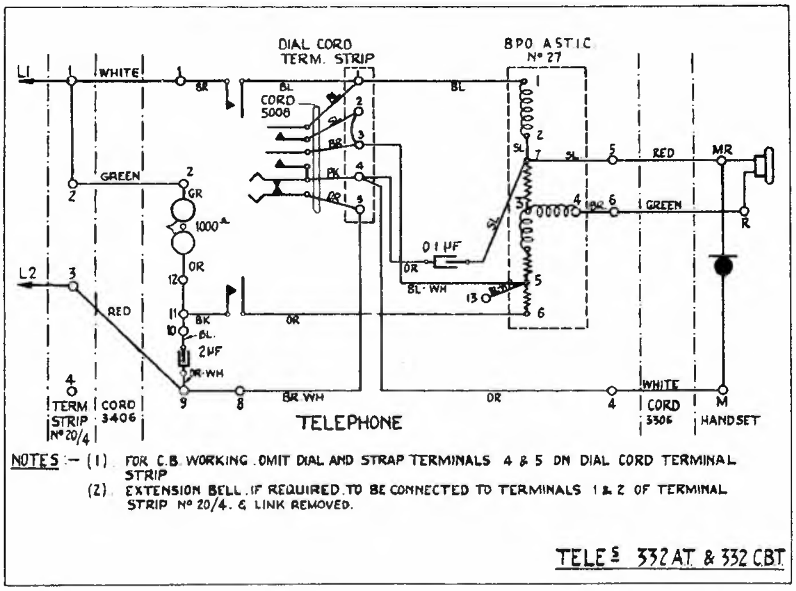


(a) 300 CBT. (b) 300 AT.

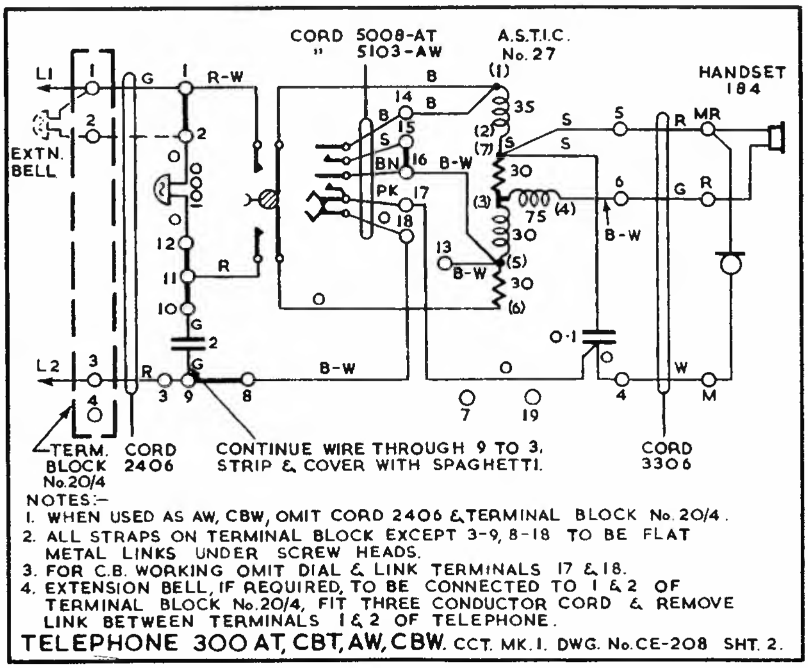
(c) 300 CBW. (d) 300 AW.

FIG. 11. 300 SERIES HANDSET TELEPHONES.

5.3 Fig. 12 shows typical schematic circuits for the types 332 and 300 telephones. These circuits are basically similar. (On early models of the type 332, an A.S.T.I.C. No. 22 was used instead of A.S.T.I.C. No. 27).



(a) 332AT and 332CBT Telephones.



(b) 300AT, CBT, AW, CBW Telephones.

SCHEMATIC CIRCUITS OF 300 SERIES TELEPHONES.

FIG. 12.

5.4 The A.S.T.I.C. No. 27 (Fig. 13), has five windings, the usual values being -

(i) a 35 ohm winding of 2,600 turns,
(ii) a 75 ohm winding of 1,800 turns,
(iii) a 30 ohm winding of 800 turns,
(iv) two 30 ohm non-inductive resistances.

These values may vary slightly in some circuits. For example, in some coils, the inductive windings are 34, 64 and 26 ohm respectively.

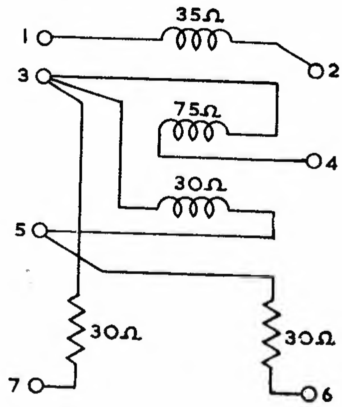


FIG. 13. THE A.S.T.I.C. NO. 27.

5.5 The speaking circuit operation is similar to that described in paragraph 4.2, and can be developed from Fig. 14 which shows the basic connections to the A.S.T.I.C. No. 27.

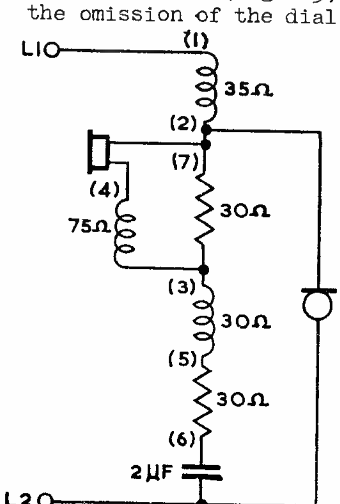
The receiver circuit is connected across the 30 ohm N.I.R. wound between terminals 3 and 7. The P.D. across this resistance due to speech currents flowing through it, opposes the e.m.f. induced in the receiver winding from the other two windings, and provides a good sidetone suppression.

The balance network is made up of the 2 μF capacitor, 30 ohm winding and the two 30 ohm N.I.R.'s, connected in series.

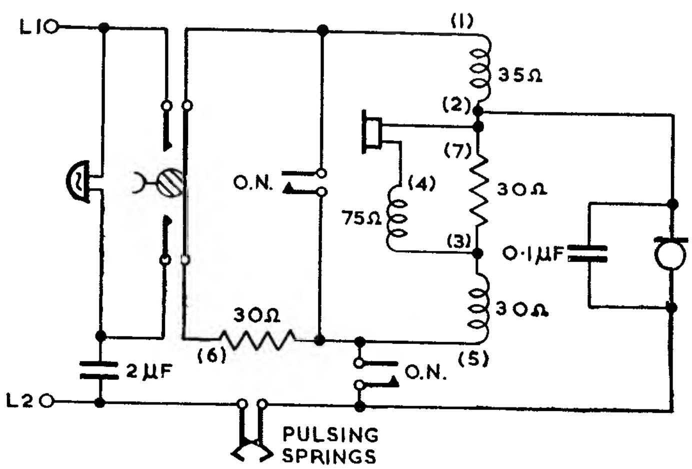
The 30 ohm N.I.R. between terminals 5 and 6 also forms part of the spark quench dialling circuit when the A.S.T.I.C. is used in an automatic telephone (see para. 5.7).

5.6 To produce a practical telephone circuit, a bell and cradle switch contacts are added to the speaking circuit. The reasons for these additions and the operation of the signalling circuit are the same as for the telephone without sidetone suppression. (See paragraph 2.5).

In the 300 series automatic telephone, dial pulsing and off-normal (O.N.) springs are also added (Fig. 15). The 300 series C.B. manual telephone is similar, with the omission of the dial.



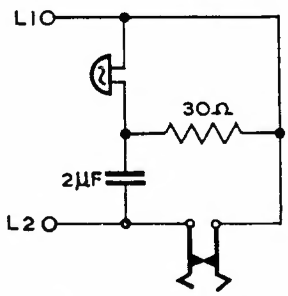
SPEAKING CIRCUIT.
FIG. 14.



SIMPLIFIED CIRCUIT OF 300 SERIES TELEPHONES.
FIG. 15.

5.7 The Dialling Circuit (Fig. 16). During dialling, the off-normal springs operate to -

(i) Short circuit the speaking circuit and connect the pulsing springs direct to the telephone line. This prevents the dial pulses from passing through the resistance of the speaking circuit and also from being heard as clicks in the receiver.
(ii) Connect the spark quench circuit consisting of the 2 μF capacitor and 30 ohm N.I.R. across the pulsing contacts.
(iii) Connect the 30 ohm N.I.R. across the bell, to prevent tinkling of the bell.



DIALLING CIRCUIT.
FIG. 16.

5.8 Sequence of operation of cradle switch contacts. When the switch contacts are open, the capacitor is charged to the exchange battery voltage (about 50 volts) via the bell. At the instant the contacts close, the capacitor discharges through the telephone circuit to approximately the P.D. across the transmitter (about 5 volts). The discharge current normally causes clicks in the receiver. To reduce the loudness of the clicks, the contacts are adjusted so that the transmitter circuit closes before (and opens after) the receiver circuit. Thus, the initial high discharge current does not flow through the path that includes the receiving circuit.

5.9 Wetting of contacts. Experience has shown that contacts which do not carry D.C. tend to develop a high resistance to alternating speech currents of small value. This is because the contacts may become contaminated with a thin surface film of insulating or semi-conducting substances such as dust, tarnish, grease or water. If, however, a D.C. voltage is applied to the contacts as they close, the film breaks down in much the same way as the dielectric of a capacitor. This is called wetting the contacts.

In modern C.B. telephones, a D.C. flows through the bell and cradle switch contacts to "wet" the contacts, when the telephone is in use. The D.C. also flows through the receiver coils; but the value is small (less than 0.5 mA) and does not affect the sensitivity of the bell or receiver.

5.10 The functions of the 2 μF capacitor in the "anti-sidetone" telephone circuit are -

(i) During incoming ringing conditions, it 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.
(ii) During speaking conditions, it forms part of the balance network for satisfactory sidetone suppression; and also ensures that some of the operating D.C. is not shunted away from the transmitter.
(iii) During dialling conditions, it forms part of the spark quench circuit.

As a result, the value of this capacitor must be a compromise to give satisfactory performance for each condition of operation.

5.11 The 0.1 μF capacitor in parallel with the transmitter, prevents radio signals induced in the telephone line from being "detected" by the carbon granules in the transmitter, and heard in the telephone receiver. At radio frequencies, the reactance of this capacitor is much lower than the transmitter resistance, and the capacitor by-passes the radio signals around the transmitter. At voice frequencies, however, the capacitive reactance is much greater (X_c is about 1,600 ohms at 1,000 c/s) than the transmitter resistance, and the capacitor has negligible effect on the operation of the speaking circuit.

6. 400 SERIES TELEPHONES.

6.1 The 400 series telephones use a rocking armature receiver which is superior, both in volume efficiency and frequency response, to receivers previously used. They also use 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 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.

The sidetone balance has been modified to suit the light gauge cables which are likely to be used more with the higher efficiency telephone. However, the sidetone balance is less effective on short lines and this results in loud sidetone under short line conditions.

6.2 Some of the telephones in this series, are the types 400 CBT and 400 AT (Fig. 17). These are available in black or ivory, and are made up of two units -

(i) A moulded case (similar to the 300 series) containing a 1,000 ohm bell, A.S.T.I.C. No. 30, 1.8 μF and 0.9 μF capacitors (in the one metal can), cradle switch contacts, and either a dummy dial or automatic dial.

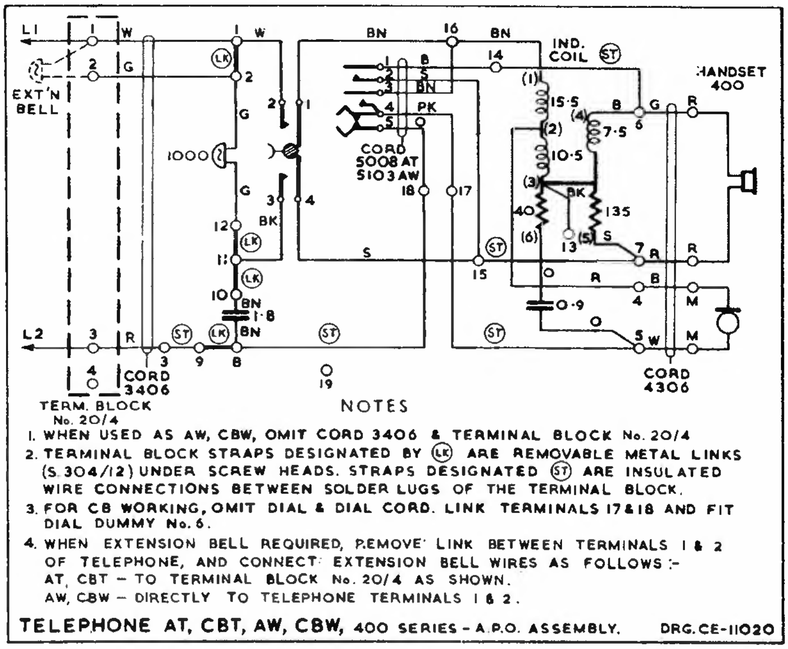
(ii) A handset 400 containing the transmitter No. 13 and rocking armature receiver.

The exchange line terminates on a terminal block No. 20/4 which is connected to the case by a cord 3406; and a cord 4306 connects the handset to the case.

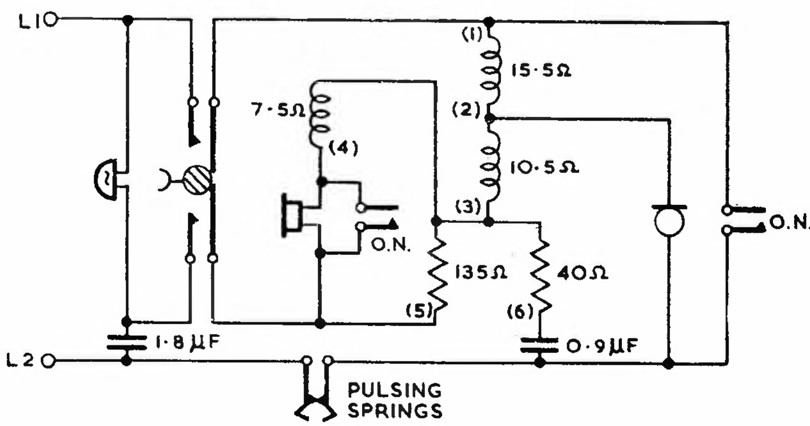
400 SERIES HANDSET TELEPHONE.

FIG. 17.

6.3 Fig. 18a shows the routed schematic circuit for the 400 series telephone. A simplified equivalent schematic circuit is shown in Fig. 18b.



(a) Routed Schematic Circuit.



(b) Simplified Circuit.

SCHEMATIC CIRCUITS OF 400 SERIES TELEPHONE.

FIG. 18.

6.4 The A.S.T.I.C. No. 30 (Fig. 19) has five windings -

(i) A 15.5 ohm winding of 1220 turns.
(ii) A 10.5 ohm winding 666 turns.
(iii) A 7.5 ohm winding of 420 turns.
(iv) A 135 ohm non-inductive resistance.
(v) A 40 ohm non-inductive resistance.

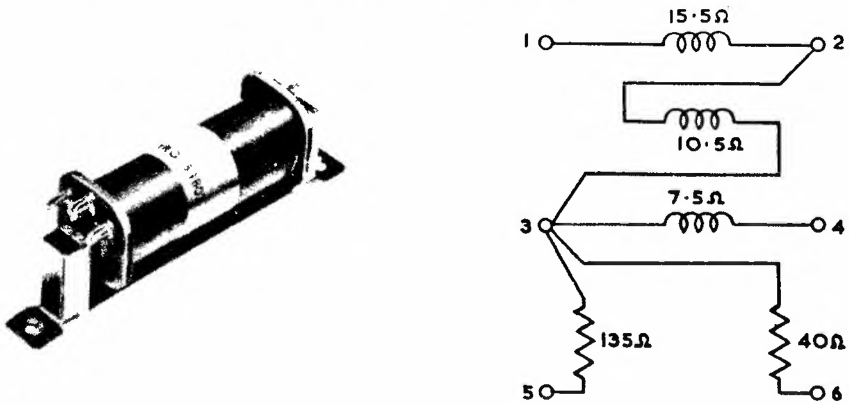
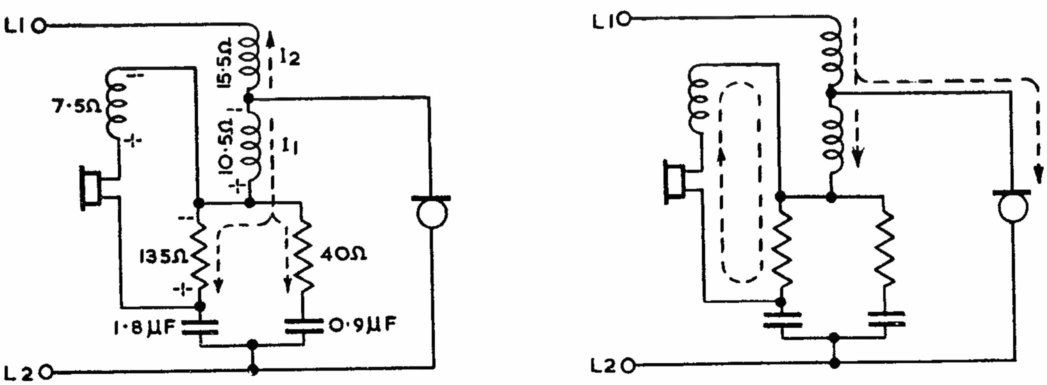


FIG. 19. THE A.S.T.I.C. NO. 30.

The silicon iron core is built up in two sections, each L-shaped and laminated to reduce eddy current loss. An aluminium spacer (0.002 inch) provides a small gap in the magnetic circuit to avoid saturation with high transmitter currents. The higher permeability 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. 27. Thus, the higher overall efficiency of the A.S.T.I.C. No. 30 is the result of reduced magnetic and copper losses.

6.5 The speaking circuit operation is similar to that described in paragraph 4.2, and can be seen from the simplified speaking circuit (Fig. 20), which shows the conditions at a particular instant during speech.



(a) Transmitting. (b) Receiving.

FIG. 20. OPERATION OF A.S.T.I.C. NO. 30.

The receiver circuit is connected across the 135 ohm N.I.R. wound on the A.S.T.I.C. The P.D. across this resistance due to speech currents flowing through it, opposes the e.m.f. induced in the receiver winding from the other two windings, and provides a greater degree of sidetone suppression.

Owing to the improved efficiency of the speaking circuit compared with the 300 series telephones, the balance network (comprising the 135 ohm and 40 ohm N.I.R's wound on the A.S.T.I.C., and the 1.8 µF and 0.9 µF capacitors) is designed to balance more accurately the line impedance variation to ensure satisfactory sidetone suppression over the voice frequency range.

6.6 To produce a practical telephone circuit, a bell and cradle switch contacts are added to the speaking circuit. The reasons for these additions and the operation of the signalling circuit are the same as for the telephone without sidetone suppression. (See paragraph 2.5.)

To reduce the loudness of clicks in the receiver when the switch contacts operate, the contacts are adjusted so that the transmitter circuit closes before (and opens after) the receiver circuit. (See paragraph 5.8.)

As in the 300 series telephone, a small D.C. flows through the bell, switch contacts and receiver to provide for wetting of the contacts. (See paragraph 5.9.)

In the 400 series automatic telephone, dial pulsing and off-normal springs are also added (See Fig. 18). The 400 series C.B. manual telephone is similar, with the omission of the dial.

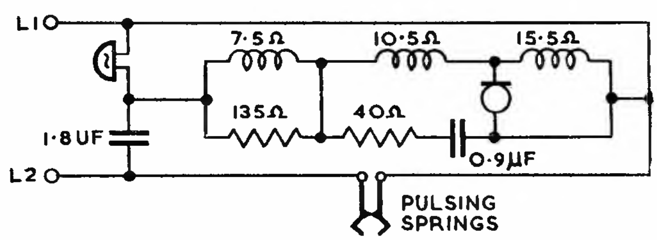
6.7 The Dialling Circuit (Fig. 21). During dialling, the off-normal springs operate to -

(i) Short-circuit the resistance of the speaking circuit and connect the pulsing springs direct to the telephone line.

(ii) Short-circuit the receiver to prevent dial pulses being heard.

(iii) Connect the spark quench circuit across the pulsing contacts. The spark quench circuit consists of the 1.8 µF capacitor connected in series with a network comprising the induction coil windings, the balance resistors and 0.9 µF capacitor, and transmitter. This network has a D.C. resistance of about 30 ohms.

(iv) Connect the low resistance of the spark quench circuit across the bell, to prevent tinkling of the bell.



DIALLING CIRCUIT.

FIG. 21.

6.8 As a matter of interest, there is no capacitor shunting the transmitter in the 400 series telephones, as in the 300 series telephones. Investigations have shown that such a capacitor is required in only a very few cases, and that it is more economic to provide it as an extra when required.

NOTES

NOTES

7. TEST QUESTIONS.

1. What is meant by the code letters AT, AW, CBT, CBW, when applied to telephones?

2. Draw a simple C.B. speaking circuit using a two-winding induction coil, and explain the circuit operation during transmitting and receiving.

3. *Why are switch hook (or cradle switch) contacts necessary in a C.B. telephone?*

4. In what sequence should the switch contacts operate, to reduce the loudness of clicks in the receiver?

5. What is meant by the term "wetting of contacts"?

6. What are the functions of the pulsing and off-normal springs in a telephone dial?

7. Draw a simple spark quench circuit and explain its operation.

8. Explain how a simple three-winding induction coil can be used to reduce sidetone in a telephone circuit.

9. What is a necessary requirement of the balance network for satisfactory reduction of sidetone?

10. Draw the schematic circuit of an automatic 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) during dialling.

11. What are the functions of the $2 \mu F$ and $0.1 \mu F$ capacitors in a 300 series telephone?

12. Why can the 400 series telephones be used on longer lines than the 300 series telephones?

13. What are the main differences in construction between the A.S.T.I.C. No. 27 and A.S.T.I.C. No. 30?

END OF PAPER.

THE AUSTRALIAN POST OFFICE

COURSE OF TECHNICAL INSTRUCTION

Engineering Training Section, Headquarters, Postmaster-General's Dept., Melbourne

SUBSCRIBERS' TELEPHONE SERVICES.

1. INTRODUCTION.

1.1 Subscribers often require telephone facilities or services additional to that provided by one telephone in a fixed location permanently connected to an exchange line.

Telephone facilities are methods of arranging items of telephone equipment at subscriber's premises to provide a speaking or a combination of speaking connections. Various accessories, including alarm equipment, may be fitted as required.

1.2 Each standard facility is allotted a plan number for identification. For example -

- Plan 1 consists of one telephone permanently connected to an exchange line. The telephone may be either a wall handset or table handset instrument of the magneto, C.B., or automatic type, depending on the exchange area.

1.3 This paper briefly describes some of the more common facilities. Other facilities which include equipment not described in this book, are described in other papers of the Course.

2. EXTENSION BELLS.

2.1 Alarm equipment is often installed some distance from a subscriber's telephone to indicate that a call is incoming. The alarms may be intermittent or continuous ringing extension bells (Fig. 1), sirens or visual signals.

Diameter of gongs: 2½" - 6".

(a) Magneto Bell.

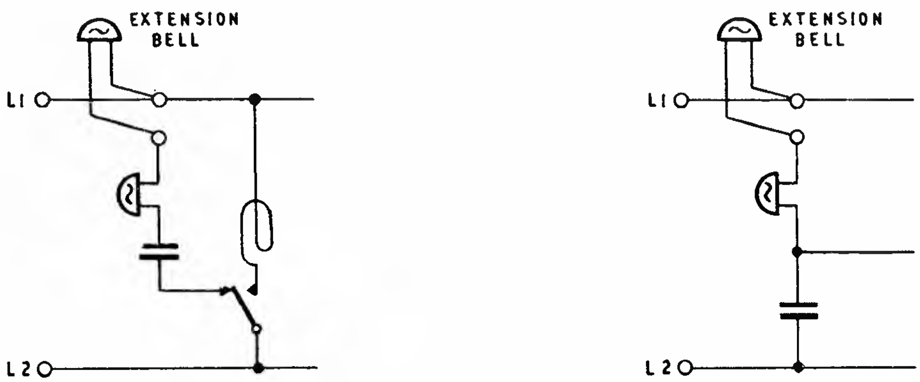
Diameter of gong: 2½" - 10".

(b) Trembling Bell.

TYPICAL EXTENSION BELLS.

FIG. 1.

2.2 For intermittent ringing, an extension magneto bell is connected in series with the magneto bell in the telephone. (Fig. 2.) The extension bell is operated by the exchange ringing current and rings only while the telephone bell is ringing.



(a) Magneto Telephone. (b) C.B. and Automatic Telephones.

CONNECTION OF EXTENSION MAGNETO BELL.

FIG. 2.

2.3 A tumbler switch can be installed with an extension magneto bell to provide one of two arrangements. (Fig. 3.)

In Fig. 3a, the telephone bell always rings but the extension bell may ring or be silenced, as desired. When operated, the switch short-circuits the extension bell to prevent it ringing, but a circuit is still provided for the telephone bell.

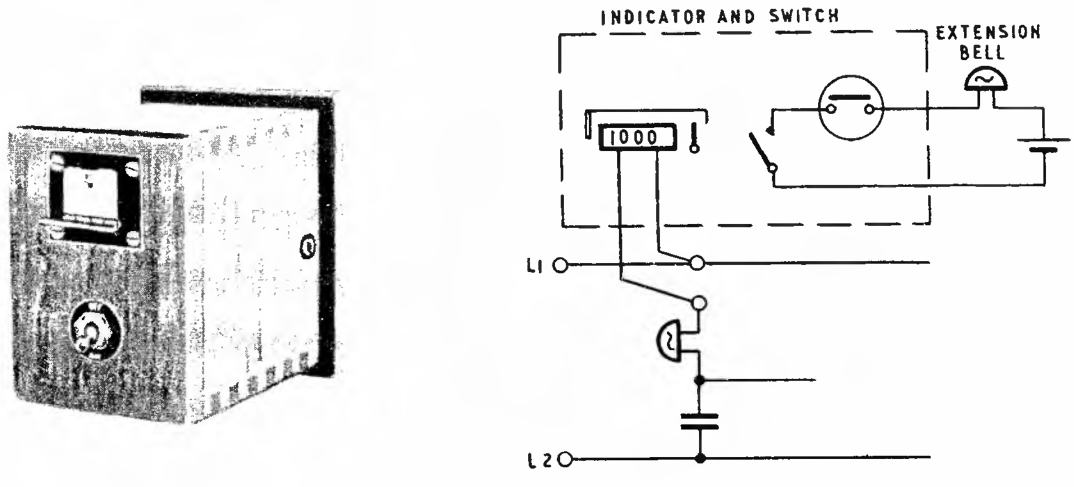
In Fig. 3b, either the telephone bell or the extension bell rings, the other being silenced. In this case, the extension bell is not in series with the telephone bell. The switch connects either the extension bell or the telephone bell across the exchange line. The 2μF capacitor in series with the extension bell prevents a D.C. loop being applied to the exchange equipment. To answer or make a call, the switch is operated to connect the telephone to the exchange line.

(a) S.P. one-way switch. (b) S.P. two-way switch.

EXTENSION BELL WITH CUT OFF SWITCH.

FIG. 3.

2.4 For continuous ringing, a drop indicator is connected in series with the telephone bell (Fig. 4). Continuous ringing alarms are not used on services connected to exchanges with an automatic ring or on party lines.



(a) (b)

INDICATOR AND SWITCH.

FIG. 4.

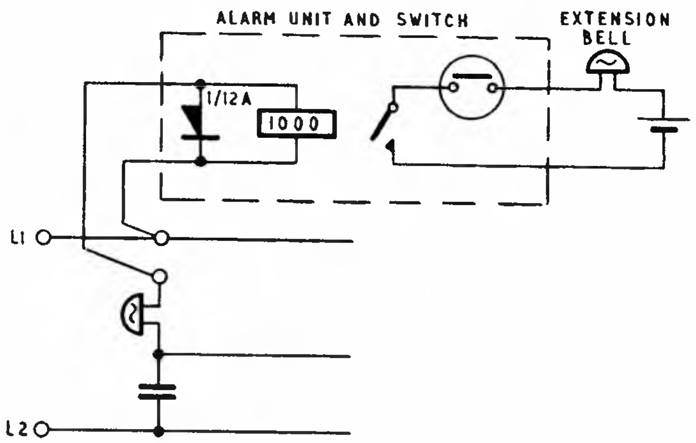
When the exchange rings, the drop indicator operates and the alarm contacts complete the circuit for an extension trembling bell (low voltage) which operates from a local D.C. supply. The bell continues to ring until the subscriber restores the indicator shutter. The extension bell should be switched off when the premises are unattended.

2.5 An alarm unit and switch or a loud sounding alarm (siren) is sometimes installed where magneto bells do not provide a sufficiently loud or distinctive signal.

In the alarm unit and switch (Fig. 5), a 3000 type relay with make contacts is connected in series with the telephone bell.

The rectifier by-passes each alternate half-cycle of ringing current and the relay is operated by a unidirectional current.

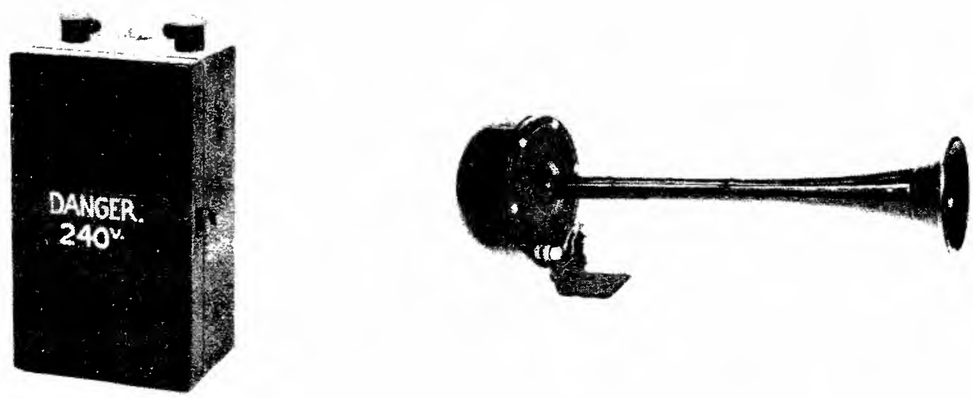
The contacts complete the circuit for a trembling bell, which operates from a local D.C. supply and rings only while the telephone bell is ringing. The switch disconnects the extension bell when it is not required.



ALARM UNIT AND SWITCH.

FIG. 5.

The loud sounding alarm (Fig. 6) is similar in operation. A rectifier unit which operates from 200V - 240V A.C. supplies 12V D.C. to operate the siren.



LOUD SOUNDING ALARM.

FIG. 6.

3. PARALLEL TELEPHONES.

3.1 Either two or three telephones may be installed in different parts of a subscriber's premises and permanently connected in parallel to an exchange line. (Plan 2.)

Calls may be answered at or originated from each telephone. Intercommunication between the telephones is not practicable and secrecy is not provided. Thus, when one telephone is in use, a person may listen to the conversation on another telephone. The exchange line terminates on the main telephone and the other telephones are the extensions.

Telephones are not connected in series because

- the transmission efficiency of the telephone in use would be greatly reduced by the high impedance of the bells in the other telephones, and
- in C.B. and automatic telephones, the capacitors in series with the bells of the other telephones would prevent D.C. flowing through the transmitter of the telephone in use.

3.2 Fig. 7 shows a basic signalling circuit for two magneto handset telephones in parallel. Three wires are used between the telephones and the connections between the L1 and L2 telephone terminals are reversed. This connects the bells in series for an incoming ring, and open-circuits both bells to prevent ringing when either generator is turned for an outgoing call.

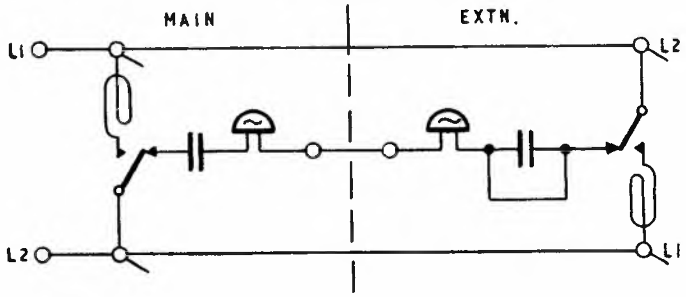
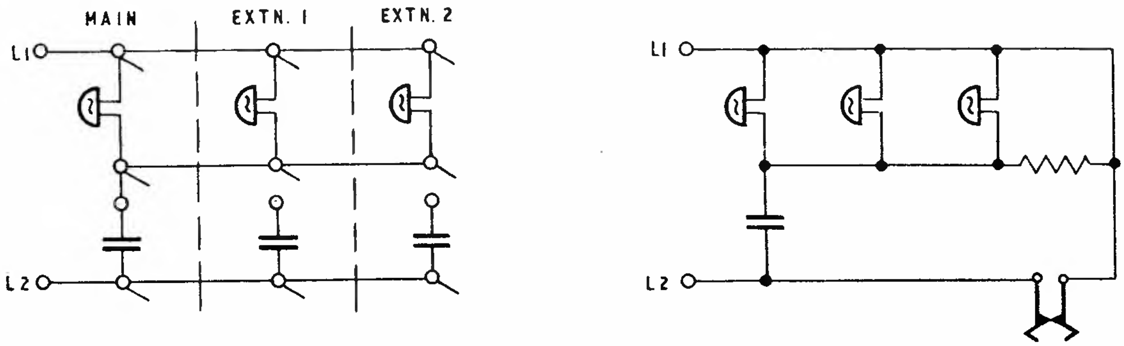


FIG. 7. TWO MAGNETO TELEPHONES IN PARALLEL.

The capacitor in the extension telephone is short circuited to reduce the reactance and improve the performance of the bell circuit to alternating ringing current.

3.3 Fig. 8 shows basic signalling circuits for C.B. or automatic handset telephones in parallel.



(a) Basic Ringing Circuit.

(b) Simplified Dialling Circuit.

C.B. OR AUTOMATIC TELEPHONES IN PARALLEL.

FIG. 8.

When all telephones are the handset type, each bell may be left in circuit, if desired.

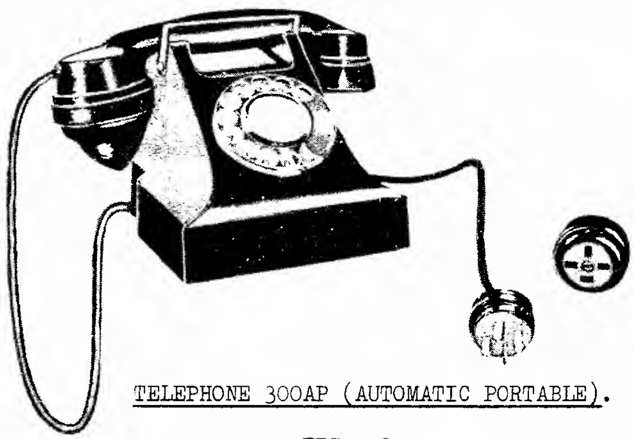
The L1 and L2 wires are commoned to all telephones and the capacitors in the extension telephones are disconnected. A third wire connects the speaking and dialling circuits of an extension (when in use) to the capacitor of the main telephone. (Fig. 8a.) More than one capacitor affects the operation of the anti-sidetone balance network circuit and causes distortion of the dial pulses when speaking and dialling from any telephone.

The additional wire also connects the bells in parallel for an incoming ring and prevents the bells tinkling (by shunting them with the spark quench resistance) when a call is dialled from any telephone. (Fig. 8b.)

4. PORTABLE TELEPHONES.

4.1 This service (sometimes called an adapter service) enables a subscriber to use a telephone at any one of several locations. (Plans 3 and 4.) The telephone cord terminates on a 4-pin plug and is connected to the exchange line by inserting into sockets (maximum six) located at points selected by the subscriber. Fig. 9 shows a typical portable telephone fitted with a handle for carrying the telephone from socket to socket, as desired.

A bell and capacitor (in either a bell set or fixed telephone) is connected permanently across the line to receive rings from the exchange whether the portable telephone is plugged into one of the sockets or not.



TELEPHONE 300AP (AUTOMATIC PORTABLE).

FIG. 9.

