EARTH TESTING, BATTERY TESTING, AND GUARDING CIRCUITS

CONTENTS

INTRODUCTION

The arrangement of the control circuit associated with a selector is determined by the type of mechanism and the function of the selector in the switching system. It is usual for the circuit associated with a uniselector to provide for automatic wiper stepping under the control of a condition on a particular bank outlet, this is known as 'finding', or by the condition of the outlet on which the wiper is standing, this is known as 'hunting'. The two-motion selector circuits usually provide for a dial pulse controlled vertical stepping, but the rotary stepping may be pulse controlled or by a hunting action. In certain applications not considered in this pamphlet, both the vertical and rotary stepping is by a finding action.

All control circuits must also provide for the following basic requirements,

(i) Operate to the incoming signal and thereby apply a guarding condition to the incoming test, or private (P), wire to mark the selector busy to other circuits.

(ii) Switch the incoming circuit through to the selected outlet.

(iii) Apply a guarding condition to the P-wire of the seized outlet to mark that circuit busy to other selectors.

(iv) Hold the wipers to the seized outlet until the connexion is terminated.

(v) Apply a guard condition to its incoming P-wire until the wipers are stepped back to the normal position.

To economise in the use of equipment, particular relays and contact units often feature in circuit elements which satisfy several of the requirements. As an example, the circuit arrangements for automatic wiper stepping and outlet testing are such that they may be considered as one element; for clarity, however, the principles of automatic stepping and testing circuits will first be considered separately, and then as combined practical circuit elements.

INCOMING GUARD CIRCUITS

The guarding condition must be applied to the incoming P-wire of a selector circuit as soon as possible after the circuit has been seized in order to

(a) reduce the probability of another circuit seizing the selector in the period between the initial seizure and application of the guard condition, or

(b) cover the guard condition which has been applied by a previous circuit and which is maintained after that circuit has switched, by the release lag of a relay.

The shortest period between seizure and guarding is obtained when the guard condition is applied directly by the relay operated on seizure, and this method is in common use when the relay is held continuously during the stepping, testing and switching actions. The elementary circuit arrangement is shown in Fig. 1. A loop is extended to operate relay L which at contact L2 extends a guard earth condition to the P-wire. Subsequently relay L is disconnected but has a release lag sufficient to maintain the guard condition at contact L2 until covered by the circuit in the next stage in the connexion.

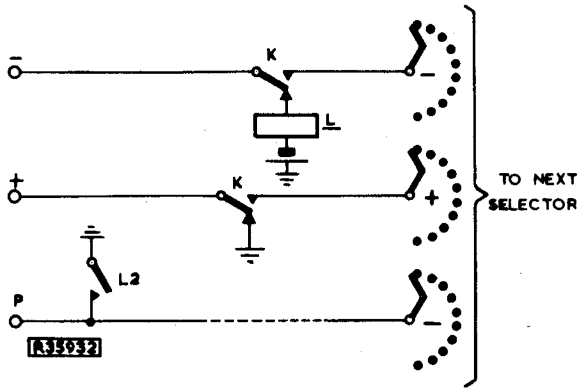

Fig. 1

When the relay which is operated on seizure is required to respond to dial pulses, another relay is used to apply the guard condition. A typical circuit arrangement is shown in Fig. 2. Relay A is operated by a loop extended on the positive and negative wires when the circuit is seized. Contact A1 disconnects the short-circuit on relay B which then operates and at contact B3 extends an earth as a guard condition to the P-wire. Relay A subsequently responds to dial pulses and contact A1 short-circuits relay B during the release periods. Relay B, however, is made slow to release by the short-circuit on its coil and consequently remains operated during the pulsing of A relay. Subsequently, relay A releases when the selector switches to the next stage in the connexion, contact A1 reconnects the short-circuit to relay B. The release lag of relay B is sufficient to maintain the guard condition at contact B3 until covered by the circuit arrangement in the next stage.

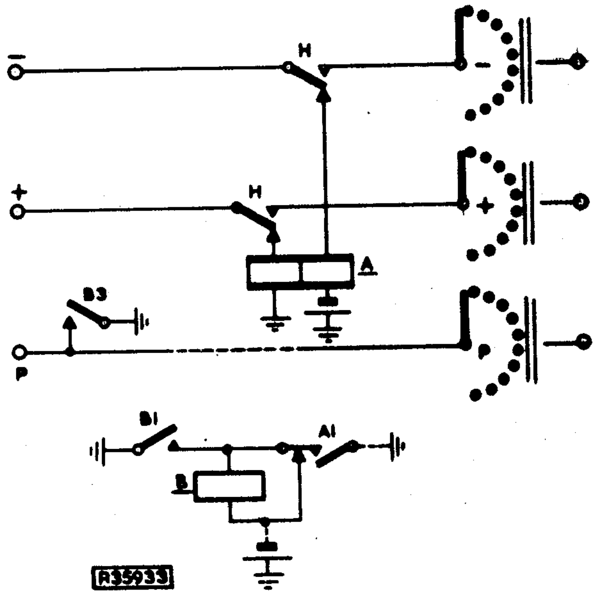

Fig. 2

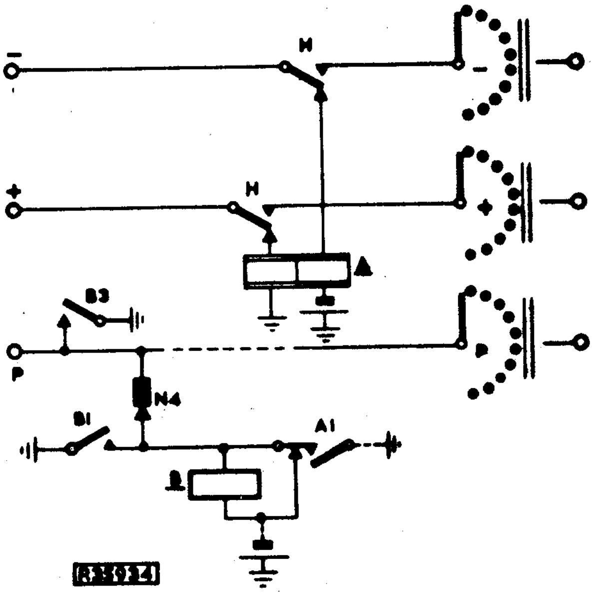

Fig. 3

In practice circuits having guard arrangements as in Fig. 1 work into those having the arrangements shown in Fig. 2. Under the conditions of a high resistance operate circuit for relay L and a short operate period, the release lag of the relay is insufficient to cover the time required for contact B3, Fig. 2, to apply the guard condition. The circuit element shown in Fig. 3 is a modified version of that shown in Fig. 2 and provides what is known as 'fast guard' condition. When relay A operates, the earth at contact A1 is immediately extended via the contacts N4 to guard the P-wire. The contacts N4 are disconnected when the selector moves from the normal position, the guarding condition on the P-wire is then under the control of contact B3 as in the circuit of Fig. 2.

AUTOMATIC STEPPING CIRCUITS

The mechanical action of the types of selector mechanism used in the standard step-by-step switching system may be classified under the headings,

(i) Reverse acting - the wipers are stepped by the release action of the magnet armature, uniselectors operate on this principle.

(ii) Forward acting - the wipers are stepped by the operate action of the magnet armature, all two-motion selector mechanisms operate on this principle.

The selector magnet circuits, and consequently the wiper stepping, are of the two basic types,

(i) dial pulse

(ii) automatic

Dial pulse controlled circuits are beyond the scope of this pamphlet. The automatic stepping circuits are of the two main types, self-interacting and relay-interacting, and these will now be considered separately.

The elementary self-interacting, usually known as self-drive, circuit arrangement is shown in Fig. 4. The contacts dm, termed interrupter contacts, are mechanically linked to the magnet armature so that they open during operate stroke and close during the release stroke. The operation of the circuit is as follows. The circuit for the drive magnet coil DM is completed at contact L1 when relay L in an associated circuit is caused to operate. The magnet attracts its armature, and at some point late in the operate stroke the interrupter contacts dm open to disconnect the magnet circuit. The armature completes its operate stroke due to the momentum of the moving parts. With the magnet circuit disconnected at the interrupter contacts, the armature releases under the tension of its restoring spring. At some point in the release stroke the contacts remake and so complete the magnet circuit. The strength of the restoring spring, or springs, however, is such that the release stroke is completed before the cycle of operate and release is repeated. The self-drive continues until relay L subsequently releases.

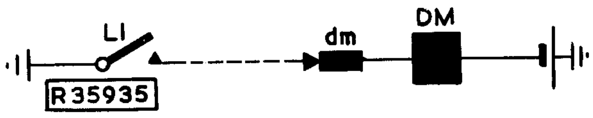

Fig. 4

Ideal stepping conditions require that the dm contacts open late in the operate stroke of the magnet armature and close late in the release stroke. The points at which the contacts are opened and closed is dependent on both the momentum gained by the armature in the operate and release movements, and the time required for the flux in the magnet to decay sufficiently to allow a complete release stroke. Thus if the contacts operate too early in the armature strokes or the period for which they are open is too short, the armature will not function correctly and so produce intermittent wiper stepping. The ideal requirements cannot be obtained when the contacts are controlled by a striker directly connected to the magnet armature, as on uniselectors and early type two-motion selector mechanisms, because they are opened and closed at the same point from the normal armature position. The interrupter contact operating mechanisms fitted to the modern two-motion selectors, however, employ a toggle mechanism arranged to allow the contacts to be opened and closed at any points in the operate and release strokes. Thus ideal self-drive conditions can be obtained with the modern two-motion selector mechanisms but not with uniselectors and pre-2000 type mechanisms.

It is possible to obtain tolerable self-drive conditions with a uniselector mechanism because of its reverse action type wiper stepping. The wipers on a reverse action mechanism remain stationary during the armature operate stroke and are moved from one contact to the next by the release stroke. Thus the length of the operate stroke can be increased beyond the point needed to engage the armature pawl with the next notch on the ratchet, without upsetting the wiper to contact relationship. There is a considerable reduction in the load on the armature when the pawl engages the next notch, and if the contacts are opened at this point, or just before, the momentum of the armature is sufficient to complete the stroke. Thus the additional travel to the fully operate point and back to the point where the pawl engages the ratchet tooth, allows the magnet flux to decay sufficiently so that initially all the tension of the armature restoring springs is used to move the wipers. The interrupter contacts close at about the same instant as the pawl engages the ratchet, but the flux increases gradually and is not sufficient to prevent the armature completing the release stroke.

Satisfactory self-drive stepping cannot be obtained with the earlier type two-motion mechanisms because their forward type action moves the wipers on the armature operate stroke. The interrupter contacts must be opened late in the operate stroke because the armature is subjected near the end of its stroke to a sudden increase in load as the wipers engage the next set of contacts. The load is reduced when the wipers are on the contacts, but the armature travel under these conditions is restricted because the wipers must not overshoot the contacts. Thus the pattern of the load on the armature and the restriction on travel, limits the period for which the interrupter contacts are open, and satisfactory stepping can only be obtained with an interrupter contact adjustment which is too critical for practical purposes.

