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THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Post Office Standard P.A.B.X.s

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Part 3.—The P.A.B.X. No. 3

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This series of three articles concludes with a description of the P.A.B.X. No. 3, which provides for 50 extension lines and over, and is the largest in the range. Some details are also included regarding satellite working with P.A.B.X. No. 3 equipment, e.g. where it is desired to centralise the manual board for two or more separate installations.

Introduction

CONCURRENTLY with the development of the smaller P.A.B.X. units described in the previous articles,[1] the P.A.B.X. No. 3 was designed to provide for the larger installations exceeding 50 automatic extension circuits. Its introduction was somewhat later, the first installation, of 350 lines (extension circuits), being completed in 1952. Considerable progress has been made since then, and some 100 installations have been completed or are projected, totalling approximately 25,000 lines.

Standardisation is not so complete as for the P.A.B.X.s Nos. 1 and 2. Components and circuits are standard for all installations but manufacturers are free to arrange and interconnect the equipment in a manner best suited to individual manufacturing and installation methods, always provided the installation as a whole conforms to approved current practice. Within these terms there is little scope for any important differences between installations and the smaller installations do, in fact, follow a common pattern. Larger installations invariably need to be arranged in accordance with the circumstances of the particular case and are to that extent "tailor made." Complete uniformity, even if it could be attained, would, in any case, be undesirable economically, and all the advantages of standardisation from the maintenance angle have been realised while leaving an essential measure of flexibility.

The equipment has been designed with the average case in mind but a limiting size has not been laid down. The largest installation so far has been one of 2,400 lines and enquiries have been made for installations up to 4,000 lines. The size of the manual board extension multiple must of course be kept within reasonable limits and with the type of manual board normally used, the limit is approximately 2,400 lines. This limit can, however, be exceeded if main-exchange-type manual boards are used.

Fig. 1 gives a picture of the apparatus for a 500-line installation and at first sight it might seem that public exchange automatic equipment could be readily adapted for large P.A.B.X.s. While in principle there is much in common between the two, important differences are apparent when their respective functions are more closely studied. Apart from some differences in the facilities required, the special design of P.A.B.X. equipment is necessary because:

(1) The standard methods of signalling used for main exchanges cannot be applied to P.A.B.X.s. The main exchange to P.B.X. connection is by means of ordinary exchange lines, and signalling is thus limited in scope to that provided for the direct exchange line. The necessity for designing a P.B.X. network which must have through access over this link is a controlling factor in the choice of signalling methods throughout the whole of the P.B.X. network.

(2) The transmission and signalling limits for exchange line connections must not be greater than those allowed for the D.E.L. This factor introduces problems in design because most P.B.X. circuits must be capable of connection to exchange circuits.

FIG. 1.—TYPICAL 500-LINE INSTALLATION OF P.A.B.X. NO. 3.

(3) Incoming exchange calls must always be dealt with manually, and it follows therefore that a manual multiple of extension circuits should be provided as the best means for setting up exchange connections. Such manual connections must permit through signalling and dialling.

(4) Sleeve-control principles cannot be economically applied to P.B.X. working.

Outline of Equipment

The P.A.B.X. No. 3 employs 50-point uniselectors as line finders, with 2,000-type group selectors and final selectors. The relay sets are for the most part of standard "jack-in" type and all equipment is mounted upon open-type racks. The layout of the equipment varies somewhat between manufacturers, but, in general, an installation consists of three main types of rack,

(*a*) Line and Final Selector rack,
(*b*) Group Selector Rack,
(*c*) Relay Set Rack.

It is usual for small installations to combine the group selectors and relay sets into one rack, and one manufacturer uses a design whereby all the equipment for a 50/100-line installation is mounted upon one composite rack. Generally, 7 ft. 6 in. equipment racks are used, this height being suitable for most subscribers' premises and affording easy access for maintenance. For large installations, where the accommodation allows, 8 ft. 6½ in. racks may be employed. The mounting of equipment on racks is such that an installation may be easily extended in multiples of 50 lines and is arranged in units, as far as practicable, to facilitate stock provision.

Automatic Equipment.

