CHAPTER XI

PRIVATE MANUAL BRANCH EXCHANGES

SUBSCRIBERS' installations involving a main instrument and several extensions have already been dealt with under "Plan Numbers" in Chapter IX. When the number of extensions exceeds one or two, and particularly when intercommunication between the extensions is required, it is necessary to install at the subscriber's premises a *Private Branch Exchange* (abbreviation P.B.X.) A P.B.X. may be a small local automatic system, or more usually may consist of a manually operated switchboard. To differentiate between the two types, automatic installations are referred to as P.A.B.X.s (*Private Automatic Branch Exchange*) whilst purely manual switchboards are known as P.M.B.X.s (*Private Manual Branch Exchange*).

Broadly speaking, P.M.B.X.s may be classified under three main headings:

(*a*) *Cordless switchboards.* These are small boards designed for installation on a table and where switching is effected by means of keys.

(*b*) *Cord type switchboards.* These are usually floor pattern switchboards employing jacks and cord circuits.

(*c*) *Multiple switchboards.* For very large installations where three or more positions are required.

In addition, there is the House Exchange system which gives direct communication between extensions coupled with exchange line service without the assistance of a P.B.X. operator.

Through Clearing. All modern P.M.B.X.s are arranged to give *through clearing* from the extension to the exchange, i.e. on an exchange call when an extension replaces his receiver a clearing signal is given both to the P.M.B.X. operator and to the public exchange. This ensures that trunk and junction time is not wasted due to delay in clearing by the P.M.B.X. operator. Apart from this, however, through clearing has become essential for the proper timing of trunk calls since the introduction of automatic timing devices under the control of the subscriber's switch-hook. The main disadvantage of through clearing at P.M.B.X.s is that an extension cannot attract the attention of his local operator without the risk (particularly in automatic areas) of releasing the connexion. To meet this requirement, operator *recall facilities* can be provided on some types of installation.

Power Supply. The smaller P.M.B.X.s are designed to operate with a power supply at a minimum pressure of 12 V. Normally power is supplied for these smaller boards by means of primary cells or a power lead from the exchange. Both these sources possess an appreciable impedance at speech frequencies and hence it is usual to provide a large capacitance condenser (8 μF) across the P.M.B.X. busbars to prevent overhearing. The larger P.M.B.X.s are usually served by a 24 V secondary cell installation. (See Ch. XX.)

Transmission Bridge. On most P.M.B.X.s there is very little difference in line resistance between the various extensions. Advantage is taken of this to provide a cheap form of transmission bridge with a single two-winding impedance coil to serve both extensions (see Fig. 95). The transmission bridge is, moreover, required only on extension-to-extension calls, and a high degree of balance and transmission efficiency is therefore not necessary.

Night Switching. All P.M.B.X.s provide facilities for connecting selected extensions to the exchange lines during the night period when the switchboard is not staffed. Under normal day conditions, a clearing signal is given at the P.M.B.X. when the receiver of an extension so extended is on the rest. Switching relays are also operated to cut out the local transmission bridge on exchange calls. It is undesirable (especially from a power wastage point of view) that these relays and supervisory indicators should remain operated throughout the night period. Night service switching keys are therefore provided to disconnect the local transmission bridge and supervisory indicators under night service conditions.

Switchboard Designation. Non-multiple P.M.B.X. switchboards are designated in the Post Office by a fractional index which describes the quantity of equipment and the capacity of the board. Thus the designation:

$$\frac{2+4}{6} = \frac{\text{equipment for two exchange lines plus four extensions}}{\text{capacity for six lines (exchange + extension)}}$$

Similarly: $$\frac{10+60}{180} = \frac{\text{equipment for ten exchange lines plus sixty extensions}}{\text{capacity for 180 lines (exchange plus extension)}}$$

Cordless Switchboards. There are four standard cordless type switchboards;

$$\frac{1+3}{4}, \frac{2+4}{6}, \frac{3+7}{12} \text{ and } \frac{3+9}{12}.$$

They are all of the same general appearance and differ only in the number of lines and connecting links. Fig. 310 illustrates the $\frac{2+4}{6}$ type switchboard. The exchange lines are terminated on drop indicators whilst eyeball indicators are provided for the extensions. Two rows of three-way keys complete the face equipment of the switchboard. The keys are wired so that when two keys in the same horizontal row are thrown in the same direction the appropriate lines are connected together through a link circuit. Operating is facilitated by adding coloured strips to indicate the direction in which the keys must be thrown to associate with a given connecting link. The bottom position of the lower row of keys is reserved for applying hold conditions on the exchange lines and for ringing the extensions. The vertical row of keys on the extreme left is for night switching, whilst the operator's telephone is associated with the similar row on the right.

An incoming call drops the indicator of the exchange line and the operator answers by selecting a disengaged connecting link and throwing the appropriate exchange line key and her telephone key in the direction of the selected link circuit. After ascertaining the number required, the operator calls the required extension by depressing the Ring Key and turning the handle of the generator. When the extension answers, a key of that extension is moved to the chosen connecting link, and after verifying that the call is correctly established the operator restores her telephone key. The procedure on outgoing and extension to extension calls is very similar, but great care is necessary on outgoing calls to ensure that the connexion is not released. The operator must be certain that the extension loop is holding the call before she dissociates her telephone. If this is not possible, the exchange line Hold Key must be operated until the extension receiver is lifted. At the termination of a call the extension indicator reoperates as a clearing signal until such time as the keys are restored.

The circuit arrangements of the connecting keys and link circuits are shown in Fig. 311. The 80 + 80 Ω retard coils in each link circuit provide the simple transmission bridge. The coils are so connected that the operation of any exchange line key cuts off the transmission bridge from the link. Similarly the operation of any extension key breaks the circuit of the relevant calling indicator. A supervisory relay (*AA*, *AB*, etc.) is inserted in the *B*-line of each link. The contact of this relay (*AA*1, *AB*1, etc.) provides a circuit for the reoperation of the extension indicator at the end of a conversation until the switching key is restored. Alarm contacts on all indicators energize a buzzer to provide an audible alarm. When the night switching key is thrown, the supervisory circuit is broken

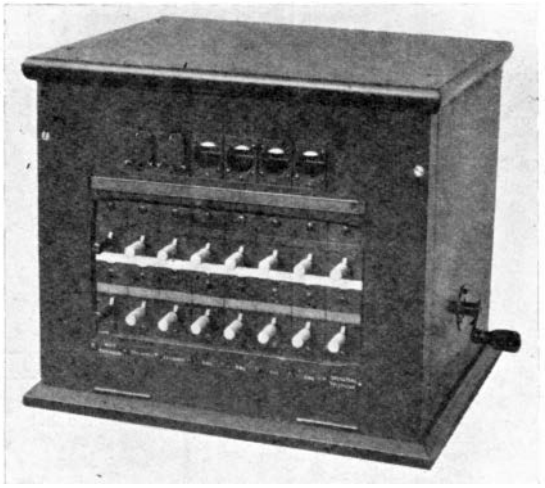


FIG. 310. TYPICAL CORDLESS P.M.B.X. SWITCHBOARD
(Switchboard No. $\frac{2+4}{6}$)

at ***NS*2**, ***NS*3**, etc., whilst the alarm circuit of the exchange line indicators is disconnected at ***NS*1**. (The transmission bridge is cut out at the exchange line key.)

The circuit conditions when an exchange to extension call is set up are summarized in Fig. 312, in which the key contacts have been omitted for clarity. Fig. 313 shows in a similar manner the conditions on an extension to extension call. It will be noted that relay *AA* is in the common battery feed to both extensions, and hence the clearing signal energizes both extension indicators only when the *last* party replaces his receiver.

Cordless Switchboard—L.B. Areas. The cordless switchboard described above is suitable for use in C.B. or automatic areas. A switchboard of similar appearance is also available for use in C.B.S.1, C.B.S.2 or magneto areas or on long lines in C.B. or auto areas. Fig. 314 shows the elements of one connecting link. The key contacts have been omitted, but the detailed connexions can be readily deduced by a comparison with Fig. 311. No transmission bridge is necessary with this switchboard, but a supervisory relay *R* is provided in each connecting link and is isolated from the exchange

line by the 2μF condensers. Contact *R*2 provides a reoperate circuit for the extension indicators via the switching key to give a positive clearing signal. Contact ***R*1** places the 250 Ω hold coil across the condensers so that an extension can call the exchange direct under N.S. conditions. Contact ***NS*2** breaks the clearing signal circuit to the extension indicator as before. It is interesting to compare

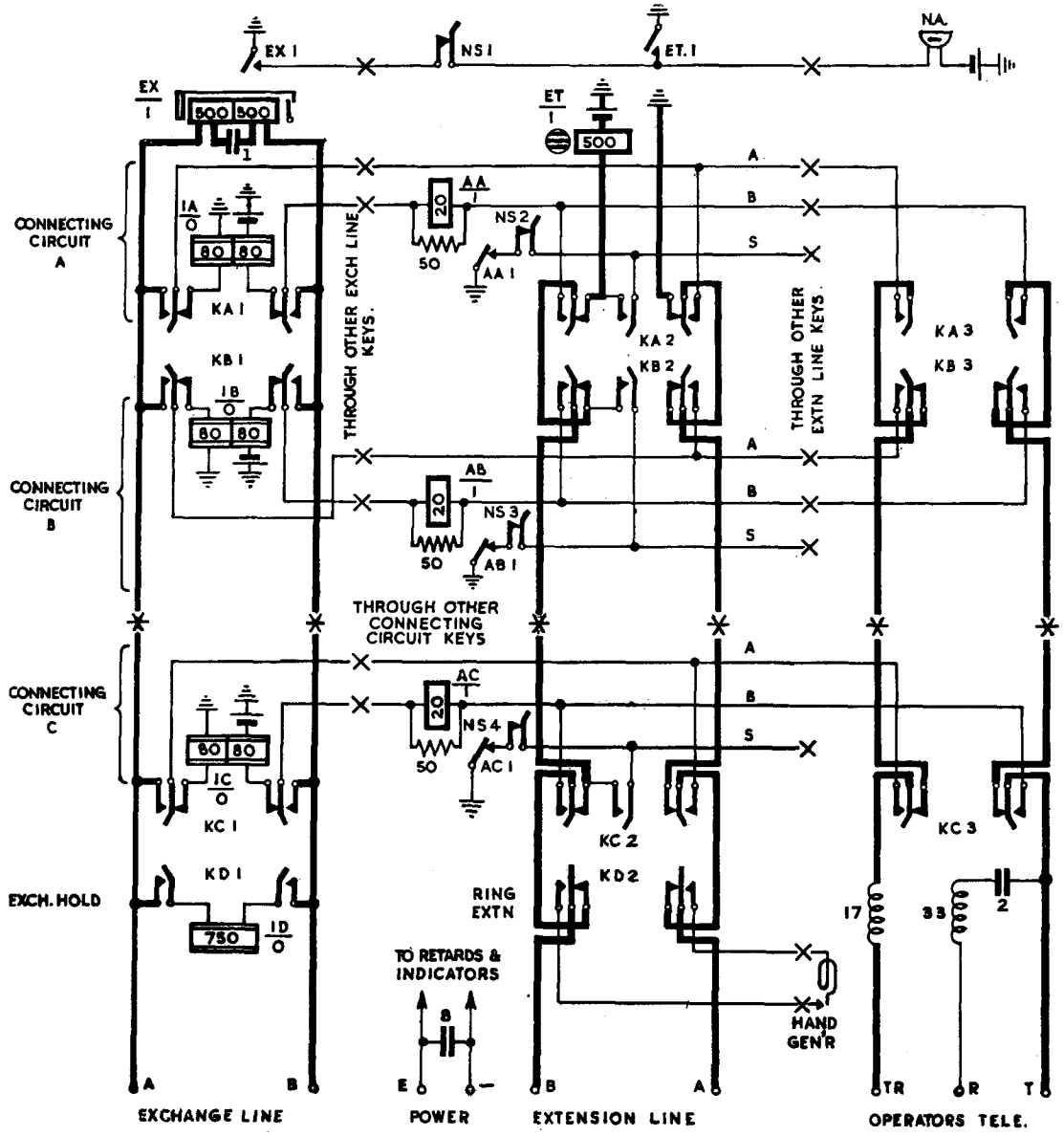


FIG. 311. CIRCUIT ARRANGEMENTS OF CORDLESS SWITCHBOARD

exchange line whilst the extension receiver is off, thereby providing a holding loop to the exchange. In C.B.S.1 areas, the back contact of *R*1 is wired to earth to give the normal clearing signal at the termination of a call (earth on *A*-line). The night switching key disconnects *R* and bridges the the circuit arrangements after switching (Figs. 315 and 316) with those of the C.B. type switchboard (Figs. 312 and 313). In magneto areas, a generator must be associated with the operator's instrument and must also be fitted at each night service extension.

Magneto Switchboards. Although magneto working is rapidly becoming obsolete, mention should perhaps be made at this stage of two types of magneto switchboard which have proved very useful during the war period for the switching of circuits where generator signalling is employed.

The single cord type of magneto P.M.B.X. is illustrated in Fig. 317, whilst Fig. 318 gives the fundamental circuits. The principle of single cord working has already been discussed in Chapter X. A plug and jack are associated with each line and

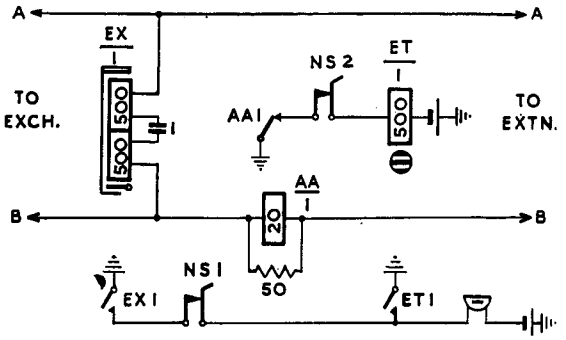


FIG. 312. THROUGH CONDITIONS ON AN EXCHANGE-TO-EXTENSION CALL

with the operator's telephone. When two lines are connected together one of the drop indicators is left across the line to receive the ring off signal. This indicator is condensered to maintain switchhook control of the exchange timing device. The generator of the operator's instrument is so arranged that when calling a line via the plug, the

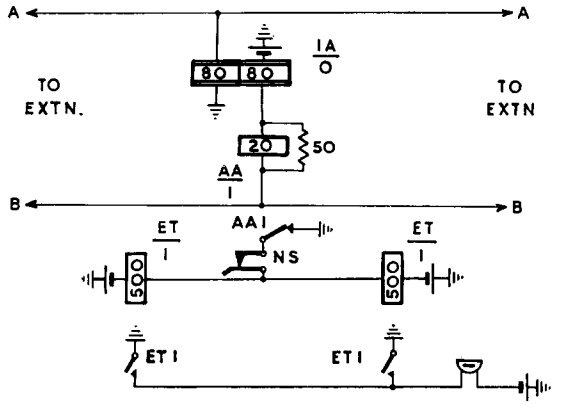


FIG. 313. THROUGH CONDITIONS ON AN EXTENSION-TO-EXTENSION CALL

ringing current does not pass to a waiting party connected to the operator's jack.

The double cord wall type switchboard (Fig. 319) is of more conventional lay-out with break jacks and a ring-and-speak key in the cord circuit. The

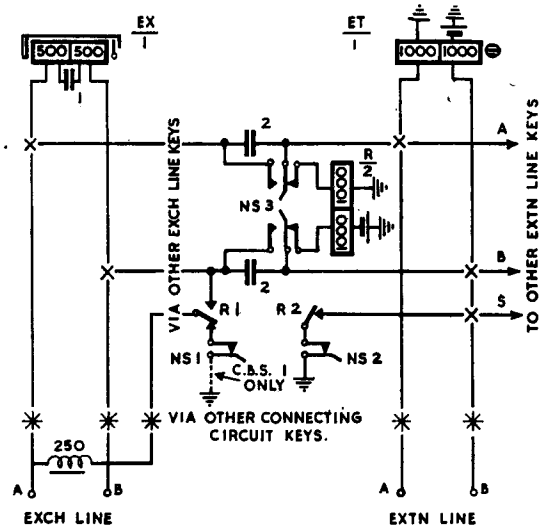


FIG. 314. ELEMENTS OF CORDLESS SWITCHBOARD FOR USE IN L.B. AREAS

cord circuit ring off indicators are permanently bridged across the line and hence are of the high impedance type.

25-Line P.M.B.X. The smallest floor pattern

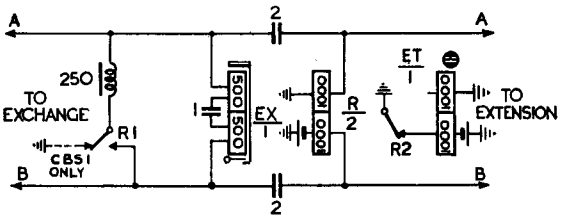


FIG. 315. THROUGH CONDITIONS, EXCHANGE-TO-EXTENSION CALL

cord type switchboard for use in C.B., automatic, and C.B.S. areas is illustrated in Fig. 320. It has a capacity for five exchange lines and twenty extensions, and provision is made for a maximum of eight cord circuits. It is usually installed with its

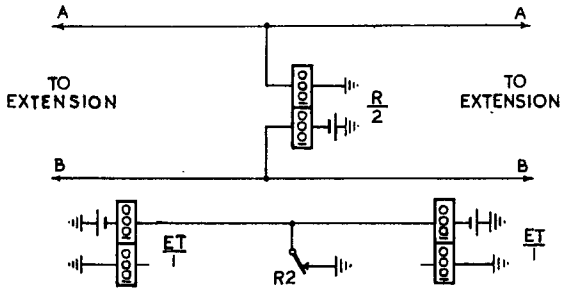


FIG. 316. THROUGH CONDITIONS, EXTENSION-TO-EXTENSION CALL

back adjacent to a wall, and access to the interior is obtained by swinging open the hinged front.

