A PRIVATE AUTOMATIC BRANCH EXCHANGE USING HIGH-SPEED UNISELECTORS

by B. H. GEELS *).

In large automatic telephone exchanges economy demands that the number and dimensions of the necessary equipment be as small as possible without limiting the facilities available to subscribers. Only with the development of high-speed uniselectors and their associated test-relays, replacing the conventional two-motion selectors, has it been possible to utilize fully the advantages of the so-called indirect systems. The description of a large private automatic branch exchange (PABX) given in this article will elucidate this matter and will also give an idea of the elaborate measures necessary in order to meet all kinds of secondary requirements in a private telephone system. This article will be followed in due course by a description of the high-speed uniselectors and of a public exchange developed along the same lines.

The traffic handled by private branch exchanges can be divided into two main classes, viz. the internal traffic and the incoming or outgoing traffic via the public telephone exchanges. Although the requirements made upon private exchanges as regards internal connections are generally less stringent than those made upon public telephone exchanges (it is not necessary, for instance, to count the calls), the establishment of connections for incoming and outgoing calls via the public lines makes very high demands on the private branch exchange. The development of PABXs has therefore followed entirely different lines from that of public exchanges.

For manual private exchanges there was no reason for any special development: an efficient telephone operator could be expected to cope with the demands of the incoming and outgoing traffic. Although automatic equipment has now been widely adopted for private traffic, the well-known manual exchanges equipped with flexible cords, jacks and plugs are still frequently used for external connections via the public line.

Although manual exchanges with jacks for every extension and for every public line offer the advantage of individual handling of every external call, they nevertheless have many disadvantages. Their operation makes considerable demands on the operator, as she must act promptly both at the beginning and at the end of each call. It may be necessary to employ a large number of operators, if the traffic is very heavy. Finally, the arrangement of the desk becomes confused in large installations on account of their very size. For these reasons the modern development of private branch exchanges aims at the introduction wherever possible of automatic devices for the establishment of local calls whereby the demands made on the operator are reduced. In this way the cost of operators is cut to a minimum, and in addition local calls are handled in a much shorter time.

The development of the PABX type UB 49 is also based on this principle. By the use of various modern components developed by Philips Telecommunications Industries since the war, it has been possible to incorporate in this exchange a number of important features 1).

In order to appreciate these features it is necessary to discuss the development of automatic telephone equipment and in particular that of private automatic branch exchanges. The function of elements such as final selectors, group selectors, line finders, pre-selectors, etc., which form the component units of all automatic telephone exchanges is briefly explained in the diagrams in fig 1a and 1b for those readers who are not acquainted with these matters.

Direct systems

The first automatic telephone system was developed by the American Strowger. The systems derived from this original Strowger system, which have been very widely applied, are called direct systems, because the dial pulses from the caller's extension are used directly for the positioning of the automatic telephone selectors 2).

1) A description of the PABX type UB 49 by the same author appeared in Communication News 15, 2-19, 1954 (No. 1).
Direct systems have the advantage of a relatively simple design and for a long time it was considered that they were the fastest type of system. Direct positioning of selectors ensures that the connection is established as soon as the subscriber has dialed the last digit of the required number and practically immediately afterwards the ringing current is applied to the called person’s telephone. On closer examination, however, it will be found that the rapid action of these systems is illusory, as the telephone dial functions relatively slowly. The selectors of the direct systems are only just capable of following the dialling pulses, but as the subscriber does not realize the fact that time also passes during the dialling operation, he gets the impression that the establishment of a connection takes no time at all. If the modern selecting methods were to be used, however, the selectors of the direct systems would no longer be able to follow the selecting signals, which are much faster in the modern systems.

The nature of the direct systems is such that a number of devices are necessary for positioning the selectors and, after having established the connection, remain engaged although inactive during the entire call. Consequently, a relatively large number of these devices are necessary in the exchange and it is difficult to design them so as to be cheap to make.

The selector normally used in direct systems is a modified version of the Strowger two-motion selector (fig. 2). It has 100 outlets, so that 100 subscriber’s lines can be connected to it. The selector must then react to two series of dialling pulses i.e. two digits of the required number. In order to make all the 100 outlets accessible in this way they are arranged in 10 rows of 10. The brushes of the selector can be moved by means of two electro-magnets which may be termed the vertical magnet and the rotary magnet. The pulses relating to the first digit are passed to the vertical magnet via the contacts of relays forming part of the selector circuit. The magnet lifts the brushes step by step till they face the row of outlets corresponding to the first digit. Some relay contacts are then tripped, so that the dialling pulses of the second digit are fed to the rotary magnet. The brushes then rotate step by step in a horizontal plane touching the contacts of the row as they pass, until they connect with the contacts of the desired subscriber. Since the positioning mechanism is discontinuous, the not inconsiderable mass of the brush mechanism must be accelerated and stopped again and again. The pulse repetition frequency, therefore, must not be too high: otherwise the selector will not be able to follow the pulses. For this reason a pulse repetition frequency of only 10 pulses per second was used in most direct systems.