Fig. 2 shows three typical "basic" racks. The line and final selector rack (Fig. 2 (*a*)) is equipped for 100 extensions with 10 final selectors. Some investigation was made to

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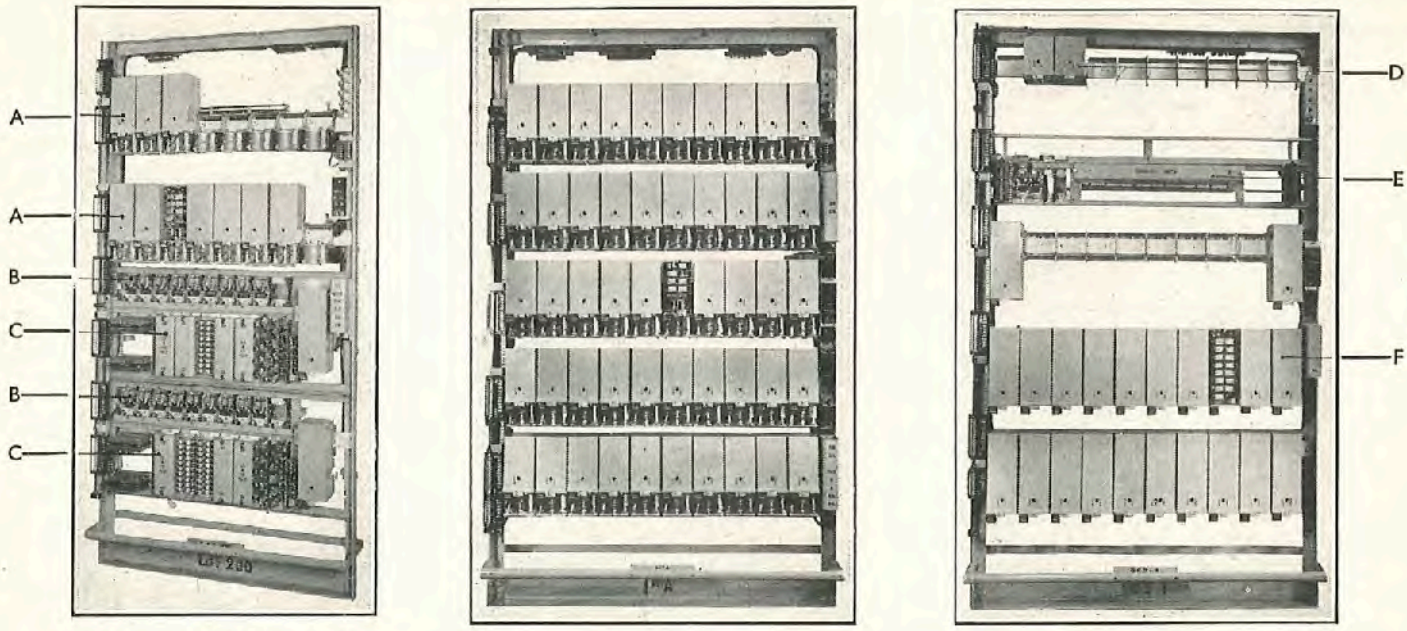
[1] *P.O.E.E.J.*, Vol. 46, p. 159, and Vol. 47, p. 41.



(*a*) Line and Final Selector Rack.
A.—Final Selectors
B.—Line Finders
C.—Line Circuits

(*b*) Group Selector Rack.

(*c*) Relay Set Rack.
D.—Miscellaneous Relay Sets
E.—Enquiry Circuit
F.—Exchange and I/S Line Relay Sets

FIG. 2.—TYPICAL AUTOMATIC EQUIPMENT RACKS.

determine the maximum traffic likely to be encountered at the average installation, and it was found that a provision of 10 linefinders per 50 extensions and 14 final selectors per 100 extensions would meet the majority of cases. Thus, 50 extension line circuits and 10 linefinders are mounted on a composite shelf and each rack accommodates two such shelves, making a 100-line unit. The final selectors are mounted above, the rack shown providing for a maximum of 16. The number of final selectors per rack depends upon the particular manufacturer's standard and in the event of a greater number being required they must be mounted elsewhere. Connection between the final selector multiple and the corresponding extension line circuit is by means of permanent cabling on the rack, but limited I.D.F. facilities are available on the final selector shelf multiple strips.

