ELECTROMAGNETIC INDICATING DEVICES

CONTENTS

INTRODUCTION

The magnetic effect of an electric current flow is fully described in E.P. - Draft Series PRINCIPLES 3/3.

Various applications of this electromagnetic effect are used in telecommunications to operate both audible and visual indicating devices.

Audible indicating devices such as bells, buzzers and sounders, have a moving armature which may either produce sound waves direct as in the case of the buzzer, or may strike a stop or gong.

Visual indicators for use in telecommunications have a shutter or disc, which is actuated by the passage of current through an operate coil. Other applications are electrical pulse-counting mechanisms providing a visual indication of the number of pulses passed through the operate coil.

AUDIBLE INDICATING DEVICES

THE SOUNDER

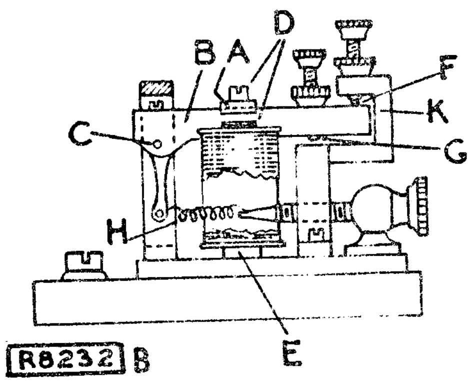

Fig. 1

This instrument is actuated by pulses of current and produces an audible click due to the armature striking a stop. The sounder shown in Fig. 1 consists of a two coiled electromagnet with a soft iron armature. The magnetic circuit consists of a soft iron yoke E, which joins the two cores D, the circuit being completed through the armature A. The two coils of the electromagnet are connected in series, and the ends terminated on two screws on the wooden base of the instrument.

The soft-iron armature, A, is carried on a bell-crank lever B pivoted at C and fitted with an adjustable restoring spring H. When a current flows through the coils, the resulting magnetic flux passes through the cores, the yoke, across the air gaps and through the armature, which is attracted towards the cores against the action of the spring H.

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The lever B has an adjustable stop G arranged to strike K and this indicates the commencement of a signal. Another adjustable stop is mounted on K, and a small projection F on lever B strikes this stop to indicate the end of a signal. A short air gap gives greatest sensitivity, but least intensity of sound. The tension of H should be adjusted so that it exerts a restoring force equal to the magnetic operating force, so that the time intervals during operation and restoration are the same, and the sounds emitted in these cases are of the same intensity.

For use with primary cells, this sounder is wound to a resistance of 21 ohms with a shunt of 420 ohms, giving a joint resistance of 20 ohms. The normal working current is 60 to 90 milliamperes, and the minimum about 55 milliamperes. Where a sounder is required to work with accumulators the coil and shunt resistances are 1,000 and 9,000 ohms respectively, giving a joint resistance of 900 ohms. In this case the normal operating current is 20 to 26 milliamps and the minimum 11 milliamps.

A shunting resistor is fitted across the coils to dissipate the current due to self induction, which would otherwise give rise to sparking at the contacts of the transmitting key on breaking the circuit.

THE POLARIZED SOUNDER

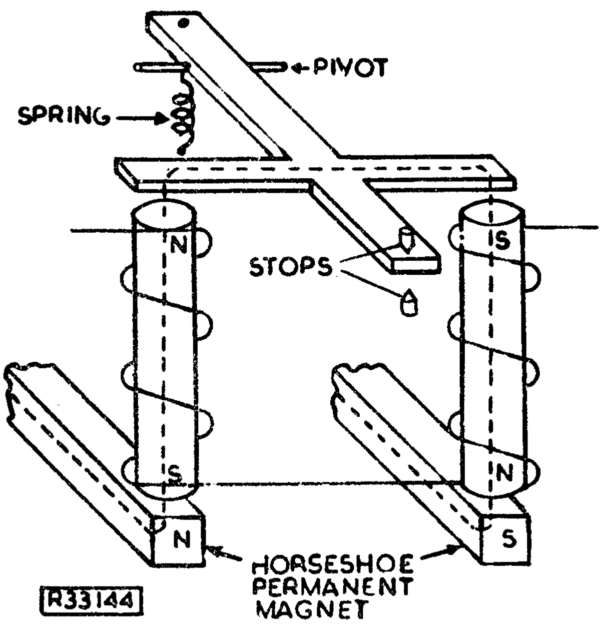

Fig. 2

The polarized sounder is similar in construction and use to the ordinary sounder already described. The yoke of the electromagnet is, however, replaced by a permanent horseshoe magnet and a piece of non-magnetic material, 5 mils thick is interposed between the magnet and the cores. The effect of the magnet is to polarize the cores. In the upper position the pull of the spring prevails, whilst in the lower position the magnetic attraction is greater than the pull of the spring, therefore the armature, whether moving upwards or downwards, is rapidly accelerated and strikes the stops with considerable force. The addition of the polarizing magnet also increases the sensitivity of the sounder as the armature is always subjected to a slight attraction and the adjustments can be such that a very small current through the coils is sufficient to displace the armature.

The magnetic circuit is shown in Fig. 2.

Sounders are used to receive code signals which may be transmitted by the Morse Key. This type of instrument is also used on test desk positions at telephone exchanges, the sounder being connected to subscribers lines for testing purposes.

D.C. BELLS AND BUZZERS

The simple D.C. bell, or trembler bell as it is often called, is to be found in many signalling and alarm circuits used in telecommunications. Fig. 3 illustrates the principle of the bell, complete with a simple operating circuit.

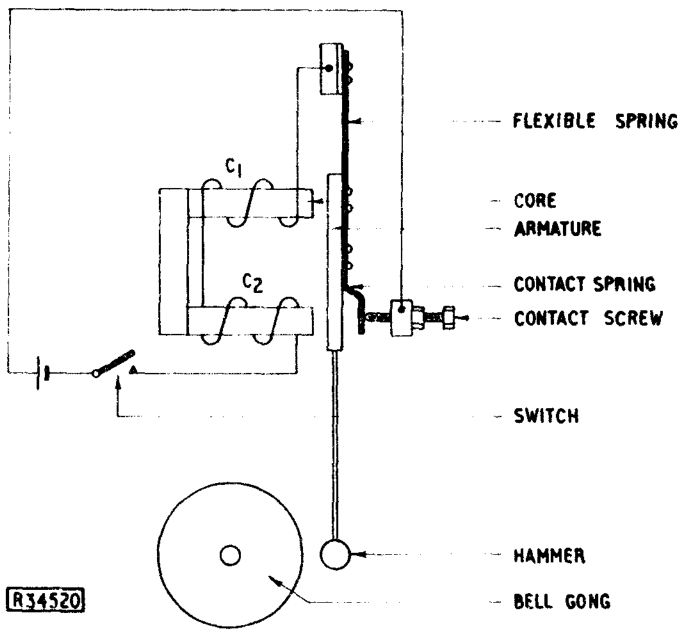

Fig. 3

The armature is fixed by a flexible spring and carries a contact spring which is held in contact with an adjustable contact screw. When the switch is closed, current flows through the coils C_1 and C_2 via the contact screw and contact spring. The coils are so arranged that a large flux is present in the gap between the cores and the armature, and the armature is attracted. Shortly after the armature commences to move, the electrical circuit is broken at the contact screw and the attraction of the armature decreases as the flux decays. The momentum of the moving system allows the armature to continue its movement towards the cores for a short time after the circuit is disconnected, causing the hammer to strike the bell gong. The tension of the armature spring and the recoil of the hammer return the armature to normal restoring the continuity of the operate circuit at the contact screw. This cycle of operation and release is continued for the period that the switch is closed, the armature vibrating at a regular frequency.

The electromagnet coils are wound with the number of turns which will provide sufficient flux for the satisfactory operation of the bell on the voltage available.

The inductance of the coils produces a large back e.m.f. when the contacts break, therefore the contact screw and the contact are tipped with a hard metal which will not oxidize and is not fusible except at high temperatures.

The effect of the back e.m.f. may be considerably reduced by fitting a spark-quench circuit consisting of a series connected resistor and capacitor across the contacts. It is essential to locate this suppression unit close to the contacts and so prevent interference with adjacent speech circuits due to radiation from the leads of the unit.

Figs. 4 and 5 show a typical D.C. bell used by the British Post Office.