**Fig. 1. Schematic diagrams illustrating automatic telephony.**

The extensions (sub) connected to a telephone exchange are mostly divided into groups of one hundred, which are then connected to the contact banks of selectors having 100 outlets (final selectors FS) to enable them to be selected.

If the exchange is equipped for 100 to 1000 subscribers the final selectors FS are preceded by the group selectors GS; in this way it is made possible to choose a free final selector to the desired group of 100 subscribers. In the case of 1000 to 10,000 subscribers it is required to introduce another group selector stage preceding the first one in order to make it possible to select a free group selector to the desired group of 1000 subscribers.

Consequently, to establish the desired connection the subscriber must have a group selector at his disposal. Only a small number of subscribers make a call at the same moment; it is, therefore, wasteful to connect every set to the brushes of a group selector. The subscriber’s lines are therefore connected to a considerably smaller number of group selectors via one or more reducing stages consisting either of pre-selectors or of line finders. The number of group selectors depends on the average number and duration of the calls in the busy hour. It may be necessary, for example, to provide a group of 100 subscribers with 10 group selectors.

a) If pre-selectors (PS) are used as a reducing stage, then the contacts of each pre-selector are connected to the brushes of the 10 group selectors via cord circuits (CC), while the brushes of each pre-selector are connected to a subscribers’ line. In this case 100 pre-selectors with 10 outlets are thus required for a group of 100 subscribers. If a subscriber lifts the receiver, then the brushes of the pre-selector relating to this subscriber start hunting the contacts; they stop at the contacts leading to the first free group selector. A relay, the test relay, which is consecutively connected to the various group selectors by the pre-selector, is provided for checking whether a group selector is engaged or disengaged. If the test relay is connected to a disengaged group selector, then it is energized, on account of which the pre-selector comes to a standstill. (In order to prevent existing calls via engaged group selectors from being disturbed by the testing, this is done not via one of the two speech lines, but via a third line and a third contact bank of the pre-selector.)

b) If line finders (LF) are used as a reducing stage, their contacts are connected to the subscriber’s lines, while their brushes are connected to those of the group selectors. Consequently in this case 10 line finders with 100 contacts per bank are required. If the receiver is now lifted, the brushes of a free line finder start rotating along the contacts in order to hunt the calling subscriber. For this purpose a test relay is connected to a brush of the line finder which is connected in turn to the line circuit of the various subscribers. As soon as it is connected to that of the calling subscriber, the relay is energized and in this way the line finder is brought to a standstill.
Indirect systems

In *indirect systems*, as the name implies, the principle of direct control of selectors by the dialling pulses is no longer applied. The dialling pulses are instead received by a central switching device (register or director) which is connected to the cord circuit. The register can start positioning the selector only after it has wholly or partly received the number that the caller desires. As a consequence of this it is, in general, impossible to avoid some delay between the termination of the last series of dialling pulses and the establishment of the connection, though the selectors used in indirect systems are no slower than those of direct ones.

A second cause of delay in the indirect systems is the fact that in general they are designed as line finder systems, whereas in the direct systems pre-selectors are more usual. The latter have only a small number of contacts whereas line finders have a large number of contacts (see Fig. 1a-b); hence positioning of a line finder will, on an average, take more time than that of a pre-selector.

Although the indirect systems commonly used up till now have had the drawback of a somewhat slower operation as compared with the direct systems, the use of registers nevertheless offers many advantages. These central switching devices are only active while the connection is being established and for that reason they are only engaged for a few seconds during every call. The consequence of this is that it is not necessary to equip all cord circuits with a register of their own: a small number of registers will suffice for a large number of simultaneous calls. The registers are connected to the cord circuits (CCt) via a reducing stage, the cord circuit finder (CCtF); see fig. 3. (It is true that this finder is a further cause of delay, because it must first be positioned before the subscriber hears the dialling tone, which is the signal that he may start dialling.)

As the required number of registers is small, their complexity has only an insignificant influence on the cost of an automatic exchange. On the other hand there is the great advantage of indirect systems that the provision of special facilities is simpler and less expensive than in the case of direct systems. Some of these facilities will be discussed below.

![Fig. 3. Connection of the register Reg to the cord circuits CCt with the cord circuit finders CCtF acting as a reducing stage. The other letters correspond to those of fig. 1.](image)

Outgoing traffic

If it is required that outgoing calls are established automatically, i.e. without the intermediary of an operator, this imposes certain special requirements on the selectors. In general, it is further required that outgoing calls can be made automatically only from a number of specified extensions. This means that the selectors must then be able to distinguish between those extensions from which outgoing calls may be made automatically and those from which these calls should pass through the operator. Yet another subdivision of the former group is desirable, viz. the extensions from which trunk calls may be made automatically and those from which these calls should pass through the operator. Finally it may be desirable to block altogether outgoing calls via the operator from certain extensions (normally the operator can connect any extension with an external number by first obtaining the latter via the public
line and then connecting the extension by dialling the internal number).

