AUTOMATIC TELEPHONE CIRCUIT ELEMENTS

Part 2

This Pamphlet is in two sections, the first describing the essential features of the 2000-type selector and the circuit elements particular thereto, while the second deals with more advanced circuit elements applicable to automatic telephony in general. Before proceeding to study this Pamphlet it is desirable that the student shall understand fully the circuit elements described in Educational Pamphlet, Telephones 2/2, which in general are applicable only to pre-2000-type equipment and to which references are made in this Pamphlet.

SECTION 1

MECHANICAL FEATURES OF THE 2000-TYPE SELECTOR

The present standard two-motion selector mechanism is the 2000-type. The mechanism is shown schematically in **Fig. 1,** and **Fig. 2** is a photograph of the selector.

The chief point affecting circuit design is the absence of a release magnet. The wipers and ratchets are mounted on a hollow wiper carriage which slides on a fixed shaft, the carriage being raised and rotated by the action of the vertical and rotary pawls upon their respective ratchets. The carriage is supported during the vertical action by the vertical detent, which is in engagement with the vertical ratchet; during the rotary action it is supported by the comb plate, which engages the rotary disk on the first rotary step. The rotary detent holds the carriage against the tension of the restoring spring.

To release the selector, the rotary action is continued until the wipers are disengaged from the bank at the 12th step. In this position the disk is disengaged from the comb plate by a notch in the rotary disk, and the wiper carriage falls. When the wipers are clear of the bank, i.e. below the first level, the rotary detent is freed from the ratchet and the wiper carriage is restored to its normal position by the restoring spring.

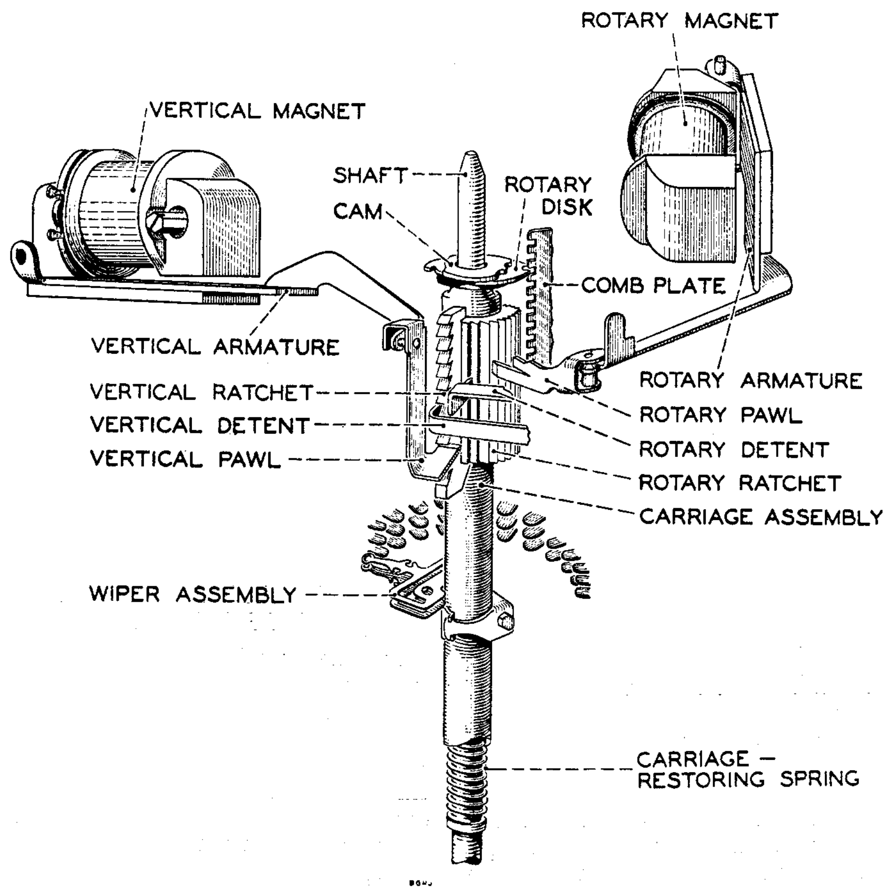

FIG. 1

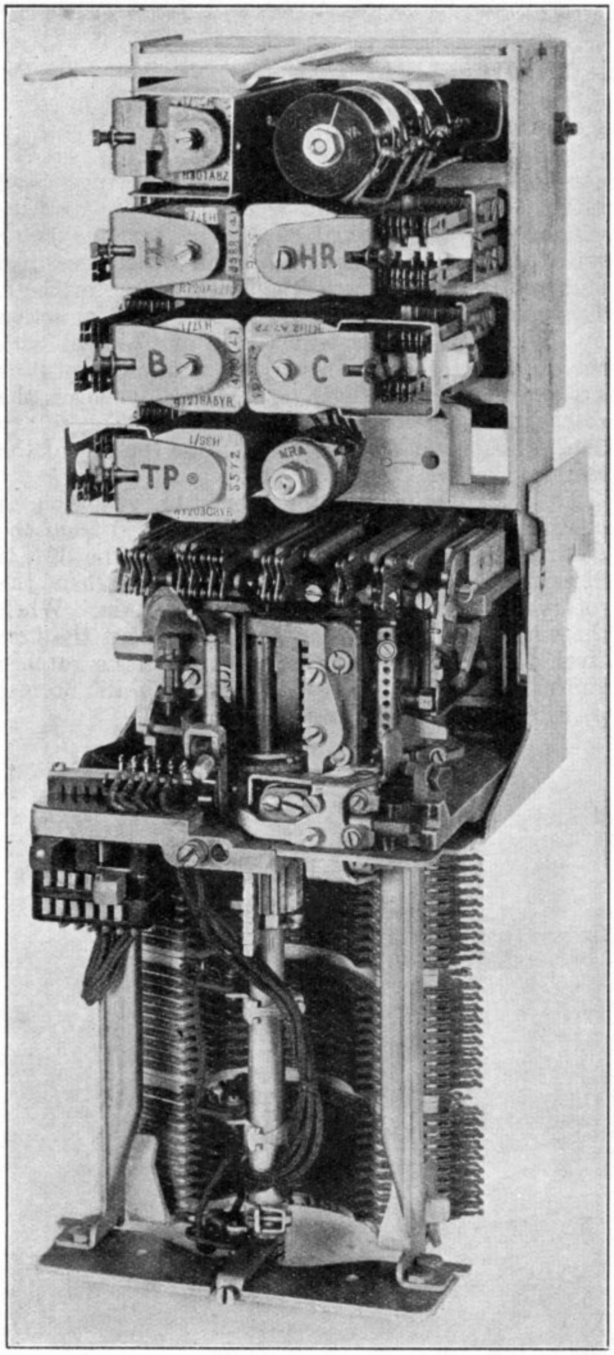

FIG. 2

IMPULSE-CONTROLLED VERTICAL ACTION

A vertical stepping circuit of a 2000-type selector is shown in **Fig. 3.** On comparing this with the vertical stepping circuit shown in E.P. Telephones 2/2 Fig. 19, it will be seen that several changes have been made in the circuit. These changes are mainly to reduce the possibility of failure of the B and C relays when distorted impulses are received.

A fast-operating B relay is used so that its flux rises quickly during the ' make ' period of the impulse, and, to obtain the slow-to-release feature, the relay is short-circuited by contact A during the ' break ' period. Relay B is initially operated via A, N1 and C2, and at B1 provides the earth to which the vertical magnet subsequently operates and a locking circuit for itself against the change-over of N1 and the break of C2. B2 contact provides for the operation of relay C, the C1 contact in the vertical-magnet circuit preventing a false impulse from being given to the vertical magnet at the moment when all three springs of the A contact unit are in contact on the initial operation of A.

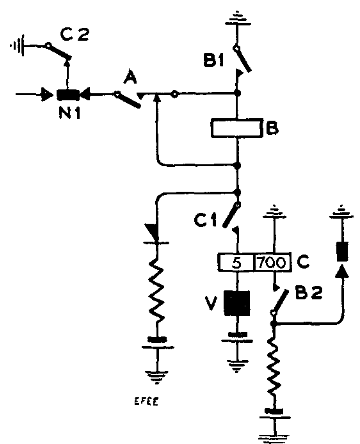

FIG. 3

The vertical magnet is energized via the 5-ohm winding of C, C1, the break section of the A contact, to earth at B1. After the initial operation of A, the N1 and C2 contacts do not function in the stepping circuits. To make the release of C dependent on the cessation of impulsing, its pre-operating coil is short-circuited by the N2 springs immediately the shaft is raised from normal; this short-circuit also has the effect of making the relay slow to release.

It will be seen that the vertical magnet is shunted by the battery circuit of relay B; this tends to make the magnet slow to release and, to prevent this effect, a metal rectifier is placed in series with the battery.

AUTOMATIC ROTARY ACTION USING CUT-DRIVE ' EARTH ' TESTING

In the pre-2000-type selector the automatic rotary-drive circuit is obtained by inter-action between relay G and the rotary magnet. This results in the hunting speed being slower than that obtainable with a self-interrupted drive circuit, as used for a uniselector. A self-interrupted drive circuit can be applied to the 2000-type selector, however, because of the special mechanical action of its interrupter springs, which are mechanically linked to the rotary-magnet armature by a ' toggle ' action. The toggle action causes the springs to break contact when the armature approaches the end of its operating stroke, and prevents the springs remaking contact until the armature has nearly completed its release stroke. The circuit of the rotary magnet is, therefore, maintained until the armature is near the end of its operating stroke and, when disconnexion does occur, is not reconnected until the armature is near the end of its release stroke. It should be noted that the heavy restoring-spring tension of a uniselector causes the armature of the uniselector to restore despite the fact that the magnetic flux begins to rise at an early stage of the release stroke.

A self-interrupted circuit for a two-motion selector cannot be completed via the P-wiper and bank as in a uniselector circuit, because the two-motion selector is a forward-drive switch and the motion would be erratic owing to the disconnexion in the magnet circuit as the wiper moved from contact to contact. The sparking due to the heavy current required to operate the magnet would also cause rapid destruction of wipers and banks.

The essential feature of earth testing is that engaged contacts are connected to earth potential. The rotation of the wipers can, therefore, be stopped by arranging that a relay, a contact of which completes the rotary-magnet circuit, shall remain operated whilst the wipers are moving over earthed contacts and that the relay shall release and cut the drive circuit when a disengaged outlet is found. This principle of disconnecting a local drive circuit by means of a testing relay is known as a " cut-drive " principle. It will be appreciated that with such a circuit the speed of the drive is independent of the testing, and the testing relay must release very quickly so that the drive circuit is cut before the rotary-magnet interrupter springs reconnect the circuit.

Fig. 4 (**a**) shows a circuit element using the cut-drive principle and controlling an automatic rotary action. During the first vertical step, H is operated via B1, N1, C1 to earth. The release of relay C at the conclusion of the vertical train completes a self-drive circuit for the rotary magnet via C1 normal, N1, R and H1, relay H being held via B1, R and H1 until the wiper rests on the first rotary contact, when the R springs break.