The complete circuit arrangements are given in Fig. 321. A simple undivided transmission bridge

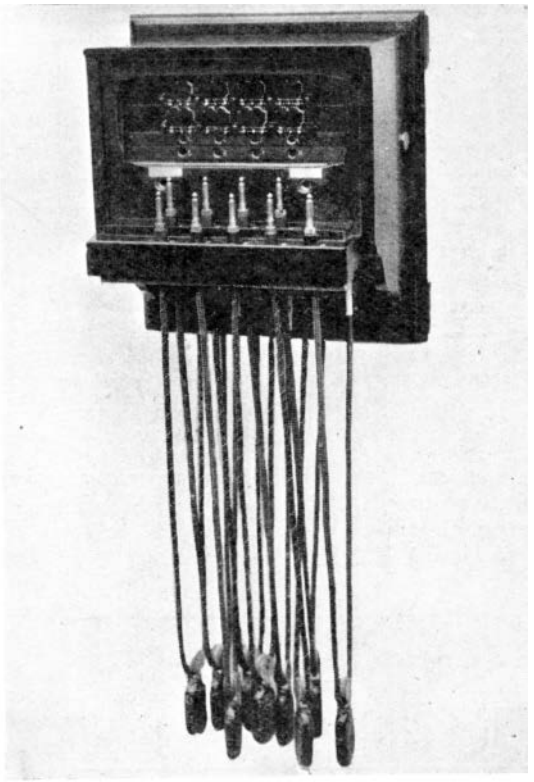


FIG. 317. SINGLE CORD MAGNETO SWITCHBOARD

(*FR/O*) is provided in the cord circuit and is disconnected on exchange calls at ***S1*** and ***S2***. The bush of an extension line is left disconnected, whilst a full earth is connected to the bush of each

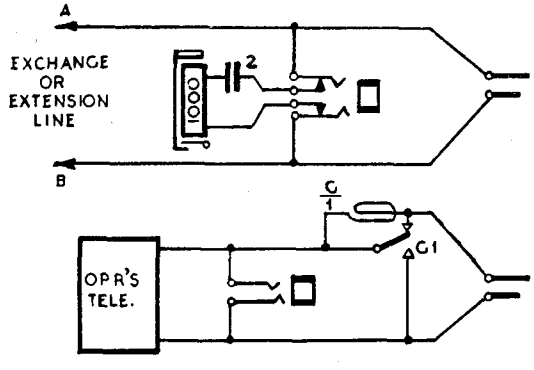


FIG. 318. CIRCUITS OF SINGLE CORD MAGNETO SWITCHBOARD

exchange line jack. If, therefore, a plug is inserted in an exchange line jack, relay *S* operates to remove the transmission bridge. The supervisory relays (*A*) are, contrary to the usual practice, associated with the extension line circuits. At the termination of a call, relay *A* releases due to the break in the extension loop, and at *A*1 reoperates the extension indicator to give a positive clearing signal until the plug is removed from the jack. The operator's

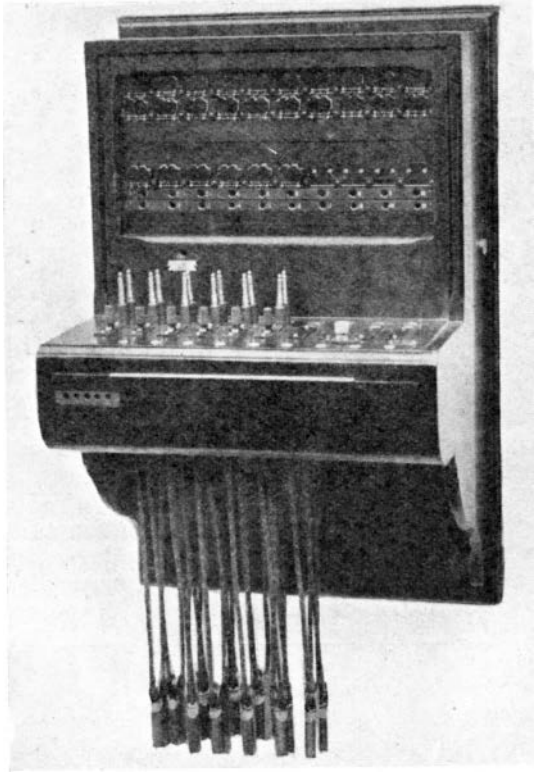


FIG. 319. WALL PATTERN DOUBLE CORD MAGNETO SWITCHBOARD

telephone circuit is provided with an anti-sidetone coil and is of normal design. In addition to the cord circuit speak-and-ring key, a ring-back key is also provided. This latter key is also operated when dialling on the calling cord to dissociate the answering plug from the dialling circuit. The night service switching key disconnects the extension indicator, the transmission bridge and the alarm bell. It also removes the earth from the bushes of the exchange line jacks to prevent the unnecessary operation of relay *S*.

65- and 180-Line P.M.B.X.s. A larger type of floor pattern non-multiple P.M.B.X. is available when the requirements exceed the capacity of the 25-line switchboard. Two models of the large

board have been standardized. The first provides for an ultimate capacity of fifteen exchange lines and fifty extensions $\left(\frac{10+30}{65} \text{ and } \frac{10+50}{65}\right)$ whilst the second has a maximum capacity of twenty exchange lines and 160 extensions $\left(\frac{10+60}{180}\right)$. The two types are very similar in appearance (Fig. 322) apart from the fact that the jack field of the larger board is arranged in two panels. There is also some slight difference in the positions of the exchange line jacks, and the 180-line switchboard has a capacity for eighteen cord circuits as compared with fifteen on the smaller model. Access to the interior is obtained through the removable rear panel and hence it is essential to leave a space behind the switchboard for maintenance. Although the switchboard is not intended to form part of a suite, the design is such that two positions can readily be installed in a continuous line if required.

The main difference between this switchboard and the 25-line P.M.B.X. is the provision of supervisory indicators in the cord circuits. The indicators are of the "sixpenny" type and separate indicators are provided for the answering and calling cords. These supervisory signals are "negative" in operation, i.e. the indicator discs are visible whilst a call is in progress and disappear at the termination of a call. This is the reverse of the "positive" clearing signals provided on the cordless and 25-line switchboards. The extension and exchange indicators are of the doll's eye and drop type respectively and the usual speak, ring, and ring-back/dial keys are provided.

Fig. 323 shows the circuit arrangements. As before, exchange line discrimination is effected by earthing the bushes of all exchange line jacks. On extension to extension calls relay *S* is not operated due to the absence of an earth on the sleeve conductor and the 80 + 80 Ω transmission retard coil (*FR*) is connected to the speaking conductors. The supervisory indicators *A* and *B* operate to the calling and called extension loops and provide to the operator a visual indication of the progress of a call.

When a connexion is set up through an exchange line, relay *S* operates to the earth on the bush of the exchange line jack. ***S*1** and ***S*2** remove the transmission bridge from the tip and ring wires and substitute a holding loop (*FR* and *HR* in series) under the control of *C*1. Whilst the extension receiver is off the rest, relays *A* and *B* operate in series from the current in the loop to the exchange. ***A*1** and ***B*1** complete a circuit for relay *C* which locks via the speak key contacts and ***C*2** to the earth in the sleeve circuit. ***C*1** in turn removes the holding loop from the cord circuit. This arrangement ensures that a call is not accidentally released whilst it is being extended to an extension, but at the same time it allows through clearing at the termination of a call.

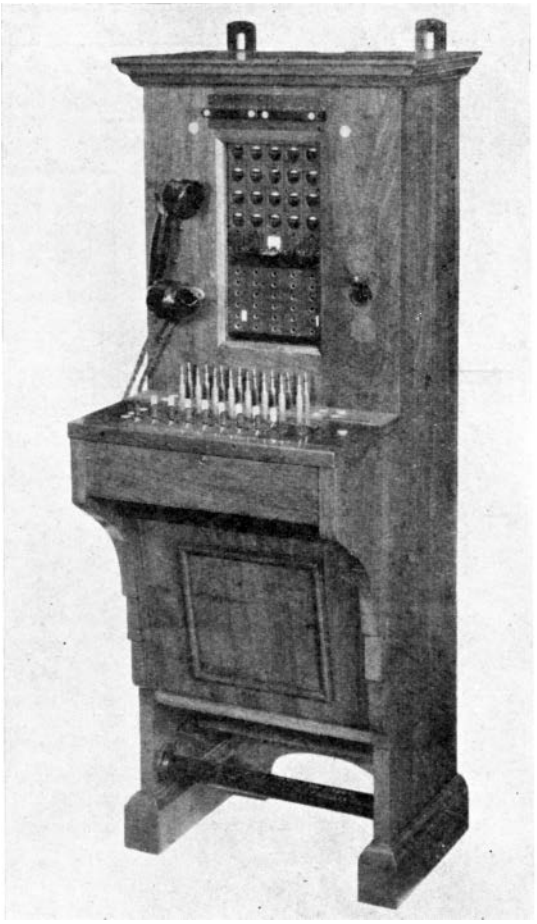


FIG. 320. 25-LINE P.M.B.X. SWITCHBOARD
(Switchboard $\frac{5+20}{25}$)

The night service key when operated removes the transmission bridge and breaks the operate circuit for relays *S* and *C*. The operator's telephone circuit is of modern design which minimizes sidetone and prevents acoustic shocks to the operator (see Chapter V). It will be noted that in order to economize in power consumption the operator's transmitter circuit is completed only when a speak key is thrown. The 200 Ω resistor and 1 μF condenser act as a spark quench circuit for the speak key contacts.

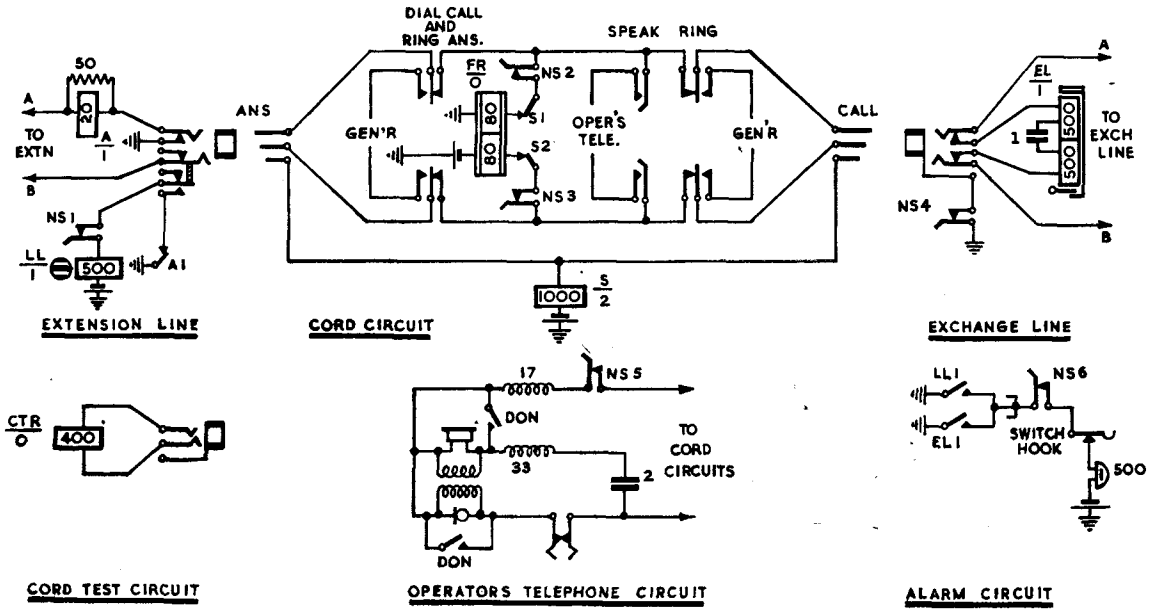
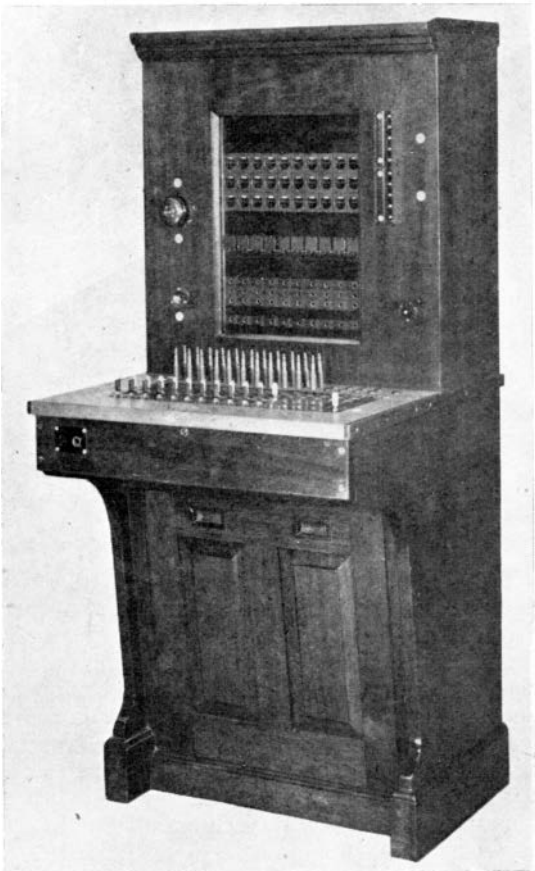


FIG. 321. CIRCUITS OF 25-LINE SWITCHBOARD



No. 9 Type P.M.B.X. The Post Office No. 9 type switchboard is a floor pattern, double-cord board of the multiple type and until recently was the standard P.M.B.X. when more than two positions were required. It has now been superseded for new work by the P.M.B.X. No. 1A described later.

The switchboard is made up of single position sections each of two panels. Each section has a capacity for twenty exchange lines, 200 extensions, and seventeen cord circuits. There are no separate answering jacks, but all lines are multipled on a four-panel repetition basis throughout the suite. The multiple space available limits the total capacity of the switchboard to 160 exchange lines and 800 extensions.

Figs. 324 and 325 illustrate the extension and exchange line circuits. A series multiple with break jacks is employed and when a plug is inserted into any jack, auxiliary contacts place a 200 Ω engaged test battery on the bushes of all other jacks in the multiple. On earlier installations, self-restoring drop indicators (Fig. 163) were provided on the exchange lines. The indicator disc was operated by the incoming ringing current, and when a plug was placed in a line jack, auxiliary springs completed a circuit for a restoring coil on the indicator to the battery on the sleeve of the plug. This arrangement has now been superseded by the circuit shown in Fig. 325 in which an eyeball

FIG. 322. 65-LINE P.M.B.X. SWITCHBOARD
(Switchboard $\frac{10 + 30}{65}$)

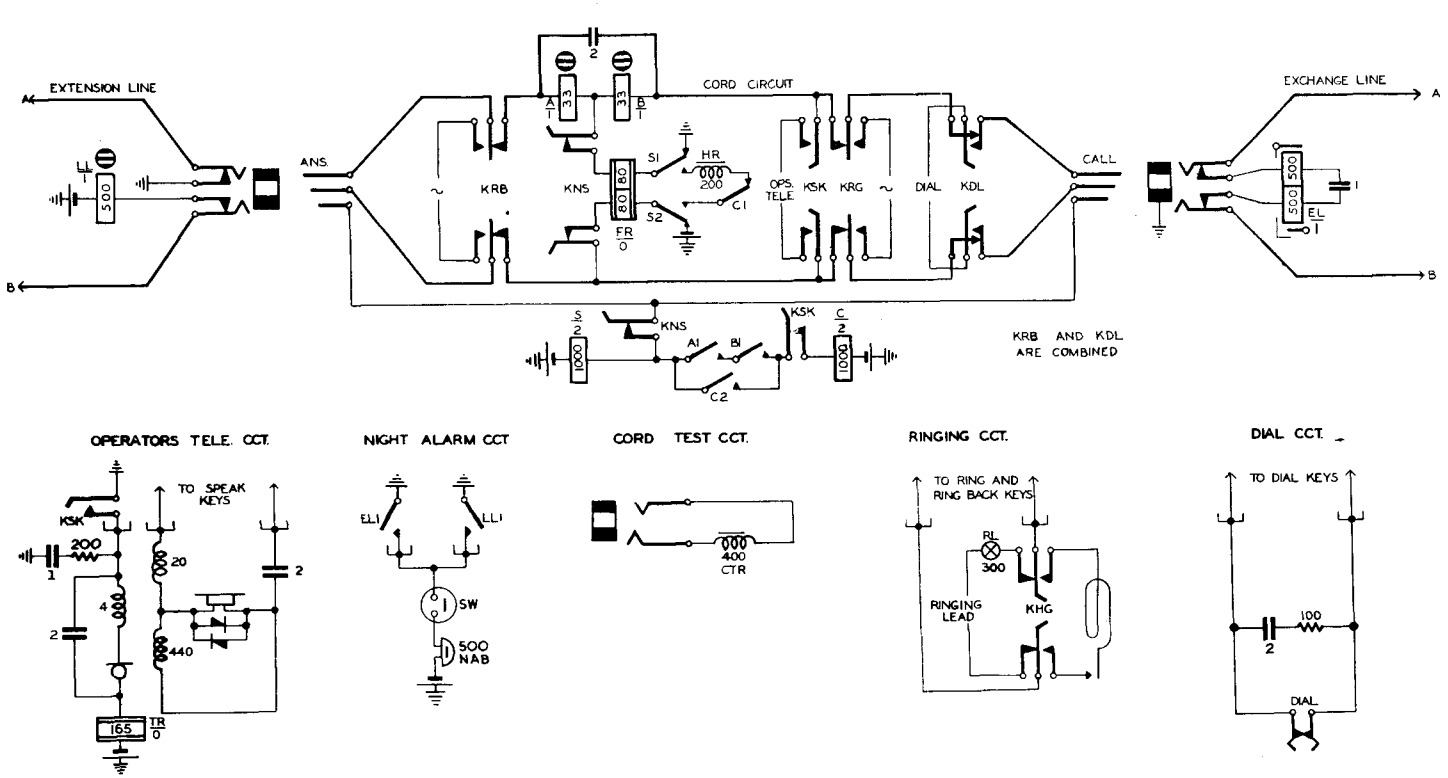


FIG. 323. CIRCUIT DETAILS OF LARGE TYPE FLOOR PATTERN P.M.B.X.