The many special requirements thus imposed on the selectors and the various circuits imply a certain preference for an indirect system. The demands made by incoming local calls confirm this preference.

The principal new component is the high-speed uniselecter U 45A shown in fig. 4. It is a selector with 100 outlets. As it only makes one single rotary movement, its construction is simple and it has the very high speed of 300 contacts per second, as a result of which the selector can hunt all its outlets in only $\frac{1}{3}$ of a second. It is driven by clutching the rotor of the selector to a continuously-rotating spindle which extends through a number of selectors mounted in parallel. The clutching is controlled by the appropriate register.

The selector is thus not driven step by step, as is the case with the two motion selectors used in direct systems. Here the selector is driven uniformly and as a consequence it runs smoothly in spite of its high speed, which is most important from the point-of-view of wear. Using this high-speed selector reduces the delay between lifting the receiver and hearing the dialling tone to an average of 0.5 sec. Similarly, after the last digit is dialled, the connection is established and the ringing current is then applied within an average time of 0.5 sec. Apart from this obvious advantage, the high speed uniselecter possesses other desirable characteristics; these will be discussed later.

A very fast-acting test relay is required to make it possible to stop the selector (running at a speed of 300 contacts per second) stop at any desired contact without error. The relay S 50 shown in Fig. 5 was developed for this purpose. In an appropriate circuit this relay opens its break contact 0.3 millisecond after the actuating current is switched on. To make possible this extremely high switching speed the relay is of very light construction, yet it is very robust and has a normal contact pressure (20 grams).
The private automatic branch exchange UB 49

This system may best be described with the aid of a diagram showing the connections of a PABX for more than 100 extensions (fig. 6). The various possible connections will now be dealt with in turn.

Internal connections

For each extension there is a line circuit (LCt) which is connected both to appropriate contacts on 15 (or less) line finders and to contacts on the same number of final selectors.

If there are more than 100 cord circuits, then a second cord circuit finder may be introduced as shown in fig. 6. It is then possible to connect 200 cord circuits.

When the receiver is lifted from an extension, a signal is sent via the corresponding line circuit (LCt) to the call detector (CD) which, in turn, applies a starting signal to a register (Reg) appropriate to this call. The appropriate register is determined by a call distributor or alloter (All).

As soon as the register in question receives a starting signal from a call detector, it causes its cord circuit finder to start hunting a free cord circuit whose associated line finder gives access to the group of 100 to which the caller belongs. These free cord circuits are marked as being free by applying a voltage to their contacts in the cord circuit finder via 1. The cord circuit finder is stopped on the contacts of a free cord circuit, by means of a high-speed test relay (type S 50) in the register which is actuated by the marking voltage. When the cord circuit finder has found a free cord circuit, the register starts the line finder of that cord circuit.

Now the line relay in the line circuit of the caller's line is activated: hence the callers line in the contact bank of the line finder is marked by a voltage via 2. This voltage again actuates the test relay in the register, as a result of which the line finder comes to a standstill at the caller's contacts.

Both the line finders (LF) and the final selectors (FS) are rotary switches with 100 outlets; the extensions are therefore conveniently subdivided into groups of a hundred. A call detector (CD), which comes into action as soon as the caller wants to make a call is provided for each group of 100 extensions. A cord circuit (CCt) is permanently connected to the brushes of each line finder. This will be explained presently. The cord circuit is also connected to the brushes of a group selector (GS) giving access to a number of final selectors and to a number of public line circuits (PLCt). All cord circuits are connected to the contact banks of cord circuit finders (CCtF) by means of which a register can be connected with any required cord circuit.

3) The selection of this number depends on the number and duration of the calls made by a group of 100 extensions during the busy hour.
As was stated earlier, the extensions are divided into several classes according to whether they are granted the facility of automatic outgoing and/or trunk calls. At the moment the line finder tests the callers' line, the register also determines the class to which the caller belongs. For this purpose class identification wires ("identification multiple") pass along the rows of registers; the appropriate register is connected to these wires at the moment it is designated by the call distributor. In view of the fact that more than one register can never be simultaneously active in searching for a caller, it is never possible for more than one register to be connected to the identification multiple at the same time. For every class to be identified there is one multiple-wire and one class relay per register. In every line circuit the contact of the line relay that is to carry the marking voltage to the contact bank of the line finders is connected, by means of a wire, to the multiple-wire of that particular class to which the extension belongs. The caller's line is now marked in the contact bank of the line finder by a voltage from the register via the particular class relay that is connected to the contact of the line relay in the line circuit by means of its multiple-wire. Consequently, both the test relay and the class relay in the register are actuated in the same circuit. As soon as one of the class relays is actuated, the connection between the register and the identification multiple is broken and then the call distributor is in a position to designate another register for answering a call.

