THE INSTITUTION OF
POST OFFICE ELECTRICAL ENGINEERS

Private Branch Exchange Installations.

Requirements Governing the Design of Automatic Equipment for, and their Practical Application.

BY

R. T. A. DENNISON.

A PAPER

Read before the London Centre of the Institution on the 8th March, 1932, and at the Manchester Centre on the 11th January, 1932.

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Synopsis.

P.B.X. INSTALLATIONS—REQUIREMENTS GOVERNING THE DESIGN OF AUTOMATIC EQUIPMENT FOR, AND THEIR PRACTICAL APPLICATION.

1. *Introductory*—definition of P.B.X.—utility of P.B.X.—three types of extension.

   P.B.X's—general facilities and requirements—standard of service.

   Keysending from P.B.X. to public auto exchanges—A.E. Co., G.E. Co. and G.P.O. types of keysender—advantages and disadvantages.

   Requirements governing the design of P.A.B.X. equipment—Two classes of P.A.B.X. maintained by G.P.O., *i.e.*, " rental and private purchase." Post Office requirements—general requirements.

   Other considerations affecting design—tieline, bothway junction, and through junction working. Testing and other facilities on automatic plant—location of plant at subscriber's premises—noise caused by plant—position of charging plant—power plant, ideal type fully automatic.

2. *Application of requirements in practice.*

   Systems approved by Post Office Administration.—A.E. Co. 30/30 system and 100/125 system—Siemens No. 16 equipment and Relay No. 1 and No. 2 systems—G.E.C's " G.P.O." system—Unit Auto No. 4 (S.T. & C.)—Messrs. Ericsson's " Type A " installations. Brief descriptions are given of the above.

   The practice of other Administrations.—Additional facilities such as conference, staff call, preference, etc.—small manual Board. S.T. & C. 7030 and 7020 systems—4200 D Rotary system—A.E. Co. 20/50 and " Mixed service " systems—G.E.C's auto-cord system—Messrs. Ericsson's " Type B " installations—S.T. & C. 30 and 100 line systems employing " Bypath " types of uniselector. Brief descriptions are given of the above.

3. *Standardisation of systems employed by the Post Office*—is it possible—points in favour of—suggested unit formation of equipment and advantages—standardisation of equipment.

P.B.X. INSTALLATIONS.

Requirements governing the design of Automatic Equipment for, and their Practical Application.

INTRODUCTORY.

The British Standards Institution has defined the term " P.B.X." as follows :—

" An exchange which is usually installed on the premises of a subscriber and which is connected to a public exchange."

A P.B.X. can function on a manual or automatic basis, the terms P.M.B.X. and P.A.B.X. being applied, respectively, to each type; and the object of this paper is to describe how automatic aids similar to those employed in public automatic exchanges are adapted to meet the peculiar needs of the P.B.X. with special reference to the practice of the Post Office Administration.

A private branch exchange constitutes a convenient and economical means of concentrating several office telephone lines at one point on the subscriber's premises for inter-office communication and extension to the public telephone system.

Office telephones so connected are termed " extensions " and can be one or more of the three types mentioned below :—

(1) Extensions which can obtain access to the public exchange and can also be connected with other extensions, and

(2) Extensions which can be inter-connected with others at the private branch exchange, but have no access to the public exchange.

(3) Special types of extension are sometimes provided having facilities for switching calls to other extensions which may or may not have inter-communication facilities, *e.g.*, Plan No. 9.

The private branch exchange in its complete form consists of a manual (or manual and automatic) switching point at which the extensions and exchange lines are terminated on switching and signalling equipment.

PRIVATE BRANCH EXCHANGES— GENERAL FACILITIES, REQUIREMENTS AND STANDARD OF SERVICE.

Facilities provided.

Owing to the growth in the use of P.B.X. installations, particularly by large business organisations, various facilities have been devised such as—

(*a*) Tie line and junction working between two or more P.B.X's.

(*b*) Access to private wires from all extensions and vice versa.

(*c*) Night service facilities.

Facility (*a*) is generally employed where a subscriber's business is split up into two or more groups; say, a Head Office situated in a town, and a Factory in an adjacent suburb and may provide bothway or unidirectional communication.

Facility (*b*) is provided where it is desired to connect private wires to the ordinary extensions at the Private Branch Exchange.

Facility (*c*) is provided where night operating staff are not on duty at the subscriber's premises and makes provision for incoming and outgoing telephonic traffic *via* the public exchange to be routed to or from certain extensions which are permanently connected with the exchange lines during periods when the operators are off duty.

Various subsidiary facilities are provided arising particularly out of the three outlined above, and will be dealt with later.

Standard of Service provided.

The P.M.B.X. or P.A.B.X. will require the services of an operator. The P.M.B.X. operator will, of course, control the extension to extension traffic and also the extension to exchange and exchange to extension traffic; but in the case of the P.A.B.X., the operator will control only a small percentage of the total traffic. The standard of service will, therefore, in either case be bound up with the efficiency of the operator, but where automatic switching plant is installed the standard of service will depend primarily upon the design of the automatic switching equipment and the quality of main-

tenance. The higher speed of operation as compared with P.M.B.X. operation will alone effect a great improvement in the standard of service.

With both manually and semi-automatically (P.A.B.X) operated systems the standard of service will be reduced during the night periods unless arrangements are made for the continuous attendance of an operator. In this respect the manual operating problem will be the same in manually or semi-automatically operated systems because, generally speaking, a P.B.X. system cannot be completely worked while the operator is off duty.

If the manual operator could be eliminated entirely and full automatic working substituted, as in the case of a public automatic exchange, then a full standard of service could be maintained throughout the whole 24 hours. Unfortunately this is not possible, however, because enquiries and incoming calls from the public exchange must, of necessity, be dealt with on a manual basis. There would be, of course, no great engineering difficulty in providing full automatic conditions at the P.A.B.X., but the general provision of such a service would devolve upon the public a full knowledge of the ramifications of every business organisation with which they deal and a knowledge of the extension telephone numbers allotted to the various departments. Difficulties would also arise in connection with the transfer of calls from one department to another and in answering enquiries. Attempts have been made to overcome these obstacles to full automatic working, and are briefly described later.

Given suitable automatic plant, therefore, the operator will be concerned only with the routing of incoming calls from the public exchange to the proper extension, answering enquiries and giving general assistance to extensions and other callers in setting up their connections.

Keysending to automatic Public Exchange.

At the present time the manual positions at P.B.X's in public automatic exchange areas are equipped with dials in order that connections may be set up *via* the public exchange. This method of setting up connections is slow, especially when seven digits have to be dialled; and the Post Office has recently experimented with various types of mechanical and electrical keysending devices suitable for use at P.B.X. manual boards.

The various types, however, suffer from some or all of the following defects:—

1. A call cannot be set up on the keysender until the previous call has been sent out by it.
2. The digit keys in some cases have to be depressed in a certain manner.
3. Complex mechanical or electrical equipment is necessary at the P.B.X. and requires highly skilled maintenance.
4. One equipment is required for each position, making provision expensive.
5. The space occupied is often considerable.

There are, under investigation, several types of keysender, designed especially for keysending from P.B.X. manual boards. Some of these are briefly described below:—

An Automatic Electric Co's type of keysender, which is a mechanical device driven by a small fractional horse power electric motor, mains operated. The motor is fitted at the top of the machine and is normally enclosed in a metal cover. This instrument forms part of a subscriber's telephone set. The digit keys are arranged, similar to those of a small typewriter, at the base of the instrument. A " cancel " key for cancelling a partial set-up and a " start " key for initiating the start sending condition are also provided.

A set of 8 rows of 10 stop pins are provided inside the instrument and for each digit key depressed a particular stop pin in a row is pushed through a plate so that it projects from the back of the plate above the level of the other pins. The 8 rows cater for an 8 digit set-up. The plate is moved one step by a ratchet and pawl during the release of a digit key and so brings another row of stop pins into alignment with the digit key operating levers. When all digits have been stored in this manner the " start ' key is depressed and causes the motor to rotate, the trains of impulses being sent out by means of a dial type of impulse mechanism. The " start " key is locked until sending has been completed.

Care must be taken in setting up digits as it is possible to depress more than one digit key at a time owing to their spacing assembly.

A General Electric Co's type of keysender is electrical in operation, and consequently the standard type of keyset

employed at public exchanges can be used. The digits are stored on five groups of storage relays, the circuit arrangements being such that sending commences on release of the first digit key to be depressed. The employment of switching relays allows 7 digits to be set up on five storage relay groups, the 6th and 7th digits being stored in the 1st and 2nd storage relay groups. The digit keys must necessarily be operated with due regard to this feature. If operated too quickly, non-storage of the last two digits may result.

Forty-eight relays are employed and the system is designed to operate on 40 volts obtained from the mains, if necessary.

The impulse trains are sent out by means of a pendulum relay designed to vibrate at a frequency of 11 impulses per second. This controls an impulse relay and the speed of setting up a connection is approximately that of an 11 i.p.s. dial.

A " cancel " key, a " dial " key and " engaged " lamp are fitted, the " dial " key being in the operated position while digits are keyed up. The engaged lamp glows until sending is completed.

One of the models developed by the G.P.O. is shown in Fig. 1, and employs a type of dial mechanism the spring of which is wound up as the digit keys are depressed.

When a digit key is depressed, a ratchet wheel is actuated and sets a lever opposite a pin which corresponds to the keyed digit. Upon release of the digit key, a pin is caused to be projected through a plate and the dial mechanism is allowed to rotate over the plate surface until an extension on the impulse spring assembly meets the displaced pin. Impulses corresponding to the digit dialled are sent out, therefore, during rotation of the dial mechanism. These operations occur at each depression and release of a digit key and consequently any number of digits may be sent, sending commencing as soon as a digit key is depressed and released.

Greater pressure is required to operate the digit keys than in other types of keysenders, as the action of the digit keys also winds up the dial mechanism spring. At present, no engaged signal or cancel facilities are provided.

The author considers that the device ultimately chosen by the Post Office for the purpose of keysending from P.B.X. manual boards should preferably be installed wholly at the

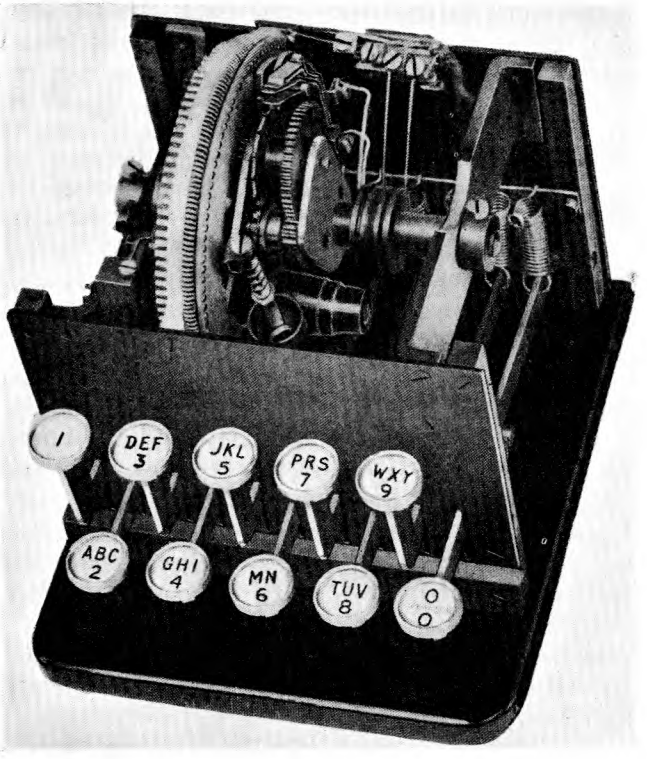


FIG. 1.

P.B.X., as it will be appreciated that if part of the equipment is installed at the public automatic exchange, *e.g.*, senders, then all extensions using the " direct access " facility and extensions used for night service would have to be fitted with keysending devices. This, of course, rules out the possibility at present of employing straightforward junction or voice-frequency keysending methods.

REQUIREMENTS GOVERNING THE DESIGN OF P.A.B.X. EQUIPMENT.

P.A.B.X. installations maintained by the Post Office may be divided into two main classes (*a*) those which subscribers may obtain from the Post Office on a rental basis and (*b*) approved systems which subscribers may obtain by

" private purchase " from Contractors approved by the Post Office.

P.A.B.X's of not more than 30 lines ultimate capacity fall into category (*a*) and those ultimately or initially having more than 30 lines capacity into category (*b*).

As a rule, subscribers are canvassed by the approved Contractors. This applies to both " rented " and " private purchase " P.A.B.X. installations.

The Post Office requirements.

The Post Office requirements aim at maintaining uniformity of practice as regards the facilities provided, and ensure satisfactory signalling and transmission conditions when P.A.B.X. extensions are connected with the public exchange network or to tie lines. The principal requirements are set out below :—

Calls to and from Public Exchange. Incoming calls from the public exchange should be dealt with by the P.A.B.X. operator, who should be in a position to complete such calls by plugging into a jack directly associated with the required extension. This action should engage the associated extension or exchange line multiple on the automatic equipment.

The provision of jacks individual to each extension line also allows the P.A.B.X. to be manually operated in the event of certain major faults occurring in the automatic equipment such as ringing machine failure, blown fuse, etc., which although of rare occurrence would be liable to cause considerable confusion. It is also possible to add manual extensions and the operator is able to " trunk offer " and connect incoming calls to extensions without having to dial, thus increasing operating speed.

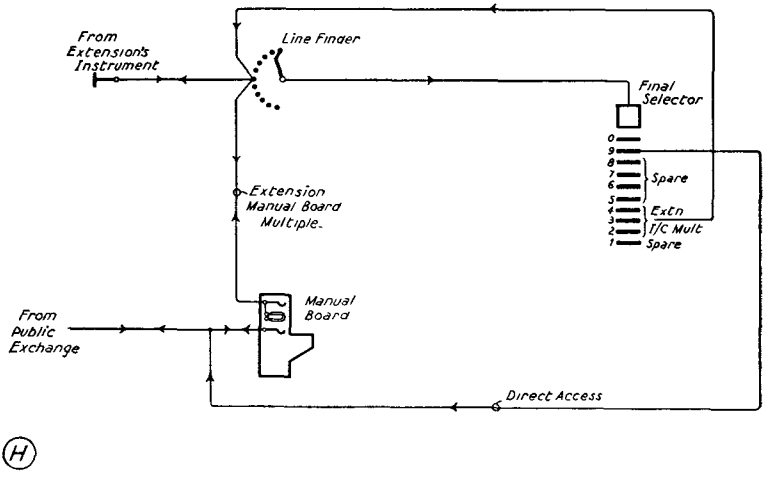
This condition implies that extension lines must be multipled to the automatic equipment and to the manual board as shown schematically in Fig. 2.

Outgoing calls from extensions to the Public Exchange may be dealt with in either one or both of the following ways :

(*a*) By dialling " 0 " and thus obtaining the services of the manual operator, or,

(*b*) By dialling " 9 " and thus obtaining a direct connection to the public exchange *via* the automatic

equipment. This facility is termed "direct access."



SCHEMATIC OF TYPICAL 30 LINE P.A.B.X.

FIG. 2.

Manual Control. Under method (*a*) the automatic equipment taken into service should be released when the lamp associated with the calling extension glows. In some of the earlier systems, however, the automatic equipment is not released until the operator inserts a plug into the extension manual board jack. Provision should be made for the calling extension to release the connection before the manual operator answers; and the insertion of the answering plug into the extension line jack should place the calling party under the control of the P.B.X. operator, thus preventing the connection from being released until the plug is withdrawn and allowing the extension to be recalled if necessary.

Direct Access. Under method (*b*) the type of public exchange to which the P.B.X. exchange lines are connected must be considered and it is specified that, when this is of the manual type, the connection shall not be released until both the extension caller has replaced the receiver and the operator at the public exchange has withdrawn the answering plug. The calling extension should, however, be in a position to release the connection before the public exchange operator

answers. When the public exchange is of the automatic type, the calling extension, being the calling party, should have control of the release of the whole of the connections set up *via* the P.A.B.X. and the public exchange equipment.

Trunk Offering. For the purposes of trunk offering the manual operator must be able to plug into the multiple jack of any engaged extension without breaking down the connection, if any exists, on the automatic equipment.

Manual Board Cord Circuits. Through signalling between extensions and the public exchange *via* the manual board cord circuits is required when the public exchange is of the automatic type, but when the public exchange is of a manual type the P.A.B.X. manual board operator will control the connection and obtain switch-hook supervision from the extension. It is therefore laid down by the Post Office that the P.A.B.X. manual board cord circuits should, if necessary, be easily convertible to through clearing when required. An audible as well as a visual clearing signal can be provided when specified. This condition is specified as a result of the general introduction of automatic telephony and, lately, trunk demand working; and consequently does not apply to all the existing P.A.B.X. installations. Systems have, however, recently been developed—notably the A.E. Co. 30/30 system—which meets this requirement.