(Switchboards $\frac{10+30}{65}$, $\frac{10+50}{65}$, and $\frac{10+60}{180}$)

indicator in conjunction with a metal rectifier is used to receive the incoming ring. The eyeball indicator locks in the operated position on its second coil. When a plug is placed in the line jack, relay *S* operates to the battery on the sleeve of the plug and at ***S1*** releases the calling indicator.

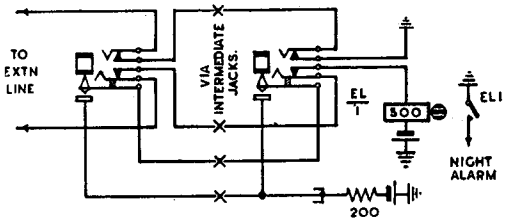


FIG. 324. EXTENSION LINE CIRCUIT
(No. 9 type P.M.B.X.)

The cord circuit of the No. 9 P.M.B.X. is substantially the same as that of the 65- and 180-line switchboards.

A secondary cell installation providing a minimum bus bar voltage of 16 is required, the consumption of a typical four-position exchange being in the order of 16–20 Ah/day.

P.M.B.X. No. 1A. The P.M.B.X. No. 1A is the new standard switchboard for subscribers' installations where more than two positions are required. The new item supersedes the C.B. No. 9 type switchboards already described. The basic unit of a P.M.B.X. No. 1A is a two-panel single-position section of modern design and is 4 ft. 6 in. high by 2 ft. 2 in. wide (Fig. 326). The sections are designed to bolt together to form a continuous switchboard and the suite is completed by 1 ft. 0 in. wide cable turning sections fitted at each end. The keyshelf is equipped with twelve cord circuits with wiring for an ultimate of sixteen cord circuits per position. Each pair of cords is fitted with a speak-and-ring key and a ring-back/dial key. Separate supervisory lamps are provided for the answering and calling cords.

Each panel of the jack field has a capacity for forty exchange lines arranged in strips of ten jacks, and for 200 extension lines arranged in strips of twenty jacks. Each position has therefore a maximum capacity of eighty exchange lines and 400 extensions. All lines are multipled on a four-panel repetition basis throughout the suite, and hence the maximum capacity of the P.M.B.X. No. 1A is 160 exchange lines and 800 extensions. Inter-switchboard lines and private wires are fitted in the exchange line multiple.

All circuits are lamp calling and an unusual feature is the absence of separate answering lamps and jacks. Normally ebonized blanks are inserted between the multiple jack strips, but at one of the multiple appearances this blank is replaced by a strip of calling lamps above the multiple jacks. The switchboard does not provide multiple answering facilities or ancillary working for the extension lines, there being only one calling lamp per circuit. The distribution of calling signals is normally determined at the design stage by traffic requirements, and it is usual to arrange for the calling lamps of each group of twenty extensions to appear on one specified panel. Flexibility may, however, be obtained when required, by providing a second lamp strip at another multiple appearance so that individual calling lamps may be transferred from one answering position to another in order to equalize the operators' loads.

A series multiple is employed for the extension circuits in order to avoid the provision of a cut-off relay per line. A special low consumption lamp (17 V 45 mA) has also been introduced to eliminate the need for a line relay on internal extensions of low line resistance. The lamp is connected in series with the battery feed to line and lights from the current in the line when the wires are looped by the lifting of the extension receiver. Amber-coloured lamp caps are used to produce a light of uniform colour irrespective of the line resistance. Provision is made for line relays to be fitted when the extension circuits exceed 200 Ω loop resistance.

The exchange line and private wire multiple is of the parallel type and facilities are provided for a

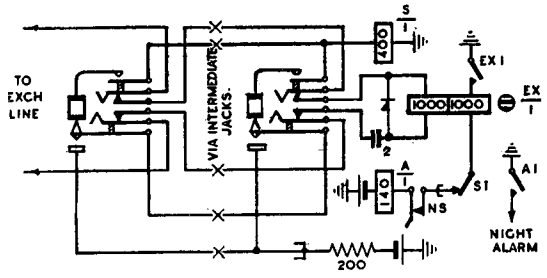


FIG. 325. EXCHANGE LINE CIRCUIT
(No. 9 type P.M.B.X.)

"primary" and a "secondary" calling lamp. Usually, the primary appearances are concentrated on the centre positions of the suite with the secondary lamps spread evenly over the remaining equipped panels.

The cord circuit and miscellaneous position apparatus is fitted at the rear of the section in the usual way, but separate racks are required for the line termination apparatus. The apparatus racks are 2 ft. 9 in. wide and 7 ft. 0 in. high and have been reduced to two standard designs. The first and more common unit contains the necessary

connexion strips for the termination of the cables from the M.D.F. and multiple together with the long extension line relays, the fuse panels, and the relay sets required for exchange lines, etc. The second is a supplementary rack to accommodate relay sets on installations where there is an abnormal number of exchange lines, private wires, etc. All the usual forms of signalling on private wires are catered for by two standard relay sets which are provided with strapping facilities to meet the required signalling conditions.

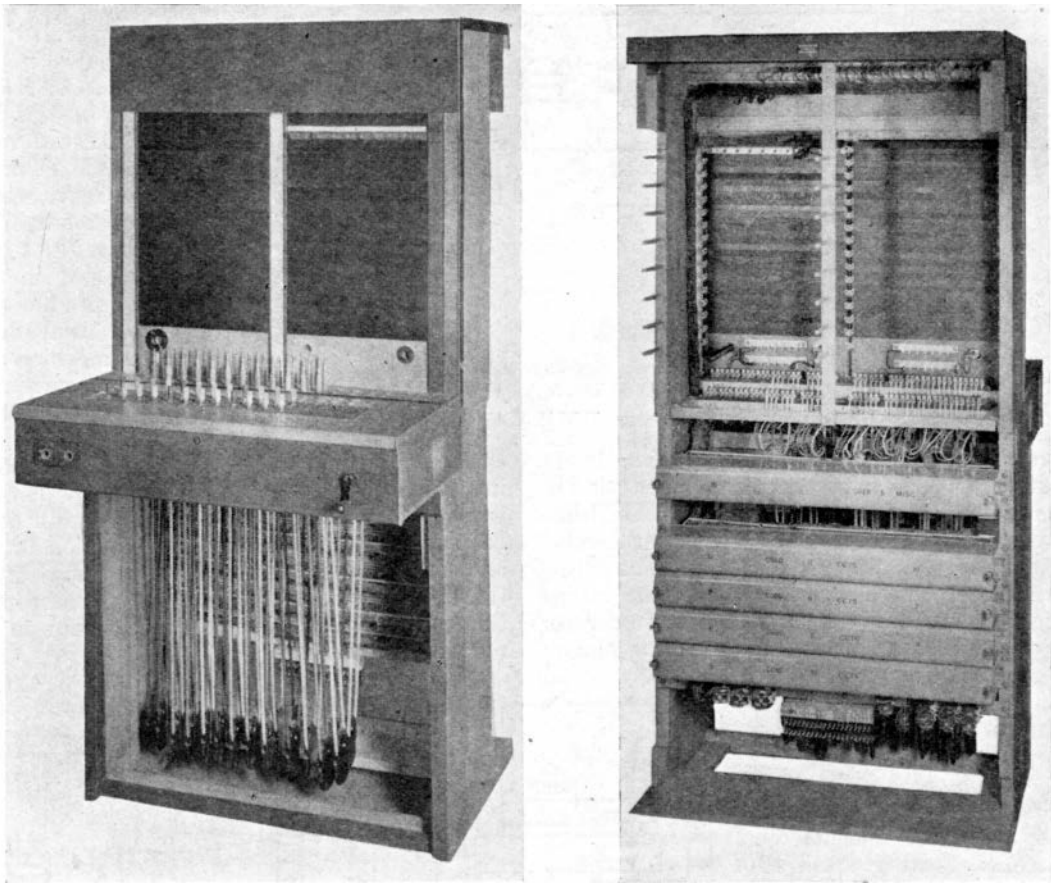


FIG. 326. P.M.B.X. No. 1A
Multiple jacks not fitted.
Front view. Rear view.

Facilities of P.M.B.X. No. 1A. The P.M.B.X. provides the following facilities:

1. Individual positive supervision is given on extension-to-extension calls.
2. Separate battery feed is given to the calling and called lines on extension-to-extension (or P.W.) calls.
3. Ring and dial facilities are provided on the calling cord, and the ring-back facility is provided on the answering cord.
4. The standard "click" engaged test is provided.
5. Through clearing from extension to public exchange is standard and both supervisory lamps on the P.M.B.X. light when the extension clears.
6. Direct dialling from extension to public exchange is possible.
7. Press button operator recall can be provided when required.
8. When an incoming exchange call is received before the operator clears the previous connexion, the supervisory lamps will flash and the incoming ring is prevented from calling the extension.
9. Night service conditions can be set up without the use of separate cords or night service keys.

10. A pilot lamp per position and a common alarm bell for the suite are provided.

Extension-to-extension Calls. The extension and exchange line circuits of P.M.B.X. No. 1A are given in Figs. 327 and 328, whilst Fig. 329 shows the cord and miscellaneous position circuits. In the extension line circuit, an earth is applied via the contact springs of the multiple jacks to the *A*-line and battery via the 17 V calling lamp (or *L* relay on long lines) is placed on the *B*-wire. The lifting of the receiver at the extension lights the calling lamp in the usual way via the loop. The operator at the calling position places the answering plug of a free cord circuit in the line jack of the calling extension and throws the speak key. The speak key contacts place the operator's telephone across the cord circuit and energize relay *SK* and its relief relay *SKR*. Further springs of the speak key complete the operator's transmitter circuit. The operation of contact ***SK*3** causes relay *AS* to operate from the earth at ***SK*7** to the 250 Ω battery in the sleeve circuit of the extension line. At the same time, the current in this circuit produces a potential drop across the 250 Ω resistor to give the necessary conditions for the click engaged test. The original operate circuit of *SK* is broken at ***AS*5**, but an alternative holding circuit is now provided through ***SK*4**, ***AS*4**, and *LC*2; the momentary break during the movement of *AS*5 and *AS*4 being covered by the slow release feature of *SK*. ***AS*3** and ***AS*6** complete the transmission bridge to the calling extension. Relay *LA* now operates to the extension loop.

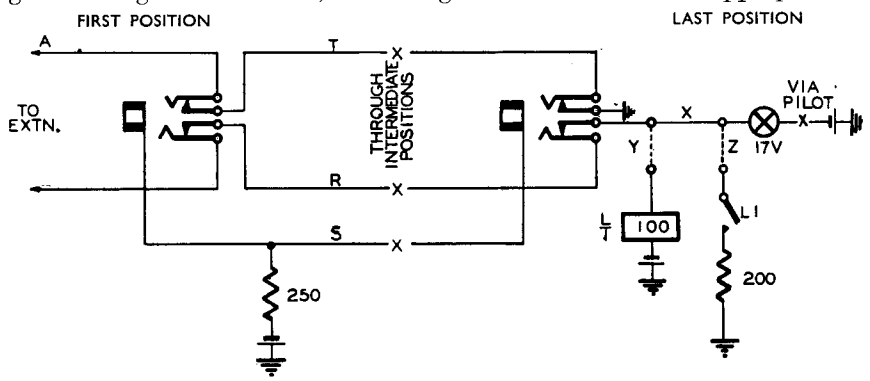


FIG. 327. EXTENSION LINE CIRCUIT, P.M.B.X. 1A

After ascertaining the number required, the operator taps the tip of the calling plug on the bush of the appropriate multiple jack. A circuit is completed from battery, the 2 μF condenser and 20 000 Ω resistor in parallel, speak key springs, *LC*3, *CS*6, one coil of relay *LC*, ***SKR*5**, ring and dial key to the bush of the jack. If the required line is engaged, the potential drop in the sleeve resistance gives rise to a surge of current to charge the 2 μF condenser. This surge in passing through *LC* produces a momentary potential across the speaking pair which in turn gives rise to a current pulse and click in the operator's receiver. The effect is further enhanced by an induced e.m.f. in the second winding of *LC* during the surge of current in the first winding. It should be noted that a full negative battery on the bush is the free condition and either an earth or reduced negative potential indicates that the circuit is engaged. This arrangement is the converse of the usual arrangement in public manual exchanges.

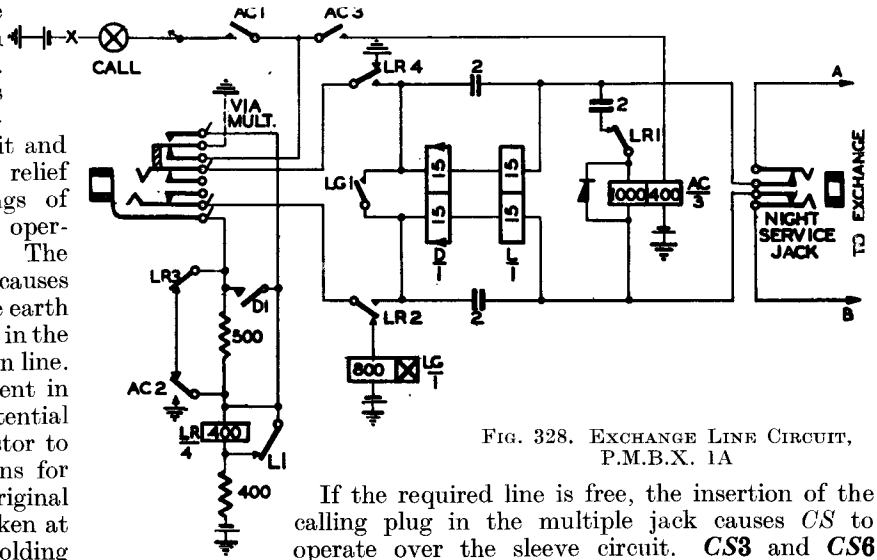


FIG. 328. EXCHANGE LINE CIRCUIT, P.M.B.X. 1A

If the required line is free, the insertion of the calling plug in the multiple jack causes *CS* to operate over the sleeve circuit. ***CS*3** and ***CS*6** complete the second half of the transmission bridge, whilst ***CS*2** lights the calling cord supervisory lamp via ***SK*6** and *LC*1. Ringing of the called extension is effected in the usual way and, when the extension

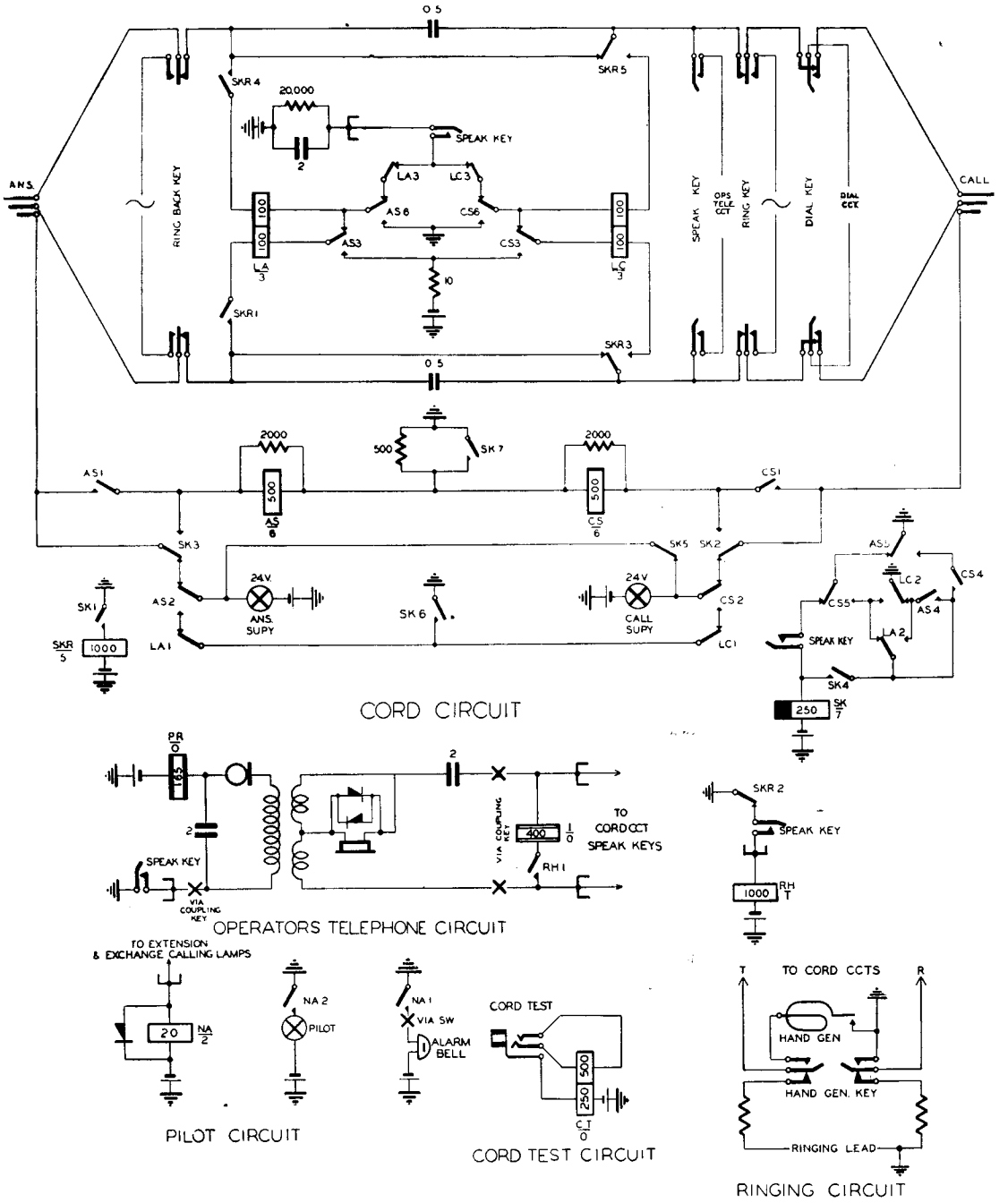


FIG. 329. CORD AND MISCELLANEOUS CIRCUITS, P.M.B.X. 1A

answers, relay *LC* operates over the loop. ***LC1*** extinguishes the supervisory lamp and ***LC2*** removes the holding earth from the *SK* relay. The latter is, however, now held under the control of relays *AS* (at ***AS5***) and *CS* (at ***CS4***).