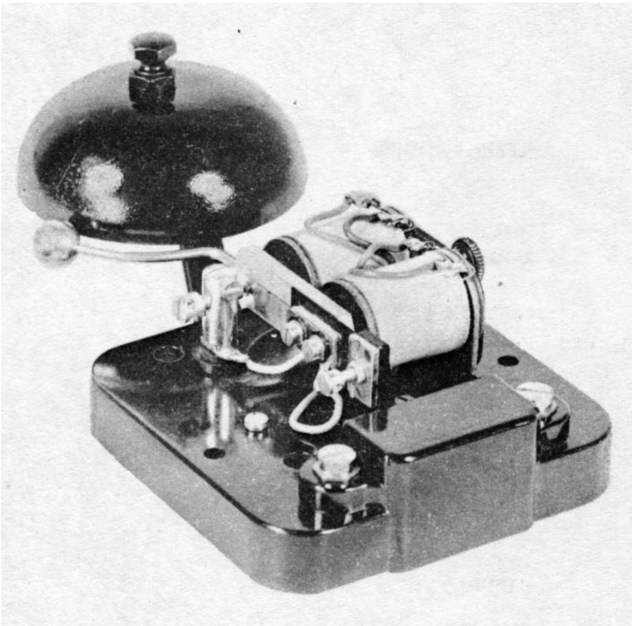

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Fig. 4

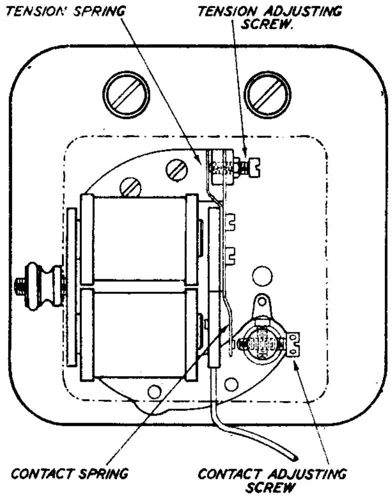

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Fig. 5

This bell is provided with an adjustable tension spring in place of the flexible spring shown in Fig. 3, thus the restoring action of the armature no longer relies on the flexible spring returning to its neutral position, but on the actual pressure applied by the tension adjusting screw.

The spark quench circuit which is usually incorporated in this type of bell consists of a 300 ohm resistor and 0.1 μF capacitor, the components being mounted on the coil framework.

Fig. 6 is a photograph of a trembler bell fitted in an extension telephone instrument.

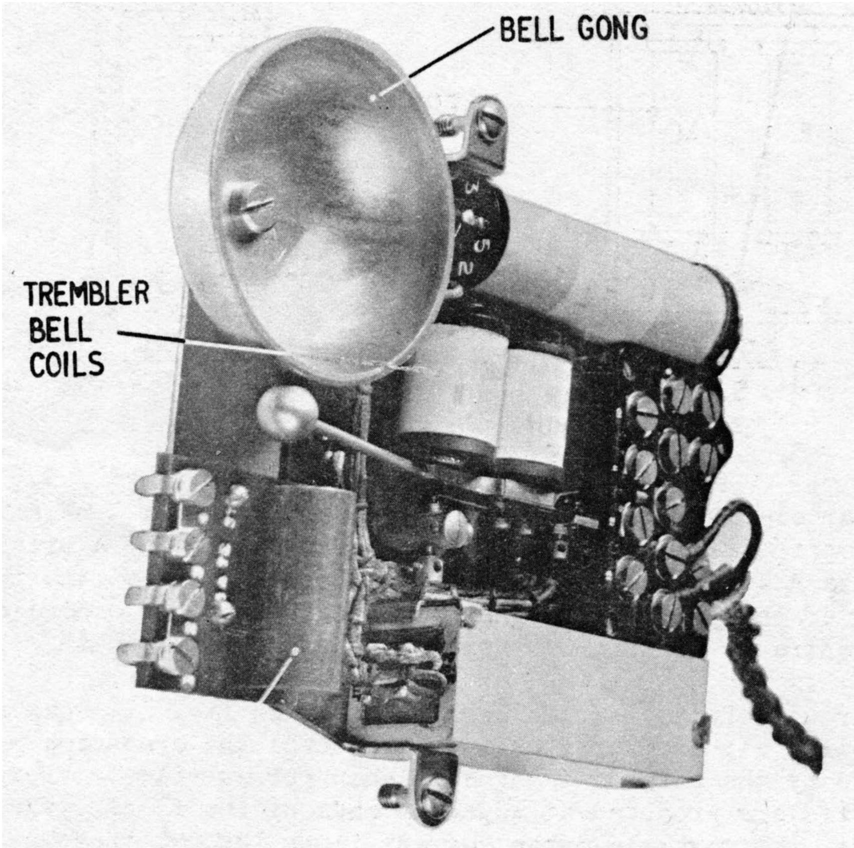

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Fig. 6

Occasionally a less-distracting signal than the normal bell is required; for these installations a buzzer, which is a modified form of the bell, is used. This consists of the coils and armature similar to the bell, but without the bell hammer and bell gong. The movement of the armature produces the sound waves.

A.C. BELLS

The trembler bell as a means of producing an audible signal is not entirely satisfactory due to the high e.m.f. produced when the contacts are broken. Also the interrupter contacts of a trembler bell have a high fault liability with resulting high maintenance costs. To overcome these difficulties, a type of bell in which the circuit is not disconnected by contacts is desirable. The 'magneto' bell which is designed to operate from alternating current supplies, fulfils these requirements. A permanent magnet is used to polarize the bell enabling the armature to respond to the alternations of current flow.

Fig. 7 illustrates one form of magneto bell.

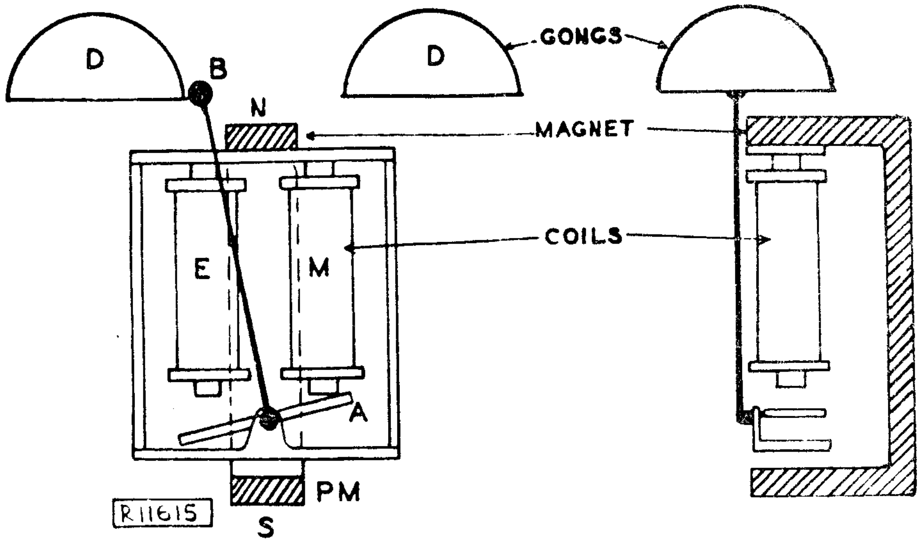

Fig. 7

It consists of an electromagnet E M with a pivoted armature A magnetized by induction from a permanent magnet P M. A thin steel rod carrying a brass ball B is fixed to this armature A at right angles to it, and placed between the two bell domes D. The S pole of the permanent magnet is placed below the centre of the armature, thus the centre is of north polarity and both ends of south polarity.

The magnetic circuit of the magneto bell is shown in Fig. 8. When no current is flowing in the coils, either magnet core will attract the armature, as the armature is polarized by the permanent magnet. When current flows through the windings opposite poles are produced at adjacent ends of the electromagnet due to the method of winding. For example, when current flows through the windings as shown in Fig. 9 the cores become magnetized so that E has a N pole and M has a S pole. Since the armature has a S pole at each end, one end will be attracted by the core having a N pole, and the other end will be repelled by the core having a S pole. If the current through the coils is reversed, the polarity of the magnet cores will be reversed, causing the armature to be tilted in the opposite direction.

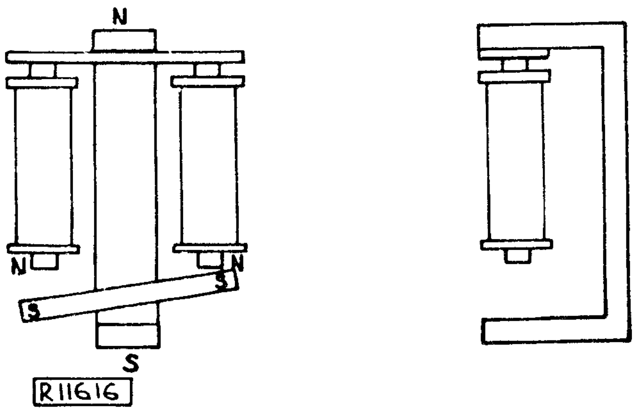

Fig. 8

If the r.m.s. value of the ringing current is such that it produces a smaller magnetic flux than that due to the permanent magnet then there is no reversal of polarity at the electromagnet core. In this case the flux density will be greatly reduced at one core and very much increased at the other; the bell will operate in the same manner since the armature is attracted to the core where the flux density is greatest.

