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On cover: Inside view of a workshop department at LM Ericsson's factory at Midsommarkransen, Stockholm: assembling and adjustment of telephone dials

Waiting Times when Traffic has Variable Mean Intensity

C PALM, TELEFONAKTIEBOLAGET L M ERICSSON, STOCKHOLM

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In automatic telephone plants it is customary to give the circuit and selector groups such capacity that blocking due to shortage of devices only arises in exceptional cases and so that waiting times caused by blocking are not long enough to inconvenience the subscribers. In order traffic, of the kind existing in non-automatic or semi-automatic toll traffic installations, however, even very long waiting time is a normal occurrence owing to the fact that the circuit groups or the order position operators are occupied almost 100 per cent, at least during the busier parts of the day. In such case, the occurrence of waiting times is due, not only to temporary traffic peaks, but also to the possibility that the ordered traffic may in busy hours considerably exceed the maximum capacity of the circuits available. Such overload is often present without interruption several hours a day and during these periods the waiting times are continuously increasing. In order to obtain a conception of the waiting time conditions in such cases, the current waiting time formulae are, unfortunately, not applicable as these formulae anticipate that the traffic mean intensity is less than the maximum handling capacity.

The present article presents a method for computation of the waiting times which is applicable to varying mean intensity in the traffic load and which is exceptionally suitable when the intensity exceeds the maximum handling capacity. Thus, the simple final formulae may also be employed for order traffic with prolonged periods of overload.

In fixing the capacities of circuit groups and selector groups in telephone plants, one may at first use blocking and waiting time formulae derived on the assumption that the traffic varies at random around a constant mean value which has been present for such a long time that the traffic conditions show statistical equilibrium. The wellknown *Erlang* expressions are examples of such formulae. Unfortunately, these assumptions do not always agree with the properties of telephone traffic in practice. In more accurate computations, therefore, the mean value assumed as constant may be replaced by a mean value varying with time and around which the traffic at each instant varies at random. Combining this starting point with certain assumptions regarding statistical equilibrium, we arrive at the *theory for slow variations in mean intensity*. In certain cases, e. g., with overloads of the kind referred to in the introduction, even this theory becomes inadequate and one is then compelled to discard the assumption of statistical equilibrium and to try instead to build up a theory for *rapid variations in mean intensity*. The basis for such a theory is presented in a previous paper by the author.[1] Unfortunately, when trying to apply these principles to waiting systems, the mathematical procedure becomes exceedingly complicated; it has not so far been possible to put forward any exact solution. Nevertheless it is possible, by means of very elementary reasoning, to find very simple expressions for the waiting time values desired — expressions which will give good approximate solutions in the case of heavy overload. The method as described below is, therefore, particularly applicable when making investigations concerning order traffic with long waiting times.

[1] *C Palm:* »Intensitätsschwankungen im Fernsprechverkehr», Ericsson Technics No. 44, 1943. See chap. 7.

The Continuity Equation

Let us consider the traffic conditions in a full-availability group comprising n devices (circuits or selectors) arranged in a waiting system under such conditions that all calls ocurring when all devices of the group are occupied are assumed to wait until they are handled in the group. Immediately after one of the group's devices becomes free it is used for handling one of the calls waiting, if any such call exists. The calls to the group are assumed to be distributed at random around a mean value which may be variable with time. This means that the probability of a call occurring between the instant T and the immediately following instant $T + dT$ is expressed by $y(T)dT$ and is further independent of the location of the previous calls. We may consider $y(T)$ as a known function of the time T. The assumptions made agree entirely with the properties of traffic having intensity variations. Regarding the occupation times for the calls, we assume that they vary according to some distribution function with a mean value s, which has no variation with the absolute time. We introduce the following designations:

$\nu(T)$ = the mean value of the number of occupied devices at the instant T; that is, the number of calls proceeding in the group.

$N(T)$ = mean value of number of waiting calls at instant T.

Let us now consider the traffic conditions in the group during the time interval T, the beginning of which may be taken as zero point on the time scale. As all waiting calls remain until they are connected, the following must apply:

The number of occupations proceeding at the instant zero
plus the number of calls waiting at the instant zero
plus the number of calls occurring up to instant T

is equal to (1)

the number of occupations handled in the group up to instant T
plus the number of occupations proceeding at the instant T
plus the number of calls waiting at the instant T.

As this equation applies to the actual numbers of occupations and calls, it must also apply to the mean value of the same magnitudes. Thus, throughout (1) we may replace »the number» by »the average number». The equation may then easily be expressed with the aid of the functions introduced above. The average number up to instant T of occurring calls is expressed by

$$\int_0^T y(t)\,dt$$

Further, it may easily be seen that the sum of all occupations handled in the group up to instant T is expressed by

$$\int_0^T \nu(t)\,dt$$

As s is the average occupation time, $1 : s$ times the above expression will express the average number up to instant T of occupations handled in the group. From equation (1) therefore we obtain

$$\nu(0) + N(0) + \int_0^T y(t)\,dt = \frac{1}{s}\int_0^T \nu(t)\,dt + \nu(T) + N(T) \quad \ldots\ldots\ldots (2)$$

This relation may be called the *continuity equation*, as it gives expression to the continuity in time of the traffic flow. The integrals in (2) may be described simply in the following manner. It is evident that

$$Y(T) = \frac{1}{T}\int_0^T y(t)\,dt \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

expresses the mean value of the number of calls per unit of time during the interval from time zero up to T. Moreover it is seen that the dimensionless magnitude

$$\alpha(T) = \frac{1}{nT}\int_0^T v(t)\,dt \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

gives the average utilisation per device in the group during the time interval from zero to T.

With the aid of the expressions (3) and (4) we may write the equation (2) in the form

$$v(0) + N(0) + T\,Y(T) = \frac{n}{s}\,T\,\alpha(T) + v(T) + N(T) \quad \ldots\ldots \quad (5)$$

It should be observed that the above reasoning for derivation of the continuity equation is not mathematically binding. Space does not permit further analysis. However, on closer examination, it is found that the result is correct if the occupation times follow an exponential distribution function, while in other cases there is obtained a correction term. This, however, may be entirely ignored in further applications.

Average Waiting Times

In judging the waiting time conditions, we are at first interested in the average waiting time for a call occurring at the instant T. This may be designated in what follows as $V_0(T)$. In judging the average waiting time conditions during a given interval of time, one is also interested in the average waiting time for all calls occurring between the instant zero and instant T. For this the designation $V_m(T)$ may be employed.

Let $L_p(T)$ designate the probability that at instant T all devices of the group are busy and moreover that p (= 0, 1, 2, ...) calls are waiting. The mean value of the number of waiting calls at the instant T, that is $N(T)$, is then expressed, as may easily be seen, by

$$N(T) = \sum_{p=1}^{\infty} p\,L_p(T) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

The probability of blocking prevailing at instant T, that is all devices are busy, no matter how many calls are waiting, may be designated $R(T)$. Obviously then

$$R(T) = \sum_{p=0}^{\infty} L_p(T) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

Assume now that the waiting calls are handled in the order of their occurrence, which is of course customary in order traffic. A call that has p waiting before it in the queue will then obviously not be dealt with until $p + 1$ calls in the group have been terminated. As the average occupation time in the group is s and, as soon as there are calls waiting, the total number of calls proceeding simultaneously in the group is n, then the mean value of the time between the termination of one call and the next time a call in the group terminates should be $s : n$. As a call with p waiting before it must await $p + 1$ such terminations of calls, then obviously its average waiting time will be $(p + 1)\,s : n$.

Now $L_p(T)$ represents the probability that a call occurring at the instant T finds all devices of the group busy and in addition has p waiting before it. The average waiting time for a call occurring at the instant T is then expressed by

$$V_0(T) = \frac{s}{n}\sum_{p=0}^{\infty} (p + 1)\,L_p(T) \quad \ldots\ldots\ldots\ldots \quad (8)$$

which with the aid of (6) and (7) may be written

$$V_0(T) = \frac{s}{n}\{N(T) + R(T)\} \quad \ldots\ldots\ldots\ldots \quad (9)$$

Regarding this reasoning the following may be noted. If the occupation times follow an exponential distribution function, so that $e^{-t:s}$ represents the probability of an occupation lasting at least the time t, then the mean value of the remaining time of an occupation is always s, no matter how long the occupation has already lasted. In such case the reasoning leading to (8) is entirely correct. If on the other hand the occupation times follow another distribution function then the already past times of the calls proceeding at instant T will affect the result and (8) applies only approximately. From research[1] made earlier, however, it is found that this effect will have very little influence, especially for large groups, say $n > 5$ or 10. In practice, however, this source of error is of no importance.