In the method of identification described above every possibility of incorrect identification is excluded, as at any given moment only one register is connected to the multiple. This also means that only one register at a time is ever engaged in positioning a cord circuit finder and a line finder. If there are several simultaneous calls, they are not handled at the same time, but consecutively. Such a method can be adopted only if high-speed selectors, such as the Philips uniselector U 45 A, are employed. The cord circuit finder and the line finder are then positioned so rapidly that the delay caused by the consecutive handling of simultaneous calls is negligible.

The positioning of the cord circuit finder and the line finder may be somewhat clarified with the aid of the simplified diagram of fig. 7. This shows the four contact banks of a line finder LF and the 8 contact banks of a cord circuit finder CCtF; a line circuit, a register and a cord circuit CCt, are, however, shown in simplified form.

As soon as the receiver of one of the extensions is removed, the line relay L (with three windings) is actuated by the closing of the cradle switch C5 of the extension. When contact I1 closes the relay CD (call detector) is actuated, as a result of which the register designated by the call distributor (the contacts r of this register being closed) attracts the relay S via cd. This causes the test circuit for the cord circuit finder (with test relay T) to be closed in the register by means of contact a1. Also the release magnet RM of the cord circuit finder is actuated by the closing of contact s1, after which this selector starts rotating. As a result of the closure of contact cd, all the free cord circuits (CCt) relating to the group of 100 lines to which the caller's extension belongs, are marked in arc I of the cord circuit finder, for the contact a1 in the free cord circuits is closed, whereas this contact is open when the cord circuit is engaged. As soon as the brushes of the cord circuit finder touch the contacts of a free cord circuit, the high-speed test relay T is actuated, as a result of which the release magnet RM of the cord circuit finder releases by the opening of contact s1; the finder then comes to a standstill. At the same time the closure of relay T causes the actuation of a relay A (not shown in the figure) having contacts a1 and a2. In this way the test relay T is connected into the test circuit for the line finder by way of contact a2, after which T releases and s1 closes again. Consequently on the tripping of contact a1, the release magnet RM of the finder is actuated and the latter starts rotating. As soon as the brushes of the line finder are positioned on the contacts of the caller's line, the test relay is actuated again, in the circuit: earth, contact S1, test relay T, contact a1, contact bank P1 of the cord circuit finder CCtF, contact bank d of the line finder LF, the closed contact l2 of the line relay, contact c0 of the relay CO, the connecting wire to the class-identification multiple, the class-identification wire, contact r, the class relay of the class to which the extension belongs is fixed in the register. Even though the subscriber does not belong to the class LT, the class relay LT is nevertheless energized by the class relay that does close (in this case TT). Relay R releases on account of the opening of contact h1, so that the contacts r open as well. The register is then no longer connected to the class-identification multiple; nor can it be influenced by the call detector CD via relay S, if there is another call. As a consequence of the activation of the test relay, a relay C (not drawn) in the cord circuit CG is actuated. If the contacts c2 and c3 are then tripped, the result will be that the a and the b wire of the calling station are connected to the register. The relay co is actuated by the closing of contact c1. The opening of contact co disengages the call detector for the next call. The connection between the line circuit and the class-identification multiple is broken by means of contact co, while by opening the contacts co and c0, the supply of the extension via the line relay L is broken.

After positioning of the line finder, the register gives the caller the dialling tone as a sign that the dialling may be started. Three digits will have to be selected, if a layout as shown in fig. 6 is involved. The number of dial impulses of every digit chosen by the caller is counted in the register with the aid of a relay counting circuit. After the counting of a digit the counting relays transfer the result to a group of storage relays, after which the counting relays return to their neutral position. There is no
As soon as the marker is disengaged, the register is connected to it, after which it transfers the dialling data obtained from the caller to the marker. The marker then marks the group of final selectors through which the desired number can be reached in the bank of the group selector and furthermore the line itself is marked in the bank of the final selector (via 3 and 5 respectively in fig. 6). The register consecutively positions the group selector and the final selector, after which the marker is disengaged and available for the next register.

As it is feasible to connect only one register to the marker at a time, there is also a common gate lockout GoLo which ensures that the registers are admitted in groups and dealt with one by one, after which a new group is admitted.

As soon as the marker is disengaged, the register is connected to it, after which it transfers the dialling data obtained from the caller to the marker. The marker then marks the group of final selectors through which the desired number can be reached in the bank of the group selector and furthermore the line itself is marked in the bank of the final selector (via 3 and 5 respectively in fig. 6). The register consecutively positions the group selector and the final selector, after which the marker is disengaged and available for the next register.

In this case again, only one register out of a group
is enabled to position a group selector - final selector combination. This method offers considerable advantages, as it makes it possible to introduce important simplifications into the circuits and the establishment of double connections, for example, is entirely prevented. This, again, is possible only by the use of the high-speed uniselector U 45A, for then the holding times of the marker are so short that the resulting delays are negligible.

It will be noted that in the entire exchange — if its capacity does not exceed approximately 600 numbers — there are never more than two selectors running at the same time, viz. one in the group selector - final selector category and one in the cord circuit finder - line finder category. As a result of this, the exchange is not only practically silent, but the severe mechanical vibration occurring when many selectors are running simultaneously are also avoided. In this way less electric noise voltages occur and, as a consequence, the system UB 49 is remarkably free from selector noise.