Whilst the wiper is passing over earthed contacts the circuit of the rotary magnet is maintained at H1, and relay H is held operated in one of the following ways :—

(*a*) Via H1, R and B1 whilst the wiper is passing from contact to contact

(*b*) Via P-wiper and H2 whilst the wiper is resting on an engaged contact.

When a disengaged outlet is found, the absence of earth on the P-wire allows H to release when the R springs break contact. The release of relay H disconnects the drive-magnet circuit at H1 and relay C is re-operated in a manner which is explained later. The re-operation of relay C switches the negative, positive and P-wire to the seized outlet, and re-operates H via B1, N1 and C1. Relay H locks via H2 to the guarding earth on the P-wire and, when relay B releases, holds relay C operated.

To prevent an outlet being left unguarded during the time that H and C are released after a disengaged outlet has been found, i.e. during the operating time of C, the outlet is guarded by an earth applied to the P-wiper via B2, N2 and a break contact of relay H (H3).

In the foregoing explanation it is stated that relay C is re-operated consequent on the release of relay H. **Fig. 4** (**b**) gives the circuit conditions of relay C and these will now be explained in detail.

When the selector is seized, relay C is operated with both coils in series via H4 normal and B4 and, when H operates during the first vertical step, C retains in series with the vertical magnet, the initial operating circuit of C being broken at H4 and the earth at H5 short-circuiting the 700-ohm winding and thus making C slow to release. At the conclusion of the vertical train, C releases and rotary stepping commences.

When a disengaged outlet is found, the release of H causes C to be re-operated via H4 and B4, and C in turn re-operates H. After the guard relay (B) has released, relay C holds via C2, NR2 and H4 and is dependent on relay H holding to the earth returned on the P-wire.

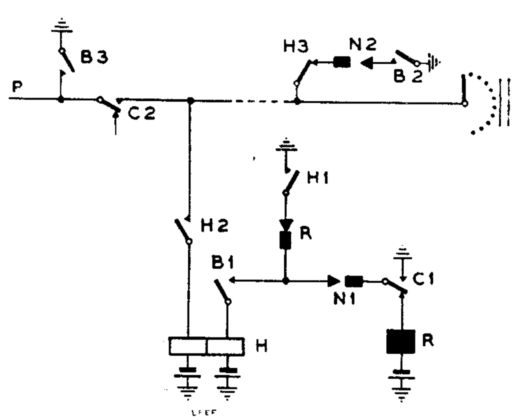

FIG. 4 (*a*)

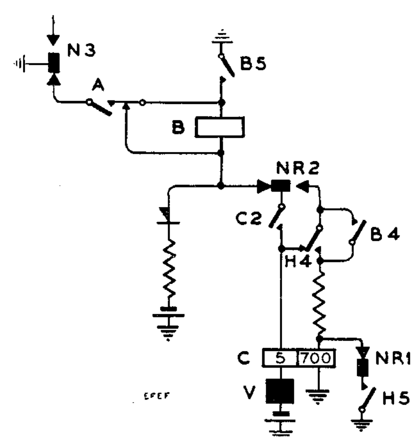

FIG. 4 (*b*)

It should be noted that, after rotary stepping, the NR1 contacts prevent C being made slow to release by the H5 contacts, and that the break contacts of NR2 prevent an impulse from being given to the vertical magnet when relay A releases after the negative, positive and P-wire have been switched to the succeeding stage.

AUTOMATIC ROTARY ACTION USING 'BATTERY' TESTING

Earth testing arrangements have the following disadvantages :—

(*a*) It is possible for a circuit, searching for a free outlet, to switch to a faulty outlet having a *disconnected* P-wire.

(*b*) When release conditions apply, earth potential must be disconnected from the P-wire for a period sufficient to allow switching relays, etc., to release. During this period the circuits releasing are in an unguarded condition.

(*c*) Should two circuits, both searching for a disengaged outlet, test on such an outlet simultaneously, there is a possibility that they both seize the outlet.

NOTE.—In battery testing circuits the foregoing misoperations (*a*) and (*b*) cannot occur and the possibility of (*c*) occurring is very much reduced.

An example of a battery testing circuit using the cut-drive principle is shown in **Fig. 5.** Disengaged outlets are indicated by battery, fed via a resistor to the P-wire, the testing coil of the combined testing and switching relay H being connected to the P-wiper. The testing coil of H is of very low resistance, so that when an outlet is seized the potential on the P-wire is reduced to a value below that required to operate another testing relay and the outlet is thus marked engaged.

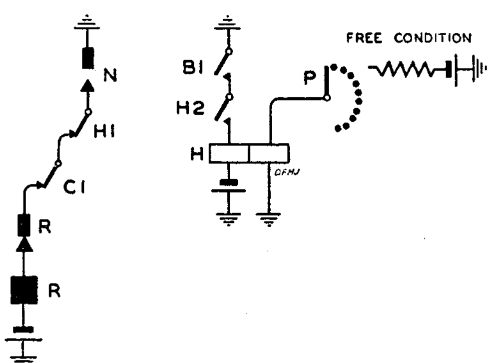

FIG. 5

On the release of C, a self-drive circuit for the rotary magnet is completed via R, C1, H1 and the N springs, the drive circuit being disconnected at H1 when the combined testing and switching relay H operates to a free condition on the P-wire. To prevent an H relay, which has already switched to an outlet, from being released by the shunting effect of the low-resistance coil of another H relay which may test the outlet, the H relay when operated is held via a second winding and contacts H2 and B1.

An example of battery testing as applied to the uniselector is given in section 2 of this Pamphlet.

IMPULSE-CONTROLLED ROTARY ACTION

The circuit element shown in Fig. 3 has been expanded in **Fig. 6** to include a typical circuit element controlling rotary stepping. At the end of the vertical train, C is released by the earth at B1 applied to the 700-ohm coil of C via N2 operated, NR1 and E3, the slight current through the 5-ohm coil of C from the vertical magnet being insufficient to maintain C or the vertical magnet. The release of C causes the operation of E via NR2, C2 normal, coil of E, N2 operated, B1 to earth. E1 disconnects the vertical magnet and connects the rotary magnet to the stepping circuit, E2 prepares a holding circuit for relay E against the re-operation of C and the breaking of the NR2 contacts, and E3 disconnects the earth which released C at the end of the vertical train.

On the re-operation of C, the rotary magnet is able to accept impulses, the magnet being energized via E1, 5-ohm coil of C, C1, break section of A, B1 to earth. Just prior to the completion of the first rotary step, the NR contacts change over and NR1 reconnects earth to the 700-ohm coil of C, so causing C to become slow to release.

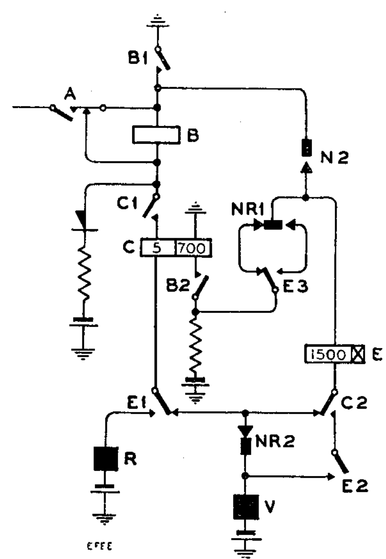

FIG. 6

At the end of the impulse train, C releases and this causes E to release, the initial operating circuit of E being broken by NR2. During the slow-release period of E the called subscriber's line is tested, and when E is released C re-operates because the earth at B1 is no longer extended to the 700-ohm coil of C, NR1 being operated and E3 normal.

TESTING CIRCUIT OF FINAL SELECTOR

The testing circuit of a 2000-type final selector is shown in **Fig. 7.** When the called subscriber's line is disengaged, H operates on the release of C to the battery from the called subscriber's K relay and locks via H1, N2 and B1 ; C3 prevents an earth from being extended to the P contacts of lines passed over during rotary stepping. Should the called subscriber's line be engaged, G operates on the release of E via H3, E4, NR1, N2 and B1 and applies busy conditions to the calling subscriber's line.

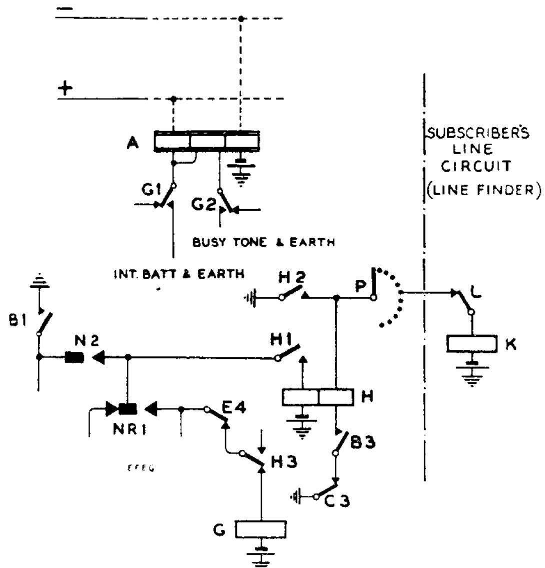

FIG. 7

In 2000-type equipment the tones are passed inductively to the negative and positive wires by means of a third winding on the A relay, and this method of applying tones to the line overcomes the out-of-balance difficulty encountered when the tones are connected to only one of the wires as in the pre-2000-type equipment. With the arrangement shown, the interrupted battery signal which causes the cord-circuit supervisory to flash is connected via G1 to the positive wire and to one end of the third winding of A, busy tone and earth being connected to the other end of the winding. Relay A repeats the tone to the line by means of its normal operating coils, in a similar manner to a transformer.

As the interrupted battery signal is also applied to the third winding, a current flows through the coil to the busy-back earth whilst the flash signal is being transmitted. This maintains A in the operated condition during this period and it is, therefore, not necessary to provide a holding coil on the B relay as in the pre-2000-type equipment.

RINGING CIRCUIT OF FINAL SELECTOR

It will be seen from **Fig. 8** that the circuit element controlling ringing in the 2000-type final selector differs in only a few minor details from that of the pre-2000-type selector shown in E.P. Telephones 2/2, Fig. 23. The slow-release period of relay E provides the delay period necessary for the operation of the called subscriber's K relay. When relay E releases, relay J is operated and at J1 connects ringing to the called subscriber's line, whilst J2 connects ringing tone to the calling subscriber's line, the tone being passed to line inductively via the windings of the A relay. Relay F is arranged to hold in series with the holding coil of H when ringing has been tripped.