4.2 Fig. 10 shows typical bell sets used with portable services (Plan 3).

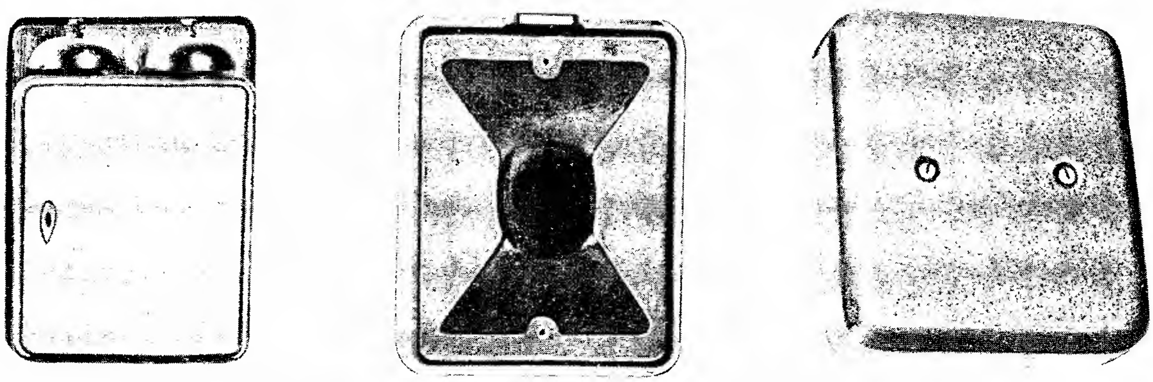
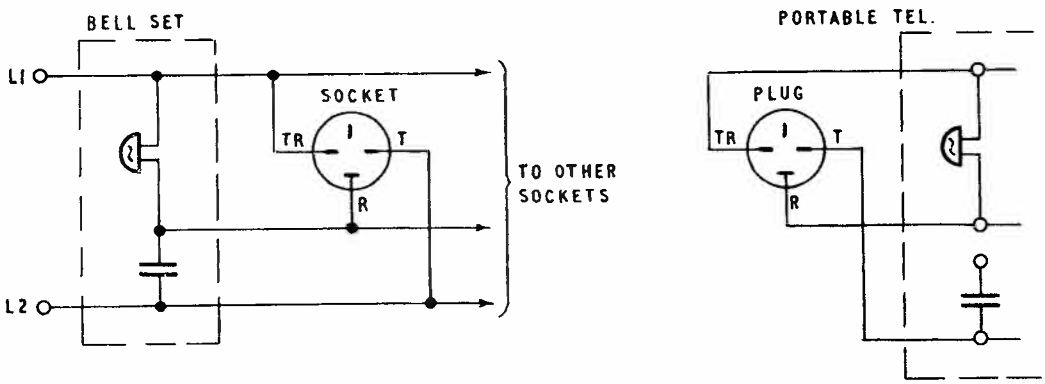


FIG. 10. TYPICAL BELL SETS.

For the same reasons as in a parallel telephone service, three conductors are used between the bell set and the portable telephone, and the capacitor in the portable telephone is disconnected. (Fig. 11.) The portable telephone bell is left in circuit or disconnected, as required.



PORTABLE TELEPHONE CONNECTION.

FIG. 11.

In magneto areas, the dry cell battery for the operation of the transmitter in the portable telephone, is wired via the bell set.

4.3 As an alternative arrangement (Plan 4), the bell set is replaced by a fixed telephone permanently connected to the exchange line with the portable telephone service in parallel.

5. ALTERNATIVE TELEPHONES.

5.1 When a subscriber desires a telephone service in two places at different times (for example, in a shop during normal business hours and in a private residence at other times), a tumbler switch is used to connect either telephone to the exchange line (Plan 5.). The switch is operated to either short circuit (Fig. 12a) or open circuit (Fig. 12b) the telephone not in use.

(a) S.P. two way switch. (b) D.P. two way switch.

ALTERNATIVE TELEPHONE SWITCH CONNECTIONS.

FIG. 12.

5.2 Intercommunication between telephones is not possible; but, as both cannot be connected at the same time, secrecy is provided.

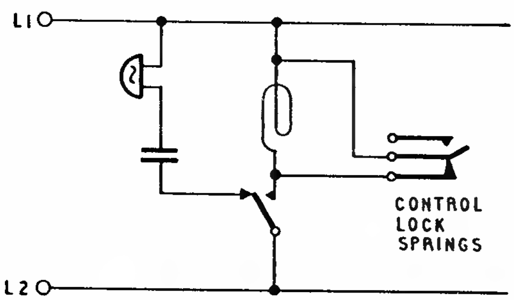
6. CONTROL LOCK TELEPHONES.

6.1 When a subscriber desires to prevent unauthorised persons from originating outgoing telephone calls, a control lock is fitted. (Plan 29.) This consists of a small lock with a set of change-over springs operated by a key held by the subscriber. This facility does not interfere with incoming calls which are answered in the usual manner.

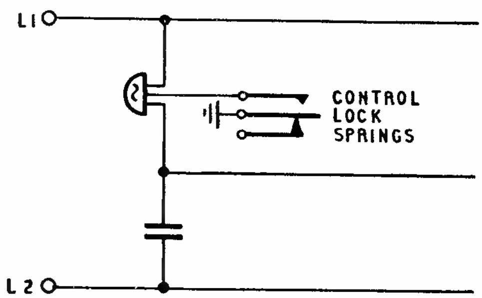
6.2 In a magneto telephone, the generator armature is normally short circuited by the control lock springs (Fig. 13a). When the key is inserted and turned in the lock, the short circuit is removed allowing the exchange to be signalled.

6.3 In a modern C.B. system, the earth which normally completes the circuit for operation of the subscriber's calling apparatus (refer paper "C.B. Exchange Principles") is disconnected at the exchange. This prevents operation of the apparatus when the C.B. telephone handset is lifted. When the key is turned in the lock, however, an earth is connected via one of the telephone bell coils, the subscriber's speaking circuit and line 2 to signal the telephonist (Fig. 13b). The subscriber releases the key when the telephonist answers, and the control lock springs (non-locking) restore to normal.

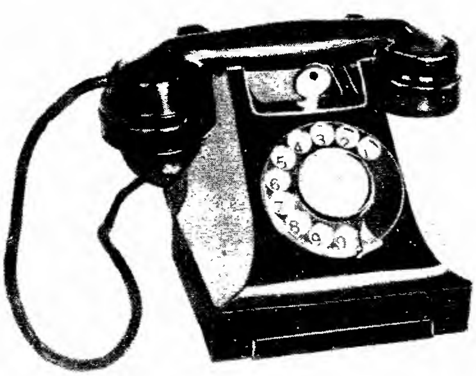
6.4 In an automatic telephone, the dial pulsing springs are normally short circuited by the control lock springs (Fig. 13c). The short circuit is removed when the key is turned in the lock.

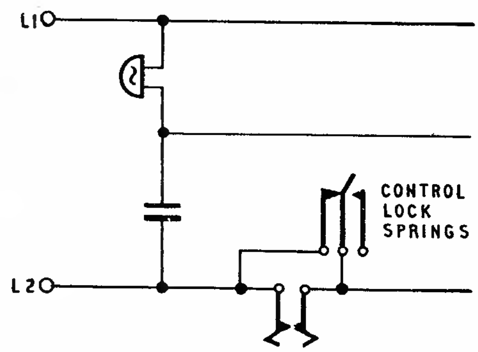


(a) Magneto Telephone.



(b) C.B. Telephone.





(c) Automatic Telephone.

TELEPHONE FITTED WITH CONTROL LOCK.

FIG. 13.

7. EXTENSION SWITCHES.

7.1 These are key-switching units used in subscribers' premises to provide intercommunication between two telephones (installed, for example, at a business office and private residence), each of which requires connection to an exchange line. (Plan 6.)

Two types of extension switch are used

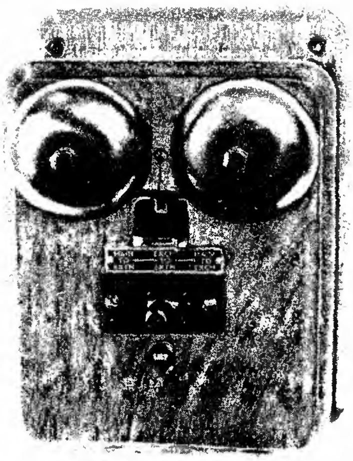
- a magneto extension switch for magneto exchange areas, and
- a C.B. extension switch for C.B. manual and automatic exchange areas.

The switch is installed near the main telephone where the exchange line terminates, and the other telephone is the extension.

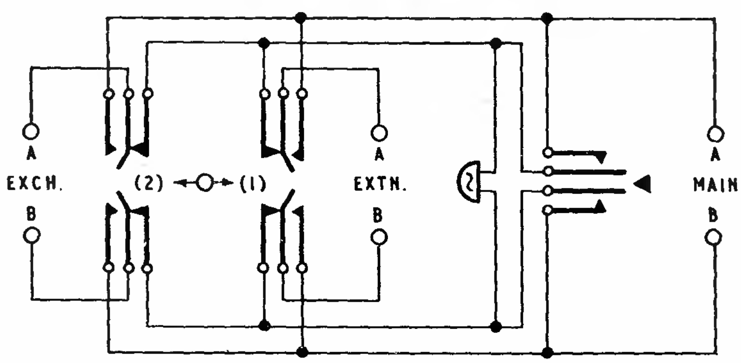
In a more modern arrangement used in C.B. manual and automatic areas, the switching apparatus is in the same case as the main telephone and the unit is called an intermediate telephone. This is described in Telephony 2.

7.2 Magneto extension switch (Fig. 14.) The three-position locking lever key provides the following connections -

Main to Extension; key handle moved to left, operating contacts marked (1).
Exchange to Extension; key in centre position.
Main to Exchange; key handle moved to right, operating contacts marked (2).



(a) Face layout.



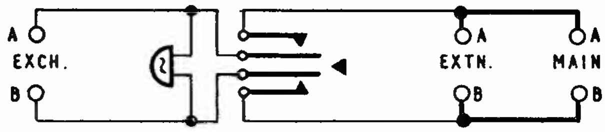
(b) Schematic Circuit.

MAGNETO EXTENSION SWITCH.

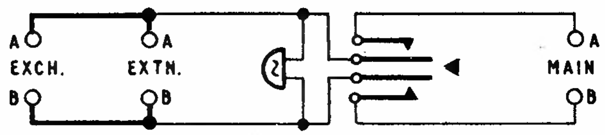
FIG. 14.

7.3 Circuit operation. (Refer simplified circuits in Fig. 15.) In any position, a ring from either exchange or extension is received on a magneto bell in the main telephone or the associated extension switch.

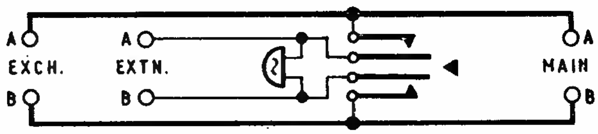
A shutter on the face of the extension switch is normally held in position by a thin rod attached to the bell hammer. When the bell rings, the shutter drops to give a visual signal to the main. This shutter is similar to that fitted on a drop indicator but the coil and alarm contacts are not provided.



(a) Main to Extension.



(b) Exchange to Extension.



(c) Main to Exchange.

SIMPLIFIED CIRCUITS (MAGNETO EXTENSION SWITCH).

FIG. 15.

In the main to extension position (Fig. 15a), the exchange is connected to the bell in the extension switch, and the extension telephone to the bell in the main telephone. The local connection, therefore, does not interfere with the exchange service. The main calls the extension by turning the hand generator in the main telephone. Similarly, the extension uses the telephone generator to call the main.

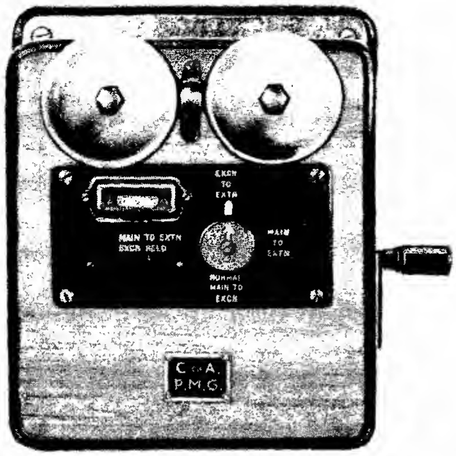
In the exchange to extension position (Fig. 15b), the bells in both the extension telephone and extension switch are across the exchange line. The main telephone is connected across the line by pressing the non-locking plunger type key. This enables the main to supervise an exchange to extension connection before switching to, say, the main to exchange position.

In the main to exchange position (Fig. 15c), the exchange is connected to the bell in the main telephone and the extension telephone to the bell in the extension switch.

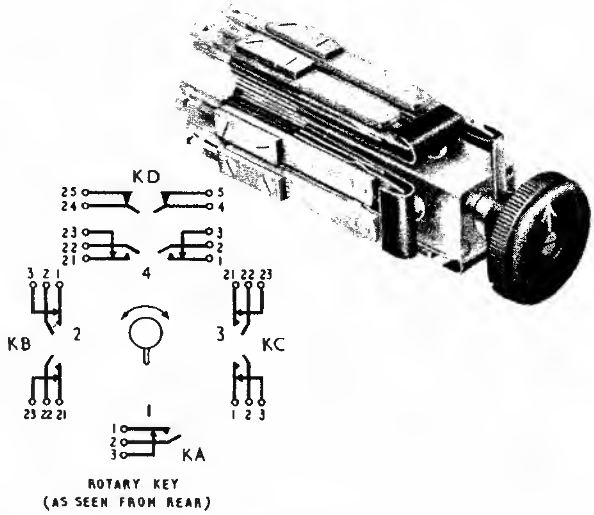
When a ring from the exchange is received on the main telephone and it is desired to extend the call to the extension, the key is first switched to the main to extension position, and the extension is rung from the main telephone. When the extension answers, the key is switched to the exchange to extension position.

The procedure is similar when the extension rings the main and wants the exchange. Alternatively, the key may be switched to the exchange to extension position after the extension has been advised to ring again.

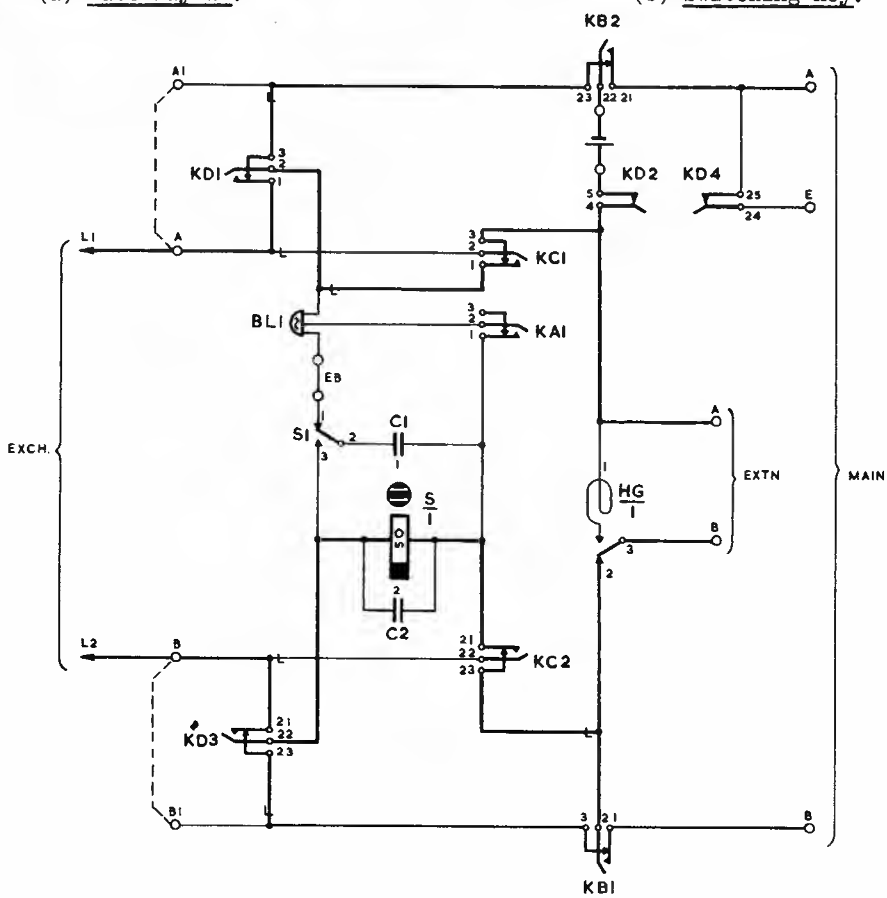
7.4 C.B. Extension Switch. (Fig. 16.)



(a) Face Layout.



(b) Switching Key.



SWITCH POSITION	1	2	3	4
SWITCH FUNCTION	MAIN TO EXCH (NORMAL)	MAIN TO EXTN. $\left(\frac{KB}{2} + \frac{KC}{2}\right)$	MAIN TO EXTN. EXCH. HELD $\left(\frac{KA}{1} + \frac{KB}{2} + \frac{KC}{2}\right)$	EXCH. TO EXTN $\left(\frac{KD}{4}\right)$

(c) Schematic Circuit.

FIG. 16. C.B. EXTENSION SWITCH.

The four-position rotary switching key provides the following connections -

Main to Exchange; all spring-sets normal.
Main to Extension; spring-sets KB and KC operated.
Main to Extension with Exchange held; spring-sets KA, KB and KC operated.
Exchange to Extension; spring-set KD operated.

Three conductors are used to connect the main telephone to the extension switch.

7.5 Circuit operation. (Refer simplified circuits in Fig. 17.) In any position, a ring from either exchange or extension is received on a magneto bell in the main telephone or the associated extension switch.

In the main to exchange position (Fig. 17a), the exchange is connected to the bell in the main telephone (via contacts KD4), and the extension telephone to the bell in the extension switch. This is the normal position of the switch.

In the main to extension position (Fig. 17b), the exchange is connected to the bell in the extension switch, and the extension telephone to the bell in the main telephone (via contacts KD4). The local connection, therefore, does not interfere with the exchange service. The main calls the extension by turning the hand generator in the extension switch. Similarly, the extension uses a hand generator to call the main. A local dry cell battery at the main supplies the transmitter current for the main and extension telephones.

In the main to extension with exchange held position (Fig. 17c), one 500 ohm winding of the bell in the extension switch is connected across the exchange line to provide a D.C. loop. This enables the main to "hold" an exchange call while an enquiry is made to the extension. The subscriber on the exchange line does not hear the main to extension conversation. If the key were switched to the main to extension position in this case, the D.C. loop would be opened giving a clearing signal to the exchange. The use of the bell as a "hold coil" enables the exchange to ring the main when the switch is incorrectly left in this position.

In the exchange to extension position (Fig. 17d), the bells in both the extension switch and the extension telephone are across the exchange line.

Relay S in series with the connection acts as a supervisory indicator at the main by showing a white disc when an exchange to extension call is in progress. The relay is operated by the line current from the exchange battery to the extension.

S1 opens the bell and 1μF capacitor from across the connection to prevent distortion of the dial pulses, and connects the 1μF capacitor in parallel with the existing 2μF capacitor across the S relay to provide a lower impedance path for speech currents.

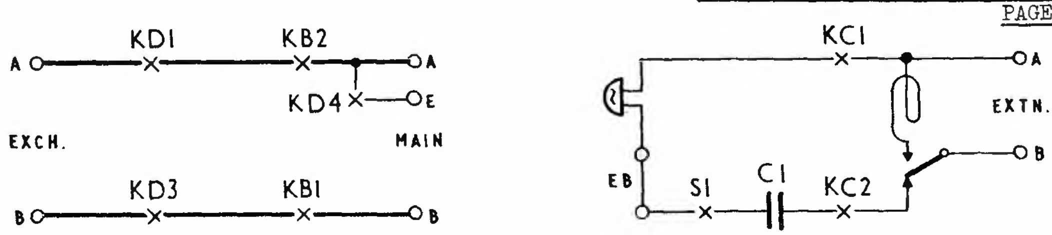
The relay is slow release to prevent intermittent operation (chattering) on dial pulses from the extension to an automatic exchange.

When the extension hangs up, relay S releases and S1 reconnects the bell so that a ring from either exchange or extension can be received at the main, with the switch in this position.

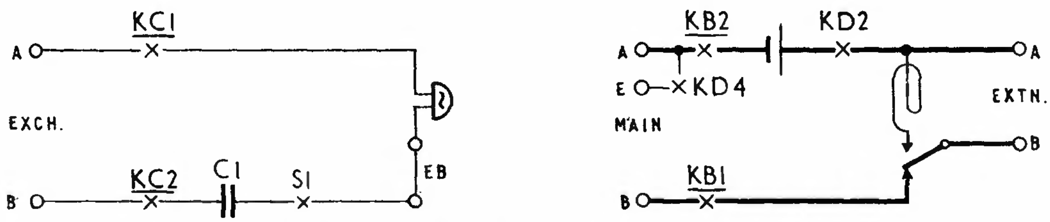
The bell and capacitor in the main telephone are disconnected from the exchange line (by operated contacts KD4) to prevent distortion of dial pulses from the extension.

A 2μF capacitor in series with the hand generator at the extension prevents a D.C. loop to the exchange when the extension rings the main with the switch in this position. The exchange battery would operate relay S via the D.C. loop, disconnecting the extension switch bell at S1.

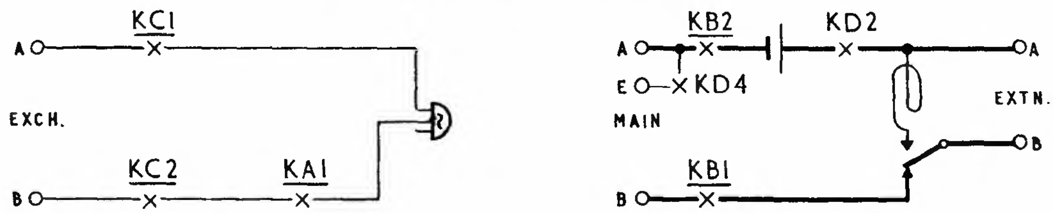
At the wish of the subscriber, secrecy is given to the extension so that the main does not hear the exchange to extension conversation. This is done by removing the wire straps between A-A1 and B-B1 terminals, which disconnects the main telephone from across the connection.



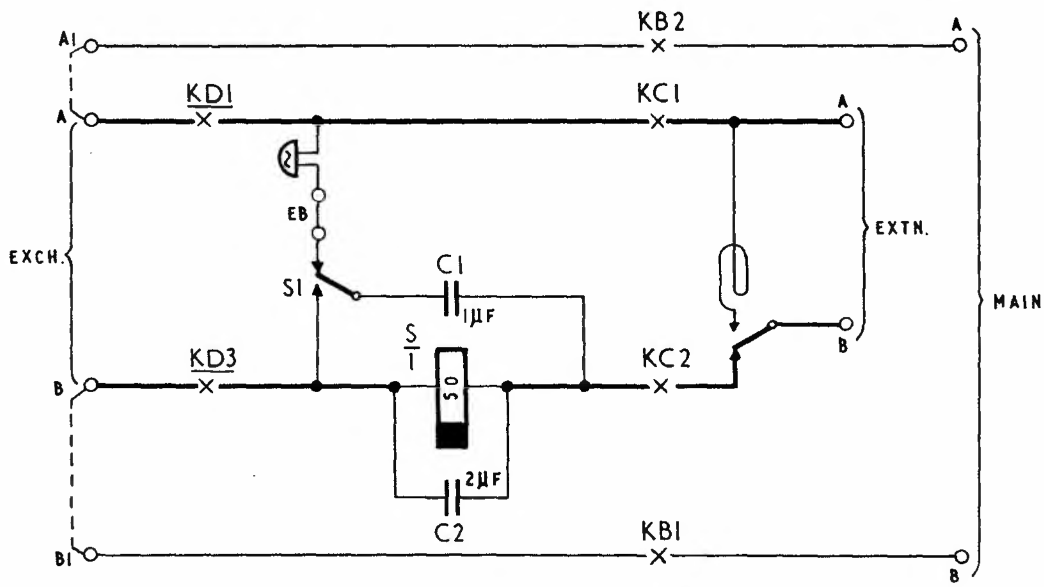
(a) Position 1. Main to Exchange.



(b) Position 2. Main to Extension.



(c) Position 3. Main to Extension with Exchange held.



(d) Position 4. Exchange to Extension.

NOTE: Switching Key units in operated condition are shown under-lined.

SIMPLIFIED CIRCUITS (C.B. EXTENSION SWITCH).

FIG. 17.

8. PRIVATE MANUAL BRANCH EXCHANGES.

8.1 Manual switchboards (Plan 23) are installed at subscribers' premises to enable simultaneous connection between a number of exchange lines and extension telephones.

These switchboards are called P.M.B.Xs. (private manual branch exchanges) to distinguish them from P.A.B.Xs. (private automatic branch exchanges).

P.M.B.Xs. for C.B. manual and automatic exchange areas are either cordless (key-switching) or cord types.

8.2 Cordless type P.M.B.Xs. (Figs. 18a and 18b) are in the following sizes

- one exchange and three extension lines (1 + 3); this is no longer being manufactured and is becoming obsolete,
- two exchange and four extension lines (2 + 4),
- three exchange and nine extension lines (3 + 9).

Early boards use drop indicators on exchange lines and eyeball indicators on extension lines. Modern boards for automatic areas, however, use eyeball indicators on all lines.

These boards are fully equipped when supplied and if the subscribers requirements exceed the capacity, the switchboard is replaced by a larger one.

8.3 Cord type P.M.B.Xs. are used for larger installations. Early models (Fig. 18c) are indicator signalling with a maximum capacity of

- 8 exchange and 30 extension lines (8 + 30), or
- 15 exchange and 80 extension lines (15 + 80).

The modern types (Fig. 18d) are lamp signalling of either 40 or 80 extension line capacity and up to 15 exchange lines.

8.4 In magneto areas, cordless and cord type switchboards similar to those used in magneto exchanges and described in the paper "Magneto Switching Principles", have been installed in subscribers' premises. Modern practice, however, is to use C.B. type P.M.B.Xs. in magneto areas, provided a suitable power supply is available to operate the switchboard.

8.5 Facilities. C.B. type P.M.B.Xs. provide facilities for the telephonist -

(i) to receive a visual calling signal on incoming exchange line calls or on calls from the extensions,

(ii) to answer the call,

(iii) to ring any extension or originate an outgoing call on any exchange line,

(iv) to connect
- any exchange line to any extension, or
- any extension to any other extension,

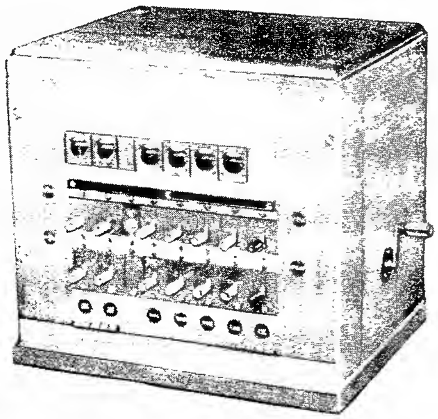
(v) to supervise (monitor) a through connection,

(vi) to receive a visual clearing signal at the end of a call,

(vii) to receive an audible alarm signal, sometimes called a night alarm (N.A.), if required, in conjunction with (i) and (vi) above,

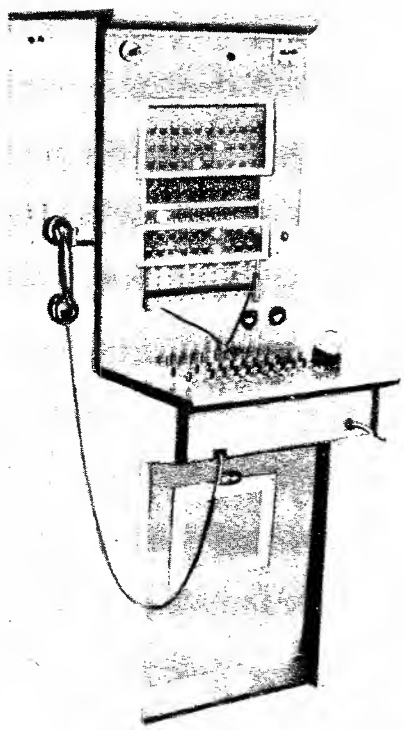
(viii) to "hold" any exchange line, while an enquiry is made to an extension, and

(ix) to connect (night-switch) exchange lines to selected extensions when the switchboard is unattended.

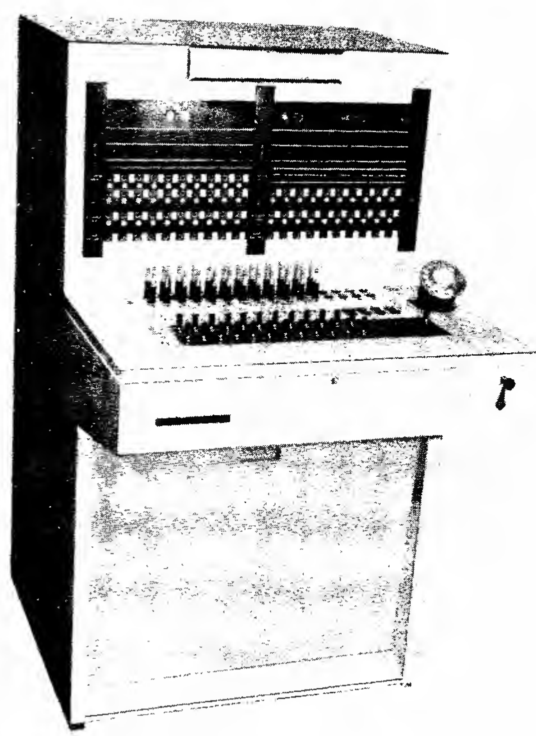


(a) Cordless type, 2 + 4.

(b) Cordless type, 3 + 9.



(c) Cord type, indicator signalling.



(d) Cord type, lamp signalling.

TYPICAL P.M.B.Xs.

FIG. 18.

8.6 Power supply. D.C. for operation of the P.M.B.X. (eyeball indicators, lamps, relays, N.A. buzzer, telephonist's transmitter) and for the transmitter currents on extension to extension calls may be provided from the exchange battery over P.B.X. power leads.

Alternatively, a mains-operated rectifier unit may be installed at the subscriber's premises.

On exchange to extension connections, the transmitter current for extensions is supplied over the exchange line, but battery must still be connected to the P.M.B.X. for other functions.

8.7 On cordless P.M.B.Xs., indicators are used for calling and clearing supervisory signals, and lever keys connect and night-switch the lines.

The telephonist uses a C.B. or automatic telephone to answer and monitor calls, and a hand generator to ring the extensions. Lever keys connect the telephone or hand generator to the desired circuit, and also provide the exchange "hold" facility.

The N.A. buzzer can be disconnected from the extension indicators but not from the exchange line indicators. A switch disconnects the D.C. power supply to prevent unnecessary operation of apparatus when the switchboard is unattended.

8.8 On cord P.M.B.Xs., either indicators or lamps are used for calling and supervision, and plug-ended cords connect the lines.

The telephonist uses a handset transmitter and receiver similar to that provided with an ordinary telephone, to answer and monitor calls. Alternatively, on larger switchboards, a headset transmitter and receiver (see Section 9) is used which leaves both hands free for switchboard operation.

The ringing current may be supplied from the exchange over ringing leads or from a mains-operated static device called a sub-cycle ringer, installed at the subscriber's premises. Hand generators are also fitted as an alternative should the power ring supply fail.

Lever keys connect the telephonist's speaking circuit and either power or hand ringing current to the desired line.

The N.A. buzzer and D.C. power supply can be switched off when the switchboard is unattended.

8.9 Additional facilities fitted to P.M.B.X. services include

- exchange line (Plan 13),
- single extension telephone (Plan 14),
- two extension telephones in parallel (Plan 15),
- two extension telephones and extension switch (Plan 16),
- two extension telephones with change-over switch (Plan 17),
- extension telephone with portable service (Plan 18),
- extension night alarm bell or buzzer at the switchboard,
- extension alarm equipment, as required, at the extension telephones.

8.10 A tie line (Plan 26) is a circuit between two switchboards which provides intercommunication between the extensions connected to each. Exchange access is not usually provided on tie lines.

8.11 Further details of P.M.B.Xs. are in Telephony 2.

9. TELEPHONIST'S HEADSETS.

9.1 Fig. 19 shows an early type of telephonist's transmitter and receiver. The carbon transmitter is fitted with a movable acoustic horn into which the telephonist speaks.

The head receiver type 10A is similar to the inset receiver type 2P but the weight is reduced by substituting a bakelite case to which a headband is attached. The D.C. resistance is about 60 ohms, and the impedance is about 225 ohms at 1,000 c/s.

TELEPHONIST'S TRANSMITTER AND RECEIVER (EARLY TYPE).

FIG. 19.

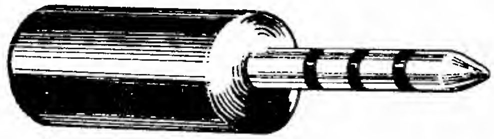
9.2 Fig. 20 shows a modern lightweight type of telephonist's headset. The weight without cord is about 5 ounces.

MODERN LIGHTWEIGHT TYPE OF TELEPHONIST'S HEADSET.

FIG. 20.

This headset uses a miniature type carbon transmitter and rocking armature receiver (both of the inset type), in a moulded plastic case. A movable acoustic horn is fitted to the case, and a headband is attached to the case cover.

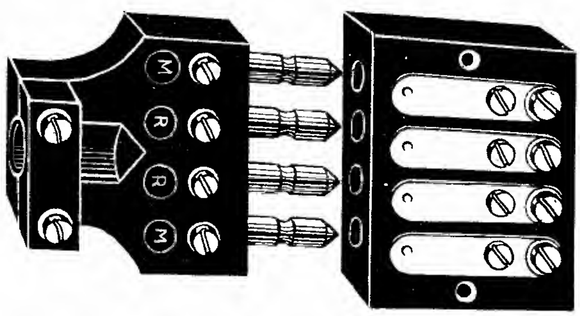
9.3 A 4-conductor cord connects the transmitter to the inner rings of a concentric type instrument plug (Fig. 21), and the receiver to the outer rings. This plug is inserted in a jack mounted on the switchboard and wired into the telephonist's speaking circuit.



CONCENTRIC PLUG.

FIG. 21.

9.4 On some early switchboards, a 4-pin plug and socket (Fig. 22) are used. The transmitter connects to the outer pins and the receiver to the inner pins.



4-PIN PLUG AND SOCKET.

FIG. 22.

9.5 A subscriber's telephone or switchboard extension telephone may also be fitted with a telephonist's headset (Plan 28) instead of the normal handset, to enable a telephone user to conduct a conversation and have both hands free to do other work.

10. PRIVATE LINES.

10.1 A private line (Plan 27) is a circuit installed by the Department between subscribers' premises, which does not have access to the public telephone network.

Private lines are leased for such uses as D.C. signalling and alarm purposes (for example, fire and burglar alarms), broadcast programme lines, telegraph lines. Single wire circuits are not provided.

10.2 These lines connect via the exchange M.D.F. (see paper "Protective Apparatus") and special care must be taken to prevent interruption when working near them. For example, when a fire or burglar alarm circuit is opened, an alarm is given at a fire or police station, or night watchman's premises.

NOTES.

11. TEST QUESTIONS.

1. What is the function of an extension magneto bell?

2. Draw a simple circuit to show how an extension magneto bell may be silenced, when not required.

3. Why are extension trembling bells sometimes used instead of magneto bells?

4. Explain the operation of an "alarm unit and switch".

5. Is secrecy provided with

    (i) A parallel telephone service? ....

    (ii) An alternative telephone service? ....

6. Why are telephones never connected in series?

7. In a parallel telephone service -

    (i) Why are three wires used between the telephones?

    (ii) Why are the capacitors disconnected in the extension telephones?

8. What is the function of the bell set in a portable telephone service?

9. Why are three conductors wired between the sockets of a portable telephone service?

10. Draw a simple circuit to show how either of two telephones can be connected to an exchange line.

11. What is the function of a control lock?

12. Show, by simple circuits, the connections of the control lock springs in a typical magneto, C.B. and automatic telephone.

13. What are the functions of an extension switch?

14. Draw the simplified circuit of a magneto extension switch for each position of the lever key, and describe the circuit operation.

15. In a C.B. extension switch -

    (i) how does the extension call the main,

    (ii) how does the main call the extension,

    (iii) how is transmitter current supplied for a main-extension conversation,

    (iv) what is the reason for the "hold" facility,

    (v) how is this facility obtained,

    (vi) what is the reason for relay S,

    (vii) why is this relay slow release,

    (viii) why are the capacitors connected in parallel with this relay,

    (ix) how is secrecy given to the extension?