The problem of automatic wiper stepping when using a forward acting mechanism has been overcome by arranging that the interrupter contacts control a relay, a break contact of which controls the drive magnet circuit. The elementary circuit arrangement is shown in Fig. 5. The drive magnet circuit is completed when a relay, say CD, releases in the associated selector circuit. The interrupter contacts R1 close late in the armature operate stroke and complete an operate circuit for relay G. After the normal relay operate lag, contact G1 disconnects the drive magnet circuit. The operate lag of relay G allows for the R1 contacts to close towards the end, rather than at

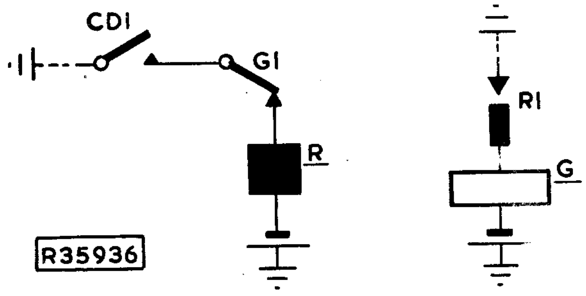

Fig. 5

the end, of the armature operate stroke. The R1 contacts open early in the armature release stroke and disconnect relay G. Contact G1 on the release of relay G completes the circuit for the drive magnet. The release lag of relay G can be arranged so that, although the relay is disconnected early in the release stroke, the contact G1 does not remake the drive magnet circuit until late in the stroke. Thus, the ideal self-drive conditions can theoretically be obtained by the use of what is termed an 'interacting relay'.

ELEMENTARY TEST CIRCUITS

GENERAL

The testing circuit element in a selector control circuit is based on one of the following two principles.

(a) Earth testing, in which only an earth potential on the P-wire marks an outlet engaged.

(b) Battery testing, in which only a specified battery potential on the P-wire marks an outlet disengaged.

Switching in earth testing circuits takes place when an outlet which is free from earth potential is encountered. In addition to the normal free circuit condition, however, earth is also absent for short periods from an occupied outlet during the switching and release features. If testing takes place during such periods, switching may occur and result in a lost call. Also any fault in the circuit which results in a disconnected P-wire will result in false switching and consequent lost calls.

In battery testing circuits switching can occur only if the tested outlet is marked with a specified potential. Any periods of disconnexion which occur, therefore, due to normal circuit operation or fault conditions will not allow false switching.

Earth testing circuits are less costly of equipment than battery testing arrangements, and their inherent false switching feature only becomes troublesome when the number of tests made over a specific period is high. Consequently various forms of earth testing circuits are widely used in selector control circuits.

EARTH TESTING

Basic circuit

The elementary circuit arrangement of one widely used form of earth testing circuit is shown in Fig. 6. For convenience, the relay codes shown are those used in a practical circuit, and details of the wiper stepping circuit are omitted.

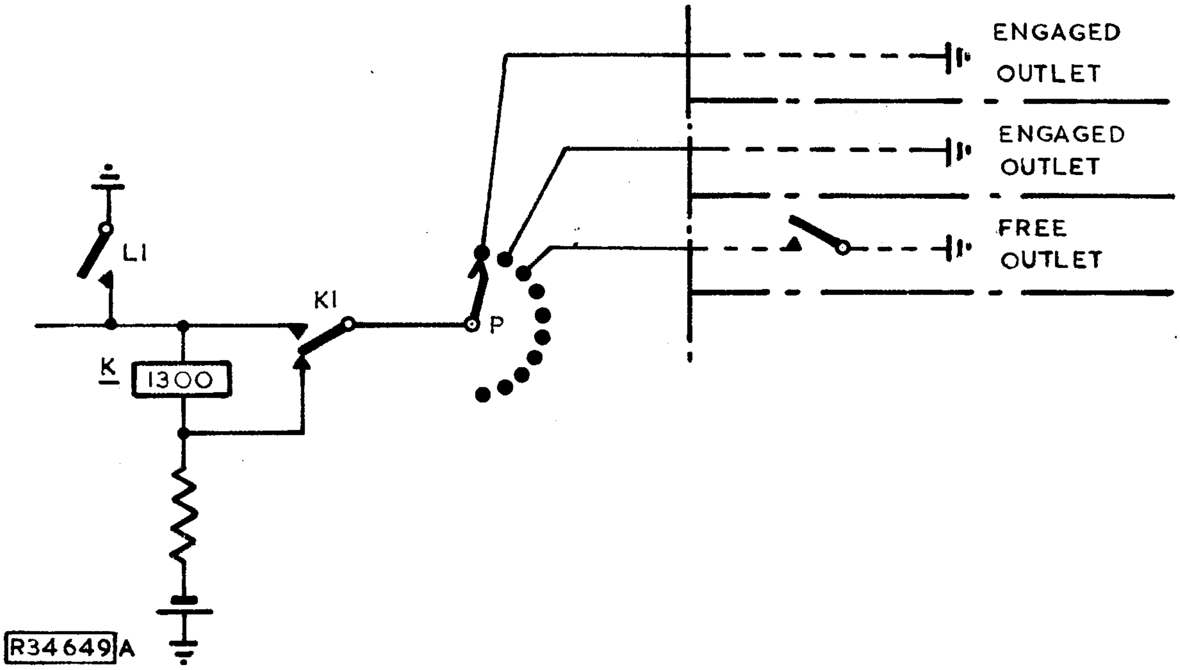

Fig. 6

The circuit arrangement is such that, with contact L1 operated relay K only operates when the selector wipers step on to a disengaged outlet. Relay L operates initially and at contact L1 extends an earth condition to one side of the test relay K, the other side of which is connected to a resistance battery. When the selector P-wiper is standing on an engaged outlet, relay K is effectively short-circuited by the earth condition extended through contact K1 from the outlet, consequently the relay does not operate. If the P-wiper is standing on a free outlet, however, the disconnexion on the outlet removes the short-circuit on relay K which then operates; earth, contact L1, relay K, resistor and battery. Contact K1 operated disconnects the testing circuit and extends its relay to the P-wire of the outlet. Contacts of relay K not shown in Fig. 6, extend the positive and negative wires of the circuit to the outlet and also disconnect the slow to release relay L. The release lag of relay L is sufficient to maintain a hold circuit for relay K at contact L1 until an earth is applied to the P-wire at the next selector, as indicated in Fig. 6.

It is necessary to use a bridging type wiper on the P-bank to prevent false operation of relay K to the momentary disconnexion which would occur as a normal wiper moved from one contact to the next.

When the P-wiper steps to a free outlet, relay K operates as previously explained, but for a period equal to the time taken for contact K1 to operate, the outlet is not marked with an earth. Thus there is an unguarded period equal to the operate lag of relay K during which it is theoretically possible for another testing circuit to switch to the outlet, thereby providing a double switching failure and two lost calls.

Circuit without bridging wiper

A testing circuit similar in principle to that shown in Fig. 6 can be used with an ordinary type wiper if the battery to the test relay is connected only when the P-wiper is on a bank contact. The elementary arrangement of a circuit used in conjunction with a two-motion selector is shown in Fig. 7. A springset R1, termed a rotary interrupter, is included in the circuit and is arranged by means of an extension to the rotary magnet armature, to close when the wipers are standing on bank contacts and open whilst the wipers are moving from one contact to the next. Thus when the P-wiper, Fig. 7, is moving from an engaged outlet, the battery to the

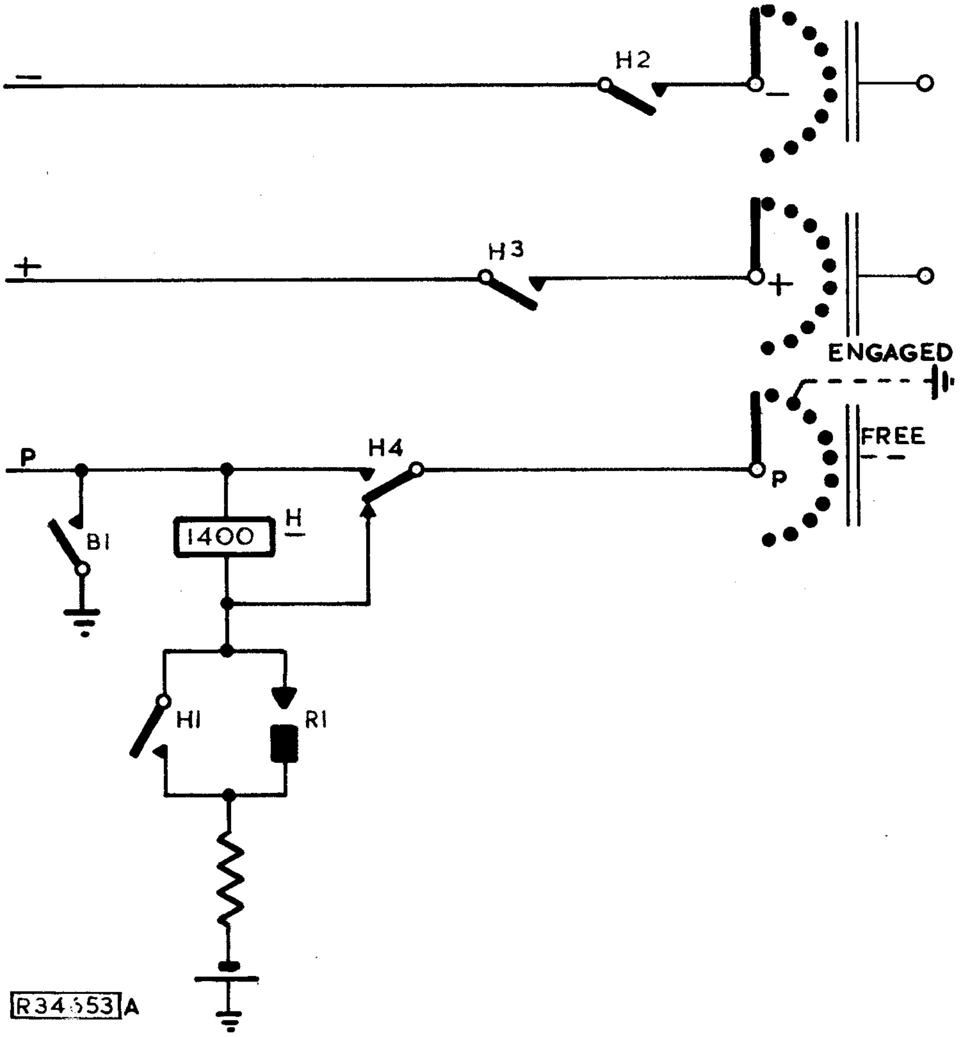

Fig. 7

H relay is disconnected at contact R1 before the short-circuiting earth is disconnected due to the wiper leaving the P-bank contact. Contacts R1 operate when the wiper steps on to a contact and if this outlet should be free, the absence of earth allows relay H to operate;

> earth, contact B1 operated, H relay coil, contact R1 operated, resistor and battery.

Contact H1 operated provides a holding circuit for relay H against the subsequent release of the R1 spring set. Contacts H2 and H3 extend the positive and negative wires through to the next selector. Relay B is disconnected but has a release lag sufficient to cover the period before an earth is returned on the P-wire to hold relay H.

Pre-operated test relay

Modern two-motion selectors fitted with the toggle type interrupter can be self-driven at a higher speed of stepping than that obtained with the relay interacting circuit. The high speed of stepping obtained with self-drive requires the test relay to respond very quickly to a disengaged condition because the P-wiper is on each outlet only for a very short time, and one of the relay contacts disconnects, or cuts, the drive circuit. If the test relay also carries out the switching of the positive and negative wires, it will have a number of contact units and be quite heavily loaded. In practice, the relay would be required to have an operate lag of some 5 milliseconds, and this could only be obtained by the use of high speed design techniques. A general purpose telephone type relay with several contact units, however, may readily be arranged to have a release lag of some 5 milliseconds.

The elementary arrangement of an earth testing circuit which employs a pre-operated test relay is shown in Fig. 8.