After the positioning of the group selector and the final selector it is checked via the register whether the selected line is engaged or disengaged. If the line to the called station is engaged, then the register breaks the entire connection. All circuits are cleared and the caller hears the engaged signal from his own line circuit. If the called station’s line is disengaged, then the register only disengages itself, so as to be in a position to handle further calls. The called station now receives the first ringing current and the subsequent periodical rings from the cord circuit which also supplies the current for the microphones of both the called station and the caller’s station.

The microphone current flows via a relay in the cord circuit called the guard relay. This current is interrupted when the microphone is put on the hook; the guard relay then releases, which initiates the process of clearing the connection.

**Outgoing traffic via public lines**

Usually the circuits of the system UB 49 are so designed that the lines to the local exchange are accessible when the caller dials one particular digit. These lines are connected to contacts in the banks of the group selector, and the register designated by the call distributor starts positioning it as soon as the pulses from the aforesaid single digit are received. When discussing internal connections it was mentioned that the register has determined the class to which the caller’s extension belongs before the dialling tone is emitted. If he is not allowed to make outside calls, i.e. if his line relay is not connected to the relevant wire of the identification multiple, then the register does not start the group selector, but it breaks the entire connection built up so far and and the caller hears the engaged signal from his line circuit. If he is entitled to make local calls, then the register adjusts the group selector to a free public line circuit. Furthermore it applies a special signal to the cord circuit and disengages itself for the next call. The result of the special signal is that the supply in the cord circuit is not switched on and that the speech wires are connected from the line circuit to the public line circuit \( P L C \) (fig. 6), from which the microphone is now fed via a guard relay in the public line circuit. The question whether the connection is broken or not, thus no longer depends on the cord circuit, but on the public line circuit.

The group selector is positioned to a free public line with the aid of the marker by means of a marking connection from the register to the contact bank of the group selector, via the marker and the free public line circuits. This connection also serves for passing the signals to the public line circuit in order to indicate whether or not the caller is entitled to make trunk line calls, a datum that is fixed in the register by the actuation of the relevant class relay \((IT, LT \text{ or } TT, \text{ see fig. } 7)\). If the caller is not authorized, then this signal switches on a device in the public line circuit which prevents trunk calls from being made \((TTR)\). The way in which such a device operates depends on the way in which trunk connections are established in a given country. We shall not enter further into this matter here.
The exchange UB 49 enables a caller who has built up an outgoing public line connection to consult with another person in the private system during this call. The way in which this is done will be discussed in the next section.

Incoming local calls

In the case of incoming calls on the public lines the operator's assistance is needed for the connection of these lines to the extensions. For this purpose use must be made of a control desk (fig. 8) or a control set (fig. 9). In principle both installations offer the same facilities. The (smaller) control set will mainly be used in those cases where the operator has not got a fulltime job; in such cases it is more economical to put the operators set on a normal desk at which the operator does her other work.

A new system is used for the standard version of desk and set, which will now be described. In this system the public lines no longer appear individually on the operator's desk. In order to estimate the new technique at its true value, it is necessary to consider the various possible situations which can arise during a call from outside.

a) The call has been received, but has not yet been answered.

b) The call has been answered, but has not yet been put through.

c) The desired person is not immediately available after being called. In this case the public line is switched to the waiting position and remains engaged while the operator handles other calls in the meantime.

d) If there is no reply from the extension called, the operator has to inform the caller of this fact.

e) If the called person's line is engaged, then the operator may interfere in the conversation and offer the outside call. If the called person does not wish to interrupt the conversation at once, then the operator has to try again after some time.

f) The called person answers and the conversation proceeds.

g) The called person requests the operator to transfer the call to another extension.

h) The called person may return call to the operator without any comment.

i) The caller may request to be consecutively connected to various extensions. In this case the operator must see to it, by carrying out a special switching operation, that the call is passed back to her desk, whenever the receiver of an extension is put down.

j) The operator must receive a special signal, if she has chosen an extension which may not receive local calls, or if she has carried out some incorrect manipulation.

When all the public lines are permanently connected with the operator's desk, it is not possible to fit more than two or three lamps per line for lack of room. One should then try to indicate the various situations mentioned above with the aid of lenses of different colours, lamps dimmed or full on, or with lamps that flicker at various frequencies. The picture of the lamp panel, however, soon becomes distracting in that case, while the signalling system still does not come up to standard.