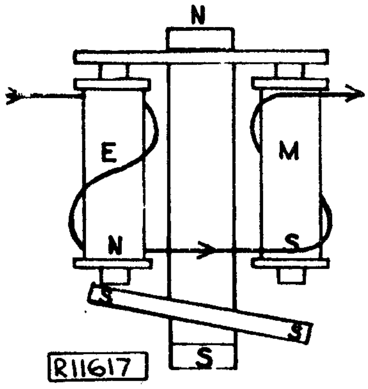

Fig. 9

As alternating current is used for ringing, the polarity of the magnet cores reverses just as often as the direction of the current in the coils reverses. Thus the armature is alternately attracted and repelled by each core causing the hammer which it carries to strike the gongs. The coils are wound with a considerable number of turns and the magnetic circuit is of low reluctance. Hence the inductance and therefore the impedance at speech frequencies is high. Each coil is 500 ohms resistance and they are usually connected in series; provision however is made to enable the coils to be connected in parallel.

The magneto bell used in conjunction with the microtelephone is shown removed from its mounting in Fig. 10. The principle of operation is the same as that just described the only difference being in the construction. It will be seen that a cylindrical bar magnet is used and that the armature is cut to allow one end of the magnet to be inserted; the armature is suspended by a brass spindle.

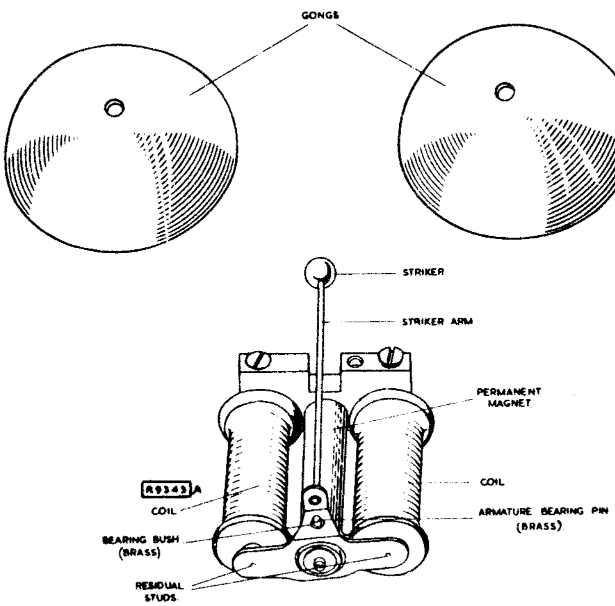

Fig. 10

Fig. 11 shows a photograph of this type of bell mounted in the bell-set case; this is often used as an extension bell at a subscriber's premises.

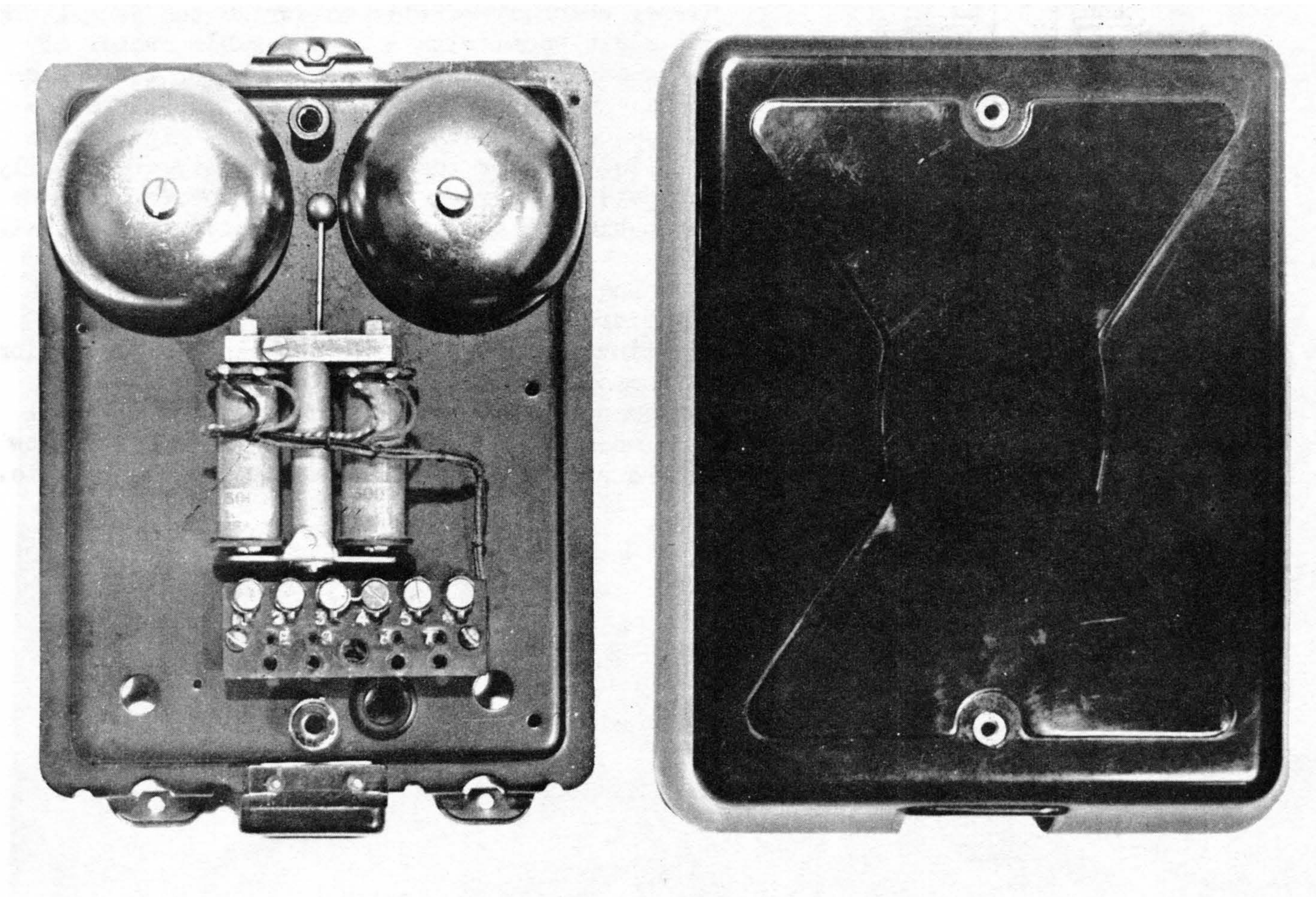

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Fig. 11

The size and shape of the gongs fitted on both trembler and magneto bells, and consequently the overall dimensions of the bell, are decided by the local conditions where the bell is fitted.

For the magneto bell it is usual to provide two gongs having a slightly different pitch, the gongs being the same in diameter but stamped from metals of different thickness.

Bell gongs of diameters $2\frac{1}{2}$ inches to 12 inches are manufactured.

Fig. 12 shows a magneto bell with 6 inch gongs suitable for installation outside a subscriber's premises.

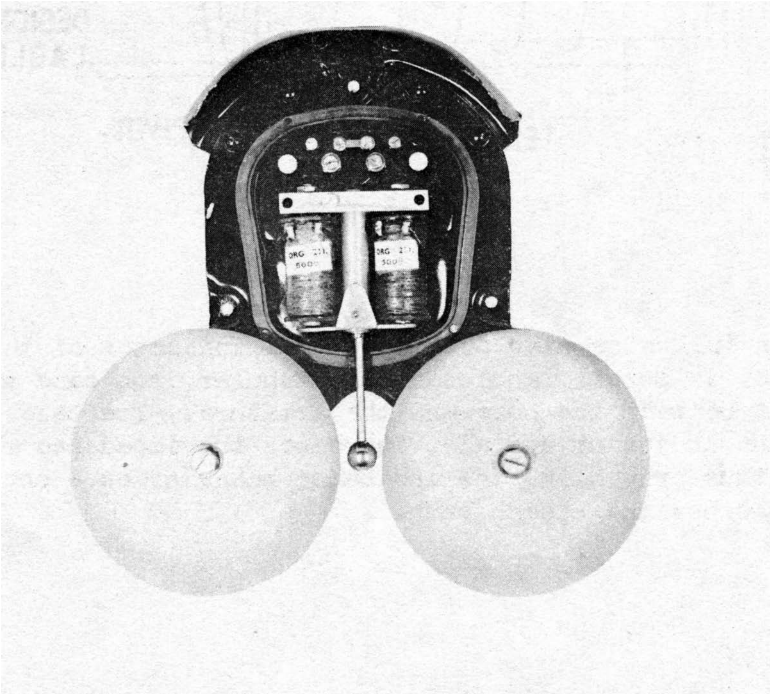

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Fig. 12

VISUAL INDICATING DEVICES

CALLING AND SUPERVISORY INDICATORS

Indicators are of two main types:-

(a) Drop Indicators, which are designed to display a continuous signal after the receipt of a short duration signalling pulse.

(b) Flag or Eyeball Indicators, where the signal is only displayed for the period the signalling current is flowing.

In either case local contacts on the indicator are usually provided to complete an audible alarm circuit such as a trembler bell or buzzer.

DROP INDICATORS

Fig. 13 illustrates the principles of a simple drop indicator. When the energizing current is passed through the coil, the armature is attracted to the pole-face. This rotates the shutter release rod about its pivot, thus releasing the shutter, which falls under its own weight to the position shown dotted in Fig. 13. The designation label is then in view and this indicates to the attendant the identity of the calling circuit.