16. The abbreviation P.M.B.X. stands for ....

17. What are the facilities given to the telephonist by a P.M.B.X?

18. What is the function of a P.B.X. power lead?

19. Why is it necessary to disconnect the D.C. supply from a P.M.B.X. when it is unattended?

20. What is a ringing lead?

21. What is a tie line?

22. What is a private line?

23. The telephonist's transmitter connects to the .... rings of a concentric type instrument plug; and to the .... pins of a 4-pin plug.

END OF PAPER.

THE AUSTRALIAN POST OFFICE

COURSE OF TECHNICAL INSTRUCTION

PROTECTIVE APPARATUS.

---

1. INTRODUCTION.

1.1 Telecom apparatus connected to telephone lines must be protected against damage from electrical hazards, such as -

(i) Lightning discharges, which may be as high as 2½ million volts.
(ii) Contact with or induction from electric supply circuits carrying from 200 to 132,000 volts.

Aerial lines, in particular, are exposed to these hazards. The use of underground cables reduces the dangers.

1.2 These "foreign" voltages are much higher than those for which a telephone or telegraph system is designed, and they may puncture the insulation or cause excessive currents in telecom circuits. The high voltages may also endanger lives and property.

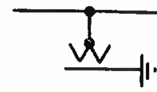
The heating effect of the foreign currents may melt conductors or char insulating materials. Combustible materials may catch fire.

1.3 The more common protective devices are arresters, fuses and heat coils. They are not affected by normal speech and signalling voltages and currents, but operate when the foreign voltage or current on the line is excessive. The line is then disconnected automatically from the equipment or a connection to earth is provided clear of the equipment. When one or more protective devices are mounted as a unit, that unit is called a protector. Protective apparatus is fitted at subscribers premises (unless the line is entirely underground), at the exchange main distribution frame (M.D.F.), and in "protected" cable terminal boxes.

1.4 This paper describes the apparatus used in protectors, and gives some details of the exchange M.D.F.

2. ARRESTERS.

2.1 Function. Arresters provide a path to earth for high voltages usually arising from induced lightning discharges, and less frequently from contact with or induction from electric supply lines.



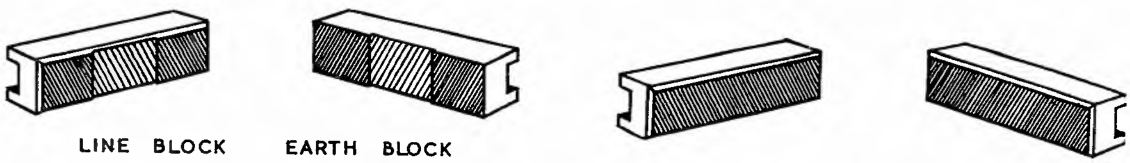
SYMBOL

An arrester consists of two conducting electrodes - one connected to line and the other to earth - separated by a thin layer of insulation. They are fitted in subscribers (substation) and exchange protectors, and in protected cable terminal boxes. Separate arresters are provided for each side of the line. The arrester normally provides a high insulation resistance from each wire to earth, but when the voltage on the wire exceeds a particular value, the insulation between the electrodes breaks down to provide a low resistance path to earth. When the high voltage is removed, the insulation resistance should restore to its normal high value.

2.2 Early types. Many different types of arresters have been used. A comparatively early obsolete type has two carbon blocks separated by a mica strip about 4 mils thick.

In other early types (Figs. 1a and 1b), mica separators are not used and the operating surface of each carbon is coated with an insulating varnish to provide a small gap of about 3-4 mils between the carbon blocks. With carbons No. 14, only one type of carbon block is used instead of the two types in earlier arresters.

The breakdown voltage of these arresters is between 500 and 750 volts.



(a) Carbons 591A and 591B Insulated. (b) Carbons No. 14.

FIG. 1. SOME EARLY TYPES OF ARRESTERS.

The main disadvantages of these early types, are -

(i) It is difficult to obtain micas and insulating coatings of uniform thickness, and hence breakdown voltages vary over a wide range.

(ii) Atmospheric dust tends to accumulate on the exposed edges of the carbon blocks, bridging over the insulation and lowering the insulation resistance. To reduce this trouble, the edges of the operating faces of some carbon blocks are bevelled and coated with insulating varnish.

(iii) During operation, the thin varnish film is punctured and fine carbon dust often bridges between the carbon blocks, permanently earthing the line.

2.3 A typical arrester (Fig. 2) commonly used in substation and exchange protectors, is the Arrester Electrode No. 1 with a plain carbon block (Carbon No. 1).

(a) Electrode (Line Block). (b) Carbon (Earth Block).

FIG. 2. ARRESTER ELECTRODE AND CARBON BLOCK.

They are fitted in protectors so that the electrodes connect to line, and the carbon blocks to earth.

The electrode consists of a moulded plastic block, into which is inserted a phosphor-bronze discharge blade. With the operating faces placed together, the air gap between the metal blade and the carbon block is about 4 mils, and the breakdown voltage is between 750 and 1,000 volts.

The design of this arrester reduces the collection of atmospheric and carbon dust between the operating faces and, as the gap is finely toleranced, the breakdown voltage is not so variable as with earlier types.

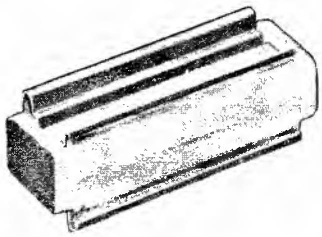
2.4 Improved types of arresters have recently been developed and are being used in protected cable boxes. Some new types are -

The metal electrode arrester (Fig. 3). This consists of two brass electrodes separated by a slotted insulating strip, the whole being sealed in a plastic moulding of high insulation resistance and low inflammability. The flanges of the electrodes project from the moulding. The complete sealing of the gap together with the one-piece construction, minimises low insulation resistance troubles and ensures a more consistent breakdown voltage. Two voltage breakdown ranges are manufactured -

Type 1B, 5 mil gap, 630-920 volts.
Type 1C, 8 mil gap, 1050-1350 volts.

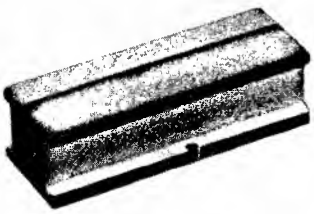
It is expected that this type of arrester will gradually replace the carbon block arresters in substation and exchange protectors.

The "Atmite" (silicon carbide) arrester (Fig. 4). This consists of a block of the semi-conductor, silicon carbide. The exterior is metal sprayed, except for the ends and the air gaps along two sides of the block. The resistance between opposite surfaces of the block depends on the applied voltage. With low voltages, the resistance is normally very high, but when the voltage exceeds about 500-900 volts, flashover occurs across the air gaps as in the other type arresters.



METAL ELECTRODE MOULDED ARRESTER.

FIG. 3.



SILICON CARBIDE ARRESTER.

FIG. 4.

Gas arresters. (Fig. 5.) These consist of metal electrodes sealed in a glass envelope containing some inert gas, for example, neon. The gas normally provides a high insulation resistance between electrodes, but breaks down and conducts when the line voltage exceeds about 250-350 volts.

FIG. 5. TYPICAL GAS ARRESTERS.

3. FUSES.

3.1 Function. Fuses protect telecom apparatus and wiring against damage due to excessive currents. A fuse consists of a thin wire with a low melting point, connected in series with the circuit to be protected. When excessive current flows, the heating effect melts the wire and opens the circuit.

The "rating current" of a fuse is the maximum current which it can carry continuously without fusing.

3.2 Tubular fuses protect against excessive current due to lightning discharges or accidental contact between telephone lines and electric supply lines. They are fitted between mounting clips in substation and exchange protectors. Separate fuses are provided for each side of the line.

The modern type (Fig. 6) consists of a thin phosphor bronze wire inside a ceramic (porcelain) or glass tube with metal ends to which the fuse wire is soldered. The fuse wire is enclosed to ensure more uniform operating characteristics, and to prevent the molten wire being scattered about when the fuse operates.

TUBULAR FUSE.

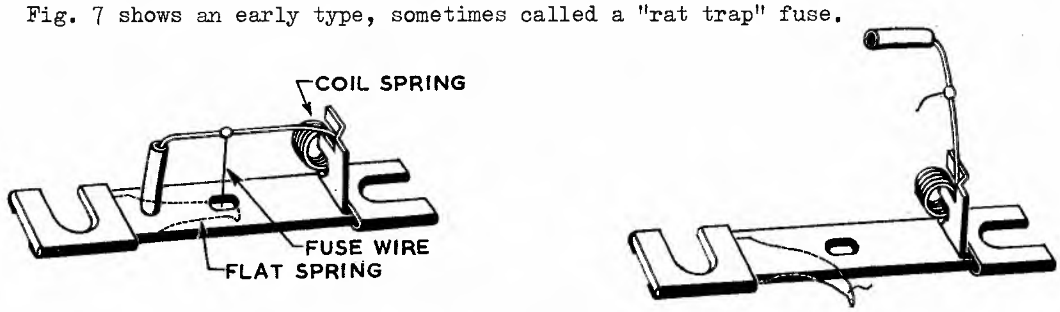
FIG. 6.

The rating current of the fuse is 1.5A. It is designed to operate in 30 seconds with twice the rated current, but not to operate for at least 10 seconds with $1\frac{1}{2}$ times the rated current. Currents greater than 3A cause the fuse to operate in a shorter time. Although the rating current is much higher than the working currents in most telephone and telegraph circuits, a lower rating would be unsatisfactory, because the finer fuse wire would then blow and interrupt services unnecessarily on lines subject to mild lightning discharges.

An early obsolete type used in substation protectors, had a hexagonal tube with knife edges on the end caps.

3.3 Alarm fuses protect against excessive current due to fault conditions, for example, a short circuit. They are used in power and ringing distribution circuits in telephone exchanges, and are normally clamped between screws on a fuse panel fitted with an alarm busbar arranged to give an alarm immediately a fuse operates.

Fig. 7 shows an early type, sometimes called a "rat trap" fuse.



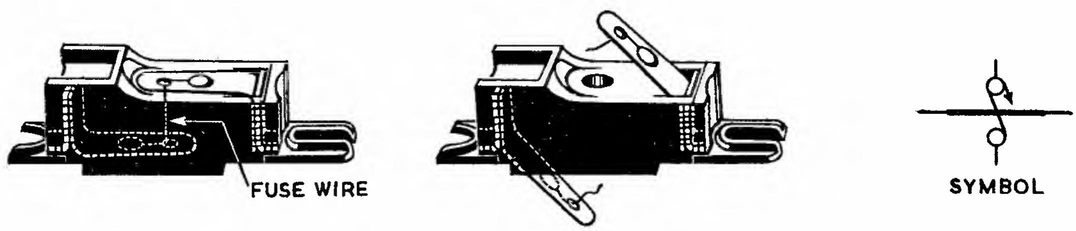
(a) Unoperated. (b) Operated.

EARLY TYPE OF ALARM FUSE.

FIG. 7.

The fuse consists of an oblong strip of insulating material with metal mounting lugs. One lug carries a coil spring fitted with a coloured sleeve or bead; the other lug connects to a flat spring underneath the fuse. The fuse wire passes through a hole in the mounting, and is soldered to and held under tension between the springs. When the fuse wire melts, the back spring connects with the alarm bar, and completes the circuit for operation of a bell and lamp. The front spring is raised to indicate which fuse is open.

A modern type (Fig. 8) has a moulded plastic body fitted with brass mounting lugs. The fuse wire passes through a hole in the body, and is soldered to and held under tension between the ends of two flat springs mounted on either side of the body. Each spring makes electrical contact with a mounting lug. The operation of this fuse is similar to the early type.



(a) Unoperated. (b) Operated.

MODERN TYPE OF ALARM FUSE.

FIG. 8.

3.4 The rating current is indicated by the colour of the sleeve on the end of the coil spring (Fig. 7) or fuse body (Fig. 8), for example -

Blue	=	0.5A
Red	=	1.5A
Black	=	3.0A

Alarm fuses are designed to blow within 30 seconds when carrying twice the rated current, but not to blow within 10 seconds with $1\frac{1}{2}$ times the rated current.

3.5 Fuses for use in higher current power distribution circuits are generally of the cartridge type or the semi-enclosed rewireable type. These are described in other papers of the Course.

4. HEAT COILS.

4.1 Function. Currents greater than about 0.5A, if allowed to flow through telephone equipment for a long enough time, damage the equipment by the heat produced. It is impracticable, however, to use a tubular fuse which operates much below 1.5A, because of the fine wire which has to be used. (The diameter of the wire in 1.5A fuses is about 0.003".)

Heat coils protect apparatus from damage by currents usually too small to blow fuses, but which would overheat apparatus (and possibly cause fire) if allowed to flow for a long time. The heat coil is essentially a delayed action fuse which, when operated, earths the line wire.

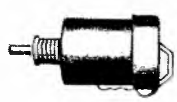
Each side of a subscribers' telephone line has an earthing type heat coil connected in series at the exchange protector.

4.2 The earthing type heat coil (Fig. 9) is the modern type. A coil of fine insulated resistance wire (D.C. resistance, 3.5 to 4.1 ohms) is wound on a small copper tube which is soldered to a centre pin by a low melting point solder. The pin is screwed into a fibre cover. One end of the coil connects to the copper tube; the other end passes through a slit in the cover and is soldered to the brass cap. The heat coil is held in the protector mounting by spring clips (see paragraph 6.6).

The brass cap has a projection which fits into the mounting clip on the protector strip. This prevents the heat coil turning in the clip and provides a more reliable contact.

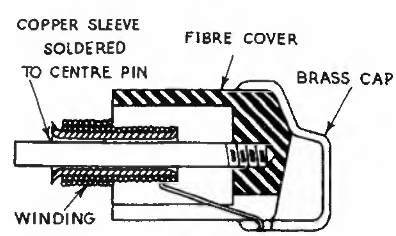
When excessive current flows in the coil, the heating effect melts the solder and a spring clip on the protector mounting forces the copper tube along the pin which then contacts a supplementary spring connected to earth, and the line is earthed without being disconnected. The fault current then no longer passes through the coil and exchange apparatus.

The coil is designed to carry a current of 350 mA for 3 hours without operating, but to operate within $3\frac{1}{2}$ minutes when 500 mA flo .

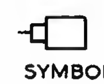


(a) Unoperated.

(b) Operated.



(c) Cross-section.

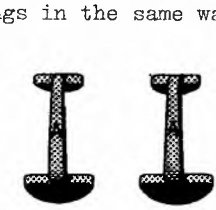


EARTHING TYPE HEAT COIL (TYPE "BB").

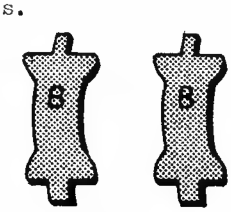
FIG. 9.

4.3 An earlier obsolete break type of heat coil was similarly operated, but the tension of the mounting clip pulled the pin from the core and opened the circuit.

4.4 Dummy Heat Coils. (Fig. 10.). These are brass stampings to replace the two patterns of heat coil. They are shaped to fit between the spring clips in the protector mountings in the same way as the actual heat coils.



(a) Type A.



(b) Type B.

DUMMY HEAT COILS.

FIG. 10.

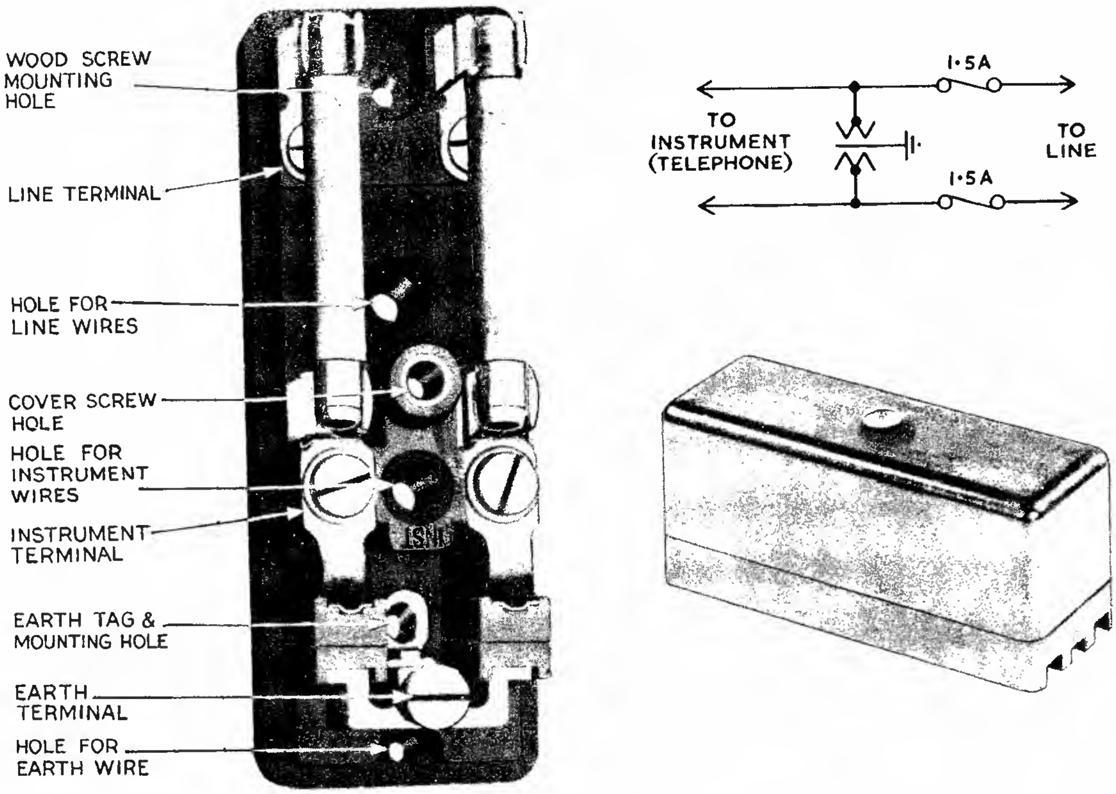
Dummy heat coils type A replace the break type heat coils in early substation protectors.

Dummy heat coils type B are used on circuits, such as power leads and ringing leads, which carry currents close to the operating limit of the earthing type heat coils.

5. SUBSTATION PROTECTORS.

5.1 These prevent damage to substation apparatus by excessive voltages and currents, and reduce fire risk. They are fitted at subscribers' premises on all lines with aerial construction. When the line is wholly underground, substation protectors are not provided, and a terminal block is used to connect the inside and outside wiring.

5.2 The modern substation protector (Fig. 11) has a moulded base with spring clips for mounting two arresters and two 1.5A tubular fuses. A plastic cover is fitted to exclude dust.



SUBSTATION PROTECTOR.

FIG. 11.

The protectors may be fitted individually or, in locations where several are required, on a Protector Mounting. These mountings are iron frames with jumper rings and mount 5 and 10 protectors respectively.

An efficient earth is provided as close as possible to the protector. Normally the earth wire connects to the earth terminal, and the earth tag hole is used for one of the two round-headed mounting wood screws. When the protector is fitted on a mounting, the earth terminal is not used and the earth connection is made by the metal screw which fixes it to the mounting frame.

5.3 Early type. The modern protector is smaller than an earlier obsolete type in which the 1.5A tubular fuses and carbon arresters are mounted on a porcelain base. Break type heat coils were originally fitted but, as the provision of heat coils at both the subscriber's premises and the exchange is not necessary, these were subsequently short-circuited at the substation protector or replaced by dummy heat coils type A.

6. MAIN DISTRIBUTION FRAME.

6.1 Functions. The exchange M.D.F. (Figs. 12, 13 and 14) is an earthed iron structure on which is mounted equipment to provide facilities for the connection, testing and protection of line plant and exchange apparatus.

The M.D.F. provides -

(i) A point for the termination of the external and internal cables.

(ii) A means of cross-connecting the external cable pairs which have a random geographical distribution, to the numerical sequence of the wiring within the exchange.

(iii) A point of access for the testing of lines and exchange equipment.

(iv) A location for the mounting of protective apparatus.

6.2 Termination of Cables. Subscribers' lines usually enter an exchange in a number of large capacity underground cables, each of which serves a different part of the exchange area. The numbers allotted to these lines have no relationship to the geographical location, and hence the exchange numbers in any one cable are entirely haphazard.. The cables may also include junction lines, power and ringing leads, fire and burglar alarms, broadcasting and telegraph lines, private lines and spares for development.

The underground cables terminate on fuse mounting (or link mounting) tags on the "line" side of the M.D.F. in order of the cable pairs. This order is maintained to facilitate terminating, identification and testing.

The exchange cables terminate on protector mounting tags on the "exchange" (or "equipment") side of the M.D.F. in order of subscribers' numbers.

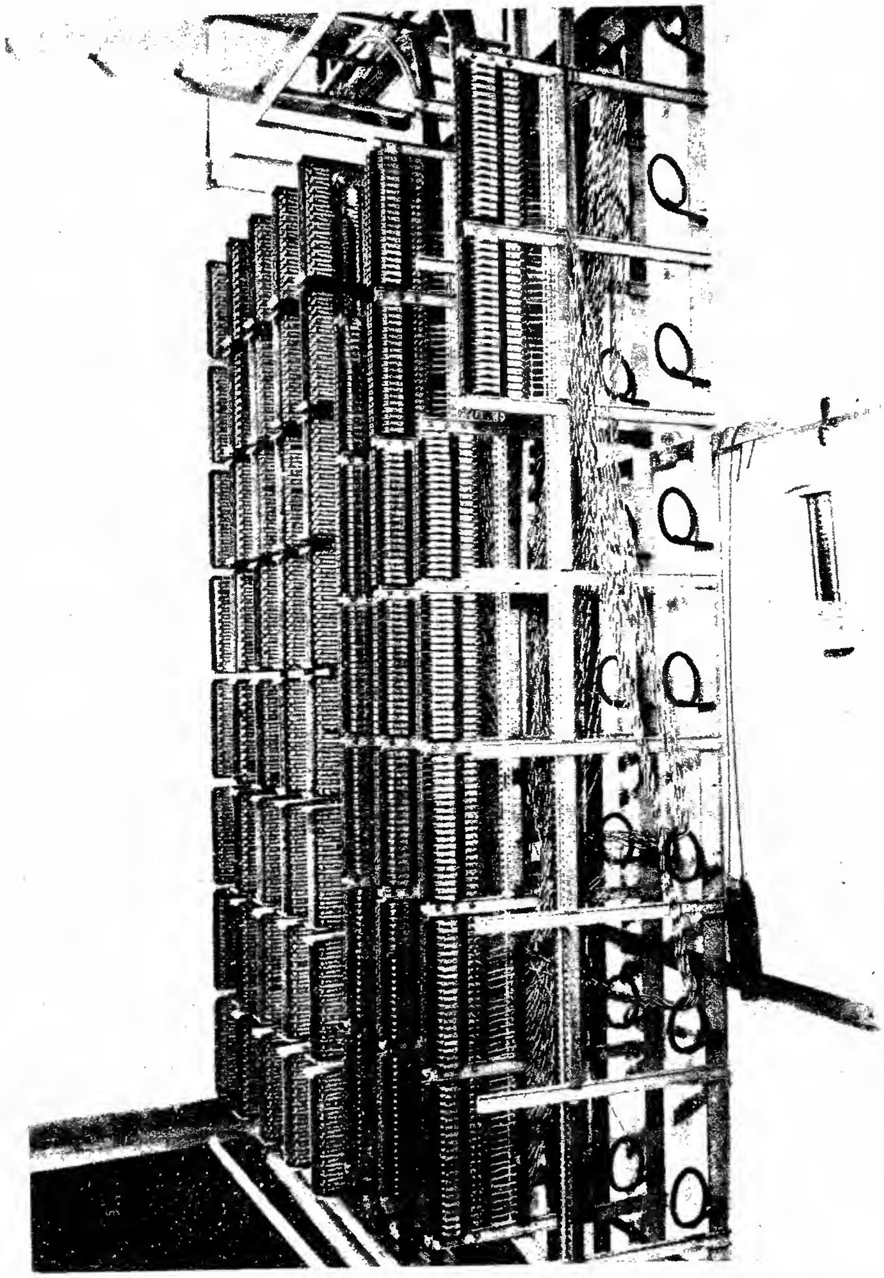
As some cable pairs are for development and others do not require connection to the exchange equipment, the M.D.F. has a greater capacity for underground cable pairs than for exchange cabling.

6.3 Cross-connecting or "Jumpering". The lines terminating on the M.D.F., are generally cross-connected (jumpered) by twisted and insulated jumper wires (sometimes called jumpers) to tags on the protector mounting.

This type of connection provides a convenient and flexible means of "sorting" the subscribers' lines into their numerical order. Also, it means that, when a subscriber changes his address within the same exchange area, the same telephone number can be retained by a transfer of the jumper termination on the fuse or link mounting. Similarly, disconnection of cancelled services and connection of new services can be easily made.

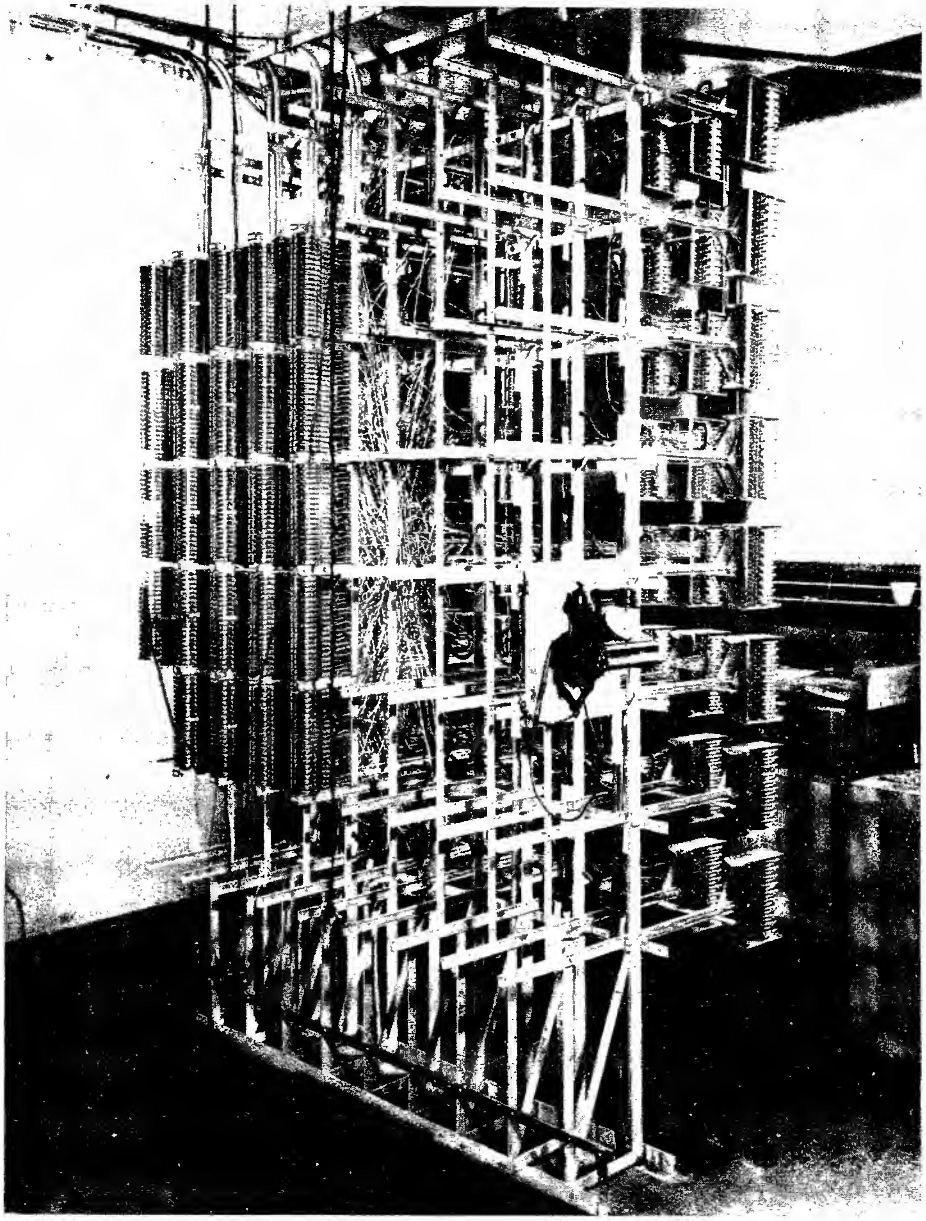
Some types of circuits, for example, junction cable pairs, which are brought in and out of the exchange without serving the exchange itself, do not have to be connected to exchange equipment. These are jumpered on the line side of the M.D.F.

The jumpers are run horizontally through smaller jumper rings on the line side and vertically through larger rings on the exchange side. These rings keep the jumpers tidy and prevent them chafing on the ironwork of the frame. On fuse, link and protector mountings, the permanent cabling terminates on the left-hand side (viewed from the front of the mounting) and the jumpers on the right-hand side. The white jumper wire connects to the "A" tags, and the coloured wire to the "B" tags.



WALL TYPE M.D.F.

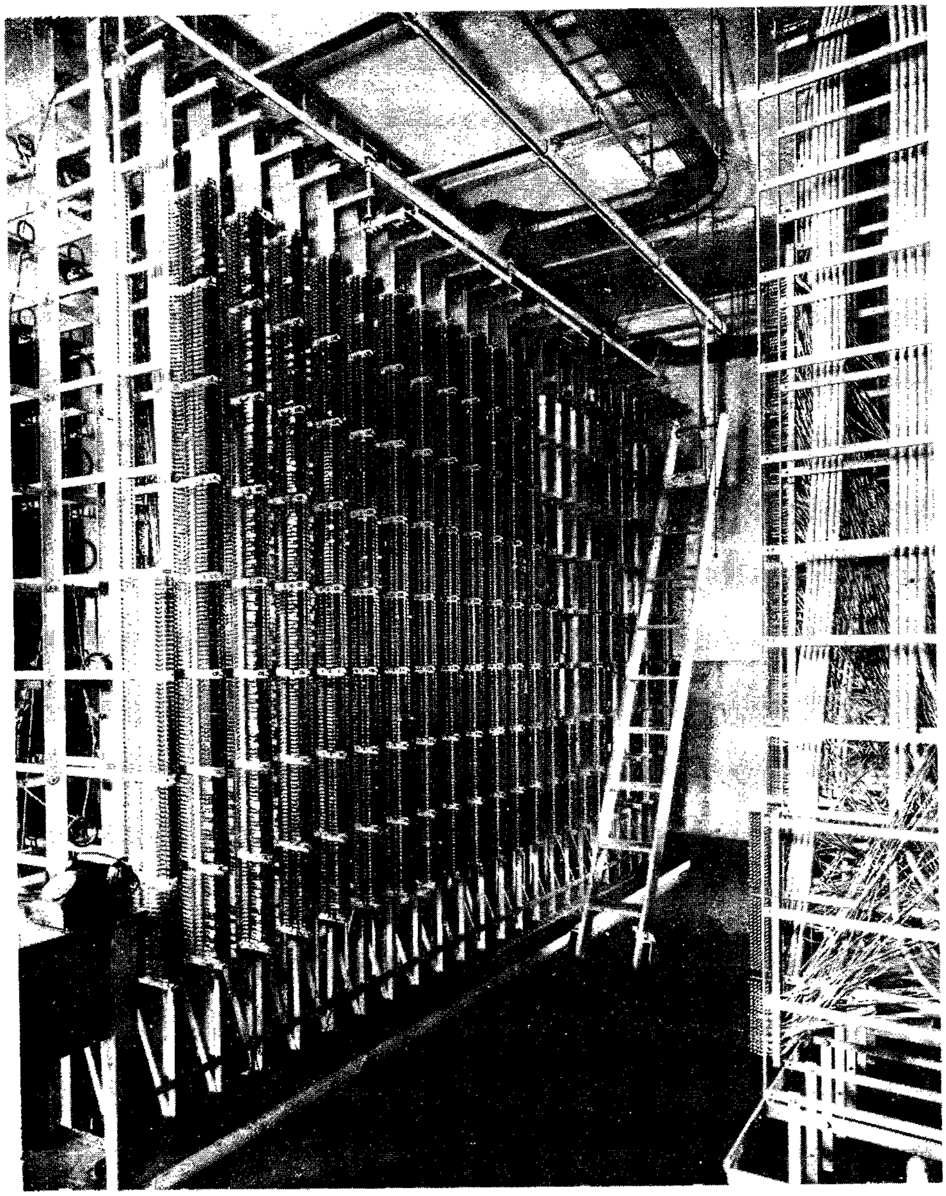
FIG. 12.



Note arresters, fuses, jumpers, underground cables, earth bar and cables to exchange apparatus and testing shoe.

FLOOR TYPE M.D.F. FOR A SMALL EXCHANGE (ABOUT 400 LINES).

FIG. 13.



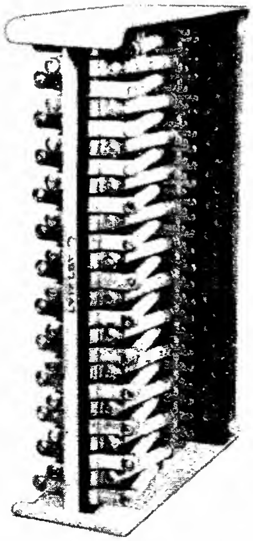
NOTE: In large exchanges which have a very tall frame, it is usual to have a platform around the M.D.F. for access beyond the reach of the normal travelling ladder.

M.D.F. IN A LARGE EXCHANGE.

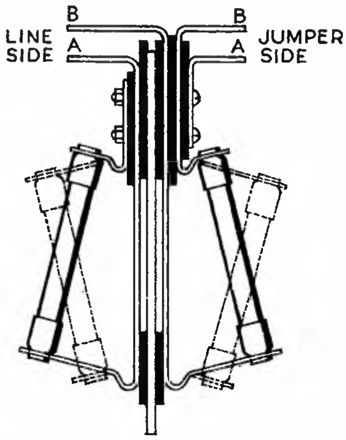
FIG. 14.

6.4 Fuse Mounting (Fig. 15). This is a mild steel frame with clips to mount 25 pairs of 1.5A fuses. The clips are insulated from the frame and each other, and are tilted in opposite directions for easy removal and replacement of fuses. An earlier type of fuse mounting has 20 pairs of fuses, but this type is not now installed because the larger size allows more pairs to be terminated in the same space.

By removing the fuses and inserting test plugs between the mounting clips, tests may be made either into the exchange or directly to line.



(a) Side View.



(b) Cross-Section (Viewed from Top).

FIG. 15. 25 PAIR FUSE MOUNTING.

The cable and pair identification number are generally printed on the fuse mountings, numbering from the bottom upwards. The outside ends of the fuse clips are coloured to denote special circuits, as follows -

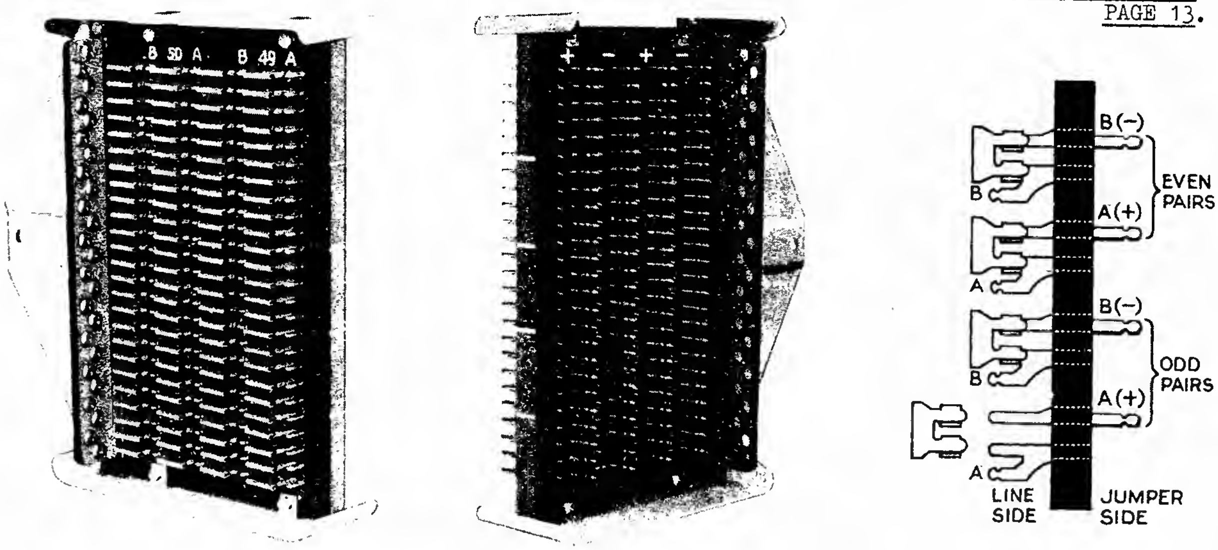
- Red. To show that special care must be taken when working near these circuits to avoid interruptions, crosses, earths, etc; used for fire and burglar alarms, police and ambulance lines, broadcasting and telegraph lines, private lines and other important circuits.
- Blue. To show that special precautions are necessary before testing; used for power leads and ringing leads.
- Yellow. To show that under fault conditions, the lines must be busied and not connected to N.U. tone; used for P.B.X. exchange lines in automatic exchanges only.