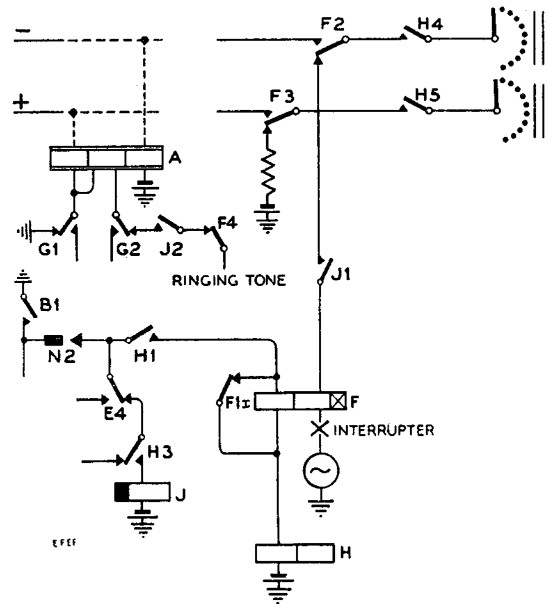

FIG. 8

TRANSMISSION BRIDGE

In **Fig. 9,** a ballast resistor is shown in series with relay D in the transmission bridge. When a subscriber's line of high resistance is connected to the called side of the bridge, the ballast resistor in conjunction with a low-resistance (50 + 50 ohm) nickel-iron sleeved relay, gives an increase in transmission efficiency compared with that obtainable

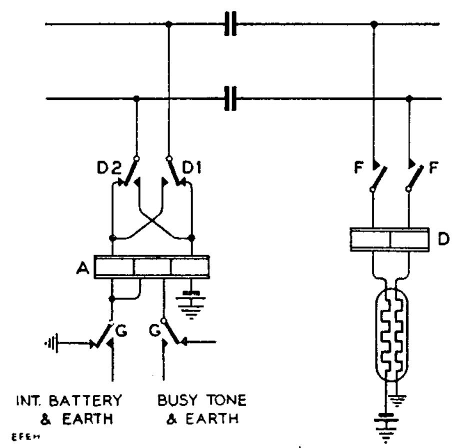

FIG. 9

with a normal 200 + 200 ohm relay alone (the ballast resistor is described in more detail in another pamphlet).

The use of the ballast resistor to increase transmission efficiency is only warranted on junction calls, but as it is not economical to provide separate groups of final selectors for junction and for local calls, all final selectors are equipped with ballast resistors on the called subscriber's side of the bridge, the ballast resistors for a calling subscriber being provided in the transmission bridge at the originating exchange when a junction is involved.

When ballast resistors are incorporated in the bridge, simple change-over contacts are fitted to the D relay, as this arrangement results in the clicks received by a calling subscriber (on the reversal of the current flowing in the negative and positive wires) being less intense than when these contacts are of the make-before-break type as shown in E.P. Telephones 2/2, Fig. 26. It will be seen from Fig. 9 that contacts of the F relay are used to keep the condensers disconnected until impulsing has been completed.

RELEASE CIRCUIT

As already mentioned, a release magnet is not required in the 2000-type selector. A self-drive circuit for the rotary magnet is completed when release conditions obtain, and the wipers are rotated out of the bank and drop below the first level of the bank contacts, being then restored to their normal positions under the control of a spring. After the completion of the 12th rotary step a mechanical device prevents the full operation of the rotary-magnet armature and, therefore, stops the rotary-magnet interrupter springs from breaking contact. This prevents the continuance of rotary action during the restoration of the wipers, the rotary-magnet armature being held in a partially-operated position whilst they restore to their normal positions. When the wipers are fully restored, the release circuit is opened by N springs.

A typical release circuit is shown in **Fig. 10.** It will be remembered that, after the rotary train, relay C is re-operated and holds over a contact of relay B. With the release of B the circuits of both H and C relays are disconnected. After the release of H and during the slow release period of C, the P-wire is disconnected and any switching relays holding to the selector are released.

The release of H completes a self-drive circuit for the rotary magnet via the rotary interrupter springs and, when C has released, a guarding earth is applied to the P-wire via the N1 springs and a contact of C. Whilst C is releasing the selector is unguarded and, so that B shall not be operated and disconnect the release circuit should the selector be seized during this period, it is arranged that the operating circuit of B via the A-relay contacts shall be broken by the N springs at N1.

To prevent the release alarm being operative during normal rotary stepping, the release-alarm circuit is connected in series with the earth lead to the rotary-magnet interrupter contacts.

Busy-back tone and flash is given from the 11th rotary contacts of group selectors, and circuit arrangements prevent selectors from switching to the 11th step under release conditions although under the 'all outlets engaged' condition selectors stop on the 11th contacts.

SECTION 2

GENERAL ARRANGEMENT OF 200-OUTLET SELECTORS

The type of selector so far discussed is the 100-outlet type, that is, one which has 10 levels and 10 outlets per level. Although, because of the decimal dialling system, selectors cannot normally have more than 10 levels, it is often desirable to use selectors having 20 outlets per level. The bank capacity of the selector is increased by duplicating the wipers and banks so that, although the wipers may still be set on any one of 100 positions, there are two outlets per position. As simultaneous connexion to two outlets is not required, only one set of wipers is electrically connected for each call.

The wiper-switching arrangements in the 200-outlet final selector differ from those in the 200-outlet group selector and the 200-outlet line finder. In the 200-outlet final selector for example, the set of wipers to be used is generally determined by the

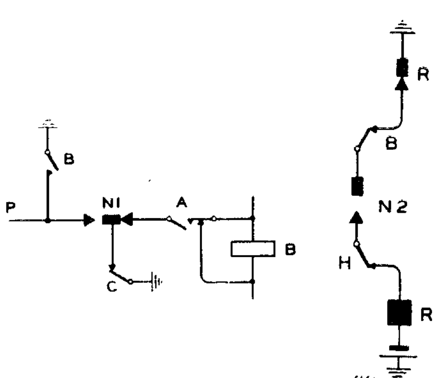

FIG. 10

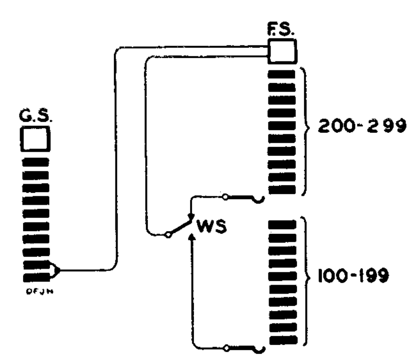

FIG. 11

'hundreds' digit, which, in a 4-digit switching scheme, is received by the second group selector and the appropriate set of wipers is switched into use immediately the final selector is seized. In the 200-outlet group selector and the 200-outlet line finder, however, wiper switching does not take place until the wipers have been rotated to the position occupied by a free outlet or calling line respectively.

200-outlet final selector

The wiper-switching arrangements are illustrated in **Fig. 11.** The final selector shown in this figure serves the two groups of lines 100-199 and 200-299, so that when the selector is stepped to position 78, for example, one set of wipers rests on line 178 and the other on line 278. Connexion to the appropriate line is determined by the operation or non-operation of the wiper-switching relay (WS), and this, in turn, is determined by the level of the group selector from which the final selector is seized.

The circuit arrangements of relay WS are shown in **Fig. 12.** When the final selector is seized from level 2 of the group selector, relay WS does not operate, but when it is seized from level 1, the caller's signalling loop causes the operation of relay WS, which locks to the P-wire and switches the caller's

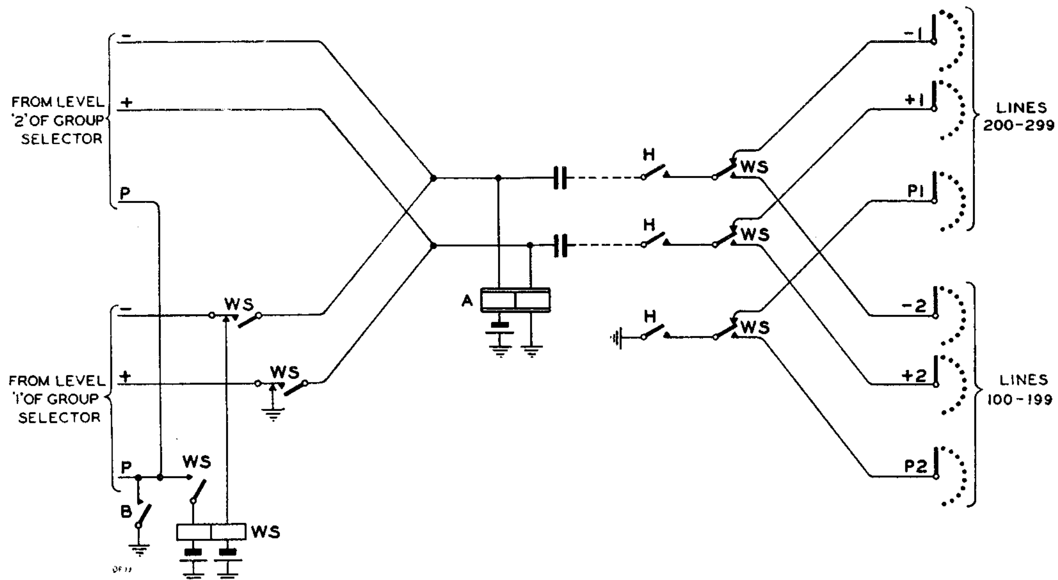

FIG. 12

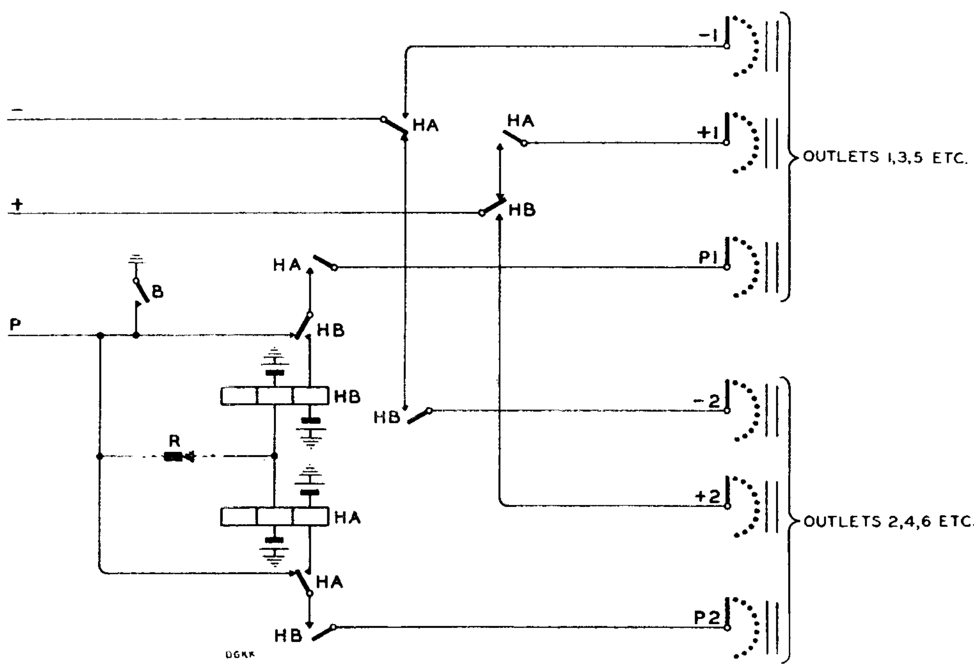

FIG. 13

line to relay A. The incoming P-wires are commoned because the busy condition must be connected to both levels of the group selector. This method of determining the set of wipers is known as " path of entry " discrimination, that is, the set of wipers taken into use is dependent on the path over which a call enters the selector.