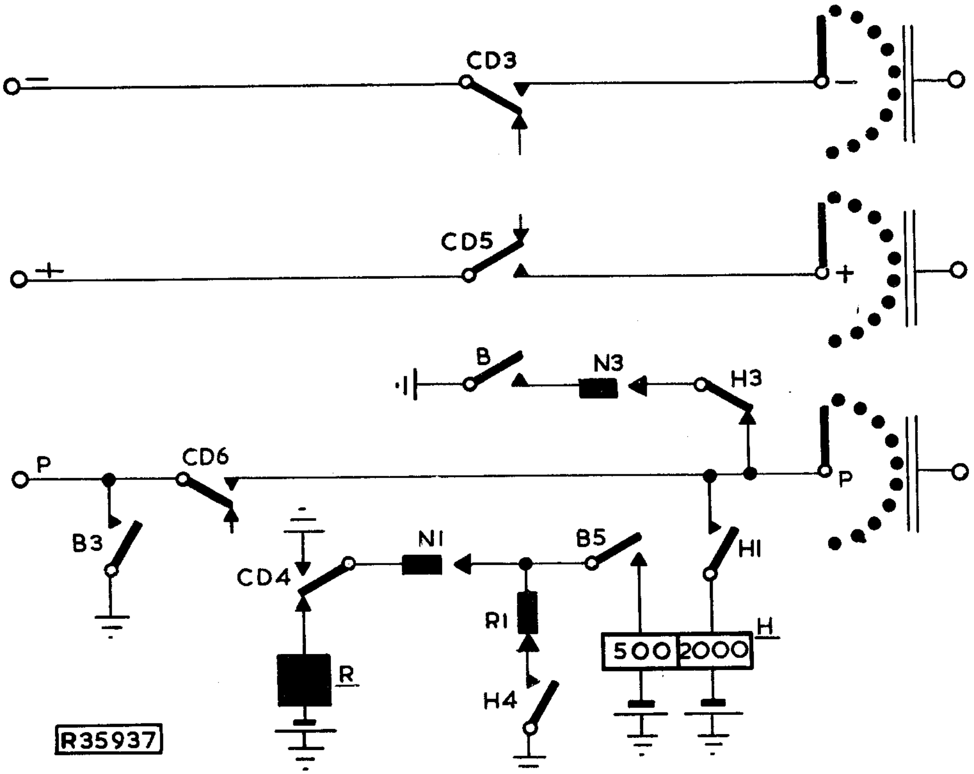

Fig. 8

When the circuit is first seized, relays B and CD are caused to operate, and when the selector wipers are stepped from the normal position the mechanical spring-set N1 also operates. Thus an operate circuit is completed for relay H; earth, contacts CD4, N1, B5, the 500 ohm coil of H, and battery. Relay H operates, and at contact H4 completes a hold circuit independent of contact CD4 but dependent on the rotary interrupter contacts R1. Contact H1 extends the 2000 ohm coil of its relay to the P-wiper.

At the end of a pulse controlled vertical stepping action relay CD is caused to release, thereby completing a self-drive circuit for the rotary magnet; earth, contacts H4, R1, N1, CD4 normal, rotary magnet coil R and battery. The wipers step to the first rotary position and when they are on the contact, the R1 contacts open. The rotary magnet circuit and the hold circuit for relay H over the 500 ohm coil are disconnected at contact R1.

Testing now takes place;

(i) Outlet busy; the earth on the P-wire of the outlet completes an alternative hold circuit for relay H which, therefore, remains operated. The rotary magnet circuit is completed when the R1 contacts remake during the armature release stroke, and the wipers are stepped to the next outlet. Testing again takes place when the R1 contacts open and if the outlet is engaged, the wipers are stepped to the next outlet as previously explained.

(ii) Outlet free; the absence of earth on the P-wire of the outlet allows relay H to release during the period when the R1 contacts are open to disconnect the 500 ohm coil circuit; this period may be as short as 7 milliseconds. The release of H at contact H4 disconnects, or 'cuts', the rotary magnet circuit against the remaking of the R1 contacts when the rotary armature releases. Contact H3 extends earth to guard the seized outlet. The period of unguard on seizure is, therefore, equal to the release lag of H, which is approximately 5 mS.

The switching functions cannot conveniently be completed directly by contacts of the test relay in a pre-operated type test circuit. In practice relay CD is used as the switching relay in addition to its other functions. The circuit is arranged so that the release of relay H allows relay CD to reoperate which, in turn, completes a reoperate circuit for relay H and a hold circuit for itself dependent on an operated H relay contact.

Relay B is disconnected during the switching process, but its slow to release period is sufficient to provide a holding earth at contact B3 for relay H until an earth is returned from the seized outlet.

BATTERY TESTING

Battery testing circuits can generally be classified under the two headings

(i) Marginal operate - the constants of the test circuit are such that, if two test relays test the same outlet simultaneously insufficient current flows to operate either relay.

(ii) Marginal hold - the constants of the test circuit are such that two test relays can operate simultaneously to the same outlet, but only one of them will subsequently hold to the outlet.

In practice, it is usual to use marginal hold type circuits because of the practical difficulties involved in the design of an efficient marginal operate circuit.

Marginal operate circuits

A simple form of marginal operate circuit is shown in Fig. 9 and the circuit conditions for normal and dual testing are given in Fig. 10(a) and (b). In the circuit shown, relay CD is caused to release when the wipers have been stepped to the particular outlet, contact CD1 extends earth to the 900 ohm coil of relay H, the other side of which is connected to the outlet. If the outlet is marked engaged by an earth condition, or disconnected by some fault condition, there is no operate path for relay H, the non-operation of which can be used either to return busy tone to the caller or step the wipers on to the next outlet. When the outlet is free, the battery condition completes an operate path for relay H. Contact H2 extends an earth to mark the outlet busy and also short-circuits the 900 ohm coil of relay H. The release lag due to the short-circuit is sufficient to cover any small delay between the making of contacts H2 and contacts H1 which complete the local hold circuit for relay H. In the circuit Fig. 9, the free battery condition is extended through the coil of a relay K, which operates in series with relay H. In certain circuits the battery is extended through a non-inductive resistor.

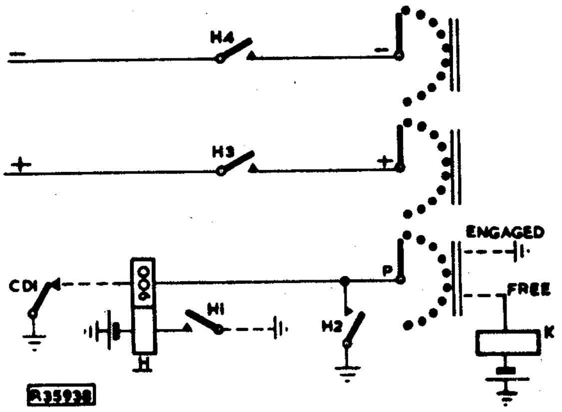

Fig. 9

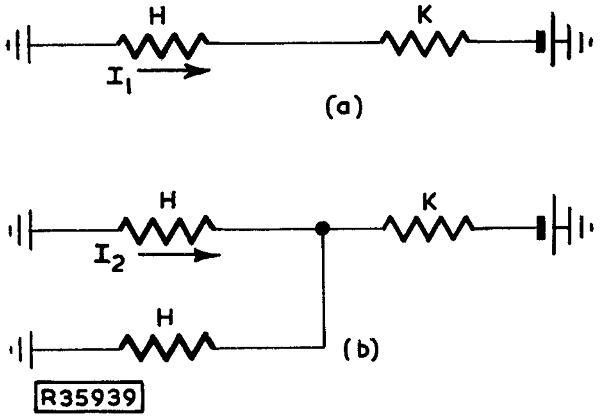

Fig. 10

The main problem in the design of a marginal operate circuit is to obtain a reasonable ratio between the minimum current in relay H under normal test conditions and the maximum current under dual switching conditions. The ratio between the two currents represents the ratio between the ideal operate and non-operate currents of the test relay, and for efficient circuit operation when using a normal type relay, this ratio should be as high a value as possible. There is, however, a maximum value which cannot be exceeded, as shown in the following:

Let H = resistance of the test relay,
K = " " " free outlet,
R = ratio of K to H,
I_1 = current in test relay, Fig. 10(a),
I_2 = " " " " Fig. 10(b),

The resistance of H and K is ± 5% of the nominal value, and
The exchange voltage is between the limits 46V and 52V.

Under the most adverse of conditions, assuming an exchange voltage of 46V and H and K 5% over value, the value of I_1 is given by

$$I_1 = \frac{46}{1.05\ (H + K)}$$

The maximum value of I_2, assuming 52 volts and H and K 5% under value, is given by

$$I_2 = \frac{1}{2} \times \frac{52}{0.95\ (H/2 + K)}$$

The ratio between the ideal operate and non-operate currents is given by,

$$\frac{I_1}{I_2} = \frac{46}{1.05\ (H + K)} \times \frac{2 \times 0.95 \times (H/2 + K)}{52}$$

and this simplifies to

$$\frac{I_1}{I_2} = \frac{46 \times 2 \times 0.95}{52 \times 1.05} \times \frac{(H/2 + K)}{(H + K)}$$

Now multiply numerator and denominator by 2, then

$$\frac{I_1}{I_2} = \frac{46 \times 2 \times 0.95}{52 \times 2 \times 1.05} \times \frac{(H + 2K)}{(H + K)}$$

$$= 0.8 \times \frac{(H + 2K)}{(H + K)} \qquad \dots\dots\dots\dots\dots\dots\dots\dots\ (1)$$

The resistance values chosen for H and K have a bearing on the values of I_1 and I_2, and the lower H is with respect to K the higher the ratio I_1/I_2. It is convenient, therefore, to evolve an expression which gives the current ratio in terms of the resistance ratio K to H. In equation 1, express H in terms of the ratio $R = K/H$, then

$$\frac{I_1}{I_2} = 0.8 \times \frac{(K/R + 2K)}{(K/R + K)}$$

$$= 0.8 \times \frac{K/R\,(1 + 2R)}{K/R\,(1 + R)}$$

$$\therefore \quad \frac{I_1}{I_2} = 0.8 \times \frac{1 + 2R}{1 + R}$$

Thus even when the ratio between the resistances of the relays K and H is infinitely high, the ratio between the two currents cannot exceed 1.6. The value of the current ratio increases rapidly with increase in the value of R and when R = 8 the current ratio is a little over 1.5, but there is very little gain in the ratio for further increase in R.

A further need for a large value of R is to reduce the operate time of the test relay. The rise of current in the relay coil, and hence its operate time, is proportional to the ratio of the relay inductance to the total resistance of the test circuit. The inductance of the relay, however, is directly proportional to the square of the turns on the coil, which in turn is approximately proportional to the resistance of the coil. Thus a large value of R, in addition to providing the necessary current ratio, also tends to reduce the operate time of the test relay.

A factor which imposes a limit on the value of R is that a high value of R in reducing either the number of turns on the test relay or the current in the test circuit, also reduces the number of ampere-turns available to operate the relay. Thus, if immunity from double switching is required, it is not possible to heavily load the test relay. One type of circuit used in practice employs a lightly loaded low resistance test relay and a test relief relay; an elementary circuit arrangement suitable for use in a selector which has a pulse controlled rotary stepping action is shown in Fig. 11.