For the above reasons another solution has been chosen. One lamp and an associated push button are now provided for each of the possible situations. The
public lines are no longer in permanent connection with the operators desk. This connection is established only for one line at the moment at which the push button is operated and only the situation of that particular line is indicated on the desk. Moreover, there are lamps for showing that one or more connections to the public exchange are in one of the situations $a, b, c, d, e, g, h$ or $i$, and that the operator must take some action. Another advantage of this system is that the design of the operators desk is independent of the number of public lines to be controlled. If there is too much local traffic for one operator, then two positions can simply be connected in parallel. The signal lamps for all the situations enumerated above, for which the operator's assistance is called in ($a, d, e, g, h$ and $i$) are white. The waiting lamp is red, as the situation indicated in this way requires the operator's special attention. Green-coloured lamps indicate whether the operator's desk is connected to a public line or to an extension.

If there is an incoming call on one of the public lines $PL$, a general calling lamp lights up on the operators desk $OpD$. If the operator depresses the appropriate button, the public line finder $PLF$ of the corresponding operator's circuit $OpCt$ is started, as a result of which she is connected to the caller's exchange line. Once the caller has told her to whom he wishes to speak, she depresses the button for internal interconnection and she is then connected to the transfer line of the public line circuit $PLc$. By switching over to this transfer line ($TrL$), which is connected to the banks of the line finders as a normal line to an extension, the operator makes a normal call, so that a register is started. This register hunts for a free cord circuit and positions the latter's line finder to the transfer line. The operator is thus connected to a register in the same way as an extension and she receives the dialling tone from the register.

At the moment when the register positions the line finder to the transfer line ($TrL$) it is also ascertained that the call comes from an operator. The means by which this is done will not be discussed here, as this would carry us too far. As a consequence

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**Fig. 10.** Layout of a PABX type UB 49 for more than 100 extensions (see also fig. 6), with provisions for the operator and for call-back added to it. $PLF$ public line finder, $OpCt$ operator's position circuit, $OpD$ operator's desk, $TrL$ transfer line, $CbL$ call-back line. For other letters see fig. 6.

We shall now give a brief description of the way in which an incoming local call is put through (fig. 10). If there is an incoming call on one of the public lines $PL$, a general calling lamp lights up on the operators desk $OpD$. If the operator depresses a direct connection is established via 4 wires between the operator's position circuit and the register. The four-wire connection enables the operator to store the digits in the register very rapidly by means of the push buttons on her desk. The
connection is established within 0.5 sec after the button is depressed for the last digit, as high-speed selectors are incorporated.

In this case as well, the cord circuit is connected through while being controlled by the register. The latter then ascertains by means of a subsequent test whether or not the caller is entitled to receive local calls. If not, then the private connection is broken and a lamp on the desk warns the operator. If, however, the caller is authorized to receive local calls, then his extension is fed from the public line circuit, whence the call is made. In that case the operator may either remain in the circuit until the called person answers, or withdraw from it at once by depressing a button provided for the purpose. In the latter case the called person’s station is automatically connected to the public line, if he answers the call. If he does not, however, the call is automatically passed back to the operator’s desk after about 20 sec. If the called person’s line is engaged, then the operator can enter into the circuit and offer the local call. By depressing a button provided for the purpose the operator can re-establish the connection with the calling subscriber in order to inform him of her findings.

Once the connection between the public line and the extension has been established, the called person using the extension may consult with another person using an extension without breaking the connection with the public line. In order to achieve this, the public line circuit is connected to the contact bank of the line finders by another line, the call-back line (CbL). As soon as the button for calling back on the extension is depressed, a call starting from the public line circuit is made by way of the call-back line. The public line is temporarily cut out, but retained in the public line circuit by means of an auxiliary circuit. At the same time the station connected to the transfer line is connected with a cord circuit and a register by way of the call-back line. As soon as the dialling tone is heard, the desired number is dialled, after which both extensions are connected in the usual way. If the button for call-back of the first extension is then depressed again, the connection via the call-back line is broken and the connection with the public line is re-established, if, however, the button for call-back of the second extension is depressed, then the connection between the public line circuit and the first extension — by way of the transfer line — is broken and the second extension is connected to the public line by the call-back line. This procedure can be repeated as often as desired; the transfer line and the call-back line then change their function alternately.

**Overflow group selectors**

Once the exchange has attained a certain size it is no longer possible to connect all final selectors and public lines to every group selector. In most cases the group selectors are then divided into two (or, in large exchanges, into more) parts, after which the final selectors of each group of a hundred extensions are uniformly distributed over these parts. The consequence is, however, that the final selectors are accessible to a limited extent only. For, if a certain group selector is chosen, then only part of the final selectors in the hundred-group required are accessible. All these final selectors may be engaged, while it may be possible that the final selectors for that particular hundred-group which are connected to the group selector of the other part are still disengaged. In that case the efficiency of the final selectors and exchange lines drops 4).

In an exchange with more than about 600 lines the system UB 49 obviates this disadvantage by using overflow group selectors. A certain number of the final selectors for every group of one hundred extensions (e.g. 7 or 8 out of 15) are directly connected to every group selector (GS, fig. 11).