The standard type of Post Office cord circuit is shown in Fig. 3. With this type of cord circuit an extension can " dial through " the public exchange equipment, thus saving operating time at the manual board. An extension can dial into the public exchange *via* this cord circuit only when " through clearing " is provided.

The cord circuit ringing keys should provide a ringer start circuit so that operation of the ringing key will also start up the ringing machine.

Auxiliary equipment for exchange line terminations at the P.A.B.X. The type of public exchange serving the P.A.B.X. will determine the type of auxiliary equipment it is necessary to fit at the P.A.B.X. as ordinary exchange line, and/or direct access service terminations; *e.g.*, if the public exchange is of the magneto type then equipment similar to that shown in Fig. 4 must be fitted at the P.B.X. in order to provide correct calling and clearing conditions. This equipment provides for generator calling and clearing conditions

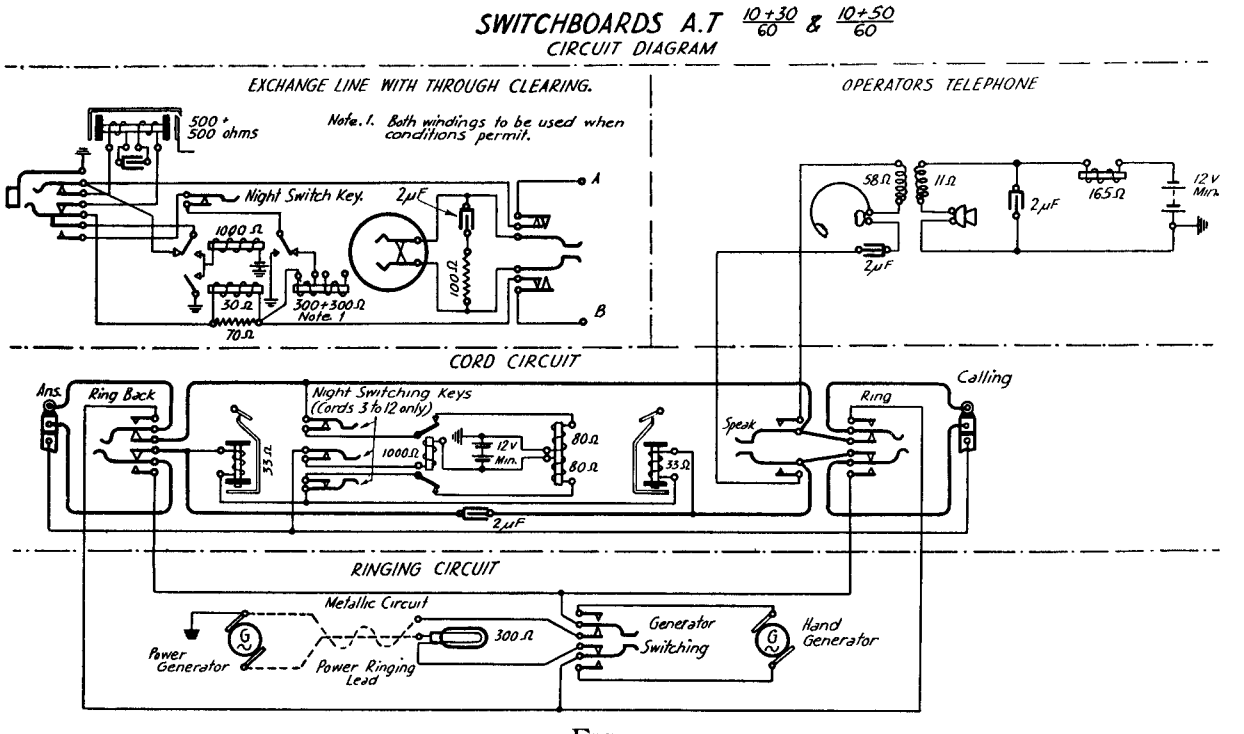
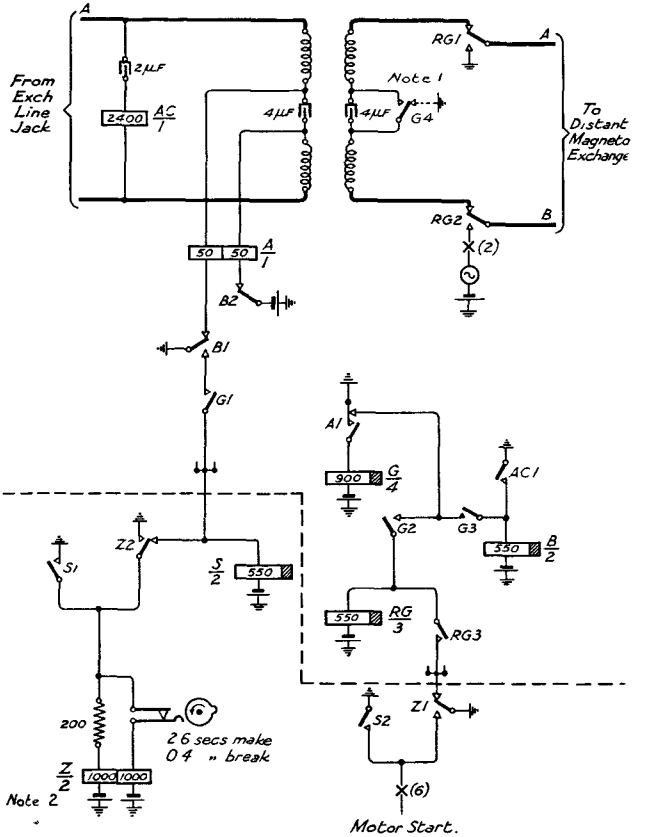

SWITCHBOARDS A.T 10+30/60 & 10+50/60
CIRCUIT DIAGRAM
EXCHANGE LINE WITH THROUGH CLEARING.
OPERATORS TELEPHONE
500 + 500 ohms
Note. 1. Both windings to be used when conditions permit.
Night Switch Key.
2μF
1000 Ω
30 Ω
70 Ω
300+300 Ω Note. 1
100 Ω
A
B
58 Ω
11 Ω
2μF
16.5 Ω
12 V Min.
2μF
CORD CIRCUIT
Ans.
Ring Back
Night Switching Keys (Cords 3 to 12 only)
33 Ω
1000 Ω
12 V Min.
80 Ω
80 Ω
33 Ω
2μF
Speak
Ring
Calling
RINGING CIRCUIT
Metallic Circuit
Power Generator
Power Ringing Lead
300 Ω
Generator Switching
Hand Generator

FIG. 3.



EXCHANGE LINE CIRCUIT TO MAGNETO.

FIG. 4.

to be applied to the public exchange line at the commencement and finish of a call. Similar equipment is necessary for C.B.S. lines except that generator calling and clearing will not be required.

Calls from extension to extension. Calls from one extension to another will be completed automatically. " First party " or " forced " release conditions should be provided

—as a P.A.B.X. is generally an " unattended " exchange—thus preventing one extension holding another or common automatic equipment for an abnormal period of time.

Line finder systems. The automatic plant is generally operated for the sake of economy on a line finder basis. Line finder systems are economical as regards uniselectors, *e.g.*, in a system containing 50 extensions and 5 connecting channels (or circuits) only five 50-point line finder uniselectors are required.

Larger P.A.B.X. installations require further groups of 50-point uniselectors and associated connecting channels, although in some systems, such for instance as the Standard Telephones & Cables 30 and 100 line system, a " Bypath " type uniselector of larger capacity is employed, having 50 point banks and 10 levels over which two sets of 5 wipers may be arranged to hunt in succession, thus increasing the capacity of the uniselector to 100 outlets.

It is necessary, with line finder systems of large capacity, to keep a close watch on the distribution of traffic to ensure that the busy extensions are not all concentrated on one line finder group.

Line finder systems can either be arranged (*a*) so that when an extension calls, all line finders in the group hunt for the calling line, as in the Unit Auto No. 4, or (*b*) an assigner or distributor switch can be provided, as in the A.E. Co. 30/30 system, which pre-selects a free line finder and allows only one in a group to hunt for a calling line. This arrangement spreads the calls more evenly over the connecting circuits.

With method (*a*) it is necessary to guard against two line finders simultaneously finding the calling line, and with (*b*) it is necessary to prevent a faulty line finder being assigned to a caller. A faulty line finder should either give an alarm after a pre-determined period or cause the assigner to hunt for another line finder.

The connecting channels associated with the line finders are provided on a busy hour basis, and in the case of small installations are seldom less than four in number.

Tones. Standard tones and a time pulse earth are supplied from a ringing machine in order to supervise the various stages of the call. The tones and their uses are

shown in Fig. 5. The ringing circuit is specified to be from earthed battery, generator and tripping relay during the ringing period and from earthed battery and tripping relay during silent periods. The ringer should only run during the time that it is actually required to supply ringing current or any one of the various tones or time pulses obtainable from it. A typical ringing machine circuit is shown in Fig. 6 and provides the facilities specified.

Dial Tone	33 cycles per sec.	Continuous	Indicates that the selective apparatus is ready to receive a call and the caller may now proceed to dial.
Busy Tone	400 cycles per sec.	0.75 secs. on 0.75 secs. off	Indicates that the No. dialled is engaged, or that trunks to the called No. are engaged.
Number Unobtainable Tone	400 cycles per sec.	Continuous	Indicates that the No. dialled is either spare, O.O.O. or T.O.S.
Ringing Tone	133 cycles per sec. superimposed on ringing frequency $16\frac{2}{3}$ cycles per sec.	0.4 secs. on 0.2 secs. off 0.4 secs. on 2.0 secs. off	Indicates that the selective apparatus has selected the called line and ringing current is being sent out to the called line.

FIG. 5.

Line Limits. The P.A.B.X. system should operate satisfactorily on lines varying from zero to 350 ohms loop resistance and with a minimum wire to wire insulation resistance of 50,000 ohms. Under these conditions the automatic switching plant should operate satisfactorily from dials having speeds varying from 7-14 impulses per second.

Extension telephone instrument. Standard Post Office dial and telephone instruments are employed on extensions at all P.A.B.X's.

Long Line equipment. Approved long line equipment is installed on extension lines requiring it.

" Restricted service." If it be desired to restrict certain extensions, tie lines, etc., from obtaining the public exchange, it is usual to associate " exchange prohibition " relays with

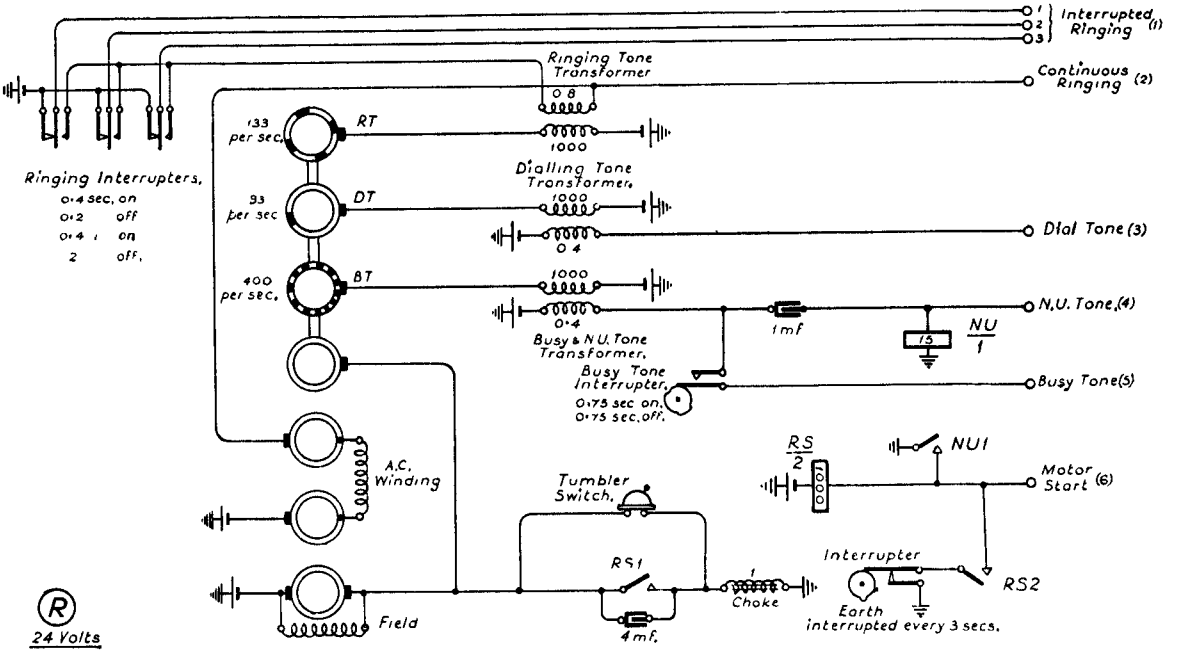

1
2
3
Interrupted Ringing (1)
Continuous Ringing (2)
Ringing Tone Transformer
0·8
133 per sec.
RT
1000
Dialling Tone Transformer.
1000
93 per sec
DT
0·4
Dial Tone (3)
400 per sec.
BT
1000
0·4
N.U. Tone (4)
1 mf
NU 1
15
Busy & N.U. Tone Transformer.
Busy Tone Interrupter.
0·75 sec on.
0·75 sec. off.
Busy Tone (5)
Ringing Interrupters.
0·4 sec. on
0·2 off
0·4 " on
2 off.
A.C. Winding
Tumbler Switch.
RS 2
NU1
Motor Start (6)
RS1
Interrupter
RS2
Choke
Earth interrupted every 3 secs.
4 mf.
Field
R
24 Volts

FIG. 6.

the extension equipment. When " direct access " to exchange lines or tie lines is to be provided, it is usual to make certain alterations in the automatic unit which will cause restricted extensions to be connected with the manual board or to N.U. tone when digit 9 is dialled. The former condition is the more desirable because the manual operator can then exercise discretion as to setting up a connection.

Night service. " Night " jacks are provided when necessary for extending certain extension lines to exchange lines at any desired period of the day or night when an operator is not at the manual board. In some systems, it is not necessary to provide special " night " jacks and the normal " day " jack will function for both types of connection. In all systems an extension so connected should function as a direct exchange line. Extensions so connected cannot call, or be called by, other extensions unless special facilities are required for this purpose when they can be fitted with the standard Post Office circuit shown in Fig. 7 (switchboard $\frac{1+1}{2}$ AT1837). This circuit allows calls from the public exchange to be dealt with by the extension connected for night service. An extension so connected can, by the

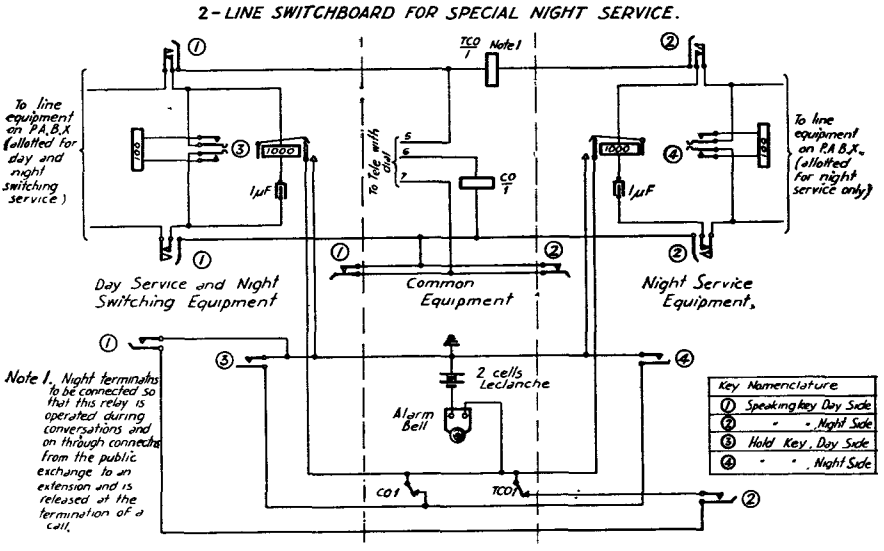


FIG. 7.

operation of suitable keys, extend the exchange line to another extension by dialling *via* the automatic equipment, or can put another extension through to the public exchange. Suitable calling and clearing (audible and visual) alarms are provided on the small 2-line cordless board constituting the switching point.

The night connections in all cases are effected by operating special night switching keys at the manual board, which, in the operated position, convert the manual board cord circuits into " straight-through " connections. The plugs and cords are then used to connect certain extensions direct through to the exchange lines.