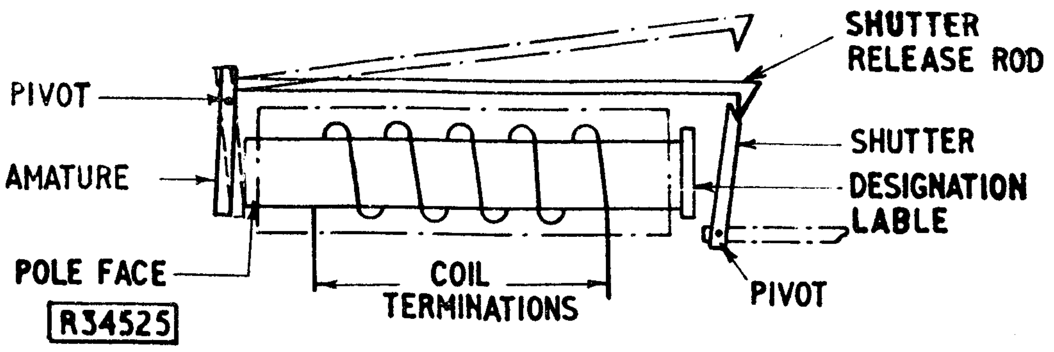

Fig. 13

Fig. 14 shows a full size view of a practical indicator of this type. The coil of the indicator is totally enclosed in a tubular iron case which completes the magnetic circuit between the core and the armature. The case restricts the external field of the indicator and also increases the impedance of the coil at speech frequencies thus preventing the indicator behaving as a short circuit when directly connected across the speech path.

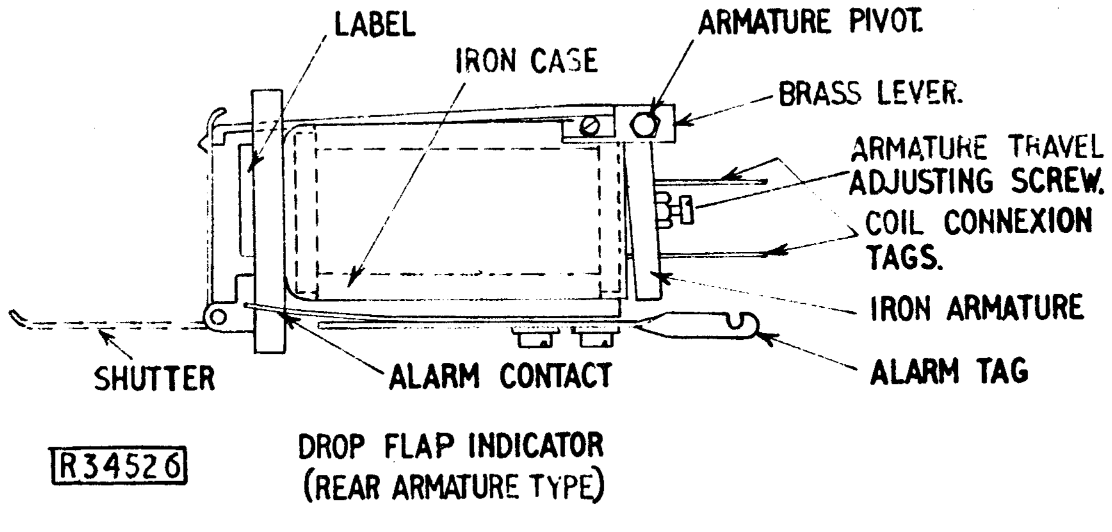

Fig. 14

The energizing coil consists of two sections whose resistance is 500 ohms per section, four coil connexion tags being provided. The two sections are connected together at the coil tags either directly or by means of a capacitor. This type of indicator is designed to operate from either a low frequency alternating current or direct current, the first operating condition being the more usual for normal switchboard circuits. When the indicator is used in a circuit which has a permanent direct current flowing through it, the insertion of the capacitor prevents the d.c. from operating the indicator, but allows its operation to alternating current from the ringing supply.

The disadvantage of this type of indicator when used in conjunction with a capacitor, is that if connected to a circuit where dialling pulses are present, the charging of the capacitor due to the pulses of d.c. allows the coil to be momentarily energized, thus releasing the shutter.

In some switchboards this is obviated by the disconnexion of the indicator when the circuit is in use, but in the cordless type of private branch exchange switchboard, the disconnexion of the indicator is not possible. To overcome the false operation in this type of switchboard an indicator having a more complex armature arrangement is used. One of this type is shown in Figs. 15 and 16.

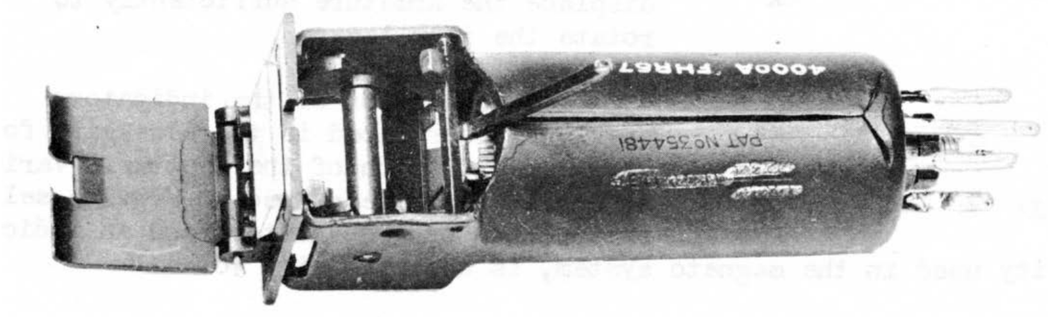

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Fig. 15

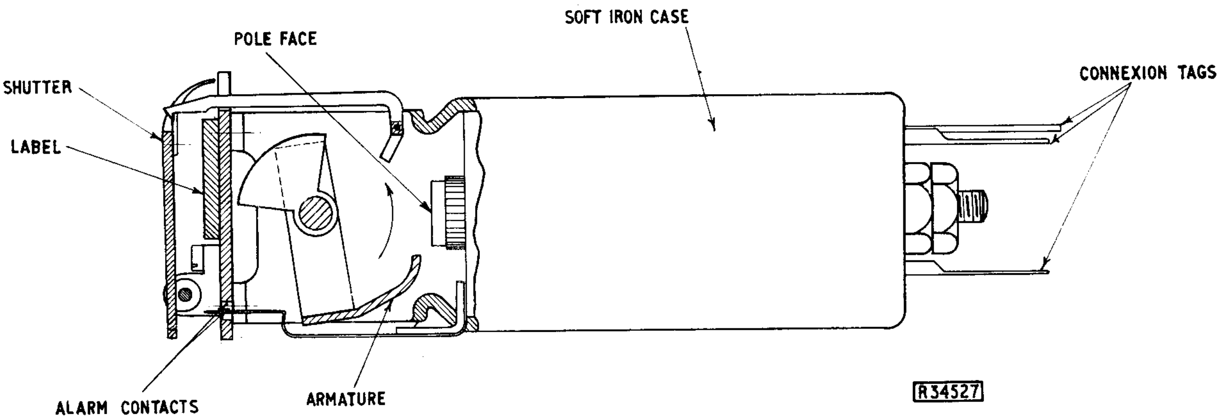

Fig. 16

In Fig. 16, which is full scale, a portion of the indicator casing has been removed to show the operating mechanism more clearly. The coil arrangement is similar to the type previously described, the armature however is mounted at the front end of the electromagnet, the magnetic circuit being completed via the soft iron circular case. The armature consists of a tongue-shaped piece of soft iron which is pivoted in the forward portion of the case.

When the coil is energized, the magnetic forces are such as to attract the maximum volume of iron to produce the least reluctance in the magnetic circuit. The armature thus rotates so that the wider parts of the tongue are progressively brought in front of the pole face.

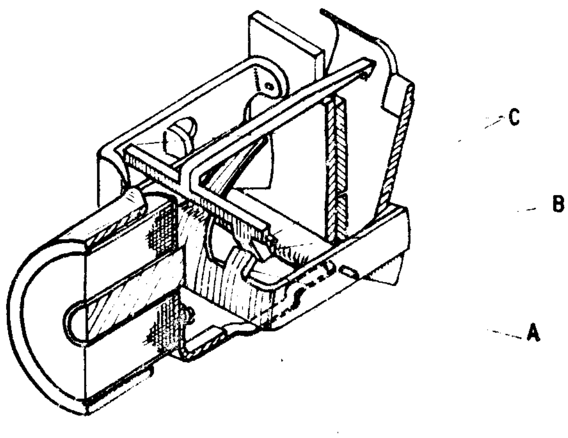

Fig. 17

When the armature is fully attracted as shown in the cut-away view in Fig. 17, the projection A engages the trip lever B, which rotates about its pivot C. This raises the shutter release rod and allows the shutter to fall.