Fig. **2** (*b*) shows the group selector rack, on which grading facilities are provided on the shelf tag blocks. The wiring of the shelves of the relay set racks (Fig. **2** (*c*)) has been arranged so that it is possible to accommodate either exchange or inter-switchboard line relay sets on the same shelf.

Manual Board.

P.M.B.X. 1A sections are used for the manual board as previously described for the P.A.B.X. No. 2 except that a multiple of extension circuits is now required. A 4-panel multiple is used and for sizes up to 800 lines an individual "0" level calling lamp per extension is provided. (This is known as "lamp per line" working and was described in the previous article). Only one lamp appearance is permitted and distribution of the "0" level traffic is accomplished by fitting lamps to the extension circuits in selected panels only.

When 800 lines are exceeded "0" level working is used and the whole multiple space is made available for extension jacks. The total number which can be accommodated with a standard P.M.B.X. 1A section is 1,200. By increasing the height of the sections, a multiple of 2,400 can be provided. Above this capacity, the manual boards will be specially constructed and will be similar in physical design to main-exchange-type manual boards. The circuits will, however, conform in all respects to the standard P.A.B.X. arrangements.

GENERAL DESCRIPTION

Facilities.

The facilities provided are very similar to those of the P.A.B.X. No. 2. Automatic transfer of calls is not provided, however, and it follows that "dial 8" night service cannot be given. Automatic transfer would greatly increase the complexity of the switching arrangements and, as an operator is available to transfer calls, would not be a worthwhile provision. Again, "dial 8" night service is considerably less important for larger P.A.B.X.s and the more conventional methods of providing night service are followed. The enquiry facility is retained but is available only on exchange line calls. Free-line signalling and ancillary working are available on exchange and inter-switchboard circuits, and P.B.X. final selectors, 2-10 lines, can be provided. Manual extensions can be provided as desired with, or without, incoming automatic access.

Trunking Arrangements.

Fig. **3** shows a typical trunking scheme for a P.A.B.X. No. 3. Depending upon the size of the installation, 3-digit, mixed 3- or 4-digit, or 4-digit numbering is used for extensions. Level "0" is used for manual board assistance and level "9" for direct access to the public exchange. Levels "7" and "8" are either trunked direct or via second selectors to give dialling access to inter-switchboard lines working on an automatic signalling basis.

Extension Line Circuit.

The line circuit is the same as that previously described, having "P.G. lock-out" facility. Extensions can be individually barred from direct access.

Linefinders and Group Selectors.

One hundred outlet selectors are used for both first and second group selectors; 10 linefinder-first selector circuits can be provided per group of 50 extensions and will handle the maximum traffic normally encountered. While it may be

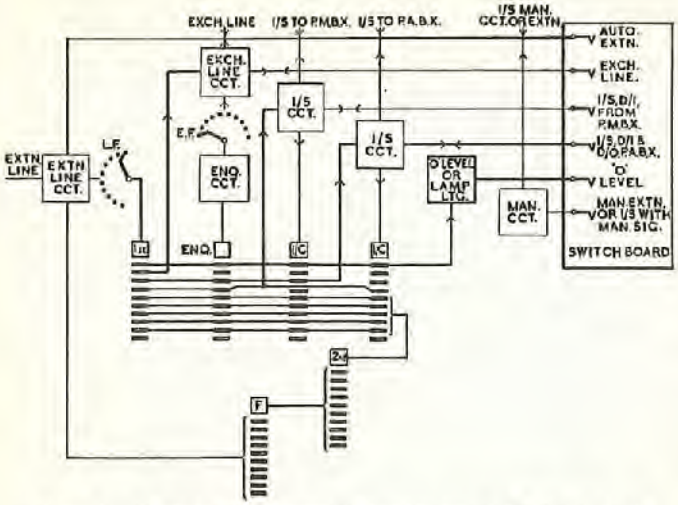


FIG. 3.—TYPICAL TRUNKING DIAGRAM OF P.A.B.X. NO. 3.

necessary to allocate heavily worked extensions to even out the traffic over 50-line groups, no case has yet arisen where additional first selectors have been required. To keep within the standard scheme the number of extensions per group could be reduced if such a case arises or, alternatively, special arrangements would have to be made. The first selector circuit arranges for the P.G. condition to be applied if dialling is delayed, and for N.U. tone to be returned if spare levels are dialled or if a "barred" extension dials the exchange. It is also forcibly released when the operator answers an "0" level call.