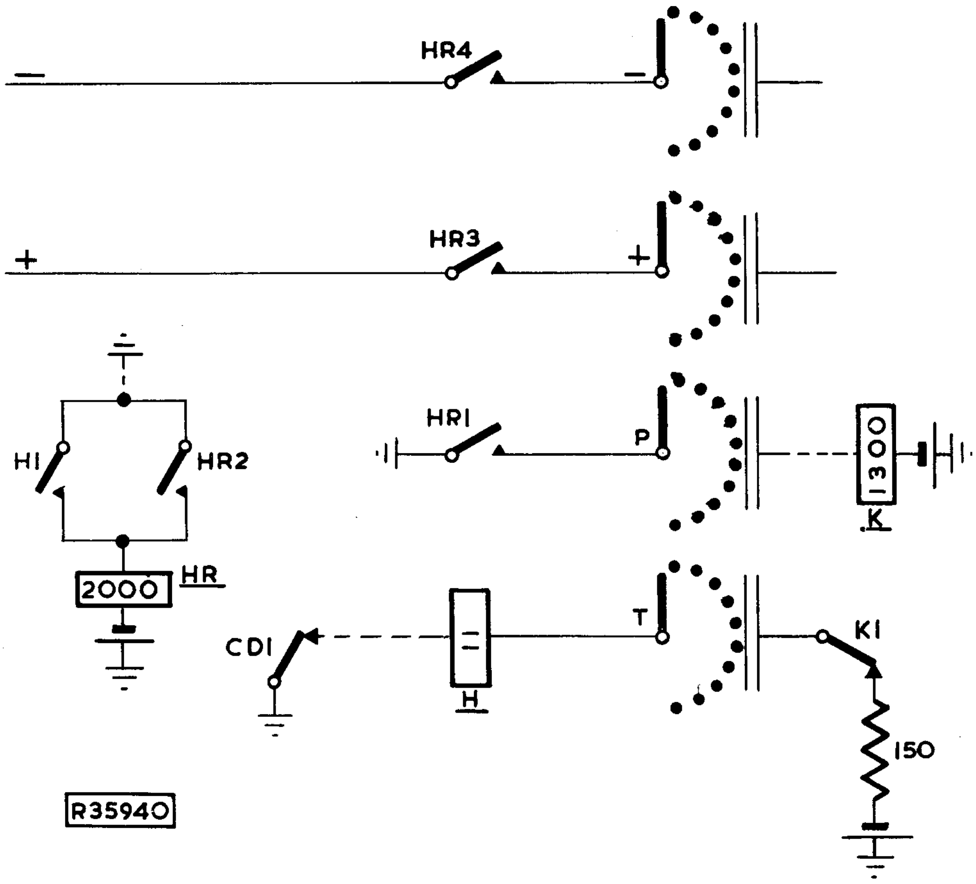

Fig. 11

When the wipers are stepped to the particular outlet, relay CD is caused to release. Contact CD extends earth to one side of relay H, thus if the outlet is free relay H operates to the 150 ohm battery condition on the T-bank outlet. Contact H1 completes an operate circuit for relay HR, which then completes a hold circuit at contact HR2 and extends the positive, negative, and private wires to the outlet at contacts HR3, HR4 and HR1. Relay K operates to the earth extend by contact HR1, and at contact K1 disconnects the battery condition from the outlet. Relay H releases but the switching relay HR remains held over the circuit completed by contact HR4. The use of a non-inductive resistance in the test circuit reduces the $^L/_R$ ratio and so improves the current build up time and consequently the H relay operate time. One practical disadvantage of the circuit arrangement is that it requires an additional bank on the selector.

Marginal hold circuits

The principle of marginal hold is that two test relays can operate simultaneously to the same outlet, but neither can hold to the outlet. The holding path for the test relay is, therefore, to a condition on the seized outlet and not over a separate local circuit as in the marginal operate system. The elementary circuit arrangement of the marginal hold system is shown in Fig. 12, for simplicity the associated wiper stepping circuit is not shown.

Relay K is extended with its high and low resistance coils in series to the P-wire of the outlets, and on a free outlet it operates to the resistance battery condition, Fig. 12. Contact K1 short-circuits the high resistance coil of its relay and so reduces the potential on the outlet to a value insufficient to allow another K relay to operate. Thus the unguarded interval is merely the operate lag of contact K1. Relay K holds over its low resistance coil, and other contacts of the relay extend the positive and negative wires to the seized outlet.

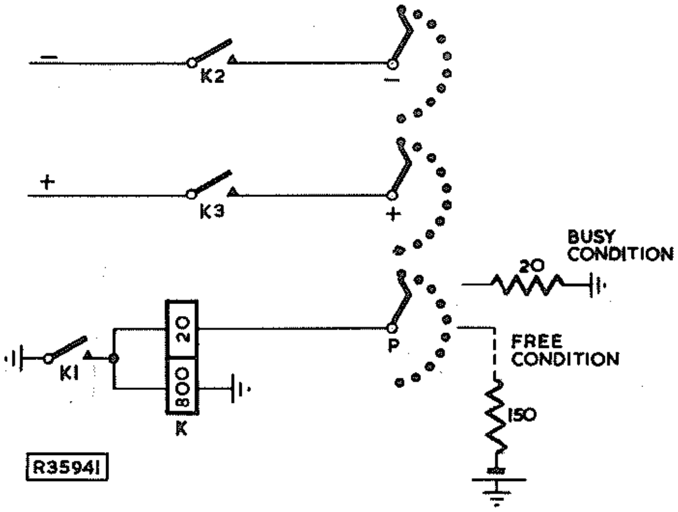

Fig. 12

An engaged outlet is marked either with a low value of potential as already explained or in some circuit arrangements with a disconnexion. Thus when the wipers step on to an engaged outlet, relay K does not operate and in practice this will cause circuit changes to suit the particular circumstances.

If the wipers of two selectors simultaneously step on to the same free outlet, the two K relays operate in parallel to the battery condition. When the two K1 contacts operate and complete the hold circuits for their relays, the current in each low resistance coil is insufficient to hold the relays operated. Both relays release, and in automatic stepping circuits both wipers step to the next free outlet but variations in hunting speeds and relay characteristics make it improbable that simultaneous testing conditions will be repeated.

The circuit arrangements for one relay holding to an outlet and two relays holding to one outlet after simultaneous switching, are the same as those for a marginal operate circuit, Fig. 10, therefore as already explained, the ratio between the hold and not hold, or release, currents cannot exceed some 1.6. The characteristics of a relay are such, however, that it is easier to obtain hold and release conditions than operate and non-operate conditions within a current ratio of 1.6. Another advantage of the marginal hold circuit is that the $^L/_R$ ratio of the operate circuit can be made low because consideration does not have to be given to the resistance ratio of the testing and outlet circuits under operating conditions.

Differential holding

A bigger hold to release current ratio and consequently a reduction in the restrictions on relay design can be obtained by a circuit arrangement which provides differential holding conditions. The principle of the arrangement is that on the hold feature of relay K, contact K1 instead of merely short-circuiting the high resistance coil, establishes a local circuit to produce ampere-turns in opposition to those holding the relay. The elementary circuit arrangement is shown in Fig. 13.

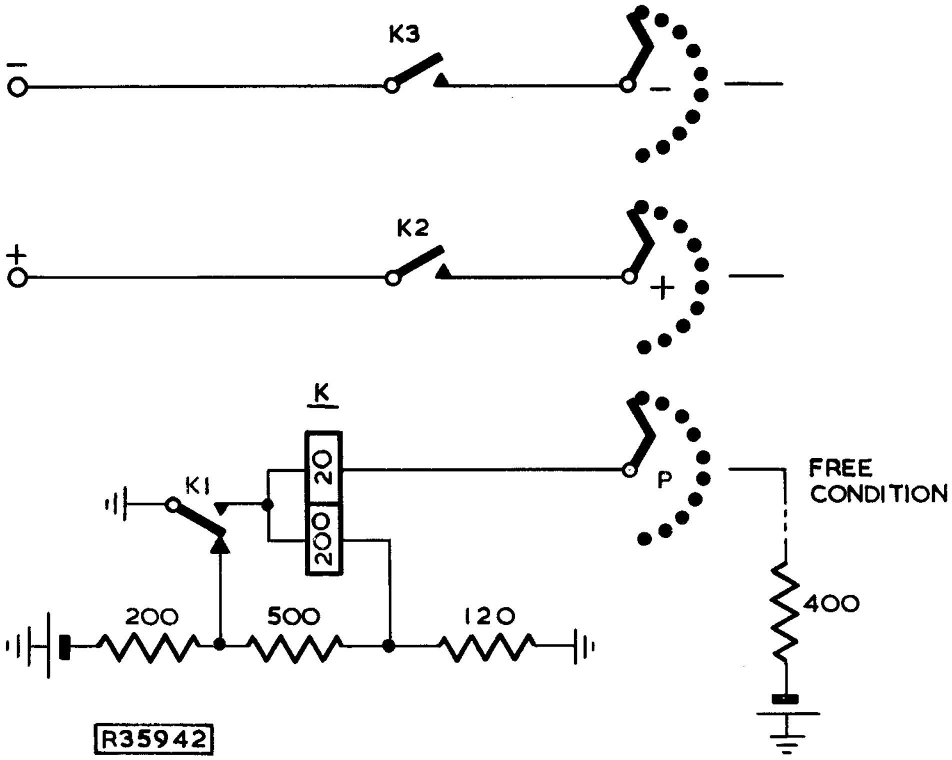

Fig. 13

When the P-wiper is stepped to a busy outlet, that is one marked by an earth potential or disconnexion, there is no operate circuit for relay K. On a free outlet, however, an operate circuit is completed for relay K from the resistance battery on the outlet, the two coils of K in series to the earth at K1 and the 120 ohm resistor. It should be noted that during the operate feature, conventional current flows from right to left in the high resistance coil of relay K, Fig. 13. When K operates, contact K1 completes a hold circuit over the 20 ohm coil to the resistance battery at the outlet and also a local circuit for the 200 ohm coil; earth, K1 contact, 200 ohm coil, 500 ohm and 200 ohm resistors to battery. The current flow in the 200 ohm coil of relay K is now from left to right in the diagram and produces a magnetic effect which opposes but is not greater than that generated by the current in the 20 ohm coil; relay K holds under these conditions.

When two K relays simultaneously test the same outlet they both operate but the margin of the magnetic effect produced by each 20 ohm coil over that produced by the 200 ohm coils is insufficient to hold either relay. The ratio of the effective tractive force to hold the K relay when one circuit tests to that available for each K relay when two circuits simultaneously test may be determined as follows:

In practice it is likely that the K relay shown in Fig. 13 will have 4220 turns on the 200 ohm coil and 1850 turns on the 20 ohm coil. The circuit conditions existing when one and two circuits are holding to an outlet are shown in Fig. 14(a) and (b) respectively.

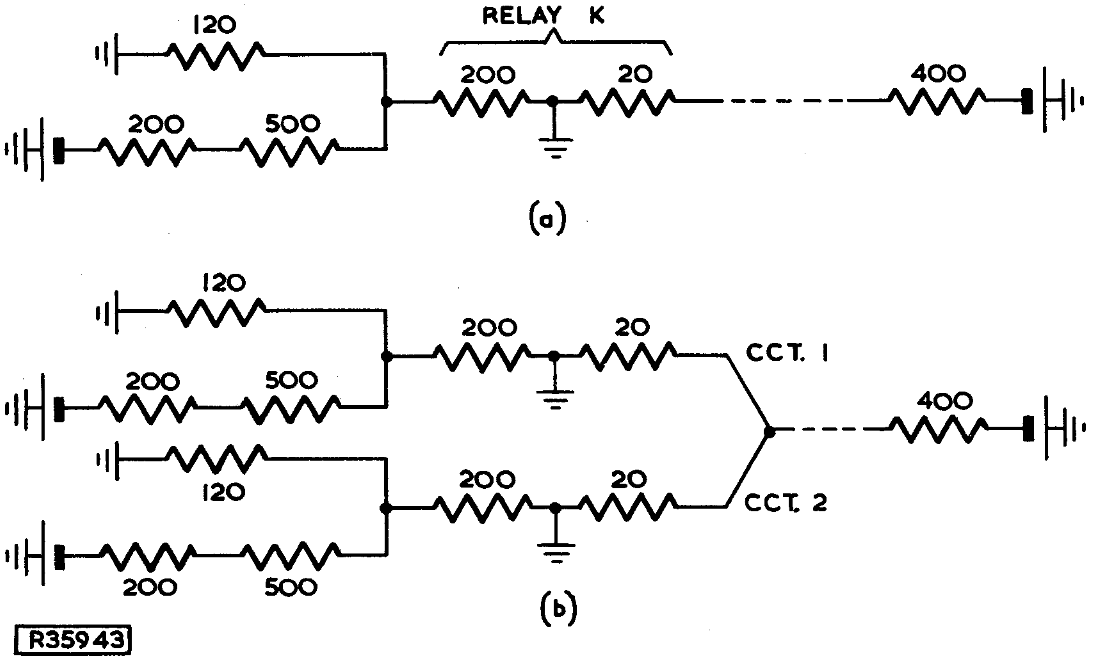

Fig. 14

With one circuit holding and considering the worst circuit conditions in terms of resistance and voltage tolerances, the 20 ohm coil of relay K produces some 193 ampere-turns and the 200 ohm coil 105 ampere turns. There is, therefore a balance of 88 ampere-turns to hold the relay. When two circuits switch simultaneously and set up hold conditions, some 123 ampere turns are produced by the 20 ohm coils, and 95 ampere turns by the 200 ohm coils under the most favourable conditions. Thus in the dual switching condition there is a balance of 28 ampere turns in each relay. Hence in terms of ampere-turns, the ratio between the hold and release conditions is given by,

$$\frac{\text{Hold ampere-turns}}{\text{Release ampere-turns}} = \frac{88}{28} = 3.14$$

Non-bridging P-wipers

A disconnexion is not a free condition to a battery testing circuit, thus there is no need to connect the test relay to the outlet through a bridging type wiper. In practice, the test relay is offered to the outlets through a non-bridging wiper for the following additional reasons.