The construction of the armature is such that whilst the shutter is released by a sustained energization of the magnet coil, very short duration pulses do not displace the armature sufficiently to rotate the trip lever.

The limitation of the indicators previously described is the necessity for manual restoration of the shutter. Various mechanisms have been used to provide self-restoration of the shutter, and an indicator with this facility used in the magneto system, is shown in Fig. 18.

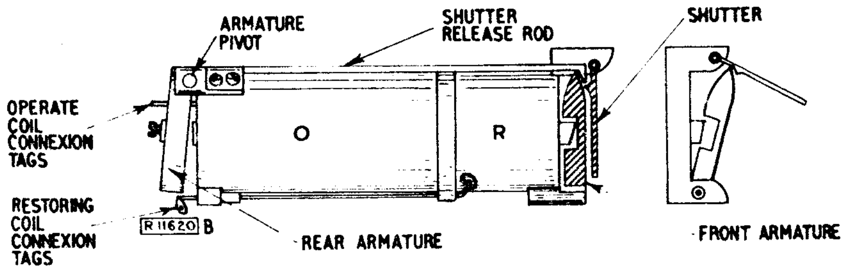

Fig. 18

The construction of this indicator is similar to that of Fig. 14. There are two coils, the operate and release coils. The rear coil O is the operate coil and has a resistance of the order of 1000 ohms. When current is passed through this coil, the rear armature is attracted thus releasing the front armature, which falls to the position as shown at the right hand side of the diagram. The armature, in falling forward, lifts a light shutter and discloses the identity of the calling line.

The front coil R is the restoring coil and has a resistance of the order of 40 ohms. When the restoring current is passed through the coil R, the front armature is attracted and restored behind the catch on the shutter release rod. The efficiency of the restoring action is increased by extending the core of the restoring electromagnet into the recess cut in the front armature.

EYEBALL INDICATORS

Fig. 19 shows an 'eyeball' type indicator, and Fig. 20 shows the front view and a side view with a portion of the case cut away to show the armature more clearly. The indicator has a single energizing coil of 500 ohms resistance.

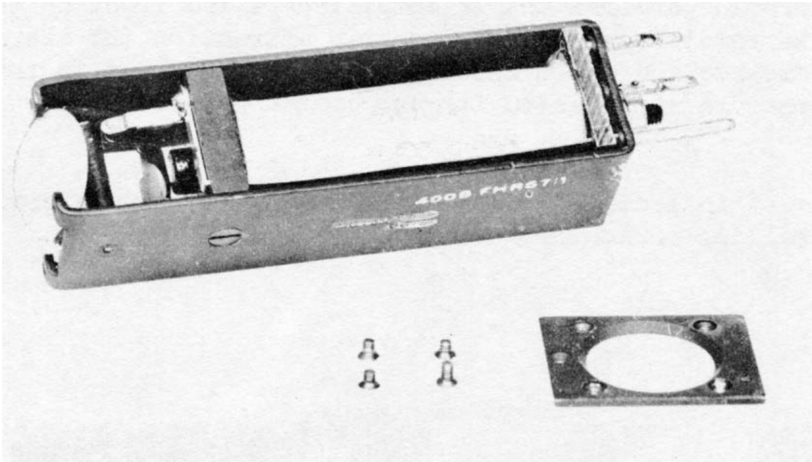

Fig. 19

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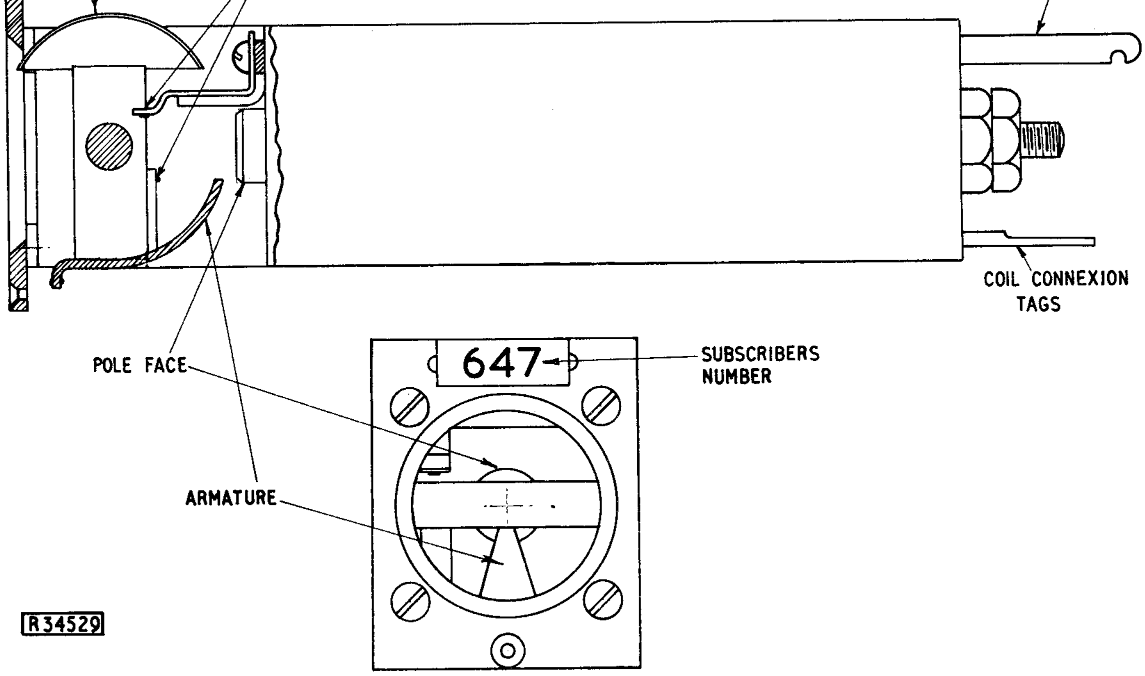


Fig. 20

The armature consists of a pivoted piece of shaped metal similar to the one described in conjunction with Fig. 17. Fixed to the front of the armature is a section of a hollow metal sphere which moves into the aperture at the front of the indicator when the armature is attracted.

The magnetic circuit of the indicator consists of the centre core with the two side members in parallel and is completed at the front by the armature. When the armature is rotated due to the magnetic attraction the alarm contacts come together to complete the alarm circuit. When the current in the indicator coil ceases, the armature restores to its unoperated position under the influence of gravity.

This type of indicator is used mainly at small private branch exchanges as an extension calling indicator.