The linefinder start arrangements are similar to those of the P.A.B.X. No. 1 in that test circuits of the first group selectors serving each linefinder group are arranged in the form of a chain, the start condition being connected through the pulse circuit to distribute the traffic over the first selectors and to reduce the possibility of lost calls if a selector becomes faulty.

The Final Selector.

Again, 100 outlet selectors are used, ordinary, or with 2-10 P.B.X. facilities. The facilities given by the final selectors follow common practice with the exception that N.U. tone is returned from the selector on a P.G. or when an unallotted number is dialled; also, first party release is given. The discrimination is done over the hold (H) wire of the line circuit. Fig. 4 shows the elements of the circuit. Relay HT tests the conditions on the H-wire during the release time of relay E (operated during rotary stepping). If the line circuit is free, HT will operate to the 250-ohm battery of the line circuit and during the release time of E will operate

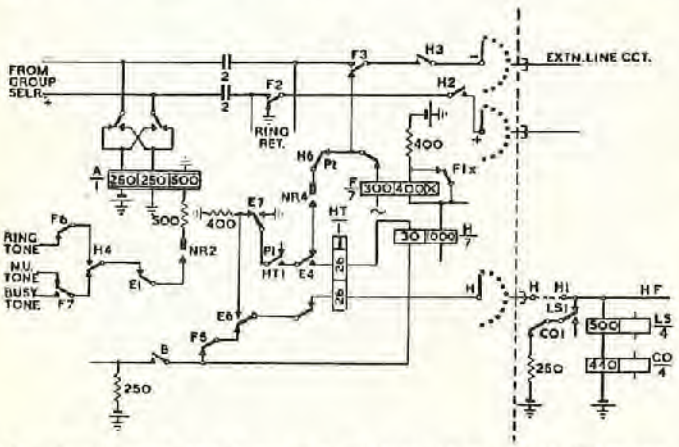


FIG. 4.—TESTING AND SWITCHING ELEMENTS OF FINAL SELECTOR.

II. If the engaged condition, earth on the H-wire, is met, HT does not operate until the release of E, when F will also be operated to return busy tone. Under P.G. conditions relay CO will be operated and the testing battery removed, or if unallotted, the H-wire is left disconnected. HT will not operate under these conditions and with F and H unoperated N.U. tone is returned to the caller.

The Exchange Line Circuit.

The exchange line circuit is perhaps the most complicated of the P.A.B.X. No. 3 circuits. It must provide:—

(*a*) Direct routing of incoming exchange calls to the manual board, and supervisory control.
(*b*) Direct access to the exchange line from the 9th level of the first selectors.
(*c*) Upon the receipt of the "enquiry" signal, for holding the exchange connection and connection of the extension through to the enquiry circuit.
(*d*) "Disconnect clearing" (described in the first article on the No. 1 equipment).
(*e*) Follow-on call trap.
(*f*) Free-line signalling or ancillary working if required.

Additionally, the circuit must work to any type of main exchange, but to avoid including equipment which will be rarely used, a separate "adaptor" relay set is fitted when the main exchange is either C.B.S. or magneto.

Inter-Switchboard Circuits and Through Dialling.

The demand for interconnection between P.B.X.s is growing and standard circuits have been designed to provide for the various types of connection required. All circuits provide for both-way working as it is rare for unidirectional circuits to be provided. There are four main types of circuit as follows:—

(*a*) Both-way dialling, P.A.B.X. to P.A.B.X., with joint access from the P.A.B.X. manual board at each end.
(*b*) Both-way P.A.B.X. to P.M.B.X., with access from selector levels and manual board at the P.A.B.X. and "dialling-in" from the P.M.B.X.
(*c*) As above, but without "dialling-in."
(*d*) Manual to manual.

(*a*) and (*b*) are used where possible, i.e. whenever the circuit length is within pulsing limits; (*c*) is used for circuits beyond pulsing limits, but where D.C. signalling can be used and (*d*) where A.C. signalling methods must be employed. Incoming access to the P.A.B.X. manual board in the case of (*a*) and (*b*) is obtained by dialling "0" but the seizure of an "0" level circuit or lamp-lighting circuit causes the calling lamp of the circuit concerned to light and the circuit to be switched directly to the manual board, releasing the I/C selector.