To arrive at an expression for $V_m(T)$, that is the average waiting time for all calls during the time interval from zero to T, we may argue in the following manner. The probability of a call occurring at instant t is $y(t)dt$. The average waiting time for such a call is $V_0(t)$. This evidently gives

$$\int_0^T V_0(t)\,y(t)\,dt$$

as mean value of the sum of all present waiting times during the interval zero to T. If we divide this sum by the sum of all calls occurring during this interval, that is according to (3) by $T\,Y(T)$, we should arrive at $V_m(T)$. We then find

$$V_m(T) = \frac{1}{T\,Y(T)}\int_0^T V_0(t)\,y(t)\,dt \quad \ldots\ldots\ldots\ldots \quad (10)$$

With the aid of the continuity equation (5) we may now eliminate $N(T)$ from (9). We then get

$$V_0(T) = T\left\{\frac{s}{n}Y(T) - \alpha(T)\right\} + \frac{s}{n}\left\{R(T) - v(T)\right\} + \frac{s}{n}\left\{v(0) + N(0)\right\} \quad (11)$$

If we insert this in the right-hand part of (10), the result will include an integral of the form

$$\int_0^T t\,Y(t)\,y(t)\,dt$$

Using the relation (3), it is possible to directly perform this integration and then obtain

$$\frac{1}{2}\,T^2\{Y(T)\}^2$$

[1] See *C Palm:* »Bidrag till teorin för väntsystem». Tekn. Medd. från Kungl. Telegrafstyrelsen, Specialnummer för teletrafikteknik, Stockholm 1946.

As final expression for $V_m(T)$ we then get

$$V_m(T) = \frac{1}{2}\frac{s}{n} T\, Y(T) - \frac{1}{T\, Y(T)} \int_0^T t\, \alpha(t)\, y(t)\, dt +$$

$$+ \frac{s}{n}\frac{1}{T\, Y(T)} \int_0^T \left\{ R(t) - \nu(t) \right\} y(t)\, dt + \frac{s}{n}\left\{ \nu(0) + N(0) \right\} \quad \ldots\ldots (12)$$

The Equilibrium Case

Before considering more closely the simplifications that may be made in the formulae obtained for overloading, we shall deal briefly with the case where statistical equilibrium prevails and where, therefore, the wellknown *Erlang* results should be obtained. In waiting systems, as is known, statistical equilibrium arises if both s and y have been constant for a long time (theoretically infinitely long) and if, in addition, $sy < n$. In such cases we obtain as may easily be seen

$y(T) = Y(T) = y$

$\nu(T) = sy;\ \alpha(T) = sy : n.$

Both (11) and (12) are then reduced to the following form that coincides with (9)

$$V_0 = V_m = \frac{s}{n}\{N + R\} \quad \ldots\ldots\ldots\ldots\ldots\ldots (13)$$

N and R are now constants. We may eliminate N by the following reasoning. As also the magnitudes L_p must now be constants, the sum of all waiting times in the interval zero to T are expressed by

$$\sum_{p=1}^{\infty} p\, L_p \cdot T$$

which according to (6) is equal to $T \cdot N$. The average number of calls during this interval is now yT. The average waiting time per call will then be $TN : yT$, or $N : y$. The same average waiting time is expressed also by (13). This relation then gives us

$$N = \frac{sy}{n - sy} R \quad \ldots\ldots\ldots\ldots\ldots\ldots (14)$$

We now obtain from (13)

$$V_0 = V_m = \frac{s}{n - sy} R \quad \ldots\ldots\ldots\ldots\ldots\ldots (15)$$

which is exactly *Erlang*'s wellknown formula for the average waiting time.

It should be observed that the reasoning presented is correct only if N and y are constant and do not vary with T. It is of course obvious that (14) cannot be correct in all cases, for example when $sy \geq n$.

The Continuous Overload Case

Even if the initial condition, that is $\nu(O)$ and $N(O)$, as well as $y(T)$ as function of T are considered to be known, the right-hand parts of (11) and (12) contain unknown functions of T and these cannot be exactly computed by the elementary methods here used. For the case of continuing high

overloads, however, this difficulty may be overcome, since these functions may with good approximation be replaced by constants relatively easy to estimate. With continuing overload, where we therefore always have $s\,y(T) > n$, we may naturally expect that the group will constantly be almost fully occupied, which means that $\nu(T)$ has a value approaching n, say n_0, which may be regarded as constant. In that case the magnitude $\alpha(T)$ will be constant and equal to $n_0 : n$. At the moment we need only assume that it has a constant value α_0 which is less or equal to $n_0 : n$. As regards the blocking $R(T)$ this should always lie very near 1, so that we may put it as constant and equal to R_0 which is smaller than or equal to 1. We may then therefore write (11) and (12)

$$V_0(T) = T\left\{\frac{s}{n} Y(T) - \alpha_0\right\} + \frac{s}{n}\left\{\nu(0) - n_0\right\} + \frac{s}{n}\left\{R_0 + N(0)\right\} \quad \ldots\ldots (16)$$

and

$$V_m(T) = \frac{1}{2}\frac{s}{n} T\, Y(T) - \frac{\alpha_0}{T\, Y(T)} \int_0^T t\, y(t)\, dt +$$

$$+ \frac{s}{n}\left\{\nu(0) - n_0\right\} + \frac{s}{n}\left\{R_0 + N(0)\right\} \quad \ldots\ldots\ldots\ldots (17)$$

These formulae allow of relatively simple numerical computations. If $y(T)$ is obtained by measuring, then $Y(T)$ is conveniently computed by graphic or numerical integration.

Overload with Constant Mean Intensity

As an example of the application of the final formulae arrived at we will discuss a simple case, corresponding to a question frequently arising in practice. Prior to the instant 0, traffic equilibrium prevails in the group, so that there is a constant average utilisation $\alpha' = sy_0 : n$, which is smaller than 1. At the instant 0 there occurs a sudden rise in the traffic level, whereby a constant overload sets in. Thus one has $y(T) = y$, where $sy > n$. As the initial condition we then have $\nu(O) = n\alpha'$ and as per (14)

$$N(0) = \frac{\alpha'}{1 - \alpha'} R$$

We then get from (16)

$$V_0(T) = \left(\frac{sy}{n} - \alpha_0\right) T + \frac{s}{n}\frac{R_0}{1 - \alpha'} - s\left(\frac{n_0}{n} - \alpha'\right) \quad \ldots\ldots (18)$$

and from (17)

$$V_m(T) = \frac{1}{2}\left(\frac{sy}{n} - \alpha_0\right) T + \frac{s}{n}\frac{R_0}{1 - \alpha'} - s\left(\frac{n_0}{n} - \alpha'\right) \ldots\ldots (19)$$

In this form the formulae may easily be expressed in words. We note that

$$\frac{s}{n}\frac{R_0}{1 - \alpha'}$$

is equal to the average waiting time before overload began. Moreover

$$s\left(\frac{n_0}{n} - \alpha'\right)$$

obviously represents the reserve that the group on the average displayed before overload began. As α_0 indicates the group's maximum grade of utilisation, which theoretically should be 1 but which, owing to technical conditions, is often somewhat lower, one may suitably call $sy : n - \alpha_0$ the *relative overload* of the group.

If we ignore the influence of the above mentioned reserve, we may read (18) thus: The increase in average waiting time at the instant T after the setting in of a constant overload is equal to T times the relative overload. The increase in average waiting time reckoned for the whole overload period will be half of this.

As numerical example, let us consider a group of 20 devices, which before overload are loaded by 18 erlang, so that $a' = 0.9$. The average occupation time may be 4 min. The load increases to 24 erlang after which it remains constant. We put $a_0 = 1$ and $n_0 = n$. The blocking before the overload R_0 is approximately 0.5.

From (18) we then get

$$V_0(T) = \left(\frac{24}{20} - 1\right) T + \frac{4}{20}\,\frac{0.5}{1 - 0.9} - 4(1 - 0.9) = 0.2\,T + 0.6 \qquad (20)$$

$$V_m(T) = 0.1\,T + 0.6$$

After one hour, therefore, the average waiting time has increased to 12.6 min. The average waiting time for the whole hour is 6.6 min.