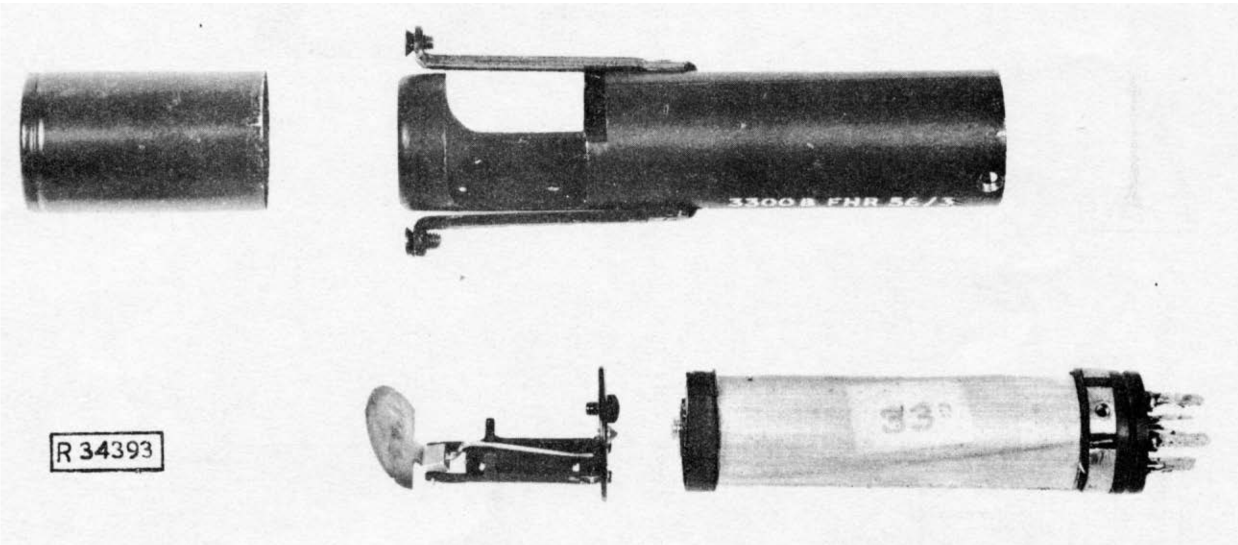


Fig. 21

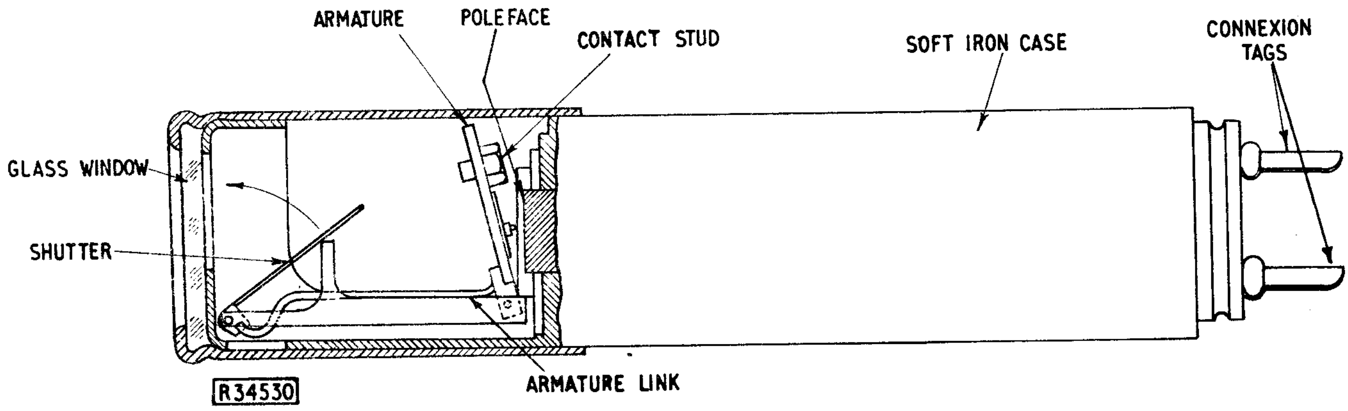


Fig. 22

The indicator shown in Figs. 21 and 22 is designed to be mounted either horizontally or vertically, and when energized a coloured disc appears at the glass window. The indicator may have one or two coils whose resistance is adjusted according to the circuit in which the indicator is to be used.

When the coil is energized the movement of the armature raises the light aluminium shutter in front of the glass window by movement of the armature link. The magnetic circuit is completed via the tubular soft iron frame of the indicator. When the armature is attracted the contact stud bears upon a flexible contact spring to complete an audible alarm circuit if this is required.

This type of indicator is used as a supervisory indicator at private branch exchanges, and sometimes as a calling indicator on public central battery signalling switchboards.

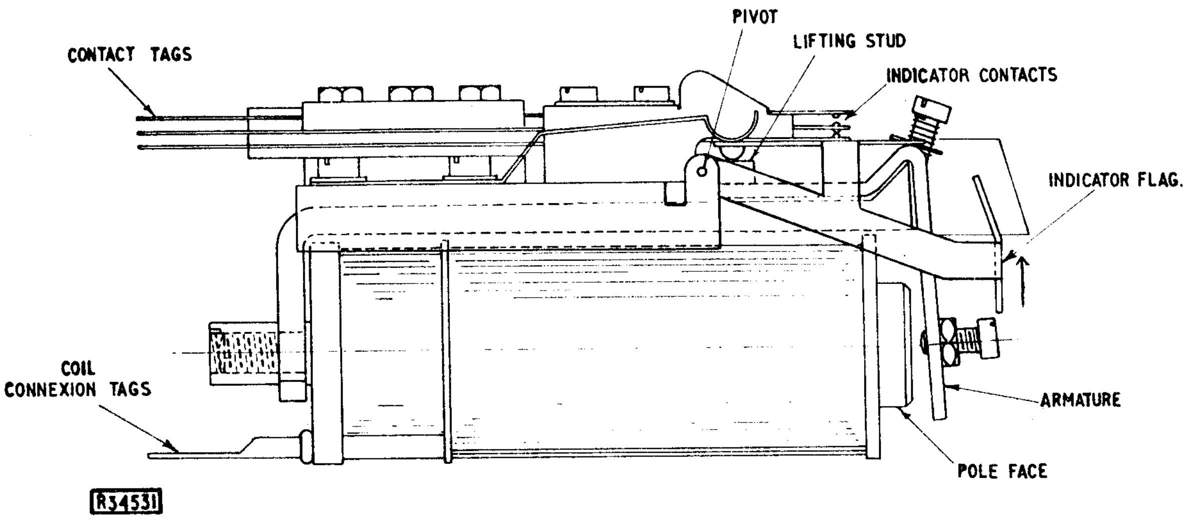


Fig. 23

The indicator shown in Fig. 23 is a modification of an ordinary 3000 type relay and is designed to be mounted horizontally. When the armature is attracted to the pole face the lifting stud moves upwards and engages the indicator flag extension. Thus the movement is transmitted to the indicator flag extension which rotates around its pivot and the indicator flag is raised.

This type of indicator is often used in subscribers telephone instruments. It is fitted in such a position that when operated the flag is visible through an aperture in the case of the instrument. The indicator is provided with a changeover contact.

COUNTING MECHANISMS

Counting mechanisms such as subscribers' call register meters and electrically operated timing clocks are used extensively in public telephone exchanges. Their operation, which is somewhat similar to the indicators previously described, depends upon the attraction or release of the armature to rotate drums or number wheels.

When the drums are rotated by the attraction of the armature the mechanism is known as the 'direct acting' type; conversely when the drum is rotated by the release of the armature it is then known as the 'reverse acting' type.

The mechanisms are usually pulse operated, each pulse rotating the drum a portion of a revolution. The pulses may be provided manually by the operation of a key, or automatically at specific time intervals by mechanical or electronic switches.

SUBSCRIBER'S METER

The 4 digit type of meter used in the British Post Office for the registration of the number of calls originated by a subscriber is shown in Fig. 24, and a cross-section of the meter in Fig. 25. This meter is also suitable for the registration of pulses in any circuit where the pulse frequency is not greater than 5 per second.

The meter is the reverse - acting type. When the armature operates the pawl slips over one tooth of the ratchet wheel without moving the number drum. When the operate-coil circuit is disconnected the spring loaded armature returns to normal and the pawl, which has dropped in engagement with the ratchet wheel, steps on the drum one tenth of a revolution which corresponds to one digit.

The meter is fitted with four drums, each being engraved at regular intervals around their periphery with the numbers 0 to 9. The four drums are known as the 'Units', 'tens', 'hundreds', and 'thousands' drums, and after one complete revolution of the drums in the order given, the succeeding drum is rotated mechanically one tenth of a revolution. For example, after the receipt of 25 pulses the unit drum will have completed two and one half revolutions thus indicating 5, and the tens drum will have rotated two tenths of a revolution thus indicating 2.

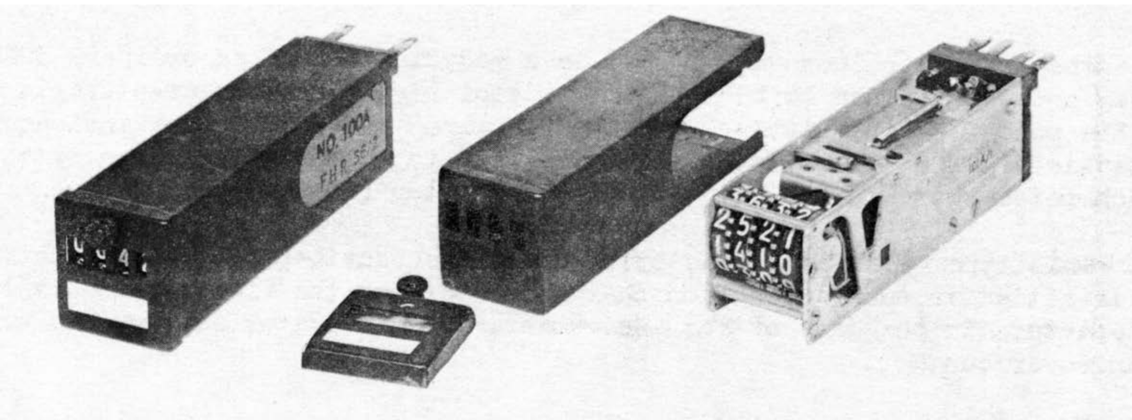


Fig. 24

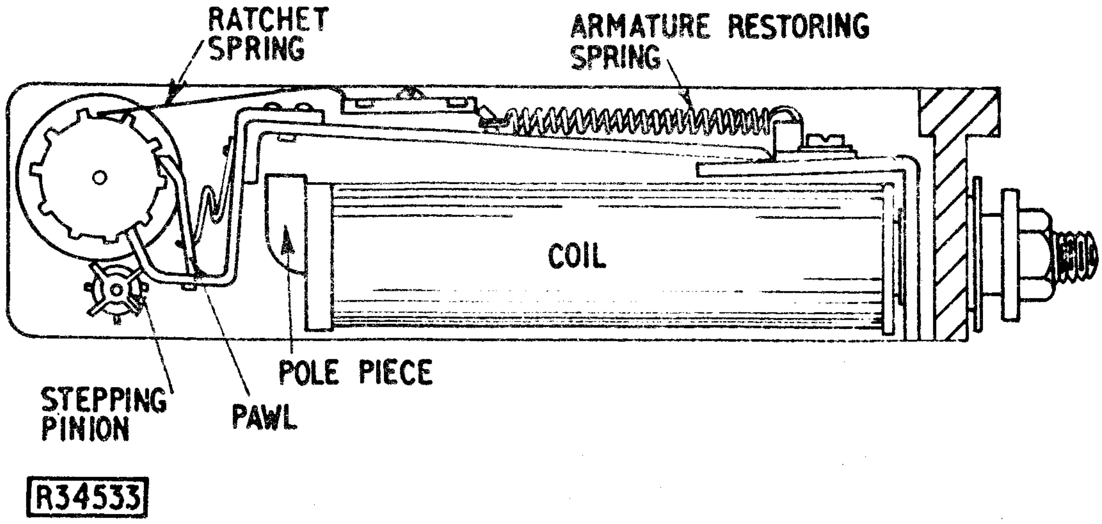


Fig. 25

The armature which is pivoted on a knife-edge and held in position by a helical spring, has residual studs fitted on its under-side to prevent sticking due to residual magnetism and to take the impact of the armature on the pole piece. Its bearing is formed by a plate mounted on the yoke of the meter which can be adjusted to align the armature in the frame and to obtain the correct air gap at the pole piece. The front end of the core turns upwards at right angles to the axis of the coil, whilst the front cheek of the coil has a recess moulded into it which acts as a buffer block for the local contact springs. A circular nut clamps the coil and yoke to the frame, and the coil windings are brought out to a tag block attached to the heel of the frame.