In the general case, P.B.X.s are not required to give "tandem" or "through switching," but there is a limited demand for the facility where a number of installations are linked together by private circuits. Signalling terminations are therefore arranged to give supervision when through connections are made, but "backward through-clearing" cannot be provided. The P.A.B.X. No. 3 has been designed to provide for through dialling and thus a P.A.B.X. can be used as a "tandem" switching centre within a group of associated P.B.X.s.

Enquiry and Operator Recall.

The enquiry facility is available on exchange line calls only. If it is desired to transfer a call from one extension to another, the P.A.B.X. operator must be called into the circuit to set up the new connections. As shown on the trunking diagram, Fig. 3, the enquiry circuit is connected directly to a first selector and to a finder which searches for the exchange line circuit on which enquiry is being made.

The normal provision of enquiry circuits is one per ten exchange lines. A single depression of the recall button on an extension telephone connected to a public exchange call, either direct or via the P.A.B.X. manual board, will cause the enquiry finder to hunt for the exchange line circuit. The extension will be connected to an enquiry first selector and the exchange connection held. An enquiry call can be made and a second depression of the recall button causes a return to the previous connection. Two consecutive depressions of the recall button will recall the operator by flashing the exchange line calling lamp, and should the enquiry circuit be engaged this will automatically happen on the first depression.

"O" Level.

"Lamp per line" working, as described for the P.A.B.X., No. 2 is used for the majority of the installations. While this method of calling has advantages from an operating standpoint, it is expensive in manual board space and the extension line lamps cannot be accommodated if the number of extensions exceeds 800. Separate "0" level circuits are therefore provided for all large installations. To economise in switching equipment, the circuits are used to book the call only, the operator setting up the connection over the extension multiple. For an "on demand" call, the "0" level circuit and selector are automatically released when the operator plugs into the multiple jack.

Night Service Switchboard.

Direct extension night service, i.e. the connection of selected extensions to exchange lines by plugging through at the manual board, is available and satisfies the needs of most subscribers. There is the special case where a separate manual board is required, upon which certain exchange lines may be concentrated with access to the main automatic equipment. These cases are most usually met by the provision of a "subsidiary night service switchboard," which has been specially designed for the P.A.B.X. No. 3. This switchboard is generally remote from the manual board and has no function during normal hours. It is brought into use when the night service keys are operated on the manual board and is a cordless board, providing for the extension of four exchange lines (maximum six) with directly associated both-way circuits to the P.A.B.X.

Fig. 5 shows the arrangement schematically. The contacts marked NS refer to the night service key on the manual board. When this key is operated the exchange line circuit is disconnected from the manual board and transferred to the night service switchboard. Four "0" level circuits or lamp-lighting circuits are specially arranged so that they will provide access to the automatic equipment via specially allocated extension line circuits and also call the night service switchboard if a P.A.B.X. extension dials "0." When the main switchboard is unstaffed, therefore, exchange line calls are received at the night-service switchboard and the night service operator may dial over the "0" level and extension circuit, connecting the caller to the required extension. Alternatively, any extension dialling "0" may be connected to an exchange line. The night service switchboard has been designed primarily to be simple to operate (the operator may be a night watchman) and flexible switching has not been provided. If an "0" level call and exchange line call are received simultaneously on the same circuit, the "0" level call is forcibly released and the exchange circuit connected. The "0" level caller must recall. If more elaborate arrangements are required, then a standard switchboard can be used or alternatively a section of the main switchboard would remain staffed at night.

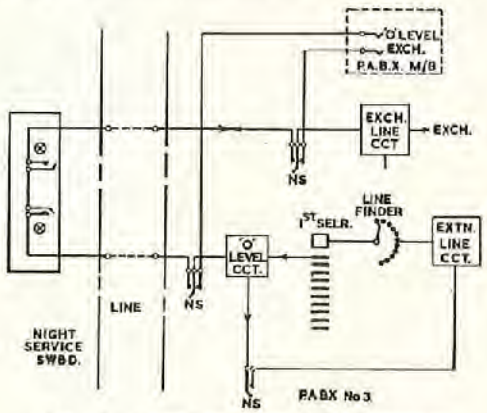


FIG. 5.—NIGHT SERVICE ARRANGEMENTS.