At any time during the progress of the call, either extension can obtain the attention of the operator by flashing the switch-hook. This breaks the loop and allows relay *LA* or *LC* to release, thereby completing a circuit for the appropriate supervisory lamp at *LA*1 or *LC*1 (Fig. 330). At the termination of the call the continuous glowing of the supervisory lamps gives a positive indication to the operator that the connexion can be taken down. The removal of the plugs releases *AS* and *CS* and they in turn allow relays *SK* and *SKR* to release.

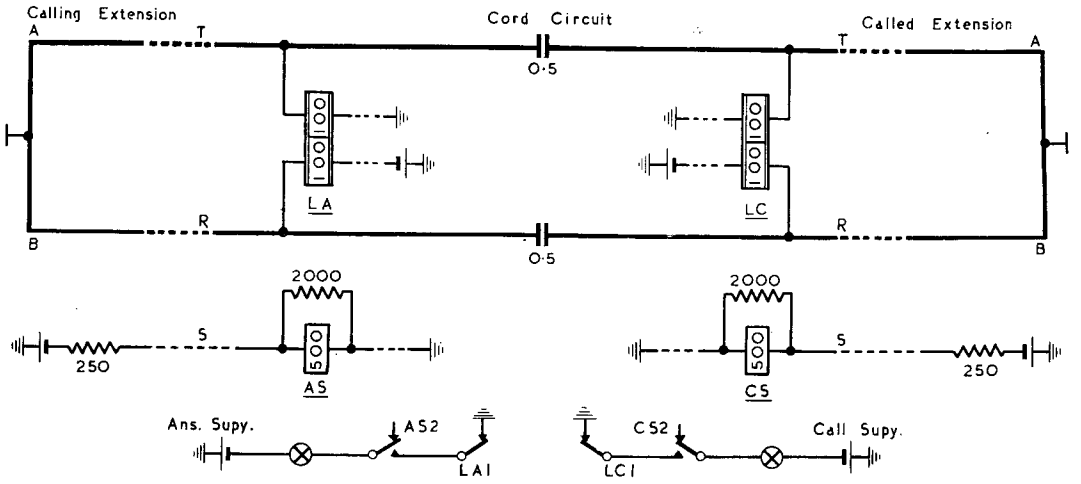


FIG. 330. CONVERSATIONAL CONDITIONS ON EXTENSION-TO-EXTENSION CALLS (P.M.B.X. 1A.)

Incoming Exchange Call. The exchange lines are terminated on eight-point jacks with auxiliary contact springs (Fig. 328). These auxiliary springs are wired in series throughout the multiple, but the line springs are wired in parallel and not in series as the extension multiple. Relay *AC* operates to the ringing current received from the exchange. ***AC1*** lights the calling lamp from the earth through the auxiliary jack springs, whilst ***AC3*** provides a locking circuit for *AC* from the same earth. ***AC2*** applies earth via 500 Ω to the bushes of all jacks to provide the necessary engaged test as described above. It should be observed that an engaged condition is placed on the exchange line multiple from the moment the calling signal is received, whereas the multiple jacks of an extension line are not busied until the calling condition is answered by the insertion of a plug.

The placing of an *ANS* plug into the jack of the calling line operates the auxiliary jack springs and thereby releases relay *AC* and extinguishes the calling lamp. The make contacts of the auxiliary springs provide a full earth on the bush of the jack to replace the function of *AC*2. Both cord circuit supervisory lamps glow to the earth on the bush. When the speak key is thrown, the supervisory lamps are disconnected at ***SK3*** (Fig. 329). The same contact applies relay *AS* to the sleeve circuit, but the relay does not operate due to the absence of battery in the circuit. ***SKR1*** and ***SKR4*** apply both coils of relay *LA* in series to the tip and ring of the *ANS* plug. This 200 Ω loop operates relay *LG* in the exchange line termination via contacts *LR*2 and *LR*4 (Fig. 328). ***LG1*** completes a d.c. loop across the exchange *A*- and *B*-lines through the both coils of relays *L* and *D* (i.e. a 60 Ω loop). The loop trips the ringing (if automatic) and provides the necessary conditions for metering and supervision at the exchange. Relay *D* is differentially wound and does not operate with the loop current. Relay *L* operates and at ***L1*** removes the short circuit from relay *LR*. ***LR1*** removes relay *AC* from the speaking pair to cut out the transmission loss, whilst ***LR3*** inserts 500 Ω in the earth connexion to the sleeve circuit. ***LR2*** and ***LR4*** switch through the exchange line to the cord circuit and break the circuit for *LG*. The loop across the exchange line is now provided by relay *LA* in the cord circuit, the slug on *LG* ensuring that the loop is not momentarily broken during this change over. *LA* in the cord circuit and *L* in the line termination are now operated in series.

After ascertaining the extension required, the operator tests and (if free) seizes the line. Relay *CS*

operates to the battery in the extension sleeve circuit and at ***CS3*** and ***CS6*** provides a temporary transmission bridge for the extension. The hold circuit of *SK* is broken at ***CS5***, but an alternative circuit via ***SK4***, ***LA2***, and *LC*2 was provided on the operation of *LA*. ***CS2*** lights the calling cord supervisory lamp. When the extension replies, *LC* operates to the loop and at ***LC1*** extinguishes the supervisory lamp. ***LC2*** allows *SK* to release.

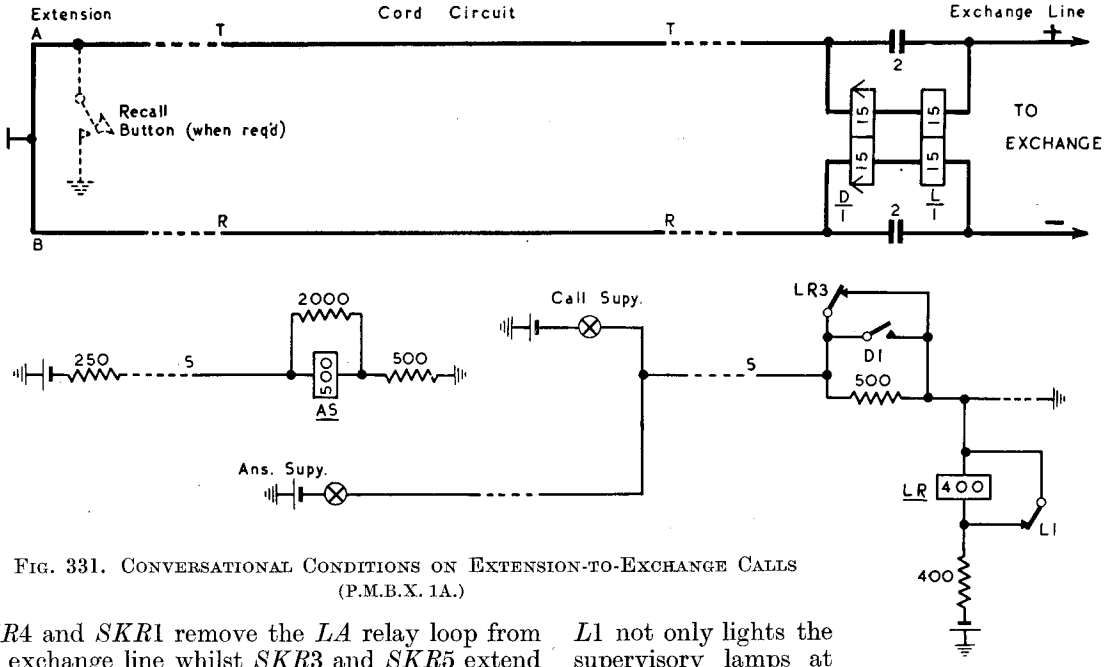


FIG. 331. CONVERSATIONAL CONDITIONS ON EXTENSION-TO-EXCHANGE CALLS (P.M.B.X. 1A.)

*SKR*4 and *SKR*1 remove the *LA* relay loop from the exchange line whilst *SKR*3 and *SKR*5 extend the extension loop to the exchange line by short-circuiting the cord circuit condensers. The speaking conductors of the cord circuit are now straight through without any bridging or series apparatus. On the release of *SK*7, relay *CS* holds to the 500 Ω earth and the reduced current in the sleeve circuit maintains the engaged condition on the extension multiple. Both supervisory lamps are now controlled by the conditions on the sleeve of the exchange line jack. (See Fig. 331 for outgoing exchange calls.)

The operator may monitor the call at any time by throwing the speak key. Under these conditions, *CS*5 avoids interruption of the circuit by preventing *SK* and *SKR* from operating when the speak key is thrown. When the call is terminated, relay *L* releases and at *L*1 short-circuits *LR*. *LR*3 in turn short-circuits the 500 Ω resistance in the sleeve circuit and the increased current allows both supervisory lamps to glow.

Follow-on Call. When a call incoming to the P.B.X. is released by the calling subscriber or public exchange operator, the exchange line immediately tests as a free line. Special arrangements are provided to ensure that if a "follow on" call is received before the P.B.X. operator has cleared the previous call, the calling signal will be properly received and the extension to which the exchange line is connected will not be troubled unnecessarily. At the termination of an exchange call, the short-circuiting of *LR* by the release of *L*1 not only lights the supervisory lamps at *LR*3 but also disconnects the exchange line from the switchboard at *LR*2 and *LR*4. The incoming ringing current of a follow-on call is received by relay *AC*, but the locking circuit of this relay is broken at the auxiliary jack springs. ***AC2*** therefore pulses in synchronism with the received ringing current, and by removing the short circuit from the 500 Ω resistance causes both supervisory lamps to flash in unison with the received ring.

Outgoing Exchange Calls. The circuit operation during an originated exchange call is very similar to the incoming call already considered. The operator places the calling plug of a convenient cord circuit into the multiple jack of a free exchange line and throws the speak key. ***SKR3*** and ***SKR5*** apply the *LC* relay loop to the line which operates *LG*. ***LG1*** repeats the loop to the exchange and the current in this loop operates *L*. ***L1*** in turn removes the short circuit from *LR* which at ***LR2*** and ***LR4*** extends the exchange line to the cord circuit. Relay *LG* now releases after a lag period and removes the temporary loop at *LG*1. This sequence

of operations ensures that, in automatic areas, a false initial impulse is not given to the exchange due to the momentary short-circuiting of the *T* and *R* jack springs during the insertion of the plug.

The required number is passed orally in a manual area, or the number is set up by means of the dial key and dial in automatic areas. At the end of the call, both supervisory lamps glow and the exchange line is released when the calling extension receiver is replaced.

Operator Recall. In an automatic area it is not possible for an extension to recall the P.B.X. operator on an outgoing exchange call by flashing the switch-hook. When the facility is required, separate recall press buttons are fitted at selected extensions (Fig. 331). The operation of this button applies an earth to the *A*-wire of the extension. Normally, the current in the two windings of relay *D* (exchange line termination) are equal and their magnetic effects are arranged to neutralize. When the recall button is pressed one winding is in effect short-circuited by the earth. Relay *D* operates and at ***D*1** cuts out the 500 Ω resistance, thereby lighting the supervisory lamp associated with the exchange line.

Night Service. On those exchange lines where night service facilities are required, an extra night service jack is provided. These jacks are located at the top of the jack field and are so wired that the insertion of a plug cuts off the normal exchange line terminal equipment (Fig. 328). Night service conditions are set up by inserting the answering and calling plugs of any convenient cord circuit into the required extension jack and the exchange line night service jack. All cord circuit keys are left normal. Under these conditions, the *T* and *R* conductors of the cord circuit are straight through and the supervisory relays are out of circuit. There is also no operating circuit for the sleeve relays or supervisory lamps. The extension can therefore receive and originate calls in exactly the same way as a direct exchange line. If the speak key is accidentally operated whilst a night service connexion is set up, relay *SK* locks up, the sleeve relay associated with the extension side of the cord circuit is operated, and the supervisory lamp glows. Under these conditions the connexion must be taken down and re-established.

Private Wires. Private wires terminating on a P.B.X. may employ diverse signalling methods depending upon the characteristics of the line itself and on the type of the distant equipment. The normal combinations of calling and clearing signals on a bothway circuit call for well over a dozen different arrangements of terminal apparatus. In the P.M.B.X. No. 1A the maximum degree of standardization consistent with reasonable economy can be attained by two types of relay set. The first (Fig. 332) is designed primarily for d.c. signalling only, whilst the second (Fig. 333) is a universal relay set which can be arranged to work with any of the usual combinations of d.c. and generator signalling.

D.C. Signalling P.W. Relay Set. The relay set normally responds to a calling signal of earth on the *A*-line, although it can be used for loop calling by the insertion of strap *Y* (Fig. 332). The calling earth operates relay *LL*, which through ***LL*1** lights the calling lamp. The insertion of an answering plug into the line jack and the throwing of the speak key allows relay *S* (line termination) and relay *AS* (cord circuit) to operate in series. ***S*1** operates the relief relay *SR* which locks via its own contact (***SR*3**) to the earth on the auxiliary jack springs. ***S*2** and ***S*3** switch through the speaking conductors, whilst ***SR*2** extinguishes the calling lamp and provides an operate circuit for *LR*. ***SR*1** returns a supervisory earth on the *B*-wire to the distant end. ***SR*4** in conjunction with strap *X* provides a hold circuit for *S* to the auxiliary jack spring earth. Strap *X* is inserted if the facility of extending the private wire to an exchange line is required. As described previously, relays *SK* and *SKR* release on the restoration of the speak key after connexion is made to an exchange line jack. When strap *X* is omitted, the release of *SK* removes the full earth from the sleeve circuit and so releases *S*. *S*2 and *S*3 disconnect the speaking conductors and thereby prevent access to the exchange line.

After the operation of *SR*, relay *LR* is held under the control of ***LL*1**. ***LL*2** applies a loop through *I* to operate the cord circuit supervisory relay (*LA* or *LC*) or to hold an exchange connexion. When the calling earth on the *A*-line is removed at the termination of a call, *LL* and *LR* release, and the disconnexion of the *I* loop gives the required clearing signal.

On outgoing calls, *S* and *SR* operate when the speak key is thrown and ***SR*1** applies the calling earth to line. When the distant end answers the supervisory signal operates *LL* and ***LL*1** operates *LR* to close the supervisory loop at ***LR*2**. It should be noted that the *A*- and *B*-lines must be reversed at one end of the circuit to give correct calling and supervisory conditions. Usually a circuit which employs d.c. signalling in one direction is also capable of d.c. signalling in the other direction. Circumstances do, however, occasionally arise when the type of terminal equipment enables d.c. signalling in one direction only. By connecting strap *Z*, the circuit can be arranged for generator

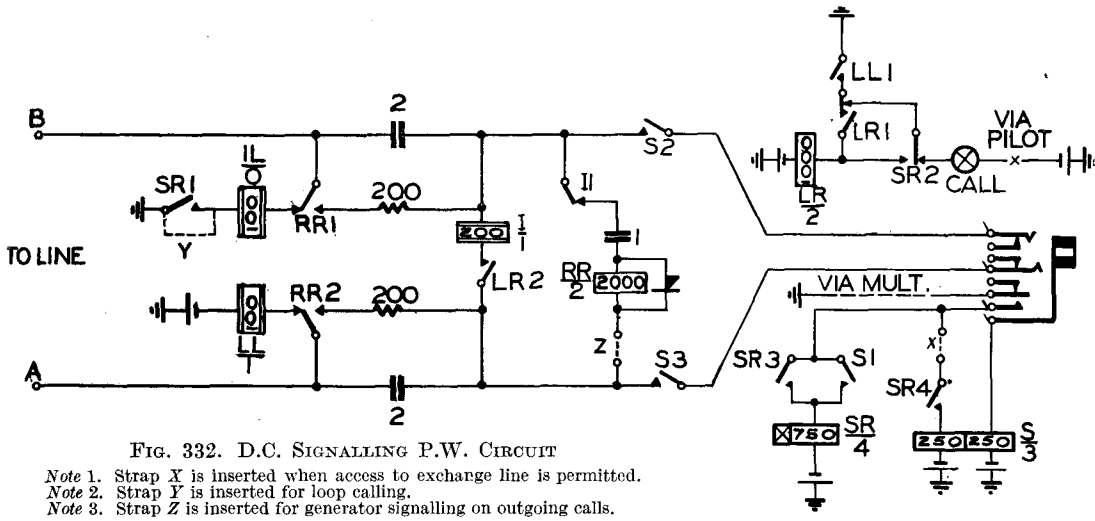
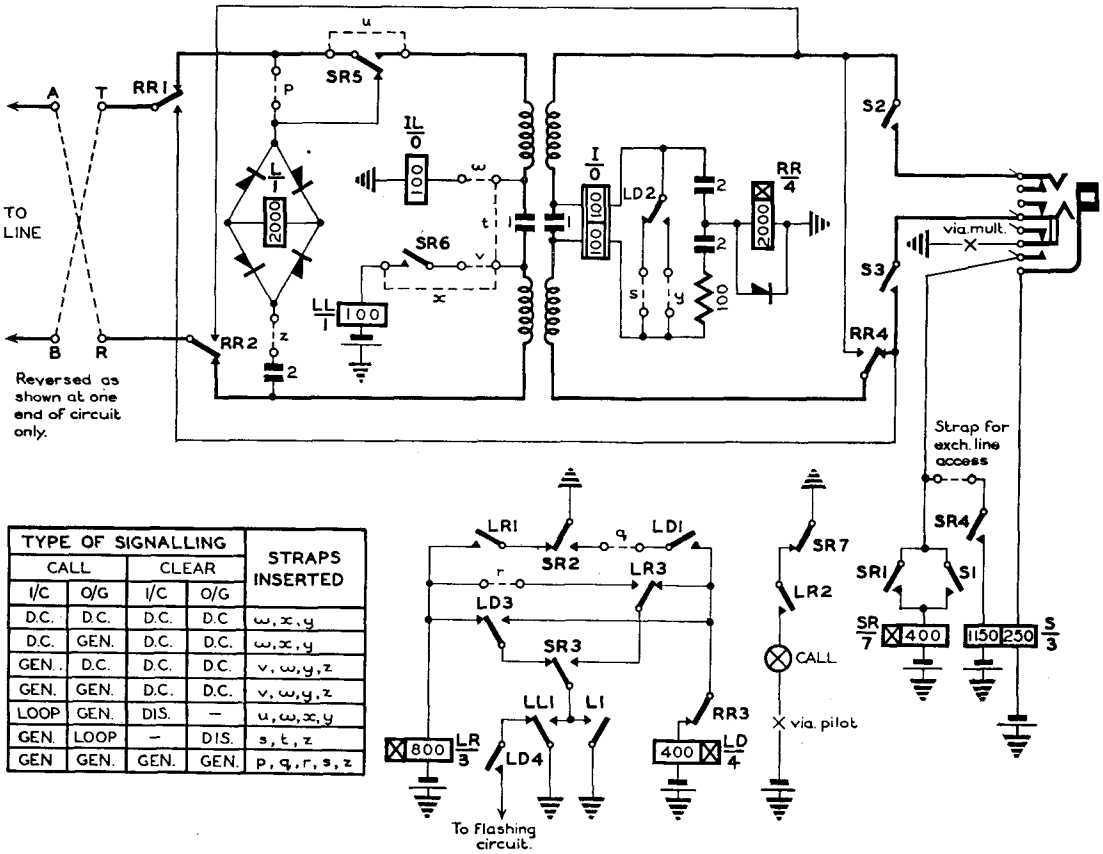


FIG. 332. D.C. SIGNALLING P.W. CIRCUIT

Note 1. Strap *X* is inserted when access to exchange line is permitted.
Note 2. Strap *Y* is inserted for loop calling.
Note 3. Strap *Z* is inserted for generator signalling on outgoing calls.