6.5 Link Mounting (Fig. 16). Fuses are not needed on lines which are wholly underground. On some recent M.D.F. installations, therefore, the fuse mounting is omitted on these lines and replaced by a link mounting. This consists of tags for terminating the underground cable pairs and separate tags for the jumper wires. Metal links are used instead of fuses to connect between the cable and jumper tags. This mounting occupies the same space as a 25 pair fuse mounting, but provides terminations for 50 pairs.

By removing the connecting links and inserting test clips between the tags, tests may be made either into the exchange or directly to line. Special circuits are indicated by a sleeve of coloured insulation slipped over one of the tags.

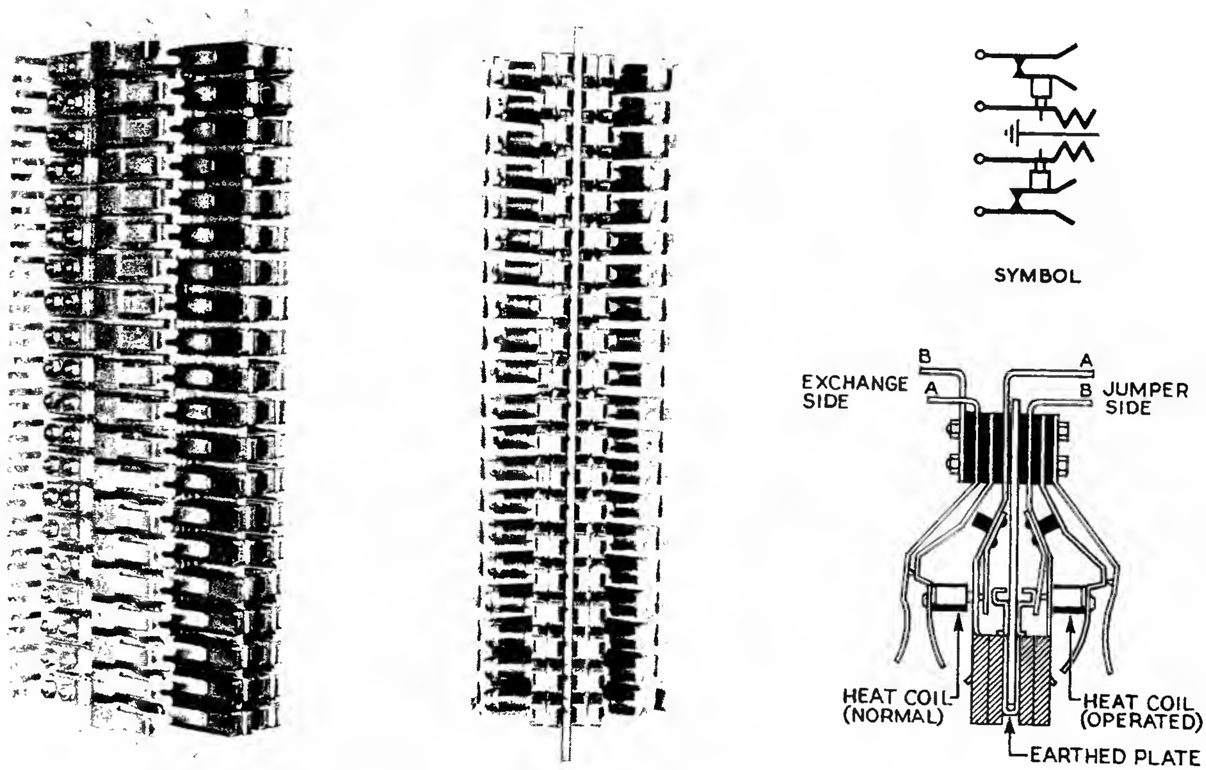
6.6 Protector Mounting (Fig. 17). This is a metal plate with clips to mount 20 pairs of arresters and earthing type heat coils. The metal plate is connected to earth via the iron structure of the M.D.F.

The outside spring of each group makes contact with the adjacent spring. By inserting a divided test "shoe" between these springs, tests may be made either into the exchange or out to line, without removing heat coils or jumpers. The protector mountings are numbered from the bottom upwards to conform to the exchange numbering system.



(a) Line Side. (b) Jumper Side. (c) Cross-Section (Viewed from top).

FIG. 16. 50 PAIR LINK MOUNTING.



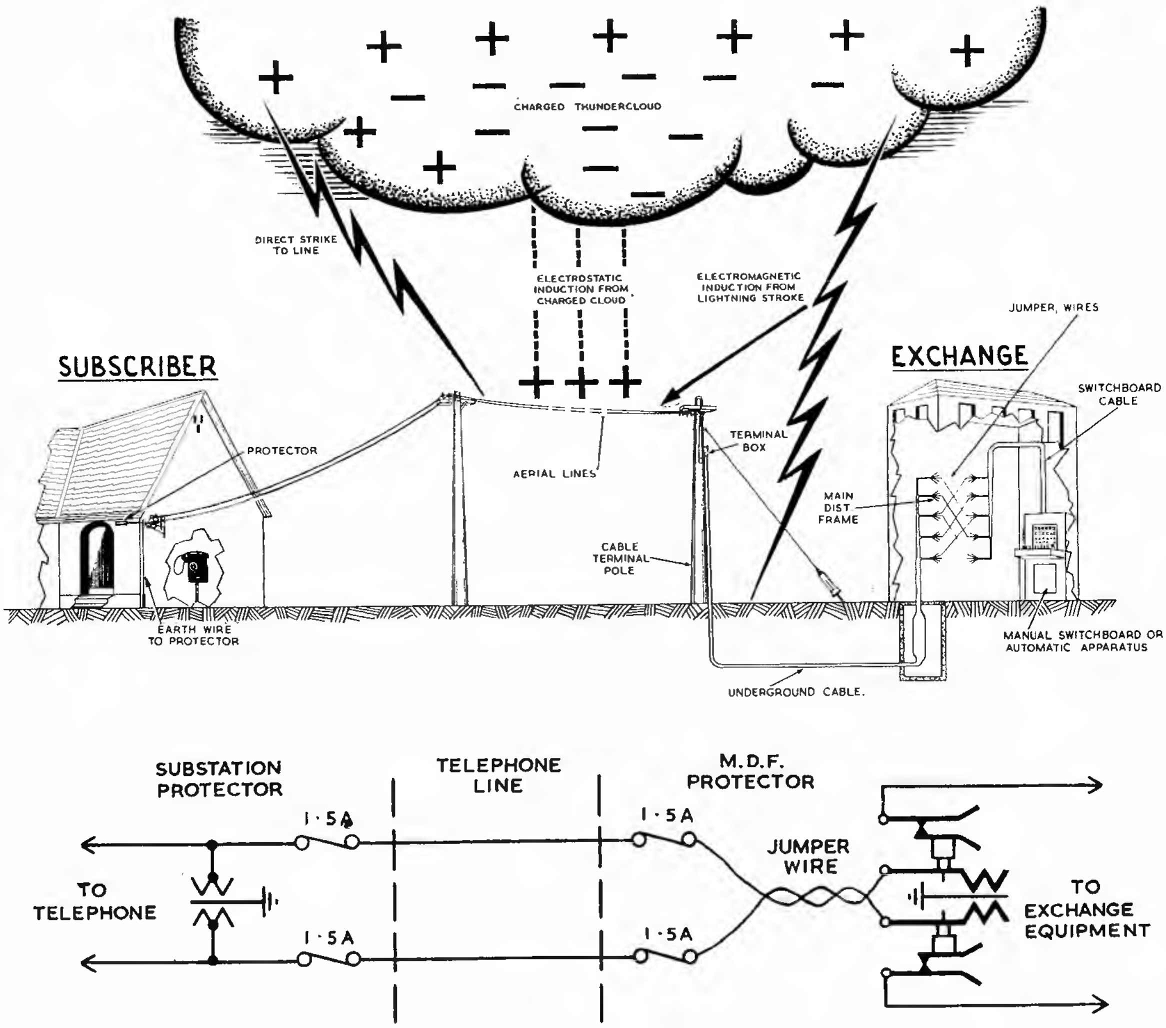
(a) Side View. (b) Front View. (c) Cross-Section (Viewed from top).

FIG. 17. PROTECTOR MOUNTING (ARRESTER AND HEAT COIL).

7. SUMMARY OF PROTECTION PROVIDED.

7.1 On a typical subscriber's line containing underground cable and aerial wires, protection is provided at both the subscriber's premises and the exchange. The various items of protective apparatus are mounted in pairs to protect each wire of the circuit. Fig. 18 shows the sequence of connections. Note that the fuses are connected on the line side of the arresters.

When the subscriber's line is wholly underground, protection is provided only at the exchange.



PROTECTION ON A TYPICAL TELEPHONE LINE (AERIAL AND CABLE).

FIG. 18.

7.2 A cable terminal box is mounted on the cable terminal pole to connect the underground (U.G.) cable pairs to the aerial lines. In areas subject to severe electrical storms and power hazards, protected cable boxes are used. In early types of protected boxes, arresters and fuses were provided but, in modern types, arresters only are fitted.

7.3 Summary of operation. High voltage surges induced in telephone lines by lightning discharges, normally pass along the line and through the fuses, causing an arc across the gap between the arrester blocks. The discharge is then conducted to earth and dissipated.

In the rare case of a very heavy surge or direct lightning strike, the energy to be dissipated is so great that the arrester may be destroyed, the line wires fused and insulators shattered. It is not practicable to provide complete protection from direct lightning strikes.

When the telephone line touches a high or medium tension power circuit with a voltage greater than the breakdown voltage of the arrester, a foreign current in passing along the line, arcs across the gap between the arrester blocks. Also the fuse may operate, which isolates the telephone line.

When the telephone line touches a power circuit with a voltage less than the breakdown voltage of the arrester, the arrester does not operate. The foreign current passes through the heat coil at the exchange, to the exchange equipment, where it ultimately finds a path to earth. When the current value is high enough to damage the equipment, the heat coil operates and earths the line. The increased current may also blow the fuse which isolates the faulty line.

7.4 Complete details of the protection provided for different types of circuits, are in E.I. TELEPHONE Protection E 0101. The protection for subscribers' services is shown in Table 1.

TYPE OF CIRCUIT	PROTECTION AT EXCHANGE	PROTECTION AT SUBSTATION
Direct exchange lines. Private lines. P.B.X. extensions.	Fuses, arresters and earthing type heat coils. (The fuses may be omitted when line is wholly U.G. cable).	Fuses and arresters (when aerial wire exists in circuit). Nil (when wholly U.G. cable).
Power leads. Ringing leads. Burglar alarms. Fire alarms.	Fuses, arresters and dummy heat coils.	

TABLE 1.

8. TEST QUESTIONS.

1. What is the function of an arrester?
2. Describe the construction and operation of the arrester commonly used in protectors. What are the advantages of this type compared with earlier types?
3. Where are arresters generally installed?
4. Briefly describe the operation of a gas arrester.
5. What is the function of a fuse?
6. Describe the construction of a tubular fuse.
7. Tubular fuses have a current rating of .... The fusing current is ....
8. Where are tubular fuses generally installed?
9. Describe the construction and operation of a modern alarm fuse.
10. The colour red on an alarm fuse indicates that the current rating is ....
11. What is the function of a heat coil?
12. Describe the construction and operation of a modern earthing type heat coil.
13. The coil is designed to carry .... for 3 hours without operating, but to operate within 210 seconds when .... flows.
14. What is the difference in basic operation between an earthing type and a break type heat coil?
15. Where are earthing type heat coils generally installed?
16. What are dummy heat coils? On what types of circuits are they used?
17. What is the function of a substation protector?
18. Briefly describe the construction of a modern substation protector.
19. What are the functions of an M.D.F.?
20. Why has the M.D.F. a greater capacity for underground cable pairs than for exchange cabling?
21. What is a fuse mounting?
22. Why are small coloured bands painted on fuse mounting clips?
23. What is a link mounting?
24. What is a protector mounting?
25. On what side of these mountings (viewed from the front), is the jumper connected?
26. Draw a simple schematic circuit diagram to show the protection provided on a typical telephone line containing both U.G. cable and aerial wires.
27. What protection is provided (i) in the exchange, and (ii) at the subscriber's premises, for each of the following cases -

    (a) subscribers line (wholly in U.G. cable)

    (b) subscribers line (aerial)

    (c) power leads.

    (d) ringing leads.

END OF PAPER.

MAGNETO SWITCHING PRINCIPLES.

1. INTRODUCTION.

1.1 A telephone system enables connections to be made between telephones which are connected by aerial or cable lines to a telephone exchange. The exchange provides a switching centre for interconnecting the lines.

The telephone systems used in Australia are :-

(i) Magneto (or Local Battery).
(ii) Central Battery (C.B.) Manual.
(iii) Automatic.

1.2 Magneto non-multiple exchanges are used in some small country districts where comparatively few subscribers are connected. They vary in size from small offices with one trunk line and one subscriber to those having a number of trunk and junction lines and several hundred subscribers. To reduce maintenance costs as the number of subscribers increases, these exchanges are being converted to C.B. manual or automatic working.

Magneto multiple exchanges with several thousand subscribers have been installed, but very few are now in use. In recent years all new multiple exchanges have been C.B., as a C.B. area is more readily converted to automatic.

1.3 This paper describes the basic principles of magneto switching. The principles of C.B. manual and automatic switching are described in other papers.

MAGNETO FLOOR PATTERN SWITCHBOARD.

Note the drop indicators, jacks, plugs and cords, lever keys, dial, telephonist's headset and handset, and the tally card on the keyboard for recording calls.

2. MAGNETO SWITCHBOARDS.

2.1 In manual telephone systems -

The calling subscriber (or calling party) is the person originating a call.

The called subscriber (or called party) is the person for whom a call is intended.

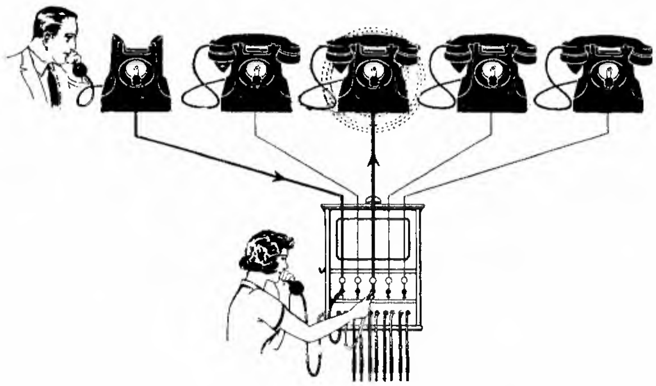
Switchboards are provided at the exchange to interconnect the lines.

The telephonists (or operators) make the switchboard connections between the lines.

The operator's position (or simply position) is the part of a switchboard normally controlled by one telephonist.

2.2 Facilities. Magneto switchboards provide facilities for the telephonist -

(i) to receive a visual signal from a calling subscriber,
(ii) to answer the calling subscriber,
(iii) to signal the called subscriber,
(iv) to connect the two subscribers' lines,
(v) to supervise (monitor) the through connection,
(vi) to receive a visual clearing signal at the end of the call,
(vii) to receive an audible alarm signal, sometimes called a night alarm (N.A.), if required, in conjunction with (i) and (vi) above, and
(viii) on some boards, to record the calls made by the calling subscribers for charging purposes.



CONNECTING THE SUBSCRIBERS' LINES.

FIG. 1.

2.3 The magneto switchboards commonly used in magneto exchanges are -

(i) Pyramid type, cordless; 4, 6 and 10 lines.

(ii) Wall pattern, cord type; up to 30 lines.

(iii) Floor pattern, cord type; up to 100 or 200 lines.

These switchboards are also used as private manual branch exchanges (P.M.B.Xs.) in subscribers' premises; but all new P.M.B.Xs. in magneto areas are the C.B. type.

3. CORD SWITCHING.

3.1 Cord type magneto switchboards are designed for either wall or floor mounting. They consist of -

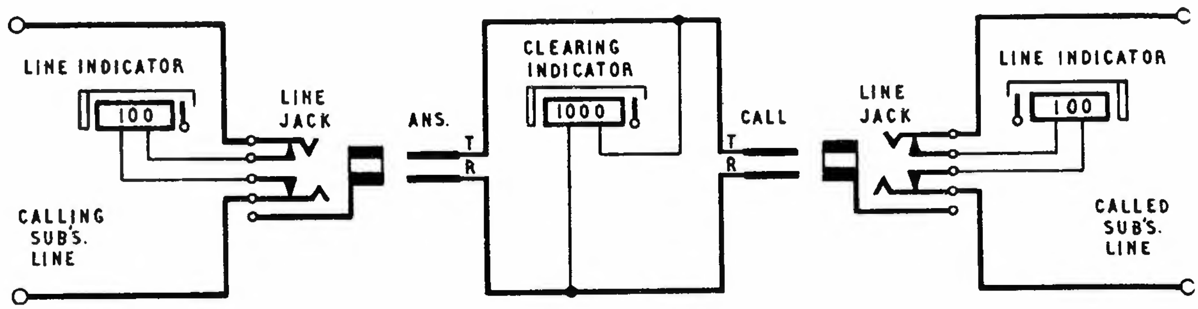
(i) A line circuit for each subscriber, comprising

- a line jack on which the subscriber's line terminates, and
- a line indicator for signalling purposes.

(ii) A number of cord circuits, each consisting of -

- two plugs and cords, one used for answering an incoming call and one for calling (ringing) the required subscriber,
- a clearing indicator for supervisory purposes, and
- a three-position lever key for connecting the telephonist's speaking and ringing circuits.

3.2 Basic Magneto Switchboard. Fig. 2 shows the basic principle of connecting two magneto telephones by a cord circuit. The subscribers' lines connect via the exchange M.D.F. to the tip and ring springs of the line jacks. The line indicators connect to the inner springs.



BASIC MAGNETO SWITCHBOARD CONNECTION.

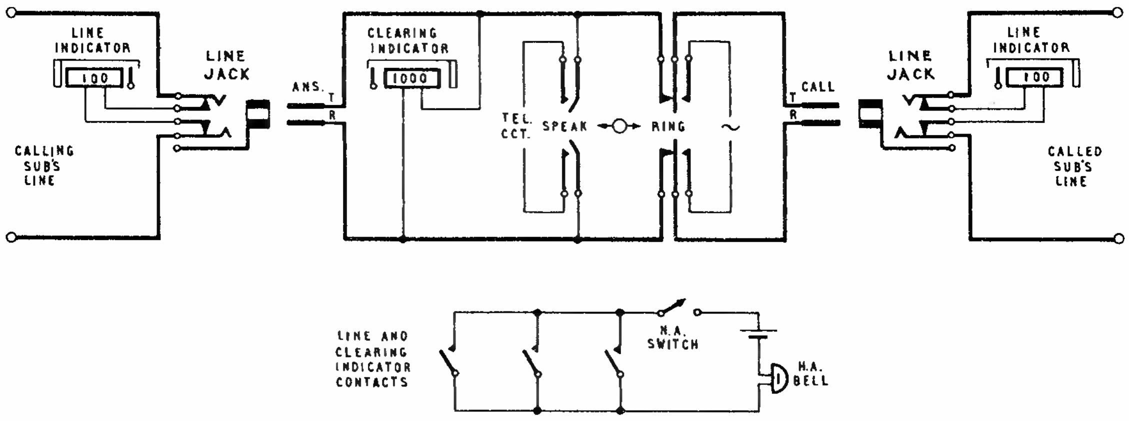
FIG. 2.

Each cord circuit, however, must have speaking and ringing facilities, and a lever key, sometimes called and R and L key (for ring and listen), is connected as shown in the simplified schematic circuit of Fig. 3.

A telephonist's (or operator's) anti-sidetone circuit similar to the 300 type magneto telephone circuit can be connected to any cord circuit to enable the telephonist to speak to the caller and ascertain the required number, or to supervise (monitor) the progress of the call once it is set up.

Ringing current can be connected to any cord circuit to signal the called subscriber. This is obtained from a hand generator at small exchanges and at larger exchanges from a machine-driven generator or a mains operated static device called a sub-cycle ringer, both of which supply all the switchboards at an exchange. Hand generators are individual to each board and are usually provided as an alternative should the power ring supply fail.

3.3 Circuit operation (refer Fig. 3).



SIMPLIFIED MAGNETO SWITCHBOARD CIRCUIT.

FIG. 3.

Incoming signalling. The A.C. ring from a calling subscriber's hand generator operates the line indicator via the inner springs of the line jack. The shutter drops to give the telephonist visual notice of the subscriber's number. The indicator contacts complete the night alarm bell or buzzer circuit, if the N.A. switch is closed.

To answer the call, the telephonist inserts the answering plug of any pair of cords in the calling subscriber's line jack. This disconnects the line indicator, the shutter of which is restored by hand. The telephonist's circuit is connected to the calling subscriber's line by operating the lever key associated with the cord circuit to the "speak" (locking) position.

To ring the called subscriber, the telephonist inserts the calling plug of the same cord circuit in the called subscriber's line jack, operates the lever key to the "ring" (non-locking) position, and turns the hand generator if power ringing is not provided. The ring is not heard by the calling subscriber, since this line is disconnected at the inner springs of the key in the ringing position.

To connect the lines, the telephonist restores the lever key to the normal (centre) position.

To monitor the call, the telephonist operates the lever key to the "speak" position. This connects the telephonist's circuit across tip and ring of the cord circuit, but does not interrupt the through connection.

When the subscribers "ring off" at the end of the call, the clearing indicator operates to give a visual signal and also an audible alarm, if the N.A. switch is closed. The clearing indicator is connected across the speaking circuit, but has no appreciable shunting effect on the conversation as it offers a very high impedance to A.C. at speech frequencies.

The telephonist records the call against the calling subscriber on a tally card, and takes both plugs from the line jacks, restoring the circuits to normal.

4. WALL SWITCHBOARDS (CORD TYPE).

4.1 Cord type switchboards for wall mounting (Fig. 4) are wired for a maximum capacity of 30 subscribers' lines, 10 outgoing junction or trunk lines, and 10 cord circuits.

The switchboards, however, may be installed partially equipped for either 10 or 20 subscribers' lines.

4.2 The face layout (Fig. 4a) covers -

- four rows each of ten indicators, three for line and one for clearing indicators,
- a row of ten lever keys (3-position) for speaking and ringing,
- four rows each of ten line jacks, one row of which is for outgoing junction or trunk lines,
- a special jack for testing cord circuits, and
- a night alarm switch.

The cord shelf carries two rows of ten switching plugs and cords (two-conductor). The rear cords (nearest the face of the switchboard) are for answering and the front cords (nearest the telephonist) for calling. Each cord is fitted with a weighted pulley which hangs below the switchboard.

A telephonist's handset is provided on the left hand side of the switchboard, and a hand generator (not shown in Fig. 4a) on the right hand side.

4.3 The circuit operation (Fig. 4b) is similar to that described in Section 3. The transmitter circuit is closed by a pair of auxiliary springs when any lever key is operated to the "speak" position.

4.4 The Cord Test Jack enables testing of the switching cords for faulty connections and the operation of the clearing indicators. When any plug is inserted, the clearing indicator should operate, proving continuity of the cord conductors. With the speaking key operated, hold the plug and shake the cord. Fractured cord conductors are indicated by noise in the receiver.

4.5 Junction and trunk lines. This type of switchboard is often installed at small country centres which are connected by junction and trunk lines to other exchanges.

Calls originated by local subscribers may be switched -

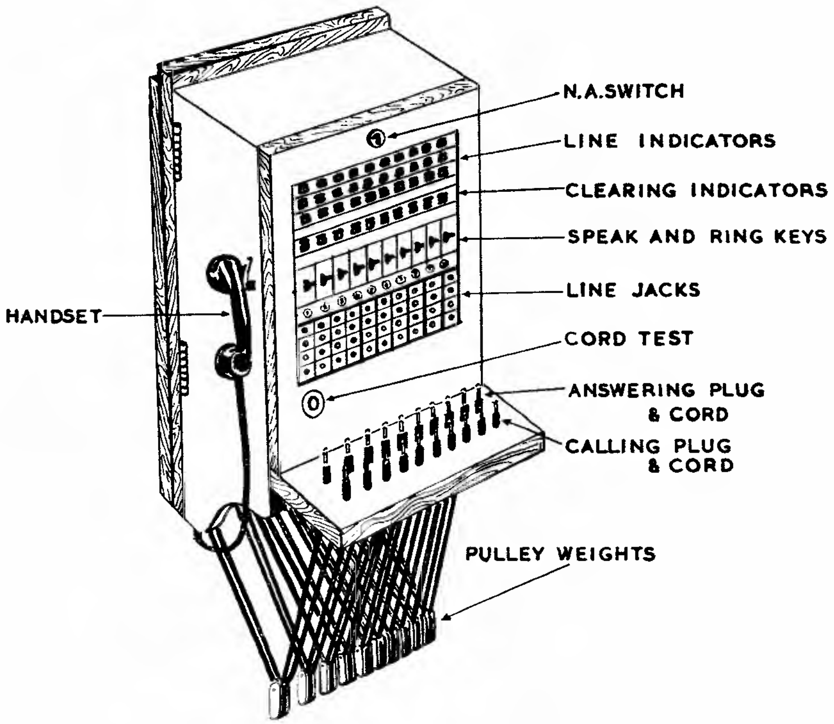
- to another subscriber in the same exchange area,
- to another exchange within the unit fee area over a junction line, or
- to a distant exchange beyond the unit fee area over a trunk line.

Also incoming calls over these junction and trunk lines may be switched to local subscribers.

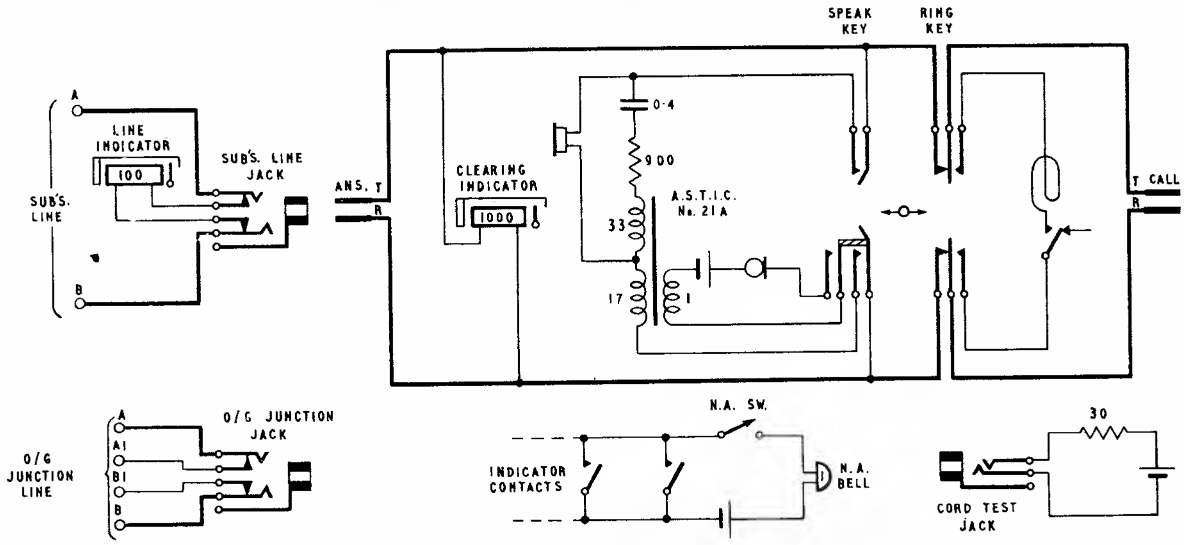
Incoming or both-way junction and trunk lines are terminated on subscribers' line circuits, with consequent reduction of subscriber capacity. Both-way lines are used for both incoming and outgoing calls.

For incoming signals on trunk lines, particularly when the switchboard is not constantly attended, the line indicator is generally replaced by a magneto bell which is connected permanently across the line.

Terminations are often arranged so that a trunk line may be "sectionised" to permit simultaneous calls over two different sections. This requires three jacks, one for termination of each direction, and one for listening across the line (see paragraph 7.4).



(a) Face Layout.



(b) Schematic Circuit.

MAGNETO WALL SWITCHBOARD (CORD TYPE).

FIG. 4.

5. FLOOR SWITCHBOARDS (CORD TYPE).

5.1 Cord type switchboards for floor mounting (Fig. 5) have a maximum capacity of either 100 or 200 subscribers lines. 100 line switchboards can be installed equipped for 30, 50, 80 or 100 lines, and 200 line switchboards for 100, 140, or 200 lines. The number of cord circuits varies from 10 to 17, depending on the number of lines connected. In magneto exchanges with more than 200 subscribers, a number of these switchboards may be placed side by side.

5.2 The general principles and circuit operation are similar to the wall pattern cord type switchboard, and the following additional facilities are provided.

The Generator Switching Key is a two-position locking lever key which connects either the hand generator or power ringing current to the cord circuit.

The Ringing Vibrator, in series with the ringing supply, gives the telephonist a visual indication that ringing current is going to line. On some boards, an A.C. relay is used, contacts of which complete the circuit to a "Ring Pilot" lamp.

The Ring-back and Coupling lever key is a three-position key. The telephonist's circuit is connected via this key, in its normal position, to the "speak" keys.

The Ring-back (non-locking) position is used in association with the "speak" key of any cord circuit, so that the telephonist can ring and recall any calling subscriber via the answering plug. In the wall pattern board, it is necessary to interchange the plugs. The clearing indicator is connected to the inner springs of the "speak" key, which open to prevent the operation of the indicator when ringing back.

The Coupling (locking) position is used when more than one board is installed, so that a telephonist can attend to more than one position. When operated. the key connects the telephonist's circuit to the "speak" keys on the other coupled positions. This enables all cords on coupled positions to be used with the transmitter and receiver plugged into any one position.

5.3 Trunk and junction lines terminate on jacks below the subscribers' line jacks. The trunk line indicators are mounted immediately below the subscribers' line indicators.

5.4 A and B Positions. In some large exchanges, the trunk and junction lines terminate on trunk or "B" positions separate from the subscribers' lines which terminate on local or "A" positions. To give full interconnecting facilities, either transfer or multiple working is used, or some combination, such as -

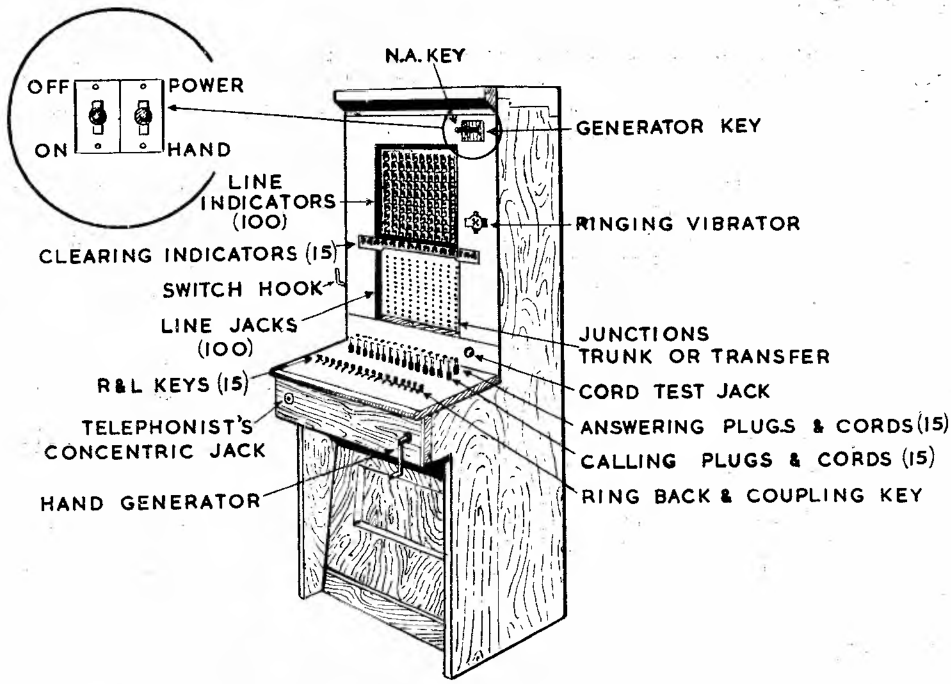
(i) A subscriber's multiple on the "B" positions only, and transfer working between "A" positions.

(ii) Transfer working between all positions, plus a full or partial trunk multiple between the "B" positions and alternate "A" positions.

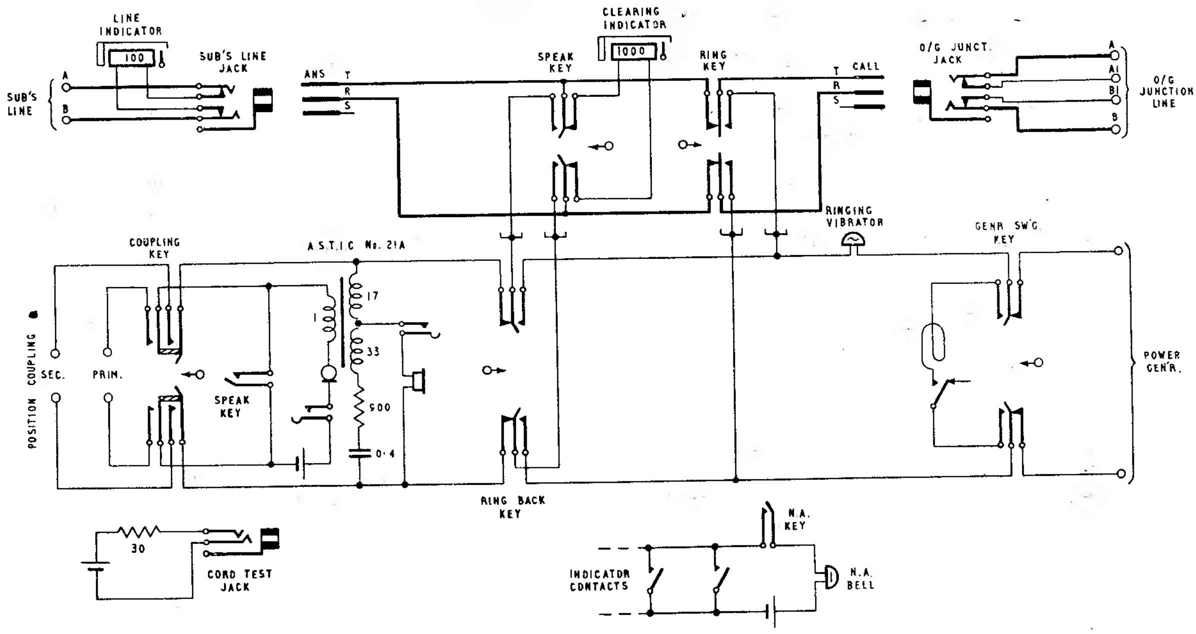
These and other similar expedients have been added to magneto centres as the size of the exchange and the volume of traffic have increased. They facilitate the handling of traffic but are not ideal.

Magneto multiple exchanges having meters, electrically self-restoring indicators or lamp signalling for both calling and supervisory purposes, and full I.D.F. facilities have been installed, but very few are still in service.

The principles of transfer and multiple working, lamp signalling, metering and the I.D.F., which are used also in C.B. manual exchanges, are described in the paper "C.B. Exchange Principles".



(a) Face Layout (100 line switchboard).



(b) Schematic Circuit.

MAGNETO FLOOR SWITCHBOARD (CORD TYPE).

FIG. 5.

6. PYRAMID SWITCHBOARDS.

6.1 These cordless switchboards (Fig. 6a) are used at small exchanges, usually of non-official status, and may be either table or wall mounted. To connect any two lines (subscribers or trunk), the telephonist inserts a plug which has the tip and ring connected together in a jack appropriate to the required connection.

The plugs normally remain in the bottom row of jacks, termed the indicator jacks. Answering and calling on any line is done from the line jacks immediately above the indicator jacks. The remaining jacks are arranged in the form of a pyramid, one for each possible cross-connection, such as 1-2, 1-3, 1-4, 2-3, 2-4, 3-4. A jack must be provided for each possible connection and, thus, the scheme is not practicable for more than 10 lines.