200-outlet group selector

The wiper arrangement of a 200-outlet group selector using ' cut-drive ' earth testing is illustrated in **Fig. 13.** As there are two outlets on each of the 10 rotary positions, two switching relays (HA and HB) are provided to allow the connexion of the calling line to either outlet. Gradings are designed on the principle that outlets will always be seized in consecutive order and, to meet this requirement, a circuit arrangement (not shown in the figure) ensures that when the wipers reach a rotary step having both outlets disengaged, the odd-numbered outlet is seized.

200-outlet line-finder

The wiper-switching arrangements of the 200-outlet line-finder are similar in principle to Fig. 13, in that two switching relays are provided to enable the associated 1st selector to be connected to either set of wipers.

UNISELECTOR CIRCUIT USING ' BATTERY ' TESTING

Fig. 14 shows the circuit arrangement of the testing relay (K) when battery testing is applied to a uniselector circuit. The resistors shown in the figure are incorporated in the P-wire circuits of the apparatus connected to the bank contacts.

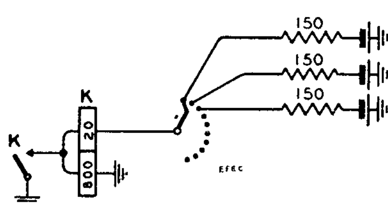

FIG. 14

Disengaged outlets are indicated by battery fed via a resistor to the P-wire, the relay (K) being adjusted to operate with both coils in series. Until the time that the contact of K makes contact, both coils of K are effective in operating the relay and, assuming an exchange battery voltage of 50V., the voltage-drop across K will be 42·2V. When the K contact closes, however, the 800-ohm winding of K is short-circuited, and the voltage across the relay is reduced to 5·9V. The relay holds to this voltage on the 20-ohm winding alone. Other K relays which may test on this contact will now receive insufficient current to operate them. To reduce the voltage further, and thereby afford a bigger margin between the operating and holding voltages, the circuit of the apparatus connected to the bank contacts is usually arranged so that the resistance through which the holding current is passed is increased when the apparatus is seized. An example of a circuit element using this arrangement is shown in **Fig. 15.**

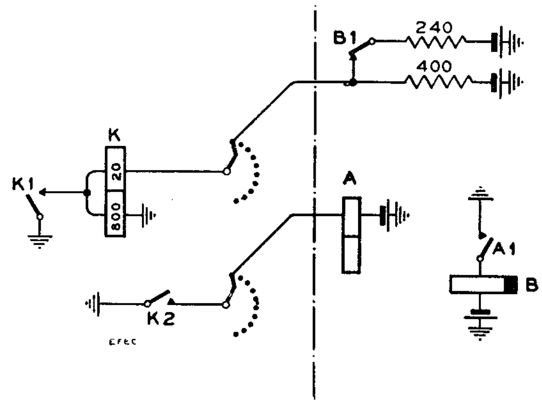

FIG. 15

The 400-ohm and 240-ohm resistors are both effective until K switches, but when relay A operates to the earth from K2, B operates and the 240-ohm resistor is disconnected from the P-wire, so increasing the resistance in the circuit from 150 ohms to 400 ohms and reducing the voltage on the P-wire to 2·5V.

Other relays testing on an engaged outlet do not affect the holding voltage on the P-wire to any great extent, as both coils of the testing relay are in series whilst testing ; hence, the shunt placed across the 20-ohm winding of the relay switched to the P-wire is of high resistance.

The complete uniselector circuit is shown in **Fig. 16.** The interrupter contacts of the uniselector

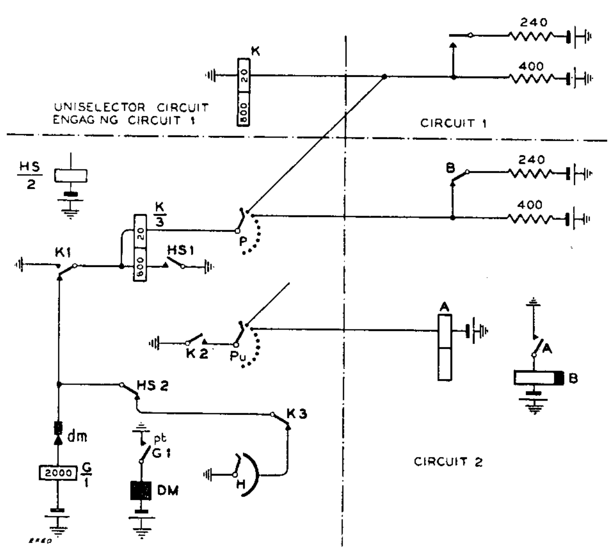

FIG. 16

are not joined directly in circuit with the drive magnet as in an 'earth' testing circuit, but with the control relay G which, in turn, is responsible for opening and closing the drive-magnet circuit at G1. The G relay is adjusted to operate in series with the 800-ohm winding of K, and repeats the normal make and break sequence of the dm contacts to the drive magnet at G1.

When HS is operated, G operates via the dm springs, K1 normal, 800-ohm coil of K to the earth at HS1. G1 closes the drive-magnet circuit, and, when the magnet operates, G is released by the breaking of the dm springs. On the release of G the drive-magnet circuit is disconnected, the armature is released and the uniselector wipers are stepped to the first contact in the bank.

The first bank contact of the P arc in Fig. 16 is shown as being in the engaged condition and K will not therefore be operated by the low potential on the contact. On the remake of the dm springs, G re-operates over the 20-ohm and 800-ohm coils of K in parallel, and the wipers are stepped to contact 2.

Contact 2 is shown as being disengaged, and an analysis of the circuit condition which exists when this contact is reached is shown in **Fig. 17.** It will be seen from this figure that the 20-ohm winding of K and the 150-ohm resistor in the P-wire circuit are shunting relay G. The shunt on G reduces the current through the coil of G to below that required to operate the relay, and therefore the drive-magnet circuit is not reconnected. Relay K operates from the high potential on contact 2 to the earth at HS1 and K1 disconnects the circuit of G and engages the outlet by short-circuiting the 800-ohm winding of K. K2 passes an earth forward to the A relay of the apparatus connected to the outlet, so causing the resistance in the private circuit to be increased, and K3 disconnects the homing circuit against the release of HS.

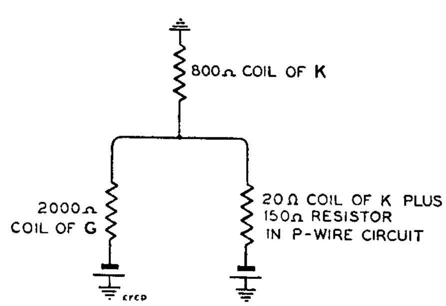

FIG. 17

So long as a potential is maintained on the P-wire, K is held operated and HS can therefore be released without affecting the circuit, but on the disconnexion of the potential, K releases. With HS and K normal and the uniselector off its home position, a circuit is established for G via HS2 normal, K3 normal, homing arc H to earth and G re-operates, interacts with the drive magnet as before, and the wipers are consequently stepped to the home position.

USE OF AUTO-TO-AUTO RELAY-SETS

It is shown in E.P. Telephones 2/2 that, when a call is passed between two subscribers in the same exchange, the negative, positive and P-wires are normally switched through from stage to stage in such a manner that the caller, by controlling the supervisory and guard relays in the final selector, controls the release of the connexion. It is uneconomical however to provide 3-wire junction circuits for calls between subscribers in different exchanges and, so that the resistance of a junction shall not reduce the current below that normally fed to a calling subscriber's instrument on a local call, it is necessary to provide a transmission bridge at the caller's exchange. Although the principle of calling-subscriber control holds good on junction calls, the method of effecting control differs slightly from that used in the case of calls between subscribers on the same exchange.

Suppose that in a simple automatic system a caller dials 2XXX for local numbers, and 3XXX for numbers in another exchange. In both cases, the same 1st selector is used and its circuit will be such that on the switching of relay H, the selector will rely for its hold on the earth returned over the P-wire. As the P-wire is not extended between the 3rd level of a 1st selector and the distant 2nd selector it is necessary to provide equipment between the 1st selector and the junction to give the holding facility which would have been provided by the succeeding selectors had the caller dialled 2XXX. The equipment is arranged so that when the 1st selector H relay operates, the extension of the caller's loop operates an A relay, which in turn operates a B relay to hold the chain of selectors already set up.

This equipment between the 1st selector and the junction is called an "auto-to-auto relay-set" and, because its purpose is to hold the selectors at the originating exchange and to provide a transmission bridge for the calling subscriber, its A relay must always be in circuit. Serious difficulties would be experienced if, at each switching stage, the A relays of the selectors at the distant exchange were directly connected to the coil of the A relay of the auto-to-auto relay-set and to the caller's line. To overcome these difficulties, condensers are inserted in the speaking wires between the A relay of the relay-set and the junction. The presence of these condensers however, makes it necessary for relay A in the relay-set to repeat to the distant selectors all the signals received from a calling subscriber and, to effect this repetition, the junction wires are looped in series with a contact of relay A. For the same reason it is necessary to repeat signals from the called end back to the caller's end of the circuit.

The complete arrangement is shown in **Fig. 18.** The loop circuit across the junction wires consists of two supervisory relays (D & I), which are later used to receive signals transmitted from the distant exchange. It is essential for this circuit, which is shunting the speaking circuit, to offer a high impedance to alternating currents of speech frequency. Relay D is necessarily of low impedance, as it is a shunt-field relay, and the required high impedance is therefore provided by relay I. As the inductance of the D and I relay circuit would seriously distort the form of the repeated impulses, the relays are short-circuited during impulsing by a contact of relay C, which is operated throughout each impulse train.

Three methods of operating the meter are in general use :—

(*a*) Booster metering,

(*b*) Fourth-wire metering,

(*c*) Positive-battery metering.

Methods (*a*) and (*b*) are used in exchanges having a uniselector in the subscriber's line circuit, and method (*c*) in exchanges having line-finder equipment.

Two methods of fourth-wire metering have been employed, known as "fourth-wire earth metering" and "fourth-wire battery metering," the particular method being determined by the connexion of the meter and the potential employed to operate it. For example, in fourth-wire earth metering the meter is connected to battery and an earth pulse is sent back over the fourth wire to operate the meter.