Centralized Private Branch Exchanges

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U.D.C. 621.395.26

As a rule telephone switching systems for small organizations require a large number of exchange lines compared with the number of extensions needed and they are without exception expensive, particularly if they are to provide automatic connections with all the latest facilities

L M Ericsson has now introduced a new centralized automatic branch exchange system, which is advantageous economically, and technically meets all telephone demands for small organizations.

The centralized automatic branch exchange system may be applied to advantage in offices having up to 10 extensions, but under certain conditions it can also be employed in larger offices having 20 or more extensions.

In the following article an account is given of the economy, design and traffic facilities of a centralized automatic branch exchange.

I. Introduction

A centralized automatic branch exchange (C. A. B. X.) is a telephone exchange common to a number of separate concerns, installed at the public exchange and forming part of the equipment of that exchange. Though the connecting devices are common to and accessible by all the extensions connected to the exchange, the new telephone system has in the main the same properties as small decentralized private branch exchanges installed on the subscribers' own premises.

Each extension instrument and operator's instrument is connected to the C. A. B. X. by two-wire lines and instead of using press buttons or keys for distributing incoming calls and lamps for signals, the dial alone is used for operation and only audible signals are employed. Thus even blind persons may be employed as operators, which may be important in certain conditions.

For incoming trunk call, the operator has the facility of breaking local calls and establishing the trunk call to the wanted extension. Both the operator and an ordinary extension may transfer incoming local calls to a waiting position on a busy extension, provided the busy extension can take external traffic and is not restricted to internal calls.

From extensions connected to the public exchange it is possible to make inquiry calls to all extensions belonging to the same C. A. B. X. subscriber. In conjunction with inquiry it is possible to make transfer to extensions that are open for public exchange traffic.

As a certain number of extensions can always be reached direct from the public exchange no special devices for night service connection are required, especially as these extensions have the same facilities as the operator's instrument.

The call indicating signals for the operator are:

1. Slowly repeated ringing signal		Call
2. Rapidly repeated ringing signal		Re-call
3. Slow tick-tack signal	while call	Local call waiting
4. Rapid tick-tack signal	is connected	Trunk call waiting

Guiding signals for operation are:

1. Steady tone	Dialling tone
2. Slowly interrupted tone	Extension is unoccupied
3. Interrupted short-long tone	Locally busy. Waiting connection can be made
4. Rapidly repeated tone	Fully busy. Waiting connection cannot be made
5. Rapidly repeated weak tone	Listening signal
6. Repeated weak buzzing signal	Heard after waiting and break preparation. Indicates that the connection in question is completed.

The manipulations of the dial are:

1. One impulse initiates operator's switching call, switches between called extension and calling public exchange subscriber and restores connection after switching to a busy extension.
2. Two impulses cancel waiting or break preparation.
3. Three impulses produce waiting or break preparation.

Other manipulations are:

1. Replacement of handset after operator's call completes an incoming switching to extension.
2. Replacing handset for an instant after uncompleted operator's switching call produces return to the public exchange subscriber.

This simplified method of operation may on casual comparison with other wellknown methods be considered less rational, but owing to its simplicity it is in fact particularly easily carried out and can be learned in a very short time — especially as operation agrees in the main with the methods for inquiry and transfer of public exchange connections.

The first practical application of this new telephone system was made by the Rotterdam Telephone Administration, who ordered a C. A. B. X. as early as 1940. The material was delivered during the war and was stored without suffering damage until the war was over, when assembly was at once put in hand. The first extensions were connected to the new system at the close of 1946 and now — November 1947 — the exchange is fully occupied.

The exchange has operated perfectly and fulfilled all anticipations in regard to this unique system. Up to now it would seem that no similar telephone system is to be found in any other telephone administration throughout the world.

II. Comparison between Centralized and Decentralized Private Branch Exchanges from the Technical and Economic Points of View

The diagram, Fig. 1, shows how a C. A. B. X. and a normal P. A. B. X. are connected to a public exchange. It will be seen from the diagram that there are nothing but extension instruments in the offices of subscribers connected to the C. A. B. X. Trunk and local incoming calls are routed over separate trunks *FITR* or *FIR*, these being connected to the public exchange *GVII*, i. e., to the multiple of the final group selector. The outgoing traffic is routed over trunks *FUR* direct to the first group selector at the public exchange.

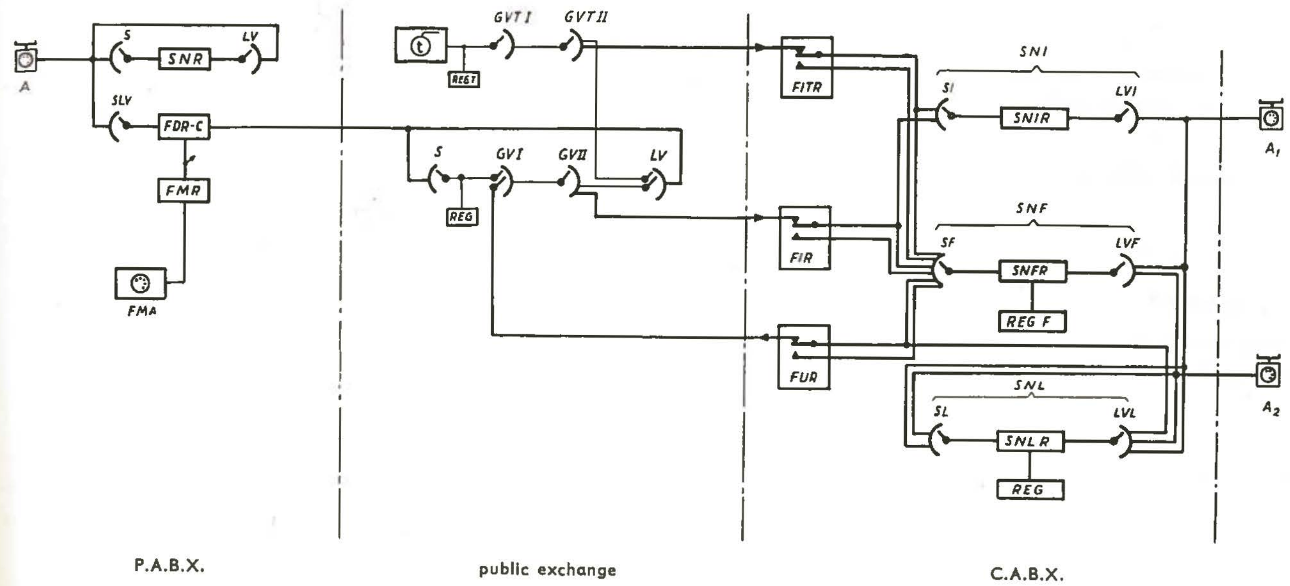

Fig. 1 X 7453

C.A.B.X. and P.A.B.X.

connected to a public exchange

P.A.B.X.

A	extension
FDR—C	public exchange line
FMA	operator's instrument
FMR	operator's equipment
LV	line finder
S	line finder
SLV	line finder
SNR	connecting circuit

public exchange

GV I, GV II	group selectors for local traffic
GVT I, GVT II	group selectors for trunk traffic
LV	final selectors
REG	register
REGT	trunk register
S	line finder

C.A.B.X.

A_1	operator's instrument
A_2	extension
FIR	incoming local traffic trunk
FITR	incoming traffic trunk
FUR	outgoing traffic trunk
LVF	final selector, transfer traffic
LVI	final selector, incoming traffic
LVL	final selector, internal and outgoing traffic
REG	register, local and outgoing traffic
REGF	register, operator's switching and inquiry calls
SF	line finder, transfer
SI	line finder, incoming
SL	line finder, internal
SNI	connecting circuit, incoming traffic
SNIR	relay unit, connecting circuit
SNF	connecting circuit, switching and inquiry traffic
SNFR	relay unit, connecting circuit
SNLR	relay unit, connecting circuit

There are three different kinds of connecting circuits, *SNI*, *SNF* and *SNL*. Over the first of these, all incoming traffic is routed and the final selector *LVI* is positioned under control of the public exchange register. The relay unit *SNIR* serves as operator's equipment, accessible to all subscribers connected to the C. A. B. X. The connecting circuit *SNF* is employed as connecting device in dealing with incoming calls and for inquiry and transfer. The *SNL* connecting circuit is used for local connections in the C. A. B. X. and for outgoing calls to the public exchange.