![Fig. 11. Diagram of connections with overflow group selectors.](https://via.placeholder.com/150)

The remaining final selectors are connected to the contacts of each of the overflow group selectors (OS). It is then checked for all calls whether the final selectors connected to the group selectors are disengaged. The portion of calls that cannot be handled by these final selectors is passed on to the

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4) By the efficiency of, say, a group of lines we understand the ratio of the traffic (number of call-minutes per hour) that can be handled by this group with a certain grade of service, to the traffic that would occur if all lines were continuously engaged. The efficiency of a large group is higher than that of a small group, if the grade of service remains the same. This means that a group of, say, 100 lines can handle more traffic than two groups of 50 lines each, with the same grade of service. See for example J. Atkinson, Telephony (footnote 4).
overflow group selectors. These selectors thus receive the remaining calls from all groups of one hundred stations; the overflow group selectors still get a fairly large number of calls to deal with and consequently their efficiency is good.

The marking (via the lines 3 and 5, if a direct connection can be established, and via the lines 3, 4 and 5, if the connection is established by way of an overflow group selector) is ensured by the marker circuit \( M \) in combination with the register. In the case of an indirect connection, the marker circuit brings the register to the state required for the positioning of three selectors, viz. CS, OS and FS.

The local traffic is, in a similar way, offered to the public line circuits \( PLC_i \) connected to the group selectors and then to the circuits connected to the overflow group selectors.

**Networks**

If various scattered private exchanges have to co-operate (external private traffic), a cable network must be laid between these exchanges. The system UB 49 can be adapted to any required network configuration. The use of a central marking device makes it possible to determine the most favourable route for every connection in this external traffic. The marking device also investigates whether the traffic can be passed to the other exchange directly, or — if all lines to this exchange are engaged — by way of a third exchange (overflow traffic). In mesh-shaped networks a considerable improvement of the efficiency of the groups can be achieved in this way.

**Special provisions in the system UB 49**

Although they do not belong to the normal equipment of the UB 49 exchange, all kinds of special devices can be fitted;

a) Night traffic installation. Normal equipment may control the public lines during the evening and night hours and on Sundays in the operator's absence. After a normal extension has answered a local call the desired extension may be called by way of the call-back line; this extension may then take over the call.

b) Conference device. A conference device enables a maximum number of 10 users of extensions to hold a telephonic conference, either together or in groups. The connections are controlled by the operator who first dials all the desired extensions, after which the bells of all these sets are rung simultaneously.

c) Automatic staff location. Persons who are wanted on the phone can be warned by means of acoustic and optical signals. The device in question is switched on by dialling a call number, which causes signals to be automatically given according to a fixed code. As soon as the called person dials a certain number (the report-number) on an arbitrary extension, he is automatically connected to the caller's extension.

The provision of all these facilities presents no special difficulties and need not be described further here.

**Summary.** After an introduction dealing with the general development of private telephone exchanges, a description is given of the UB 49 exchange. This operates on the register system in which the characteristic disadvantage (slower action) of register systems is overcome by the use of a high-speed uniselector, the Philips U 45 A. The characteristic advantages, (reduction of equipment in large exchanges), however, are retained, while many additional advantages are obtained. For instance, the system requires a minimum of maintenance and it is remarkably free from selector noise.

A special operator's desk has been developed for the establishment of incoming calls. The special feature is that the public lines are not permanently connected to the desk; they are connected to it only at the moment when control is required. This renders the design of the desk independent of the number of public lines to be controlled. In addition much more complete signalling of the various situations applying to the public lines is possible. The introduction of selection by means of push-buttons makes it possible to pass on local calls to extensions very quickly.

Ferro-resonant effects, i.e. instabilities occurring in the steady state response of non-linear circuits by gradual variation of some circuit parameter are briefly discussed and the application of these effects in trigger and flip-flop circuits is pointed out. A shifting register using ferro-resonant flip-flops is described in which the information is shifted by unidirectional pulses. By simple means it is possible to shift the information in both directions depending upon the polarity of the shifting pulses. Some details of an experimental register for a telex-on-radio system working at a supply frequency of 20 kc/s and permitting shifting pulses at a repetition rate of 0.8 kc/s are discussed. Attention is paid to the design considerations especially for the application of supply frequencies in the Mc/s range.


A condenser plate is mounted close to each side of a thin diaphragm, separating two chambers. The two capacities thus formed are part of a bridge circuit which is fed by a high frequency oscillator. An amplifier with a narrow bandwidth, a rectifier and a micro-ammeter are used as a null-indicator. At one side of the diaphragm a pressure prevails, much lower than the pressure to be measured; at the other side the gas is admitted the pressure of which is to be measured. The displacement of the membrane by the gas pressure is compensated electrostatically by the aid of a calibrated potentiometer. The reading of this potentiometer is a linear measure for the pressure as a result of the differential way of compensating. The range is from $10^{-3}$ mm—1 mm of mercury pressure difference at any absolute value. The apparatus is made of chemically fairly resistant materials, and its indication is independent of the nature of the gas, so that it can be used for almost every gas.