Alarms. Alarm signals should be provided to indicate " P.G." and " fuse blown " conditions. These alarms consist of suitable lamps fitted at the automatic and manual equipments. The P.G. and " forced release " alarm condition should be retarded by suitable apparatus (generally by a thermostat, dashpot relay or a uniselector device) so that the associated lamps will not glow until the P.G. condition has persisted for 30-60 secs. This alarm should also act as a guard against one extension holding a circuit for an excessive period after the other extension has cleared and should also clear down the automatic apparatus taken into service by the faulty condition, or misoperation, and give a P.G. signal at the manual board.

In most systems the P.G. condition is indicated at the manual board on a " non-urgent " alarm lamp, but in the late relay system now known as the Siemens Relay No. 1 and 2 systems and the A.E. Co. 30/30 system the P.G. condition is indicated on the extension lamp. In the Unit Auto No. 4 a " P.G." alarm lamp is provided at the manual board together with a " P.G. alarm " key. When this key is depressed the calling lamp of the faulty or P.G. extension glows.

Other circuit failure conditions may be indicated by suitable alarms at the contractor's discretion, subject to the approval of the Post Office. Although not definitely specified it is desirable for a " ringing failure " alarm to be provided. Where magnets for stepping and release of switches are installed a " magnet " alarm is provided.

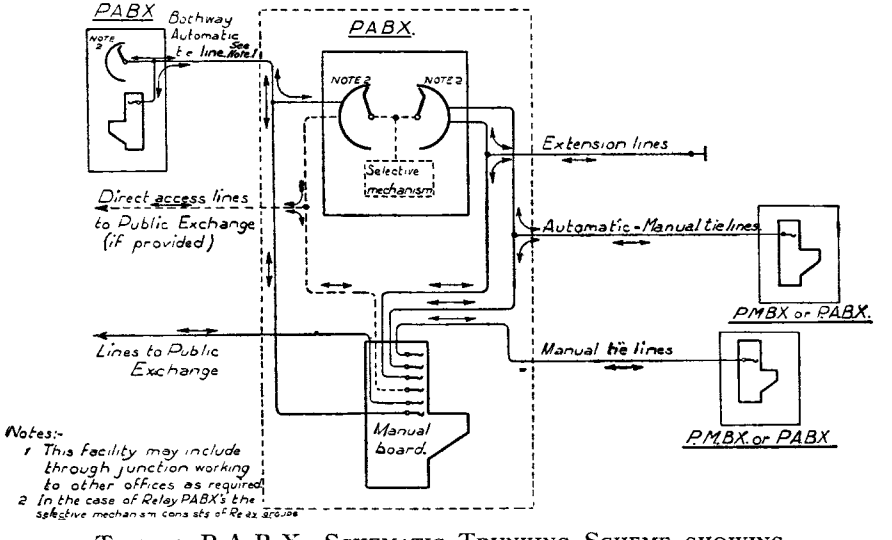
An Alarm Bell is associated with the visual alarms at the manual board, and it should be possible to cut it out of circuit by the depression of a non-locking " cut-off " key. This key,

when depressed, should disconnect the bell circuit but leave the alarm lamp locked in circuit until the fault or other mis-operation has been dealt with.

The alarm lamp and bell circuits should all be under the control of the night service switching keys, so that when night service conditions are provided all alarms are disconnected at the manual board.

General. All the equipment and the facilities provided, together with the proposed site, must meet with the approval of the Engineer-in-Chief, G.P.O., or his representative.

Fig. 8 shows in schematic form the general facilities provided by a P.A.B.X. installation.



TYPICAL P.A.B.X. SCHEMATIC TRUNKING SCHEME SHOWING FACILITIES PROVIDED.

FIG. 8.

The manual board employed in connection with " rental " P.A.B.X. installations when supplied by contractors is similar to the $\frac{10 + 50}{65}$ type often employed solely as a P.M.B.X. The $\frac{10 + 50}{65}$ type itself can be suitably modified if and when it is required for P.A.B.X. service.

OTHER CONSIDERATIONS AFFECTING THE DESIGN OF P.B.X. AUTOMATIC EQUIPMENT.

General.

Tie Line working may be provided on a manual or automatic basis. If on a manual basis, then the tie line is terminated at the manual board and the extensions will obtain access to it by dialling " o " and asking the operator for the tie line to be connected. The P.B.X. operator will then set up the connection by means of plugs and cords in the usual manner. If, however, it is desired to obtain access to the tie line, *via* the automatic equipment, one or two methods may be adopted.

1. For one tie line an extension number may be allotted and the tie line terminated at a spare extension line equipment. All extensions can then obtain access to the tie line by dialling the appropriate extension number. This arrangement has the disadvantage that the call proceeds over the usual channels and is set up *via* the transmission bridge in the local connecting circuits. Consequently, it is not possible (without special modification) to dial into other P.A.B.X. systems and so set up the desired connections on a full automatic basis. The tie line is of necessity terminated at the distant end on a jack and indicator at the manual board.

2. The digit 8 can be allotted for the tie line service and all extensions can then obtain access to tie lines by dialling this digit. This arrangement has the disadvantage that the digit 8 cannot be used to prefix any extension number, *i.e.,* extensions cannot be connected in the 80, 800 or 8000 group according to the size of the P.B.X., but has the advantage that when it is desired to dial into other P.A.B.X. installations the dialling operations are reduced to a minimum and full automatic bothway working can be provided without special modification.

In such cases a group of tie lines may be catered for, over which an automatic search will be instituted after the digit 8 has been dialled.

P.A.B.X. inter-communication schemes. Such schemes make provision for inter-communication between two or more P.A.B.X's by linking them together with " bothway automatic junction " or tie line equipments. An extension at one P.A.B.X. may then, by dialling a special digit allotted for this service, obtain communication with extensions or the

manual board operator at other P.A.B.X's on an automatic basis.

It is generally possible to supply this service on P.A.B.X's having more than 20 lines and providing the inter-office lines are not of abnormal resistance, *i.e.*, more than 750 ohms loop. Satisfactory transmission is, of course, the fundamental condition governing the installation of this service.

It is usual to provide manual access on bothway automatic junctions, with exchange prohibition where necessary, and thus cater for manual and automatic inter-communication.

Two classes of bothway junction service are shown in Fig. 9, *i.e.*, " bothway " communication between two exchanges as shown in Fig. 9(*a*) and " through " junction services between three or more P.A.B.X's as shown in Fig. 9(*b*).

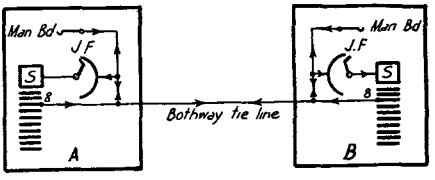
Bothway junction working. Fig. 9(*a*). In this case Exchange A can communicate with Exchange B by dialling the digit allotted for tie line working, generally digit 8. This will cause the extension to be connected with a tie line to Exchange B, the normal selective channels at A being switched out of circuit. The incoming end of the tie line at Exchange B is associated with line finding devices which will connect it to a free selective mechanism. The extension at A then dials the number of the extension required at B, and thus extends the tie line connection to the required extension in the usual manner, the dialled impulses being repeated over the tie line.

It will thus be seen that for extensions at Exchange A to obtain communication with extensions at Exchange B, the desired extension number must be prefixed by a single digit, usually the digit 8.

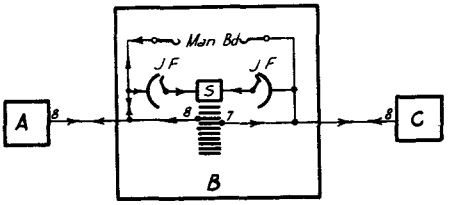
Similarly, extensions at Exchange B desiring communication with extensions at Exchange A must prefix the extension number with the digit 8.

While the tie line is in use, the outgoing section of the equipment at both ends is made busy to other extension callers and the manual board jacks at both ends will test engaged.

Through junction working. Arrangements similar to those shown in Fig. 9(*b*) are necessary to provide intercommunication between more than two P.A.B.X's. In this

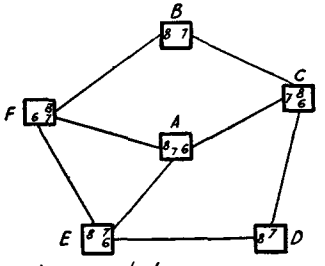


(a) Two P A B X's interconnected



(b) Three P A B X's interconnected (through junction working)

P A B X	Dialling to A	B	C	D	E	F
A	-	68	6	66	7	8
B	77	-	7	76	86	8
C	7	8	-	6	77	88
D	77	78	7	-	8	88
E	7	88	76	68	-	8
F	7	8	76	66	6	-



(c) Six P A B X's interconnected (the application of this scheme is limited.)

P.A.B.X. MULTI-OFFICE INTERCOMMUNICATION SCHEMES.

FIG. 9.

case, besides allotting the digit 8 for the bothway junction service from Exchange A to Exchange B it is necessary at B to allot another level, say 7, to bothway junctions terminated at Exchange B from Exchange C. This will mean that unless Exchange B is of a large capacity the grade of extension to extension service and the number of extensions that can be provided will be severely restricted. It would be necessary in this case to limit extension numbering to levels 2-6 and to increase the number of connecting circuits to cater for extension and tie line traffic.

It is advisable, if suitable conditions exist, to provide through junction working when more than two P.A.B.X's are to have inter-communication facilities, in order to economise in lines, and this can be done when one of the P.A.B.X's is conveniently located to act as a junction or Tandem centre for the other two P.A.B.X's. It will be seen in Fig. 9(*b*) that Exchange B is most conveniently located for this purpose, assuming that transmission conditions will be satisfactory.

Exchange A can obtain an extension at Exchange B by dialling 8 followed by the extension number, and can communicate with extensions at Exchange C by dialling 87 followed by the number of the extension required at Exchange C.

Similarly, Exchange C can call Exchange B by dialling 8 followed by the extension number, and may call extensions at Exchange A by dialling 88 followed by the number of the required extension. Exchange B may obtain extensions at A or C by dialling 8 or 7 respectively, followed by the extension number.

The scheme can be applied to larger multi-office groups as shown in Fig. 9 (*c*). The scheme shown is somewhat unwieldy and will give some idea of the limitations of inter-P.A.B.X. working. These limitations could, doubtless, be overcome by introducing a scheme such as satellite working.

Testing facilities, etc. Suitable access points in the form of " test-" jacks should be provided in each unit of equipment and multipled where necessary to allow routine and maintenance tests of the whole of the equipment to be carried out with the Post Office Tester No. 64. It should also be possible to isolate, by " busying out," any unit of equipment which develops a fault; or to remove easily, any part of the equipment for adjustment or repair without affecting the normal working. Suitable points should also be provided for connecting traffic recording meters when desired without having to interfere unduly with working equipment.

Location of plant at subscriber's premises. Apart from the requirements set out above, P.A.B.X. equipment should be capable of functioning satisfactorily in any habitable room and for economical reasons should generally not require the installation of special ventilation or humidity adjusting plant, such as is employed in public automatic exchanges. It should, therefore, be of robust construction and since most

contractors specialise in equipment for foreign administrations, where extreme climatic conditions are often met, it is suggested that advantage might be taken of their experience when any particularly bad site is unavoidable.

The site for the plant is generally allotted by the subscriber and should be accepted with discretion, care being taken to see that the temperature of the room does not reach extremes of heat and cold at any time during the year, and that no atmospheric condition of a corrosive nature such as the discharge of gaseous fumes or excessive dampness or dust exists, or will at any time exist.

Noise caused by plant. Another point to be considered is the question of noise. Charging plant employing a motor generator should not be so noisy as to interfere with the occupants of adjoining rooms or the operation of the manual board. Similarly, the ringing machine should be mounted in such a way that running noise is reduced to a minimum. If the automatic plant itself is liable to cause interference due to noise, it should be totally enclosed in a reasonably sound proof case, or alternatively a more suitable site should be found for it.

The charging plant, batteries, automatic unit and manual switchboard should preferably be in close proximity to one another in order to reduce cabling costs and risks of overhearing.

Power plant. The ideal power plant would be fully automatic in operation, thus reducing the amount of maintenance attention and size of plant required. It is not generally desirable to work the P.A.B.X. direct off the mains, however, unless a subscriber has emergency power plant on the premises. Where mains supply only is available the " full float " battery principle would appear to have a great advantage because a battery can then be " trickle-charged " continuously and if the main supply fails is able to carry the load itself. By " full float " is meant that a battery is so regulated as regards its voltage, specific gravity and discharge rate that it can be continuously charged from the main power supply, while connected to the P.A.B.X. bus bars. Only one battery is required for this purpose.

At present, however, two batteries are supplied to Post Office subscribers, and one of these serves the P.A.B.X. while the other is being charged or is standing idle, fully charged.

APPLICATION OF REQUIREMENTS IN PRACTICE.

Now that the general requirements and functions governing the design of P.A.B.X. equipment have been set out, their application in practice will be briefly considered.

Until recently, the Relay Automatic Telephone Co's 24 and 32 volt systems complied most closely with the Post Office requirements set out earlier in this paper, and most of the P.A.B.X's installed in the country are at present of this Company's manufacture. These systems have, however, been taken over by Messrs. Siemens Bros. and are now referred to as Siemens Relay No. 1 (24v) and Relay No. 2 (32v) systems.

Recently, the A.E. Co. have developed a 30 line P.A.B.X. equipment which conforms very closely with the requirements set out above, and is designed for the use of " rental " subscribers. Consequently, this system will be dealt with first.

SYSTEMS APPROVED BY THE POST OFFICE ADMINISTRATION.

The A.E. Co's 30 line P.A.B.X. This is known as the 30/30 line P.A.B.X. and provides all the requirements and facilities set out above. It is designed to cater for a maximum of 30 extensions and 10 exchange lines and 6 connecting circuits. By altering a few straps on the shelf jacks the system can be adapted to work into any type of manual or automatic public exchange system. The system functions on a line finder basis, a free line-finder being pre-selected by a distributor switch. A unit is shown in Fig. 10.

Racks and equipment. An open type of rack is employed, 7 ft. high and 2 ft. 11 inches wide.

Two shelves at the top of the rack contain the exchange line equipment, and the next shelf below these contains the Final selectors. (The system functions on a 2-digit basis and group selectors are not required).

The fourth shelf counting downwards contains the extension line equipment.

The line finder uniselectors which are of the well known A.E. Co. uniselector type, two distributor uniselectors and

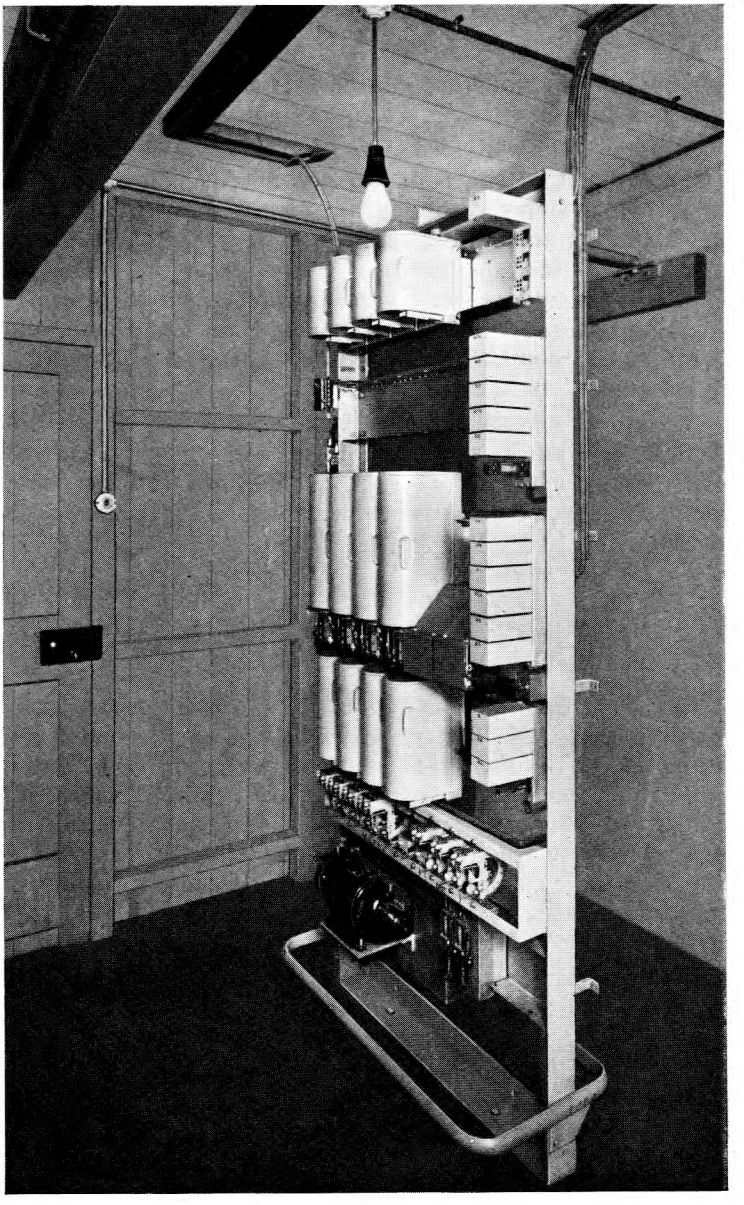


FIG. 10.

the " forced release " uniselector, which also provides P.G. delayed alarm conditions, are all contained on the fifth shelf, counting downwards.