(i) The period for which a busy earthed outlet and a free outlet are connected together by a bridging wiper reduces the time available for the test relay to operate.

(ii) When a test relay has commenced to operate on a free outlet, the connexion of a busy earth condition to the outlet by the bridging wiper of another uniselector could cause the release of the test relay.

FALSE SWITCHING CONSIDERATIONS

EARTH TESTING

Switching can only take place in earth testing circuits to an outlet free from earth potential. Freedom from earth potential, however, can also be caused by a disconnected P-wire, faulty P-wiper, removal of the earth condition to initiate the release of a connexion, and the normal period of unguard before the earth is applied after seizure of an outlet. If testing occurs during the periods when earth is not present, switching can occur, the precise result of which will depend on when the switching occurs but in all cases will result in at least one lost call.

The test relays in other than pre-operated type circuits both operate and initially hold over circuits which are independent of the outlet. The final hold condition is, theoretically, by a zero resistance earth condition applied to the outlet. Hence, if the test relays of a number of circuits are simultaneously applied to a free outlet all will operate and hold. Simultaneous switching is also possible with pre-operated circuits because after release, the test relays perform functions independent of the outlet and only finally hold to the earth condition returned from the next stage.

Absolute simultaneous testing is not always necessary to produce dual switching because of the practical tolerance in the operate times of the test relays. Referring to Figs. 6 and 7, the relay in the circuit testing during an unguard period must find the P-wire of the outlet free of earth for at least a period sufficient to allow contact K1 or H4 respectively to break. If the guard earth is applied before the contacts break, the short-circuit is reapplied on the test relay. In practice, if a second circuit tests an outlet within 10 to 15 mS of another circuit dual switching is likely to occur. In a pre-operated test circuit, a second circuit testing an outlet during the unguard period must find it free of earth for a period sufficient for the test relay to be disconnected from the outlet. Thus, referring to Fig. 8, the period for which the relay finds the outlet free from earth must be sufficient to allow contact H1 to open. In practice, one circuit must test the outlet within some 1 or 2 mS of another before double connexion is likely.

The incidence of double connexions because of unguarded intervals will depend upon the nature of the traffic. It is found, in practice, that for a given volume of traffic there is a higher probability of double connexions when the circuits connected to the outlets are held for short periods than when they are held for longer periods. Such conditions are to be expected because the calls of shorter duration mean that the incidence of testing each circuit is higher than with the calls of longer duration. As an example, for a given volume of traffic, the probability that a double connexion will occur is ten times as great with calls of 18 seconds duration as it is with calls of 3 minute duration.

BATTERY TESTING

Switching can only take place in battery testing circuits if the outlet is marked with a battery potential above some particular value. Thus false switching to disconnected P-wires or during the period when the guarding earth is removed to initiate release, cannot normally occur. The possibility of lost calls caused by the simultaneous testing of an outlet by two circuits can be eliminated by the marginal operate or marginal hold circuit arrangements. It is usual to use the marginal hold arrangement for the reasons already explained in this pamphlet.

A battery testing circuit usually requires both a test and relief switching relay and a number of resistors, thus it involves a higher initial capital expenditure than an earth testing circuit. It should be appreciated that although the pre-operated earth testing circuit requires a relief switching relay, in the 2000-type group selector circuit use is made of a relay, CD, already necessary to another function of the selector circuit. The maintenance cost of the battery testing circuit is higher because of the restricted adjustments for the test relay to meet certain current requirements.

The overall high cost of the battery testing arrangement restricts its use to equipment which carries short holding time connexions. A typical application is between the A-digit hunters and A-digit selectors, and the A-digit selectors and Directors; the holding time on these connexions is only about 20 seconds and there would be a high proportion of dual connexions for reasons already given, if earth testing circuits were used.

A reason other than cost comparison for not using battery testing arrangements in normal exchange group selectors is as follows. In a normal exchange connexion there are a number of group selectors and a final selector, the loop from the calling subscriber's telephone holds the final selector circuit which applies an earth condition to the P-wire to hold the switching relays in the group selectors. The possible elementary P-wire condition for a 4-digit non-director connexion is shown in Fig. 15. When the calling subscriber replaces the telephone handset, the final selector circuit releases and the earth is removed from the P-wire to initiate the release of the group selectors. In the example shown in Fig. 15 there will be a resistance battery condition on the P-wire when the contact B2 in the final selector opens. The resistance will have a value equal to the joint value of the relays connected to the P-wire. If it is assumed that the H relay has a resistance of 2000 ohms, the value of the joint resistance to battery is approximately 570 ohm. In a large modern non-director system, one or two additional ranks of group selectors would be used, the joint resistance would then be some 440 ohms and 365 ohms respectively. Thus unless the resistance of the H relay in the group selector circuit was made to have a resistance well above 2000 ohms, the resistance of the battery on the P-wire under the initial release conditions would approximate to the normal test condition. False switching could then occur if a circuit at any switching stage was testing the outlet at the instant contact B2, Fig. 15, opened.

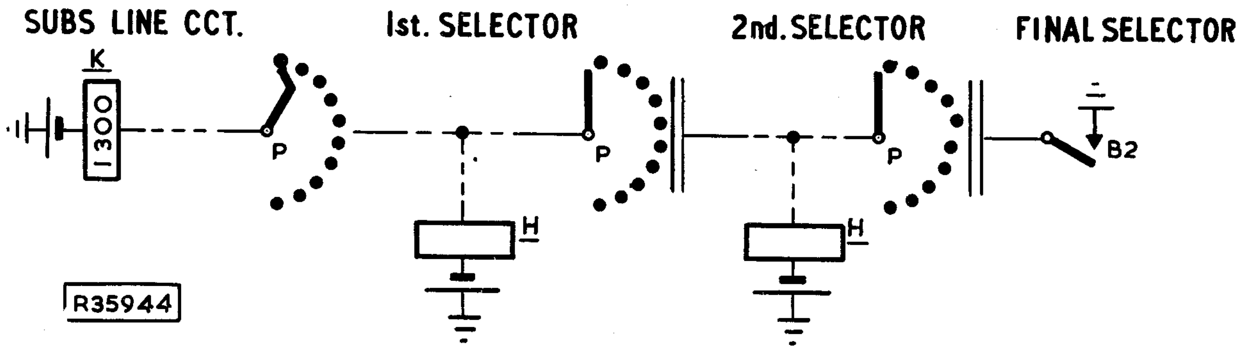

Fig. 15

In practice, there are certain switching arrangements in which false switching due to the condition just described could occur. The circuits are rearranged, however, so that the P-wire is divided at an intermediate rank and holding conditions extended back and forward. Thus at the initial release, there may be considered to be two separate P-wires, to each of which are connected, say, half the total number of switching relays concerned in the connexion. The value of the joint resistance on each wire is then well above the normal test value and false switching is obviated.

PRACTICAL AUTOMATIC STEPPING AND TESTING CIRCUITS

The earth and battery testing circuit elements described in this section of the pamphlet are extracts from selector circuits in general use, and are intended to illustrate how the elements are integrated in a practical circuit.

SUBSCRIBERS' UNISELECTOR CIRCUIT

This circuit employs earth testing and a self interrupted drive arrangement as shown in Fig. 16.

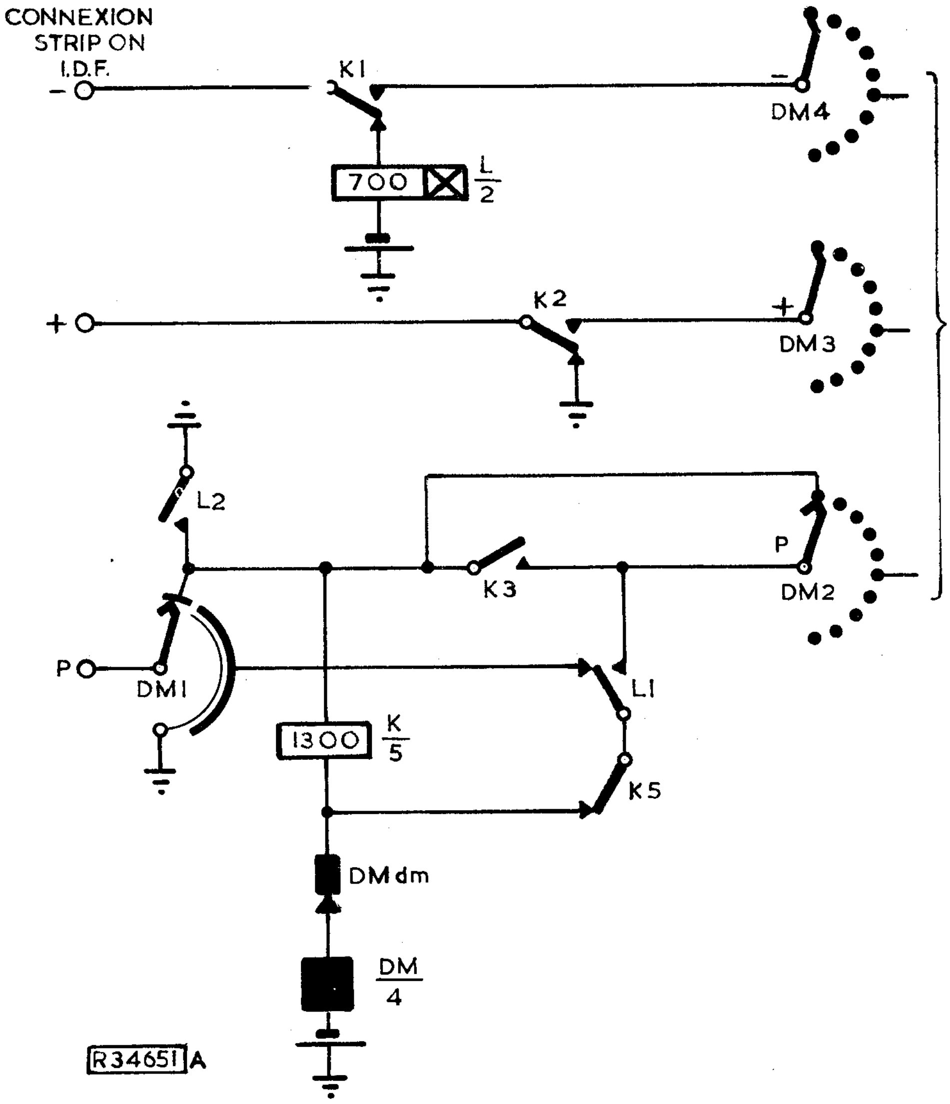

Fig. 16

When the circuit is seized, relay L operates and at contacts L1 and L2 complete the test, stepping and guarding circuits. Contact L2 extends an earth to mark the P-wire at the Final selector multiple busy and also to complete the self-drive circuit for the initial wiper step,

> earth, contact L2, P-wiper on outlet 1, contacts L1 and K5, DMdm contacts, DM and battery.