An L-shaped plate, the vertical part of which is slightly bent at the top forms the pawl, and projections on the under-side of the horizontal part constitute the pivot. A ratchet spring which can be adjusted in relation to the ratchet teeth prevents backward movement of the units drum, and at the same time exerts a backward pressure on the ratchet wheel to lock it against the tip of the pawl. The positioning of the units drum in relation to the viewing aperture in the meter cover is effected by either raising or lowering the armature back stop against which the armature rests when unoperated. The absence of spindles for the pawl and armature eliminates the possibility of loosenesss in bearings due to wear, and the long stroke of the armature allows an ample margin on the pawl movement.

Die-castings of tin-antimony alloy are used for the number drums which revolve on polished steel spindles. At the end of a revolution of the units wheel (when ten units have been registered), a notch engages with a tooth on the first intermediate pinion which is also in mesh with the teeth on the "tens" drum. The movement given to the pinion by the units drum advances the "tens" drum one-tenth of a revolution. After one revolution of the "tens" drum the "hundreds" drum is operated in a similar manner, and subsequently the "hundreds" drum operates the "thousands" drum.

The meter will step up to 300 times per minute and operate with a current of 25 m.a.

With the introduction of Subscriber Trunk Dialling, subscribers' meters with a greater capacity than that provided by the 4 digit type of meter are required. The latest subscribers' meters are now fitted with 5 number drums made from a plastic material. These meters are similar to the 4 digit meters and the method of operation is identical.

CHARGEABLE TIME CLOCK

The chargeable time clock used by the British Post Office to provide a visual indication of the duration of long-distance telephone calls is similar in principle to the meter previously described. The clock is driven by 6 sec. pulses, the current required varying between 45 mA and 105 mA, the value being dependent upon the exchange voltage available. The control circuit for the clock is such that the pulse circuit to the operate coil is disconnected when the subscriber who is controlling the call replaces the handset.

Mechanically operated contacts on the clock mechanism operate at approximately 3 min. intervals and these connect a voice frequency tone to the subscribers and provide a lamp signal to the controlling operator. The clock mechanism is fitted on the keyshelf of a telephone switchboard and the digits indicating the elapsed time are clearly visible to the operator. Fig. 26 shows the complete clock mechanism with its associated mounting plate.

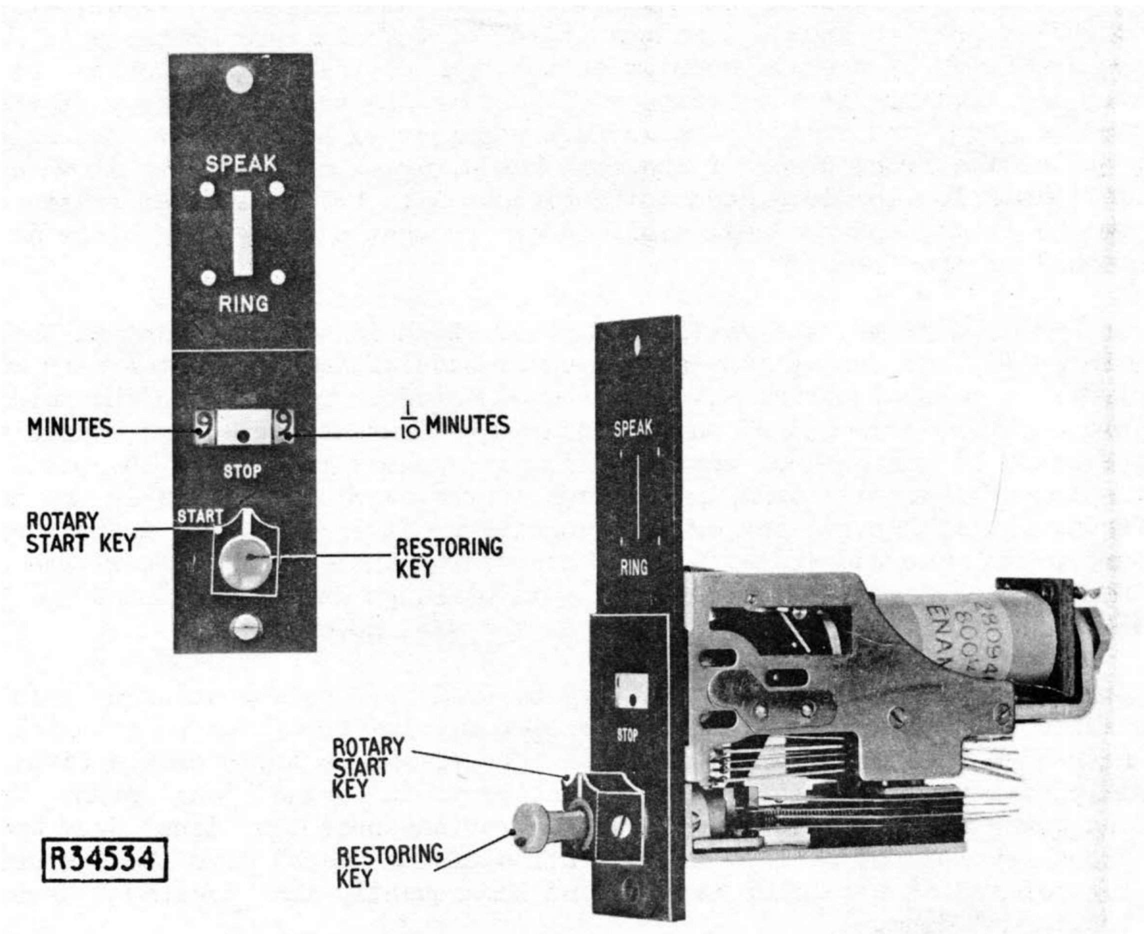
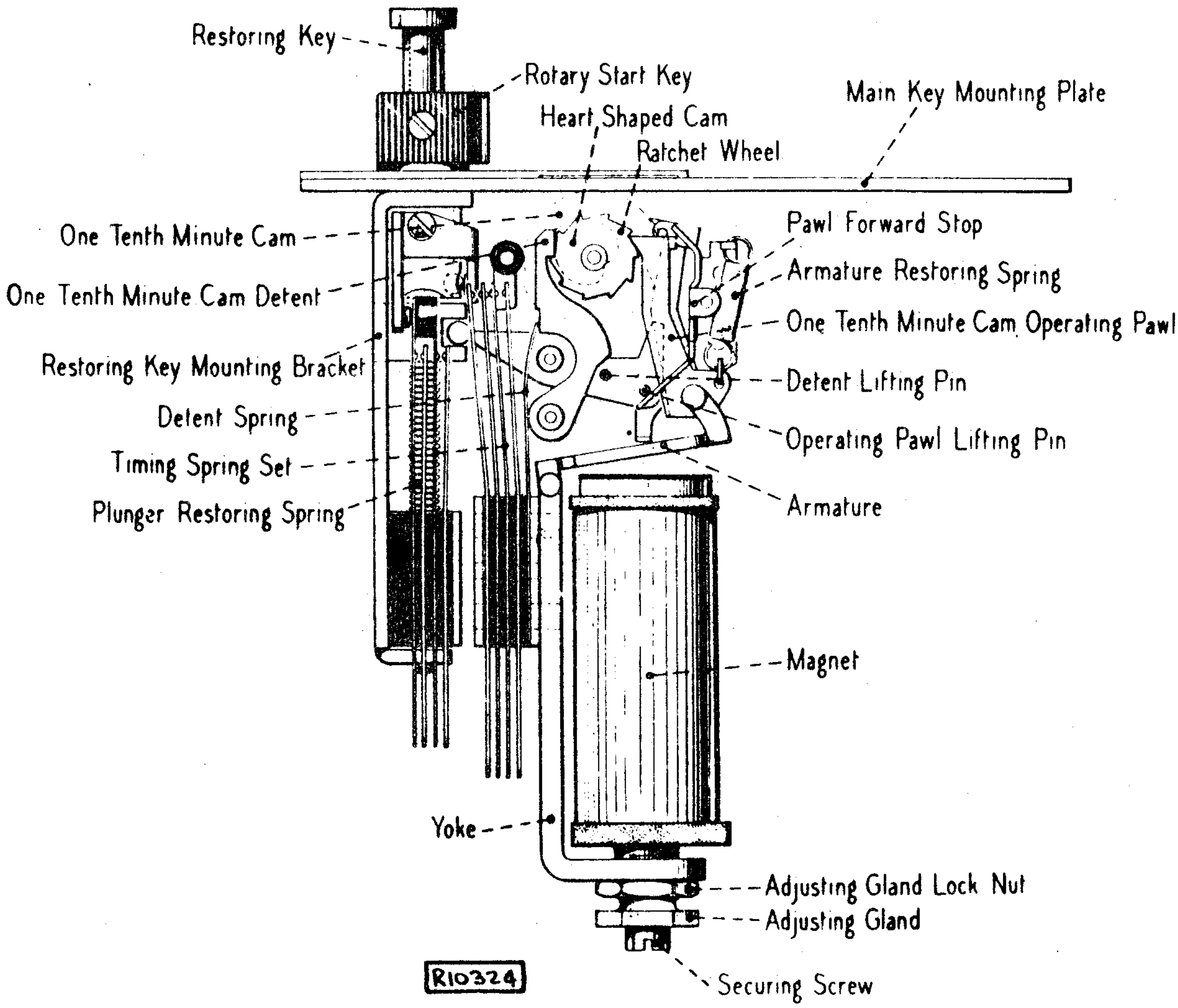