The bottom shelf contains the ringing and tone equipment.

The manual board provides circuits similar to the P.O. $\frac{10 + 50}{65}$ type and contains in addition to the usual plugs and cords, etc., the alarm lamps mentioned earlier in this paper. For " trunk offering " a special plug is provided which, when inserted into an extension jack, will not break down an existing connection.

Power. The automatic equipment operates on 50 volts obtained from secondary cells. The satisfactory voltage range is from 46-55 volts.

The ringing and tone equipment comprises a jack-in unit and is so arranged that the transformers are interchangeable, one type only being used for all tones. The usual dynamotor supplies the tones and ringing currents.

The rack for the automatic unit is fully wired and equipped with jacks and banks so that equipment up to the full capacity of 30 lines and ten exchange lines may be added at any time. Provision is also made for the addition of another shelf of exchange line equipment to be added at the top of the existing rack when more than 10 exchange lines are required. The shelves are labelled A to F upwards and accordingly this additional shelf when fitted will be labelled G.

The exchange line groups are in units of one circuit per base. Extension units contain five circuits per base. The equipment operates on the line finder principle, provision being made by means of a distributor uniselector for only one free pre-selected line finder to hunt for a calling line. The whole of the equipment is in unit form, so many units of each type being taken out of stock and jacked in, or otherwise mounted on the rack provided, to form a complete P.A.B.X. of the desired size. Fig. 11 gives a schematic diagram of this class of P.A.B.X. equipment.

The distributor switch is always standing on a free line finder circuit and thus a final selector associated with a particular line finder, will always be available to callers. If all line finders happen to be engaged, the distributor steps on

P.A.B.X. LINE FINDER SYSTEM WITH DISTRIBUTOR SWITCH.
(Maximum Capacity 90 Lines)
Elementary Connections.

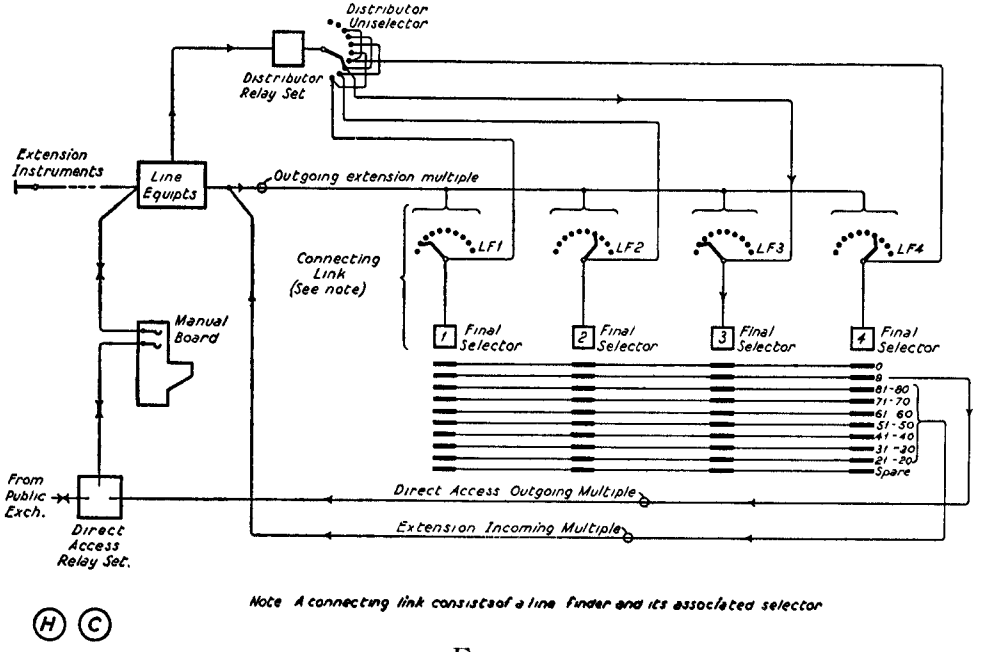


FIG. 11.

to the 25th contact and remains there until a line finder becomes disengaged, when it will step on and open it in readiness for the next call. An emergency distributor switch is provided and can be brought into operation by a change-over key.

When a calling extension is switched through to a final selector, dialling tone is connected, and the appropriate extension line jack at the manual board is " busied."

The final selectors are provided with a vertical marking bank which comes into operation on calls to levels 8, 9 or 0, *i.e.*, when tie lines, direct access or manual board facilities respectively are provided.

For extension to extension calls the final selector receives two digits which operate the vertical and rotary magnets respectively in the usual manner; when " 0 " is dialled, however, the vertical marking bank causes a circuit to be closed for the manual board calling lamp. This operation also effects the release of all the automatic equipment taken into use by the caller, thus making it available to other callers. The extension receives ringing tone until the operator answers.

Direct access and tie line working. On calls to levels 8 or 9 the vertical marking bank functions in a similar manner, but provides a circuit condition which converts the final selector into a repeater. The extension caller can then continue to dial digits (after receipt of dialling tone) into the public exchange automatic equipment or, if level 8 is dialled, into another P.B.X. installation.

Restricted service. These services *via* level 9 can be barred to certain extensions by suitable strapping arrangements in the line finder, which when applied route all calls to the manual board from restricted extensions dialling 9.

Numbering scheme. The numbering scheme is as follows:—

Extensions numbered 20-49.
Levels 1, 5, 6, 7 connected with N.U. Tone.
Level 8 may be used for tie lines.
Level 9 may be used for direct access.
Level 0 calls to manual board.
All spare lines are connected to N.U. Tone.

100/125 line system. The A.E. Co. have also designed P.A.B.X's of larger capacity for " private purchase " subscribers. A typical one employs individual forward hunting extension uniselectors and 200 outlet Final Selectors. This is known as the 100/125 line P.A.B.X. By employing 200 point banks on the final selectors group selectors are saved. The vertical marking bank in this case discriminates between the 100's groups dialled as well as performing the operations described above for the 30/30 line P.A.B.X.

Alarms. In all systems a P.G. or " called sub held "

condition is supervised by a slow alarm device, generally consisting of a uniselector stepped by impulses from the ringing machine. After a predetermined period this disconnects the automatic equipment from a faulty or P.G. extension holding it and switches the extension to the manual board, where its calling lamp is made to glow. The manual operator is thus able to deal with the faulty or P.G. extension and plug it out of service until the fault or the P.G. condition is removed. All the other alarms mentioned earlier in this paper are provided.

Siemens Bros. P.A.B.X. Systems.

The No. 16 System employs the well-known types of Siemens 10 point uniselector, two-motion selector and similar circuits to those used in their No. 16 non-director exchanges. A typical installation is shown in Fig. 12. These items are mounted on open type racks, and so many of each assembled in this manner form a P.A.B.X. automatic unit. Systems working on the No. 16 principle are classified as " small " and " large " P.A.B.X. systems.

Small P.A.B.X's are worked on a two-digit basis, and large P.A.B.X's on a 3-digit basis. Both employ 10 point uniselectors and in three-digit systems 1st and 2nd preselectors are installed. The first preselector is a homing type, and the second a non-homing type. Both are stepped, by means of impulses delivered from an impulse machine, at 34 steps per second and the rotary motion of two-digit selectors is also affected in this manner. Three-digit systems employ intermediate (or group) selectors to deal with the 100's digit.

100 outlet final selectors are installed in both large and small P.A.B.X's.

Calls to the manual board are obtained by dialling " 0," which causes the final selector in two-digit systems and the group selector in three-digit systems to take ten vertical steps. Normal post springs are provided which are actuated on the tenth level, and bring about the operation of the manual board calling lamp associated with the calling extension. All the automatic equipment taken into use is then released. The caller hears ringing tone until the operator answers.

Direct access and tie line facilities may be provided on levels 9 or 8 respectively, by the addition of suitable relay sets wired to the bank contacts of these levels. Since the

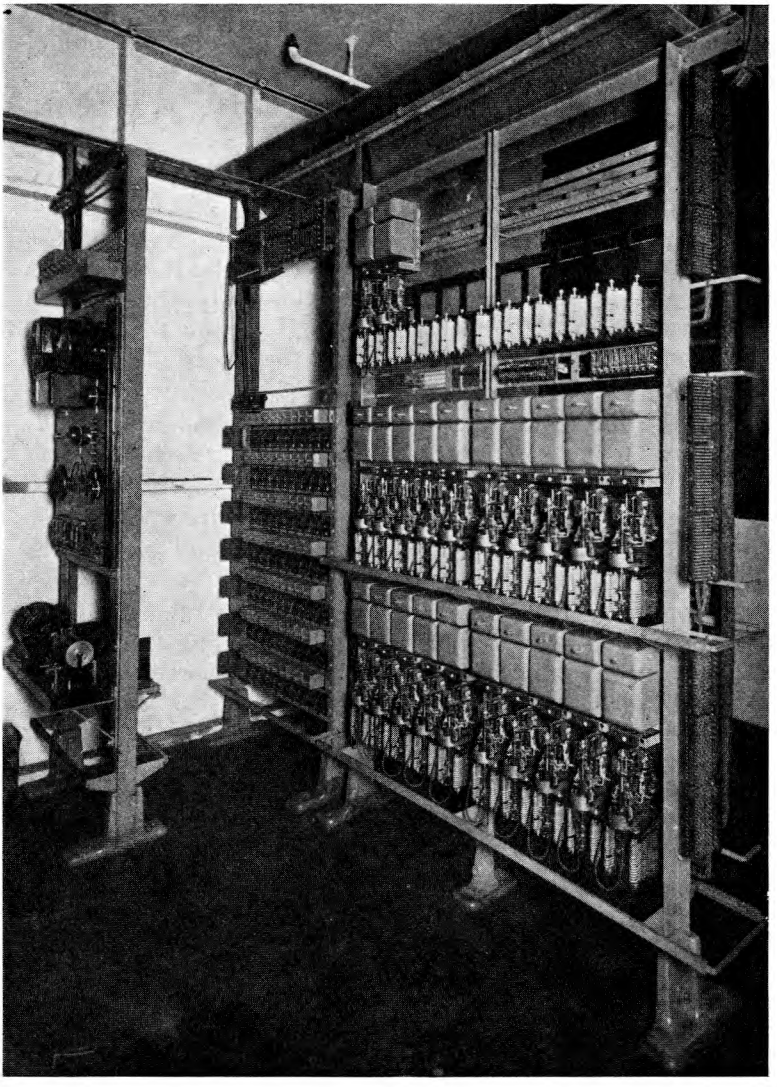


FIG. 12.

transmission bridge in the Siemens No. 16 system is located in the first selector in three-digit systems it is necessary to convert these selectors into repeaters or to cut them out of circuit when digits 8 or 9 are dialled.

P.G. and magnet alarm circuits are provided, but no provision is made for the forced release of automatic equipment taken into use under P.G. conditions.

Messrs. Siemens well known type of relay is employed throughout.

The systems operate on 60 volts, the range for satisfactory operation being from 54-66 volts.

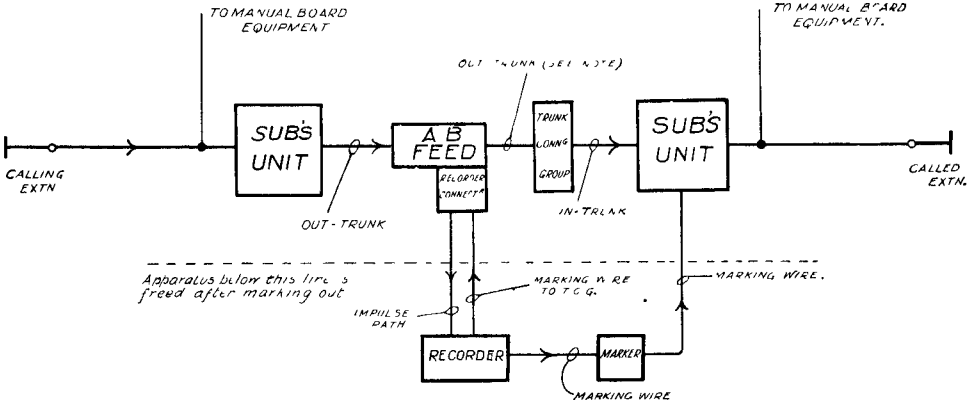
Siemens Relay No. 1 and Relay No. 2 Systems are doubtless well-known, these being originally the R.A.T. Co's 24v and 32v systems respectively. These two systems have in the past formed the basis of P.A.B.X. practice in this country, and fulfil the requirements of the Post Office.

The whole of the operations are dealt with by relay groups, and the by-path principle of operation is employed. Such a principle is essential, or the number of relays involved would be excessive.

The relays are made up into groups which are necessary to perform the functions of storing, routing and connecting the calls to their various destinations.

Operation. The system operates on a " line finder " basis, the action of removing a receiver causing the calling extension to be connected to a free trunk termed an " out-trunk." A schematic diagram is shown in Fig. 13. The " out-trunk " is associated with an A.B. Feed which forms part of the out-trunk, and contains the transmission elements, dialling tone, busy and ringing connections. The A.B. Feed so seized searches for a free Recorder, which, when found, is connected to the A.B. Feed *via* a Recorder Connector. At this stage the caller hears dial tone and commences to dial. The dialled impulses are repeated into the Recorder, which stores them until all have been received. The Recorder then " marks out " and, with the aid of a common relay group termed a " Marker," sets up a connection between the called extension line and the A.B. Feed, upon which the caller is waiting. The " Marker " can only be taken into use by one Recorder at a time. The connection is set up over an " in-trunk " *via* a " Trunk Connecting " Group. When a connection is established between the two extensions, the Recorder and Marker, which comprise the by-path circuits, are released and become available to other callers. If the called extension is engaged, then no connection is set up between the A.B. Feed and the called extension, and the A.B. Feed will return busy tone to the caller.

SCHEMATIC DIAGROM, RELAY 24V. P.A.B.X.
SHOWING CIRCUIT DISPOSITION OF THE RELAY GROUPS DURING A CALL FROM EXT'N TO EXT'N.



NOTE :—Out-Trunk from A.B. Feed to T.C.G. includes marking wire from Recorder *via* Recorder Connector.

FIG. 13.

Ten extension line equipments, in two units of five lines each, form one group, and are contained in a group case. Four A.B. Feeds and a Trunk Connecting Group of corresponding size, are mounted in another group case which is wired for a maximum capacity of six A.B. Feeds. Each Recorder is assembled into separate and smaller group cases. Similar equipment is employed in the 32v system.

The whole equipment is therefore in unit form, and so many of each type of relay group may be assembled on suit-

able racks to form a P.A.B.X. of any desired size. The group cases are cabled to terminal assemblies located above each bay, and may be cross-connected to equipment mounted in the same bay by straps, and to equipment in other bays by tie cables.

The system is very quiet in its operation, and can, therefore be installed in the room occupied by the manual board. In the author's opinion it is an ideal P.A.B.X. system, being capable of extension to 240 lines in the case of the 24v system, and from 300 lines indefinitely in the case of the 32v system. Standard P.G. and other alarms are provided and direct access, tie line and bothway junction working on an automatic basis may be provided to Post Office specification by the addition of suitable relay groups and with the minimum of alteration to existing apparatus.

The 24 volt system will operate satisfactorily over a voltage range of 22-26 volts.

The 32 volt system operates over a voltage range of from 28-34 volts.

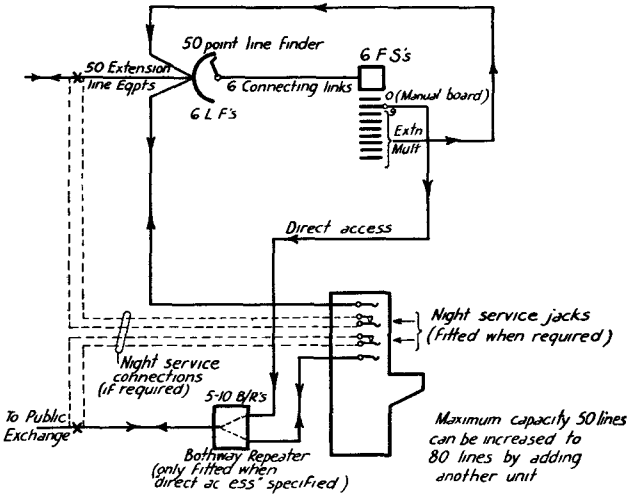
The G.E. Co's P.A.B.X.—" G.P.O." system.