At this stage contacts K5, L1 and the P-wiper complete a short-circuit on the K relay.

The self-drive circuit and short-circuit on relay K are maintained by the earth busy condition on the P-wires of the outlets. The earth on the incoming P-wire is maintained by the DM1 wiper and arc. When the wipers step on to a free outlet, the drive circuit and short-circuit on relay K are disconnected. Relay K then operates to the earth at contact L2 and the battery at DM, the current which flows being insufficient to operate the drive magnet. Contacts K1 and K2 extend the calling circuit to the seized outlet, and contact K3 prepares a hold circuit for relay K. The release lag of relay L is sufficient to maintain the hold circuit for relay K at contact L2 until the earth is returned over the P-wire from the seized outlet.

At the completion of the connexion, the holding earth on the P-wire is disconnected at some forward item of equipment and consequently relay K releases. Contacts K5 and L1 normal complete a self-drive circuit to the earth on the DM1 arc. When the wipers reach the home position the drive-circuit is disconnected and the earth disconnected from the incoming P-wire.

PRE-2000 TYPE GROUP SELECTOR

The rotary stepping, testing and switching element of a 100-outlet pre-2000 group selector is shown in Fig. 17. The circuit which provides for the earth testing of odd and even P-wires at each rotary step is beyond the scope of this pamphlet, but is dealt with in E.P. Draft Series Telephones 3/5. The circuit shown in Fig. 17 employs earth testing and a relay controlled wiper stepping circuit.

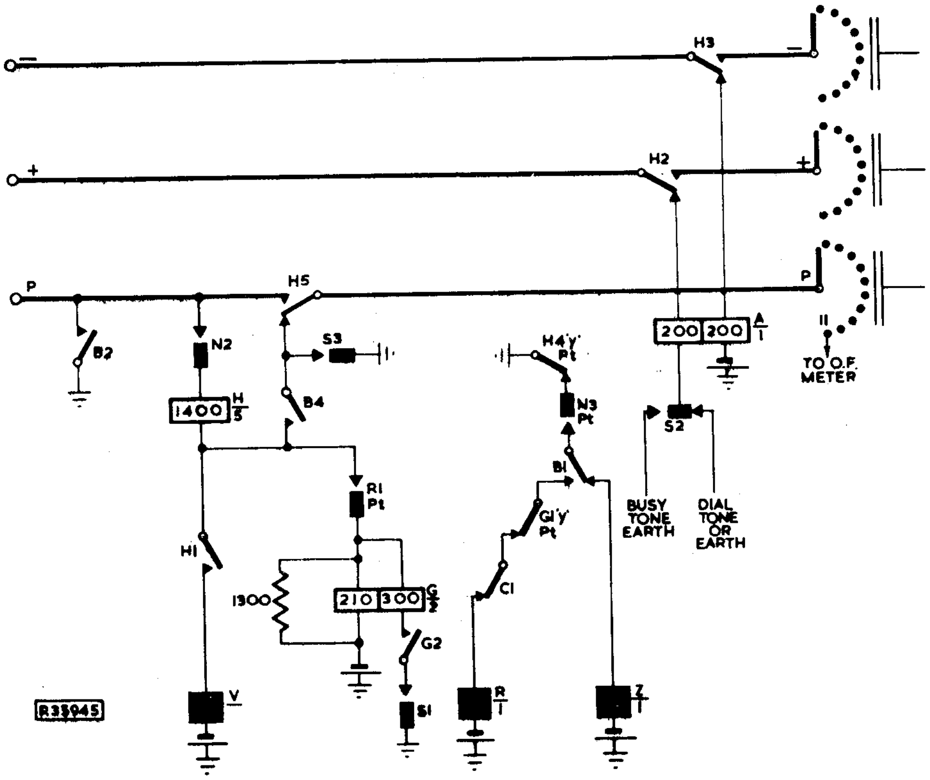

Fig. 17

Relays B and C, not shown, are arranged so that B, which is slow to release, is disconnected when switching occurs but C releases at the end of vertical stepping.

The release of relay C on completion of the vertical stepping completes an operate circuit for the rotary magnet R,

Earth - H4 (normal) - N3 (operated) - B1 (operated) - G1 "y" (normal) - C1 (normal) - rotary magnet R - battery.

The wipers step to the first outlet on the selected level and during the operate stroke of the magnet armature, the rotary interrupter R1 contacts make.

Relay G is connected via contacts R1 to the parallel paths

(i) coil of relay H, N2 contacts, contact B2 to earth, and

(ii) contacts B4, H5, P-wiper to P-wire of first outlet.

If the outlet is busy, the earth on the P-wire short-circuits relay H and operates relay G. Contact G1 disconnects the rotary magnet circuit, and during the subsequent release stroke of the magnet armature the R1 contacts break to disconnect relay G. Contact G1 on release completes the rotary magnet circuit, and the wipers are stepped to the next outlet.

Stepping continues until the wipers step on to a free outlet. The absence of earth on the P-wire of a free outlet disconnects the short circuit on relay H and the operate circuit for relay G. With the R1 contacts closed, however, relays H and G are connected in series to the earth at contact B2 but the current which flows is sufficient only to operate relay H.

Contact H1 completes a hold circuit for relay H to the battery via the vertical magnet coil, the current which flows is insufficient to operate V. Contacts H2, H3 and H5 extend the positive, negative and private wires to the seized outlet. Contact H4'y' disconnects the rotary magnet circuit, but contact H1 guards relay H against the subsequent release of the R1 contacts. The release of relay A, disconnected at H2 and H3, disconnects relay B which, after a slow to release feature, releases. Contact B2 disconnects the earth from the P-wire but by this time an earth has been returned from the seized outlet.

Contacts G1 and H4 are late to operate to ensure full operation of the rotary magnet, the late operation of G1 also facilitates adjustment of the R1 contact operation to obtain a correct stepping and testing action on busied outlets.

If all the outlets are busy the wipers step to the 11th rotary position and the contacts S1, S2 and S3 operate. Relay G operates to the S3 earth and locks via G2 and S1 to earth. Contact G1'y' disconnects the rotary magnet circuit but relay G remains held over both coils in series when the R1 contacts open. Contact S2 extends busy tone to the caller via the A relay, and contact S3 extends an earth to operate an 'overflow' meter connected to the 11th step P-wire.

The circuit is released from an effective connexion by the release of relay H when the earth is disconnected from the P-wire. Contact H4 on release completes the circuit for the release magnet Z. When the selector is normal, N3 contacts open and disconnect the release magnet circuit. On an ineffective call, relay A releases when the subscriber clears and a contact of A disconnects relay B, not shown in Fig. 17. Contact B1 on release completes the circuit for the release magnet.

2000-TYPE GROUP SELECTOR

The rotary stepping and earth testing element of a 100 outlet 2000-type group selector is shown in Fig. 18. The rotary stepping and testing features are similar to those described earlier in this pamphlet for the pre-operated test relay circuit, Fig. 8.

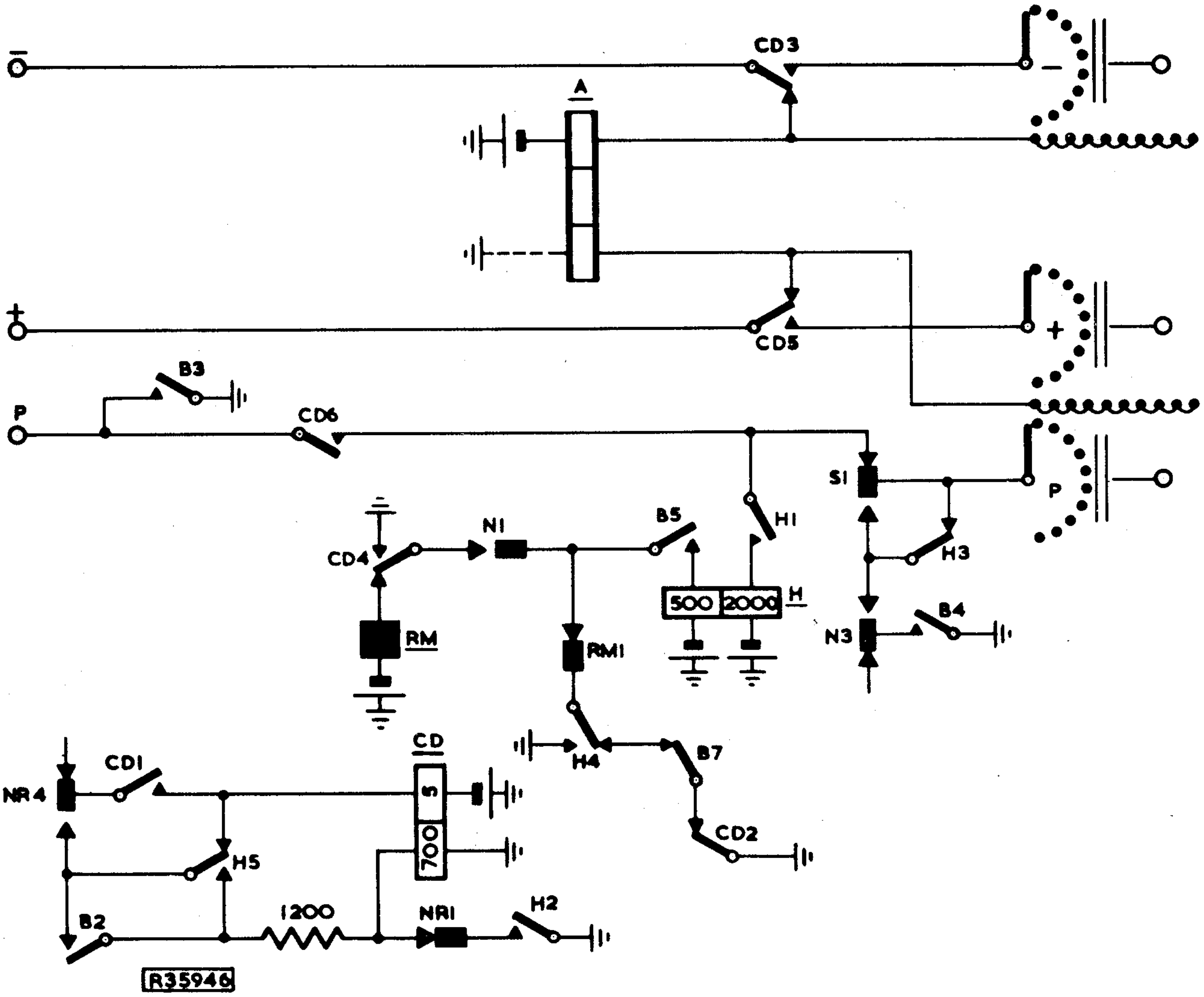

Fig. 18

Relays A and B, not shown in Fig. 18, operate when the selector circuit is first seized. Contact B3 extends earth guard condition to the incoming P-wire. Contact B2, with contact H5 normal completes an operate circuit over both coils in series for relay CD. Contact CD4, as previously explained completes an operate circuit for relay H. Contact H5 operated disconnects the original operate circuit for relay CD. The relay remains operated during the vertical stepping by earth pulses extended over NR4 normal, contact CD1 and the 5 ohm coil in conjunction with the release lag created by the short-circuit completed by contact H2 on the 700 ohm coil. At the end of vertical stepping relay CD releases, and rotary stepping and testing commences as previously described.