A telephone handset and a switch-hook are provided for the telephonist. The switch-hook also controls the battery supply to the handset transmitter. A hand generator is fitted for signalling. The drop indicators mounted at the top of the switchboard, are ironclad and are used for both calling and clearing signals. A night alarm bell with switch is commoned to all indicator contacts.

This board is cheap to manufacture and simple to operate. Also, due to the absence of switching cords, it has low fault liability, which is important as the boards are usually installed in remote country areas where delays may occur in attending to switchboard faults.

6.2 Sizes of Boards.

4-line switchboard; equipped with 14 jacks, 4 plugs and 4 drop indicators.
6-line switchboard; equipped with 27 jacks, 6 plugs and 6 drop indicators.
10-line switchboard; equipped with 65 jacks, 10 plugs and 10 drop indicators.

6.3 Circuit operation (refer Fig. 6b).

An incoming ring from a calling subscriber, say, line 1, operates the associated indicator via A side of line, auxiliary springs of indicator jack, drop indicator, tip and ring springs of indicator jack (through the connection between tip and ring of the plug), to B side of line.

To answer the call, the telephonist removes the plug from indicator jack 1, places it in line jack 1, and removes the handset from the switch-hook. This disconnects the drop indicator, the shutter of which is restored manually, and connects the telephonist's circuit to line 1.

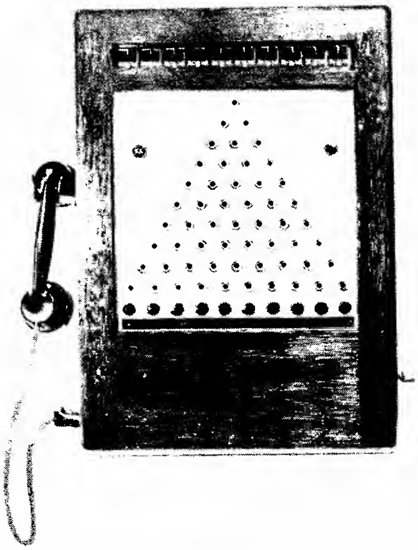
To ring the called subscriber, say, line 2, the telephonist restores plug No. 1 to indicator jack 1, and transfers plug No. 2 from its indicator jack to line jack 2. This connects the telephonist's circuit to line 2. The telephonist then replaces the handset on the switch-hook and turns the generator handle.

To connect the lines, the telephonist inserts plug No. 2 into jack 1-2. This connects the A sides of the lines via the auxiliary springs on jack 1-2, and the B sides via the connection between tip and ring of the plug. The telephonist's circuit is then disconnected and indicator No. 1 is bridged across the connection for supervisory purposes.

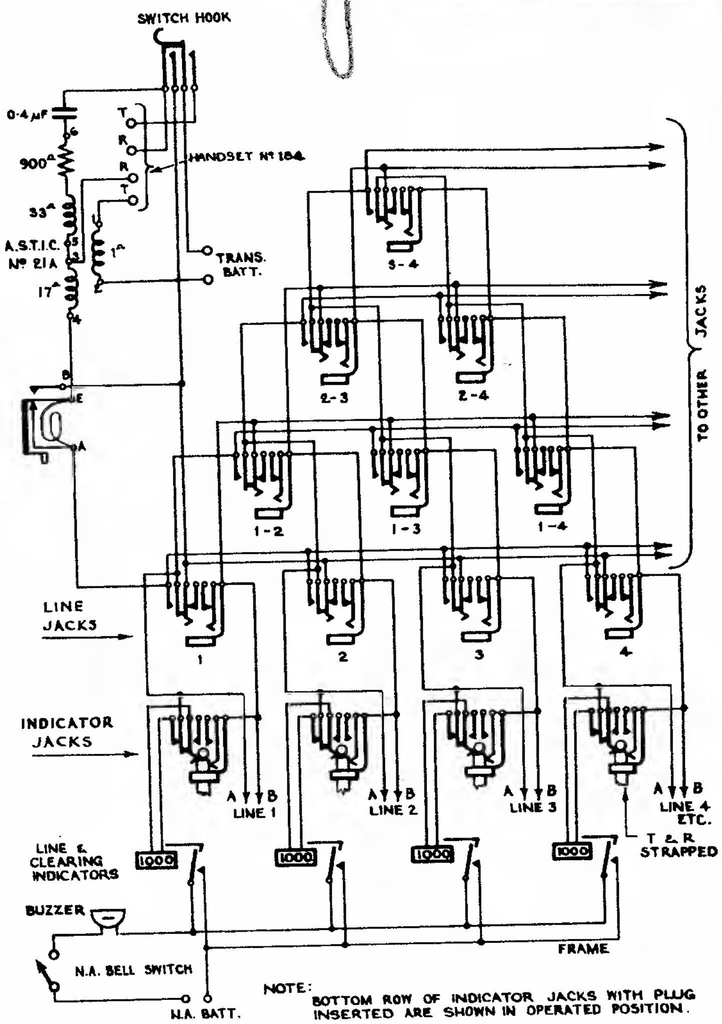
To monitor the call, the telephonist's circuit is bridged across the connection by insertion of a plug into line jack 1 or 2.

When the subscribers "ring off" at the end of a call, indicator No. 1 operates to give a clearing signal.

The telephonist records the call against the calling subscriber, and restores the switchboard to normal by transferring the plug from jack 1-2 to indicator jack 2.



(a) 10 Line Switchboard.



(b) Schematic Circuit.

FIG. 6. MAGNETO CORDLESS SWITCHBOARD (PYRAMID TYPE).

7. JUNCTION, TRUNK AND PARTY LINES.

7.1 Junction and trunk lines are used to connect magneto switchboards to nearby magneto, C.B., and automatic exchanges (see paragraph 4.5).

At the smaller exchanges, these lines terminate on jacks in the same jack field as the subscribers' line jacks; but at larger centres, separate trunk switchboards are generally used.

Between very small exchanges, a line may be both-way; but between larger exchanges it is usual to divide the lines into incoming and outgoing groups.

7.2 Signalling. High impedance 2000 ohm line indicators or 2000 ohm magneto bells are used to receive an incoming call. These have more turns than the lower impedance 1000 ohm types, to increase the sensitivity to ringing currents on long lines. They also reduce the shunting effect on the signalling and speech currents, when several are connected in parallel.

Bells are satisfactory for no more than about three or four lines at a particular exchange, the bell on each line being given a different tone for identification.

A dial is fitted on a magneto switchboard which has junction or trunk lines to an automatic exchange.

7.3 Omnibus working (Fig. 7). In smaller exchanges, many magneto trunk lines are omnibus lines (the same trunk connects to several exchanges). A 2000 ohm magneto bell is connected across the line at each exchange. Bells are preferred to indicators as each exchange is called by a different combination of long and short rings (code ringing).

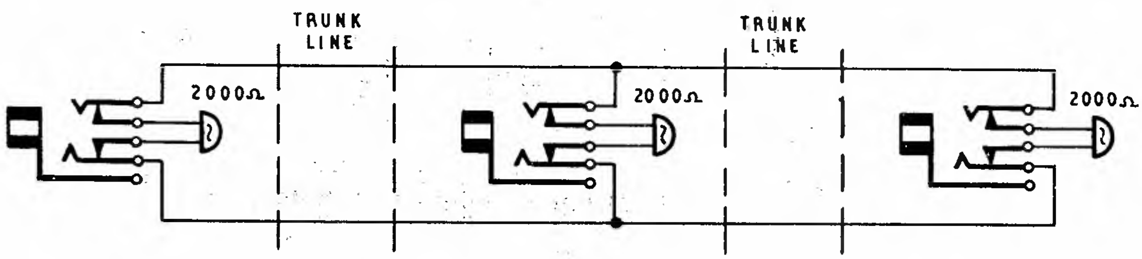


FIG. 7. PRINCIPLE OF OMNIBUS WORKING.

7.4 Divided working is used on some trunk lines so that a call on one section of the line does not busy the entire line. Fig. 8 shows the arrangement at an intermediate exchange. Note that both sections of the line can be used at the same time to set up calls. When either section is in use, the other section is disconnected at the inner springs of the jack and terminated on a high impedance indicator or bell. The listening jack enables the telephonist to monitor whether the trunk line is being used for a call over the entire line, before plugging into jack A or B to ring either terminal.

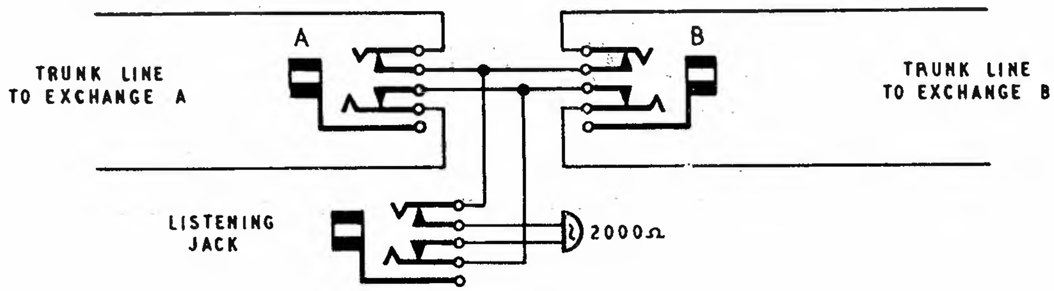


FIG. 8. PRINCIPLE OF DIVIDED WORKING.

7.5 Party Lines. In a party line service (Fig. 9), two or more subscribers (parties) are connected in parallel across the same line to the exchange.

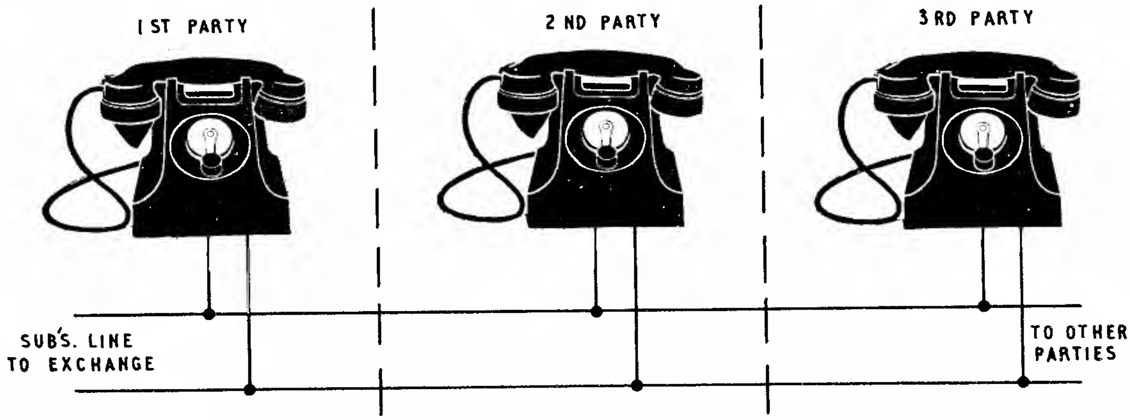


FIG. 9. MAGNETO PARTY LINE SERVICE.

A party line saves line plant, and is used to provide a service (usually in country areas where long distances are involved) for subscribers who are reasonably close to one another and in the same general direction from the exchange. The number of magneto party line telephones is generally limited to six, although more may be permitted in special cases. The same exchange number is used with a separate distinguishing letter for each party. The telephonist signals each party by using an individual code. Also, the parties can signal each other by code ringing.

The main disadvantages are -

(i) No secrecy between the parties, either on incoming or outgoing calls.

(ii) No discrimination at the exchange between calls for other parties and exchange calls, as the line indicator operates in either case.

Various selective ringing arrangements using special generators and bells, have been devised to overcome the latter disadvantage but they are not used to any great extent.

7.6 P.P.E. Lines. In certain cases, a subscriber is permitted to build portion of a telephone line. This is called a P.P.E. (part privately erected) line. In magneto areas, the privately erected portion of the line is either single-wire (earth return) or two-wire (metallic). The single-wire line connects to the two-wire Departmentally erected line via a pole mounted transformer (Fig. 10).

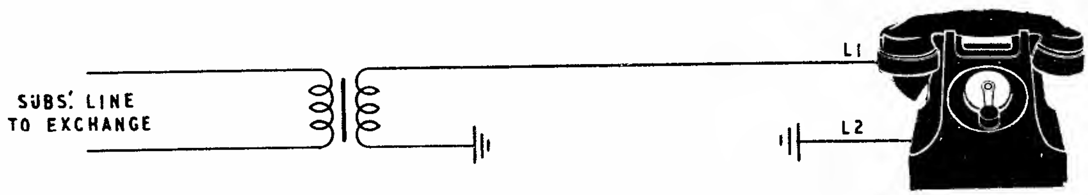


FIG. 10. EARTH RETURN P.P.E. LINE.

A party line service may be used in conjunction with P.P.E. lines.

NOTES.

NOTES.

8. TEST QUESTIONS.

1. The telephone systems used in Australia, are (1)...............(2)..............(3)..................

2. List the facilities provided by a magneto switchboard.

3. Draw the basic line, cord, and N.A. circuits for a magneto switchboard, and describe the circuit operation.

4. What is the function of the cord test jack in a magneto switchboard?

5. In the magneto floor pattern switchboard, what are the functions of -

(i) the generator switching key,
(ii) the ringing vibrator,
(iii) the ring-back key,
(iv) the coupling key?

6. What are the advantages of the pyramid type of switchboard?

7. Briefly explain how two subscribers are connected on a pyramid switchboard.

8. Why do bells and indicators used for signalling on trunk lines have a higher impedance than those used on subscribers' lines?

9. Why are dials fitted on some magneto switchboards?

10. Draw a simple sketch showing the principle of divided working on trunk lines.

11. What are the main advantages and disadvantages of a party line service?

12. What is a P.P.E. line?

END OF PAPER.

THE AUSTRALIAN POST OFFICE

COURSE OF TECHNICAL INSTRUCTION

Engineering Training Section, Headquarters, Postmaster-General's Department, Melbourne C.2.

C.B. EXCHANGE PRINCIPLES.

1. INTRODUCTION.

1.1 Non-multiple and multiple C.B. exchanges have been installed in recent years in country areas to extend or replace existing magneto exchanges. Generally known as C.B. country exchanges, they are designed for service outside metropolitan areas and provide facilities for junction, trunk and party lines.

Non-multiple country switchboards have combined local and trunk positions. They are designed to replace the 100 line and 200 line magneto floor pattern switchboards at country exchanges.

Multiple country exchanges have a maximum capacity of up to 2,000 subscribers. Separate local and trunk positions are provided. They are installed in areas where major extensions to (or replacement of) existing magneto exchanges are required and an automatic installation cannot be provided immediately.

1.2 The early type C.B. multiple exchanges which were installed in metropolitan areas have been converted to automatic working and future plans envisage the conversion of all C.B. country exchanges to automatic.

1.3 This paper describes some basic principles of modern C.B. manual exchange switching, with particular reference to multiple exchange working.

2. C.B. MANUAL EXCHANGES.

2.1 In the paper "Magneto Switching Principles" we saw that a subscriber in a magneto system signals the telephonist by turning a hand generator which operates an indicator at the exchange. A local battery at each telephone supplies the transmitter current.

Some disadvantages of magneto working, are

- the hand generator is expensive,
- local batteries are expensive to maintain,
- the subscribers often fail to ring off and to operate the clearing indicator at the end of a call.

2.2 In the C.B. manual system, the subscriber calls the telephonist by lifting the receiver or handset. Current from a central battery at the exchange operates the exchange signalling apparatus. This battery also supplies the transmitter current to each telephone in the exchange area.

Although large batteries are required at the exchange, the subscriber's telephone equipment is simplified by the omission of hand generators and batteries, and maintenance costs are reduced.

2.3 Lamp Signalling. In C.B. exchanges, lamps are used instead of indicators for signalling and supervision. This reduces the cost of exchange equipment and also improves the operating efficiency, because

- the space occupied by a lamp is smaller and more lines can be fitted per position,
- lamps require less maintenance, and are easily replaced when faulty,
- lamps are automatically extinguished when a call is answered; indicators generally have to be restored by hand,
- supervisory lamps can be mounted on the horizontal shelf near the switching cords.

2.4 Facilities. The local positions in C.B. exchanges have similar facilities to those provided by magneto switchboards.

In addition, a transmitter battery feed is supplied to each subscriber when the lines are connected.

2.5 To give these facilities, the exchange circuits provide -

(i) a line circuit for each subscriber, including

- a line jack on which the subscriber's line terminates,
- a calling lamp for signalling, and
- in multiple exchanges, a subscriber's meter to record the number of outgoing unit fee calls.

(ii) a number of cord circuits, each consisting of

- two plugs and cords, one used for answering a calling subscriber and one for calling (ringing) the required subscriber,
- speaking and ringing keys,
- supervisory lamps for each answering and calling cord,
- transmitter battery feeds for both calling and called subscribers, and
- in multiple exchanges, a key to operate the subscriber's meter at the end of a call.

3. NON-MULTIPLE SWITCHBOARDS.

3.1 A typical C.B. non-multiple switchboard (Fig. 1) is a combined local and trunk, lamp signalling board. It has a maximum capacity of

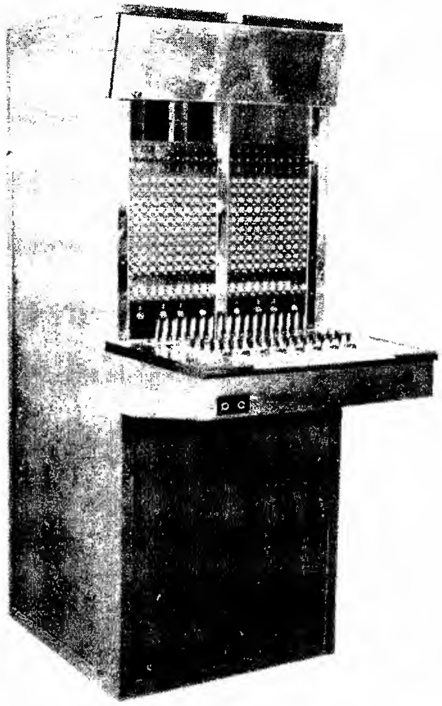
- 200 subscribers' lines,
- 18 trunk lines, and
- 16 cord switching circuits.

Up to three operating positions may be provided at an exchange.

3.2 The face layout comprises two panels. Shelves for dockets, telephone directories, etc., and a mounting board for trunk line timing clocks are at the top of the panels.

Rows of keys, jacks and lamp strips are fitted, from top to bottom, as follows

- a row of lever keys (two-position) for ringing or dialling on trunk lines. The two end keys are the N.A. switch and the key to connect either a power ringing supply or the hand generator to the cord circuits.
- ten rows each of ten jacks (5-point) and lamps (6 volt) for 100 subscribers' lines on each panel, numbered from 00 at the top left hand jack to 99 at the bottom right hand jack. The calling lamp is mounted below each line jack.
- trunk line jacks (8-point) and associated calling lamps (6 volt). The two end jacks are for cord testing.



C.B. NON-MULTIPLE SWITCHBOARD.

FIG. 1.

- pilot lamps (6 volt) for ringing, night alarm, fuse alarm, etc.

3.3 The key and plug shelf has

- answering and calling plugs and cords for calls between

  any two local subscribers, or a local subscriber and a trunk line (14 cord circuits),

  any two trunk lines (two cord circuits).
- plugs for two transfer circuits, if required.
- two supervisory lamps (6 volt) and two lever keys (three-position) for each cord circuit. The lever keys give the following facilities

  speaking on either answering or calling cord,

  monitoring the "through" connection,

  ringing on the calling cord.
- as in the floor pattern magneto switchboard, a "ring-back and coupling" key (three-position) for ringing on the answering cord of a trunk cord circuit or for coupling adjacent positions.
- two dials (one being spare), together with a change-over key, when the exchange has lines to an automatic exchange or R.A.X.

- Miscellaneous facilities, such as

  - clips for holding trunk line dockets located on the key shelf immediately in front of the telephonist,
  - twin concentric plugs for the telephonist's headset on the left front of the keyshelf, and
  - a hand generator on the right front.

3.4 Basic C.B. Connection. Fig. 2 shows the basic connection between two local subscribers via the line and cord circuits of a non-multiple C.B. exchange.

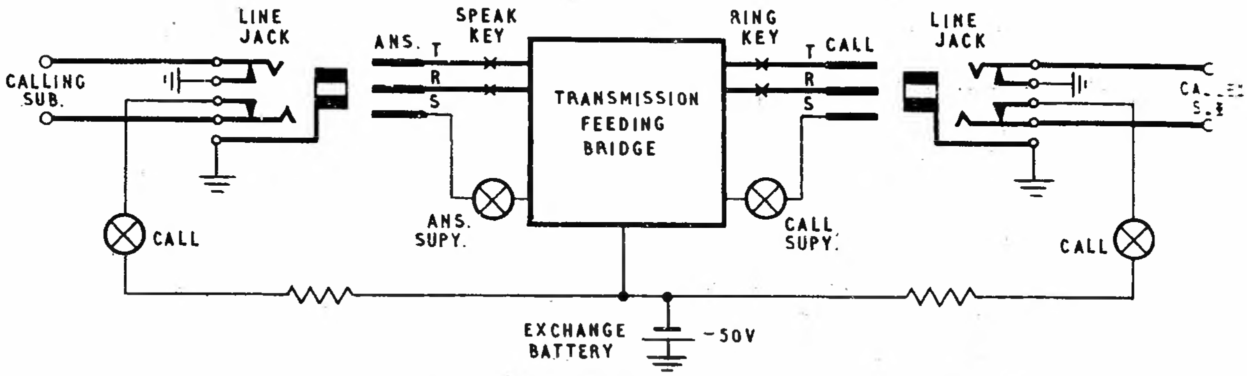


FIG. 2. BASIC C.B. CONNECTION (NON-MULTIPLE EXCHANGE).

The exchange battery voltage is applied via the calling lamp in the line circuit over the telephone line to each telephone, but a D.C. loop is prevented by a capacitor in the telephone.

When a calling subscriber lifts the handset, current through the telephone loop lights the calling lamp. This current also operates a relay (not shown in Fig. 2), which completes a N.A. buzzer circuit via N.A. key contacts.

To answer the call, the telephonist inserts an answering plug in the calling subscriber's line jack. This disconnects the lamp and N.A. circuits at the inner springs of the jack. The telephonist's circuit is connected to the calling subscriber's line by operating the "speak" key.

To ring the called subscriber, the telephonist inserts the calling plug of the same cord circuit in the called subscriber's line jack, and operates the "ring" key. The lamp is disconnected at the inner springs of the jack to prevent false operation when the called subscriber answers. The ring is not heard by the calling subscriber, because this line is disconnected at the inner springs of the ringing key when operated.

The lines are connected when the telephonist restores the ringing key to normal. The transmitter current for both telephones is fed from the exchange battery via a transmission feeding bridge in the cord circuit (see Section 4).

To supervise the progress of the call, supervisory lamps are connected in the sleeve circuit of each cord. The lamps are extinguished while the call is in progress, but the answering supervisory lamp lights when the caller hangs up. The calling supervisory lamp lights until the called subscriber answers and after he replaces the handset. The telephonist's circuit can be connected across tip and ring of the cord circuit for monitoring, without interrupting the through connection.

When the subscribers "hang-up" at the end of the call, both supervisory lamps light. A circuit is also completed for the N.A. buzzer via N.A. key contacts.

The telephonist records the call against the calling subscriber on a tally card, and takes both plugs from the line jacks, restoring the circuits to normal.

4. C.B. TRANSMISSION FEEDS.

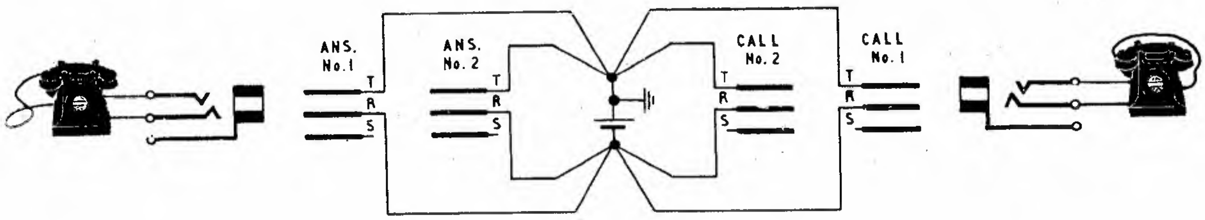
4.1 In C.B. systems, a central battery at the exchange supplies the D.C. over the subscribers' lines to all telephone transmitters in the exchange area. This battery also supplies the telephonists' transmitters, and operates the signalling and supervisory apparatus at the exchange.

A secondary battery is used instead of a primary battery, because

- it can supply larger currents for longer periods,
- it can be recharged, and
- it has lower internal resistance (see paragraph 4.4).

The size of battery depends on the number of cord circuits in the exchange and the calling rate of the subscribers.

4.2 The exchange battery is connected between tip and ring of all cord circuits, and is applied to a subscriber's line whenever any cord is plugged into the line jack. Fig. 3 shows the battery connected to two pairs of switching cords.

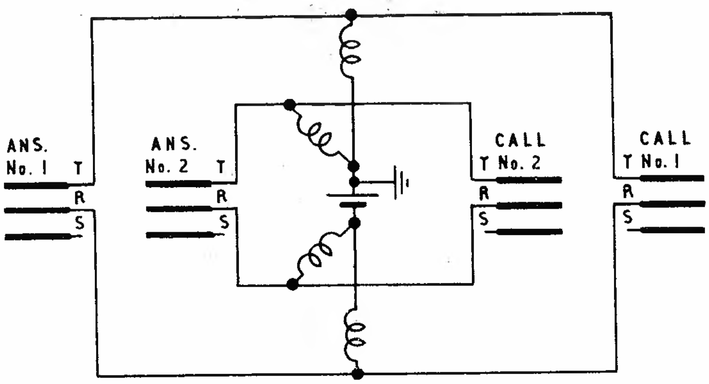


BASIC BATTERY FEED.

FIG. 3.

Subscribers connected in this way cannot speak to each other, however, as the low internal resistance of the battery acts as a short circuit to speech currents.

4.3 Parallel battery feed. In a practical circuit (Fig. 4), two inductance coils (sometimes called retards) are connected in series with the battery feed to each cord circuit.



PARALLEL BATTERY FEED.

FIG. 4.

The coils offer low resistance to the D.C. for the telephone transmitters, but have high impedance to A.C. at speech frequencies.

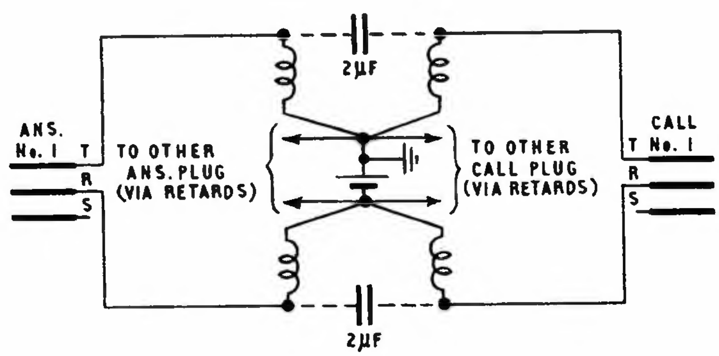
The speech currents, therefore, pass freely between the two lines connected, but not through the coils and battery across the circuit. The high impedance of the coils also prevents crosstalk, as speech currents from one circuit do not flow through the other telephones simultaneously connected to the battery.

4.4 Reasons for low internal resistance. The central battery supply must have a very low resistance (including the busbar leads) up to the point where the current divides to all connected circuits, to prevent noise and crosstalk between the circuits.

Any internal resistance in the battery circuit to this point results in a P.D. common to all circuits connected to the battery. As the current varies with switching operations in any circuit (for example, connection and disconnection of subscribers' lines, and signalling and supervisory apparatus), the P.D. across the battery resistance also varies. This causes varying potentials to be applied to all connected lines and noise or clicks are heard in the various telephone receivers. Similarly any speech currents which flow through the battery, cause crosstalk between the simultaneous connections.

4.5 Stone Battery feed. The arrangement in Fig. 4 is used with some types of switchboards (P.M.B.Xs.) in subscribers' premises where all extension lines have about the same resistance. When lines of unequal resistance are connected, however, the lower resistance shunts the higher resistance, and reduces the transmitter current in the higher resistance line. The D.C. in each line depends on the ratio of the individual resistances.

To prevent this shunting effect, separate retards are used for each line (Fig. 5). The D.C. in each line then depends only on the individual resistance, and not on their total resistance or the ratio of the individual resistances.



SEPARATE TRANSMITTER FEEDS.

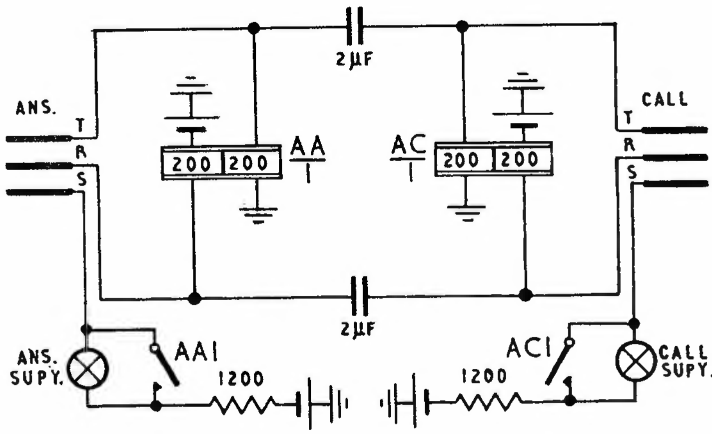
FIG. 5.

As the windings of the retards in series offer a high impedance to alternating speech currents, 2μF capacitors are connected as shown by the dotted lines. The capacitors pass the speech currents from one side to the other, but retain the individual battery feeds to the two lines. This arrangement is called the Stone (the name of the inventor) or Bridged Impedance type of transmitter battery feed.

In some early C.B. exchanges, the retards were arranged as transformer windings and the capacitors omitted. The alternating speech currents in one line were induced in the other line by the transformer action of the windings. This was called the Hayes system.

4.6 In modern C.B. exchanges, the Stone arrangement is preferred because the inductance coils in each cord circuit can be wound as relays and used for supervisory purposes. High impedance double-wound relays are used for each battery feed, as shown in Fig. 6.

Fig. 6 also shows how the battery feed relays provide individual supervision for each cord in non-multiple exchanges. (The arrangement in a multiple exchange is shown in Fig. 19.)



STONE TRANSMISSION BRIDGE WITH SUPERVISION.

FIG. 6.

When either cord is plugged into a subscriber's line jack, and a D.C. loop is not provided by the subscriber's telephone, the circuit for the associated supervisory lamp is completed to earth via the sleeve of the line jack.

When a D.C. loop is provided, the battery feed relay (AA or AC) operates and the contacts short circuit the supervisory lamp which is extinguished.

5. TRANSFER AND MULTIPLE WORKING.

5.1 The maximum number of lines which one telephonist can handle depends on the calling rate of the telephone traffic, and is usually limited to about 200; additional positions are provided when more than 200 lines are connected.

With more than two positions, however, the connecting cords on any position would need to be impractically long to reach all the line jacks in the exchange. A telephonist, therefore, can only use the cord circuits to connect to jacks on the same position and the positions on either side, and special provisions are required in larger exchanges to enable any two of all the subscribers' and trunk or junction lines to be connected.

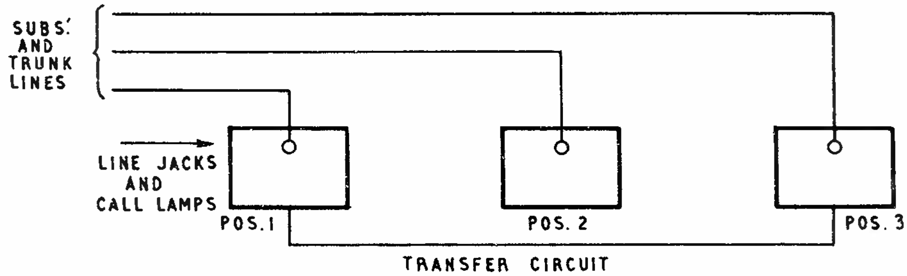
Two methods used to provide this facility are transfer working and multiple working.

5.2 With transfer working, one line jack only is provided for each line, and transfer jacks and/or plugs and associated circuits are installed for connection between the positions.

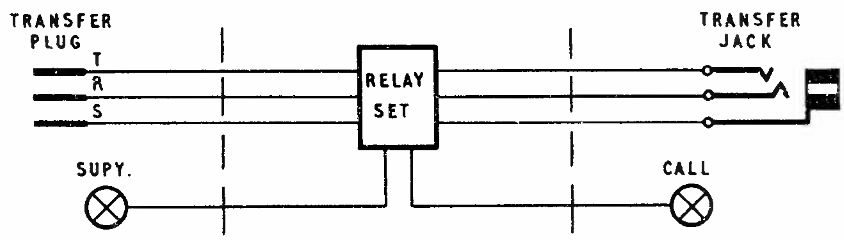
A transfer circuit is a wired connection between positions, which can be either jack-ended or plug-ended. Supervisory and calling lamps are often provided with both types.

Suppose that, at a manual exchange with three positions (Fig. 7a), a subscriber on the first position calls and requires a subscriber's or trunk line on the second position, the telephonist can reach across and plug into the required jack. When, however, the caller requires a line appearing on the third position, the telephonist on that position is requested to plug into the required jack and the connection is completed via a transfer circuit.

Fig. 7b shows the principle of transfer working between C.B. non-multiple positions. When a transfer plug on the first position is inserted in the calling subscriber's jack, the line is extended via a relay set to a transfer jack on the third position. The connection is then completed via a cord circuit on the third position.



(a)



(b)

FIG. 7. PRINCIPLE OF TRANSFER CIRCUIT.

When the number of positions makes it difficult to pass the requirements by one telephonist speaking normally to another, order wires (see paragraph 5.5) are provided between positions. The telephonist desiring to transfer a call, speaks to the wanted telephonist over the appropriate order wire.

Transfer working requires the attention of two telephonists and, in some early exchanges, two cord circuits are used for the duration of a call. It is slow and inefficient in large exchanges where the volume of traffic is great.

5.3 In multiple working, the line jacks have "appearances" at frequent intervals along the row of positions to give each telephonist direct access to all subscribers' lines. Lines or circuits which appear on more than one position are said to be multipled. Fig. 8 shows the principle of a subscriber's multiple. The tip, ring and sleeve connections are commoned at each line jack.

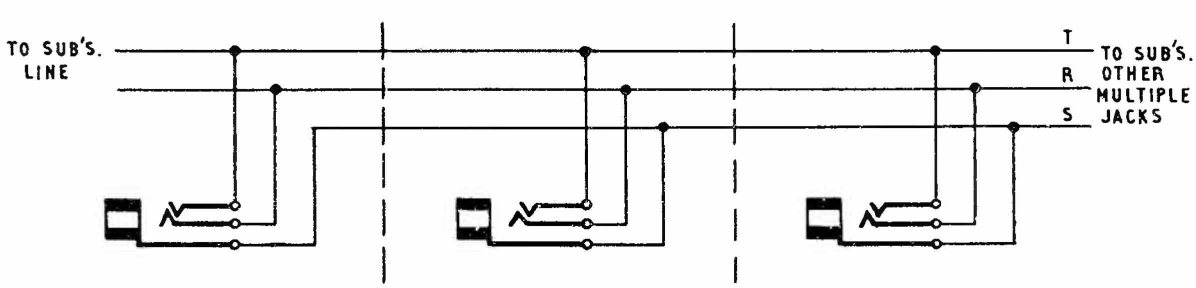


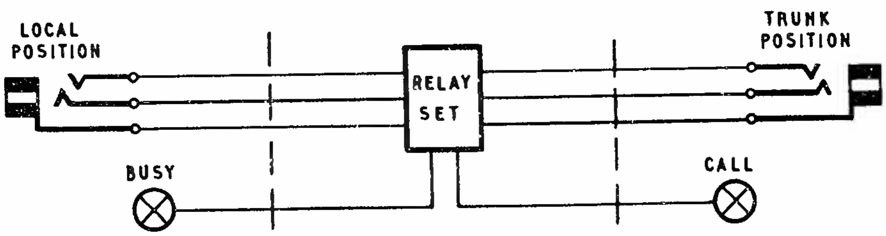
FIG. 8. PRINCIPLE OF SUBSCRIBER'S MULTIPLE.

In practice, the multiple jack field is divided into panels and there are a number of panels per position. The calling lamp for any one line usually appears on one position only.

In modern C.B. multiple exchanges, the calling lamps (one for each line) appear below the multiple jack field on the same panel for a particular subscriber, as one of the multiple jack appearances. All calls are answered in the multiple.