The operator's instrument employed is a normal automatic telephone instrument A_1. For purposes of comparison a P. A. B. X. is shown connected to the public exchange by exchange lines *FDR-C*. These exchange lines are connected in the public exchange to the line finder and final selector multiples *S* and *LV* in the same manner as ordinary subscriber's lines. Incoming calls are indicated at a special operator's instrument *FMA* and by means of this and the operator's equipment *FMR* the selector *SLV* is set to the wanted extension. Outgoing traffic to the public exchange first occupies a local connecting circuit in the P. A. B. X., but after the routing figure for outgoing call is received the connection is transferred to *FDR-C* over selector *SLV*. Internal connections occupy only the P. A. B. X. local connecting circuit.

A. *Technical Comparison*

1. *Utilization of Connection Devices*

In a C. A. B. X. the connecting devices are used in common for a large number of subscribers, the total traffic of which is so averaged that almost full utilization may be attained. If the traffic demands increase, the exchange may be enlarged by adding the requisite number of connecting devices. Thus the C. A. B. X. need only comprise the connecting devices necessary for the traffic.

Connection of new extension lines requires only a small number of reserves of line relays and cut-off relays, as these may be used for any of the subscribers connected to the centralized equipment.

Small P. A. B. X. are constructed for a definite number of extensions, connecting circuits and exchange lines. In these therefore there may often be unutilized line and extension equipments.

C. A. B. X. extensions which are likely to be used as operator's instruments, must be connected to the *LVI* multiple and very few reserves are required for this purpose. Other extensions for the same subscriber need not be connected consecutively to the *LVI* multiple.

The exchange lines of a P. A. B. X. must usually be connected consecutively to the final selector multiple in the public exchange. To allow for possible increase in traffic, reserve positions of each P.A.B.X. must always be present. There will thus always be unutilized multiple space in conjunction with the connection of P. A. B. X.

The circuits, *SNI*, can be connected to the operator's instruments *A1* of subscribers to two or three C. A. B. X. The number may therefore be restricted to existing traffic requirements. Corresponding devices *FMR* including the special operator's instrument for a P. A. B. X. are required separately for each subscriber.

2. *Availability*

In the C. A. B. X. the availability for incoming and outgoing calls is determined by the number of trunk circuits and connecting circuits. Augmentation of these means increased availability for all subscribers connected to the C. A. B. X.

The number of connecting devices for each C. A. B. X. is so large that *a subscriber can practically always establish the call connection wanted from his own offices.* Similarly the number of trunks between the centralized equipment and the public exchange will be so large that *a subscriber will probably never be barred for connection with the public exchange.*

In the C.A.B.X. incoming calls need never wait for answer from an operator's instrument. If the ordinary operator's instrument is busy or blocked, the call proceeds automatically to the next instrument connected in the *LVI* multiple for the subscriber in question. All these instruments have exactly the same switching facilities as the ordinary operator's instrument.

Any of the extensions may be given facility of direct traffic with the public exchange, by connecting the line to the *LVI* multiple. Direct incoming traffic to the extension means relief of traffic to the operator's instrument, and also quicker and more convenient connection for the calling outside subscriber.

In small P.A.B.X. the availability is determined by the number of connecting circuits and public exchange lines, which number for financial reasons is usually inadequate. The operator's instrument *FMA* is distinct, so that switching can be done only from that instrument. With a rush of traffic therefore there is delay in answering and switching.

In the small P.A.B.X. the number of night service connections is limited to the number of public exchange lines. In the C.A.B.X. there is no limit in this respect, because a subscriber may have all his extensions connected to the *LVI* multiple.

3. *Grade of Service*

In a C.A.B.X. *a subscriber will never be barred for any length of time owing to fault in the exchange.* Total interruption of operation can never happen, whereas this may take place in a P.A.B.X.

The operation of the C.A.B.X. operator's instrument is simple in comparison with that for incoming calls to a P.A.B.X.

The trunks *FITR* for trunk traffic allow of special indication, so that the operator may devote special attention to calls over these circuits, having special facilities if required.

Similar indication for exchange lines to a P.A.B.X. is not usually possible. Thus the operator has no special facilities in respect of trunk calls.

The register *REG*, Fig. 1, in the C.A.B.X. can register numbers both for the local connections and for connections to the public network. Outgoing routing figures and wanted subscriber numbers may thus be taken in their order.

Consequently connections to numbers in the public exchange take shorter time than corresponding connections over a P.A.B.X.

4. *Power Supply and Space Requirements on the Subscriber's Premises*

As the C.A.B.X. is installed at the public exchange, the exchange power plant may be used. Thus no space need be provided by the subscriber either for power plant or for connecting devices.

A P.A.B.X. takes up space on the subscriber's premises. It also requires for each switchboard a battery with charging device or a mains supply unit.

5. *Maintenance and Fault Location*

The maintenance of the C.A.B.X. is comprised in that of the public exchange and thus calls for no extra staff. The maintenance of the separate lines and instruments is looked after by the regular maintenance staff of the network.

For fault location in the C.A.B.X. the testing and measuring instruments of the public exchange are available, enabling faults to be cleared at any time of the day without disturbing traffic.

The maintenance of small P.A.B.X. requires separate staff specially trained. Any faults arising cannot in most cases be cleared immediately or without interruption of traffic.

Moreover the better maintenance facilities and more appropriate premises ensure longer life for the C.A.B.X. than for the P.A.B.X.

6. *Circuit Network*

Each extension is connected to a C.A.B.X. by two-wire lines. Nevertheless this does not involve any appreciable increase in the number of lines compared with a line network of a P.A.B.X. for the category of subscribers concerned. In the decentralized system the number of exchange lines required will often be almost as large as the number of extensions.

Subscribers with extensions in a building apart from the main subscriber instrument may more conveniently be connected to a C.A.B.X. Two lines are required and both instruments will be ordinary automatic instruments, fully equal as regards traffic.

The number of lines for a main instrument with extension in another building is usually three.

B. *Economic Comparison*

The better utilization of the connecting devices provided by the C.A.B.X. means that fewer connecting devices are required than for an equivalent plant made on the decentralized system, which means a saving of installation costs with the new system.

The relay equipments for inquiry and transfer are provided on the trunks *FUR*, *FIR* and *FITR*, Fig. 1, common for the C.A.B.X.

Corresponding equipments for P.A.B.X. are required on each exchange line. The total number of these considerably exceeds the number of trunks for the C.A.B.X.

The outgoing trunks *FUR*, Fig. 1, may be connected direct to the group selector *GVI* at the public exchange. This saves the line finder at the public exchange.

Calls from a P.A.B.X. over exchange lines must take place over line finders. If direct connection were made between exchange lines and a group selector the number of these would be so large that the cost would be higher than with line finders.

The connecting circuit *SNI* corresponds to the operator's equipment *FMR* of the P.A.B.X. This *FMR* is required for each subscriber, whereas *SNI* is only necessary in the required number, this representing an economic advantage for the new system.

Increased availability and grade of service in the C.A.B.X. mean economic advantages for both telephone administration and for subscribers.

The elimination of individual power supply for each subscriber due to the introduction of the C.A.B.X. system also means considerable saving both in cost and in other respects.

The space taken up in the public exchange by the C.A.B.X. involves extra expense for the telephone administration, but this is many times compensated by the lower maintenance costs. Elimination of the need for space on subscriber's premises is a benefit to the subscriber.

The extended line network for the C.A.B.X. represents an extra expense for the telephone administration, but this is compensated by the less expensive terminal equipments of the lines to the new system. Thus the relay equipments for the extension circuits consist only of line and cut-off relays, whereas the exchange lines for decentralized P.A.B.X. have relay equipments *FDR-C* in the P.A.B.X. switchboards as well. These latter equipments will be expensive if the exchange lines are to have inquiry, transfer etc. facilities.

From the above it will be seen that both installation and maintenance costs of a C.A.B.X. for subscribers with few extensions and relatively large public exchange traffic are much more favourable than the corresponding costs of a P.A.B.X. system for this category of subscribers.

Where the economic boundary lies between centralized and decentralized P.A.B.X. requires investigation for individual cases. To sum up it may be stated, however, that on the credit side of the centralized P.A.B.X. are: *lower installation cost, lower maintenance cost, better grade of service and longer life.* Against these we have on the debit side *increased line costs.*

III. Principle of Lay-out

The diagram, Fig. 1, shows in outline how the centralized P.A.B.X. built in Rotterdam is laid out and how it is linked with the telephone system of the public exchange. In this case a number of adaptations have been made, which are by no means standard. The double clearing signal control for disconnection of speaking connections as applied at Rotterdam, for example, may without inconvenience be altered to the clearing system desirable for each particular case.