TYPE OF SIGNALLING				STRAPS INSERTED
CALL		CLEAR		
I/C	O/G	I/C	O/G	
D.C.	D.C.	D.C.	D.C.	ω, x, y
D.C.	GEN.	D.C.	D.C.	ω, x, y
GEN.	D.C.	D.C.	D.C.	v, ω, y, z
GEN.	GEN.	D.C.	D.C.	v, ω, y, z
LOOP	GEN.	DIS.	—	u, ω, x, y
GEN.	LOOP	—	DIS.	s, t, z
GEN	GEN.	GEN.	GEN.	p, q, r, s, z

FIG. 333. UNIVERSAL PRIVATE-WIRE RELAY SET
(P.M.B.X. 1A)

signalling in an outgoing direction. The operation of the ringing key in the cord circuit operates relay *RR* which at ***RR1*** and ***RR2*** shunts the 2 μF transmission condenser to reduce the impedance to the outgoing ringing current. ***RR1*** and ***RR2*** also remove *IL* and *LL* from the line to prevent chattering of the latter. On incoming calls the release of *LL* in turn releases *LR* which at *LR*2 prevents the operation of *I* to ringing current. Contact *I*1 is provided to prevent the transmission loss of the shunt path through *RR* during speech.

Universal P.W. Relay Set. The universal private wire relay set (Fig. 333) is a more elaborate circuit employing two additional relays and a transformer type transmission bridge. It is therefore more suitable for use on very long private wires where it is necessary to maintain an accurate balance of the lines. The circuit principles are very similar to those of Fig. 332, but a number of strapping arrangements are provided to meet the various signalling requirements.

The line relay (*LL* of Figs. 332 and 333) requires a minimum signalling current of some 14 mA for satisfactory operation, and hence with a battery voltage of 20 at the P.B.X., loop signalling can be adopted when the line resistance (including that of the distant apparatus) does not exceed 1250 Ω loop. When the line resistance exceeds this figure, single wire d.c. signalling can be adopted up to a line limit of 2500 Ω. Beyond this value generator signalling must be employed. The tabulation (Fig. 333) shows the strapping arrangements for various forms of calling and clearing signals. Relay *LR* is the calling relief relay and is controlled either by *L* or *LL* depending upon the type of calling signal. ***LR2*** lights the calling lamp until *SR* operates, when a plug is inserted into the answering jack. *LD* is the supervisory relay and controls (at *LD*2) the supervisory loop to the cord circuit under the control of one or other of the line relays. With d.c. signalling, for example, relay *LL* is operated for the duration of the call and *LD* is held from the earth at *LL*1 via ***SR3*** and ***LR3***. *LL* releases when the distant switchboard clears, and at *LL*1 releases *LD*. ***LD2*** now removes the loop to the cord circuit formed via strap *y*.

When the circuit is strapped for generator signalling, the clearing signal momentarily operates relay *L* which, in turn, operates *LD* via ***SR3*** and LR3. ***LD2*** now removes the loop to the cord circuit formed by strap *s* until *SR*2 releases *LD* when the plug is withdrawn. The circuit makes provision for a flashing recall or clearing signal when required. The operation of ***LD4*** starts a common flashing circuit consisting of three interacting relays. A contact of one of the relays alternately makes and breaks the connexion at strap *y* to repeat the flashing signal to the cord circuit.

Miscellaneous Features. The metal rectifier has been introduced across the night alarm relay (*NA*) to prevent overhearing between extensions prior to the operator answering. The *NA* relay is a common impedance to all calling circuits, and, in the absence of the individual impedance of the line relay, overhearing is possible. Fig 329 shows an impedance coil *I* in the operator's telephone circuit. This coil is placed across the circuit when the speak key is thrown but when relays *SK* and *SKR* are released. This condition exists when the operator enters an established call for monitoring purposes. *I* provides a d.c. loop in these circumstances in order to give a supervisory signal at the public exchange when the operator enters the circuit. The cord test circuit provides not only noise tests on the cord but also gives a functional test to the sleeve and supervisory relays and the supervisory lamps. The P.M.B.X. No. 1A is designed for a local 24 V secondary cell power plant, and provision is made for a ringing lead with a change-over key to the hand generator.

The Keysender. The keysender (Keysender No. 5) is a device introduced as an alternative to the dial on large type private branch exchange switchboards to reduce the time expended by a P.B.X. operator when dialling numbers from the switchboard. By its use, the P.B.X. operator is free to attend to other calls whilst the keysender is still transmitting the digits which have been keyed up. The device is particularly useful in areas such as London where seven digits are required to set up a call.

The keysender (Fig. 334) is a box unit having ten keys of the typewriter pattern which are labelled to correspond with the finger holes of the standard dial. The cover is fitted with a window, through which a disc with lines on its outer edge can be seen. This disc revolves with the pulsing out mechanism and thus serves as a visual indication that the keysender is engaged. Fig. 335 gives a general view of the keysender with the cover removed whilst Figs. 336 to 339 show details of the mechanism. The ten digit keys are pivoted at their rear extremity, and when operated move a storage pawl (*P*1) through an angle which corresponds to the number of the digit. The mechanism is so arranged that the movement of all digit keys is the same, but the different angular movements of the pawl are controlled by a tapered rocker bar (*RP*1). The storage pawl turns a ratchet wheel (*RW*) which rotates about the main shaft. At the end of the movement, a cam (*SC*) attached to the lever

assembly moves a striker plate (*HC*) which engages a marking arm (*MA*) attached to the ratchet wheel assembly. Alongside the ratchet wheel is a fixed ring (*CSR*) carrying 100 steel pins which are held friction tight in holes in the flange of the storage ring by means of a coiled spring. Normally these pins protrude on the marking arm side of the storage ring. When a digit key is depressed, the pawl moves the ratchet wheel round a predetermined distance and the striker plate causes the marking arm to engage a particular steel pin in the storage ring. It is necessary to allow for an interdigital pause and therefore if, say, key 5 is depressed, a pin is pushed forward $5 + 6 = 11$ pin spaces from the preceding projecting pin. It is possible to store seven consecutive digits by operating various pins along the circumference of the storage ring.

Impulses are sent out by the interruption of impulse springs (*IS*) caused by the rotation of an

FIG. 334. KEYSENDER
(No. 5.)

impulse wheel (*IW*). The impulse wheel rotates about its own axis and in addition rotates about the main shaft, both movements being imparted by means of a star wheel (*SW*) which engages with an internal gear (*IG*) on the storage ring. The storage and sending halves of the mechanism are coupled together by means of a helical clock spring (*S*) which is wound up by the movement of the ratchet wheel during keying. During the rotation of the sending part of the mechanism, a cam (*TI*) associated with the impulse springs brushes over the face of the storage ring bearing against each

FIG. 335. KEYSENDER WITH COVER REMOVED

projecting pin in turn. Whilst the cam is bearing against a projecting pin the impulse springs are held clear of the impulse wheel. Between marking pins, the cam allows the impulse springs to engage the impulse wheel and the number of impulses thus sent out is determined by the distance between the projecting pins. A tail piece (*T*2) associated with the sending mechanism restores the code pins after the impulsing cam has passed them. On completion of impulsing or when the impulsing cam catches up with the code setting a stop pin (*DP*) fixed to the impulse mechanism engages with a restraining pawl (*P*2) which prevents further rotation when the impulse control cam commences to engage with the last operated code pin. In consequence, the last pin operated is not restored, and thus the mechanism ensures that a train of impulses always starts with a make interval. The impulse wheel, impulse springs, and the governor mechanism (*G*) are similar to those used in the standard dial. The impulse springs are wired to collector rings (*CR*), and connexion is made to the

terminals of the machine by means of phosphor-bronze brushes (*CB*). The mechanism of the key-sender is non-homing, i.e. movement of both the storage ratchet wheel and of the impulse sending unit commences from the point where it finished

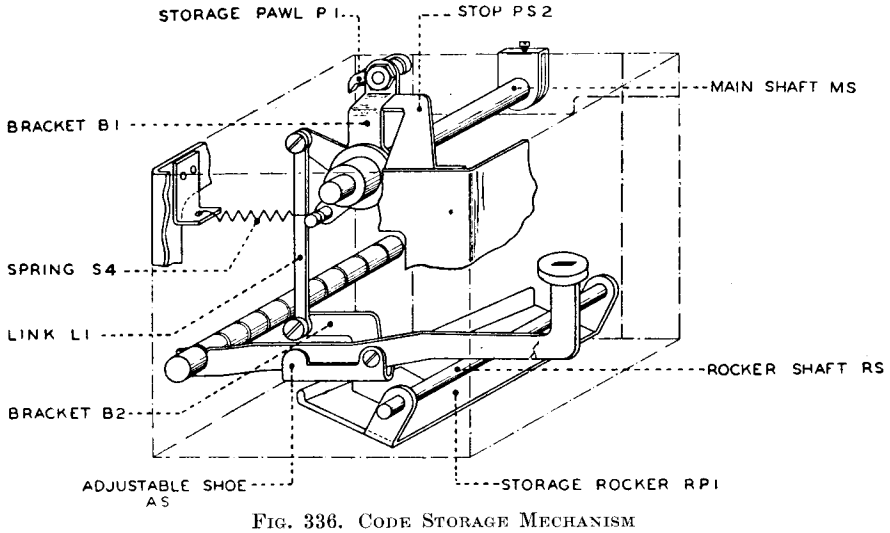


FIG. 336. CODE STORAGE MECHANISM

on the last call. The design of off-normal contact springs is therefore unusual. A plate with an internal ratchet (*IR*) is mounted concentric with the code storage ring and is free to turn through a small angle. The pressure of a stop pin (*DP*) associated with the sending mechanism against a restraining pawl turns the internal ratchet in an anti-clockwise direction, thereby holding the off-normal springs open. When a code pin has been struck the restraining pawl jumps forward, the pressure on the internal ratchet is relieved, and the off-normal springs push the internal ratchet in a clockwise direction and so close. On the completion of impulsing the pressure of the stop pin on the restraining pawl brings the impulse mechanism to rest and opens the off-normal springs.

The keysender is fitted on a small bracket

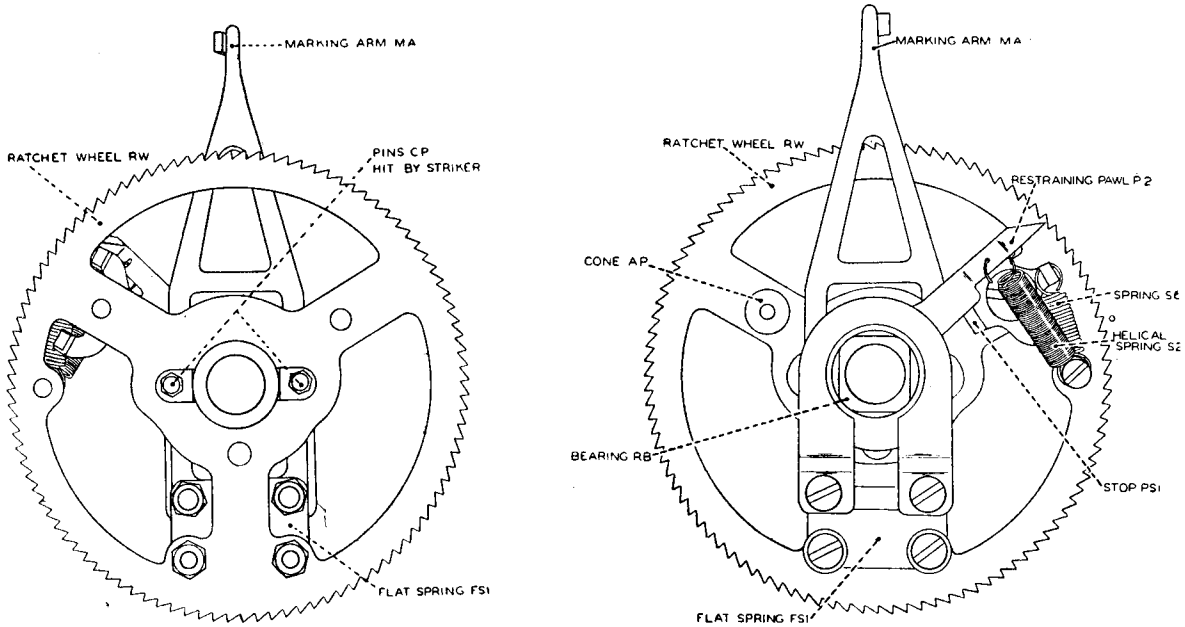


FIG. 337. RATCHET WHEEL

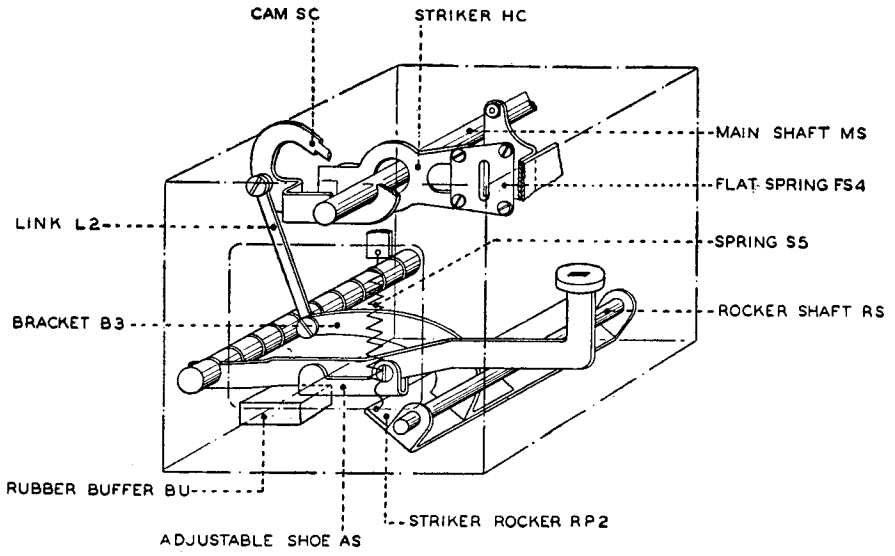


FIG. 338. STRIKER MECHANISM

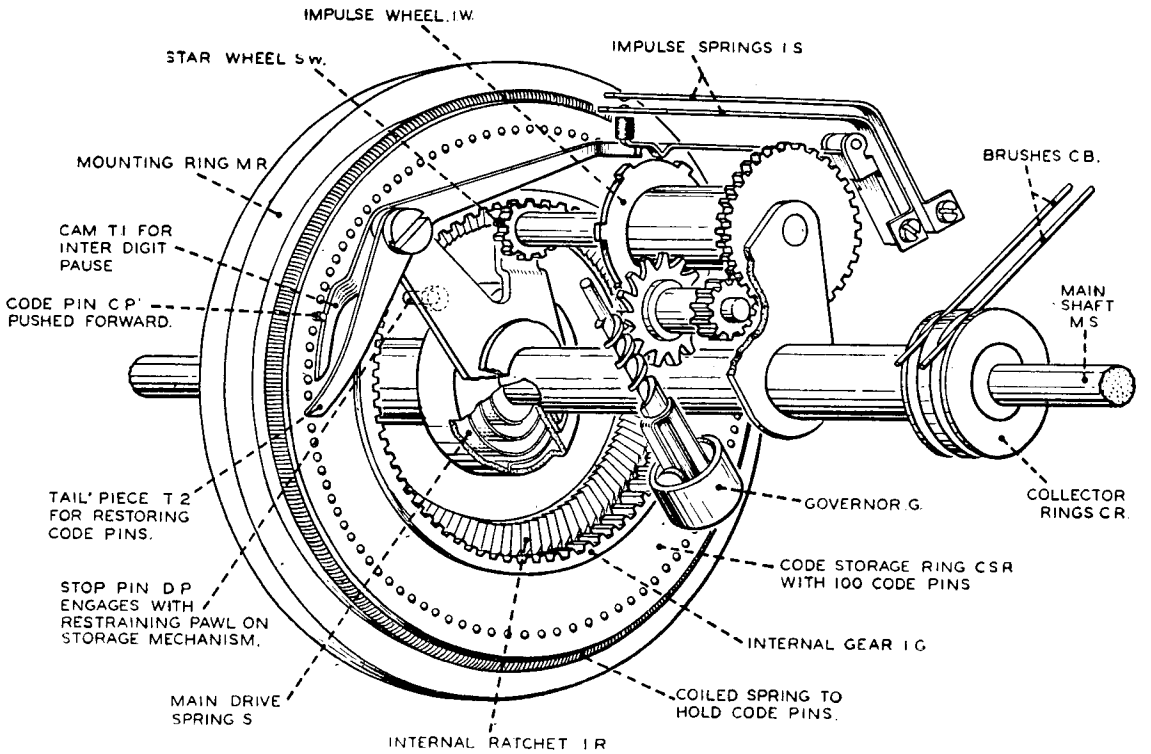


FIG. 339. CODE STORAGE AND IMPULSE SENDING MECHANISM

attached to the right-hand side of the switchboard. Whenever a keysender is fitted, an emergency dial is held in reserve at the P.B.X. In the event of failure of the keysender the dial is plugged into the switchboard. The circuit arrangements are as shown in Fig. 340. Additional contacts are provided on the cord circuit dialling keys and a relay