When relay H releases on a free outlet contact H5 again completes an operate circuit for relay CD over both coils in series, the short circuit path on the 700 ohm coil has been already disconnected by the rotary off-normal contacts NR1. Relay CD operates and at contacts CD3, CD5 and CD6 extends the incoming circuit to the seized outlet. Contact CD4 operated completes a reoperate circuit for relay H over the 500 ohm coil. Contact CD1 operated with NR4 operated and H5 now operated maintains the circuit for relay CD.

Contact H1 operated extends the 2000 ohm coil of relay H to the P-wire, and the relay holds to the earth which is applied to the P-wire in the seized outlet before relay B releases.

If all the outlets are engaged, the wipers step to the 11th rotary position and the S contact units operate. Contact S1 disconnects relay H from the P-wiper, thus allowing the relay to release. Contact H5 normal completes the reoperate circuit for relay CD. Contact H3 normal extends an earth condition to the 11th step P-wire to operate a service 'overflow' meter.

Contacts CD3 and CD5 extend the negative and positive wires to the wipers. Relay A does not release because the loop on the incoming negative and positive wires is extended over the wipers to the 11th step outlet and back to the A relay. Relay B remains operated by an operated A contact not shown in Fig. 18. Relay H reoperates to the earth at CD4 operated and B3 operated through CD6 operated.

At the termination of a normal connexion, the earth is disconnected from the P-wire to release relay H. Contact H5 normal disconnects relay CD. The release of relays CD and H complete a rotary self-drive circuit; battery, RM, CD4, N1, RM1, H4, B7, CD2 and earth. Normal 2000-type selector release then takes place.

When a subscriber clears after the wipers have stepped to the 11th rotary position, relay A releases. Relay B is disconnected by a contact of relay A, and releases after a lag period. Contacts B3 and B5 disconnect relay H. Normal release follows the release of relay H.

The 200-outlet group selector

The 2000-type 200-outlet group selector circuit in general use provides for the simultaneous earth testing of the two outlets connected to the bank at each rotary step. The circuit arrangement is such that if both outlets are free, the odd numbered outlet is always seized. The simplified circuit arrangement is shown in Fig. 19, for simplicity the 11th step facility is not included.

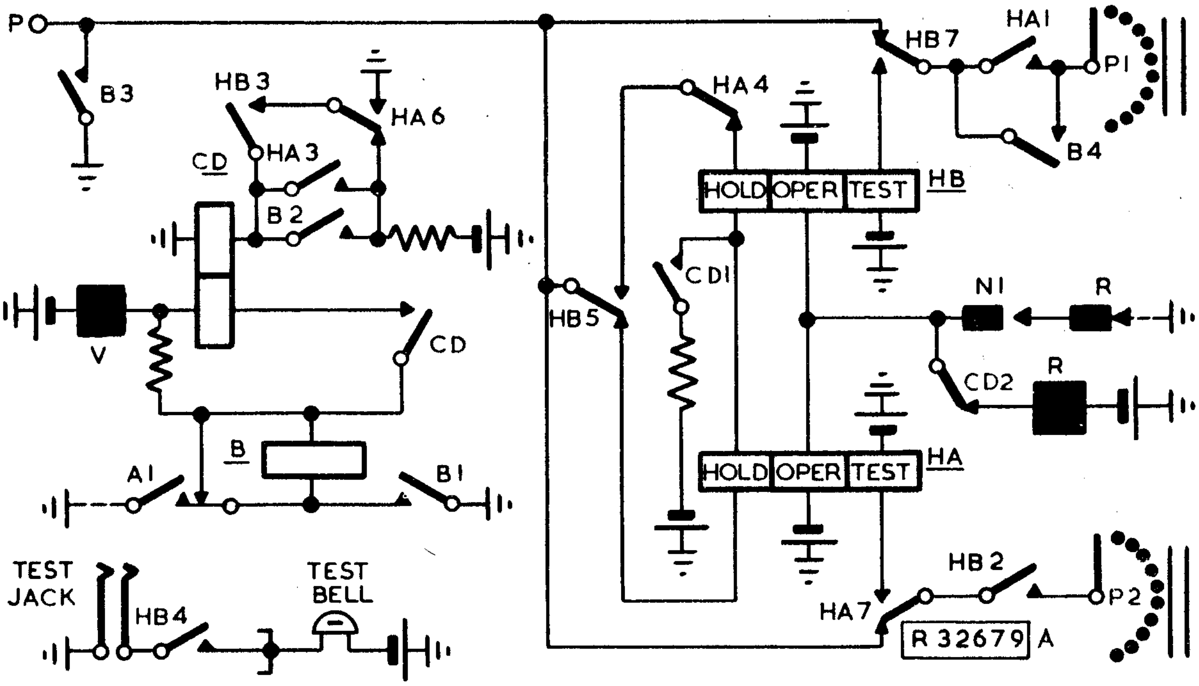

Fig. 19

When the selector is seized relays A, B, and CD operate. On the first vertical step relays HA and HB operate via N1 springs. Contacts HA6 and HB3 short-circuit the operating coil of relay CD leaving it dependent upon the pulses of contact A1. At the end of the vertical train relay CD releases but relays HA and HB hold via the N1 springs.

The rotary magnet receives its first pulse on the release of relay CD at contact CD2 and the wipers step to the first pair of outlets. The R springs open as the selector reaches the end of the rotary step thus disconnecting the 'operate' winding of relays HA and HB, and the circuit for the rotary magnet.

If both outlets are engaged, relays HA and HB hold on their 'test' coils to engaged earths via contacts HA7 and HB7 respectively and the selector steps again when the R springs remake the magnet circuit. In this way the selector continues to step through the interaction of the R magnet and R springs until either relays HA or HB fail to find an earth and thus release when the R springs open and remove the earth to the 'operate' coils.

If both outlets are free relays HA and HB release. The short-circuit is removed from relay CD at contacts HA6 and HB3, and relay CD in reoperating opens the stepping circuit at contact CD2. Relay HA reoperates on its 'hold' coil via contacts CD1, HB5 and B3, and holds to the earth returned on the P wire when the selector calling loop is switched through. Thus relay HA takes precedence over relay HB when both outlets are free.

In the event of outlet No. 1 being engaged and outlet No. 2 free, the earth on the P1 contact holds relay HB via contacts B4 and HB7 when the R springs disconnect the 'operate' winding. Relay HA has released and contact HA6 removes the short-circuit from relay CD which reoperates and holds relay HB to the P-wire earth via CD1, HA4, and HB5.

If outlet No. 1 is free and outlet No. 2 is engaged relay HB releases and contact HB3 removes the short-circuit from relay CD which operates. Relay HA is held operated by battery via CD1, HB5, B3, to earth.

FINAL SELECTOR TEST CIRCUIT

The battery testing element in an ordinary final selector circuit has the same general arrangement as the elementary circuit shown in Fig. 9. The circuit constants are such, however, that it does not provide immunity from simultaneous connexions; the chance of simultaneous testing on any particular outlet in a final selector bank is remote and trouble from this cause is negligible.

Battery testing is employed in a final selector circuit so that a relay in the subscriber's line circuit can be operated immediately on seizure; this is necessary so that the line relay can be disconnected without delay, so leaving the circuit clear for the application of ringing current. Earth testing is not suitable because the free condition is a disconnexion, and this does not allow for the immediate operation of a relay in the seized outlet.

The testing circuit of a final selector is shown in Fig. 20. On the completion of the pulse controlled rotary stepping, the testing relay is connected to the P-wire outlet through the contacts B3 operated and CD3 normal. If the outlet is free a circuit is completed for relays H and K to operate in series, relay K in the associated line circuit being arranged to have a faster operate time than relay H. Contacts of relay K disconnect the bridging equipment, relay L, and contact H1 completes a hold circuit for relay H to the earth at contact B1 operated. Contact H2 extends an earth to the P-wire to mark the circuit engaged.

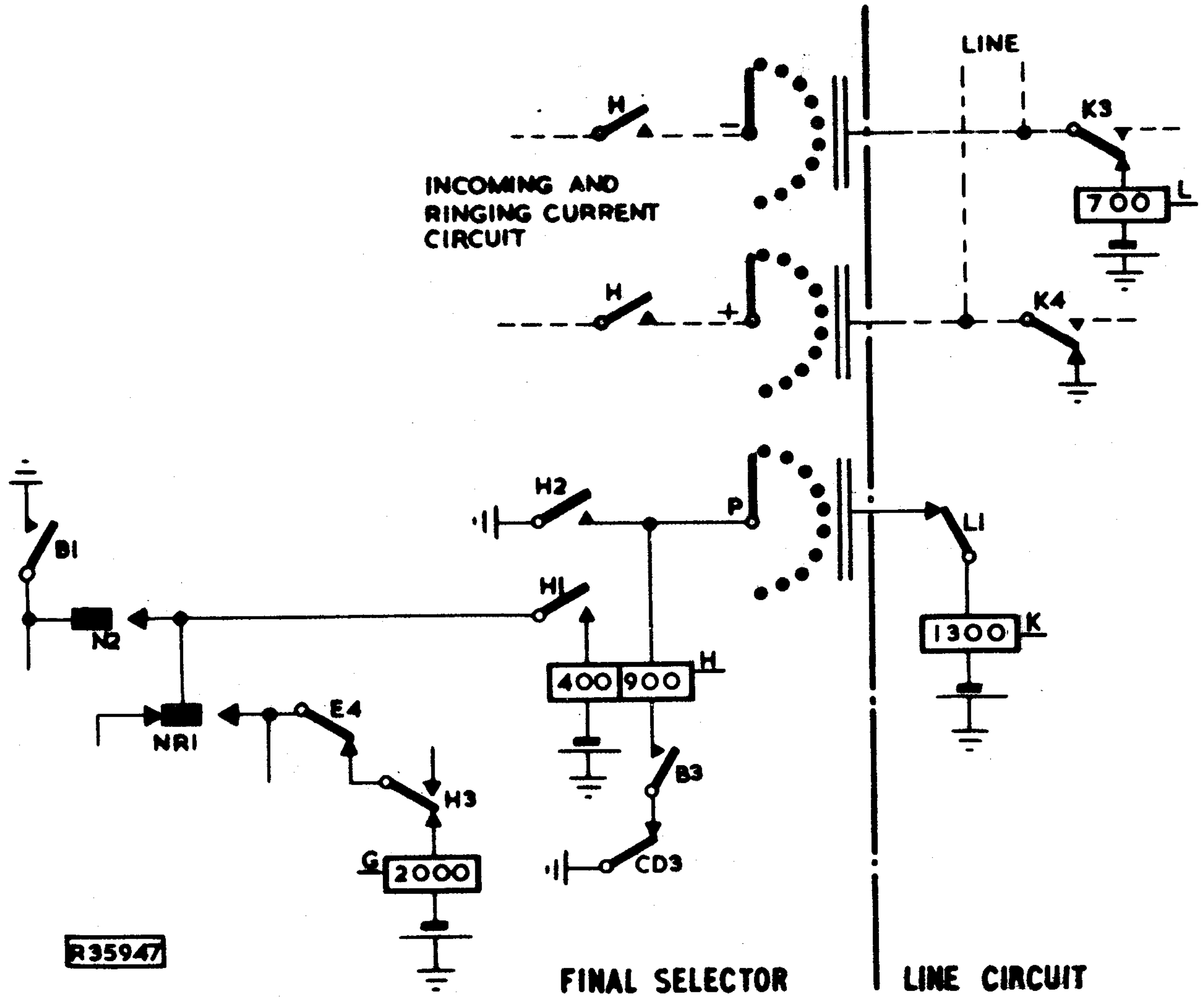

Fig. 20

If the circuit is engaged, the P-wire outlet will be either at earth potential due to an H2 contact earth or disconnected due to the operated contact L1, Fig. 20. Relay H, therefore does not operate, and when contact E4 restores to normal an operate circuit is completed for relay G to the earth at B1. Contacts of relay G are arranged to connect busy tone to the calling line.