All line finders and final selectors with multiples connected to the telephone instruments are LM Ericsson's machine-driven 500-line selectors. The line finders *SI* and *SF* whose multiples are connected to trunk circuits have 250-line multiple capacity, but otherwise are of the same design mechanically as the standard 500-line selector.

The line finders *SI* and *SF* are 9-point, the final selectors *LVI* and *LVF* are 5-point and the line finder *SL* and final selector *LVL* are 4-point. For all line finders and for final selector *LVI* there is in addition a contact band (d-contact) for the rotary movement.

The registers *REG* for the local and outgoing traffic include both the local and the public exchange number series and they direct both local connections and the connections in the public exchange.

The registers *REG F* are only employed for dealing with incoming traffic and for inquiry traffic. These registers only receive local numbers, which are three-figure in the series *140—599*. Two multiple frames in *LVL* are reserved for connection of trunk circuits *FUR* for outgoing traffic to the public exchange, which means that the number of extensions in a centralized P.A.B.X. cannot be more than 460. These 460 extensions have common access to the connecting circuits *SNL* and *SNF* and to the outgoing trunk circuits *FUR*.

In general the extensions are divided into two categories *A1* and *A2*. The first of these is connected in all final selector multiples. In the *LVI* multiple this category has a call number included in the public exchange number series. These extensions may therefore be called direct from the public exchange and may therefore act as operator's instruments, this being possible throughout the day and night. Special devices for night service connection are therefore not required. From this it will be seen that a subscriber has at least one extension connected to the *LVI* multiple and that *LVI* is equivalent to an ordinary final selector in the public exchange.

The extension group designated by *A2* in Fig. 1 is only connected in the local multiples *LVL*, *LVF* and *SL*. Consequently these extensions may only be called by numbers in the three-figure series and cannot receive direct incoming call from the public exchange.

As regards traffic with the public exchange there are »open» and »barred» extensions. An extension may be barred for outgoing traffic only, for incoming only or for traffic in both directions.

Extensions belonging to the category *A1* are usually »open» for both incoming and outgoing traffic. In the *A2* group there may be need for barring in one form or the other. A barred extension can always receive inquiry call.

Though the final selectors have a range of 460 extensions, only those extensions belonging to one subscriber can obtain direct communication with each other over the C.A.B.X. This applies to local, operator's and inquiry calls.

For a group of extensions belonging to one subscriber there is only one call meter, which records all call connections going out from that subscriber's extensions.

As only part of the extensions are connected in the *LVI* multiple, one 500-line group in *LVI* may correspond to two and possibly three C.A.B.X. with 460 extensions in each. The incoming trunk circuits *FIR* and *FITR* receive special indication in *LVI* so that the switching call is automatically routed to the *SNF* group that can reach the wanted extension. Thus the trunk circuits *FIR* and *FITR* and the connecting circuits *SNIR* exist in groups for incoming calls to two and possibly three C.A.B.X.

IV. Mechanical Construction

A. *Racks*

The mechanical construction of the racks is adapted to the principle of the system. The connecting circuit racks consist of bays for local connecting circuits *SNL*, for operator's and inquiry connecting circuits *SNF* and for connecting circuits for incoming traffic *SNI*, in full agreement with the diagram of Fig. 1.

Each such set of racks, see Fig. 2, consists of a rack for line finders, one for final selectors and one for the connecting circuit relay sets. Vertically the relay sets take up twice as much space as their selectors and they are therefore mounted on either side of the relay rack, which has odd connecting circuits at the front and even connecting circuits at the back. The capacity of the rack may be 50 or 60 connecting circuits according to the ceiling height of the public exchange.

The arrangement with the relay rack between the selector racks allows of direct connection by the selectors' plugs to jacks mounted at the ends of the racks for connecting circuit units, see Fig. 3. Thus when fitting no cabling is required between these relay racks and the selector racks.

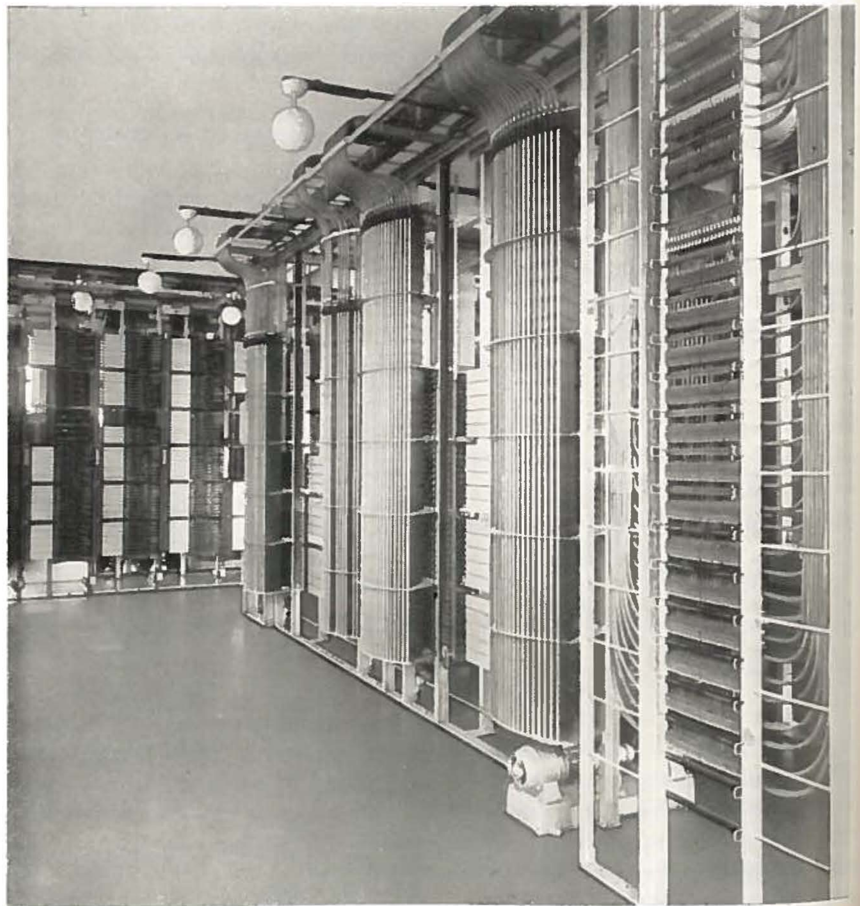

Fig. 2 X 6298

Inside of equipment room

with rows of racks each comprising racks for line finders, connecting circuit relay sets and final selectors

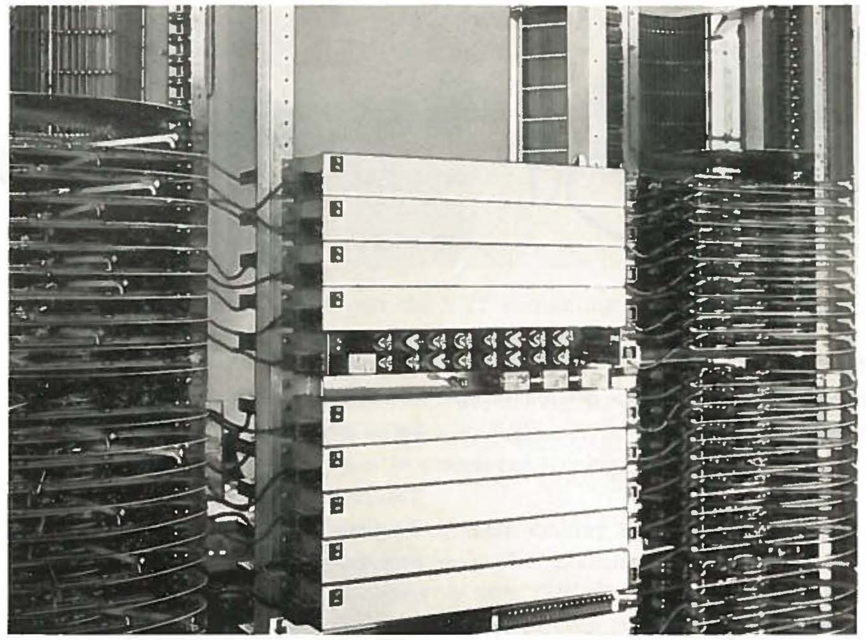

Fig. 3 X 6299

Set of racks

comprising, at left, line finders; centre, connecting circuit relay sets; right, final selectors

Each connecting circuit unit has a plug containing outgoing circuits to registers, together with signal circuits, etc. These plugs are inserted in jacks in the relay rack, whence cabling is provided to the registers and to the distribution block for signal circuits. Four connecting circuits are connected by fixed cabling to one register. The outgoing cabling from *SNIR* carries only signal circuits. This arrangement gives the smallest possible number of soldering points and in consequence simple fitting and decreased possibility of fault due to poor soldering.