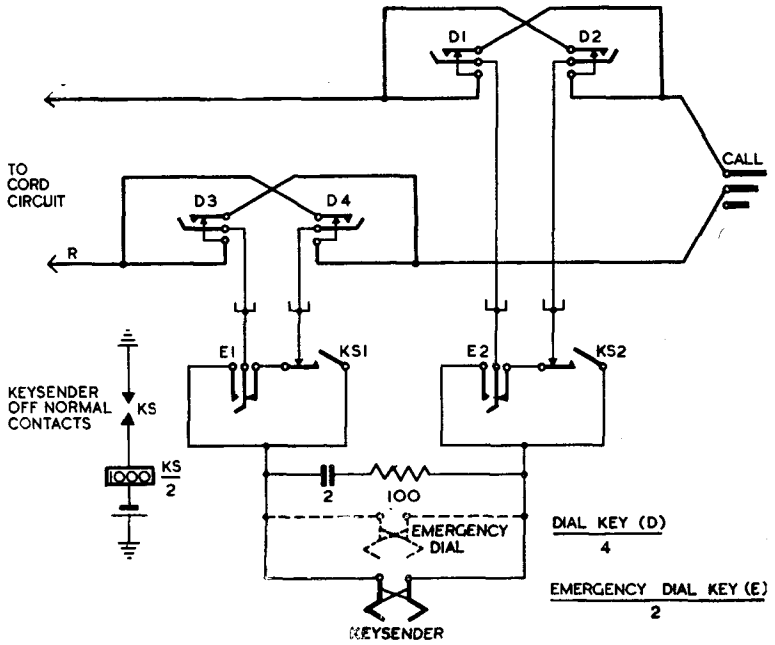


FIG. 340. CONNEXION OF KEYSENDER TO CORD CIRCUIT

is introduced into the keysender circuit so that at the completion of pulsing out, the cord circuit is restored to normal without the necessity of immediately restoring the dial key. An emergency dial key is provided to change over from the keysender to the emergency dial when necessary.

The House Exchange System. The House Exchange system combines the facilities of the earlier house telephone system with direct access from the stations to the public exchange. It was introduced several years ago to meet the requirements of subscribers who would otherwise be faced with the installation of a private intercommunication system to cater for a large internal traffic together with a public service telephone or private branch exchange. The following facilities are standardized for the system:

(1) The same instrument is used irrespective of the type of public exchange. This instrument is designed on C.B. principles and, where a house exchange system is required in conjunction with a magneto or C.B.S. public exchange, special conversion units are fitted at the public exchange.

(2) There are two arrangements of equipment to cater for:

(*a*) One exchange line and a maximum of six extensions (including one external extension).

(*b*) Two exchange lines with eleven extensions (including one external extension).

Both instruments have the same general appearance but the number of press buttons differs.

(3) Any instrument of the system may be used as the master station. An auxiliary unit is fitted at the master station, which provides calling indicators for the exchange lines and for an external extension (when fitted).

(4) In order to cater for times when the master station is unattended, a second choice master station may be provided by the fitting of a similar auxiliary unit at the selected second choice station. A transfer key fitted on the first choice main station switches the exchange and extension calling signals to the second choice station.

(5) Exchange calls are secret and cannot be overheard by any of the extensions on the system. By suitable strapping, however, supervision on exchange lines may be given to any selected station.

(6) An engaged test is provided on "busy" exchange lines.

(7) An exchange line may be held whilst a second call is made on another exchange line or on an internal extension.

(8) Exchange calls (which are normally answered at the main station) may be transferred direct from one station to another. This facility is also available for originated exchange calls.

(9) The master station is provided with trunk offering facilities where the required extension is speaking on a local call.

(10) Exchange calls may be entirely barred to any specified station, or alternatively exchange calls may be allowed only at the discretion of the master station.

(11) The system provides for direct calling and clearing from any station to the exchange.

(12) Local calls are non-secret.

(13) Conference facilities are provided so that any number of stations may be connected together.

(14) Apart from the night service facilities provided by the second choice main station, the

external extension may be allowed direct access to the exchange line under night service conditions.

(15) The equipment provides for the provision of extension bells from any instrument.

Apparatus. The house exchange instrument (*Telephone Intercommunication No.* 2) is illustrated in Fig. 341. The design follows similar lines to that of the standard one-piece instrument described in Chapter IX, but has in addition the required press buttons for establishing local calls. The instrument illustrated has two exchange line buttons, ten extension buttons, a conference button and a small trigger key associated with each exchange line. The instrument provided on smaller installations employs the same standard casework but only one row of keys (i.e. one exchange, five extension, and one conference). Figs. 342 and 343 show the internal arrangements of the telephone from which it will be noted that the lay-out has been designed to give the maximum accessibility to all parts for maintenance purposes. The complete button mechanism may be removed as a unit leaving in situ the spring banks and cabling. Each spring bank is removable as a unit and the relays (which are of the 600-type) are mounted on separate brackets so that they can readily be swung clear of the mechanism for adjustment purposes. The calling buzzer is dissociated from the telephone and is incoprorated in the external connecting block in order to facilitate adjustment without interference with the instrument proper. A further feature is that the connecting block is made in the form of a plug and jack so that the complete instrument may be removed at will.

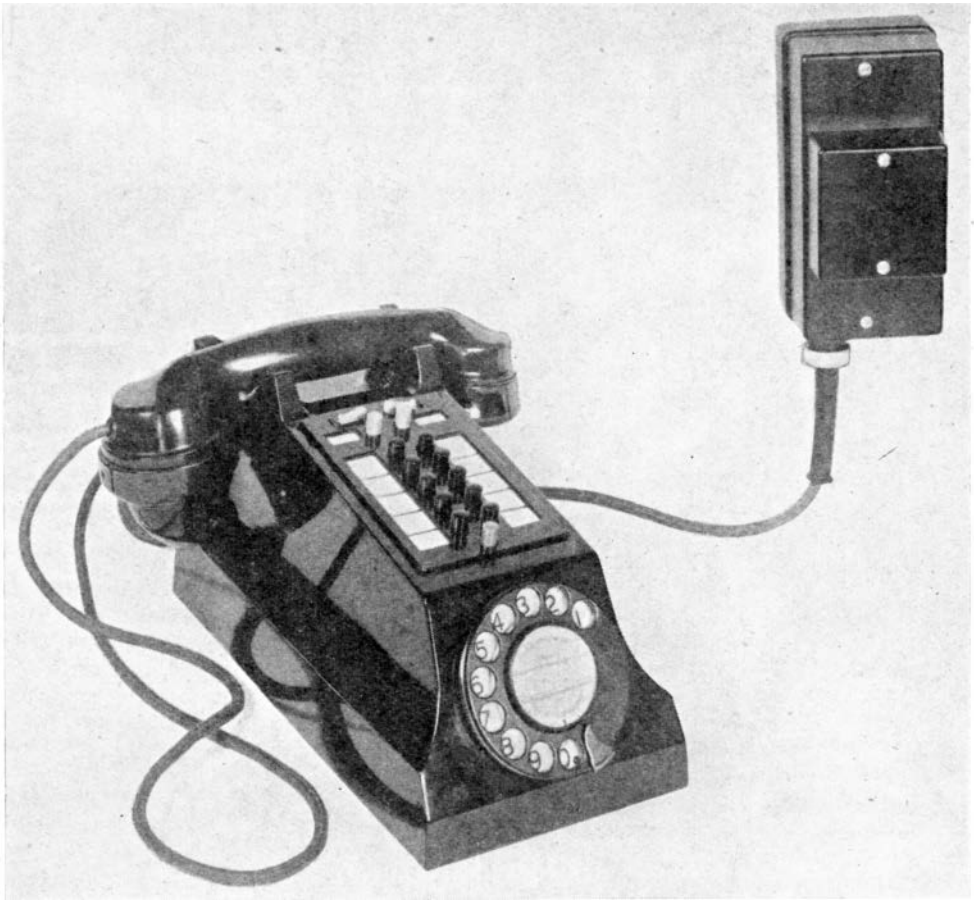


FIG. 341. HOUSE EXCHANGE INSTRUMENT
(Telephone intercom. No. 2.)

An auxiliary unit known as a *Unit Transfer Intercommunication* is required at the main station (i.e. that chosen to answer exchange calls). The unit accommodates the exchange line calling

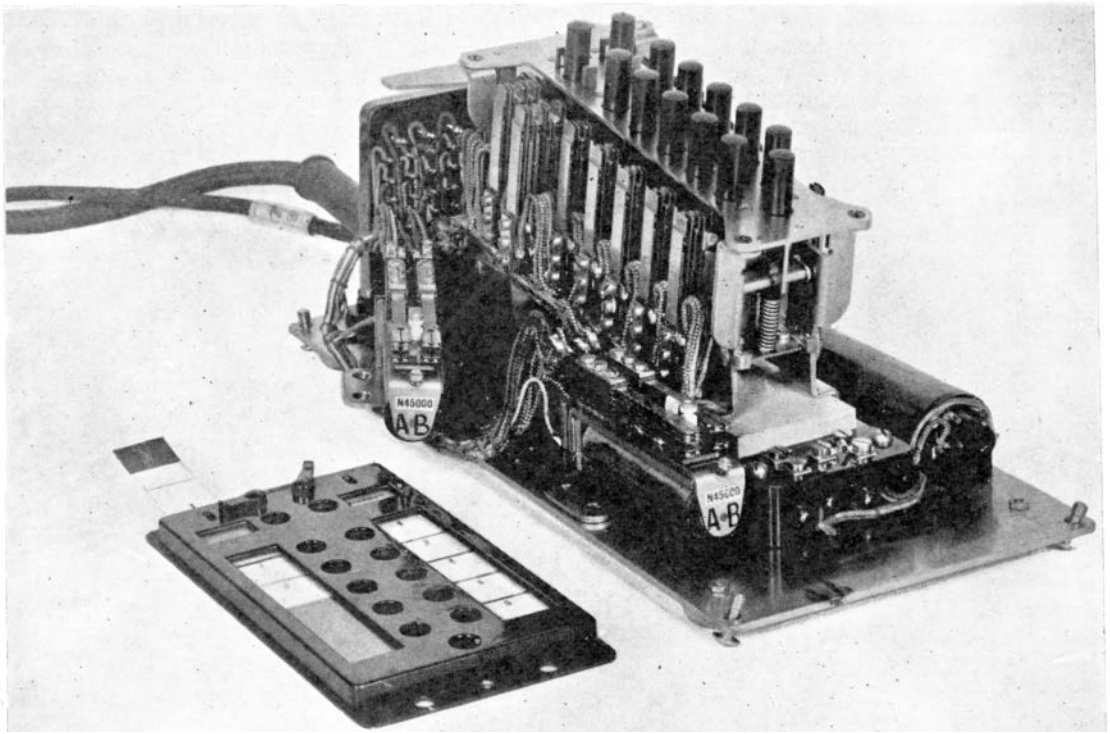


FIG. 342. HOUSE EXCHANGE INSTRUMENT
Chassis removed from case.

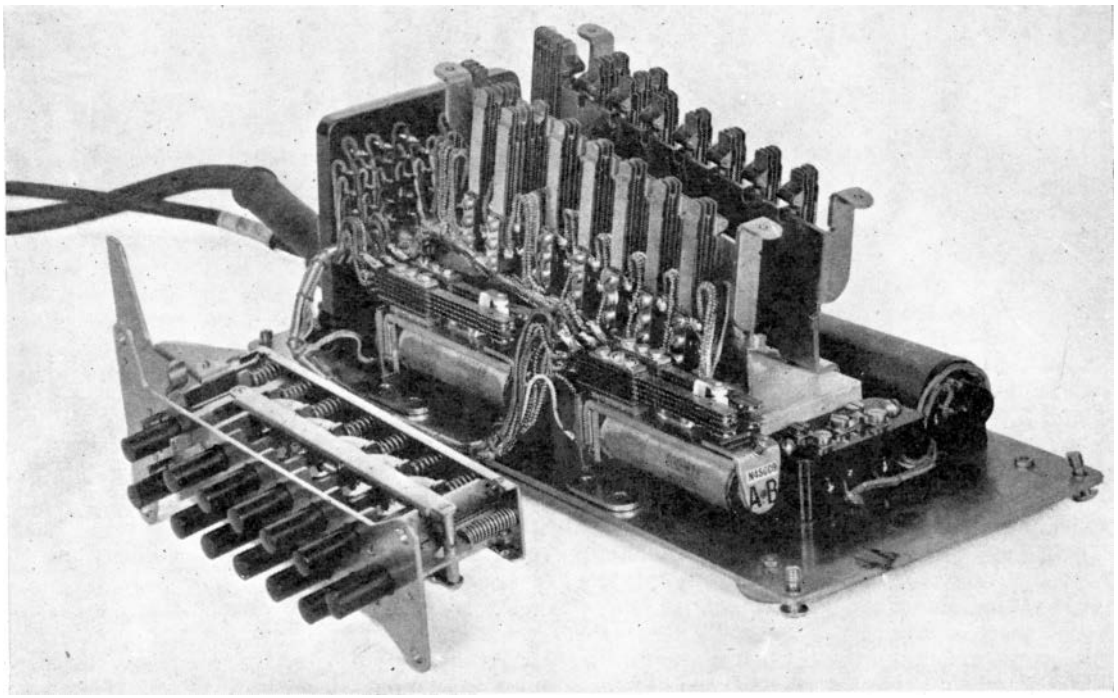


FIG. 343. HOUSE EXCHANGE INSTRUMENT
Chassis with press-buttons detached.

indicators, the external extension indicator and the associated keys. The facilities provided vary with different installations but all conditions are met by the use of one of four standard designs (Nos. 1, 1A, 2, and 3). All the four units are similar in appearance, but the number of calling indicators and keys varies. Fig. 344 illustrates Unit Transfer

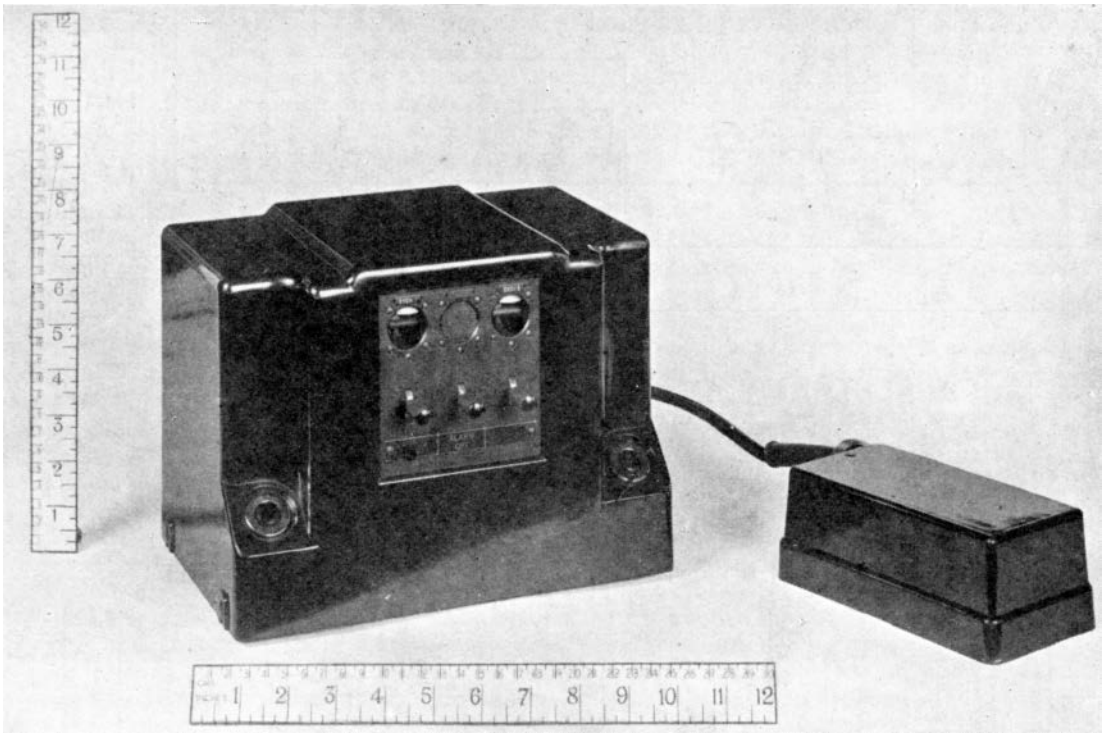


FIG. 344. TRANSFER UNIT
(Unit transfer intercom. 1A.)

Intercommunication No. 1A which accommodates eyeball indicators for one exchange line and one external extension together with a transfer key, the exchange to extension key, and the night service key.

Circuit Description—Internal Calls. Figs. 345 and 346 show complete circuits for a 1 + 5 type intercommunication telephone and for a Transfer Unit (No 1A) suitable for use at a main station where there is one exchange line and an external extension. Fig. 347 shows the circuit elements involved on local station to station calls with the exchange line switching details omitted for clarity.