Fig. 26

The mechanism is operated on the reverse drive principle and is fitted with two drums engraved 0-9, one drum recording tenths of a minute and the other recording minutes.

A two, or three, position rotary switch is provided to complete the pulse control circuit. The third position is only provided when it is necessary to time call office calls. The mechanism is restored to normal by a resetting key after the completion of a call, the rotary switch being first restored to the stop position.



Side View.

Fig. 27

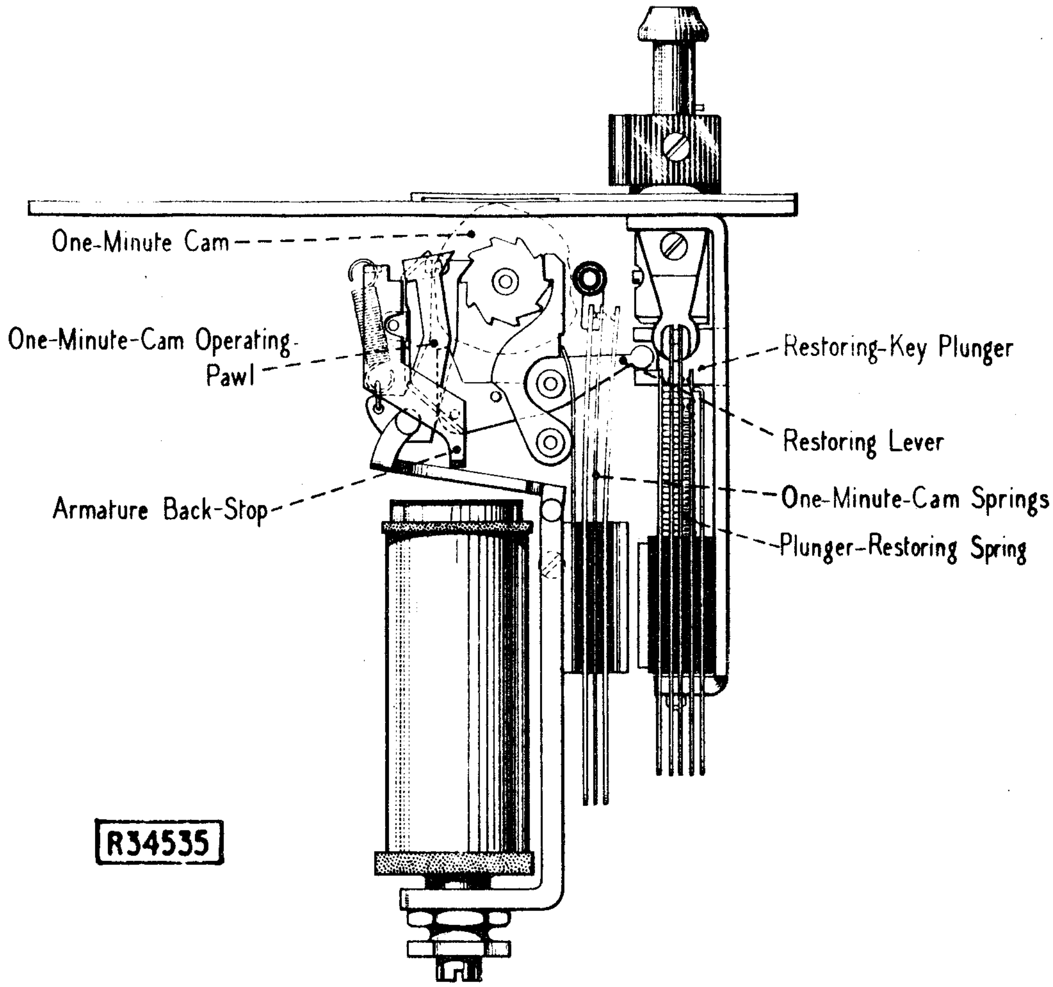

One-Minute Cam
One-Minute-Cam Operating-Pawl
Armature Back-Stop
Restoring-Key Plunger
Restoring Lever
One-Minute-Cam Springs
Plunger-Restoring Spring
R34535

Fig. 28

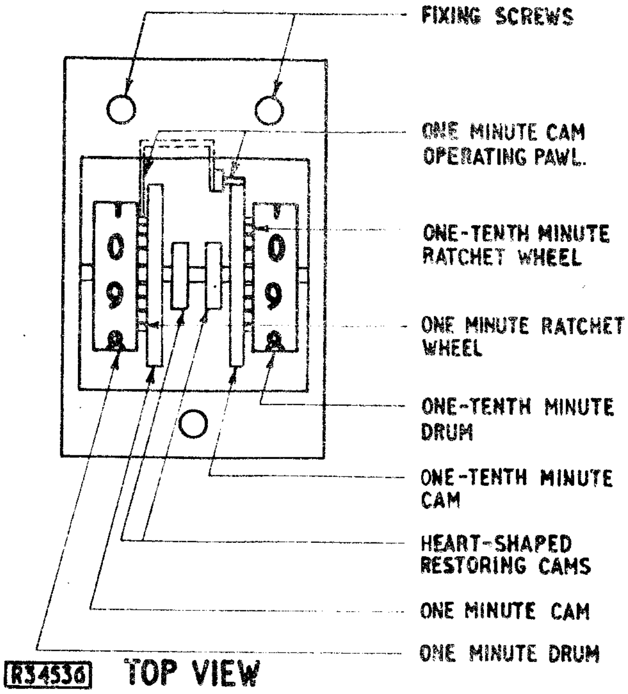


Fig. 29

Figs. 27, 28, and 29 show three views of the mechanism.

When a 6 sec. pulse is passed through the operate coil the armature is attracted thus moving the one-tenth-minute cam-operating pawl into the next tooth of the ratchet wheel. When the magnet is de-energized the armature releases, and in restoring to its unoperated position under the tension of the armature restoring spring, rotates the ratchet wheel in a counter-clockwise direction (Fig. 27). The one-tenth-minute cam detent prevents the ratchet wheel rotating more than one step. The one-tenth minute drum is fixed to the ratchet wheel and thus the number displayed is advanced by one digit. This action is repeated until the figure 9 is displayed on the one-tenth minute drum. When this position is reached the one-tenth-minute cam, which also rotates with the one-tenth-minute drum, allows the one-minute-cam operating pawl to engage with its associated ratchet wheel, therefore when the magnet is next energized and released the two number drums are rotated simultaneously. The one-minute drum then displays '1' and the one-tenth-minute drum is advanced from '9' to '0'. This action of first rotating the one-tenth-minute drum and then rotating the minute drum continues until the clock indicates 9.9 minutes, then the operate circuit is automatically disconnected.

The cams attached to the two drums are shaped so that as they rotate their movement operates the springsets associated with them.

Sticking of the armature due to residual magnetism is prevented by a pad of some sound absorbing material which is fixed to the pole-face; this provides a residual gap when the armature is attracted.

The clock may be restored to normal (9.9) at any instant by the depression of the restoring key after first returning the rotary start key to the stop position. When the restoring key is depressed the restoring lever disengages the detents and the operating pawls from their associated ratchet wheels. A hook-shaped extension of the lever engages the two heart-shaped restoring cams and rotates the cams and the number drums to the normal position.

END