The registers for local and outgoing traffic are of the same construction as the public exchange registers and are mounted in racks with them. The line equipments for extensions, consisting of a standard line and cut-off relay, are mounted in rack units for 240 extensions. The relays are joined by fixed cabling to a separate distribution frame, Fig. 4, where the cabling from the selector rack multiples is also terminated. In this distribution frame the character of the extension is determined: if it is open or barred for traffic with the public exchange, if it is to have facility of direct traffic with the public exchange, if it is to serve as operator's instrument etc.

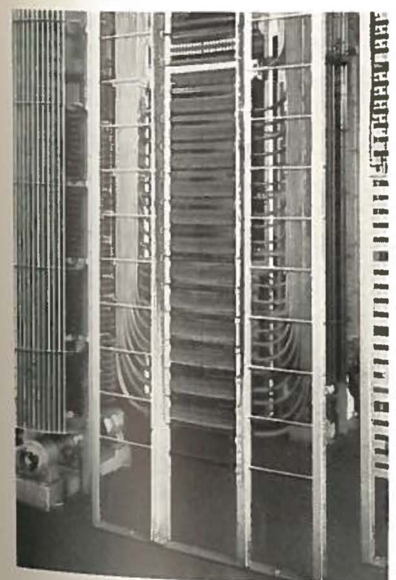

Fig. 4 X 4520

Distribution frame

In accordance with the principle of construction, for one fully fitted set of racks for incoming connecting circuits there may be two or three sets of racks with local connecting circuits *SNL* and an equal number for *SNF*. In addition there are racks for 2 × 460, or 3 × 460 line equipments for extensions.

Other connecting devices for trunk circuits *FUR, FIR, FITR* and *REG F* are mounted in plug-connected units in separate racks.

B. *Selectors and Connecting Devices*

To adapt the 500-line selectors to the special character of the system and to the rational arrangement of the connecting circuit racks, certain departures have been made from the standard design of the selectors. Thus all line finders are provided with 30-point plugs, the flexible cords of which are on the right-hand side of the selector. The final selectors' 30-point plugs are on the left-hand side of the selector.

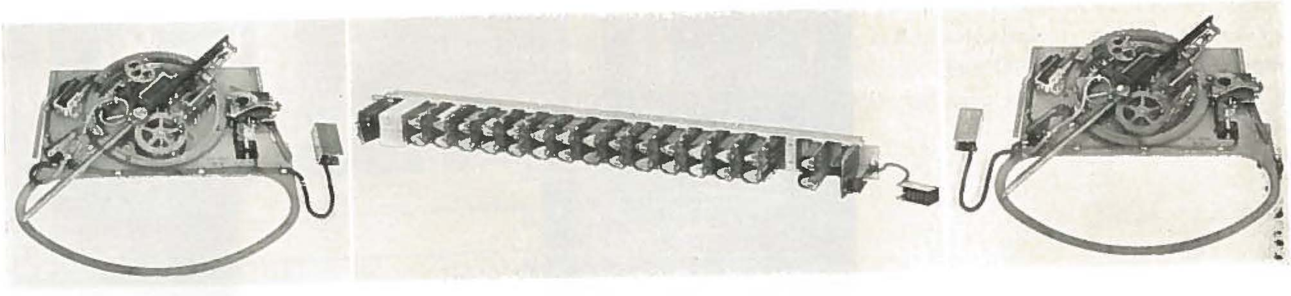

Fig. 5 X 7456
Selector and relay unit for one connecting circuit

The relay units for the connecting circuits are specially adapted for fitting with the selectors. Each unit occupies 70 mm vertically, i. e., twice the space for a selector. Fig. 5 shows selector and relay unit for one connecting circuit.

The register units *REG* are of LM Ericsson's standard mechanical construction. The register units *REG F* consist of step-by-step driven, rotary selectors with necessary relays.

The other relay sets *FUR, FIR* and *FITR* are fitted on frames, with space for 2 × 13 or 3 × 13 relays.

All relay units have covers at front and back as protection against dust and mechanical damage.

Relays and selectors all have twin contacts.

V. Power Supply

The C.A.B.X. is made for the same working voltage as the public exchange, i. e., 24 V, with tolerated variation in voltage from 22 to 28 V. Thus no separate power plant is required.

The resistance of the extension lines may not exceed 1000 ohms and the leakance resistance may not be below 20000 ohms.

VI. Installation

The installation of a C.A.B.X. is done in the same way as with similar racks for ordinary public exchanges built on LM Ericsson's 500-line system.

The detachable connecting devices are delivered separately and are fitted by easy insertion in their places in the racks, with fixing screws to hold them in place. By supplying the relay sets separately, disturbance of adjustment during transport is kept down to a minimum. Thus there is no need for tedious testing work before starting up the C.A.B.X.

VII. Functioning and Traffic Facilities of the C.A.B.X.

See diagram, Fig. 1.

A. *Internal Traffic Between Extensions Belonging to the Same Subscriber*

On call from an extension, connection is made over finder *SL, SNLR* to the register *REG*. Dialling tone is received and, when the wanted three-figure number has been dialled, *LVL* — controlled by the register — is positioned

to the extension corresponding to the number, which is called by repeated ringing signal, the ringing tone being heard by the calling extension.

If an internal call connection is cut by the operator's instrument in conjunction with call to one of the speakers, the extension cut off receives busy tone.

B. *Outgoing Traffic*

Outgoing traffic is connected over the *SNL* connecting circuit and over a free trunk circuit *FUR* direct to the public exchange group selector *GVI*.

When the calling extension has received dialling tone from the centralized P.A.B.X.'s register the routing figure *o* is dialled. *LVL* is directed to the first or the second multiple mat and a free outgoing trunk circuit, *FUR*, is hunted.

Immediately after dialling the figure *o*, fresh dialling tone is received in the register. This tone corresponds to the public exchange dialling tone. The wanted exchange subscriber's number is now dialled and the exchange connecting devices are actuated in the usual way. When the connection is established, the register is disconnected from the connecting circuit. The line branches in the connecting circuit are connected through and the extension receives transmitter feed from the trunk circuit *FUR*.

If the handset is replaced before answer, restoration takes place at once — without call metering. For calls answered, call metering takes place after double clearing signal and disconnection.

If an outgoing speaking connection is broken by the operator in connection with incoming call to the extension, busy tone is transmitted to the cut off exchange subscriber. Call metering takes place.

C. *Local Incoming Traffic*

The local incoming traffic goes over *GVII* or the last group selector in the public exchange, over incoming trunk circuit *FIR* and line finder *SI* to a connecting circuit *SNI*. The final selector *LVI* is actuated under control of the public exchange register.

For incoming calls the following cases may arise.

1. *Operator's Instrument is Unoccupied*

The exchange hears ringing tone while the operator's instrument is called by repeated signals. After answer the restoration of the connecting circuit *SNI* and the trunk circuit *FIR* is controlled by double clearing signal.

2. *The Operator's Instrument is Busy*

The exchange subscriber hears ringing tone and at the same time »tick-tack» signals are transmitted to the conversation proceeding. This announces to the operator that an incoming call is waiting and that the conversation or operation that is proceeding must hurry up.

If the operator terminates the conversation or operation, testing and ringing take place from *SNI* immediately the operator's instrument comes free.

If the exchange subscriber replaces the handset before answer, restoration of *SNI* and *FIR* takes place and the warning signal ceases.

3. The Operator's Instrument is Fully Busy

An operator's instrument is fully busy if it has a local call connection plus a waiting call or if it is trunk busy.

In these cases the exchange subscriber receives busy tone. No testing can take place to the operator's instrument in conjunction with the call. *SNI* is restored when the exchange subscriber replaces the handset.

4. The Operator's Instrument is Blocked

The exchange subscriber receives ringing tone. After about 30 s the blocking connection is cut off and the operator's instrument is rung.

5. The Operator's Instrument is Marked Unattended

By breaking the line branches at the telephone instrument the operator's instrument is marked unattended. In that case the final selector *LVI* goes direct to the next position in the multiple mat where an extension belonging to the same subscriber as the operator's instrument is connected. If this extension is free, testing and ringing is done in the normal way. This extension has the same facilities as the operator's instrument and can therefore serve as such.

Should this instrument also be marked unattended, the final selector continues its radial movement till it comes to an attended extension for the subscriber in question.