In early multiple exchanges, a subscriber's line jack appearance (called the home or local jack) and associated calling lamp was made separate from the multiple jack field and used for answering calls. Sometimes, for an urgent service, the local jack and lamp was multipled to other positions (called an ancillary appearance), to reduce the time taken to answer a call.

5.4 Recording Junctions (Fig. 9) are jack-ended transfer circuits between local and trunk positions in modern C.B. multiple exchanges. They are used to connect calling subscribers direct to the trunk telephonist.

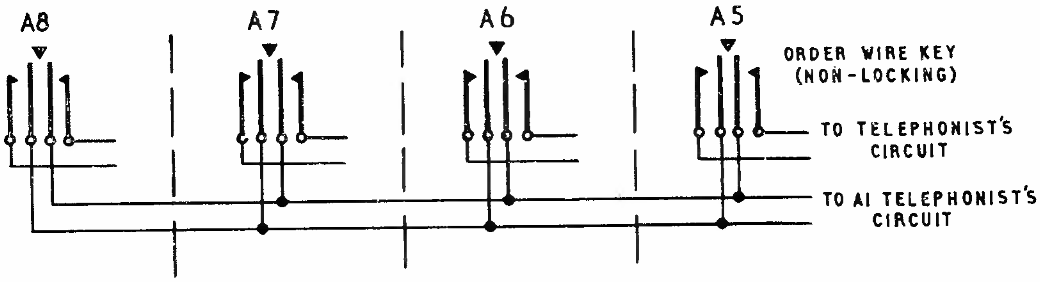


PRINCIPLE OF RECORDING JUNCTION.

FIG. 9.

After recording details of the trunk call, the trunk telephonist "overplugs" in the subscriber's multiple jack to connect to the caller (when the call is completed on demand) or recalls the subscriber via the multiple (if the call matures after a delay). In either case, the recording junction is released so that the connection is made via one cord circuit only. The recording junction jacks and lamps are generally multipled over local and trunk positions.

5.5 Order Wires. To facilitate traffic handling, in large manual exchanges, each position has a set of press type order wire keys for direct communication between telephonists. Fig. 10 shows the basic circuit to give, for example, positions A5, A6, A7, A8, direct access to position A1. For 10 positions, there could be 10 such order wires. In practice, however, a full series is not always provided as some positions do not need order wires to certain of the other positions.



PRINCIPLE OF ORDER WIRE.

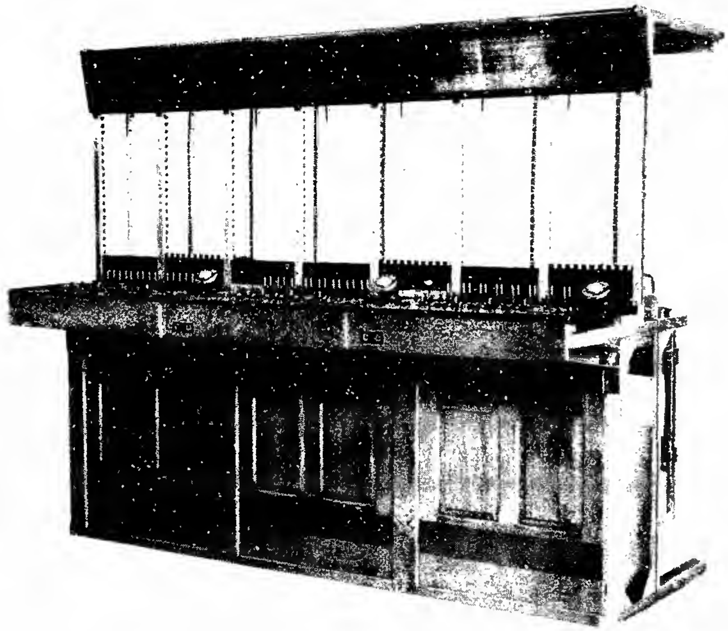
FIG. 10.

Order wires are sometimes provided between the positions of nearby exchanges to facilitate the rapid setting up of junction calls, in which case the junctions generally terminate on plugs rather than jacks. Order wires are only for speaking between telephonists and are not used for traffic.

6. MULTIPLE EXCHANGES.

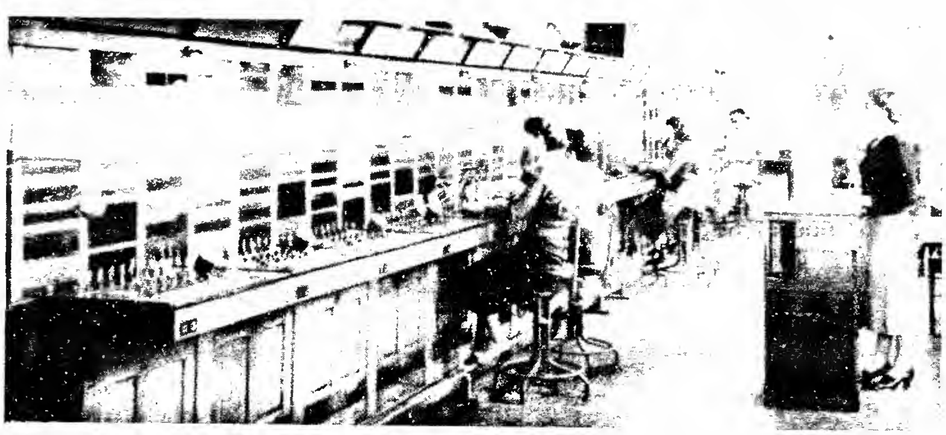
6.1 Fig. 11 shows the carcass of three positions of a modern C.B. multiple exchange. Each three-position group has seven panels for jacks and lamps. The positions are fitted together without side panels to facilitate the multiple cabling.

Fig. 12 shows a modern C.B. multiple exchange with 5 local and 12 trunk positions, using the positions shown in Fig. 11. The local positions have line and cord circuits which function as described in Section 8. The circuits on the trunk positions are different, however, and these are described in later papers of the Course.



C.B. MULTIPLE POSITIONS (BEFORE INSTALLATION).

FIG. 11.



C.B. MULTIPLE EXCHANGE.

FIG. 12.

6.2 The panel layout varies with different exchanges. Fig. 13 shows a typical layout of lines over a number of local and trunk positions. The subscribers' multiple is repeated every four or five panels over all positions. The trunk lines are multipled on trunk positions only.

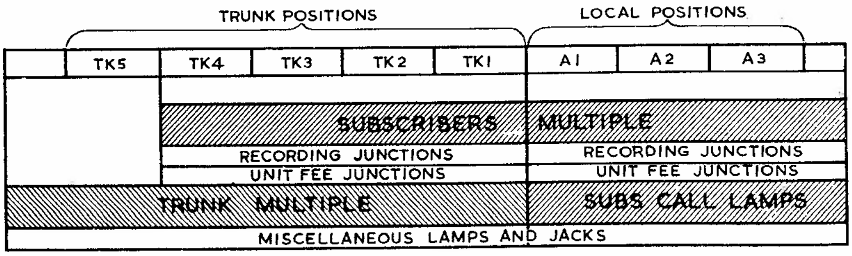


FIG. 13. TYPICAL LAYOUT, MULTIPLE EXCHANGE JACK AND LAMP FIELD.

The allocation of the jack and lamp strips, from top to bottom, is

- subscribers' multiple of line jacks only,
- jacks and lamps for recording junctions between local and trunk positions,
- line jacks and lamps for junctions to nearby manual or automatic exchanges within the unit fee area, and
- on local positions, subscribers' calling lamps only, or
- on trunk positions, trunk line multiple jacks and associated lamps.

6.3 Traffic in multiple exchanges. The local positions handle all unit fee traffic, that is, calls between

- any two local subscribers,
- a local subscriber and a unit fee junction.

When trunk line service is required, the local telephonist connects the caller to a trunk position over a recording junction.

The trunk positions are for connection between

- any two trunk lines,
- a local subscriber (or unit fee junction) and any trunk line.

6.4 The keyshelf layout of a typical local position having 16 cord circuits is shown in Fig. 14.

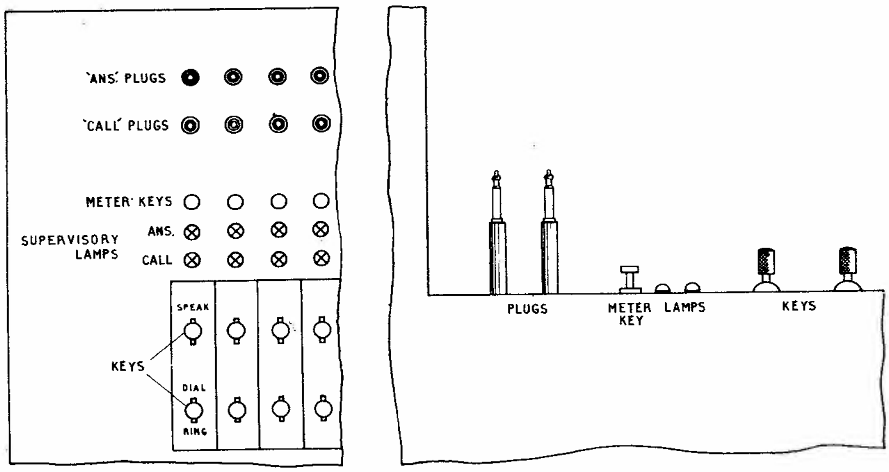
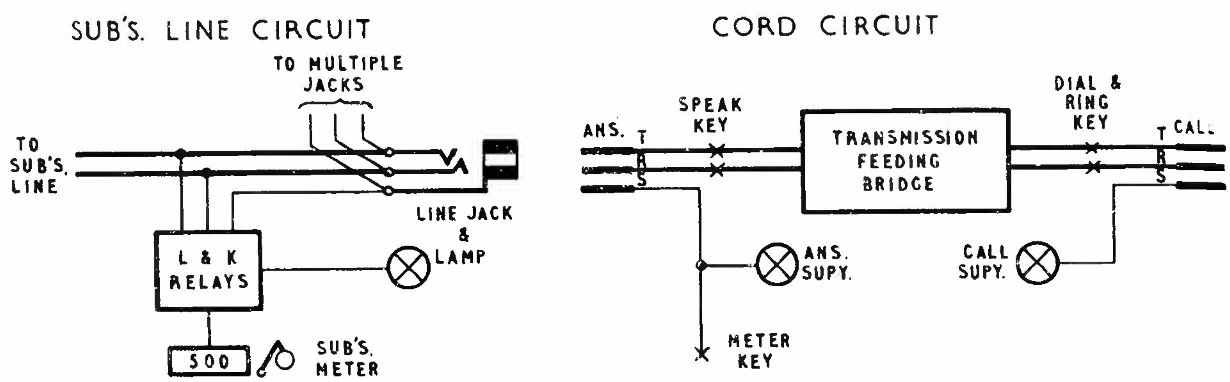


FIG. 14. TYPICAL KEYSHELF LAYOUT.

A meter key is associated with each cord circuit, together with two supervisory lamps (one for each cord), a speak key and a dialling and ringing key. Other shelf equipment (not shown in Fig. 14) includes up to 15 order-wire keys, an ineffective call metering key, a "coupling" and "call monitor" key, and a dial.

6.5 The basic functions of the line and cord circuits are summarised in block form in Fig. 15.



BASIC C.B. MULTIPLE EXCHANGE FUNCTIONS.

FIG. 15.

In addition to the multiple line jacks and calling lamp, each subscriber's line circuit has

- two 600 type relays, designated line (L) and cut-off (K), and
- a subscriber's meter for registering the number of local calls made.

A calling subscriber's loop operates relay L. The circuit for the calling lamp is completed by a contact of this relay instead of by way of the telephone directly, as in a non-multiple exchange.

When either an answering or calling plug is inserted in a multiple jack appearance, relay K operates to disconnect the subscriber's calling apparatus and prevent its false operation.

The cord circuit provides the following facilities

- speaking and signalling,
- engaged test for busy subscribers,
- transmitter battery feed to the calling and called subscribers,
- individual lamp supervision on each cord, and
- registering effective calls against the calling subscriber.

The sleeve wire provides a circuit for the engaged test, lamp supervision and metering.

For speed of operation, key metering is used instead of a docket system. The meter key is pressed at the end of a call before the answering plug is withdrawn and this adds one to the calling subscriber's meter reading.

The dial key is used to connect a dial to the calling cord when the exchange has junctions to a nearby automatic exchange or R.A.X.

7. INTERMEDIATE DISTRIBUTION FRAME.

7.1 The intermediate distribution frame (I.D.F.) is an iron structure for mounting terminal blocks. It is used in multiple exchanges to provide a convenient terminating and connection point for the exchange cabling from the M.D.F. to the switchboard multiple jacks and the subscribers' line equipment (relays, meters and calling lamps).

7.2 In early multiple exchanges with separate local jacks (Fig. 16), the I.D.F. had two sets of terminal blocks, one set for the multiple side (arranged in numerical order) and another for the local side (arranged in the order in which the local jacks appear on the local position). Jumper wires connected the multiple and local sides.

This enabled the lines of high and low calling rate subscribers to be distributed evenly over the local positions, so that each telephonist had about the same amount of traffic to handle. By changing the jumper connections on the local side, a subscriber's local jack and lamp appearance could be changed to any position as traffic conditions demanded, without altering the multiple jack appearances or the meter, both of which must be in numerical sequence.

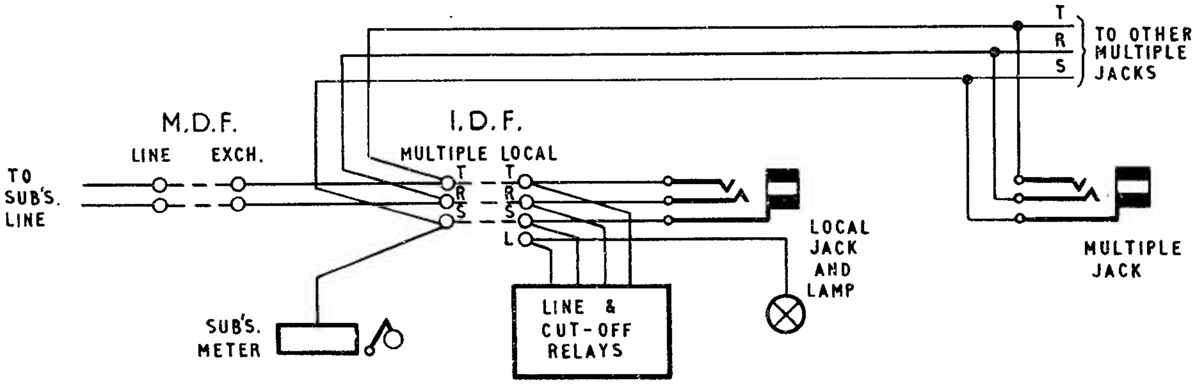


FIG. 16. I.D.F. CONNECTIONS (EARLY EXCHANGE).

7.3 In modern multiple C.B. country exchanges, separate local jacks are not provided and the rearrangement of the calling lamps for distribution of traffic is not considered necessary. This simplifies and reduces cabling and a double-sided I.D.F. is not required, but a single set of terminal blocks is used as a connection point for the cables (Fig. 17).

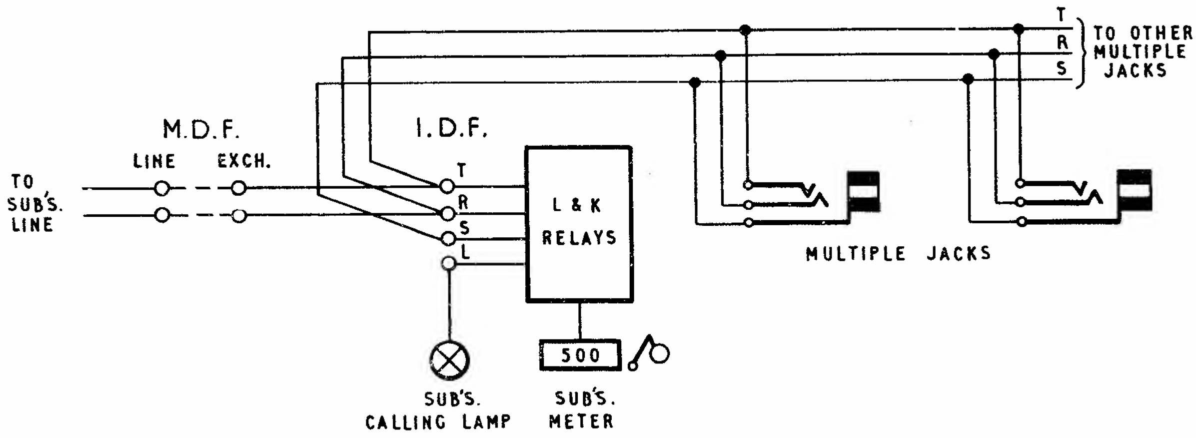


FIG. 17. I.D.F. CONNECTIONS (MODERN EXCHANGE).

8. BASIC SWITCHING CIRCUITS.

8.1 To summarise the basic functions of the local position line and cord circuits, this Section describes briefly the setting up of a local call in a typical C.B. multiple country exchange. For simplicity, only basic circuits are shown in Figs. 18 and 19.

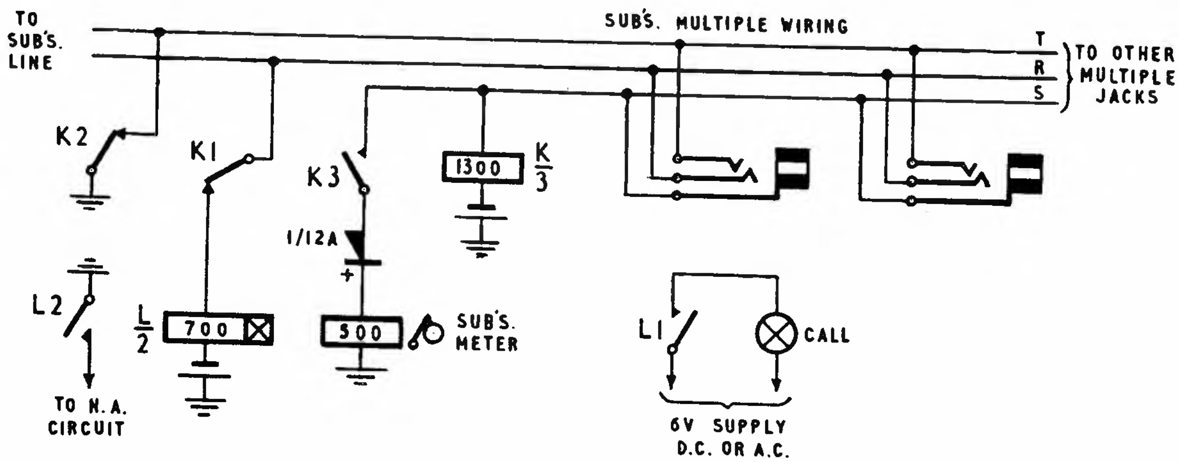


FIG. 18. SUBSCRIBER'S LINE CIRCUIT (C.B. MULTIPLE EXCHANGE).

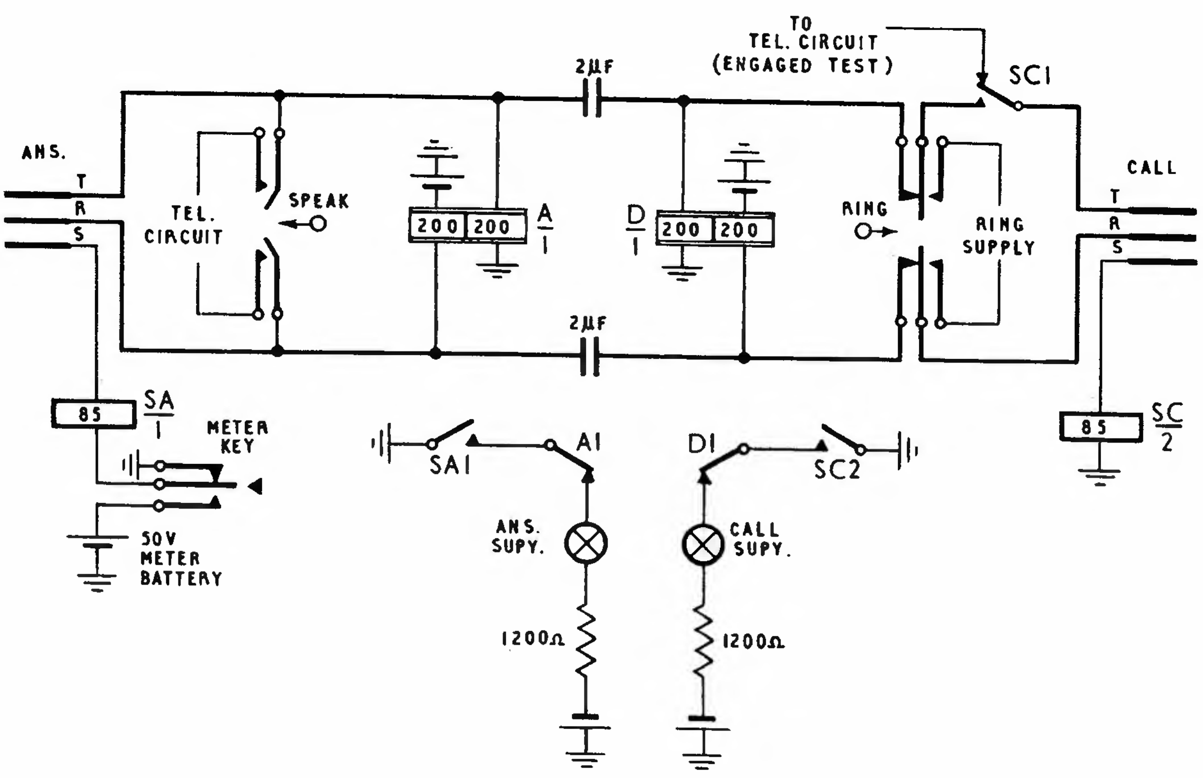


FIG. 19. CORD CIRCUIT (C.B. MULTIPLE EXCHANGE).

8.2 When a calling subscriber lifts the handset, relay L (in the line circuit) operates in series with the telephone loop.

L1 completes the circuit for the calling lamp, which lights.

L2 completes the N.A. circuit, if the N.A. switch is closed.

8.3 The telephonist answers the call by inserting the answering plug of any cord circuit, in the calling subscriber's line jack. This busies the line at other appearances in the multiple.

The transmitter battery feed is supplied via relay A which operates to the subscriber's loop.

Relay K (in the calling subscriber's line circuit) operates in series with relay SA (in the answering cord circuit) over the sleeve connection.

K1 and K2 disconnect battery (via relay L) and earth from the line.

K3 prepares the circuit for subsequent operation of the subscriber's meter.

L1 and L2 release and open the calling lamp and N.A. circuits.

SA1 closes, but the answering supervisory lamp does not light as the circuit is open at the operated contacts A1.

The telephonist operates the "speak" key to connect the telephonist's circuit to the line, and ascertains the number required.

8.4 Engaged test. (Fig. 20.) To avoid connecting calls to jacks which are engaged at another appearance along the multiple, a telephonist must be able to test if a line is free before plugging into the jack to call.

To test the line, the telephonist taps the tip of the calling plug on the sleeve of the required subscriber's jack. When the line is free, there is no sound in the head receiver, but when the line is busy, a click is heard.

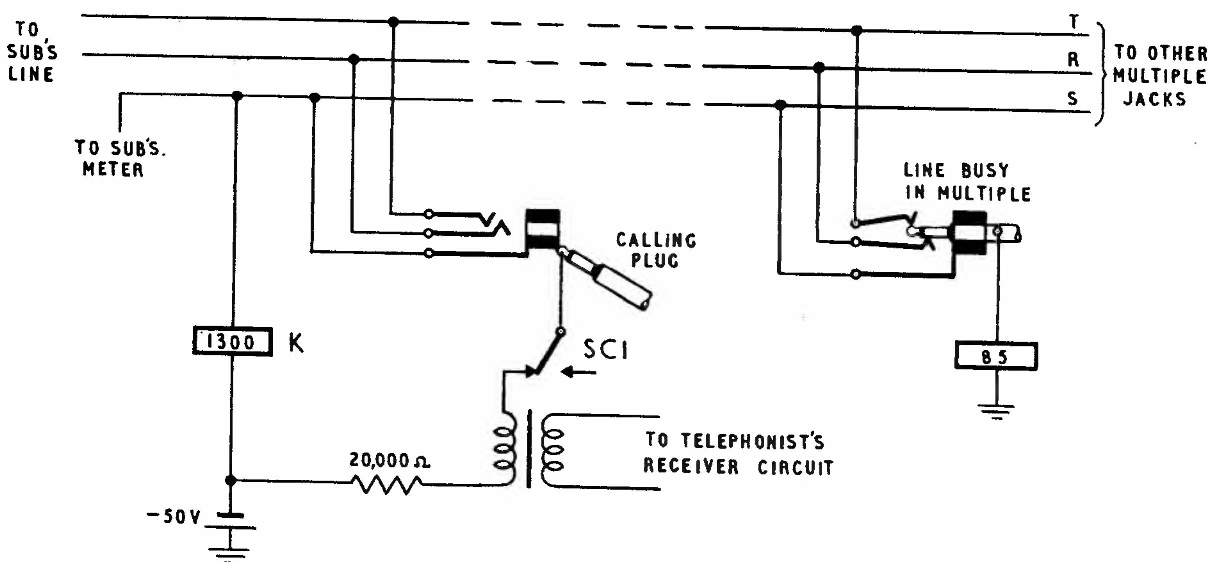


FIG. 20. PRINCIPLE OF ENGAGED TEST.

In Fig. 20, the circuits are arranged so that the sleeve of the jack and the tip of the plug are at the same potential (-50 volts with respect to earth) when a line is free, but have a potential difference when the line is busy.

A line is busied by connecting earth via the supervisory relay (SA or SC) in the cord circuit to the sleeve wire of the multiple when any plug (answering or calling) is inserted in a multiple jack appearance.

In the engaged condition, a current flows from negative battery, through the resistor and transformer in the telephonist's circuit, tip of testing (calling) plug, sleeve wire of multiple, sleeve of plug already inserted in jack multiple, and sleeve supervisory relay to earth. The induced effect in the transformer secondary causes clicks in the receiver. The 20,000 ohm resistor limits the current and, therefore, the intensity of the clicks to a satisfactory value.

8.5 Connecting and ringing. When the required subscriber's line is engaged, the telephonist informs the calling subscriber and withdraws the answering plug, restoring the circuit to normal.

When the line is disengaged, the calling plug is inserted in the called subscriber's line jack. This busies the line at other appearances in the multiple.

Relay SC (in the calling cord circuit) operates in series with relay K (in the called subscriber's line circuit) over the sleeve connection.

SC1 completes the "through" connection for the tip of the cord circuit.

SC2 closes the circuit for the calling supervisory lamp, which lights.

K1 and K2 disconnect relay L from across the called subscriber's line to prevent

- the relay shunting the ringing current away from the subscriber's line and bell,

- the calling lamp falsely lighting when the subscriber answers.

The ringing key is operated and a ring pilot lamp on the position glows to indicate that the ringing current is being sent to line.

8.6 When the called subscriber answers, the transmitter battery feed is supplied via relay D, which operates in series with the telephone loop.

D1 opens the circuit for the calling supervisory lamp.

8.7 When the subscribers "hang up" at the end of the call, the battery feed relays A and D release.

Contacts A1 and D1 complete the circuits for the supervisory lamps, which light.

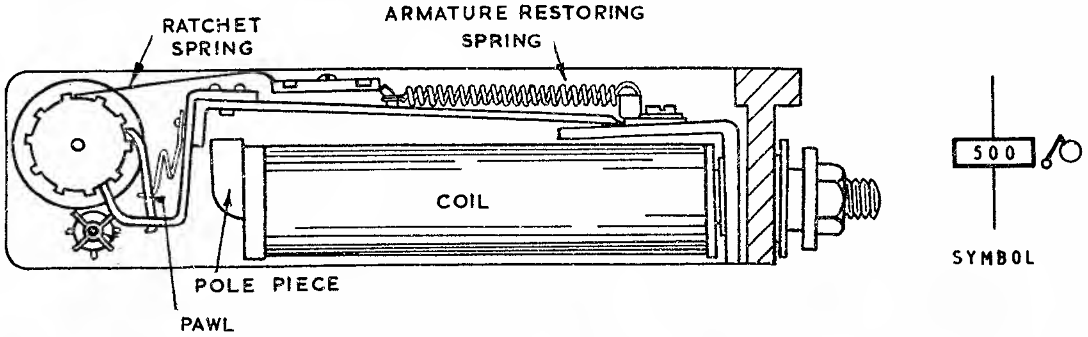
8.8 To register the call, the telephonist presses the meter key which operates the calling subscriber's meter (see Section 9).

The telephonist then takes both plugs from the line jacks, restoring the circuits to normal.

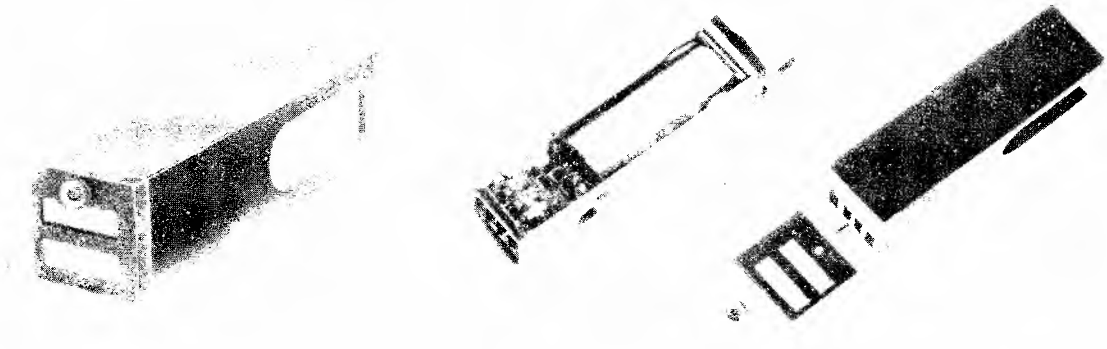
9. REGISTRATION OF CALLS (METERING).

9.1 Subscriber's Meter. In non-multiple exchanges, the telephonist writes the calling subscriber's number on a card when the call is completed.

In multiple exchanges (and also in all automatic exchanges), an electric counter called a meter or register is provided for each subscriber, and these are mounted on a rack remote from the switchboard. The modern subscriber's meter is the type 100 (Fig. 21).



(a) Construction.



(b) Meter Complete, and also with cover and label cap removed.

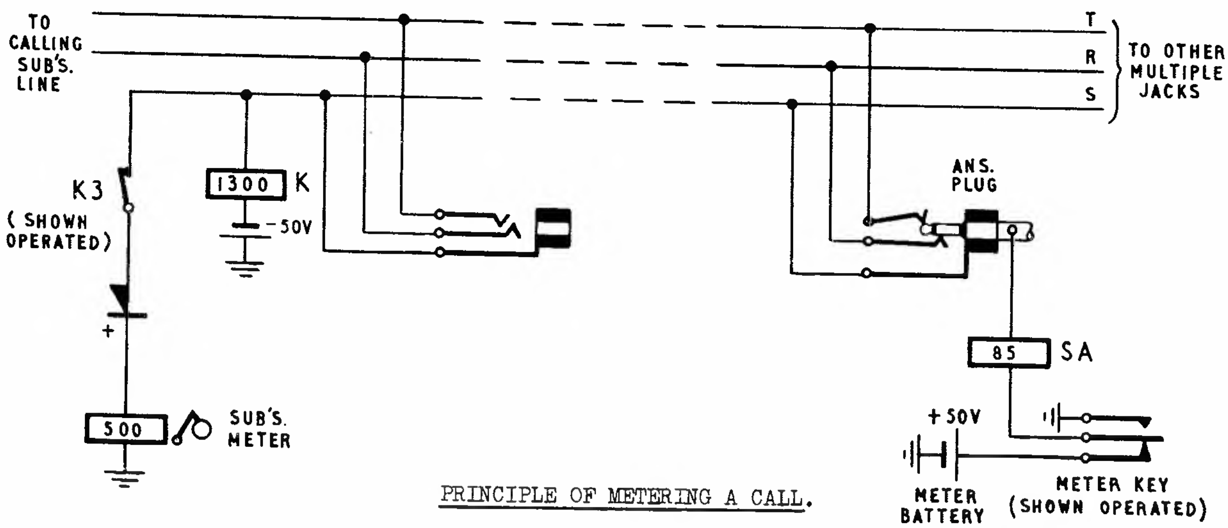
SUBSCRIBER'S METER TYPE 100.

FIG. 21.

The armature is mounted horizontally above the coil with a "knife edge" fulcrum at the mounting plate end. The armature is bent over the core face and has a pawl attached to it by a hinging pin. The register works on the reverse action principle, that is, the pawl engages a tooth of the unit number wheel when the armature is operated, and registration is effected during the return of the armature to normal under the action of the restoring spring. The pawl and detent lock the number wheels when the armature is at rest, so that they cannot be altered by hand.

Each time the armature is operated and released, the ratchet moves a "units" counting wheel forward one digit. After every 10 unit calls, the "tens" wheel is moved forward one figure, and so on for the "hundreds" wheel and the "thousands" wheel in the same manner as the mileometer of a car.

9.2 Fig. 22 shows the basic principle of the metering circuit in a modern C.B. manual exchange.



PRINCIPLE OF METERING A CALL.

FIG. 22.

A small separate "positive" battery which has the negative pole earthed, is provided for metering. This is in addition to the normal exchange "negative" battery, which has the positive pole earthed.

At the end of a call between two subscribers, the telephonist presses the meter key associated with the connecting cord circuit. This connects the positive meter battery via the sleeve of the answering cord to the sleeve wire of the multiple, and operates the subscribers meter in series with the metal rectifier which has low resistance because the applied voltage is now in the conducting direction. Note that the meter is not operated by the negative exchange battery, because this voltage is applied to the rectifier in the high resistance (non-conducting) direction.

When any cord circuit meter key is pressed, a meter pilot lamp on the position, glows to indicate that the call has been registered. Also, an effective meter which is common to all cord circuits on the position, operates to indicate the total number of calls completed at that position. An ineffective meter key which operates an ineffective meter, is provided for each position. The key is operated by the telephonist after each ineffective call (a call which involves the telephonists time but cannot be completed due to, perhaps, the required subscriber being engaged). The effective and ineffective meters (not shown in Fig. 22) enable the traffic loading on the various positions to be checked.

10. TELEPHONIST'S CIRCUIT.

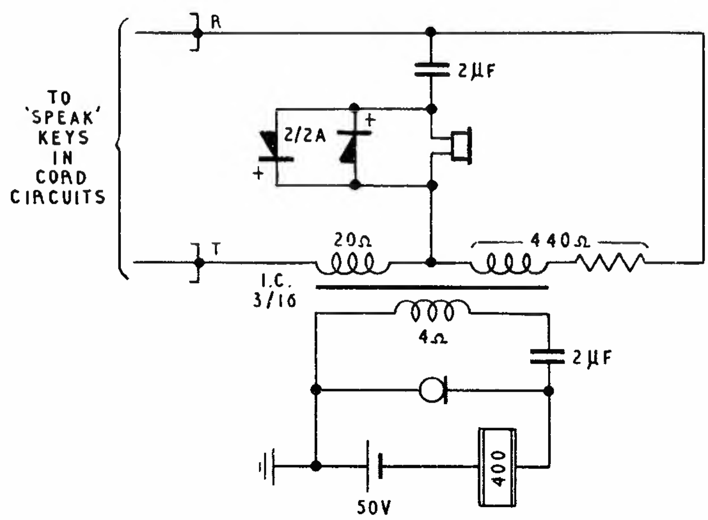
10.1 Fig. 23 shows a typical telephonist's circuit used in C.B. country exchanges.

10.2 The induction coil (I.C.3/16) has the following windings -

(i) A 4 ohm (primary) winding of 255 turns.
(ii) A 20 ohm (secondary No. 1) winding of 400 turns.
(iii) A secondary No. 2 winding of 440 turns. Resistance wire is added to this winding to give a total resistance of 440 ohms, which provides a balance network.

Alternative pairs of stalloy core stampings are interleaved and tightly packed in the winding assembly, to form a closed magnetic circuit. Adjacent stampings are insulated from each other by a coating of oxide or lacquer, to reduce eddy current losses. The unit is enclosed in a mild steel case.

10.3 The circuit operation for transmitting, sidetone suppression and receiving conditions, is similar to the A.S.T.I.C. magneto telephone circuit described in the paper "Magneto Telephones".



TELEPHONIST'S CIRCUIT.

FIG. 23.

In Fig. 23, the steady D.C. flows through the 400 ohm retard coil and the transmitter. The coil resistance limits the transmitter current to about 100 mA.