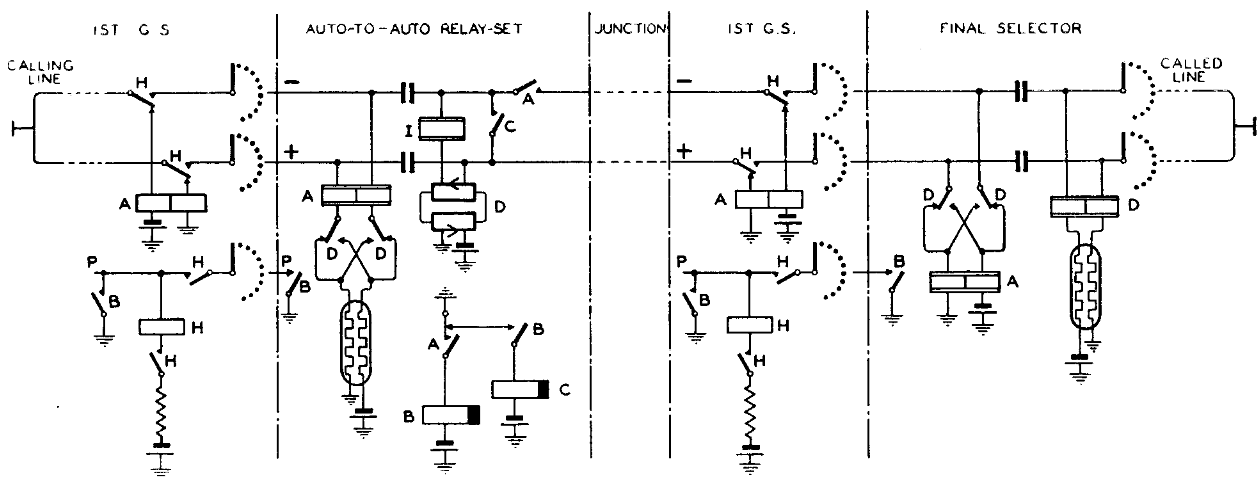

FIG. 18

When a called subscriber answers, relay D in the final selector operates. One of the functions of this relay is to cause the operation of the caller's meter, but, as the meter is in the originating exchange, the answering supervisory must be repeated to the auto-to-auto relay-set. To effect this signalling condition, contacts of relay D reverse the connexions of relay A in the final selector, thereby causing a reversal of current in the junction circuit. This reversal of current is detected by the shunt-field relay D in the auto-to-auto relay-set, and it is this relay which effects the operation of the caller's meter.

When the caller clears, relay A in the relay-set releases, and this disconnects relay A in the final selector ; the release of these A relays causes the disconnexion of their respective guard relays, and the apparatus in each exchange is restored to normal.

METERING

The operation of the D relay in the transmission bridge serving the called subscriber controls the metering of a call, the calling subscriber's meter being operated when D operates to the called subscriber's loop.

Booster Metering

In the booster metering circuit, the meter is connected in parallel with the K relay of the subscriber's uniselector, and is so adjusted that it will not operate on the current flowing from the normal exchange battery to the P-wire. When metering conditions are applied, however, the current in the P-wire circuit is increased by applying a second battery to the P-wire in series with the exchange battery, the increase in current causing the meter to be operated. To prevent the meter being actuated more than once for a call by a release and re-operation of the D relay after its initial operation, the circuit element controlling metering is arranged to be prepared during the seizure and ringing of the called subscriber's line and, when the subscriber answers, a contact of relay D acts as a trigger to this circuit.

From **Fig. 19** it will be seen that relay J is operated when relay H switches to the called subscriber's line circuit and, when relay F trips to the ringing, relay J locks via J1, F and D1, the circuit over

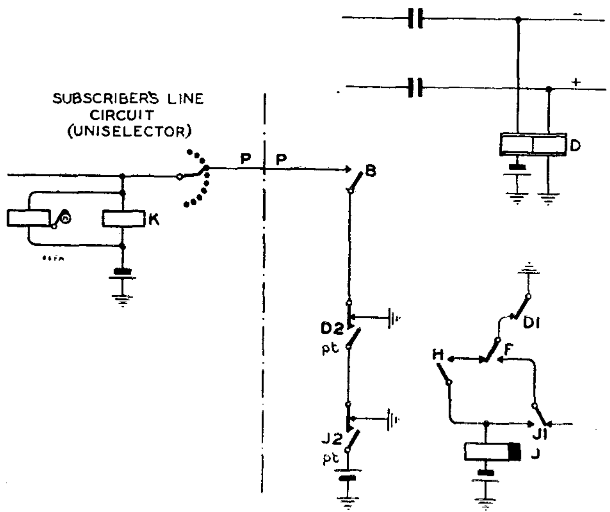

FIG. 19

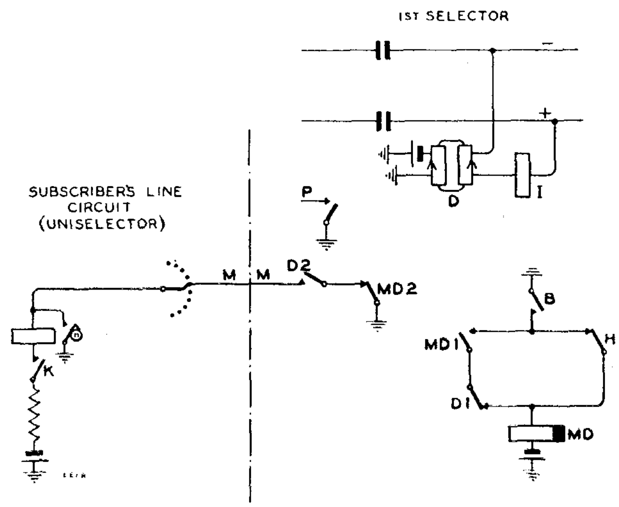

FIG. 20

which the booster battery is applied being prepared at J2. When the called subscriber answers, relay D is operated and the locking circuit of J is broken and, during the slow-release period of J, the booster battery is applied to the P-wire via, J2, D2 and B.

The booster battery is disconnected from the P-wire on the release of J, the F contact now preventing the re-operation of J, so that any further release and re-operation of D will not be effective in operating the meter.

The locking circuit of J via J1 and F is provided to guard against the meter being operated should it be required to trip the ringing current without operating the supervisory relay (D). This condition is met in connexion with certain auxiliary circuits such as service interception, service observation, etc.

Fourth-Wire Earth Metering

This method of operating the subscriber's meter overcomes the disadvantage found in the booster method, of having to adjust the meter to a critical non-operating current, but a wire additional to the normal negative, positive and P wires must be provided. Fourth-wire metering is, therefore, adopted only in systems in which a transmission bridge is incorporated in the first selector. A circuit element for fourth-wire metering is shown in **Fig. 20.**

Battery is applied to the subscriber's meter when the K relay of the subscriber's uniselector switches, and, on the operation of the guard relay (B) in the first selector, MD operates via a contact of the first selector switching relay (H). Relay MD locks via D1 and MD1, and MD2 disconnects from the M-wire the earth which ultimately causes the meter to operate, so guarding the meter from any false operation on the closure of D2 due to inductive disturbances which may occur on the line and cause relay D to flick.

The reversal of the line current when the called subscriber answers causes D to operate, and the locking circuit of MD is disconnected at D1. Relay MD releases and, at the end of its slow-release period, the earth applied at MD2 operates the meter via D2. On operating, the meter locks to earth via a contact on the armature of the meter, so preventing any further operation of the meter during the time that the call is in progress. At the conclusion of the call, the holding battery for the meter is disconnected by the release of the K relay, and the meter releases.

Positive-battery Metering

Before proceeding to deal fully with the circuit element used for positive-battery metering the basic principle of the circuit will be dealt with. Referring to **Fig. 21** it will be seen that current from battery A (which corresponds to the normal exchange battery) is prevented from flowing through the meter by the metal rectifier B. When the meter battery B is connected to the circuit, however, metal rectifier B allows current from this battery to pass through the meter and the meter operates. The metal rectifier A, applied to the circuit between the two batteries, prevents battery B from being short-circuited by the earth connexion which completes the circuit of battery A.

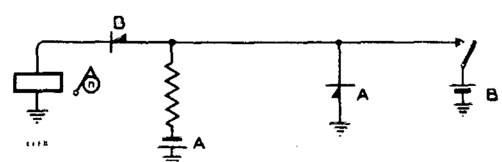

FIG. 21

A complete diagram of the circuit element controlling metering is shown in **Fig. 22.** When E releases after the operation of H to the called subscriber's line relay, J operates via H3, E4, NR1 operated, N2 operated, B1 operated to earth, and thus prepares the metering circuit at J2. The called subscriber's loop operates relay D, and D1 operates relay E, C2 being in the operated condition.

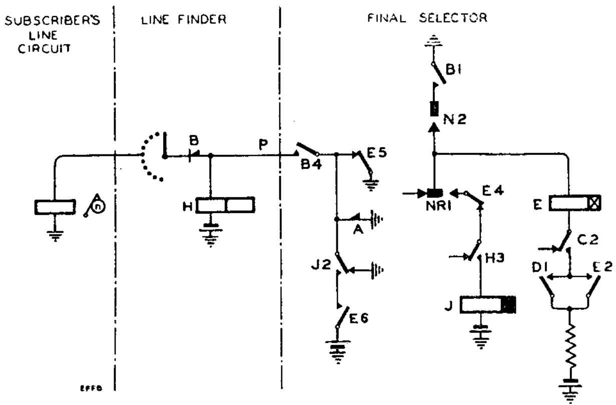

FIG. 22

E5 disconnects the earth which is short-circuiting rectifier A, and E4 disconnects the circuit of J, and during the slow-release period of J the meter battery is connected to the P-wire via E6, J2 and B4. The release of J disconnects the meter battery and restores a full earth to the P-wire at J2. Relay E having locked via E2 prevents the re-operation of J, and so guards against the meter battery being again applied with any subsequent release and re-operation of D. The use of rectifier A makes it possible to dispense with the make-before-break action found on the D2 and J2 contacts (Fig. 19), as current flowing through the rectifier for the periods during which J2, E5 and E6 (Fig. 22), are changing-over from earth to battery maintains the normal current over the P-wire circuit and so retains the switching relays of group selectors, etc.

MULTI-METERING

In the metering systems previously described, the subscriber's meter cannot be operated more than once for each call; in large areas such as London, however, calls having a value equivalent to 1, 2, 3 and 4 operations of the meter are passed automatically between exchanges, and the meter must be operated 1, 2, 3 or 4 times, depending on the fee chargeable for the call.

To discriminate between calls of differing values, the trunking of an exchange is so arranged that calls requiring any given number of meter operations are routed through particular selector levels, the level used for a call being indicated to the metering equipment by means of vertical-marking banks fitted to the selectors.