The Company's well-known types of uniselector and two-motion selector are employed and the facilities specified by the Post Office are met in most respects. The system operates on a line finder basis, which is as regards functions similar to that of the A.E. Co. 30/30 system (Fig. 11) previously described. (See also Fig. 14).

The final selectors are fitted with " normal post " springs which are mechanically actuated, when the wiper shaft reaches the 9th level, when the digits 9 or 0 are dialled.

The operation of these springs causes the manual board extension lamp to glow when the " 0 " level is reached and the selector is immediately released.

Exchange prohibition is provided for by fitting an " EP " relay in each selector. This relay operates when the selector is seized and when a restricted extension dials " 9 " for " Direct access " this relay will remain operated and N.U. tone is returned to the caller. If an unrestricted extension dials " 9 " relay EP releases and allows the selector wipers to hunt over the 9th level for a free line to the public exchange. When a free line is found the selector is converted into a " straight through " connection and the extension can dial



TRUNKING DIAGRAM FOR P.A.B.X. WITH DIRECT ACCESS.
G. E. CO'S " G.P.O." SYSTEM.

FIG. 14.

through the public exchange equipment direct, if automatic, or if manual, speak with the public exchange operator when she answers.

For direct access service, exchange lines are equipped with bothway repeaters (Fig. 14) which can be modified to provide " through clearing " conditions if the public exchange is converted at any time from manual to automatic. This equipment is inserted in the public exchange line *via* a " night " jack.

When " night " service is required a plug is inserted into the exchange line night jack and an extension can then be connected direct to the public exchange, the other plug of a pair being inserted into the extension night jack. The auxiliary equipment is disconnected from the exchange line and made to test engaged to other callers who may endeavour to dial *via* " direct access."

Alarms. The usual P.G. and C.S:H. clear down alarms are provided by means of a time pulse uniselector. This alarm actuates an " auto-non-urgent " alarm lamp at the manual board and an alarm lamp at the automatic equipment.

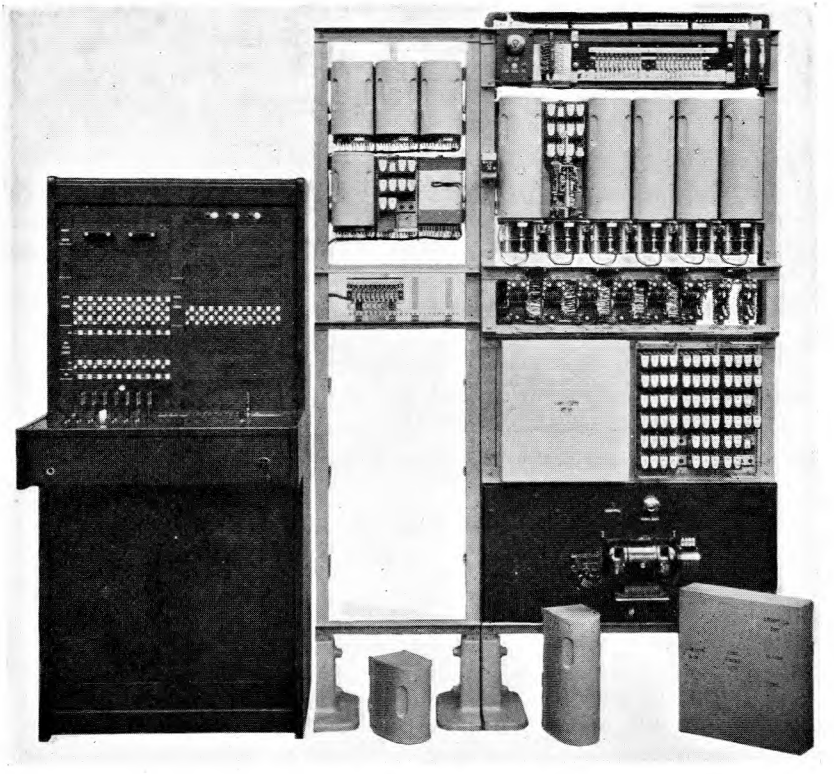


FIG. 15.

Release magnet alarms are also provided which control the " auto-urgent " alarm lamp at the manual board.

A blown fuse also lights the " auto-urgent " alarm lamp at the manual board.

If the ringing machine fails to start up, a " ringing failure " lamp glows at the automatic equipment and the " auto-urgent " alarm lamp glows at the manual board.

The manual board is fitted with alarm lamps,—*i.e.*, auto-urgent, and manual urgent, the latter for manual fuses—and provides facilities similar to the Post Office $\frac{10 + 50}{65}$ type.

The alarm lamps can be disconnected by operation of the " night service " keys.

Trunk offering. A special plug is provided at the manual board for trunk offering. This plug is so designed that its insertion into an extension jack will not break down an existing connection.

Numbering scheme. The numbering scheme is as follows:—

Extension lines 20-59.
Manual board 0.
Direct access 9.
All spare levels and lines connected to N.U. tone.

The automatic equipment is mounted on a rack 6′ 6″ high, 2′ 8¼″ wide, and 1′ 5¾″ deep, forming one unit. The main fuses, apparatus fuses, rack alarm lamps and tag blocks for wiring are at the top of the rack, and below these are the jacked-in final selectors, six in number when the unit is fully equipped. Fig. 15.

The Line Finder uniselectors are mounted below the final selectors and the assignment (or distributor) and time pulse uniselectors are mounted in the same row.

Two relay groups are mounted below the Line Finders, one containing the line equipment for extensions 20-58. The other group contains line equipment for extensions 56-69, relays associated with the line finders, and the assigner; also the alarm relays and a dead level relay group. The two relay groups have removable metal covers.

The ringing machine, together with its alarm lamp and " continuous run " switch are mounted at the bottom of the rack.

When direct access is provided a special rack is necessary and contains the " bothway repeater " relay sets.

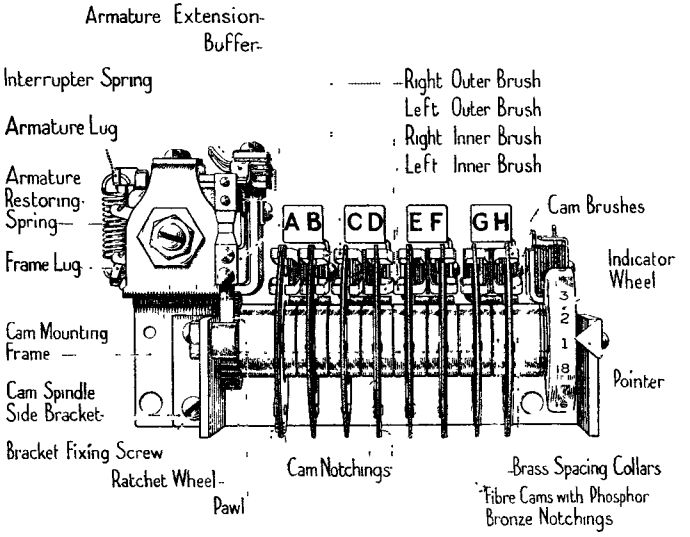
Two automatic units, suitably wired and inter-connected, increase the P.A.B.X. capacity to 80 lines, when required for " private purchase " cases.

The Unit Auto. No. 4 (S.T. & C. 4002 type P.A.B.X.).

This installation is probably well known as it has now been a Post Office stock item for some years and quite a number are in service.

The system operates on a line finder basis. The line finder uniselector is of the rotary line switch type with 22 point banks. Each selective mechanism contains two uni-

selectors both similar in construction to the line finder. These act as group selectors and are termed "upper" and "lower" selectors according to their position on the mounting frame. There is also a group of relays and a sequence switch in each connecting circuit which control the selective operations of the upper and lower selectors and the connections of the various tones, etc. A sequence switch is shown in Fig. 16. It contains eight cams lettered A to H which are mounted on a common spindle and electromechanically rotated. These switches perform functions equivalent to relay operations and reduce the number of relays required to a minimum, and the indicator associated with the spindle is useful from a maintenance point of view as it indicates the various stages through which the call passes.



SEQUENCE SWITCH MECHANISM. UNIT AUTO NO. 4.

FIG. 16.

Automatic unit. The whole of the automatic equipment for a 40 line P.A.B.X. is made up as a unit contained in a cabinet as shown in Fig. 17. The cabinet has sheet iron sides and double doors of sheet iron at the front and rear which are detachable and when removed expose the framework on which the apparatus is mounted.

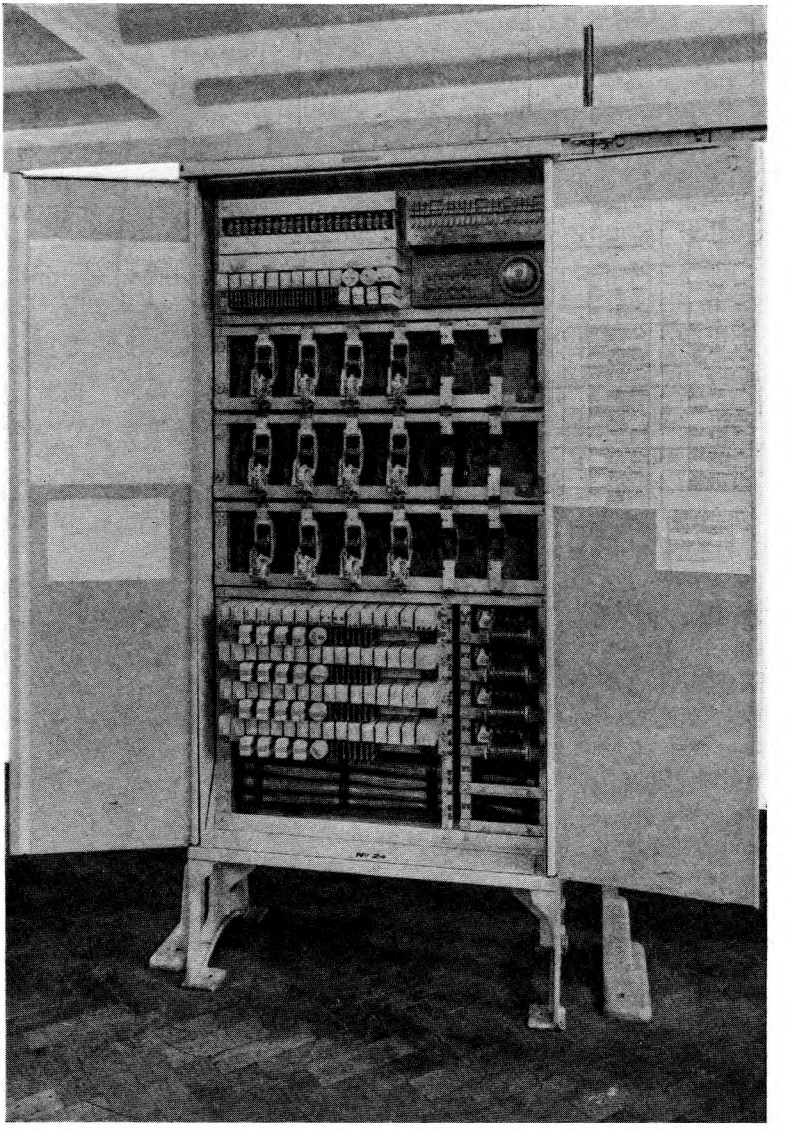


FIG. 17.

Automatic equipment. (Fig. 17). 40 extension line equipments, consisting of S.T. & C. flat type relays, are fitted at the top of the interior of the unit on the left hand

side and to the right of these is a panel containing fuses, an alarm bell, connecting circuit busying keys and three alarm lamps which indicate " Urgent," " fuse alarm " and " ringing failure " conditions respectively.

Four connecting circuits or selective mechanisms are equipped initially. Two more may be added when required, the necessary wiring and uniselector banks and sequence switch mounting plates being already in position.

Other equipment. In addition to the automatic unit a manual board and ringing machine panel are required. The manual board is usually supplied from Post Office stock, a $\frac{10 + 50}{65}$ board being slightly modified by the addition of P.G., urgent and non-urgent alarm lamps and the necessary alarm cut-off keys.

The ringing machine panel contains (in addition to the ringing machine) chokes, transformers, etc., for supplying the various tones.

Power supply. The automatic unit functions on 36 volts with a range of from 32-40 volts. Counter E.M.F. cells are inserted in the manual board battery lead in order to reduce this to 24 volts.

Two units may be connected together in order to increase the capacity to 70 lines, the necessary cross-connections between the units being made at tag blocks.

A schematic diagram of this system is shown in Fig. 18.

This system does not lend itself economically to tie line and direct access working, it being generally necessary to add a line finder unit similar in size to the Unit Auto No. 4 for this purpose, thus making the provision of these facilities an expensive matter. Exchange prohibition is also provided in a non-standard manner and the system has to be modified considerably or changed entirely if more than 70 lines are required at any time.

Ericssons " type A " equipment.

This equipment operates on a line finder basis, the functions of which are similar to those described previously for A.E. Co. 30/30 type and G.E. Co. "G.P.O. " system (Fig. 11). The line finders are 50 point uniselectors, an idle one of which is selected by an assigner, upon the origination

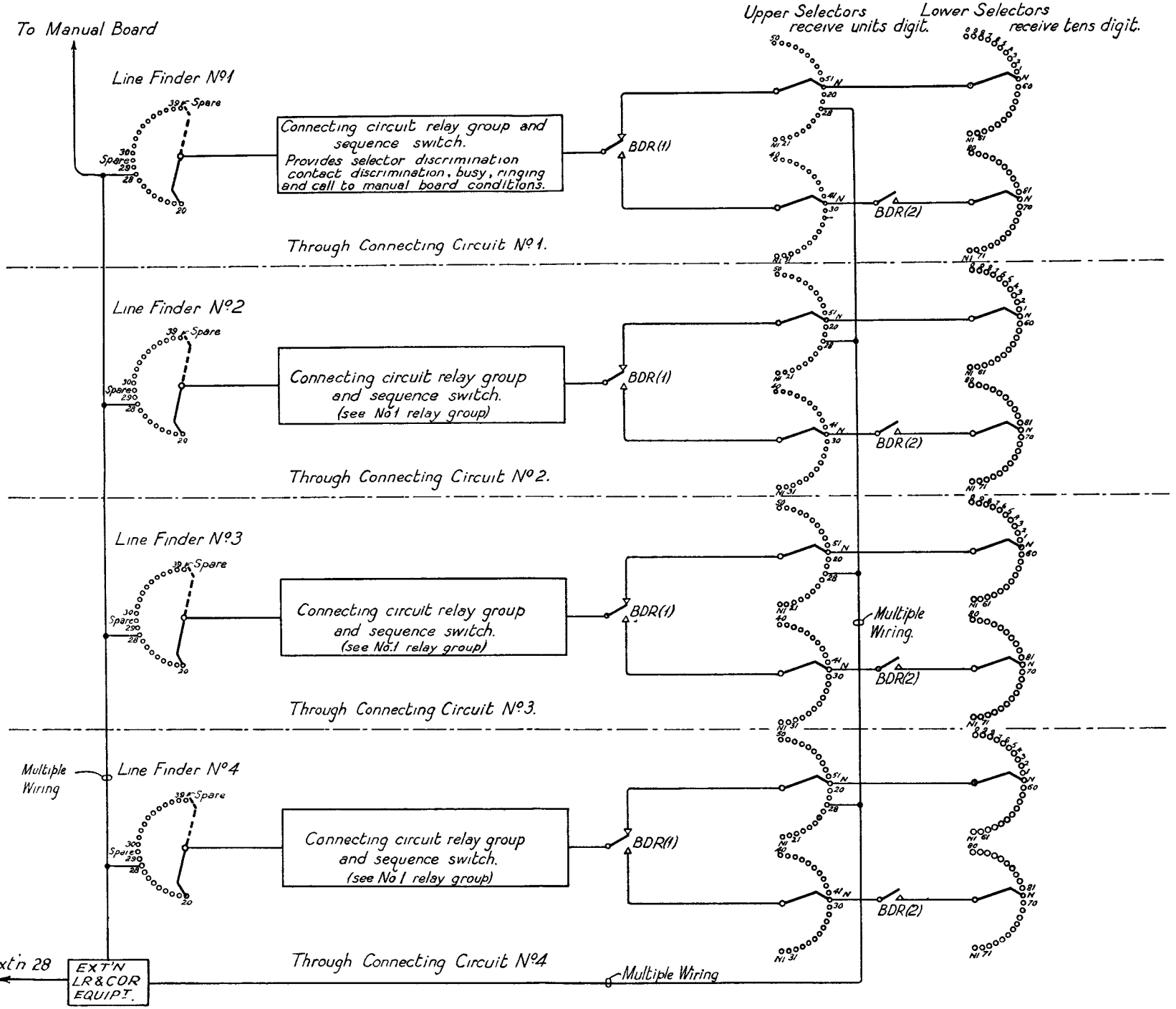

To Manual Board
Upper Selectors receive units digit.
Lower Selectors receive tens digit.
Line Finder No1
Spare
Connecting circuit relay group and sequence switch.
Provides selector discrimination contact discrimination, busy, ringing and call to manual board conditions.
BDR(1)
BDR(2)
Through Connecting Circuit No 1.
Line Finder No2
Connecting circuit relay group and sequence switch.
(see No1 relay group)
Through Connecting Circuit No 2.
Line Finder No3
Multiple Wiring.
Through Connecting Circuit No 3.
Multiple Wiring
Line Finder No4
To Ext'n 28
EXT'N LR&COR EQUIPT.
Through Connecting Circuit No 4
Multiple Wiring

FIG. 18.

of a call. When the calling line is found by the line finder the assigner is released and becomes available to other callers.