6. Operator's Instrument is Marked for Passing on

If the operator's instrument is free, testing and calling are done in the usual way. If, however, it is busy, *LVI* moves automatically to the next position in the multiple where the instrument there connected is called. Should this also be busy *LVI* continues its radial movement until it finds an attended free extension for the subscriber concerned.

7. The Subscriber's Highest Exchange Number in Series with the Operator's Instrument Number is Called or Connected to LVI in One of the Above Ways

If there is line interruption on the line branches for such an extension, this has no effect on *LVI*. The final selector in any case stops at the position for this extension.

D. Handling of Local Incoming Traffic

The handling of local incoming calls is initiated by an impulse on the operator's instrument dial. *FIR* is then switched over so that the operator's instrument is disconnected from the incoming connection.

In the group of the centralized equipment dealing with the operator's instrument there is started line finder *SF* belonging to free connecting circuits *SNF* with free registers. When a line finder comes to the multiple mat marked by *FIR* for call, testing takes place and all line finders stop their rotary movement. The finder now connected to the multiple mat changes to radial movement and hunts the call-marked multiple position. The operator's instrument is connected to *REG F* where dialling tone is received. The wanted 3-figure extension number is dialled and signal is awaited. The operator may now meet the following cases:

1. Extension is Free and Open for Incoming Traffic

When final selector *LVF* is set to the wanted extension, the operator receives ringing tone, while the extension is called by repeated ringing signals.

When the call is answered, the operator by means of one impulse of the dial at a time may alternate between the called extension and the exchange subscriber. If the extension replaces the handset while the operator is in connection with the exchange subscriber, *SNF* is restored and the extension disconnected. If the operator then dials one impulse, fresh operator call is obtained and dialling tone is received from *REG F*.

a. *Connection is Established after Answer*

If the operator replaces the handset after receiving answer, connection is immediately established between the exchange subscriber and the extension rung. Provided the called extension keeps the handset lifted, the connection is established whether the operator on laying down the receiver is in connection with the extension or with the exchange subscriber.

The connection thus established is made over connecting circuit *SNF* and *FIR*. The occupied connecting circuit *SNI* was liberated when the connection was transferred to the wanted extension.

b. *Connection is Established Before Answer*

Connecting of an incoming call can be done without the wanted extension having answered the operator's call. If the operator puts down the handset immediately on hearing ringing tone, the operator's telephone instrument is released, but the connecting circuit *SNI* remains connected to *FIR* and awaits possible call back in case the call is not answered within a certain interval.

During the time the extension is being rung the exchange subscriber hears ringing tone. When the extension answers the call the operation is completed. Connection is established and the connecting circuit *SNI* is restored at the same time.

2. The Extension is Busy but Open for Incoming Traffic

The operator receives »locally busy» tone, consisting of repeated short-long tone signals.

Return to the exchange connection is made by one impulse of the dial. This reconnects the operator with the exchange subscriber and at the same time the connecting circuit *SNF* occupied by the operator's call is restored.

Instead of return by one impulse the operator may dial three impulses to prepare waiting connection by returning to the exchange subscriber. The operator is then re-connected to the calling subscriber and at the same time a faint droning signal indicates that the waiting connection can be established.

The connecting circuit *SNF* occupied by the operator's call remains connected and the waiting connection is established when the operator replaces the receiver. If the busy extension comes free after preparation for waiting there is immediate testing in *SNF*, but no ringing signal is transmitted as long as the operator is speaking with the exchange subscriber.

The waiting signal goes over to ringing tone which informs the operator that testing has taken place. If the operator replaces the handset, ringing signal goes out to the extension connected over *SNF* and when the call is answered the connection is established, *SNI* being then restored.

In case the called extension becomes free after preparation for waiting, the operator has the facility of getting into connection with the extension before the switching is completed. If one impulse is dialled at the time the signal is changed to ringing tone, the operator comes into connection with *SNF* and at the same time ringing signal is transmitted to the extension. When the call is answered, the usual connection with the operator is obtained.

In cases where the preparation for waiting has been executed but the exchange subscriber wants instead to have connection to another extension, the waiting is cancelled by two impulses on the dial. *SNF* is then restored and the operator comes into normal connection with the exchange subscriber. Fresh operator's call can then be made and the extension now wanted is called in the usual way.

3. *Extension is Fully Busy*

If the operator's call goes to a fully busy extension the operator receives busy signal consisting of buzzer impulses rapidly repeated. There then can be no testing in conjunction with the call and restoration must be made by one impulse. The operator then comes into normal connection with the exchange subscriber and *SNF* is restored.

An extension that is barred for traffic with the public exchange can never be fully busy for inquiry call from the operator.

4. *Call-back to the Operator's Instrument*

Call-back over *SNI* to the operator's instrument can be obtained after a certain interval or immediately.

a. *Call-back after a Certain Interval*

If the operator connects before answer to an unoccupied and non-barred extension and answer is not received within about 1 min., call-back to the operator's instrument takes place over *SNI*. If this instrument is not busy the exchange subscriber still hears ringing tone but *rapidly repeated ringing signals* indicate the special character of the call-back.

If the operator's instrument is busy or special marked otherwise, the call-back must either wait or the next instrument in the *LVI* multiple is called in the same way as with the direct incoming call.

After waiting connection to busy and non-barred extension, call-back is obtained in the same way to the operator's instrument if the call passed on has not been answered in about 1 min. after the operator replaced the handset. This means that the extension must be free and answer the waiting call within that interval for the connection switched by the operator to be completed.

b. *Immediate Call-back*

If the operator replaces the handset after call to busy extension when repeated short-long busy signal is heard without making waiting connection, then call-back takes place at once. In the same way, in all circumstances, there is obtained direct call-back when the operator tries to connect to fully busy extension or to extension barred for incoming traffic.

5. *Uncompleted Operator's Call*

The operator may interrupt an uncompleted call by replacing the handset for a moment. The connecting circuit *SNF* occupied by the call is restored and when the handset is again lifted the operator is in connection with the exchange subscriber. Fresh operator's call can be started in the normal way.

6. *Connecting Waiting Calls*

If the operator hears »tick-tack» signals while occupied with a call, this means that call to the operator's instrument is waiting. The operator may then interrupt the switching she was engaged on and deal with the waiting call.

When »tick-tack» signals are heard the operator makes inquiry call to her own number, receiving then definite busy tone. If the handset is then put down the waiting call is connected in and the operator's instrument is rung. The operator's interrupted connection is re-connected and calls the operator's instrument when the previously wanted call has been dealt with.

E. *Trunk Traffic*

The trunk traffic passes over special group selectors, *GVTII*, Fig. 1, in the public exchange and over special trunk circuits *FITR* in the centralized P.A.B.X. *LVI* is the last selector directed from the trunk exchange.

The various connecting processes in relation to the operator's instrument are directed by the connecting circuit *SNI* in the same way as for incoming call over *FIR*. In accordance with this, the line branches for *LVI* are through-connected to *FITR* where the final testing and blocking control is carried out.

For incoming trunk traffic the operator's instrument is connected in much the same way as for local incoming call. The special processes for trunk call are as follows:

1. *Operator's Instrument is Unoccupied*

The trunk exchange receives through-connected signal which actuates fixed light clearing signal lamp at the trunk operator's position. When ringing signal is sent out from the trunk exchange, this is repeated in *FITR* direct to the operator's instrument, which in this case is trunk (*i. e.*, fully busy) marked. After having connection with the trunk exchange the operator's instrument may be liberated by replacing the handset. Nevertheless the connection remains over *FITR* and *SNI* as long as the trunk exchange has not disconnected. Fresh testing and call is obtained as soon as ringing signal is sent out. The trunk operator therefore has the facility of preparing a trunk call without thereby blocking the operator's instrument.

2. *The Operator's Instrument is Busy*

The trunk exchange receives through-connected signal in the same way as with call to unoccupied operator's instrument. In the speaking connection proceeding there is heard rapid »tick-tack» signal, indicating that trunk call is waiting. There is no facility for the trunk operator to connect in or break the connection. Ringing signal from the trunk exchange is not repeated until the operator's instrument is free and the trunk connection made.

3. *The Operator's Instrument is Fully Busy*

The trunk exchange receives special completed signal, causing flashing in the clearing signal lamp. At the same time the trunk operator hears fully busy tone. No testing to the operator's instrument can take place in connection with the call. When disconnection is made in the trunk exchange, *SNI* and *FITR* are restored.