A machine, common to the exchange, supplies the pulses of current necessary to operate the meters. This machine is equipped with cams which operate spring-sets; a single, double, triple, and quadruple series of pulses being given, respectively, by four of the cams. As the machine is rotating continuously, metering circuits must be connected to the machine at a definite time, i.e. at the commencement of the cam cycle, and must be disconnected when a cycle has been completed. To indicate to metering circuits the commencement of a cycle, a pulse of current is passed from the machine to a metering circuit over a wire known as the 'S' wire. During the time that the metering pulses are being sent, a further pulse of current is maintained over a second wire known as the 'Z' wire, the cessation of this current indicating the completion of the cycle. These S and Z pulses are supplied from cams of the machine, in a similar manner to the meter pulses. The arrangement and the timing of the cam-springs of the pulse machine, together with the circuit element for multi-metering is shown in **Fig. 23.** The shaded portion of the timing diagram indicates the period during which battery is substituted for the earth, which is normally connected to the metering and the S and Z wires.

The sequence of operations during the metering of a call is as follows :—

(*a*) Called subscriber answers—Relay D operates

(*b*) At the next S pulse—Relay DA operates

(*c*) At the ensuing Z pulse—Relay DB operates (relay DA remains operated) and meter pulses are connected to relay RG

(*d*) At the end of the Z pulse—Relay DA releases (relay DB remains operated for the remainder of the call)

The detailed circuit operation is as follows :—

When the called subscriber answers (*a*), the shunt-field relay D in the calling subscriber's transmission bridge is operated by the reversal of the loop on the negative and positive wires. D1 earths the coil of DA in readiness for the S pulse, and D2 prepares a locking circuit for DA; contact D2 prevents premature metering by breaking the locking circuit of DA on the release of D should D respond to an inductive disturbance on the line.

The S pulse (*b*) causes DA to operate, and DA locks via D2, DA1, DB2 to battery. DA2 prepares the operating circuit of DB in readiness for the Z pulse; DA3 and DA4 connect the rectifiers, in series, to the P-wire (the need for providing two rectifiers in series is explained later under "manual hold" and "re-ring" facilities); DA5 disconnects the normal holding earth from the P-wire; DA6 prepares the circuit of RG for the receipt of the metering pulses; and DA7 connects the positive battery, used for metering, to the metering contact of the RG relay. It should be noted that an earth is maintained on the P-wire by RG1 after the operation of DA, this being removed only during the time that metering is actually being effected.

On receipt of the Z pulse (*c*), DB operates via DA2, DA also being held by the pulse independent of DB1 and DB2. Due to the removal of the short-circuit at DB3, relay DB remains held until the release of the connexion. The BB and H contacts are contacts of the guard and switching relays, respectively. The metering pulses are passed via the vertical-marking bank wiper, DB4 and DA6 to the RG relay. In Fig. 23 a typical bank arrangement is shown and, assuming that the selector has been stepped to level 8, two pulses will be given to relay RG, thus causing the metering battery to be applied twice to the subscriber's meter via DA7, RG1 the P-wire and the M-wire.

At the end of the metering cycle (*d*), the Z pulse ceases and DA therefore releases ; DA7 disconnects the positive battery from the metering contact of RG, DA6 disconnects RG from the vertical-marking bank and DA5 restores the normal holding earth to the P-wire. The reoperation of DA to the next S pulse is prevented by DB holding over its normally short-circuited coil and maintaining the disconnexion at DB1. When release conditions are given to the selector, it is necessary that all relays shall be in the normal condition before the release guard is removed from the P-wire. To prevent the DA and DB relays remaining locked to the 2·1-sec. Z pulse should a calling subscriber clear and the guard relay (BB) be released at the beginning of the pulse, it is arranged that the DA and DB relays are released by a short-circuit applied to the Z pulse holding coil of DA when the guard relay releases. The period of 550mS. between the S and Z pulses ensures that metering will not take place should relay D flick, i.e. the period acts as a 'meter guard.'

Contacts RG2 and RG3 do not take part in the metering of a call but are shown in the figure in order that the function of contacts DB5, DB6 and DB7 may be made clear ; these DB contacts prevent the line relay (L) of the selector from being released and the ringing and ringing return from being connected to the subscriber's line during metering.

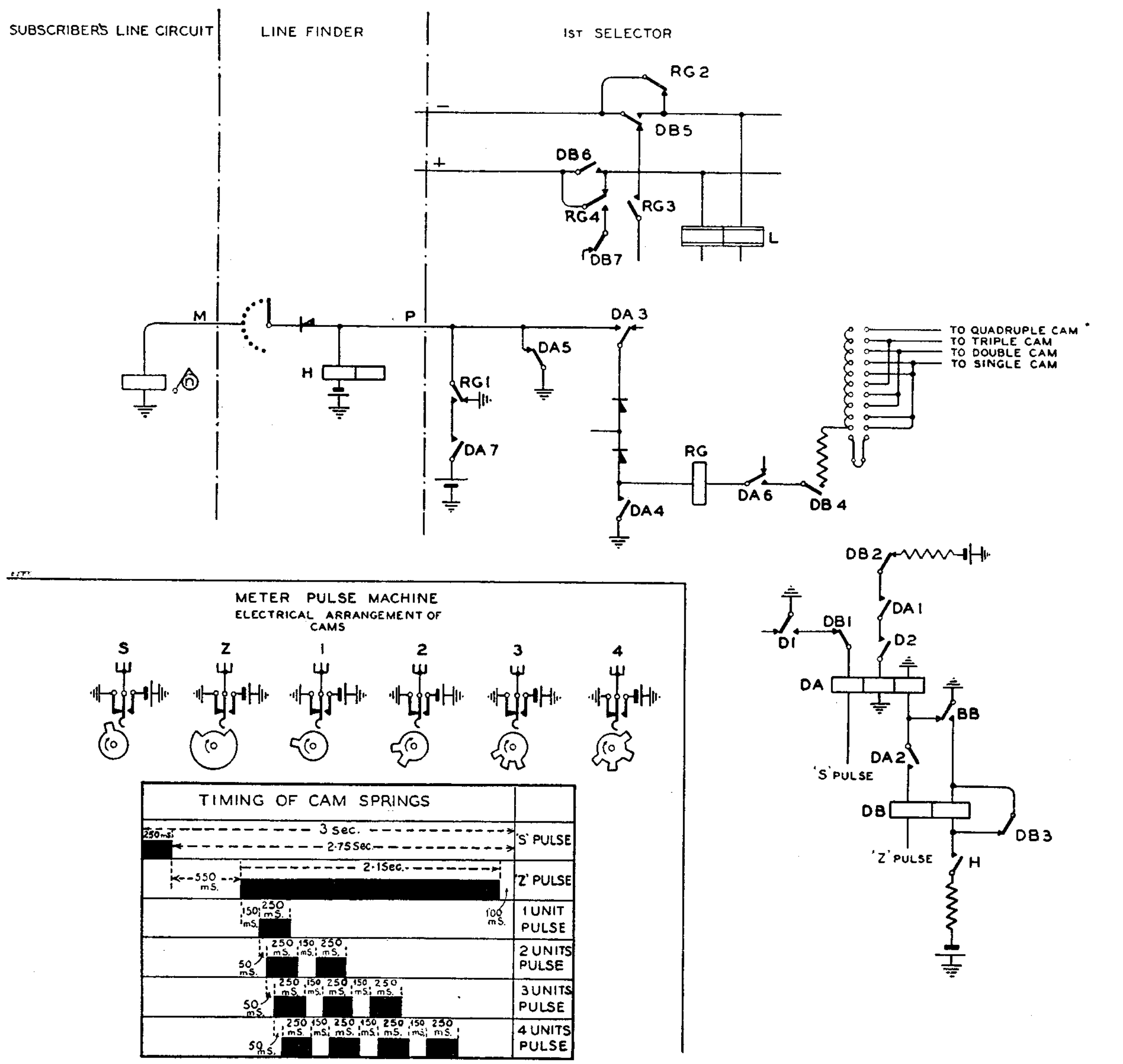

FIG. 23

ASSISTANCE CIRCUITS (GENERAL)

These circuits are provided in order that calls requiring the assistance of an operator may be received at the auto-manual board. As these circuits are cabled direct from group-selector levels, the assistance circuits are arranged to provide a transmission bridge for the calling subscriber and to return holding conditions on the P-wire to hold the train of switches set up by a subscriber; in addition, a calling lamp is lit on the auto-manual board when a circuit is seized. Supervisory signals from the calling subscriber's line must be passed from the assistance circuit to the operator's cord circuit and, for service reasons, facilities must also be provided whereby a connexion to the auto-manual board may be held by the operator after a calling subscriber has cleared the line ('manual-hold' facility). It is also necessary, in these circumstances, to provide means for ringing the subscriber over the train of switches held by an assistance circuit (re-ring facility).

The majority of the calls received at the auto-manual board are for special services and, as the fees charged for these vary, arrangements are made for the operator to record, on a docket, the fee chargeable for any particular call. Hence the subscriber's meter is not operated when a call is passed via an assistance circuit to the auto-manual board.

ASSISTANCE CIRCUIT FOR USE OF NON-DIRECTOR MAIN EXCHANGE SUBSCRIBERS

Calling and Guarding facilities and the Transmission Bridge

When a subscriber makes a call to the auto-manual board in a non-director main exchange, the negative, positive and P-wires of the subscriber's line circuit are extended through to an assistance circuit without passing through a transmission bridge, and therefore an earth applied to the P-wire by the assistance circuit will hold a connexion even if the subscriber clears. The circuit element which returns the normal guarding earth to the P-wire, lights the calling lamp and provides the transmission bridge for the calling subscriber, is shown in **Fig. 24.** Relay L operates to the calling subscriber's loop, and L1 operates relay B. B1 connects a holding earth to the P-wire and B2 connects ringing tone to the third winding of relay I, so causing ringing tone to be passed inductively to the caller, the circuit for the tone being completed by SS1. Contact B3 connects battery to the lamp relay.

The lamp relay is not part of the assistance circuit but is associated with the answering jacks and lamps, to which the relay-set is connected by means of jumpers. When a relay-set is seized, battery is passed from the relay-set to the lamp relay, which in turn, connects the 6-V. alternating current to light the lamp.

The ballast resistor in the transmission bridge is provided so that advantage may be taken of the resulting increase in transmission efficiency for calls

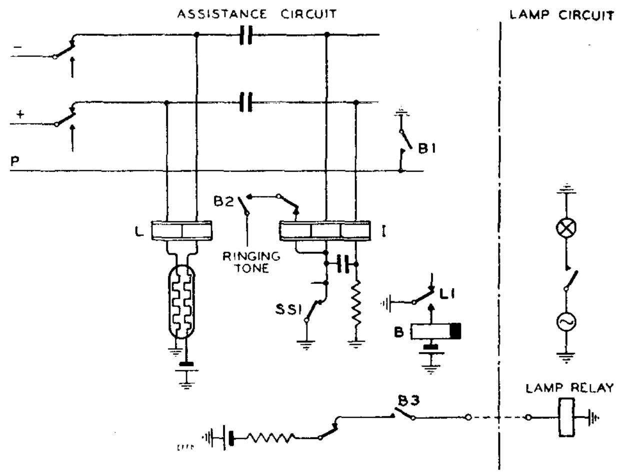

FIG. 24

extended by an operator over a junction to a distant exchange. The condenser which bridges the earthed side of the I relay prevents the transmission bridge from being electrically unbalanced by any circuit arrangement which may be connected to this side of the coil.