Equipments up to 80 lines capacity operate on a two-digit basis and 100 outlet final selectors only are employed, being directly associated with the line finder.

For equipments of more than 80 lines capacity group selectors are fitted and three-digit working is introduced. The group selector can, however, be in the form of a uniselector, thus economising in wiring and space.

Two-digit equipments are arranged as regards wiring, so that group selectors can be readily introduced if at any time the capacity of the installation grows beyond 80 lines.

The apparatus is mounted on G.P.O. type single sided racks 2′ 6″ wide and 7′ 0″ high. It consists of two shelves of line finder uniselectors and two shelves of final selectors together with the necessary alarm and assigner equipments.

Each line finder shelf contains five uniselectors which serve a group of 40 lines. The two shelves therefore serve 80 lines.

Other features. All relays are fitted with twin contacts, thus reducing duty contacts to a minimum.

If the assigner fails to find an idle line finder within 9-18 secs. an alarm is brought in.

The system operates on 50 volts.

Large P.A.B.X. installations.

For P.A.B.X. installations of more than, say, 300 lines, non-director public auto exchange equipment is generally employed. Equipments in service have been installed by the A.E. Co., G.E. Co., S.T. & C. and Siemens for the use of Post Office subscribers.

THE PRACTICE OF OTHER ADMINISTRATIONS.

Facilities. In addition to the facilities provided on P.A.B.X. systems maintained by the Post Office it is interesting to note that there appears to be a demand by other Administrations for the following facilities:—

1. *Conference*—a scheme whereby a particular extension, by dialling a special number, can be simultaneously connected to several extensions for conference purposes. If any particular extension is

engaged when called for " conference " a special signal is generally given to indicate that the line is wanted for " conference." Such a scheme is sometimes useful, for instance as a fire emergency call system, the fire chief being able to obtain immediate connection to members of the brigade.

2. *Staff Call.* By dialling suitable digit combinations special indicator lamps may be operated, or interval signals may be given on hooters or bells installed at various points throughout the premises, in order to call a particular person to the nearest telephone.

3. *Preference Calls.* By dialling certain digits, an extension provided with this facility may break in on another connection in order to give an urgent or important message.

When such facilities are required, due regard must be given to the capacity of the installation and the grade of service, in order that normal working is not affected by their introduction.

Group hunting. If there is more than one extension telephone in the same room it is possible with some systems to allot consecutive numbers to them and provide for incoming calls to hunt for a disengaged line if the extension actually dialled is engaged.

Manual facilities. There would also appear to be a desire to eliminate the manual board entirely, or at any rate to reduce its size considerably. In some systems the public exchange lines are connected *via* suitable switching keys to certain extensions, *i.e.*, each exchange line is allotted a particular extension which will deal with any incoming exchange calls connected to it. Extensions so connected may route calls from the exchange to any other extension on the automatic system by manipulating suitably wired keys and dialling the desired extension number, or may call and speak to any other extension while holding the exchange line. Other extensions not associated with exchange lines obtain access to the public exchange by dialling the number of an extension to which an exchange line is connected. This latter extension can then switch the calling extension through by operating the necessary keys. Such arrangements are very similar in principle to the Post Office special type of extension switchboard $\frac{1+1}{2}$

AT1837 equipment previously described, but do not appear to provide clearing signals at the extension acting as the switching point and also limit the utility of an extension as such when so connected.

A system similar to that described above is employed by the A.E. Co. of America, and a brief description appears in " Automatic Telephone," July-August, 1931.

In other systems a small manual board of the cordless type provides the following connections :—

Calls from the public exchange appear on lamps or indicators suitably labelled at the manual board.

Calls from extensions to the manual board appear on other lamps also suitably labelled. Clearing signals are also provided. Keys similar to those on a cordless board enable an extension to be switched to an exchange line or an exchange line to be switched through to an extension. The operator is provided with a dial telephone by which extensions may be called or calls may be set up to the public exchange and then connected, if desired, to an extension by manipulating suitable keys.

Such arrangements although considerably reducing the size of the manual board do not make provision for operating the P.A.B.X, manually, nor do they provide accommodation for the addition of manual extensions when required; consequently, although it would undoubtedly be an advantage to use a small type of manual board in connection with Post Office approved systems and thus save floor space, it is not at present possible to introduce types such as those described. It is, however, suggested that conditions in this country might be reviewed with a view to a possible reduction in the size of manual boards. For instance, it might be possible in some cases to employ some of the smaller types of Post Office P.B.X. manual board to which extensions dialling " 0 " would be automatically connected.

Some of the more interesting systems employed by other Administrations are briefly described below.

The S.T. & C. 7030 type of P.A.B.X. is shown in Fig. 19. This equipment provides most of the facilities set out in this paper and employs S.T. & C. uniselectors with 25 or 50 point banks, an 11 point " marker " switch and the S.T. & C. " flat " type of relay. An outstanding feature of this system is the unit formation adopted in which the inter-unit

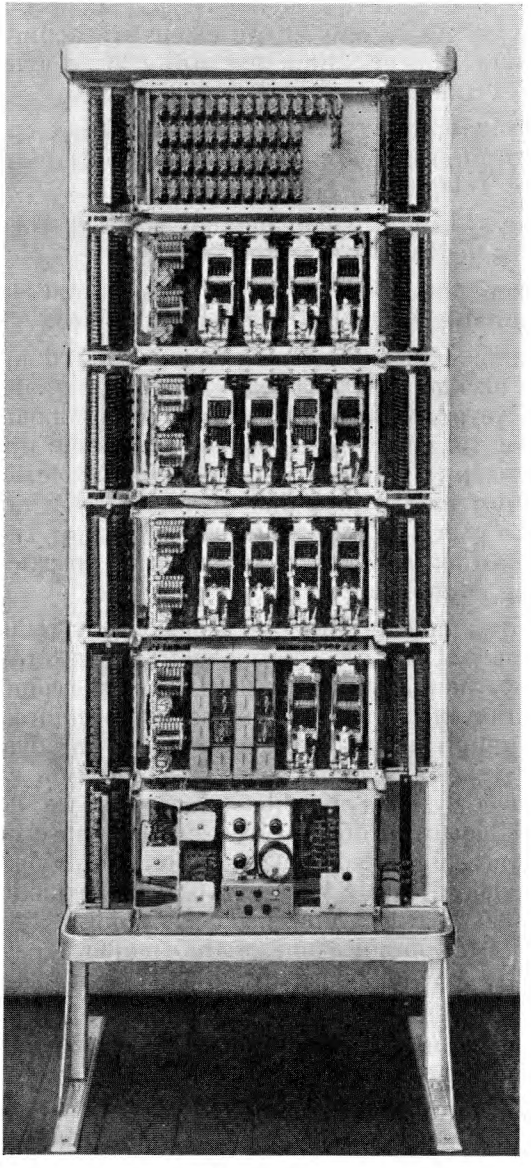


FIG. 19.

cabling is reduced to a minimum. All the units are of similar size, thereby making it an easy matter to compute the space required for a P.A.B.X. installation, before its erection on site.

The line unit comprises one or two mounting plates, each containing 25 line and cut-off relays and their common equipment which are mounted one on each side of the rack.

The connecting circuit unit comprises two connecting circuits, the relays being mounted on a plate on one side of the rack and the switches on a frame on the opposite side.

The exchange line unit. Two complete junction equipments, of which one only need be equipped, are mounted in one unit.

The power unit comprises the ringing and tone unit on one side together with the fuse alarm and junction starting relays. A rectifier, mains transformer, voltmeter and key panel are equipped on the other side.

The battery of 24v is charged and discharged on the " floating " principle. The power equipment can be suitably modified to meet various types of main supply.

Capacity of P.A.B.X.

Extensions are numbered 25-99.
Connecting circuits may be added as required.
Exchange line circuits may be added as required.
Group hunting may be employed over certain extension lines.

A smaller P.A.B.X. equipment known as the 7020 type P.A.B.X., made by the same firm, operates on the same voltage and will cater for 9 extensions, 1 exchange line and 2 connecting links, or 8 extensions 2 exchange lines and 2 connecting links. This equipment can be mounted on the wall and is very compact.

The 4200-D Rotary P.A.B.X. is based on the principles of this company's well known Rotary Public Exchange system, in which the selectors and line finders are power driven through gears from a shaft operated by an electric motor. A small " marker " switch is also employed and this is the only switch controlled by dialled impulses.

The equipment is manufactured in 100 line units, each unit being 7′ 5″ high, 3′ 10″ wide and 2′ 4½″ deep. Space in each unit is left for the addition of an auxiliary unit which

when fitted allows two additional 100 line units to be inter-connected with the first, the capacity of the installation being increased thereby to 300 lines. Two, three or four 100 line units may be inter-connected in this manner, thus increasing the capacity ultimately to 400 lines, and only two auxiliary selector units are required for this purpose.

Each 100 line unit is wired for a maximum of

100 extension line circuits, each of 2 relays.
13 connecting circuits, each comprising one line finder, one final selector, one sequence switch, one marker switch and associated relays.
1 Starting circuit.
1 Ringing and tone circuit.
1 Traffic metering circuit.
1 Alarm circuit.
13 Auxiliary final selectors (only required when the equipment exceeds or will exceed 100 lines).

The initial quantity of equipment fitted is determined by traffic requirements.

The 1/30 h.p. motor driving the shafting may be arranged to start up when a call is originated or to run continuously if desirable.

Being power driven the equipment is very robust and all the selectors are uni-directional in operation. The provision of a sequence switch reduces the number of relays and with its index disc is useful from a maintenance point of view. In addition to the usual facilities, group hunting, information, " call back," tie line, conference, preference, and code calling facilities can be provided.

The system operates on 46 volts.

The A.E. Co. also have several types of P.A.B.X. installation, of which the following are typical:—

The A.E. Co. 20/50 type P.A.B.X. This system has been recently developed. A single unit, shown in Fig. 20, has a capacity of 20 lines and four connecting circuits and contains one ringing and one distributor circuit. It can, however, accommodate as an alternative, 30 lines and four connecting circuits; thus 50 lines and eight connecting circuits are provided by two units bolted together.

Both units are interchangeable. Two-party line service may be provided on certain levels. 31 would be the X line

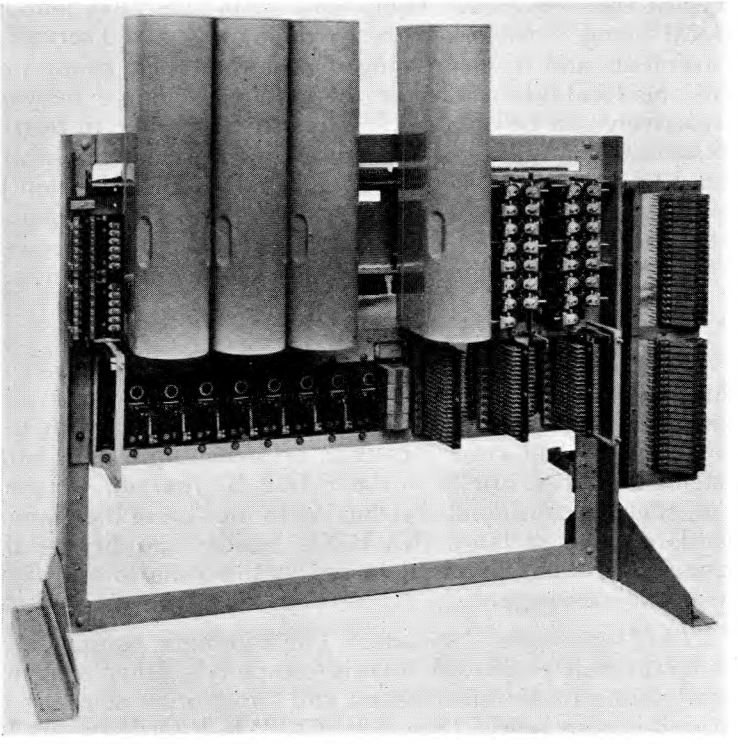


FIG. 20.

and 41 the Y line. If tie line service is not required, levels 31-30 or 41-40 are left spare. The operator's cordless board provides the facilities indicated earlier for this type of manual board.

The battery is charged on the " full float " principle, but the charging circuits can be modified to meet local requirements.

It is interesting to note that an installation of this type is in use at Hull.

" *Mixed Service.*" The A.E. Co. also manufactures a " mixed service " installation which provides for a P.A.X. and a P.A.B.X. installation to be combined as one unit. " Mixed Service " extensions are each provided with two lines, one terminated at the P.A.B.X. equipment and the

other at the " P.A.X." equipment. Suitable keys marked " local " and " network " are provided on " mixed service " instruments and by depressing one or the other, connection with the local extensions or the public exchange network respectively can be obtained. Thus, it is possible to restrict the service on any extension by providing only one line which would be terminated at the P.A.X. or P.A.B.X. portion of the equipment as desired. The connection of two separate lines to " mixed service " instruments would, however, appear to be an uneconomical feature of such a system.

The G.E. Co's System.

This Company manufactures two and three digit systems which operate on a line finder basis and employ the well known Strowger principle of operation combined with this Company's " auto-cord " method of switching. The latter system, described briefly in the *P.O.E.E. Journal,* October, 1930, effects a considerable reduction in the size of the manual board required at large P.A.B.X's besides simplifying the manual operations involved in setting up calls to and from the public exchange.

The " auto-cord " system. The automatic equipment is similar to that employed in this company's other systems, namely, line finder uniselectors and two-motion selectors of the well-known type. (See G.E. Co. " G.P.O. " system.)

Calls from extension to extension are dealt with on an automatic basis over the usual channels, and it is only in the method of providing external connections to and from the public exchange that the special features of the auto-cord system come into operation.

Calls to the public exchange are made by dialling " 0 " to obtain the services of the P.B.X. manual board operator or 9 for direct access; and these digits may be reversed, if necessary, in order to meet individual customer's requirements.

An extension dialling " 0 " causes the wipers of the selector taken into use to rise to the " 0 " level and to search for an idle auto-cord circuit which when found is made to search for the calling extension by means of an extension finder uniselector associated with it. The selector and line finder in the automatic unit are then released and the calling extension is connected direct to the auto-cord circuit. A calling lamp,

associated with the auto-cord circuit and fitted on the key shelf of the manual board, then glows to attract the attention of the operator. The operator answers by throwing a " speaking " key associated with the auto-cord circuit on which the lamp is glowing and speaks to the calling extension. If the extension desires connection to the public exchange the P.A.B.X. operator manipulates a " junction connecting " key. This action causes the " junction finder " switch associated with the auto-cord circuit to hunt for a free public exchange line. If the main exchange is of a manual type the operator will answer and either the calling extension or the P.B.X. operator can give particulars of the required call.

(If the public exchange is of the automatic type, then dial tone will be heard when an exchange line is connected and the P.B.X. operator, by suitably manipulating the keys, can dial or leave the extension caller to dial the required number). The work performed by the P.B.X. operator can therefore be limited where desirable to the manipulation of two keys.

At the termination of the call the replacement of the extension receiver causes the auto-cord circuit to be released, and no clearing signal is necessary at the manual board.

The " junction connect " key can be used as a " hold " key and by leaving it in the operated position the P.B.X. operator obtains full control of the release of the connection, and the extension may re-call by " flashing."

Direct access. Calls to the public exchange *via* " direct access " are completed over circuits virtually the same as those described above except that by dialling " 9 " the selector seizes an idle auto-cord which, having found the calling extension (and released the automatic equipment taken into use) commences to search for a free exchange line, without lighting a lamp at the manual board.