2000 TYPE A-DIGIT SELECTOR HUNTER

A differential marginal hold battery testing and 'cut' drive circuit arrangement is employed in the A-digit selector hunter circuit. The circuit element is shown in Fig. 21.

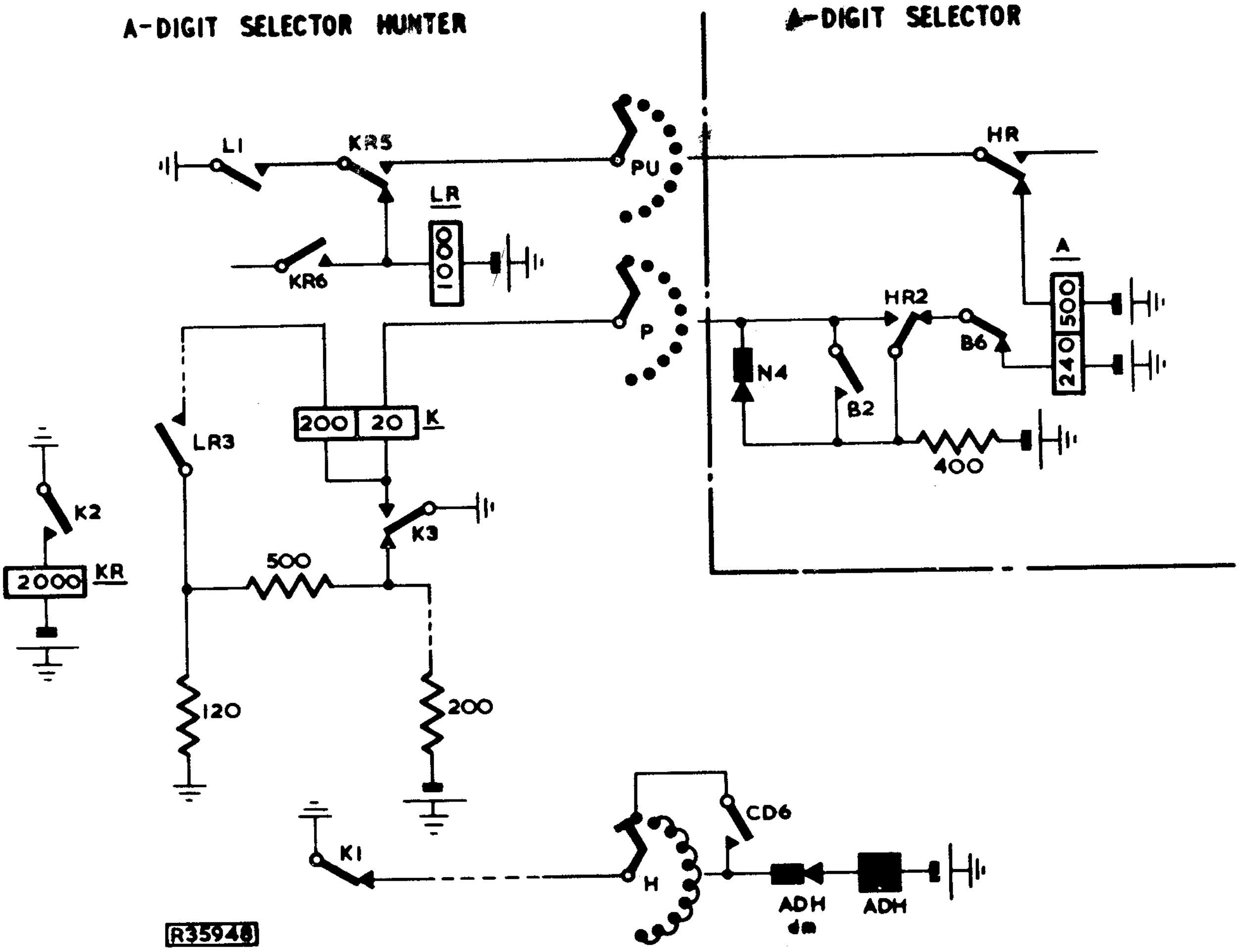

Fig. 21

When the selector control circuit is first seized, relay L, not shown in Fig. 21, operates and at contact L1 completes an operate circuit for relay LR. Relay CD is also caused to operate, and at contact CD6 completes a self-drive circuit over the home contact of the homing arc for the uniselector drive magnet. The wipers step to the first outlet and testing takes place as described in the section on differential holding. The free condition on the P-wire of the outlet is a 150 ohm resistance battery, composed of a 400 ohm non-inductive resistor in parallel with the 240 ohm winding of relay A. Such an arrangement reduces the current build up time in the test relay K, and reduces its operate time to some 5 mS. The busy condition is a low value battery potential of approximately 2.4 volts, and is produced at the junction of the earth connected 20 ohm coil of relay K in series with the 400 ohm resistor to the 50V battery.

The self-drive circuit steps the wipers until they step onto a free outlet. Relay K operates and when contact K3 short-circuits the 200 ohm coil, relay A in the A-digit selector operates. At this point in the operation, the 400 ohm resistor is still connected in parallel with the 240 ohm coil of relay A and the potential on the P-wire of the outlet is some 5.9 volts, which is sufficiently low to prevent another K relay from operating.

Contact K1 cuts the uniselector drive circuit and contact K2 operates the switching relay KR. Contact KR5 extends the L1 contact earth over the PU wiper to the 500 ohm coil of relay A, to guard against the operation of contact B6 and to place relay A under the control of contact L1.

When relay A operated initially it caused relay B, not shown in Fig. 21, to operate. Contact B2 guards the hold circuit for relay K against the subsequent operation of the N4 contacts, and contact B6 disconnects the operate coil of relay A which is now held over the 500 ohm coil. Under normal circuit conditions relay HR will operate and relays A and B release. The holding circuit for relay K is then dependent on contact HR2.

Release conditions are set up when relay HR is caused to release, and at contact HR2 disconnects the hold circuit for relay K. At the instant contact HR2 releases, the P-wire of the outlet is disconnected and remains so until the contacts N4 remake when the A-digit selector mechanism restores to normal. Relay K releases and at contact K2 disconnects relay KR. Contacts K1 and KR5*x* complete the self-drive home circuit for the uniselector. The KR5*x* contacts remake after the remaining KR contacts have restored, thus the uniselector does not step until the circuit has been disconnected from the wipers.

PRE-2000 TYPE A-DIGIT SELECTOR HUNTER

The circuit arrangement, Fig. 22, employs a relay interacting type stepping circuit to allow for a heavily loaded test and switching relay, K, in a simple marginal hold battery testing circuit.

When the circuit associated with the hunter is seized, relay C is caused to operate. Contact C2 extends the battery connected relay MG through the 25 ohm coil of relay K to the earth at the home P-wiper contact. Relay MG operates but the current is insufficient to operate relay K. Contact MG1 completes an operate circuit for the uniselector magnet ADH. The interrupter contacts ADH dm break at the end of the operate stroke and disconnect relay MG, which then releases. Contact MG1 on release disconnects the ADH magnet coil, and the wipers step to the first outlet. If the outlet is engaged, relay MG operates to the 25 ohm earth condition which has been applied by the K1 contact of another circuit. Contact MG1 operates the ADH magnet and the stepping sequence is again repeated.

When the wipers step to a free outlet, the relay K operates over both coils in series to the 150 ohm resistance battery condition. Relay MG does not operate. Contact K1 short circuits the high resistance coil of relay K to guard the outlet and to operate relay A in the A-digit selector. Contact K2 extends the L contact earth to guard against operation of relay B and to complete a pulsing circuit for relay A.

When the circuit is released, relay K is caused to release by circuit changes in the A-digit selector. Contact K3 with contact C2 now normal, completes a relay interacting drive circuit to the home position for the A-digit selector hunter.

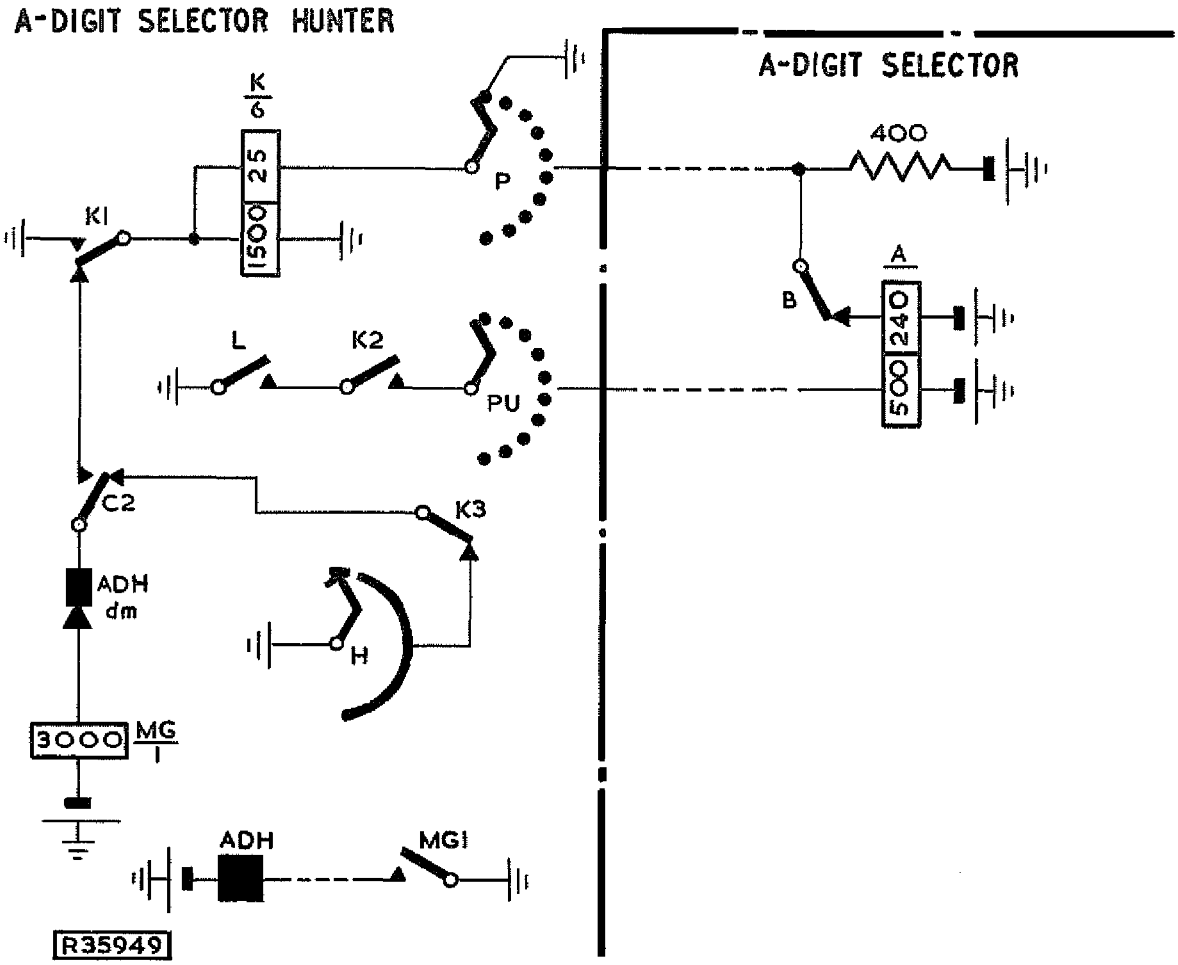

Fig. 22

END