To call any internal extension, the originating station removes the microtelephone thereby allowing the *HM* springs to operate, and then fully depresses the local key adjacent to the number of the required extension. Springs ***CB*** and ***L*** are thereby operated and an earth is extended from ***HM2*** via ***CB2*** to the *B*-line of the required extension. Contacts ***CB1*** extend the buzzer *BZ* to the common wire. If the called extension is free, the earth placed on the *B*-line is extended to the *R*-wire of the called extension circuit and thence via *HM1* to the buzzer. The called extension's buzzer is therefore actuated for the period during which the caller has the appropriate local button fully depressed. When the called extension answers by removing the handset from its rest, the ***HM*** springs operate and the telephone circuit is connected to the *HL* and *R* wires via ***HM1***, the buzzer circuit being disconnected at the latter contacts. When the caller's finger is removed from the local key, the latter partially restores to the speaking position. The *L* springs remain operated in this position, but the common bank spring set (*CB*) is released. A separate transmitter feed bridge is provided for each telephone by the application of earth at ***HM2*** via *RA* to the *A*-line and a battery through the remaining coil of *RA* via ***HM1*** to the *B*-line. If the called extension is engaged on a call to another extension, the earth on the *R*-wire incoming from the calling extension will not operate the buzzer at the called extension due to the disconnexion at ***HM1***. When the local key on the calling extension's

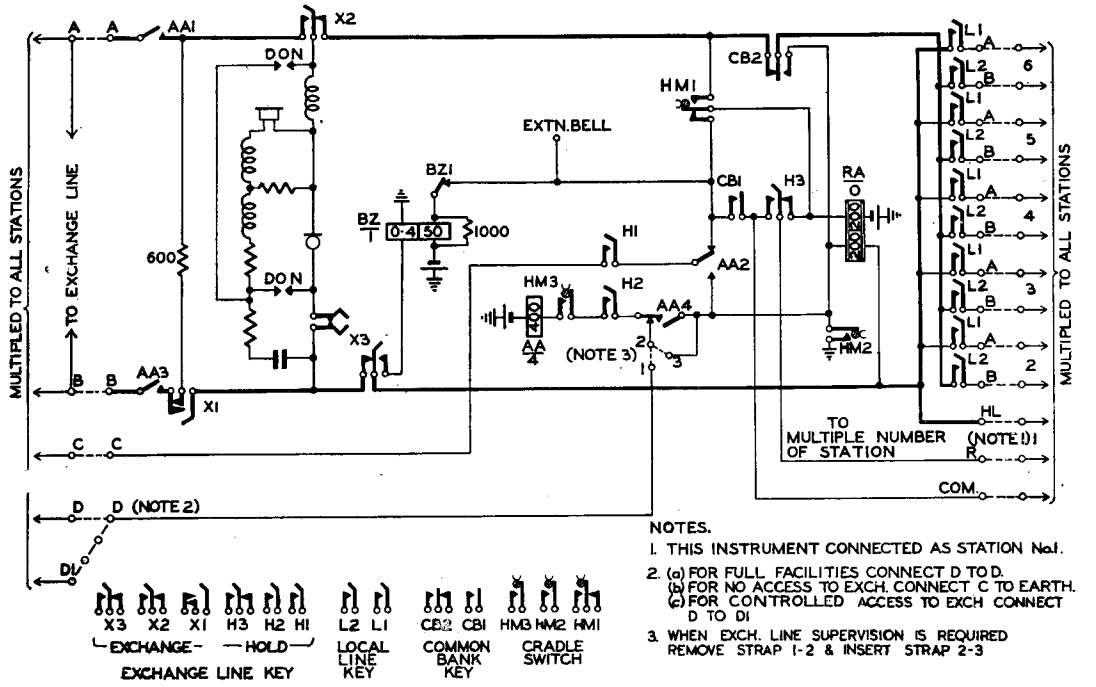


FIG. 345. CIRCUIT OF FIVE-STATION HOUSE EXCHANGE INSTRUMENT

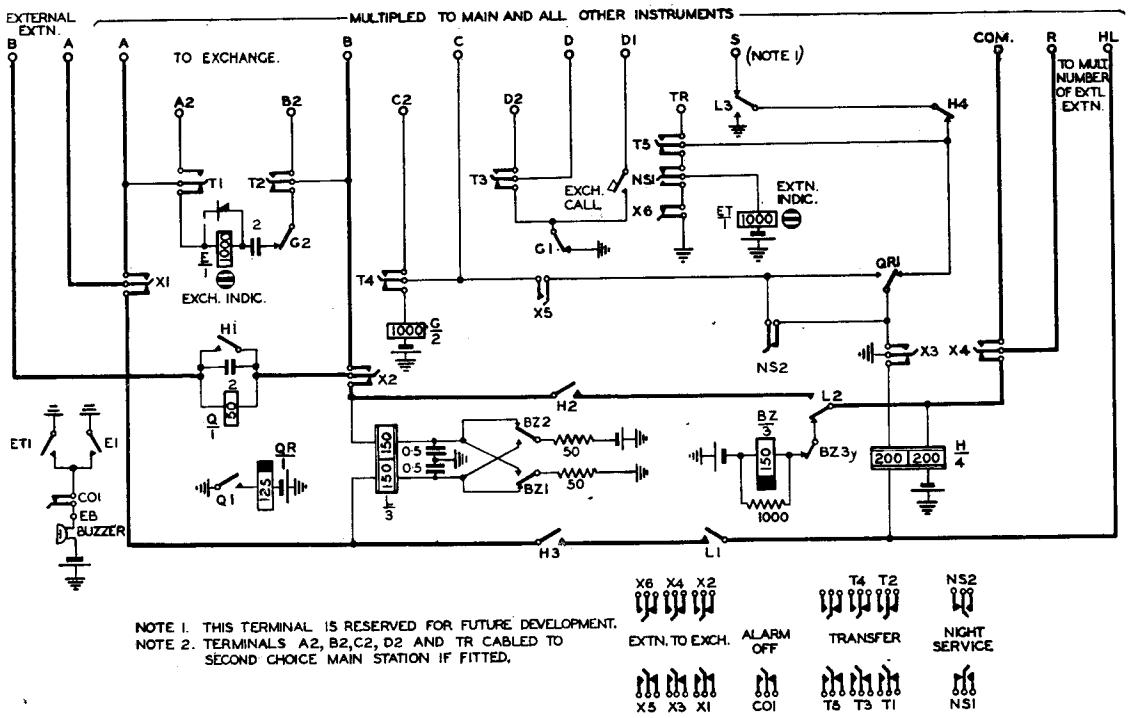


FIG. 346. CIRCUIT OF TRANSFER UNIT
(No. 1A.)

telephone set restores to the speaking position, however, the telephone circuit is connected to the *A*- and *B*-wires as described above. A caller is therefore able to break into any connexion between two other local extensions. If the called extension is engaged on an exchange call, the hold springs (*H*) on the appropriate exchange key will be operated and at ***H3*** the *R*-wire will be connected to the common (Fig. 348). When the caller fully depresses the appropriate local key the earth placed on the *R*-wire of the called extension is returned to the calling station on the common wire and operates the caller's own buzzer via ***CB1***. On the termination of a call all keys are restored mechanically to their normal position by the replacement of the microtelephone on the rest.

Internal Extension Calling External Extension. When the calling extension removes the microtelephone from its rest and fully depresses the appropriate local key an earth is extended to the *B*-line in the usual way. This earth is received on the *R*-wire of the external extension circuit and operates relays *H* and *BZ* in the Transfer Unit at the main station (Fig. 347). ***H2*** and ***H3*** extend the *R* and *HL* wires, and ***H4*** disconnects the external extension indicator in readiness for the operation of relay *L*. ***H1*** similarly shortcircuits relay *Q* which is not required on this call. If the external extension is free, relay *BZ* alternately operates and releases by breaking its own circuit at ***BZ3y***. ***BZ1*** and ***BZ2*** reverse the earth and battery connexions to relay *L* and thence to the external extension instrument. These reversals of potential across the bell of the extension instrument are the equivalent of normal alternating ringing current and energize the bell in the usual way. During the ringing period the 0·5 μF condensers act as a spark-quench to contacts *BZ*1 and *BZ*2. Relay *L* does not operate until the external extension answers and a d.c. loop is provided. If the calling party takes his finger from the external extension button before the external extension answers, *H* continues to hold from its own battery via the loop of the calling extension and the second coil of *H* to earth. Relay *BZ* is designed not to hold under these conditions, and therefore removes the ringing current from the external extension line. The operation of *L* when the external extension answers disconnects relay *BZ* and switches through to the calling line at ***L1*** and ***L2***. ***L3*** is ineffective due to the previous operation of ***H4***.

If the external extension is engaged on a local call the operation is similar except that relay *BZ* cannot operate due to the disconnexion of its circuit at ***L2***. If, however, an external extension is engaged on an exchange call spring *X*4 will be operated, thereby connecting the *R*-wire to the common (Fig. 348). Thus, when a caller fully depresses the local button his own buzzer will operate as described previously.

External Extension Calling Internal Extension. It is not possible on economic grounds to extend the main multiple of the internal stations to the external extension. There are therefore only two wires between the external extension instrument and the main station, and it is not possible to give the external extension the facility of direct access to all internal extensions. All such calls are obtained via the main station. When the external extension lifts his receiver from the rest relays *L* and *Q* operate from the battery and earth at *BZ*1 and *BZ*2 via the loop of the calling telephone. Relay *Q* (Fig. 346) has no function, but contact ***L3*** completes the circuit for the extension indicator and ***L1*** and ***L2*** prepare for the extension of the calling line to the main instrument. An audible alarm is provided from the local contacts of the extension indicator. The main station answers by removing the microtelephone and depressing the local key corresponding to the external extension number. The telephone loop of the main station is thereby connected to the *A* and *B* multiple wires of the external extension which are strapped to the *R* and *HL* wires of the Transfer Unit. The loop therefore operates relay *H*. ***H1*** short-circuits the *Q* relay, whilst ***H2***, and ***H3*** complete the circuit to the external extension. ***H4*** disconnects the external extension indicator circuit.

After ascertaining that an internal extension is required the main station calls the required extension in the usual way and the called extension upon answering is requested to call the external extension. The main station operator then replaces the microtelephone.

Conference Facilities. If a conference of several internal extensions is required, the main station calls each of the required extensions individually and each extension is advised to "hold on." When all required extensions have been called the conference button is pressed and each individual local station button is pressed for the second time. The mechanical arrangements are such that when the conference button has been pressed it is possible to press consecutive local buttons and leave them in the operated position until such time as the microtelephone is replaced on the rest. If a mass call were made instead of first calling the extensions individually, as soon as one station answered the buzzers at all the other called extensions would continue to operate until answered, even although the caller had removed pressure from the local keys. The earth from ***HM2*** of the first telephone to

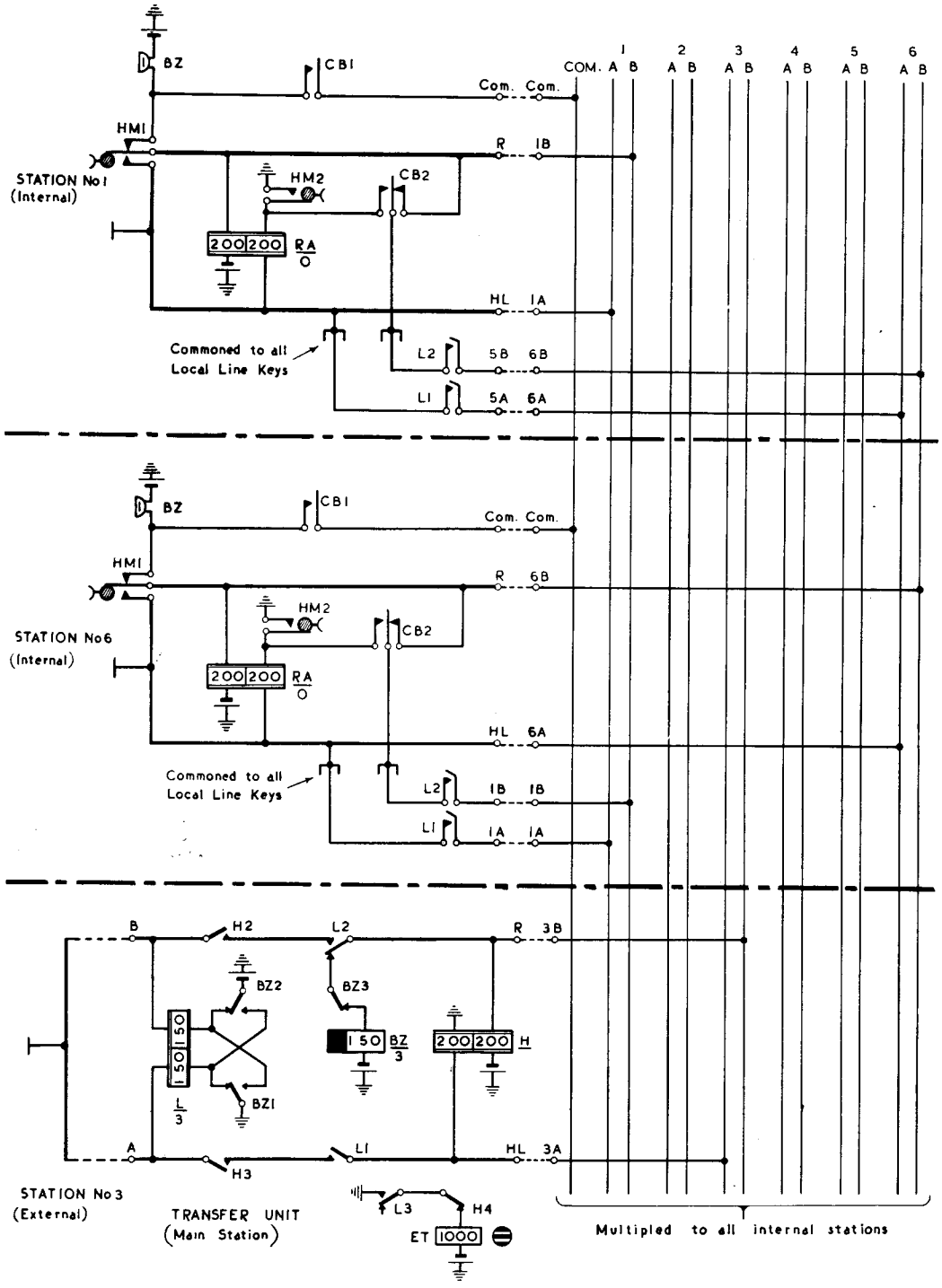


FIG. 347. CIRCUIT ELEMENTS FOR STATION-TO-STATION CALLS
House exchange system.

answer is extended via the coil of *RA* to the *B*-lines and buzzers in parallel. Continuous operation of the buzzer until an extension answers is undesirable, and in the operating instructions it is laid down that a mass call should be made only after it has been ascertained that a person is in attendance at all the called extensions.

Internal Extension Calling the Exchange. Fig. 348 illustrates the switching elements for exchange calls. It will be noted that, in addition to the *A*- and *B*-wires of the exchange line, three control wires (*C*, *D*, and *D*1) are multipled to all internal stations. To call the public exchange the internal extension station removes the microtelephone thereby operating the *HM* contacts. He then depresses the exchange key, thus operating the *X* and *H* springs. These spring piles are mechanically so arranged that the *X* units can be released by the depression of any other key on the telephone. The *H* springs, however, are not released when a second key is depressed but can only be restored either by the replacement of the hand microtelephone or the operation of the trigger key associated with the exchange line in question. Contacts ***H*3** disconnect the buzzer circuit from the *R*-wire and loop the latter to the common wire, thereby providing an engaged test to any callers. If the exchange line is free, relay *AA* operates via ***HM*3**, ***H*2**, and the *D*-wire of the multiple to the earth at *G*1 in the Transfer Unit. A locking circuit is provided for relay *AA* at ***AA*4**. ***AA*1** and ***AA*3** extend the telephone loop (via ***X*1** and ***X*2**) to the exchange line. ***AA*2** similarly extends the earth from ***HM*2** via ***H*1** to the *C*-wire of the multiple. This earth operates relay *G* in the Transfer Unit. *G* in turn removes the earth from the *D*-wire at ***G*1** in order to engage the exchange line to all other callers. ***G*2** removes the exchange indicator from across the speaking circuit. The call is set up in the usual manner and release is effected by the restoration of the *X* and *H* spring sets when the microtelephone is replaced.

If the exchange line is engaged, the absence of earth on the *D*-wire prevents the operation of relay *AA*, whilst the presence of an earth on the *C*-wire (from the ***HM*2** contacts of the engaging telephone) operates the local buzzer of any testing instrument via contacts ***H*1** and *AA*2.

External Extension Calling Exchange. To gain access to the exchange line the external extension must first call the main station. The main station, having ascertained that an exchange call is required, proceeds to test the exchange line by depressing the exchange line key on the main instrument. If the line is free, it is switched to the external extension by throwing the "extension to exchange" key on the auxiliary unit. Contacts ***X*3** and ***X*5** operate relay *G* and, at the same time, apply an engaging earth to the *C*-wire of the multiple. ***G*1** as usual prevents access to the exchange line by other parties. The main station now replaces the microtelephone and the external extension is extended to the exchange line at ***X*1** and ***X*2**, whilst relay *Q* operates in series with the loop. A slow-to-release relief relay *QR* is introduced so that contacts ***QR*1** do not respond to the dialled impulses during the setting up of a call. At the end of the call, through clearing from the external extension is provided by the release of *Q* and *QR*, whilst the restoration of *QR*1 operates the extension indicator as a clearing signal. The main station now restores the "extension to exchange" key.