Exchange prohibition may be provided on both " manual " and " direct access " exchange line equipment.

Incoming calls to this type of P.A.B.X. make connection with an idle auto-cord circuit which hunts for the calling line. A junction calling lamp glows at the manual board to indicate the class of call, and the operator throws the speaking key to answer the caller. To complete the connection the operator plugs into the jack of the wanted extension line with the single plug associated with the auto-cord circuit. A supervisory lamp associated with the auto-cord circuit indicates completion

of the call by glowing when the called extension replaces the receiver. The auto-cord circuit is not restored to service, however, until the operator withdraws the plug from the extension jack.

A maximum of 600 extensions and 12 exchange lines can be provided on one position, which is no larger than the P.O. $\frac{10 + 50}{65}$ type of P.B.X. switchboard.

The Ericsson " type B " P.A.B.X. equipment.

The company manufactures two types of P.A.B.X., both of which include the requirements of the Post Office.

Both systems operate from a 50 volt power supply.

This equipment employs forward hunting uniselectors individual to each extension and the connecting circuits contain two-motion switches of standard Strowger type throughout. A typical installation is shown in Fig. 21.

The sizes of the installations depend upon the capacity required and are divided mainly into three; viz.:—50 lines (2 digit), see page 41, 150 lines (3 digit) and over 200 lines (3 digits or more).

Racks. All the above are mounted on G.P.O. type single-sided racks.

The equipment consists of a line finder, group and final selector rack and two line apparatus racks which are of the single-sided type 4′ 6″ wide and 8′ 6″ high. The line apparatus racks are similar to those used for " type A " equipment.

Other features. All relays are fitted with twin contacts, thus reducing dirty contact faults to a minimum.

If the assigner employed in " type A " equipment is operated and fails to find a line finder the release alarm is brought in after 9-18 secs.

P.G. conditions are provided if dialling fails to take place within 30-60 secs. of a line finder being connected with an extension line either due to a fault or due to delayed dialling.

Direct access can be provided on the 9th level and restricted service can be introduced, if required, on any extension.

The manual boards supplied provide through signalling and dialling conditions when necessary.

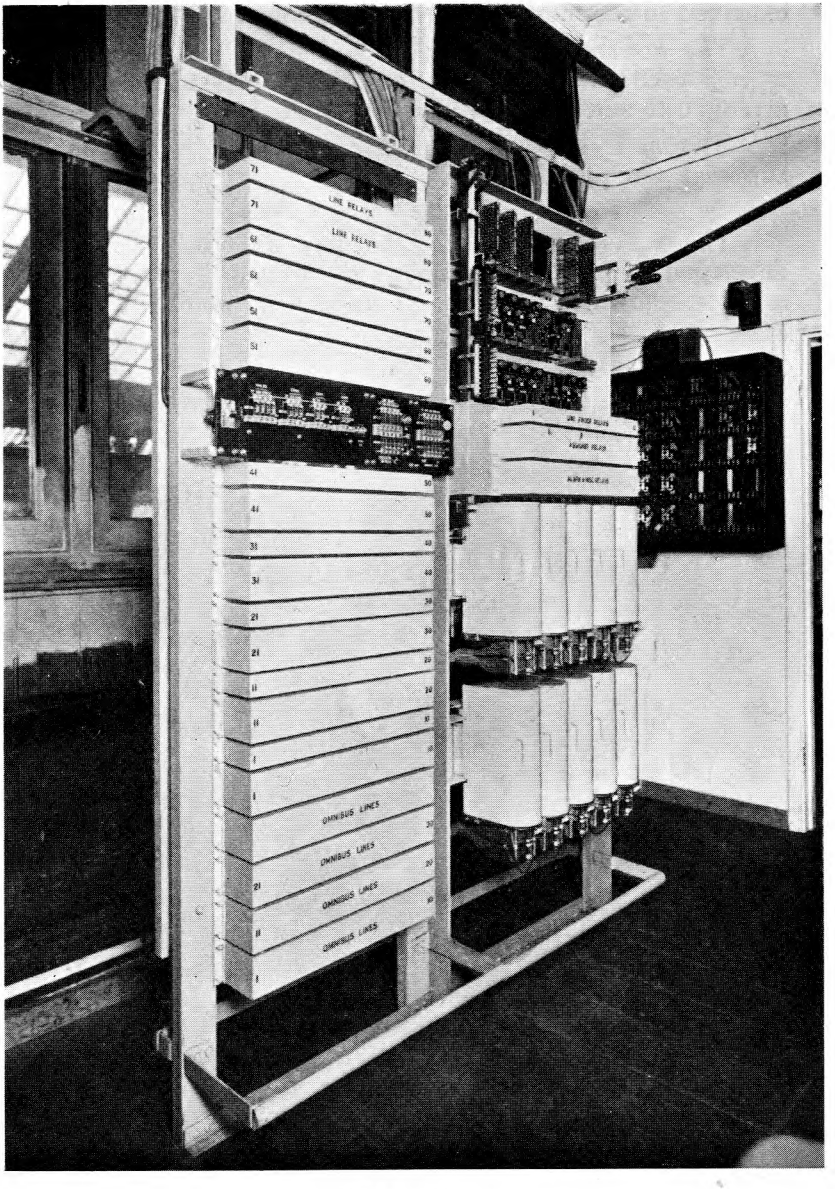

LINE RELAYS
LINE RELAYS
OMNIBUS LINES
OMNIBUS LINES
OMNIBUS LINES
OMNIBUS LINES

FIG. 21.

Alarms. The usual alarms are provided and can be extended to the manual board when required.

The power plant generally consists of two batteries of 25 cells each and motor generator charging plant, but can be arranged to suit any type of main supply.

Automatic charging and *disconnecting devices* can be supplied if required.

The S.T. & C. 30 and 100 line P.A.B.X's recently developed employ this company's " bypath " type of uniselector, shown in Fig. 22. This is a 50 point uniselector

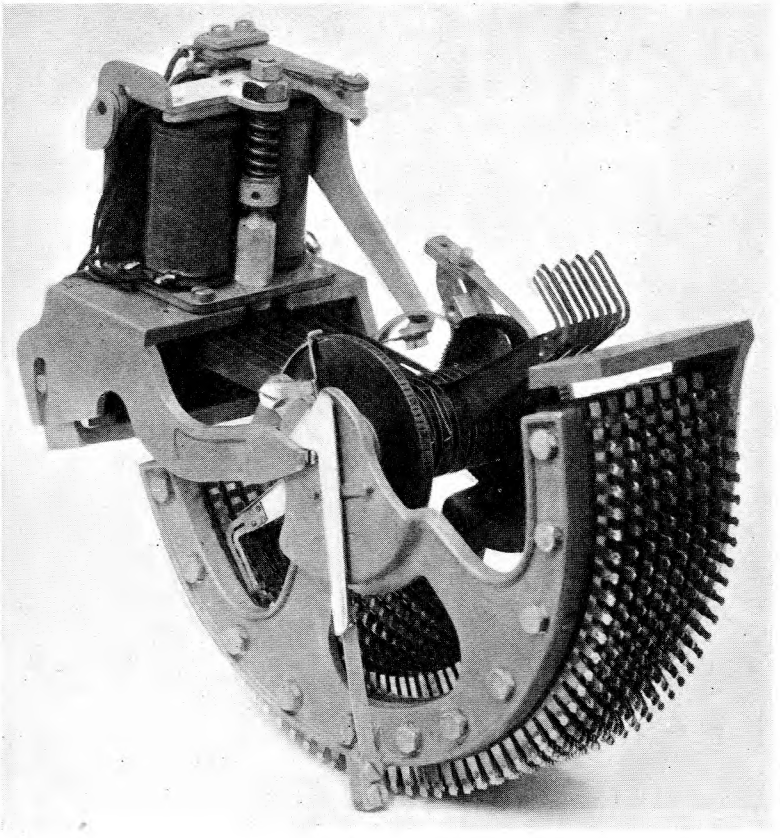


FIG. 22.

with 10 levels. This system has been designed to meet all the Post Office requirements set out in this paper.

The 30 line equipment, Fig. 23, operates as follows:— An extension T on removing the receiver will be found by a line finder F and extended to the connecting circuit C, from which dial tone will be heard.

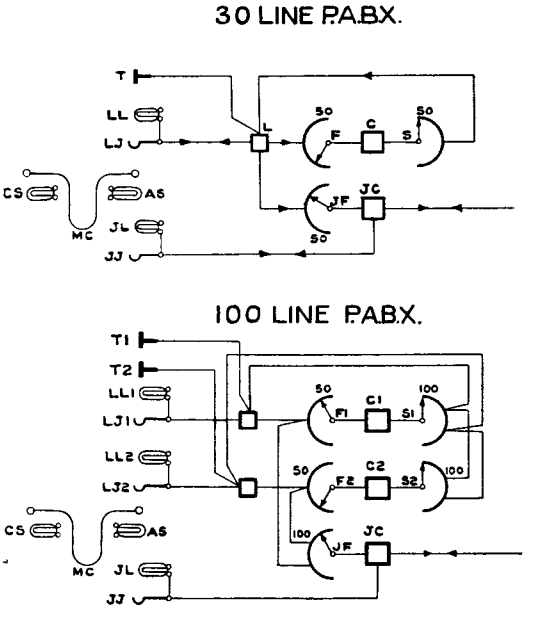


FIG. 23.

The uniselector S will respond to the first digit dialled and operate a relay combination according to the digit dialled.

If the tens digit dialled is 2, 3 or 4, S will drive to the beginning of the required tens group.

S then responds to the second (units) digit dialled and will come to rest on the terminals of the required extension line.

Direct access to the public exchange is obtained by dialling " 9." This causes a free junction JC to hunt for the calling line which will be found by the line finder JF. The connecting circuit C is released when the calling extension

is found by JF and the extension line is extended *via* JC to the public exchange.

Numbering scheme. The numbering scheme is as follows:—

Extensions, 20-49.
Tie lines, 8.
Direct access, 9.
Manual board, 0.
Other levels, N.U. tone.

The 100 line equipment functions in a similar manner. The line finders in this equipment have access to 50 subscribers and consequently are divided into two groups—those serving extensions 20-69 such as T1 in Fig. 23 and those serving extensions 720-769 (such as T2). The selectors have access to all the 100 subscribers.

An 11 point marker switch responds to the first (tens) digit dialled and pilots the selector S to the beginning of the required group.

Selector S responds to the units digit and comes to rest on the terminals of the required line.

If, however, the first digit dialled is 7 then S will stop at the beginning of the 720 group and the marker returns home. In this case the second digit dialled will be routed to the marker switch which pilots S to the beginning of the required tens group. The third digit dialled will actuate S and step it to the terminals of the required extension line.

This equipment is arranged in two 50 line units, the second being added when the capacity of the first is exceeded.

Direct access, tie lines and manual board calls are obtained by dialling 9, 8 or 0 respectively.

STANDARDISATION OF SYSTEMS EMPLOYED BY THE POST OFFICE—IS IT POSSIBLE?

The brief descriptions given of some of the various P.A.B.X. systems available for service will doubtless prompt the question heading this part of the paper, and since most of the systems described are giving satisfactory service and with a little modification would no doubt give a subscriber all the facilities he could possibly desire, the question would appear to be worthy of consideration.

The present diversity in the design of equipments employed by the Post Office necessitates the study of many complex circuit principles and apparatus adjustments. There is another difficulty which has been experienced with the present policy whereby subscribers are required to purchase P.A.B.X. equipments when the number of P.A.B.X. lines exceeds 30; *i.e.*, in some cases it is necessary to estimate for an alteration or a complete change in the type of system, at some stage during normal growth, generally involving the subscriber in a heavy outlay on plant. This policy has also introduced a tendency on the part of contractors to design P.A.B.X's with a maximum capacity of 30 extension lines. From the subscriber's point of view this feature must often make the installation of a P.A.B.X. an uneconomical proposition and undoubtedly prejudices their popularity. Further, a subscriber is likely to criticise adversely public automatic exchange development if his own installation proves costly.

It is also necessary to keep a close watch on the various systems introduced in order to ensure compliance with Post Office specifications and the training of men for the maintenance of the various P.A.B.X. installations is also complicated, special courses having to be arranged for each type. Very often a maintenance officer attends two or more training courses because two or three different types of P.A.B.X. are installed in the exchange section maintained by him. The fact that maintenance is carried out effectively reflects great credit on the training staff at the P.O. Research Station, Dollis Hill, and also upon the capabilities of the officers maintaining P.A.B.X. installations.

Suggested Unit formation of Equipment.

These difficulties could partly be overcome by asking the approved contractors to assemble their equipment in units of a standard size (to be determined by the Post Office) in order that it may be mounted on standard P.O. racks. Such an arrangement should not interfere with the contractors' systems except as regards equipment lay-out. It is suggested, as a guide, that the space occupied by the Post Office standard final selector be regarded as a unit of quarter size and that equipment of one kind be made up into units of $\frac{1}{4}$, $\frac{1}{2}$ or whole size depending upon the contractors' systems involved. Thus a full size unit would occupy the space of four final selectors and other units of equipment

would occupy a correspondingly smaller amount of rack space. Suggested typical examples of unit formation are given in the schedule below :—

Type of Equipment.	Quantity of Equipment.	To Form.
Extension line equipment (to include uniselectors if necessary).	5	½ unit
Line finder equipments (including distributor).	6	½ unit
Connecting link (Unit Auto No. 4).	1	1 unit
A.B. Feeds.	6	1 unit
Recorders.	1	½ unit
Final selectors or group selectors.	1	¼ unit
Ringing machine, choke, transformers, etc.	1	1 unit

Advantages to be gained by proposed units.

Such a scheme, while allowing each contractor to employ his own system, should have the advantage that the size of the P.A.B.X. could readily be altered, by merely removing or jacking in equipment as required. Any one of the systems described could no doubt be suitably modified so that it would never at any time be necessary for the subscriber to buy a completely new system during the growth of his installation. Systems made up in unit form would " always be complete but never finished," and maintenance should be simplified since each system would bear a resemblance to others.

It would be interesting to have the views of contractors on this suggestion. Examples of unit formation are to be seen in the A.E. Co. 30/30 system, the G.E. Co. "G.P.O." system and the Siemens Relay systems. There are, of course, others, some of which are also described in the main part of this paper.

Standardisation of Equipment.

From an engineering point of view, however, the author considers that development, maintenance and the training of men would all be simplified and less costly if one P.A.B.X. system were standardised and designed to function on (1) Post Office public automatic exchange principles, mounted on Post Office standard racking and built up of standard Post Office apparatus, *i.e.*, relays, uniselectors and two-motion selectors, or (2) of one type of equipment such as, for example,

the Relay system. Such a system should have the characteristics tabulated in the appendix I. and should be of unit formation. It should, when required provide all the facilities and conditions of service set out in this paper. There should be no necessity to change the system at any time during its growth, normal development being catered for by adding or removing units as and when required. Since such a system could be designed to provide any of the facilities a subscriber is likely to require it would not be necessary for a subscriber to choose his own system. This should cheapen production and might make it possible for the Post Office to rent such installations to a subscriber whatever the size of the proposed P.A.B.X., and thus further popularise P.A.B.X. installations.

Various types of Private Manual Branch Exchange, *i.e.*, cordless and cord types, have been standardised in this way and all are rented to subscribers.

In conclusion, I desire to express my thanks to the Contractors, whose systems are dealt with in this paper, for the loan of slides, photographs and literature; also to the Engineer-in-Chief's Training School, for the loan of several of the illustrations used in this paper.

APPENDIX I.

CHARACTERISTICS THAT SHOULD BE POSSESSED BY AN IDEAL TYPE OF P.A.B.X. EQUIPMENT.

Characteristics.	Advantages.
1. Power equipment of minimum size.	Size and cost of plant reduced to a minimum.
2. Mains operation via rectifiers, etc., or "full float" principle where mains operation undesirable or impossible.	Maintenance attention, size of plant, and cost reduced to a minimum.
3. Low power consumption.	Assists in reducing size and cost of plant. Power costs reduced.
4. Standard Post Office equipment to be used where possible or, alternatively one type of equipment at all installations.	Cheapens cost of production. Facilitates maintenance and training of maintenance staff.
5. Standard approved circuits.	
6. Standard unit formation.	Reduces development studies to a minimum.
7. Minimum of manually operated plant and connections.	Reduces size of installation and operating costs.
8. Ability to add or remove equipment at any time.	Capacity of P.A.B.X. can be increased or reduced at minimum cost to the subscriber.
9. No necessity to change system or type of installation at any time.	Economy in installation and development costs will lead to greater popularity of P.A.B.X installations among subscribers.
10. Simplicity of maintenance.	This can only be obtained by standardising equipment having the characteristics enumerated 1—9 above.