A 2 μF capacitor "blocks" the D.C. from the 4 ohm induction coil winding, and prevents the possibility of magnetic saturation of the core. It also prevents the 4 ohm winding from shunting most of the D.C. from the transmitter.

When the telephonist speaks into the transmitter, alternating speech currents flow through the 4 ohm winding via the transmitter and 2 μF capacitor. The currents induced in the secondary windings are applied to the subscriber's line via the "speak" key contacts (operated) and the tip and ring of the associated cord circuit.

As the exchange battery is common to all the telephonists' transmitters, the retard coil in each telephonist's circuit has a high impedance (greater than 4000 ohms at 1 kc/s) to prevent crosstalk between the speaking circuits.

The metal rectifiers across the receiver reduce the intensity of high levels of speech or noise from the telephonist's own transmitter. They also reduce the intensity of clicks in the receiver when making engaged tests or during switching. The rectifiers normally act as a high resistance shunt and have little effect on faint clicks or normal levels of speech. When the P.D. rises across the receiver, the rectifier resistance is reduced and this by-passes the current surge.

The 2 μF capacitor in series with the receiver prevents D.C. flowing through the receiver and rectifiers via the A relay in the cord circuit. This would reduce the efficiency of the receiver and cause unsatisfactory operation of the rectifiers.

10.4 Position Coupling. In order that fewer telephonists may be on duty during periods of light traffic, the telephonists' circuits of any desired number of positions may be coupled together. The operation of a "position couple" key on any position, connects it to the adjoining position (either right or left, depending on the exchange). This allows the cord circuits of all coupled positions to be used with the telephonist's set plugged into any one of the positions.

11. TEST QUESTIONS.

1. State two essential differences between magneto and C.B. working.

2. Why are lamps used instead of indicators for signalling and supervision in C.B. exchanges ?

3. List the facilities provided by the local positions in a C.B. exchange.

4. Draw the basic line and cord circuit connection between two local subscribers in a non-multiple C.B. exchange.

5. In a C.B. exchange, how does the telephonist -

   (i) know when a subscriber is calling,

   (ii) answer a call,

   (iii) ring the called subscriber,

   (iv) supervise the progress of a call,

   (v) know when a call is finished ?

6. Why is a battery with a low internal resistance essential for C.B. operation ?

7. Describe the Stone method of battery feed.

8. Briefly compare the methods of providing individual supervision for each cord in C.B. non-multiple and multiple exchanges.

9. Briefly compare the principles of transfer and multiple working.

10. In early multiple exchanges, the term "local jack" signifies ....

11. What is a recording junction ?

12. What is an order wire ?

13. In a multiple C.B. country exchange

   (i) the local positions handle calls between ....

   (ii) the trunk positions are used for connection between ....

14. What is the main function of the I.D.F. in a modern C.B. multiple exchange ?

15. Draw a simple sketch to show the I.D.F. connections in a multiple exchange which has no separate local jacks.

16. Draw the basic subscriber's line circuit in a C.B. multiple exchange and state the functions of the relays.

17. What is an engaged test ?

18. Why is this facility required ?

19. Explain, with diagrams, the basic principle of an engaged test.

20. Describe the basic construction and principle of operation of a subscriber's meter.

21. The symbol for a subscriber's meter is ....

22. Explain, with diagrams, the basic principle of the metering circuit.

23. At what stage during the progress of a call, is the meter key operated ?

24. Draw a typical telephonist's circuit used in a modern C.B. exchange, and state the reasons for each item of apparatus.

END OF PAPER.

THE AUSTRALIAN POST OFFICE

COURSE OF TECHNICAL INSTRUCTION

Engineering Training Section, Headquarters, Postmaster-General's Department, Melbourne C.1

INTRODUCTION TO AUTOMATIC TELEPHONY.

1. INTRODUCTION.

1.1 As the number of telephones in the larger cities continued to increase, the operating costs of the large manual switchboards became excessive. The automatic system reduces operating costs and increases the efficiency of the telephone service, and this system is replacing the manual systems.

1.2 Automatic telephony is a C.B. system in which the exchange switching equipment operates under the control of the calling subscriber's dial, to set up the desired connection without the need for a telephonist. The equipment also performs the ringing, metering and other functions. As in the C.B. manual system, a central battery at the exchange supplies D.C. to operate the subscribers' telephone transmitters and the exchange equipment.

1.3 The first automatic telephone system was developed by Strowger (U.S.A.) in 1891. The first automatic exchange in Australia was installed at Geelong, Victoria, in 1912, and the Department subsequently adopted the policy of making automatic the manual exchanges in capital cities and large country centres. In recent years, this policy has been extended to include small country exchanges, called rural automatic exchanges (R.A.Xs).

Many different types of automatic systems have been designed, but in Australia the step-by-step system invented by Strowger is the one in common use. Although many modifications and refinements have been added, the present system is similar in principle to the original system.

1.4 This paper explains some of the basic principles of automatic telephony as an introduction to the more advanced description in other papers of the Course.

2. BANKS AND WIPERS.

2.1 A simple approach to the automatic system is to consider the jack field of a C.B. manual switchboard. We have seen that this consists of a number of subscribers' line jacks arranged in rows. Each jack has two springs (tip and ring) which connect to the two wires of a subscriber's line, and a sleeve connection which is used for supervision, metering and other purposes.

After the telephonist has answered a calling subscriber, the movement of the calling plug to the called subscriber's jack is generally a diagonal movement. This is equivalent to a vertical movement to select a particular row of jacks, and a horizontal movement to select the required jack in that row.

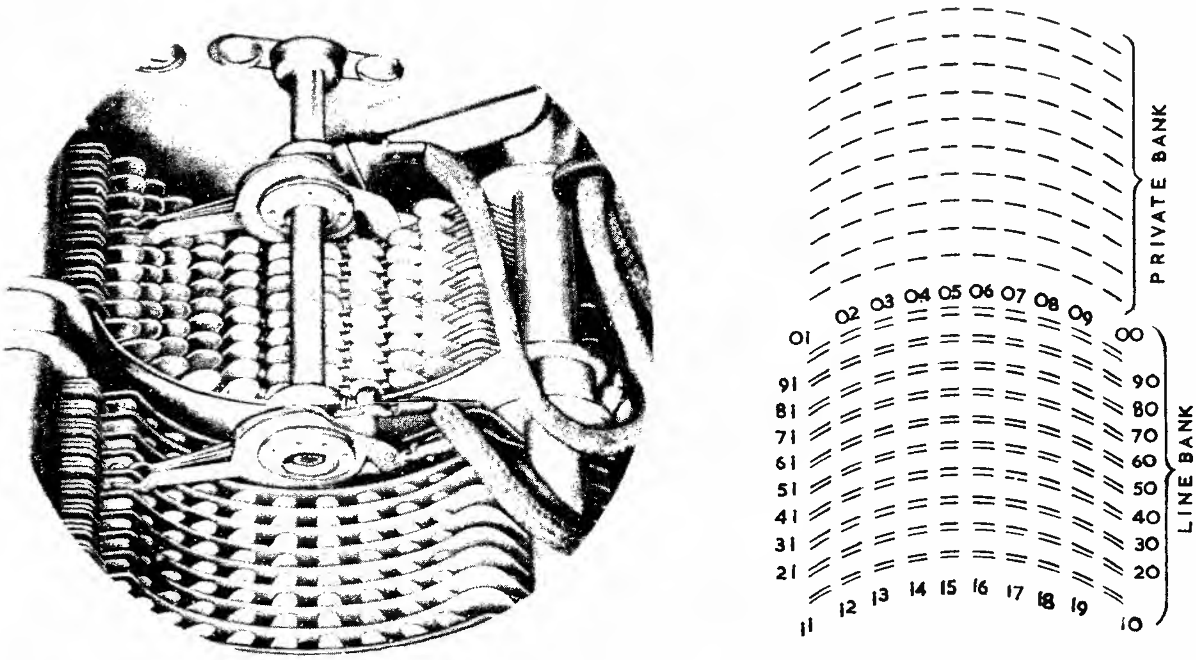
2.2 Contact Banks. Similarly, in an automatic exchange, the two wires of each subscriber's line (designated + and - within the exchange) connect to insulated contacts arranged in the arc of a circle in 10 rows or levels, each level containing 10 pairs. This is called the line contact bank and is the lower bank in Fig. 1.

The upper bank, called the private contact bank, is similar in arrangement except that single contacts are used for each line. The private (P) contacts are equivalent to the sleeve wire in a manual exchange, and are used for the engaged test, metering and other purposes.

Fig. 1 shows the banks used in early type exchanges, and is equivalent to the jack field of a 100 line C.B. manual switchboard.

2.3 Wipers. Contact brushes called wipers (line and private) which are equivalent to the calling plug in a manual exchange, make connection with the bank contacts. Flexible wiper cords are connected to the wipers in an automatic mechanism called a selector or switch. The normal position of the wipers is to the left and below the lowest level of the associated contacts.

The selector mechanism moves the wipers vertically and horizontally under the control of the calling subscriber's dial. The vertical movement steps the wipers up the side of the bank to select the particular level, and the horizontal (or rotary) movement steps the wipers over the sets of bank contacts to select the required contacts in that level.



(a) View of Banks and Wipers.

(b) Bank Contact Numbering.

FIG. 1. BANKS AND WIPERS (EARLY TYPE).

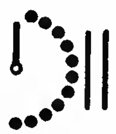
2.4 Since two distinct movements are necessary to select a particular group of contacts (+, - and P), the mechanism is called a bimotional selector (or bimotional switch). Two commonly used types are the group selector and the final selector (see Section 3).

2.5 Bank contact numbering (Fig. 1b). Note that contacts 01 to 00 are in the top level, and contacts 11 to 10 are in the bottom level. This is because ten pulses are transmitted when the digit 0 is dialled. Thus, in a final selector, contact 10 is reached by trains of one and ten pulses, not by dialling 0 (ten pulses).

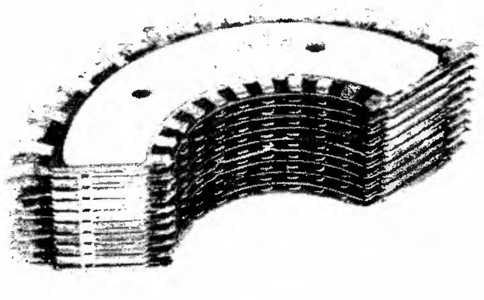
2.6 Modern contact banks. Modern bimotional selectors generally use three banks and three pairs of wipers. The bottom bank provides the + and - contacts for a group of 100 outlets or lines; the middle bank, the + and - contacts for another 100 outlets or lines; and the top bank, the P contacts for the 200 outlets or lines. This is equivalent to the jack field of a 200 line C.B. manual switchboard.

Fig. 2a shows a modern type of contact bank which has 11 contacts per level. The eleventh contact is used for traffic metering and testing purposes, and to provide a busy signal in some selectors when all outlets are in use.

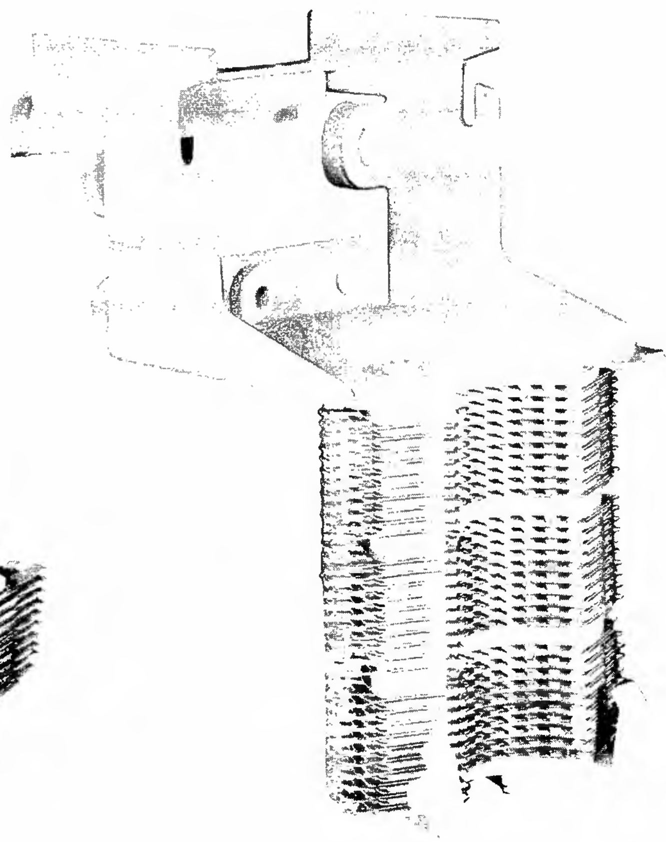
Banks are generally known by the number of contacts. Two types are available - the 220 point line or twin contact private bank and the 110 point single contact private bank. The contact banks are bolted to specially shaped cradles (Fig. 2b).



SYMBOL FOR WIPER AND BANK CONTACTS, CODED +, -, P.



(a) 220 Point Bank.



(b) Bank Assembly.

FIG. 2. MODERN TYPE CONTACT BANKS.

2.7 Bank multiple. In exchanges, the bank assemblies are mounted in rows (Fig. 3). Similarly numbered contacts on each bank are connected together by multiple wiring in a similar manner to the multiple jack wiring in a large manual exchange. The wiring terminates on tags at the back of the contact banks.

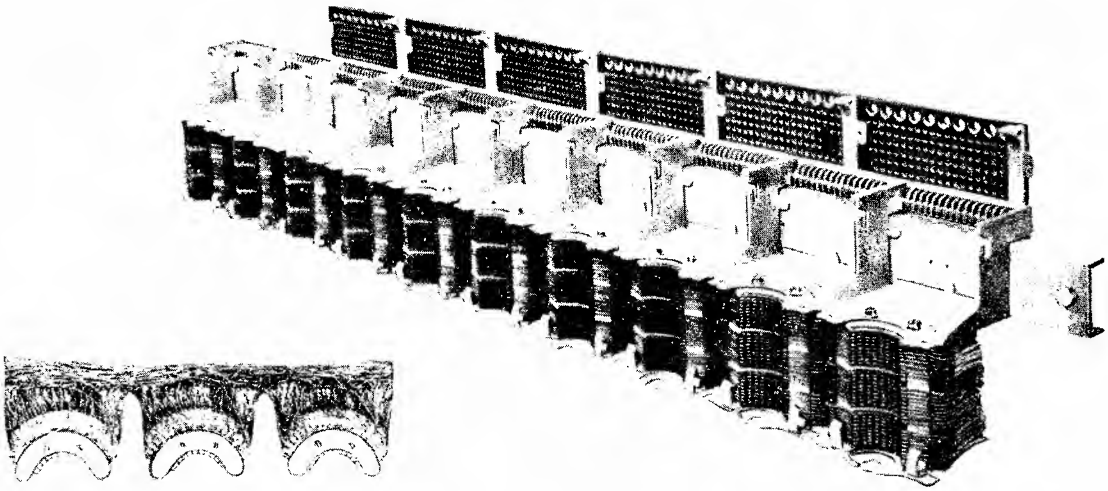
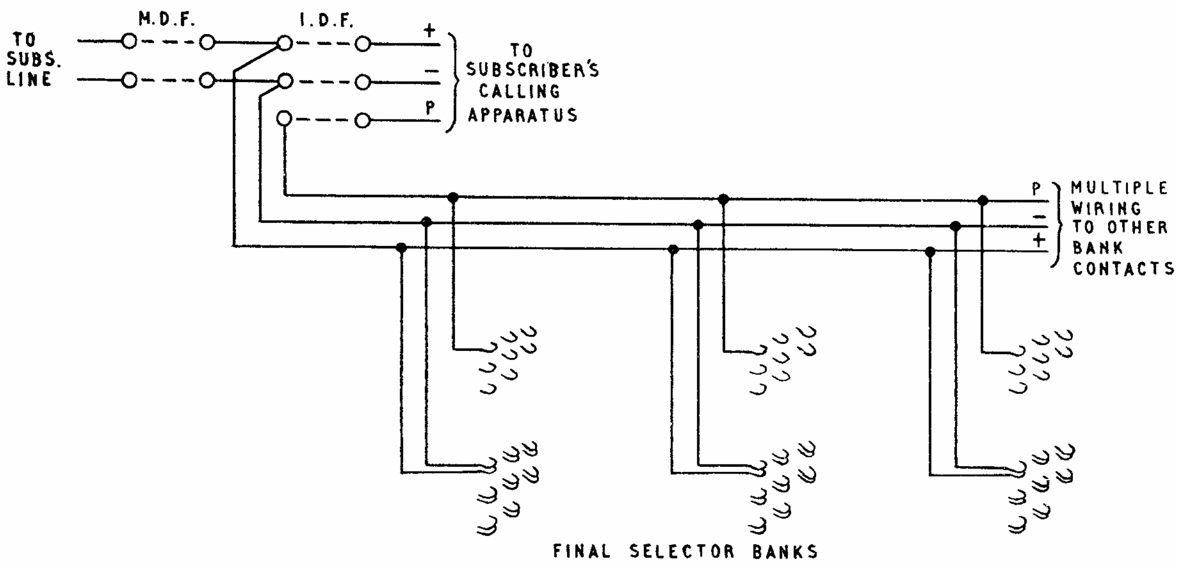


FIG. 3. MULTIPLE BANKS.

2.8 Subscriber's multiple wiring. (Fig. 4.) Each subscriber's line is connected from the I.D.F. to the final selector bank multiple. The wiring from the I.D.F. to the subscriber's calling apparatus corresponds to the local appearance in a C.B. multiple exchange. Outgoing calls (from a calling subscriber) are made via the subscriber's calling apparatus; and incoming calls (to a called subscriber) are connected via the final selector bank multiple.



PRINCIPLE OF SUBSCRIBER'S BANK MULTIPLE WIRING.

FIG. 4.

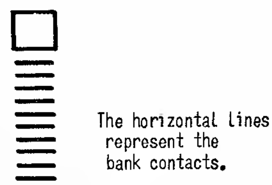
3. BIMOTIONAL SELECTORS.

3.1 In exchanges installed in Australia prior to 1938, most bimotional (two motion) selectors were 100 line (or outlet) of Strowger design or similar. The selectors installed after that year were of an improved design known as the type 2000. The switching mechanism and circuits were also redesigned to give 200 lines (or outlets) - 20 per 10 step level - but the basic principles were still Strowger. The earlier switching mechanism became known as pre-2000 type. In 1957, a new mechanism was introduced, known as the type S.E.50. For many circuits, this is interchangeable with the 2000 type selector.

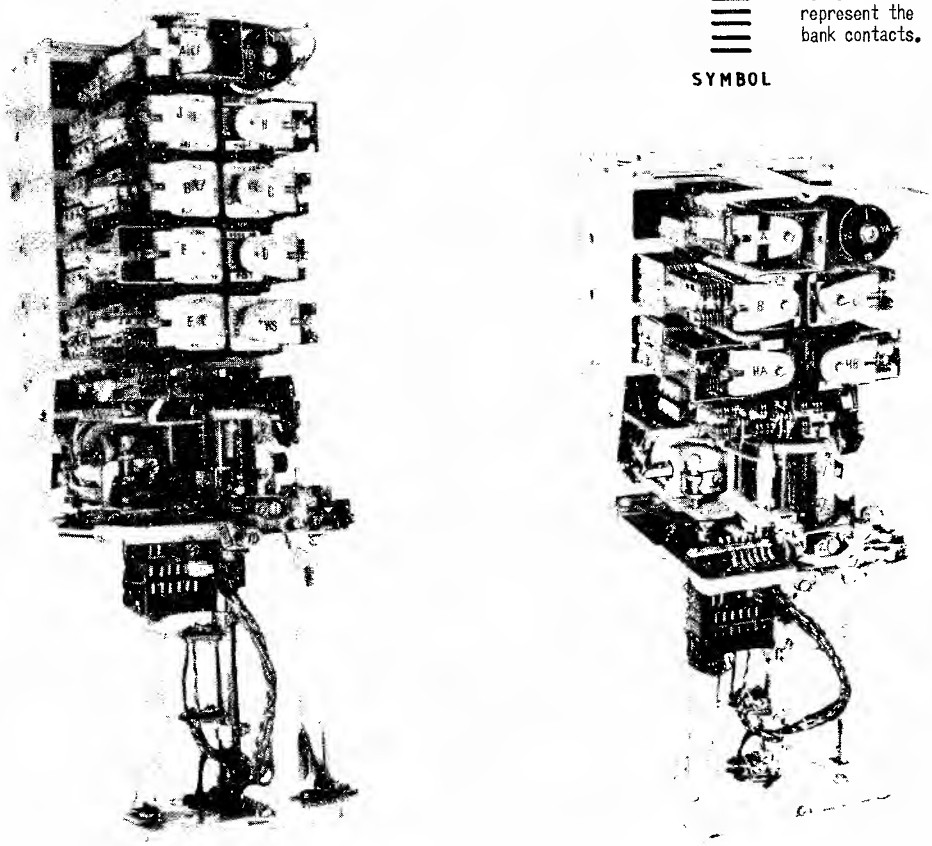
3.2 Fig. 5 shows typical 2000 type final and group bimotional selectors.

Final selectors are used to perform the final stages of connection (tens and units) to the called subscriber's line.

Group selectors are used in large exchanges to select a particular group of subscribers, for example, the ten thousands group, the thousands group and the hundreds group.



SYMBOL



(a) Final Selector. (b) Group Selector.

FIG. 5. BIMOTIONAL SELECTORS (2000 TYPE).

Each mechanism consists of a metal frame on which are mounted electromagnets, mechanically operated springs and relays to control the movement of the wiper assembly, and to enable the selector to perform its required functions. A dust cover (not shown) is fitted on each selector.

Note that the number of relays differ for each type. This is because the selectors perform different electrical functions, although the main mechanical functions are the same - each selector lifts the wipers to a particular level, rotates them around the bank and finally returns them to their normal position.

3.3 Fitting Selectors. (Fig. 6). Modern type selectors are fitted in cradles, being located by tongues engaging at the top and bottom of the banks. This enables the selectors to be withdrawn and replaced, no screws or nuts having to be removed as in earlier types.

Electrical connections (which supply battery, dial pulses, etc.) for the operation of the selectors, are made by a special type of jack (called a "U" jack) fitted between the cradle mountings. When a selector is fitted in the cradle, contacts on the back of the selector automatically make connection with these jacks.

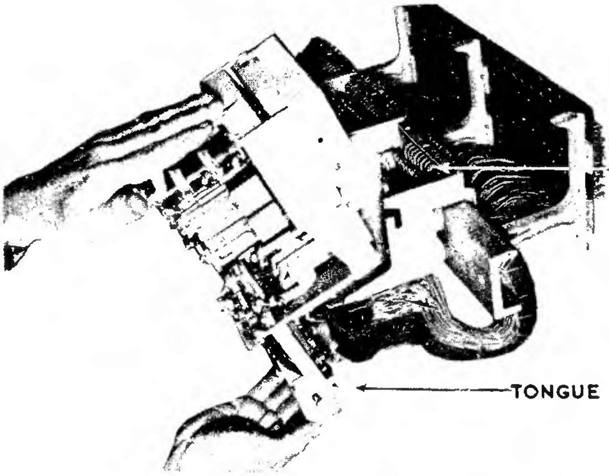


FIG. 6. FITTING BIMOTIONAL SELECTORS (2000 TYPE).

3.4 Movement of wipers. In bimotional selectors, electromagnets are used to lift the wipers vertically (vertical magnet) and to turn them horizontally (rotary magnet). Fig. 7 shows a basic arrangement.

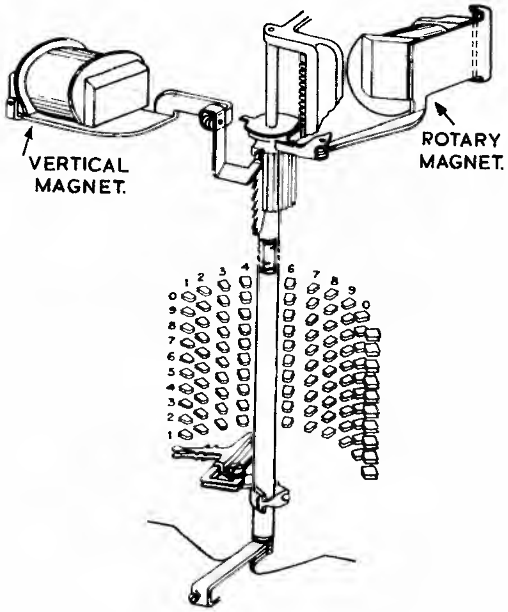
In the final selector, both the vertical and horizontal movements are controlled by a train of dial pulses. The vertical magnet lifts the wipers in a number of steps up the side of the bank to the dialled level, and the rotary magnet rotates the wipers step by step, to the set of bank contacts corresponding to the number dialled. The wipers are then connected to the called subscriber's line via the final selector bank multiple wiring.

In the group selector, the vertical movement only is controlled by dial pulses. The vertical magnet steps the wipers to the dialled level. The rotary magnet is energised immediately after the last pulse in the train, and this automatically "cuts-in" the wipers and steps them over the contacts of the level until a free outlet to the next selector is reached. This is called a hunting, searching or self-drive action and requires no dial pulses for its operation.

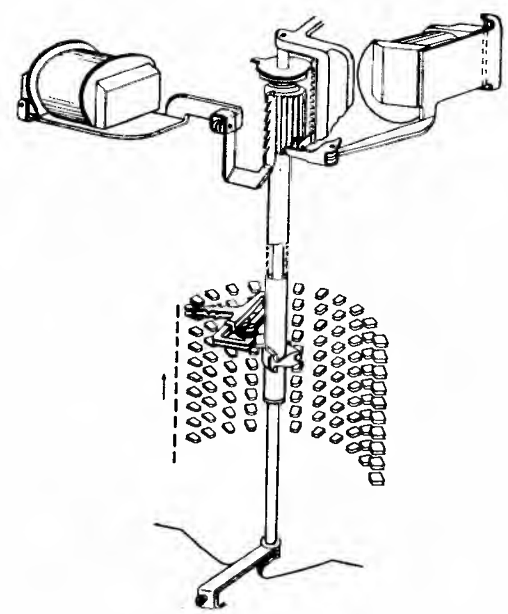
In modern selectors, the vertical and horizontal movements are against spring tension.

At the end of a call, the rotary magnet of a 2000 type selector automatically steps the wipers to the vacant 12th rotary position. The wipers then fall and return under the first level of contacts to the normal rest position.

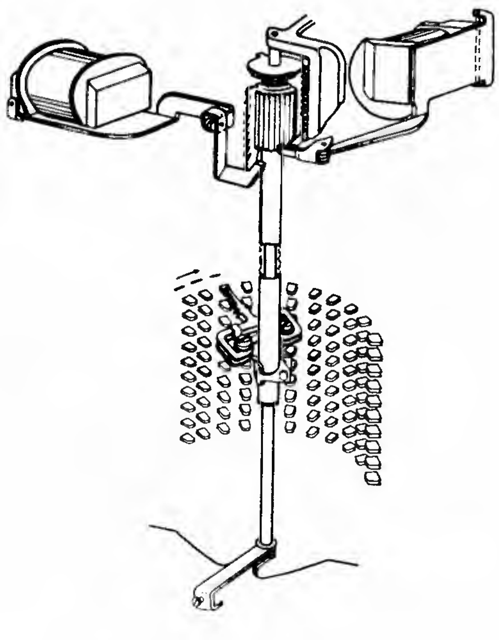
In other selectors, which do not step to the 12th rotary position before release, a release magnet operates at the end of a call. The wipers then rotate anti-clockwise out of the bank level and fall to the normal rest position.



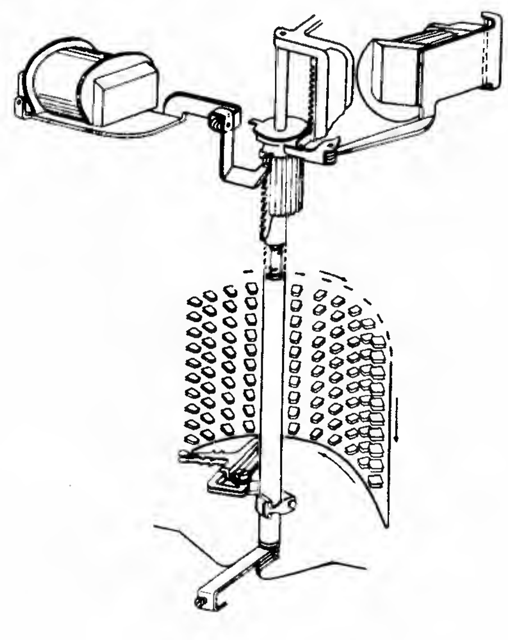
(a) Wiper Carriage in Normal Position.



(b) Wipers Stepped to 10th Level.



(c) Wipers Stepped to 3rd Contacts on 10th Level.



(d) Release Action.

VERTICAL, ROTARY AND RELEASE ACTIONS OF 2000 TYPE SELECTOR.

FIG. 7.

4. SIMPLE 100 LINE EXCHANGE.

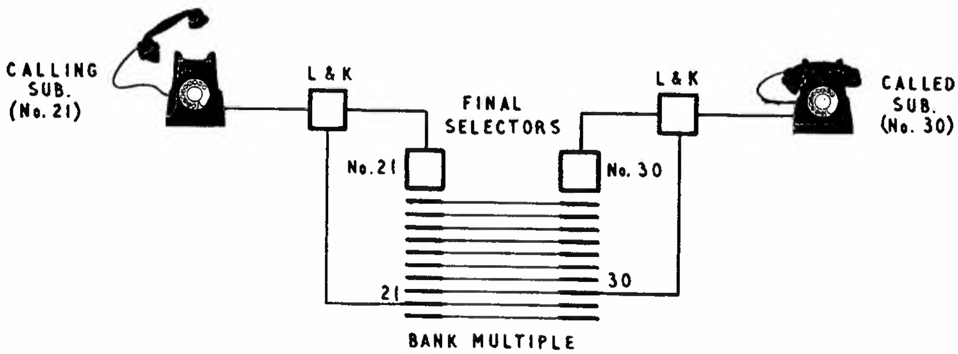
4.1 A simple 100 line exchange could consist of 100 final selectors, one for each line. Each subscriber is represented by contacts in the bank of each selector, and this is provided by the bank multiple wiring. Thus, each line has 100 multiple appearances, one on the contact bank of each selector.

When a subscriber lifts the handset to make a call, the associated final selector is taken into use, and by dialling two digits, the required connection is made as described in paragraph 4.4, via the bank multiple wiring.

4.2 Fig. 8 shows a simplified trunking diagram of a call through the exchange.

Subscriber No. 21 is calling No. 30 and, on lifting the handset, final selector No. 21 is seized. This is stepped up 3 levels by the first digit dialled and on to contacts 30 by the second digit and, providing subscriber 30 is disengaged, ringing current is applied to the line.

On calls from subscriber 30, the operation is similar but final selector No. 30 is used.



SIMPLE 100 LINE EXCHANGE.

FIG. 8.

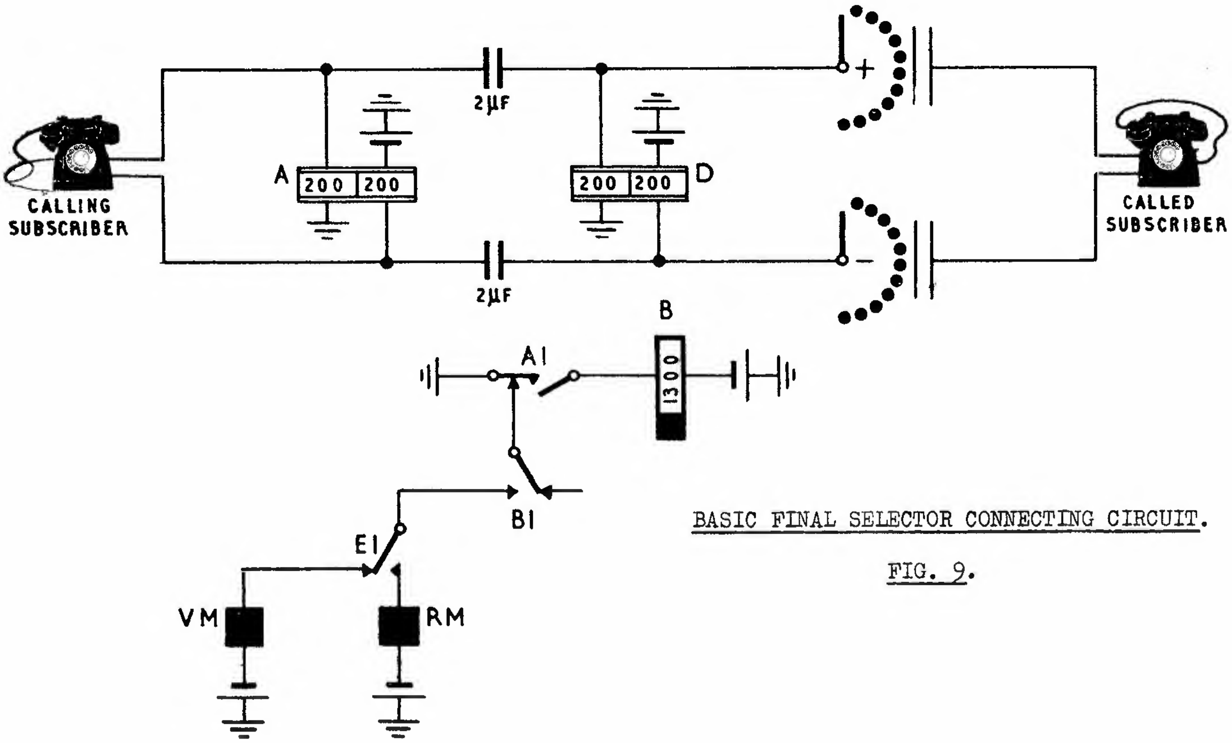
4.3 L and K relays. Two 600 type relays designated line (L) and cut-off (K) are provided for each line. These function in a similar way to the L and K relays in a C.B. manual subscriber's line circuit.

On an outgoing call, the relays extend the calling subscriber's line to a selector.

On an incoming call, they disconnect the called subscriber's calling apparatus to prevent its false operation.

4.4 Basic Connecting Circuit. (Fig. 9). One function of the final selector is to provide a transmitter battery feed for the telephones. The high impedance relays A and D are the retards in the transmitter battery feed which is the Stone or Bridged impedance type.

For economy, the battery feed relay for the calling subscriber (relay A) also operates under the control of the calling subscriber's dial to repeat the pulses to the vertical magnet (VM) and the rotary magnet (RM). It is not practicable to operate these magnets in series with the subscriber's line and dial contacts, because of the heavy current (about one ampere) required to operate the magnets.



BASIC FINAL SELECTOR CONNECTING CIRCUIT.

FIG. 9.

Relay A operates in series with the calling subscriber's telephone loop when the handset is lifted. Contact A1 operates relay B. Contact B1 prepares the circuit for VM, the circuit for which is open at the operated contacts A1.

When the subscriber dials the first digit, a number of interruptions in the line current (pulses) corresponding to the digit dialled, are transmitted. Relay A responds to the pulses, but relay B is slow to release and remains operated during the periods when A1 is normal.

With A1 normal and B1 operated, a circuit is completed for VM, which operates with each pulse and lifts the selector wipers a number of steps according to the digit dialled. The wipers are now alongside the bank level containing the required number.

At the end of the first train of pulses, relays A and B remain operated and the operation of another relay (not shown in Fig. 9) causes the change-over contacts E1 to prepare the circuit for RM.

When the last digit is dialled, the pulses repeated by the A relay operate RM, which steps the wipers on to the called subscriber's bank contacts.

Connection between the two subscribers is thus established as the result of dialling two digits and the resultant transmission of two pulse trains.

At the end of the call, the caller replaces the handset, opening the circuit of relay A which releases. Relay B then releases after its slow release period and a circuit is completed for the release of the selector switching mechanism, which restores to normal.

4.5 Importance of standard dial pulses. For satisfactory operation of the selector mechanism, the break period of the dial pulsing contacts should be $66\frac{2}{3}$ mS, and the make period $33\frac{1}{3}$ mS.

When the break period is too long, relay A may release for a time long enough to release relay B. This prevents operation of the vertical and rotary magnets.

When the break period is too short, the vertical (or rotary) magnet may not receive current for sufficient time for it to saturate and lift (or rotate) the shaft and wipers.

The make period must be long enough to saturate relay B, so that this relay will hold satisfactorily during the subsequent break period.

4.6 Table 1 summarises the basic operations when switching a call automatically, and compares the similar steps in a C.B. multiple exchange.