Power Supplies and Miscellaneous Services.

Ringing and tone supplies are generated from vibrating relays, and timed pulses from a stepping uniselector. One set of common equipment is provided per 200 extension circuits. Alternatively, especially on large installations, ringing machines may be installed. It is probable that ringing machines will become the standard provision in the future.

A 6V A.C. supply is provided for F.I.S. and multiple answering lamps. In the case of the latter, the primary appearance is fed from the P.A.B.X. battery and the secondary appearances from 6V A.C. The primary appearances will thus continue to function in the event of a mains failure.

A single battery float scheme at a nominal 50V is used, charged from a rectifier having automatic compensation. A.C. mains are normally available but if D.C. mains supplies must be used, special arrangements are made.

Automatic equipment alarms are given at the manual board but at larger installations, where full-time maintenance staff are available, main exchange practice is followed.

SATELLITE WORKING

General.

A standard satellite scheme is a recent development. Its economic advantages can be used in cases where large groups of external extensions would otherwise be necessary or where it is desirable to centralise the manual board of two or more separate installations. Its disadvantages are that an operator must dial satellite numbers; full P.A.B.X. No. 3 facilities cannot be given to satellite extensions, and unless a self-contained numbering scheme is used, a common directory for main and satellite numbers is not possible.

Where possible, standard P.A.B.X. No. 3 circuit design and equipment have been used, but some changes have had to be made, primarily to extend essential facilities over the main-to-satellite circuits. The facilities concerned are:—

(*a*) *Trunk Offering.*—A satellite extension will not appear on the manual multiple and thus the final selectors must provide for trunk offering.

(*b*) *"0" Level.*—To retain "0" as a single code for the satellite extension, the satellite-to-main relay set must be capable of discrimination, and route an "0" call direct to the manual board.

(*c*) *Alarm Extension.*—Means must be provided for the automatic extension of urgent satellite alarms to the main.

(*d*) *Night Service.*—Automatic switching of satellite extensions to inter-switchboard circuits is necessary to provide night service facilities.

It has not been found practicable to give enquiry or direct

exchange access via the main. Direct exchange access can only be given to exchange lines connected directly to the satellite, which would be unidirectional, O/G circuits only.

Trunking and Numbering Scheme.

Fig. **6** shows a typical trunking arrangement. The satellite 1st selectors do not provide for discrimination on the 1st digit, thus self-contained numbering schemes can

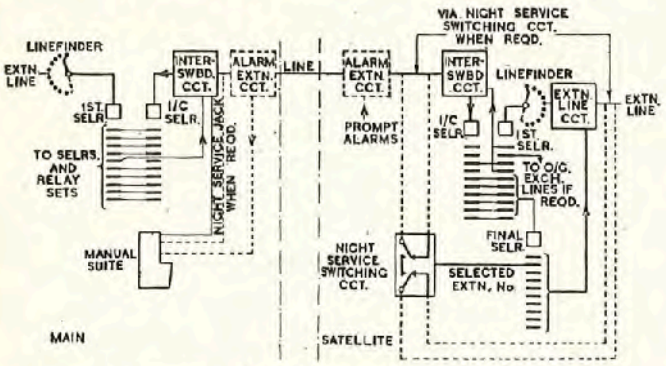


FIG. 6.—TYPICAL MAIN–SATELLITE TRUNKING SCHEME.

only be used where 2nd selectors are employed, making it possible to connect the inter-switchboard circuits to 2nd selectors at both main and satellite. While the main may be large enough to require 2nd selectors it is most unlikely that the satellite would be. In any case, mixed 3- and 4-digit numbering could not be employed. Self-contained numbering schemes are therefore ruled out in the general case on the grounds of economy. In the example shown in Fig. **6** access between main and satellite is over level 6, main to satellite, and level 7 satellite to main. Thus extension numbers at the main must be prefixed by 7 when dialled from the satellite, and satellite numbers prefixed by 6 when dialled from the main. A typical numbering scheme in this case would be:

Main	*Satellite*
Level 0—Manual board	Manual board
,, 9—Direct exchange access	Direct exchange access
,, 8— Inter-switchboard	Spare
,, 7— circuits	Main
,, 6—Satellite	F/S 200-699
,, 5— F/S 300-599	F/S 200-699
,, 4— F/S 300-599	F/S 200-699
,, 3— F/S 300-599	F/S 200-699
,, 2—F/S via 2nd sel. 2000-2699	F/S 200-699
,, 1—Spare	Spare

The range 300-599 is duplicated at main and satellite and thus the satellite numbers must always be referred to as 6200 to 6599, although the digit 6 would not be dialled within the satellite. This duplication can be avoided by the use of 2nd selectors or, where the satellite is small, by using levels 6, 7 or 8 at the satellite for extension numbers.

Trunk Offering.

The trunk offering facility is available on all regular or 2-10 final selectors at the satellite. The addition to the final selector is the incorporation of a series relay in the feed circuit, differentially connected. Circuit elements are shown in Fig. **7**. To trunk offer, the operator rings on the engaged circuit and the signal is sent over the inter-switchboard circuit, by the operation of MB, as an earth on both lines. This operates relay OC which causes the circuit to be switched through to the engaged subscriber. Replacement of the extension receiver automatically completes the re-ring circuit and the offered call can be completed without further work by the operator. To avoid the possibility of

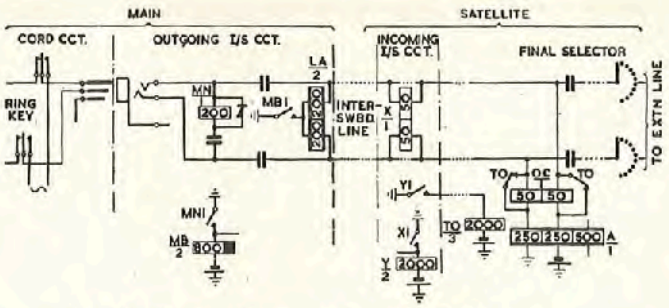


FIG. 7.—TRUNK OFFERING CIRCUIT ELEMENTS.

OC being operated from an extension call the initial "seizing" signal from the manual board is a momentary earth on both lines. This operates relay X which in turn operates TO in the final selector.

Inter-Switchboard Circuits, Main to Satellite.

Terminating circuits for both-way and unidirectional working between main and satellite are available. Normally such circuits would be worked both-way; but unidirectional circuits are made available so that advantage can be taken of economy in equipment where the number of circuits and traffic warrant unidirectional working. The normal calling condition is by loop but, in the case of relay sets at the satellite, joint access is given from the "0" level and when "0" is dialled an earthed loop is connected. The receipt of this signal at the main causes the manual board calling lamp associated with the inter-switchboard circuit to be lighted. In the reverse direction an earthed loop is used for the trunk offering facility as previously explained.

Alarm Extension.

Urgent satellite alarms are given at the manual board at the main. The last choice, inter-switchboard circuit, is intercepted at each end by alarm extension relay sets as shown dotted in Fig. **6**. One wire earth calling is used as a signal over the inter-switchboard circuit to differentiate between an alarm and a normal calling signal. The alarm extension relay sets are switched out of circuit when the normal calling signal is given.

Night Service on Satellite Extensions.

Night service is given on satellite extensions by switching them to the manual board at the main, via inter-switchboard circuits, where they may be plugged through to exchange lines as required. The switching relay set is associated with a selected extension number and to switch the extensions to night service, the operator dials this number. The application of the trunk offering signal operates the switching relays which hold. A distinctive tone is returned to the operator to indicate that switching has been accomplished. A similar procedure is used to restore the switching relays. N.U. tone is returned to any caller who may dial the switching number, and switching cannot take place unless the trunk offering signal is given. All the inter-switchboard circuits can be used for switching with the exception of the one used for setting up.

CONCLUSION

This series could not be closed without referring to the contribution of the manufacturers to the development of standard P.A.B.X.s. The whole of the development was done through the B.T.T.D.C., the major portion of the work falling upon Standard Telephones & Cables Ltd., as liaison manufacturer, and, at a later stage, upon the Automatic Telephone & Electric Co. as liaison manufacturer for the satellite development. The author is indebted to both manufacturers for their assistance in preparing the articles.