Incoming Exchange Call. All incoming exchange calls are received at the main station. The exchange indicator (*E*) is of the doll's-eye type and is shunted by a metal rectifier to give continuous operation from the received alternating ringing current. Local contacts of the exchange indicators provide an audible alarm. The main station answers by removing his microtelephone and depressing the appropriate exchange key. If the call is to be extended to an internal extension, the main station depresses the local key corresponding to the number of the extension required. This operation mechanically restores the exchange line key to the hold position but the *H* springs remain operated. The exchange line is now held by the 600 Ω resistance. The called extension is requested to pick up the exchange line by depressing the appropriate exchange key at the extension station. Due to the fact that the exchange line is engaged the buzzer at the extension will operate as described previously, and tone is passed back to the main station from the 0·4 Ω coil of the extension buzzer via ***X*3**, the *A*-wire and the appropriate ***L*1** springs to the telephone circuit. On receipt of this tone the main station replaces the microtelephone on its rest, which restores all keys to normal and removes the busy conditions from the *C*- and *D*-wires. The *AA* relay at the extension station now operates to earth on the *D*-wire and so connects this extension to the calling exchange line. If the required extension is engaged on a local call, the main station can break into the connexion (there is no secrecy) and offer the exchange call to the extension concerned. If the call is destined for the external extension the main station calls the latter by depressing the appropriate local key, the exchange line being held meanwhile. The external extension is advised that an exchange call is waiting and the main station then throws the appropriate extension to exchange key.

An exchange call can be transferred from station

to station if desired in exactly the same way, with the one exception that an exchange call cannot be transferred direct from an internal extension to an external extension except via the main station. If it is desired to transfer a call from an external extension to an internal extension, the external extension flashes the main station and the latter carries out the transfer.

On installations with two exchange lines it sometimes happens that the main station is talking on one line and a call is received on the second line. The main station may temporarily abandon the

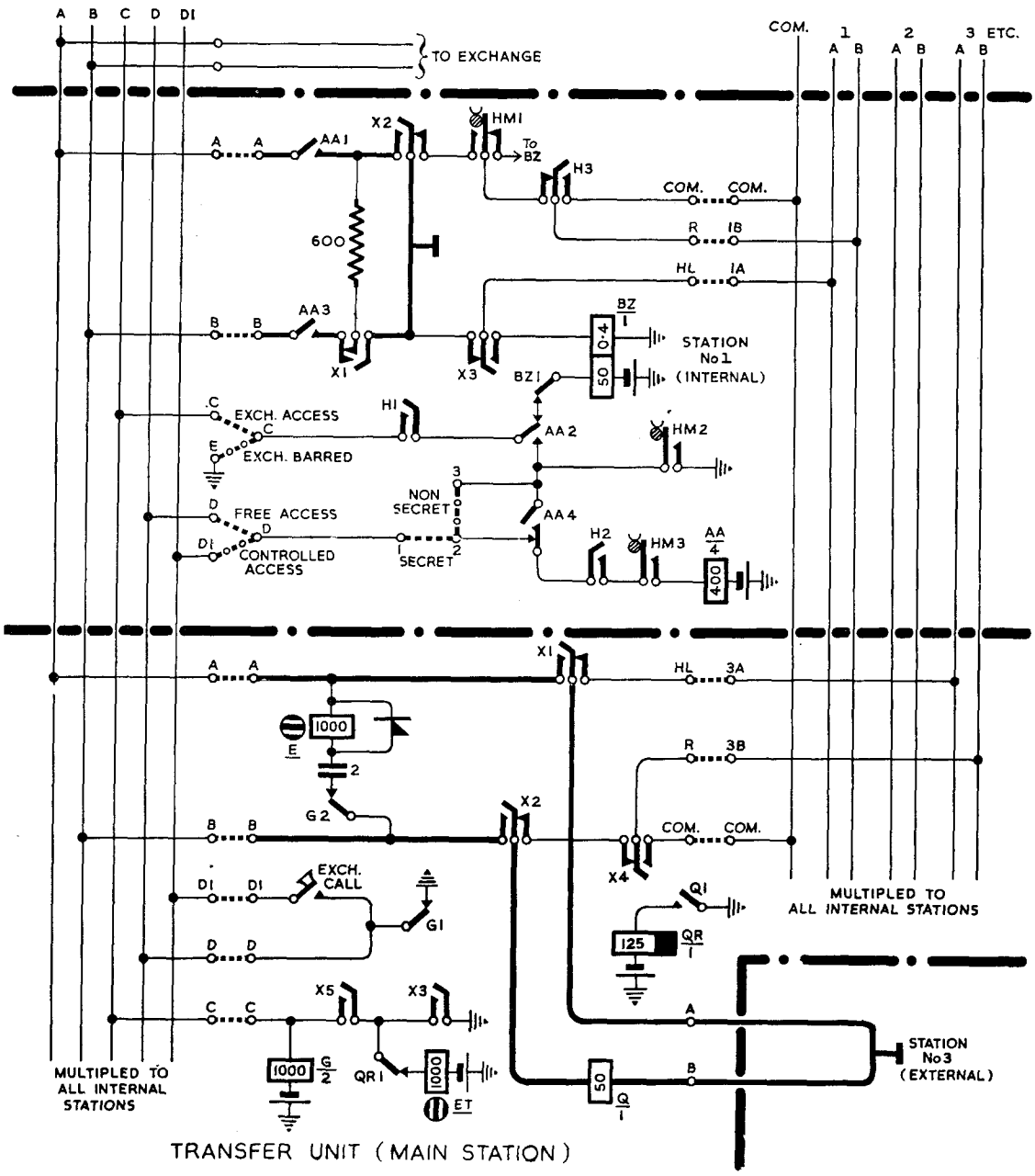


FIG. 348. CIRCUIT ELEMENTS FOR EXCHANGE LINE CALLS
House exchange system.

call on the first line and by depressing the second exchange key may accept the call on the second line. This second call can then be transferred to some other station. In these circumstances it is necessary for the main station to release his hold on the second exchange line but at the same time to maintain the holding condition on the first exchange connexion. To enable this to be done a special trigger key is provided so that by operating this key it is possible to release one exchange line without releasing the other.

Exchange Calls Barred. Any internal extension may be barred the facility of direct access to the exchange line (Fig. 348). This facility can readily be provided by disconnecting the *C*- and *D*-wires of the instrument from the multiple. The *C*-wire of the instrument is then earthed and the *D*-wire is left disconnected. The depression of the exchange line key will thus always encounter engaged condition. More often it is desirable to arrange that an extension shall not have unrestricted access to the exchange, but exchange calls may be allowed at the discretion of the main station operator. At these extensions the *D*-wires of the instruments are cross-connected at the junction box to the corresponding *D*1-wires and not to the *D*-wires as usual. The *D*1-wire is normally disconnected from earth, but by the operation of a press button labelled "Exchange Call" situated on the main station unit the *D*1-wire may be temporarily earthed and thus allow the *AA* relay to operate on the exchange barred extension. To make an outgoing call, therefore, the extension first calls the main station in the normal way. If an exchange call is to be allowed the main station operator tests and engages a free exchange line. The extension is then instructed to depress the appropriate exchange key and on receipt of buzzer tone from the extension, the main station operator holds down the appropriate Exchange Call button and at the same time replaces the main station microtelephone.

Monitoring Exchange Calls. Secrecy is normally given on exchange calls. Monitoring facilities may, however, be allowed at the main station or at any of the internal extensions. By removing the strap between terminals 1 and 2 in the *D*-wire circuit (Fig. 348) and inserting a strap between terminals 2 and 3 it is possible to provide monitoring facilities from that instrument. Under these conditions the lifting of the microtelephone and the operation of the exchange key provides an operate circuit for *AA* independent of the condition on the *D*-wire, and thereby enables the caller to break into an engaged exchange line.

Second Choice Main Station. By the operation of a key labelled "Transfer" at the first choice main station unit, the functions of that station may be transferred to the second choice main station. The spring units of the transfer key (***T1, T2, T3,*** and ***T4***) extend the *A*-, *B*-, C-, and *D*-wires to the second main station unit (Fig. 346). ***T5*** extends the extension indicator circuit in a similar manner. The second choice main station can then carry out

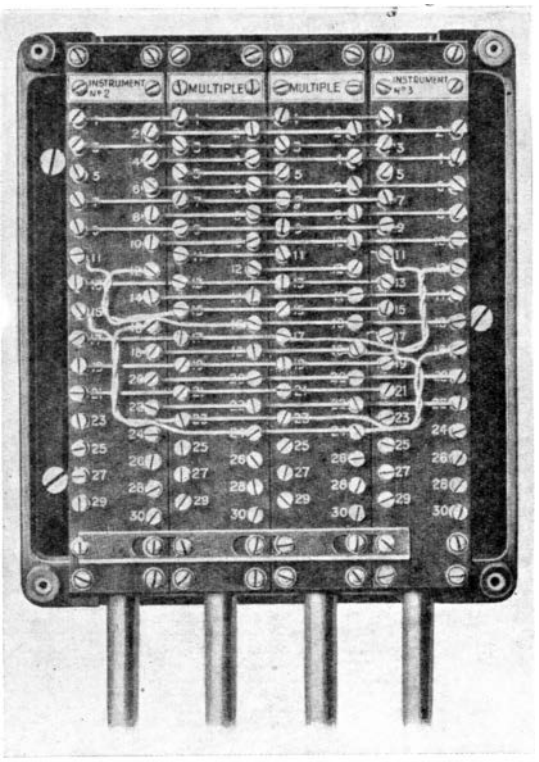


FIG. 349. HOUSE EXCHANGE JUNCTION BOX

the normal duties of the first choice main station. Arrangements are not provided, however, for the switching of the extension-to-exchange key leads and if the external extension requires a call it is necessary for the operator at the second choice main station to go to the first choice main station.

Night Service. The external extension station may be permanently switched to an exchange line at night by the operation of the extension-to-exchange key and the night service key on the main station unit. The operation of the former key gives the external extension direct access to the exchange and the night service key prevents the operation of the extension indicator and of the local audible alarm. The ***NS2*** contact prevents the *C*-wire of the multiple from being permanently earthed so that the exchange line will test free to an

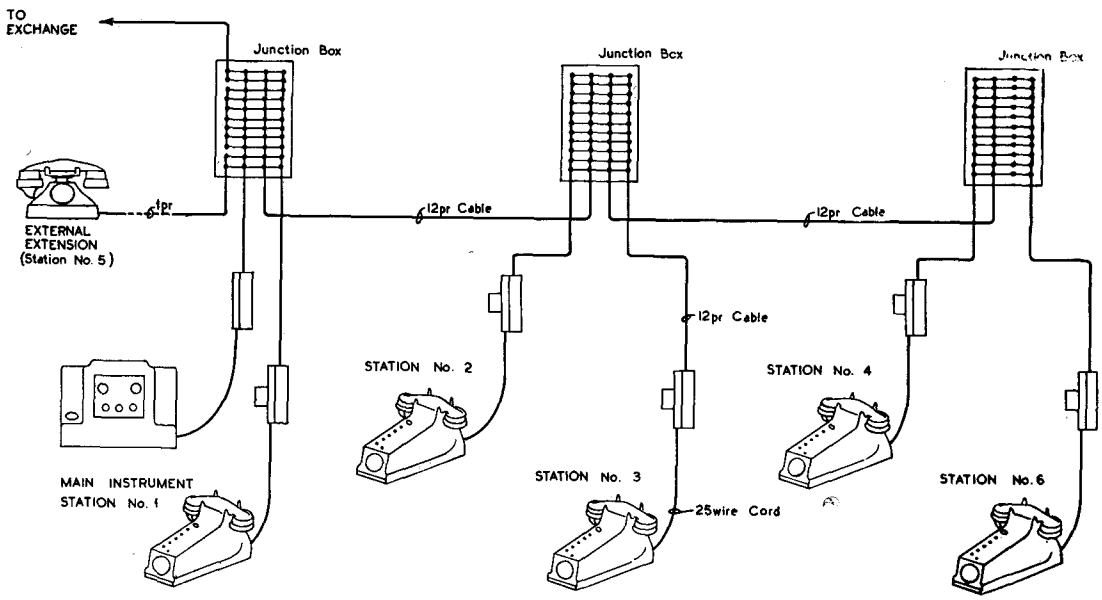


FIG. 350. TYPICAL CABLING ARRANGEMENTS OF HOUSE EXCHANGE SYSTEM

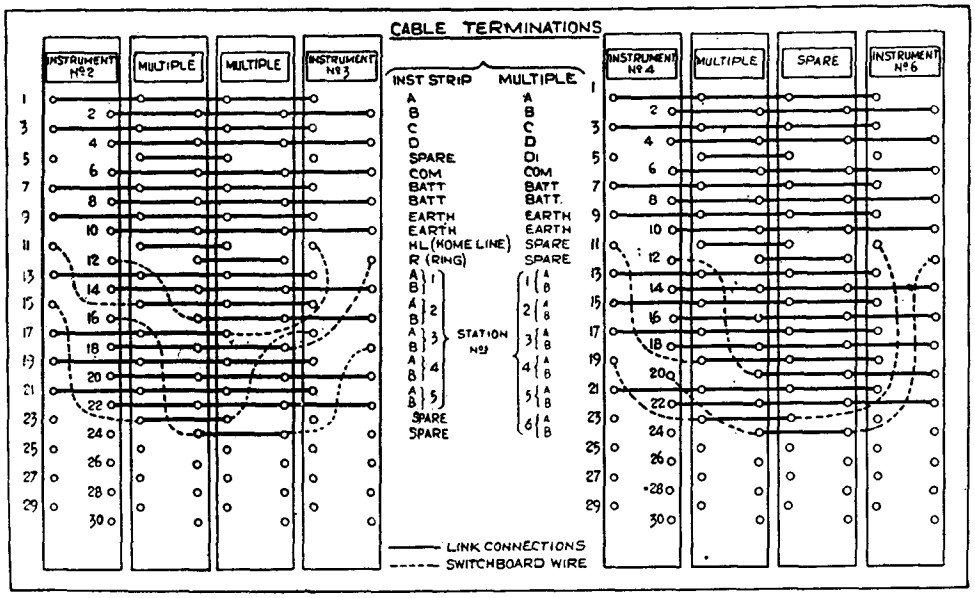


FIG. 351. HOUSE EXCHANGE SYSTEM

Cross-connexions at Junction Boxes for Stations 2, 3, 4, and 6.

internal extension when it is not in use by the external extension.

Cabling. In addition to the special plugs and jacks of the instruments themselves, junction boxes are provided for the termination of the multiple cables and on which the necessary cross-connexions can be made. These boxes are made up in two sizes, 30-way and 48-way, the former being used throughout the five-line system and also as an auxiliary box when required on the ten-line system which is normally served by the larger size.

The arrangements of a typical 30-way junction box are shown in Fig. 349. In this illustration separate strips are utilized for the incoming and outgoing multiple cables and two further strips are connected to instruments Nos. 2 and 3. It is a feature of the house exchange system that all cables are terminated on individual terminal strips, and the necessary commoning is done by means of square-section bare wire. When other cross-connexions are required they are carried out in switchboard wire.

Two sizes of cable have been standardized—a 12-pair cable for the five-line system and a 20-pair cable for the larger system. The conductors are of No. 23 S.W.G. and are tinned and enamelled, with an outer covering of two lappings of cotton laid on in opposite directions. Standard colours are utilized for the outer cotton lapping, and a helical lapping of white tape is laid over the outer layers of the conductors. The whole cable is waxed and lead sheathed. The use of twisted pairs throughout in a system of this kind is essential if crosstalk is to be avoided. A typical cabling lay-out for a six-station installation is shown in Fig. 350, whilst Fig. 351 shows, in more detail, the cross-connexions in two of the junction boxes. This lay-out may be considerably varied to suit the individual lay-out of stations. The cross-connecting of a 10 + 2 system follows the same principle as that of the five-line except that at the main station it may be necessary to have a 30-way auxiliary junction box in addition to the 48-way main box owing to the number of cables to be accommodated.

Power Supply. The power for a house exchange system is normally obtained over a power lead from the public exchange (Chapter XX), but where this is not practicable a battery of primary cells or a trickle-charged secondary cell installation may be employed. The system is designed to operate with a nominal 24 V, but the factor of safety is sufficient to permit its use on any voltage between 18 and 28 V. The maximum current consumption is approximately 1·3 A for a fully equipped 10 + 2 installation. A 10 μF condenser should be connected across the power lead in order to reduce to a minimum any crosstalk due to battery feed resistance.

EXERCISES XI

1. State the advantages and disadvantages of providing through clearing facilities at subscribers' private branch exchanges.

Describe, with the help of circuit diagrams, the way in which through clearing is provided:

(*a*) On cordless switchboards, and

(*b*) On double cord switchboards at private branch exchange installations.

(*C. & G. Telephony, Grade II*, 1940.)

2. Show by means of circuit diagrams what happens when the Night Service key of a 25-line P.M.B.X. is operated.

3. Explain why, on a 65-line P.M.B.X., a clearing signal is not given to the exchange whilst a call is being extended to an extension and before the extension replies.

4. Compare the supervisory signal arrangements of a 25-line and a 65-line P.M.B.X.

5. Describe, with the help of simplified diagrams, the stage by stage progress of an extension to exchange call on a P.M.B.X. No. 1A.

6. Explain what happens if, on a P.M.B.X. No. 1A, an exchange line is taken into use for an incoming call before the previous connexion has been taken down by the P.M.B.X. operator. Draw the circuit elements concerned.

7. Describe the main features of switchboard equipment suitable for a large private manual branch exchange at which multiple facilities are required. Give diagrams of the line and cord circuits. Assume that the exchange lines are connected to an automatic exchange. (*C. & G. Telephony, Grade I*, 1941.)

8. Give a diagram and explain the salient features of the terminal equipment at a P.M.B.X. No. 1A, on a d.c. signalling private wire.

9. Enumerate the facilities provided by the House Exchange System.

10. Explain with simple diagrams how an incoming exchange call is passed to an internal station of a House Exchange installation.

11. Give the circuit elements of a House Exchange system by means of which:

(*a*) A station can be given free access to the exchange line.

(*b*) A station can be barred access to the exchange line.

(*c*) A station can have access to an exchange line only after receiving the permission of the main station.

(*d*) A station can monitor any exchange call.