Supervisory and Manual-hold facility

The circuit of Fig. 24 has been expanded in **Fig. 25** to include the circuit elements which control the supervisory signals given to the auto-manual board cord-circuit and the manual-hold facility previously referred to. When the operator answers, the battery from the sleeve of the cord-circuit operates relay S and S1 operates relay SS. Relay SS locks via B4 and SS1, disconnecting ringing tone at SS2 and the lamp relay at SS3, the supervisory lamp of the cord-circuit being dimmed by the removal of the short-circuit from the high-resistance winding of S by SS4. Should the subscriber clear, relay L is released and the high-resistance winding of S is short-circuited by L1, so causing the cord-circuit supervisory lamp to be lit, but, so long as the plug of the cord-circuit is left in the jack, relay SS holds over S1 (B being released by L1), and the earth at SS4 to the P-wire

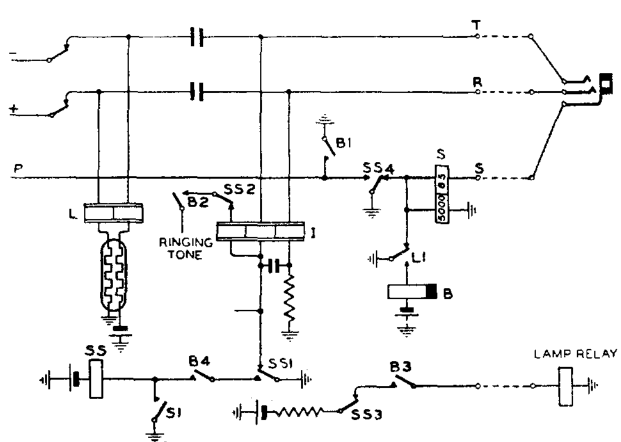

FIG. 25

holds the connexion through to the subscriber's line. The circuit arrangement whereby SS is locked via B4 and SS1 is provided so that the calling lamp will not be relit if the operator withdraws the plug from the answering jack whilst the subscriber is on the line; SS4 also provides a guard to prevent calling subscribers from seizing a circuit should an operator plug into the circuit when it is disengaged.

Re-ring facility

The circuit element by means of which ringing is applied to a subscriber's line when the subscriber has cleared and the connexion is being held from an assistance circuit is shown in **Fig. 26.** On the operation of the cord-circuit RING key, battery is applied to the T-wire of the assistance circuit, causing RR to be operated and, at RR1 and RR2, to apply ringing and ringing return to the negative and positive wires respectively.

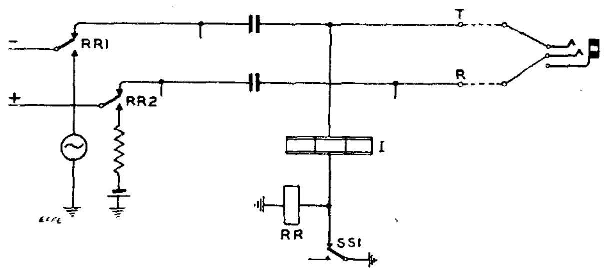

FIG. 26

ASSISTANCE CIRCUIT FOR USE OF DIRECTOR AND SATELLITE-EXCHANGE SUBSCRIBERS

Holding, Manual-hold and Re-ring conditions

In director and satellite exchanges a transmission bridge is incorporated in the first switching stage. For normal calls, this transmission bridge is used to hold the switching relays of the train of switches set up by a calling subscriber within the calling subscriber's exchange. The switching relays of stages other than the first are, therefore, held by an earth applied to the P-wire at the first switching stage. When calls are passed to the auto-manual board, however, it is necessary to provide for the manual-hold condition, and, as in such cases a connexion cannot be held by the simple expedient of applying an earth to the P-wire at the assistance circuit, a special circuit arrangement is provided in the assistance circuit and the first switching stage in order that this facility may be obtained. In addition, due also to the transmission bridge in the first switching stage, it is not possible to apply ringing from the assistance circuit as the apparatus bridged across the lines will limit the amount of ringing current reaching a subscriber's instrument. Arrangements are therefore made to apply the ringing current directly to a subscriber's line at the caller's side of the first selector transmission bridge.

The absence of a P-wire between an assistance circuit and the switching stages necessitates the passing of signals over the line from the assistance circuit to the first selector when either the manual-hold or re-ring facility is required. These signals are as follows:—

Manual Hold—Negative battery over positive wire.

Re-ring—Positive battery over positive wire.

It is also necessary that the manual-hold condition shall be operative under re-ring conditions, and the relay in the first selector which holds the connexion under manual-hold conditions is therefore arranged to be held operated when either negative or positive battery is connected to the positive line. A relay and rectifier combination, however, is connected in the circuit in such a manner that the relay only operates when positive battery is connected to the line. This relay is used to apply ringing to the subscriber's line.

Transmission Bridge and Supervisory arrangements

The transmission bridge and supervisory arrangements of the assistance circuit are shown in **Fig. 27.** A ballast resistor is not incorporated in this circuit as speaking current for the subscriber's transmitter is not supplied from this bridge. Relay L operates to the loop from the distant transmission bridge when the assistance circuit is seized, L1 connecting ringing tone to the third winding of I and L2 operating B via SS1. Relay B returns a guarding earth to the P-wire at B1, so holding the train of switches should the call be passed over a junction, and completes the circuit of the lamp relay at B2. When the operator answers, relay S is operated and completes the circuit of SS via S1. Relay SS locks via SS1 and B3 against the operator withdrawing the plug whilst the subscriber is on the line; SS2 and SS3 disconnect ringing tone; SS4 disconnects the lamp relay and SS5 causes the cord-circuit supervisory lamp to be dimmed and a guarding earth to be returned under the control of the operator.

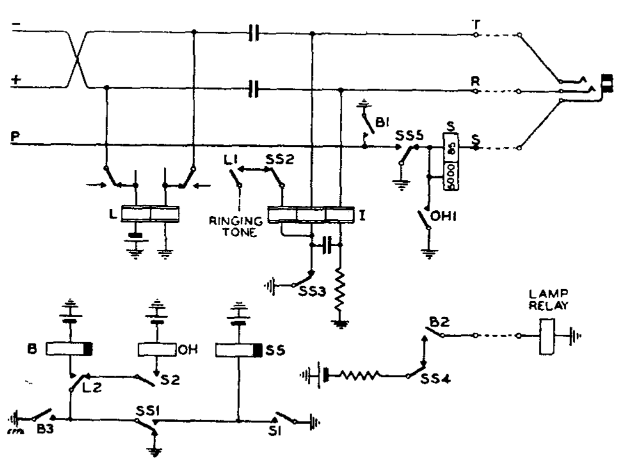

FIG. 27

When the calling subscriber clears, relay L is released and OH operates via S2, L2, SS1 and S1 and, by short-circuiting the high-resistance winding of S at OH1, causes a clearing signal to be given by the cord-circuit supervisory lamp.

Manual-hold facility

Fig. 28 shows a typical circuit arrangement by means of which the manual-hold facility is obtained, the circuit element to the left of the figure being incorporated in the first-selector circuit and that on the right in the assistance circuit. In order to show clearly the use of the rectifiers under manual-hold conditions, several of the DA contacts previously referred to in the explanation of multi-metering have been included in the figure, but the student is reminded that metering cannot occur on calls to an assistance circuit. The loop of the subscriber's instrument normally holds relay L, and the loop provided in turn by the D and I relays holds relay L of the assistance circuit. Should the subscriber clear, however, the D and I loop is broken at L1, thus allowing relay L in the assistance circuit to release. L2 falling back causes relay OH to operate to the earth via S2 and also releases relay B; OH1 causes the supervisory lamp to glow and OH2 applies battery to the positive wire, relay MH being connected to the negative wire by OH3.

The battery connected to the positive wire at OH2 holds relay I via D1, rectifier A, DA3, DA6, L1 and coil of I to positive wire. Relay RG is prevented from operating in parallel with rectifier A by rectifier B. The release of a connexion is dependent on the release of the selector guard relay B, but, as B is now held by the contact of I in lieu of a contact of the L relay (L2) of the selector, the release of the connexion cannot take place until S and OH are released by the operator withdrawing the plug from the answering jack.

Should a subscriber lift the receiver whilst a connexion is held from the auto-manual board, the restoration of the loop across the negative and positive wires at L1 operates relay MH from the battery at OH2. Relay MH connects a locking circuit for itself at MH2 and a loop across the L relay of the assistance circuit at MH1. When L re-operates, L2 disconnects relay OH and operates relay B, and the connexion of relay L to the negative and positive wires is restored by OH2 and OH3, while OH1 causes the supervisory lamp to be dimmed. Relay MH is released by the closure of the B4 contacts, the short-circuit causing MH to release slowly. The slow release of relay MH is provided to ensure that the relay will hold during the transit time of contacts OH2 and OH3 following the application of manual-hold conditions. When a subscriber clears, the short-circuit at B4 also prevents relay MH being operated by condenser surges which may occur during the time that OH is operated by the release of L.

The discharge of the condensers when the operator withdraws the plug to clear the connexion, following the application of manual-hold conditions, may also cause relay L to flick. To prevent the re-operation of B under this condition, relay SS is a slow-release relay and, therefore, SS1 does not provide a circuit for B until sufficient time has elapsed for the condensers to discharge.