Single crystals of PbS were prepared and reheated under various sulphur pressures at 1200 °K to control the stoichiometric composition. After rapid cooling of each crystal to room temperature, the concentration of free charge carriers (electrons or holes) and the hardness were determined. It was shown that stoichiometric crystals contained the lowest carrier concentrations. Reheated at higher sulphur pressures, an excess of sulphur (consistent with lead ion vacancies) was introduced together with positive holes. At low sulphur pressures sulphur ion vacancies together with free electrons were present. These concentrations vary from about $10^{-3}$% to $10^{-1}$% when reheated under various sulphur pressures. The hardness of the crystals also showed a minimum value for stoichiometric crystals; for strong n and p type crystals the highest values were observed.


Dixippus morosus has been bred since 1950, and from 1952 onwards, on a larger scale in cages about 20 x 20 x 25". In August 1954 a male occurred. It is distinguished by its smaller size, by a red stripe at the ventral side between coxae I and II, and by the lack of the red marking at the inner side of the anterior femurs.

2273: L. A. A. Sluyterman: Molecular weight of insulin as derived from paper electrophoresis (Biochim. et Biophysica Acta 17, 169-176, 1955).

Some uncertainty exists as to whether the molecular weight of insulin is 6000 or 12000. The experiments described in this paper may help to decide this question. Samples of insulin were treated with various amounts of acetic anhydride under conditions favourable for specific acetylation of the amino groups. Thus products with various contents of free amino groups were obtained. Paper electrophoresis of these products demonstrated the progress of the acetylation reaction by the successive appearance of new bands and the disappearance of the initial insuline band. A total number of three new bands were found. This shows that acetylation
of insulin occurs in three steps, which suggests the presence of three amino groups in one molecule of insulin. According to chemical analysis insulin contains three amino groups in each unit of molecular weight 6000 (Sanger, 1945). Hence the present experiments indicate that the molecular weight of insulin is 6000.


The phenomenon of photoreactivation has been studied with three cultures of bacilli. It has been shown that they could be reactivated by light with wavelengths of 3655, 4047 or 4358 Å after ultraviolet inactivation. Since these radiations also have an inactivating effect, the photoreactivation may be small, even not noticeable, when the dose-rate of the incident light is too great. Bacterial spores did not show photoreactivation.


In the frequency spectrum of the noise of a fluorescent lamp ballast, "hum" and "rustle" can be distinguished. Hum comprises small even multiples of the mains frequency, at which the dimensions of the ballast are small in comparison with the wavelength of the sound in the air. The noise at these frequencies is, therefore, mainly produced by the ballast acting as a vibration exciter to larger mounting surfaces. Rustle frequencies (about 1000—3000 c/s) are radiated directly by the ballast itself. Hum may be eliminated by use of a core construction where the displacements due to magnetic attraction across the air-gap cancel out the magnetostrictive displacements at the mounting points of the reactor. Rustle radiation must be isolated by putting the ballast in a closed box. A filling for the empty space in these boxes providing acoustical impact sound insulation and good thermal conductivity is described.


The semiconducting properties of lead sulphide single crystals have been measured after heating at various temperatures in controlled atmospheres. Thermoelectric power measurements indicate an energy gap of 0.3 eV at room temperature, and an effective electron and hole mass of about 0.25 of the electron mass in free space. With the use of the theory of Kröger, Vink and van den Boomgaard it was possible to deduce the width of the energy gap and the position of the various vacancy levels as a function of temperature, from 800 to 1200 °K.

2277: F. van der Maesen and J. A. Brenkman: On the behaviour of rapidly diffusing acceptors in germanium (J. Electrochem. Soc. 102, 229-234, 1955, No. 5).

The acceptor activity of Cu and Ni and their diffusion in germanium have been investigated. Their action as acceptors as well as recombination centres gives reason to believe that impurity atoms are placed substitutionally in the lattice. However, the value of $10^{-5}$ cm$^2$/sec of the diffusion constant makes it likely that the diffusion goes interstitially. This leads to the concept of an equilibrium existing between substitutional and interstitial atoms. The fact that the diffusivity is dependent on the range of diffusion can be explained qualitatively on the basis of the picture given above.

2278: H. C. Hamaker: De betekenis van de statistiek voor de ontwikkeling van de experimentele wetenschap (Sigma, 1, 55-58, 1955, No. 3). (The significance of statistics in the development of experimental research; in Dutch).

The application of statistics to technical problems is shown to be a basically new phase in the development of technology.


Iron and sulphur form a continuous series of compounds with compositions varying from FeS to $Fe_{1.5}S$. The sulphides with a low sulphur content are antiferromagnetic, those with a high sulphur content are ferromagnetic while an anomalous ferromagnetic behaviour appears at compositions between these two regions. The magnetic and crystallographic properties are experimentally investigated and explained using the simple theory of order-disorder phenomena.


Description of a sodium lamp constructed of a glass with improved resistance to sodium vapour. The use of this glass is made feasible by employing a xenon-neon mixture in place of the argon-neon filling commonly used in the past to reduce the ignition voltage.