AUTOMATIC	C.B. MANUAL
When calling sub. lifts handset, line is connected to a free selector and dial tone is sent to caller.	When calling sub. lifts handset, line lamp lights on switchboard. Telephonist inserts answering plug in line jack and speaks to caller.
Sub. dials.	Sub. tells required number to telephonist.
Final selector steps wipers to bank contacts of called number and tests private bank contact in the multiple.	Telephonist tests sleeve of called subs. jack in the multiple.
When line is engaged, selector sends busy tone to caller.	When line is engaged, telephonist informs caller.
When line is free, selector applies ringing current to line, and sends ring tone back to caller.	When line is free, telephonist inserts calling plug into jack and rings.
When called sub. answers, selector cuts off ringing current and ring tone, connects the two lines via a transmitter battery feed and operates the calling subs. meter.	When called sub. answers, lines are connected via cord circuit which also supplies transmitter battery feed.
When calling sub. replaces handset selectors restore to normal (release). If they do not release, an alarm is given at the exchange.	When subs. "hang up", cord circuit supervisory lamps light. Telephonist meters the call and takes down connection.

COMPARISON OF MANUAL AND AUTOMATIC SWITCHING.

FIG. 1.

5. SUPERVISORY TONES.

5.1 Supervisory tones are provided in automatic exchanges to tell the calling subscriber how the call is progressing. The tones have different characteristics for easy identification, and they are derived from Ring and Tone Generators.

5.2 The standard tones are -

Dial tone, a continuous low-pitched tone heard when the handset is lifted to indicate that the telephone is connected to a free selector, and that dialling may commence. If the subscriber dials before the selector is ready to receive the pulses, a wrong number or a "no progress" call results. The tone stops when the first digit is dialled.

Ring tone, an interrupted high-pitched tone (superimposed on the $16\frac{2}{3}$ c/s ringing current), heard after dialling is completed to indicate that the call has proceeded satisfactorily and that ringing conditions have been set up. The tone stops when the called subscriber answers.

Busy tone, an interrupted high-pitched tone which indicates that the connection cannot be made immediately but may be attempted again later. When heard before or during dialling, busy tone indicates that the connecting switches are engaged on other calls; when heard after the complete number is dialled, it indicates that the called subscriber is engaged.

Number Unobtainable (N.U.) tone, an interrupted high-pitched tone (similar to the busy tone but more prolonged) which indicates that the call should be abandoned. When heard during dialling, N.U. tone indicates that the selector has been connected to a non-working level; when heard after the complete number is dialled, it indicates that the number dialled is not a working line or is temporarily unavailable.

5.3 The standard tones are summarised in Table 2. Some of the older exchanges may differ slightly from these standards.

TONE	FREQUENCY	PERIODS OF INTERRUPTION
DIAL	33 C/S (SEE NOTE)	CONTINUOUS
RING	$400/16\frac{2}{3}$ C/S	0·4 SEC. ON, 0·2 SEC OFF, 0·4 SEC. ON, 2 SECS. OFF
BUSY	400 C/S	0·75 SEC. ON, 0·75 SEC. OFF, 0·75 SEC. ON, 0·75 SEC. OFF
N.U.	400 C/S	2·5 SECS. ON, 0·5 SEC OFF

NOTE: Although dial tone has a fundamental frequency of 33 c/s, it is rich in harmonics and most of the sound energy is actually of a higher frequency. This is necessary since the response of both telephone receivers and the ear to 33 c/s is very low and a pure tone of this frequency would be inaudible to many people.

CHARACTERISTICS OF STANDARD TONES.

TABLE 2.

6. 100 LINE EXCHANGE USING UNISELECTORS.

6.1 In the simple 100 line exchange described in Section 4, each subscriber's final selector is used only when that subscriber originates a call, but is not required on calls from other telephones. If all 100 telephones were in use, only 50 final selectors would be required. In fact, only a few subscribers are likely to be using the telephone at any one time, depending on their calling rate. Under average conditions, about 10-15 final selectors will handle calls between 100 subscribers.

6.2 As bimotional selectors are expensive, it is more economical to provide only sufficient to handle the normal traffic and to give the subscribers access to these as a common group. This may be done by connecting each subscriber's line via L and K relays to a cheaper item of equipment, known as a uniselector (see Section 7). The combination of these relays and the uniselector is called the subscriber's line circuit.

6.3 In Fig. 10a, the uniselector banks are multipled together and connected to a group of 10 final selectors. When a calling subscriber lifts the handset, the associated uniselector automatically hunts for a free final selector. The selector is seized and guarded against intrusion from other calling subscribers. The subscriber then dials the required number.

Fig. 10b shows a simplified trunking diagram where subscriber No. 21 has seized a final selector and is calling No. 30, as before. Note that on calls from subscriber No. 30, the same final selector may be used to set up a call. Fig. 10c shows a general trunking diagram for a call within the exchange.

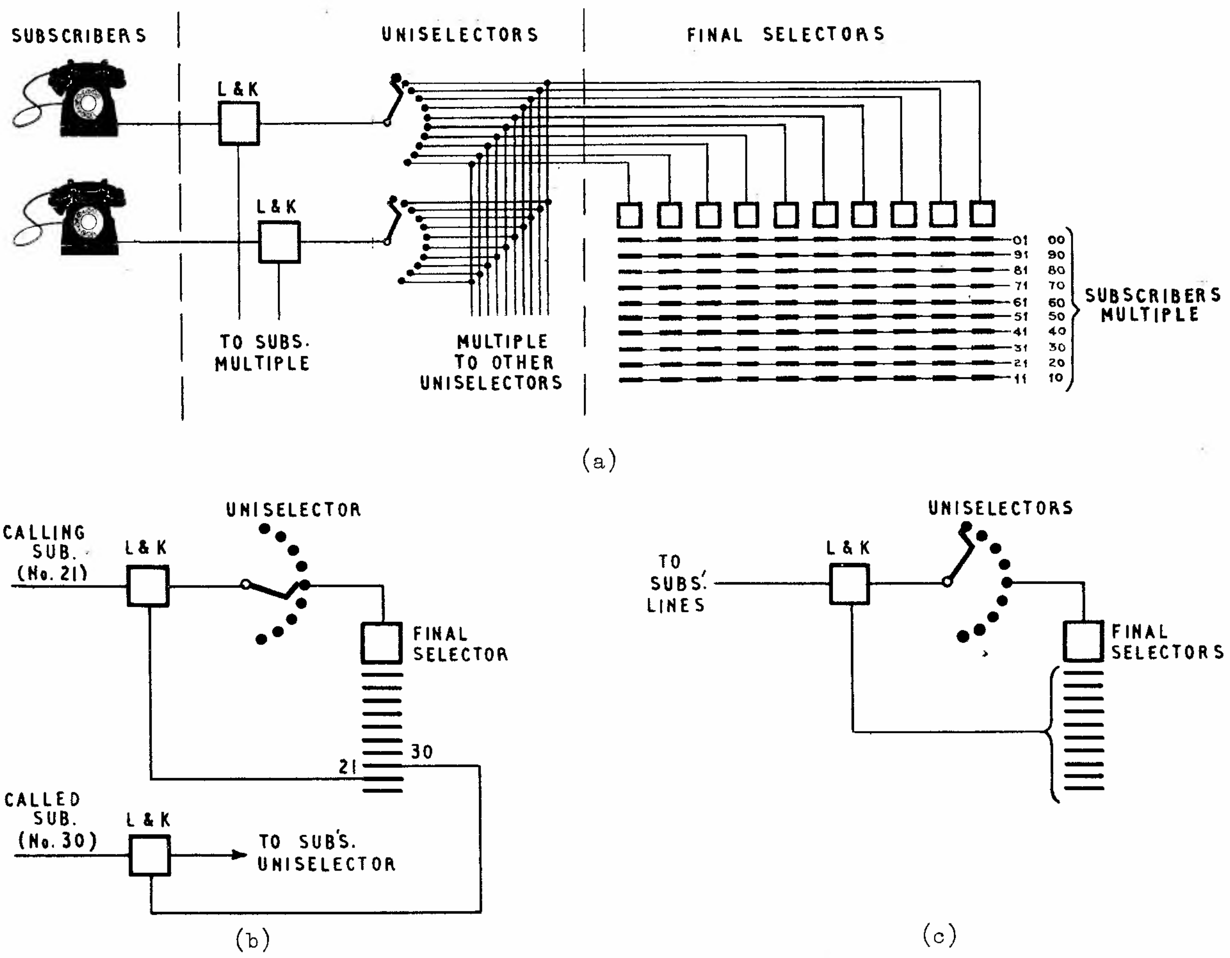


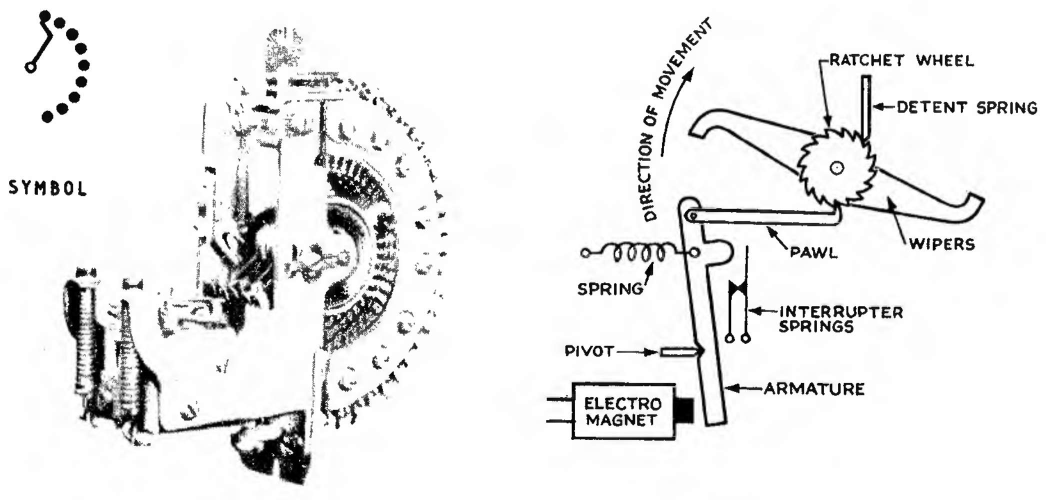
FIG. 10. 100 LINE EXCHANGE USING UNISELECTORS.

7. UNISELECTORS.

7.1 Uniselectors (one-motion selectors) are often used with bimotional selectors in automatic switching. Rotary motion uniselectors (Fig. 11a) are generally used.

In this type, a ratchet is controlled by an electromagnet and armature which operate and release in quick succession. The ratchet wheel is attached to a spindle to which the wipers are clamped, and these move in one plane only, to engage the bank contacts arranged in an arc. Wipers and associated contact banks are provided for the +, - and P circuit connections. Additional wipers and banks are also fitted to provide special circuit facilities. The + and - wipers are non-bridging, and the P wiper is the bridging type. Although 9 bank contacts only are shown in the symbol, the capacity of the bank is usually 25 or 50 contacts, depending on the type and purpose of the uniselector.

7.2 Principle of operation (Fig. 11b). When the magnet is energised, the armature slides the pawl into the next ratchet wheel tooth. A detent spring prevents movement of the wipers. When current ceases in the magnet coil, the armature restores to normal under the spring tension; the pawl draws the ratchet wheel forward one step which moves the wipers on to the next bank contact. This is a "reverse action" type. because the wipers step under spring control and not directly by electric current. In some earlier "forward action" types, the ratchet and wipers move when the magnet armature is operated.



(a) (b)

FIG. 11. ROTARY UNISELECTOR.

To provide a self-drive hunting action like the rotary operation of a group selector, the electromagnet circuit is connected in series with interrupter springs which break when the armature is attracted. The armature releases, and the interrupter springs again make. This action is similar to the operation of a trembling bell, and it automatically drives the wipers round the contacts to find a free outlet. Circuit details are described in other papers of the Course.

7.3 Unlike the bimotional selector, the uniselector wipers always engage a set of bank contacts. In modern circuits, homing type uniselectors are used in which the wipers are returned to a particular position ("home" position) after use. This type is more commonly used than the non-homing type in which the wipers remain on the last operated position.

7.4 Several other types are in use, one type (motor uniselector) having a small electric motor to advance the wipers.

8. 1000 LINE EXCHANGE.

8.1 In a 100 line exchange (two-digit system), two digits are dialled to gain connection to any number. To extend the exchange to 1000 lines, the subscribers' numbers must have three digits; and an additional switching stage (group selector) is inserted between the uniselector and final selector. The numbering in a 1000 line (3-digit) exchange is from 000 to 999 and consists of ten groups, each of 100 lines. Each group is served by a suitable number of final selectors. The group selector, controlled by the first digit dialled, selects the particular 100-line group required and gives access to a free final selector in that group.

8.2 Fig. 12a shows a typical trunking arrangement, in which it is assumed that 100 final selectors (10 for each group of 100 lines) can handle the normal traffic. The group selector outlets are multipled together and connected to the final selectors. As with final selectors, the actual number of group selectors is determined by traffic considerations.

8.3 When a calling subscriber lifts the handset, the associated uniselector automatically hunts for a free group selector. The first digit dialled (hundreds) lifts the group selector wipers to the required level, and they automatically cut-in and step over the contacts of the level reached to find the first free outlet. The subscriber is then connected to a final selector serving the particular 100-line group. The remaining two digits (tens and units) operate the final selector, as in the 100 line exchange. The selectors seized and the subscribers' lines are guarded against intrusion from other calling subscribers for the duration of the call.

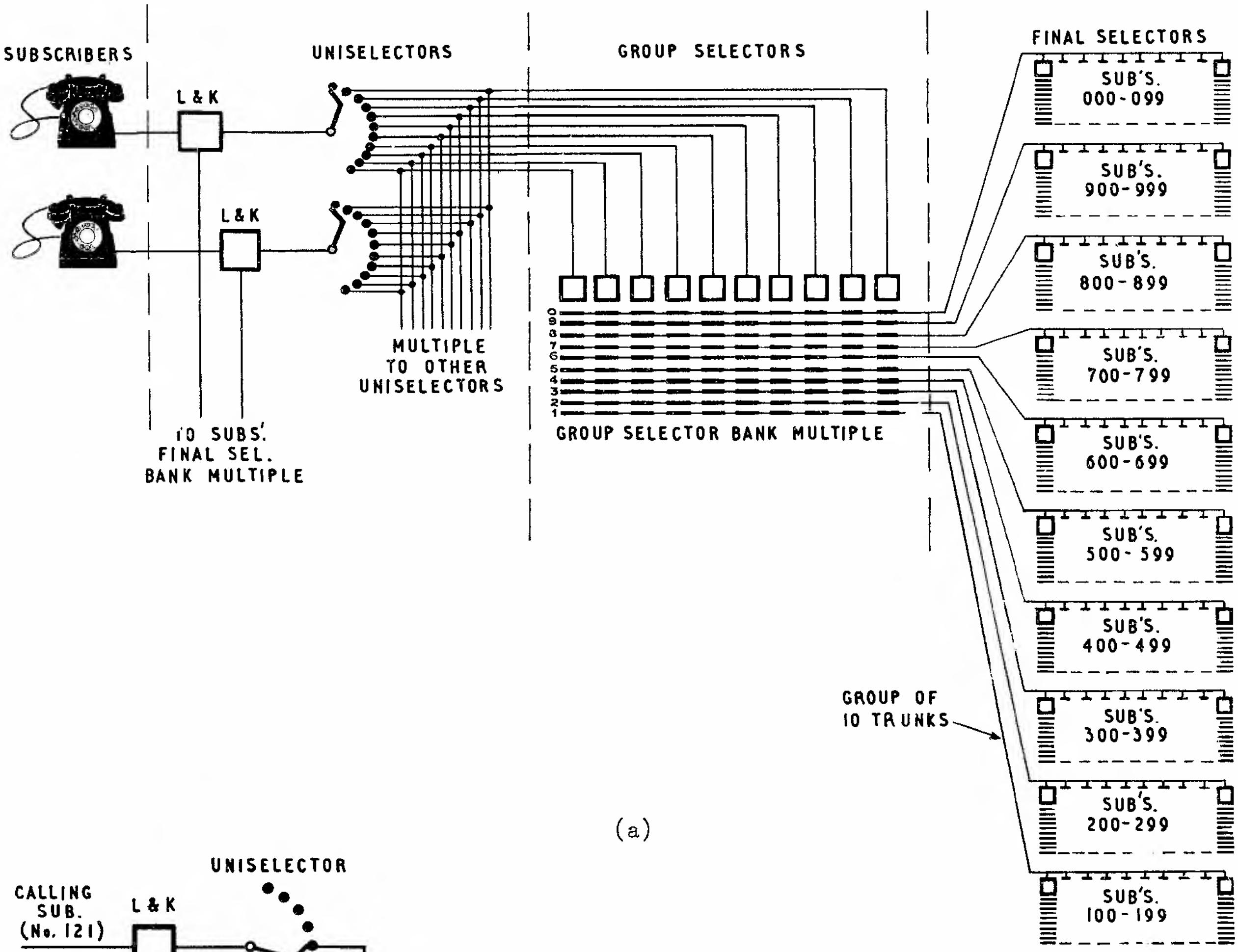
Fig. 12b shows a simplified trunking diagram where subscriber No.121 is calling No.830, and Fig. 12c shows a general trunking diagram for the exchange.

8.4 In large exchanges, many calls are handled simultaneously and this requires many selectors to handle the telephone traffic during the busy periods, and special methods of connecting between the outlets of one switching stage and the inlets of the next. It is not possible to show this completely by simple trunking diagrams which only indicate the principle of selecting the required number by a process of elimination - selecting one of 10 similar groups and one line of a hundred in that group.

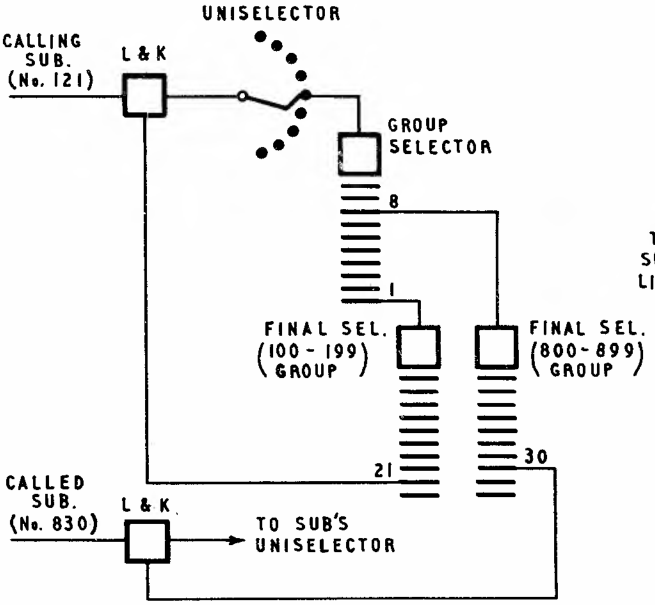
8.5 To increase the capacity of an exchange 10 times, that is, from 100 to 1,000 etc., an additional switching stage is necessary. The fact that the bimotional selectors are set up in a definite sequence, enables rank numbers to be used. For example, in the 100 line exchange, one rank of selectors only is used, that is, final selectors; in the 1,000 line exchange two ranks are used, group and final selectors; whilst in the 10,000 line exchange (4-digit system) three ranks occur, first group selectors, second group selectors and final selectors. In general, one rank of selectors is added when the capacity of an exchange is increased 10 times.

The automatic service in large cities is 5, 6, or 7 digit working, and is provided by a network of separate exchanges rather than one large exchange.

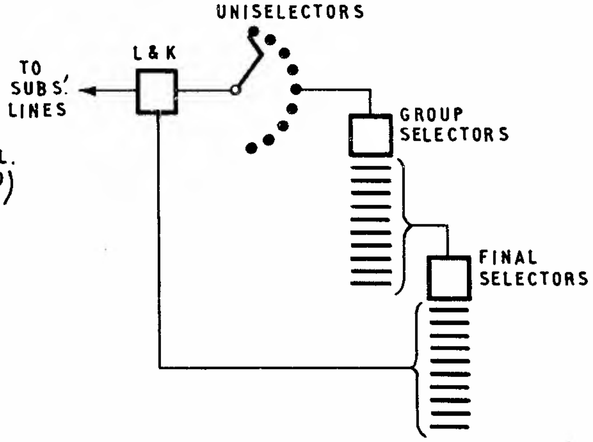
This involves several stages of group selection, special facilities for junction working between exchanges and many other problems which are described in other papers of this Course.



(a)



(b)



(c)

PRINCIPLE OF 1,000 LINE EXCHANGE.

FIG. 12.

9. BASIC SWITCHING CIRCUITS.

9.1 To summarise the basic functions of the various switches, this Section describes briefly the progress of a call through a 1,000 line exchange. For simplicity, only basic circuits are shown. Detailed descriptions of the actual circuits are given in other papers.

9.2 Subscriber's line circuit. When a calling subscriber lifts the handset -

Relay L operates to the subscriber's loop, and starts the uniselector hunting for a free outlet.

During hunting, the P wiper of the uniselector tests the outlets, and the wipers step over those which are in use on other calls.

When all outlets are busy, the uniselector stops on the last contact and sends busy tone to the caller.

When a free outlet is found, relay K operates, and the contacts disconnect the L relay, stop the uniselector hunting and connect the subscriber through to the group selector.

This selector is looped and sends dial tone to the caller. It also connects an earth to the private wire to hold up the K relay in the uniselector, and guard the outlet against intrusion from other calling subscribers. This earth also busies the calling line in the multiple.

Fig. 13 shows a simplified circuit of the subscriber switched through to a group selector. As yet no digit has been dialled.

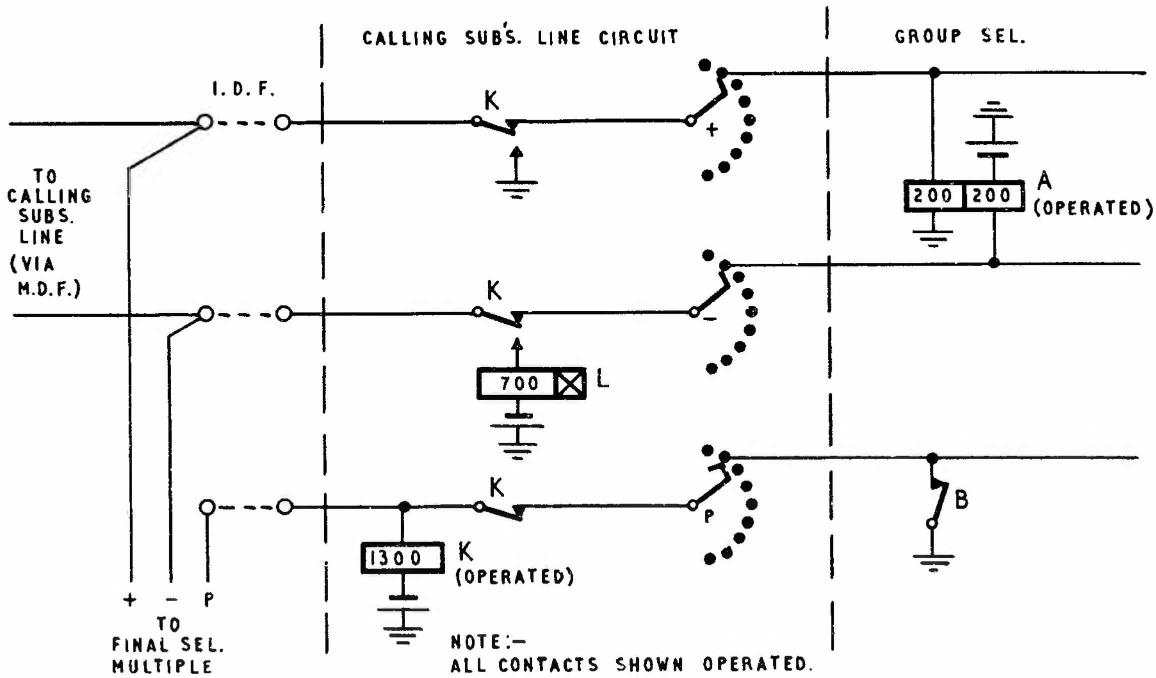


FIG. 13. CALLING SUB. CONNECTED TO GROUP SELECTOR.

9.3 Group Selector. When the calling subscriber dials the first digit -

The group selector steps vertically under control of the dial pulses.

When the dialled level is reached, the switch automatically cuts in and hunts for a free outlet.

During hunting, the P wiper of the group selector tests the outlets, and the wipers step over those which are in use on other calls.

When all outlets are busy, the group selector stops on the last (eleventh) rotary contact and sends busy tone to the caller.

When a free outlet is found, the selector stops hunting, the A relay in the group selector is disconnected and the subscriber is connected through to a final selector.

This selector is looped and it connects an earth to the private wire to hold up and busy the preceding selectors and the calling subscriber's line.

Fig. 14 shows a simplified circuit of the subscriber switched through to a final selector.

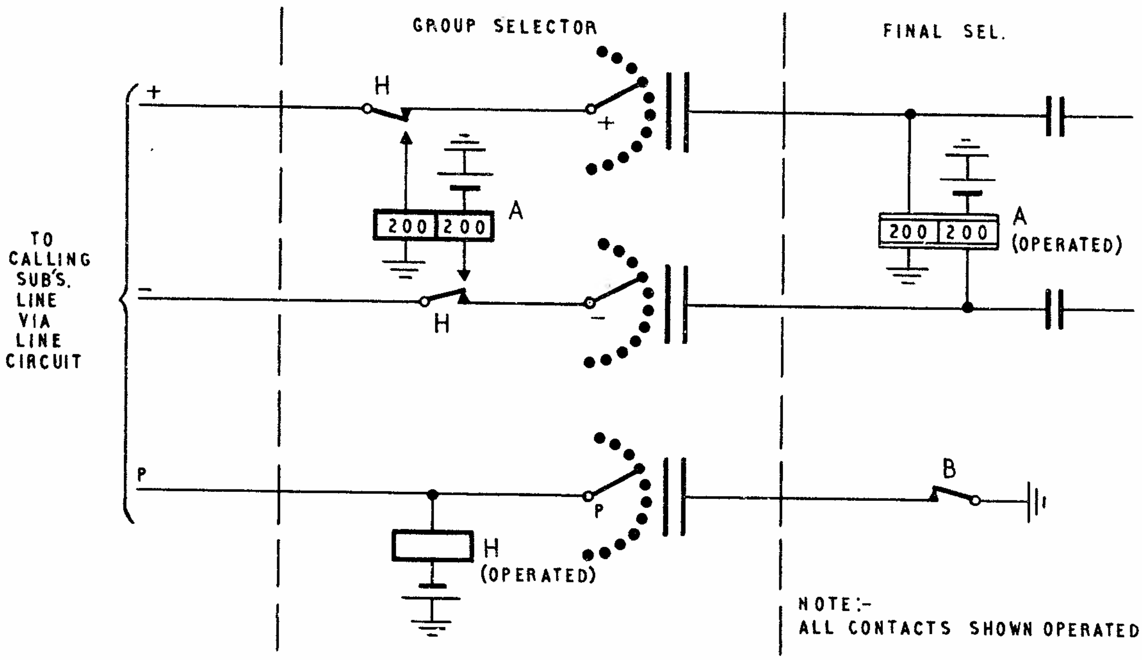


FIG. 14. CALLING SUB. CONNECTED TO FINAL SELECTOR.

9.4 Final Selector. The calling subscriber dials the second last digit and the final selector steps vertically under the control of the dial.

When the last digit is dialled, the wipers step horizontally under the control of the dial and stop on the contact number dialled.

The private wiper of the final selector tests the called subscriber's line.

When the line is engaged, busy tone is sent back to the caller.

When the line is free, an earth is extended over the P wire via the final selector's private wiper. Relay K in the called subscriber's line circuit operates and the contacts disconnect relay L and connect the line wires to the uniselector wipers. These, however, are standing on the home contacts which are not multipled and so a clear connection is given to the called subscriber's line.

Ringing current is sent out and ringing tone is sent back to the caller.

When the called subscriber answers by lifting the handset, the ring is "tripped" (disconnected) and both subscribers are connected together via a Stone battery feed.

A pulse of positive battery is applied to the private wire to operate the calling subscriber's meter.

The D relay in the final selector operates to the called subscriber's loop and reverses the battery connections to the calling subscriber's line. This is called the reversal, the reasons for which are explained in later papers.

Fig. 15 shows a simplified circuit of the call through a final selector.

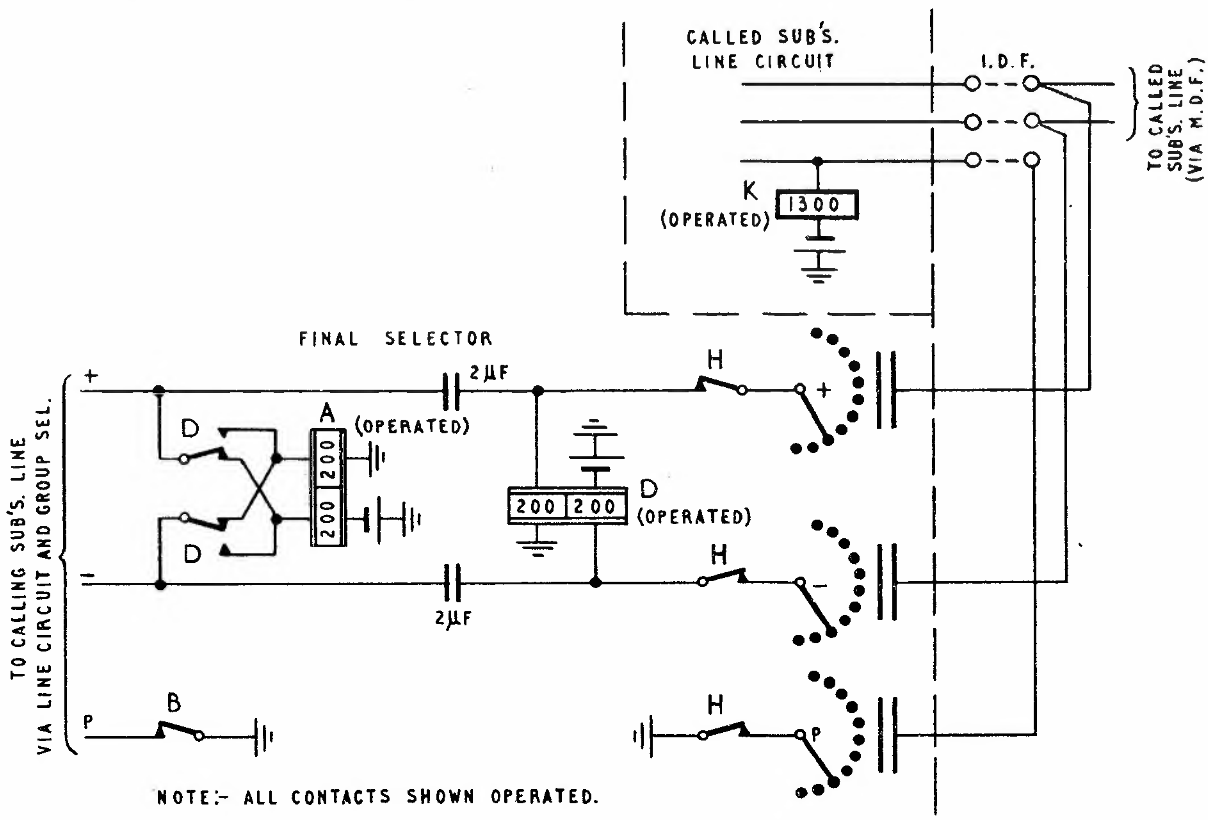


FIG. 15. CALLING SUB. CONNECTED TO CALLED SUB.

9.5 Busying the subscriber's lines. During the progress of the call, both the calling and called lines are made "busy" to prevent other selectors switching through to them. This is done by earthing the private wires in the multiple. The principle is similar to a C.B. multiple exchange in which the lines are busied by connecting earth (via the supervisory relay in the cord circuit) to the sleeve wires of the multiple while the connecting plugs are in the subscribers' line jacks.

9.6 Metering the call. As for a C.B. multiple exchange, positive battery metering is generally used. A 100 type meter is connected in the private wire circuit of each subscriber's line. The positive battery is applied to the meter over the private wire via relay contacts in the final selector. The call is automatically metered against the caller when the called subscriber answers. When the called subscriber is engaged or does not answer, the call is not metered.

9.7 Release of connection. When the subscribers replace the handsets at the end of a call, the final selector relays release, and the release circuit is energised to restore the selector to normal. The earth is removed from the P wiper, releasing the K relay in the called subscriber's line circuit. The earth is also removed from the P wire, releasing the holding relays for the preceding group selector and the calling subscriber's uniselector, which restore to normal ready for another call. An alarm is given if the selectors fail to release due to either a mechanical fault or one of the subscribers not replacing the handset.

10. SUPERVISORY ALARMS.

10.1 Every automatic exchange has an alarm system to call the attention of the maintenance staff to any abnormal conditions and to indicate the item of equipment involved. Alarms may be "Prompt" or "Deferred", the former requiring immediate attention, while the latter may be temporarily deferred.

10.2 Some of these alarms and their causes, are -

Fuse Alarm, (prompt); operation of a fuse.

Release Alarm, (prompt); failure of a selector to restore to normal when its release circuit is energised.

Permanent Loop or P.G. Alarm, (deferred); selector seized without receiving pulses.

Called Sub. Held (C.S.H.) Alarm, (deferred); calling or called subscriber holding after the other party has cleared.

Other alarms are provided for ring fail, battery fail, etc..

10.3 Details of supervisory alarms are given in other papers of the Course.

11. TERMS AND DEFINITIONS.

Line Wires. (+ and -) The two wires used for the speaking channel between subscribers.

Private Wire. (P). The third wire which is associated with the line wires inside the exchange. This wire acts as a guard to indicate whether a subscriber is busy or free, thus preventing intrusion on a private conversation.

Busy condition. The condition (usually earth) put on the private wire of an outlet when it is in use.

Free condition. The condition (either open circuit or negative battery) on the private wire of an outlet when it is disengaged.

Hunting. The action of a selector searching for a free outlet. The wipers step over busy outlets and stop on the first free outlet.

Testing. While a selector is hunting, the private wires of the outlets passed over, are tested for the busy condition.

Trunk. A connecting circuit between selectors of different rank inside the exchange.

Trunking. The branch of Telephony which deals with the provision and arrangement of switching apparatus needed to carry the traffic.

Telephone Traffic. The aggregate of telephone calls passing over a group of circuits or trunks, having regard to their duration as well as their number.

Junction. A connecting circuit between selectors in different exchange buildings.

Busy Hour. The hour during which the traffic of an exchange or the traffic over a group of junctions, is greatest.

Rank of selectors. The selectors which provide for any one stage of call selection.

12. TEST QUESTIONS.

1. Draw a simple sketch to show the location in a bimotional selector contact bank of the following numbers - 11, 10, 01, 57 and 88.
2. The wipers of a bimotional selector are designated ....
3. The schematic circuit symbol for the wipers and bank contacts of a bimotional selector, is ....
4. Draw a simple circuit to show the principle of the final selector bank multiple wiring.
5. The trunking diagram symbol for a bimotional selector, is ....
6. What are the functions of the vertical and rotary magnets in a bimotional selector?
7. The circuit symbols for these magnets are .... and ....
8. Briefly explain how these magnets are operated by the dial pulses, in a final selector.
9. Sketch the transmitter battery feed arrangement used at automatic exchanges.
10. What rank of selector provides the battery feed?
11. What is meant by a hunting action? State two types of selectors which use this action.
12. Briefly explain how the hunting action is obtained.
13. The trunking diagram symbol for a uniselector is ....
14. Why are uniselectors used?
15. What is meant by the term 'homing' as applied to uniselectors?
16. List the standard tones used in an automatic system, and state the function of each.
17. Draw a simple trunking diagram for a 100 line exchange using uniselectors, where subscriber No. 81 is calling subscriber No. 10.
18. Draw the basic trunking diagram for a 1000 line exchange.
19. What is the main switching function of the group selector in a 1000 line exchange?
20. What rank of selector provides dial tone in a 1000 line exchange?
21. What rank of selector provides the ringing tone?
22. What are the functions of the L and K relays in a subscriber's line circuit?
23. How is the switching apparatus busied in an automatic exchange?
24. How are the calls metered?
25. At what stage during the progress of the call, does the meter operate?
26. What is the purpose of the following supervisory alarms -
    (i) Fuse alarm.
    (ii) Release alarm.
    (iii) C.S.H. alarm.
27. What do the following terms mean in automatic telephony -
    (i) Trunking.
    (ii) Telephone Traffic.
    (iii) Rank of Selectors.

END OF PAPER.