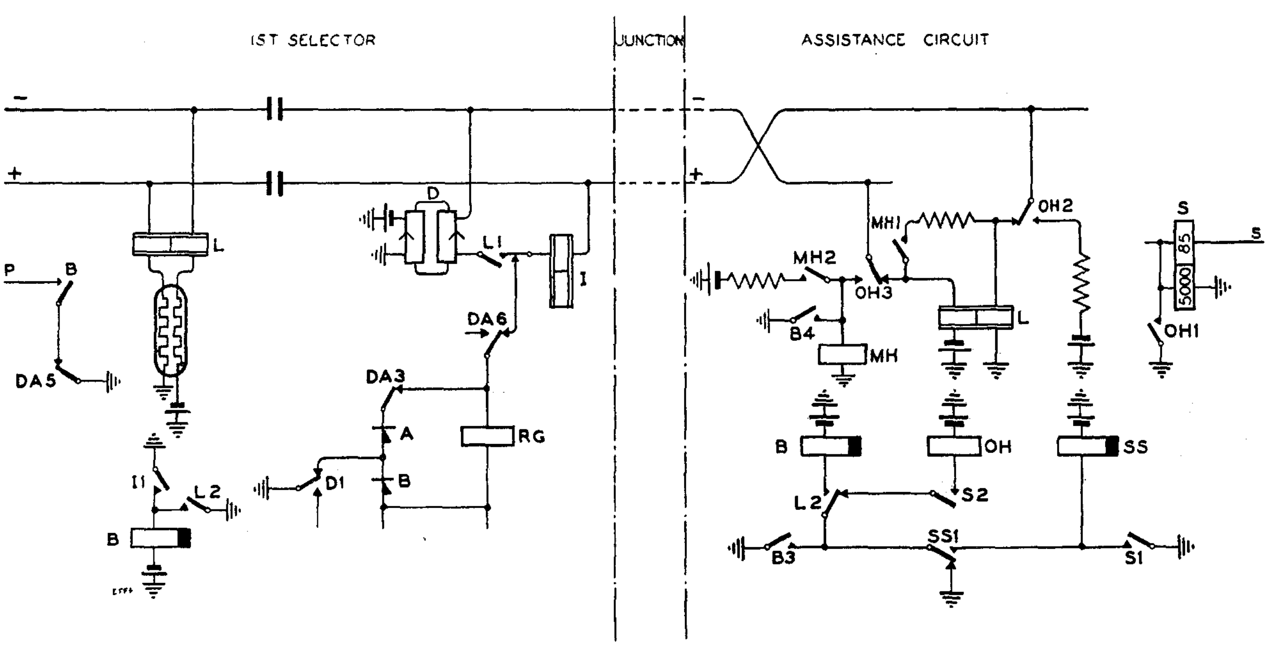

FIG. 28

Re-ring facility

The circuit element controlling the re-ring facility is shown in **Fig. 29,** the subscriber's line being held under manual-hold conditions.

When it is desired to ring the subscriber, the operator at the auto-manual board operates the cord-circuit RING key, so causing relay RR in the assistance circuit to be operated by the battery applied by the key to the T-wire. RR1 disconnects the normal exchange battery providing manual hold, and connects the positive battery to the negative wire. The positive battery holds relay I and operates relay RG in the selector via relay I, DA6, RG, rectifier B and D1 to earth. Under these conditions rectifier A prevents relay RG from being short-circuited.

On the operation of relay RG, the L relay bridging the subscriber's line is disconnected from the line by RG2 and the break contact of RG4, ringing and ringing return being applied to the line via RG3 and the make contact of RG4. It should be noted that contact DA7 prevents the metering battery being applied to the P-wire when RG is operated under re-ring conditions.

Provision is not made to trip the ringing automatically as in the final selector, but the operator can obtain an indication that the subscriber has answered at any moment that the RING key is restored to normal. In these circumstances the RR relay will be normal, relay RG will have restored and the L relay will be reconnected to the subscriber's line. Relay L therefore operates if the subscriber removes the receiver, thus giving the loop signal forward to the assistance circuit and dimming the supervisory lamp.

COMPLETE CIRCUIT ARRANGEMENTS

Circuit diagrams of a group selector and a final selector of the 2000-type are shown in **Fig. 30** and **31,** respectively.

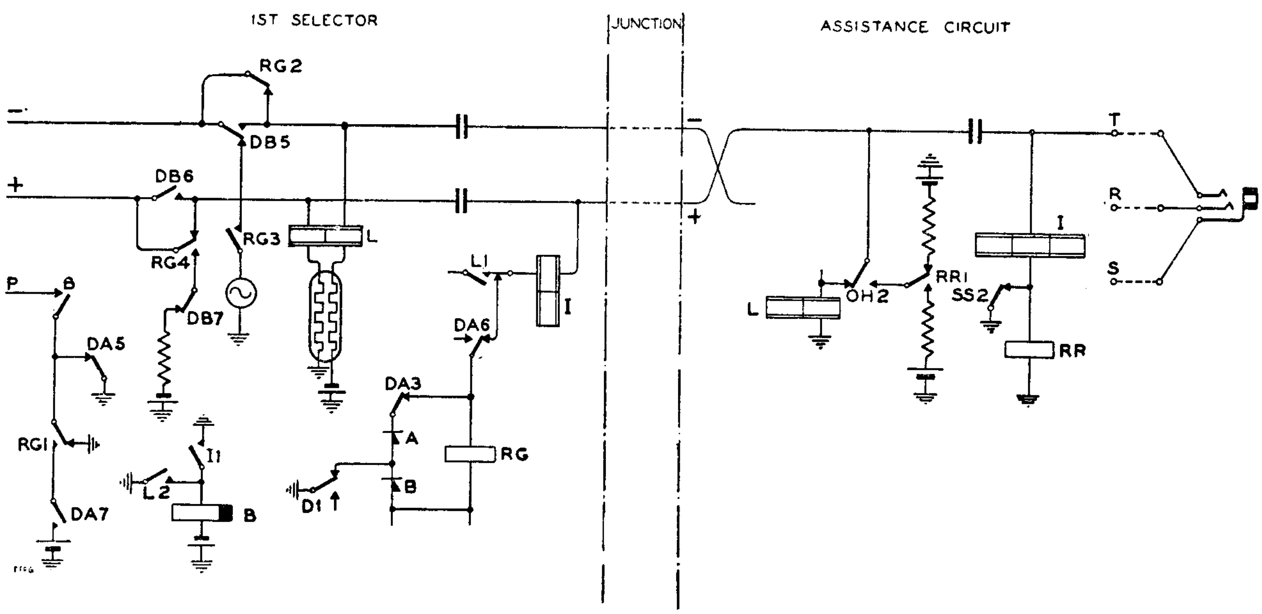

FIG. 29

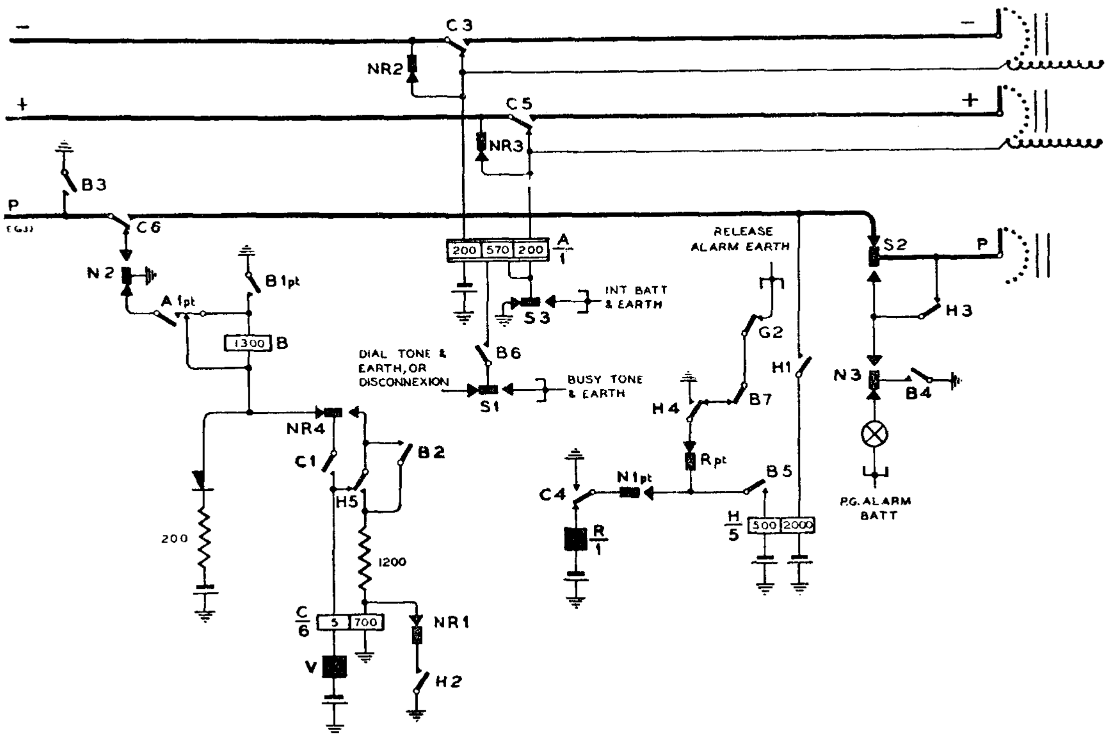

FIG. 30.—GROUP SELECTOR

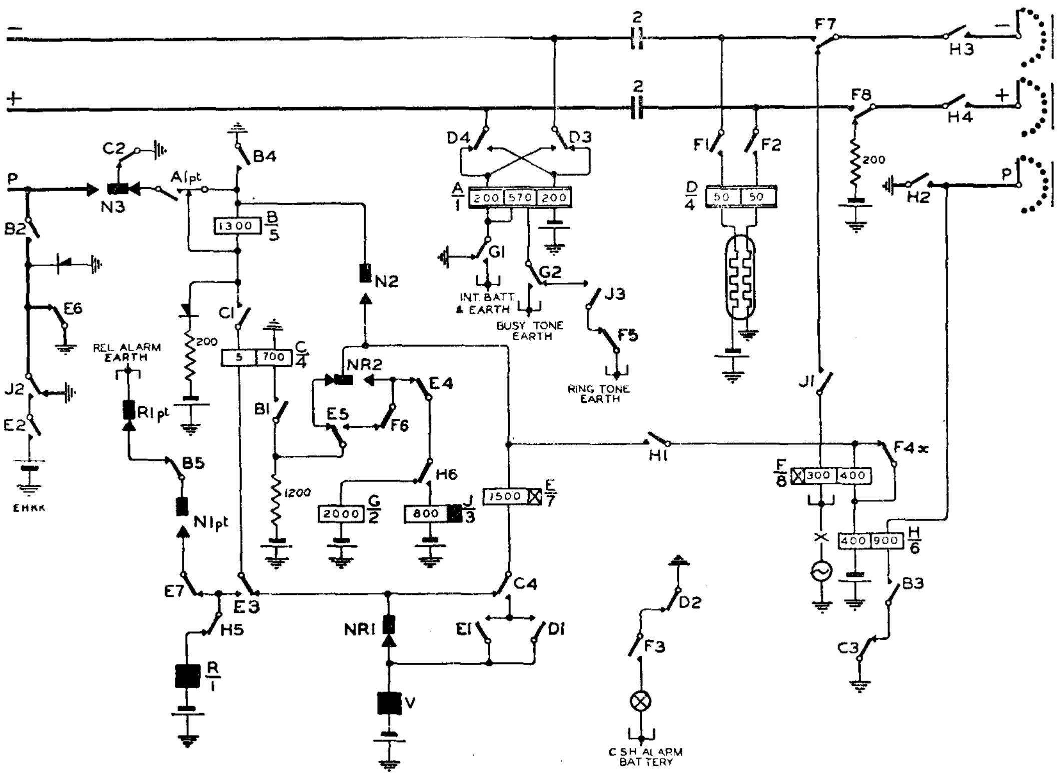

FIG. 31.—FINAL SELECTOR

END

LONDON
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased directly from H.M. STATIONERY OFFICE at the following addresses:
York House, Kingsway, London, W.C.2; 120 George Street, Edinburgh 2;
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80 Chichester Street, Belfast;
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