APPENDIX II.

BIBLIOGRAPHY.
(Publications of kindred interest).

I.P.O.E.E. professional papers.

No. 57. " Private Branch Exchanges." D. H. Kennedy and J. W. Turner, M.I.E.E.

,, 72. " Western Electric Co's Automatic System." B. O. Anson, M.I.E.E.

,, 84. " The Relay System of Automatic Switching." H. W. Dipple, A.M.I.E.E.

,, 100. " Siemens No. 16 Automatic Equipment." C. W. Brown, A.M.I.E.E.

Other Publications.

" Automatic Telephony." W. Aitken. 3 vols.

" Subscribers Apparatus in Automatic Areas." H. G. S. Peck, M.I.E.E. P.O.E.E. Journal, Vol. 20, 1928.

" Private Automatic Branch Exchanges." R. T. A. Dennison. (Pitman's, 1929).

" G.E. Co's Auto-cord System." P.O.E.E. Journal, October, 1930.

" R.A.T. & A.T.M. P.A.B.X. Systems." A. B. Eason. P.O.E.E. Journal, January, 1923.

" Development of P.A.B.X's." J. Radford. P.O.E.E. Journal, January, 1923.

" Principles of Relay Automatic System." G. H. Bryant. P.O.E.E. Journal, January, 1923.

" L.C.C. P.A.B.X., County Hall, Westminster." J. Radford. P.O.E.E. Journal, January, 1924.

" Continental P.A.B.X. Practice." Ir. W. Th. Bahler. P.O.E.E. Journal, October, 1923.

" Automatic Private Branch Exchanges." F. Bastow. P.O.E.E. Journal, January, 1925.

" Port of London Authority P.A.B.X." A. B. Eason. P.O.E.E. Journal, October, 1925.

NOTES ON THE DISCUSSION.

Mr. G. F. GREENHAM :—

Before calling on Mr. Woollard to open the discussion, I should like to express my personal thanks to Mr. Dennison for his very excellent paper.

I have gained much pleasure and profit by listening to him. He has given us a very valuable summary of present-day practice—particularly in connection with the automatic P.B.X's. It takes my mind back 24 years, when I wrote and read a paper on P.B.X's of the manual type. That was in 1906, and in the following year Mr. Ridd read another paper and I think between us we pretty well covered the ground so far as practice then was concerned. Later on, in 1914, Messrs. Kennedy and Turner read a paper and put in a plea for certain principles to be adopted, and it is clear that many of those principles have been adopted in the automatic system.

In looking through my old paper and that by Mr. Ridd, I was surprised at the small change in the number of facilities that have been demanded by the subscriber and provided by the Department. The only thing is that, instead of manual, many are given automatically.

I do not think we can overstress the importance of the P.A.B.X. Anybody listening to this paper will agree that all the complexities are not at the exchange end, and it is rather terrifying to consider the number of systems which are in use in this country. It is bad enough, no doubt, in the London area, where the maintenance is on a functional basis, but imagine, those of you who work in London, what the conditions are in a district like mine, where the maintenance man is generally a dual line-man. He has to climb poles etc., and also to adjust relays and attend to switches.

The importance of the maintenance of subscriber's apparatus cannot be overstressed because the service given depends so much on the type of apparatus and its maintenance.

Some credit must be given to those who have designed the private branch exchanges and the men who maintain the somewhat complicated apparatus. The subscriber, of course,

sees more of that end of the line, where the private branch exchange is installed, than the main exchange, and is apt to judge us by the attention given to him. The final part of the paper deals with the question of standardisation. To my mind, that is perhaps the most important part of it. If we could, as the author suggests, get down to one standard system, the work of the maintenance staff would be very greatly facilitated. I know all the difficulties in getting to that condition, but I hope to live to see the day when some of the systems in use now will have disappeared.

Mr. F. WOOLLARD :—

Mr. Dennison has described not only the types of equipment in use in this country, but has explained the more important features of those in use in other countries.

As in the case of many developments in engineering, one may ask whether the additional cost of automatic as compared with manual equipment justifies its use for P.B.X's, and whilst there is, of course, an economic solution in each particular case, the real difficulty is to say how much one is prepared to pay for an improved service.

The main advantages a P.A.B.X. provides are more rapid connection, instantaneous disconnections, and a 24 hour extension to extension service, and the latter is of importance in such cases as hospitals.

The present policy, introduced some years ago for economic reasons, whereby subscribers are required to purchase P.B.X. equipment of the automatic type, if the number of extensions needed exceeds 30, has tended to curtail the demand for, and popularity of, P.A.B.X. working.

This policy has also led contractors to concentrate on the development of a type of equipment limited in capacity to that which the Department is willing to provide on a rental basis, viz., an ultimate capacity of 30 extension circuits.

The present general financial position has, of course, been a further handicap in the growth of P.A.B.X's as even though the additional cost may well be justified by the improved service so obtained, the fact that the initial outlay, *i.e.*, the rental, is greater for the automatic equipment, determines the position in favour of manual working.

Speaking from my own experience I am firmly of opinion that in many cases of business organisations where the pro-

portion of intercommunication to public exchange calls is appreciable, the P.A.B.X. more than justifies the additional cost it entails, and the advantage of a 24 hour service is in many cases of the utmost value.

Coming now to the actual matter in the paper, Mr. Dennison has covered the ground so thoroughly that there is little to add. I have, however, one or two small points.

Keysenders.

With regard to the use of keysenders at a P.A.B.X. or P.M.B.X., it is, of course, most essential that the equipment to be installed at the subscriber's premises should be of robust construction and of a minimum fault liability. If, however, a satisfactory scheme can be devised whereby the complicated equipment is fitted at the main exchange, this seems to be the proper course and I believe a scheme on these lines has just been developed using voice frequency working.

Manual Positions.

Mr. Dennison suggests that the possibility of reducing the size of the Manual Board should be considered and, whilst I am fully in agreement that these positions should be kept as small as possible, it has to be borne in mind that the less equipment provided the more complex the operating becomes. For example, the present standard manual position has a jack and lamp associated with each extension line and these are used for all connections effected by the operator, mostly, of course, in connection with incoming calls. It is possible, as has been done in certain cases described in the paper, to omit such equipment, but if this is done it involves the operator dialling each extension required and having special tapping facilities, etc., all of which increase the operating time per call. The solution is again, of course, one of economics for the particular case.

Standardisation.

With regard to standardisation, I am quite in agreement that this is the ideal to be aimed at and with the extended use of P.A.B.X. equipments, which we hope for in the near future, no doubt a degree of standardisation will be possible. The present policy whereby a subscriber may purchase his equipment does not, of course, tend towards standardisation.

I think most people will agree that telephone development was never in a greater state of flux than it is at

the present time even in the case of public exchange equipments and the natural tendency with regard to equipment for subscribers use is for it to follow the main principles of design used for the public systems. The difficulty in effecting complete standardisation of P.A.B.X. equipments will, I think, be appreciated when one considers the many and varied nature of the facilities required by different classes of user and of which Mr. Dennison has given ample demonstration in his paper. Unlike a public system many of the facilities required by one subscriber are not those required by another and for this reason it would not, of course, be an economic procedure to attempt to include one and all of these facilities in a standard equipment. A compromise which gives a fair degree of flexibility must therefore be followed.

Power Supply.

With regard to the power supply for P.A.B.X's, it seems desirable for the designers in future to aim at the provision of plant with a wider permissible voltage range than at present, bearing in mind, of course, the characteristics of secondary cells. If this be done it would enable the " full float " system, *i.e.*, trickle charge system, referred to by Mr. Dennison, to be used. At present the voltage limits required by the apparatus prevent such means being employed, although they are now being used with satisfactory results in the case of large manual P.B.X's.

Unit formation of Equipment.

The suggestion made in the paper in this direction is attractive, and I hope we shall have the pleasure of hearing the views of some of the contractors on this point.

Col. F. REID :—

I also should like to pay a tribute to the excellence of this paper. When one considers that an operator is required for incoming calls, and that the habits of the business community are based largely on P.B.X. manual operations, one feels that for a long time at least the manual type of branch exchange will be in great demand, and I cannot help feeling that a lot of the work put into the development of P.A.B.X's would be better spent in improving private manual branch exchanges.

I contend, thanks to the genius of Mr. McAdie, that the Post Office has now the design of a keysender which is

sufficiently small to be used on existing P.B.X's, and which will give a reliable service. By its aid an operator can set up, with much less effort than it takes to dial, a 7-digit call in $2\frac{1}{2}$ seconds. We have made four models to check the design. It is some tribute to the design and thoroughness of the General Electric Co's work that the last model worked without any adjustment. The design is cheap to produce. Models in the various stages of development were sent to the Research Section and there we have been most ably assisted by Mr. Williams. Since 1st October, one model has been in use in the Research Section P.B.X. and has given much satisfaction. During that time, apart from one spring, it has required no attention whatever.

Ever since I have been interested in this question of key-sending I have found two schools of thought in the Post Office—one which contends there is no sender at all suitable for use in the P.B.X. and the other, that a cheap, reliable, keysender can be a very important contribution to the successful working of an automatic system. What are some of the arguments—One in favour of the keysender, is a psychological one. A second, is a saving of time. The keysender—especially with the 7-digit case—saves about eight seconds on each outward call.

As to cost, I am confident that, if used in quantities, the McAdie keysender cost will not exceed that of a few dials. My argument is, if you can afford the dial you can afford the keysender on every P.B.X. Another argument against key-senders, is that of complication and that you must have heavy maintenance costs. I have a watch in my pocket which is much more complicated, but neither its complexity nor its heavy maintenance deters me from carrying it about.

Another argument is bulk. Future development will certainly reduce this.

As regards the voice frequency keysending system, I would like to hear the views of some of the people who have been working on that system. It is open to a good many objections, in addition to one mentioned in the paper about night service.

Mr. E. DICKSON :—

Direct Access.

One point is on " direct access " to manual exchanges.

It is a requirement of the Post Office that the connection from an extension to the public manual exchange shall not be released until the main exchange operator clears the connection. Now, unless there is some alteration made in the line equipment at the main exchange, I cannot see how a clearing signal is passed to the P.A.B.X. apparatus. Perhaps Mr. Dennison will enlighten me.

Restricted Service.

With regard to restricted service, it is suggested that a subscriber calling from an extension that is restricted and not entitled to direct service should preferably be extended to the operator. Does that mean that when such an extension attempts to dial out it should be thrown on to the manual board? It is rather a pity to let a restricted extension have access to an operator; it would be better to tell the former he had done something wrong, by giving him N.U. tone.

Bothway junction working on the multi-office scheme.

When the call arrives at the distant P.A.B.X. the local apparatus has the incoming call, which means a double search. Is any particular signal going to be given to a subscriber, such as dialling tone? If not, there is considerable danger of losing a call.

As a matter of interest, I would like the author's views on direct dialling. Abroad, it is used quite a lot.

Mr. F. B. CHAPMAN:—

A scheme has been devised whereby dialling and key-sending can be performed from the P.B.X., and which provides for an extension on night service to be in a position to dial without the necessity of using digit keys.

Mr. R. W. PALMER:—

With regard to the details of an ideal scheme dealt with in the latter part of the paper, it seems as if efforts ought to be directed towards a reduction of the labour on the manual board as far as possible, because the smaller boards are not full time loads. It appears on an average that one operator can deal with at least 100 extensions, and there are many installations in which there are only 30 or so extensions, so that she could do other work. If we can lighten the load of the operator, it is of advantage, in running a P.B.X., to

reduce the number of interruptions of that other work as far as possible. The auto-cord principle is of great value and should be carried still further. For instance, for calls to the main exchange, you could simply depress a key and the junction finder will hunt and find an idle exchange line.

On incoming calls, the operator has to pick up the manual cord and plug into an extension, and also to watch the signal, so you really do not need a human brain; it seems that it should all be done automatically including the release of the connection.

Mr. R. T. A. DENNISON (*in reply*):—

The Chairman has made some very interesting remarks on the paper. He comments on the small number of facilities that are asked for by subscribers. Mr. Woollard, I think, has answered that question by stating that there are many.

I quite agree with the Chairman in saying that the P.B.X. is very important and that the number of systems in service increase maintenance difficulties. An engineering officer who has two or three systems to maintain is not always in a position to familiarise himself with the equipment and circuits of each especially if he visits them only once or twice a week.

Mr. Woollard has also given many interesting points.

Regarding the increased cost incurred with automatic systems, and whether it would justify the use of automatic equipment in place of manual equipment, I think that P.M.B.X's and P.A.B.X's have each their own sphere of usefulness and it is principally a matter of the subscriber's choice. The fact that he will obtain speedier operation and a full 24 hours' service without the necessity of a manual operator, from the extension to extension point of view, and can obtain other facilities such as bothway junction working on an automatic basis which cannot be added so readily to manual equipment, should be points in favour of the P.A.B.X.

The policy of limiting the types rented by subscribers to 30 lines has undoubtedly caused contractors to design systems with a maximum of 30 lines. We have, as I have shown you to-night, several 30 line systems which will require some modification if additional units are added. This means that for more than 30 lines the whole of the equipment would have

to be taken out and a new P.A.B.X. installed, for which the subscriber would have to pay. I think this is a disadvantage. My personal opinion is that we should provide a central nucleus consisting of, say, standard automatic equipment of Post Office type, *i.e.*, uniselectors, two-motion switches and relays. This equipment, mounted on standard Post Office racks, would provide extension to extension and manual board facilities. If any additional facilities are required by the subscriber they should be in the form of jack-in relay sets additional to the central nucleus of equipment. You would then have a standard P.A.B.X. built up of so many connecting circuits, etc., which could be added to as time went on. There would be no need to change it. The additional facilities (*i.e.*, relay sets) could be supplied at suitable rentals.

Standardisation.

Telephone development, as Mr. Woollard says, is in a state of flux and we are always meeting with new developments. We cannot therefore accept the ideal of one fixed standardised system, but must always move with the times. Standardisation must, of course, be developed with that end in view and must always be adapted to meet new requirements. I must not say more on this subject or I shall probably be encroaching on Mr. O'dell's paper on " Standardisation."

Power Plant.

In the case of mains operation pure and simple a breakdown in the main power supply would put the whole of the subscribers' telephone system out of order and, of course, the breakdown of the mains will also put his lighting and power services out of commission. Immediately that happens a subscriber would endeavour to 'phone the electrician to see what was wrong. He would, of course, not get through and probably confusion would be caused. It appears desirable, therefore, that a small battery be trickle-charged off the mains so that it can take the load in cases of failure. That seems to be the ideal arrangement.

I have already pointed out what I consider to be the ideal arrangement for automatic P.B.X. equipment, and I think we would reach a better position as regards standardisation if such a scheme were carried out.

P.M.B.X. requirements.

Col. Reid considers that I have neglected P.M.B.X. requirements in the paper. It seemed to me that there was only one point which could possibly be considered in connection with P.M.B.X's, *i.e.*, keysending when the public exchange is of the automatic type. I understand that keysenders are still under investigation by the Department and Col. Reid has given us some interesting details of the keysender, shown in Fig. 1, and designed by Mr. McAdie. Until the investigations are complete I do not think we can say exactly what the position will be regarding their use.

Direct Access.

Mr. Dickson has pointed out that in the case of direct access to manual public exchanges an alteration must be made at the manual public exchange. That is so, of course. Either one line or the other, depending upon the type of public exchange, is disconnected at the cut-off relay at the public exchange, so that we obtain supervisory conditions over one line while the plug is out of the jack at the public exchange.

Restricted Service.

Another point raised was: An extension having a restricted service when dialling nine, should not obtain access to the manual operator but receive N.U. tone. Well, it may so happen that a manager or director may be out in the general office and require to make an urgent call *via* the public exchange. If that extension were " restricted " he would get N.U. tone and I think it better to allow him to obtain access to the manual board. In any case it rests with the subscriber as to which service he prefers.

Direct dialling-in.

Is dealt with fully in the paper.

If it be required to ring up, say, Selfridges, it would be necessary to know the extension number of the Department concerned, which would mean a separate directory. It might be possible for the firm to provide one themselves in the form of advertisement matter, but I think it would necessitate an additional public directory also which would certainly be an unwieldy affair. From an engineering point of view, of course, " direct dialling-in " is quite possible.

V.F. Keysending.

Mr. Chapman tells us that there is such a thing as a voice-frequency keysender for P.B.X. service. I should be very interested to see it, as I had not heard of it before coming here. I think we should have solved the problem of setting up the call speedily by introducing such a scheme for, as soon as the seven digits have been set up, the keys presumably are ready for the receipt of another number and can be used immediately. That is one great advantage, even if the equipment is otherwise unwieldy.

I thank you, in conclusion, for the kind reception which you have given this paper.

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