4. *The Operator's Instrument is Blocked*

The trunk exchange receives completed signal but ringing signals are not repeated until after app. 30 s, when the blocking connection is automatically disconnected from *FITR*.

F. *Switching of Trunk Calls*

Switching of trunk calls differs somewhat from the handling of local incoming calls. The following cases occur:

1. *Extension is Free and Non-barred for Trunk Traffic*

The operator's switchings when handling trunk call are the same as for local incoming call. If, however, attempt to connect through is made before the called extension answers the call, there is immediately call-back ringing to the operator's instrument.

2. The Extension is Locally Busy and Non-barred for Trunk Traffic

On operator's call to locally busy extension the operator is directly connected in on the call proceeding. At the same time listening-in tone is transmitted, audible to all three parties.

If breaking of the call is permissible, the operator prepares for this by dialling three impulses. This puts the operator in connection with the trunk exchange while repeated faint droning signals indicate that preparations for breaking are completed.

If then the operator replaces the handset, disconnection of the waiting extension's previous call occurs and the trunk connection is established. *SNI* is restored and the operator's instrument is disconnected. The subscriber cut off hears busy tone.

If the called extension comes free while the operator is preparing break, testing takes place in *SNF*, but no ringing signal is transmitted. The repeated drone signal, however, changes over to ordinary ringing tone. In order to establish the connection, the operator in this case must return to the *SNF* connection. In this way ringing of the extension is obtained and when answer is received the connection can be established.

If the trunk exchange does not want the call in process to be broken or if the operator for some other reason wants to cancel the preparation for break, this is done by dialling two impulses. *SNF* is then restored and the operator comes into normal connection with the trunk exchange.

3. Inquiry Call to Barred Extension

In conjunction with trunk call it may happen that the operator requires to make inquiry to a barred extension.

If the barred extension is free, the operator obtains connection in the normal manner. Return is done by one impulse and when the called extension lays down the handset *SNF* is restored.

In the event the extension is busy, the operator is directly connected in on the call proceeding, listening-in tone being connected at the same time. Return to the trunk connection is done by one impulse, after which *SNF* is restored.

No transfer of the trunk call to the barred extension can be made in any circumstances.

4. Call-back

Call-back over *SNI* to the operator's instrument takes place in the same way as similar call-back with local incoming calls. Testing, supervision and ringing are done from the *SNI* connecting circuit and it is only when the call-back is answered that through connection to *FITR* is obtained, the operator's instrument being then also marked trunk busy.

G. Inquiry and Transfer

Repeated inquiry and transfer may be made for all connections with the public exchange. For these, more or less the same connecting operations are used as those carried out by the operator when dealing with incoming calls. Only the *SNF* come into service for this traffic.

1. Inquiry and Transfer with Local Incoming Exchange Connection

The inquiry call is initiated by dialling one impulse. This switches over the *FIR* unit so that the extension obtains connection over the line finder *SF*, *SNFR* to a register *REG F*. Dialling tone is heard and the wanted number may be dialled.

a. *Inquired Extension is Free*

LVF is set to the position corresponding to the number dialled, the register then being released. The inquirer hears ringing tone, while the inquired extension is called by repeated ringing signals. The inquirer may return to the exchange connection by one impulse. If return is made before answer, *SNF* is restored.

If the inquiry call is answered, the inquirer can, by dialling one impulse, alternate between the extension and the public exchange connection. If the inquired extension replaces the handset while the inquirer is in connection with the exchange, the *SNF* occupied by the inquiry call is restored.

b. *Inquired Extension is Busy*

If inquiry is made to a locally busy extension, the inquirer receives local busy tone, i. e., repeated short-long buzzer tone. If return is made by one dial impulse, the *SNF* connecting circuit used for the inquiry call is restored and the inquirer obtains normal connection with the exchange subscriber.

On inquiry to fully busy extension, the inquirer receives fully busy tone, *i. e.*, tone signals rapidly repeated. Return to the exchange connection is made by one impulse.

c. *Transfer*

Transfer to non-barred extension may be done both before and after answer. If after making inquiry call the handset is replaced as soon as ringing tone is heard, transfer preparation is made.

If transfer is done before answer, the inquirer is disconnected as soon as the handset is replaced. *SNF* for the original connection remains connected, however, to *FIR* until the called extension answers the call. If answer is not forthcoming in app. 1 min. after the inquirer has put the handset down, the inquirer is called again by the usual repeated ringing signal and at the same time the connecting circuit *SNF* employed for the inquiry is restored. The exchange subscriber hears ringing tone until the call-back is answered.

In the same way as in handling incoming call, the inquirer may prepare waiting connection to a locally busy, non-barred extension. The switching and supervisory devices then employed are in entire agreement with those used by the operator. This applies also to attempts to make waiting connection to definitely busy and to barred extension.

While waiting, the exchange subscriber hears special waiting signal until the extension is free, when the signal changes to ringing tone.

Call-back over *SNF* is signalled by ordinary repeated ringing signal, the exchange subscriber still hearing ringing tone.

If the inquirer is busy when call-back comes, the waiting signal continues even when the *SNF* connecting circuit used for the inquiry call has been restored. When the inquirer's extension comes free, testing is made from the call-back and the waiting signal changes to ringing signal at the same time as the extension is called by repeated ringing signal.

If the inquirer has become fully busy when call-back is made, the exchange subscriber receives fully busy tone. In this case testing cannot be made to the inquirer.

2. *Inquiry and Transfer with Outgoing Exchange Connection*

Inquiry and transfer with an outgoing exchange connection take place exactly the same as with corresponding connections from an incoming connection. Transfer connection from an exchange connection originally outgoing is, however, a little different. Thus the inquirer is not freed on transfer before answer, until the inquired extension answers the call, and then *SNL* also is restored. If no answer is received within app. 1 min. after the inquirer laid down the handset, the *SNF* connecting circuit occupied by the inquiry call is restored. Call metering is done and clearing signal with the public exchange is transmitted after app. 30 s. After disconnection in the public exchange, *SNL* is restored.

Repeated transfer for outgoing call connections takes place just like the corresponding connections for incoming exchange call.

Call metering for a transferred outgoing exchange connection takes place after double clearing signal, after which full restoration is obtained.

3. *Inquiry and Transfer for Trunk Connection*

Inquiry to busy extension produces connection of rapid tick-tack signals on the conversation proceeding. These signals indicate to the speakers that inquiry call from a trunk connection is waiting. If the called extension is disconnected while the inquirer is connected, testing and ringing up take place. The inquirer has no facility of interrupting the call in process.

Transfer can only be executed if the called subscriber has answered the inquiry call and the inquired subscriber's handset is kept lifted. If attempt at transfer is made under other circumstances there is immediate call-back to the inquirer.

After transfer of trunk connection, the extension then trunk connected obtains trunk busy marking.

H. *Attempted Call to Extension Belonging to Another Subscriber*

If call is attempted by three-figure number to extension belonging to another subscriber, the final selector is set out but it is immediately restored after a special testing. The register also is restored but it is not disconnected from the connecting circuit. The caller hears dialling tone again and can immediately dial a fresh number.

Thus there is no possibility of call connection over the centralized P.A.B.X. between extensions belonging to different subscribers. This applies to local, operator handled and inquiry calls.

Multiple Desk for Multi-Position L.B. Switchboards

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U.D.C. 621.395.33

A single position telephone switchboard can obviously carry only a limited number of lines. In practice, the maximum number of lines in single position L.B. switchboards is between 100 and 200. The figure varies with the frequency of calls but is naturally also governed by the ability of the operator. If this limit (100—200) is exceeded multi-position switchboards must be adopted. The demand thus arising for subscriber multiples and facilities for progressive enlargement, however, has led to a special design, the multiple desk.

Below is described such a multiple desk, which supplements the series of new manual L.B. cord switchboards referred to in Ericsson Review No 3/1946.

The Multiple Desk

The new multiple desk, Fig. 1 and 2, is constructed as a single-position, two-panel section. Each section is so made that it can be put up in combination with other sections, thus enabling rows of desks with any desired number of positions to be formed. The bearing construction in the desk consists of an iron frame on which the wood fittings are screwed. All woodwork consists of light oak veneer on a base of plywood, except for the rear door which is of light wood fibre sheet in a frame of deal. The key shelf is covered by hard-wearing material in green colour convenient for writing on. Beneath the desk top a pigeon-hole has been arranged for the operator's private belongings. In view of the fact that multiple desks require quite long cords, the distance from key shelf to floor has been made 796 cm.

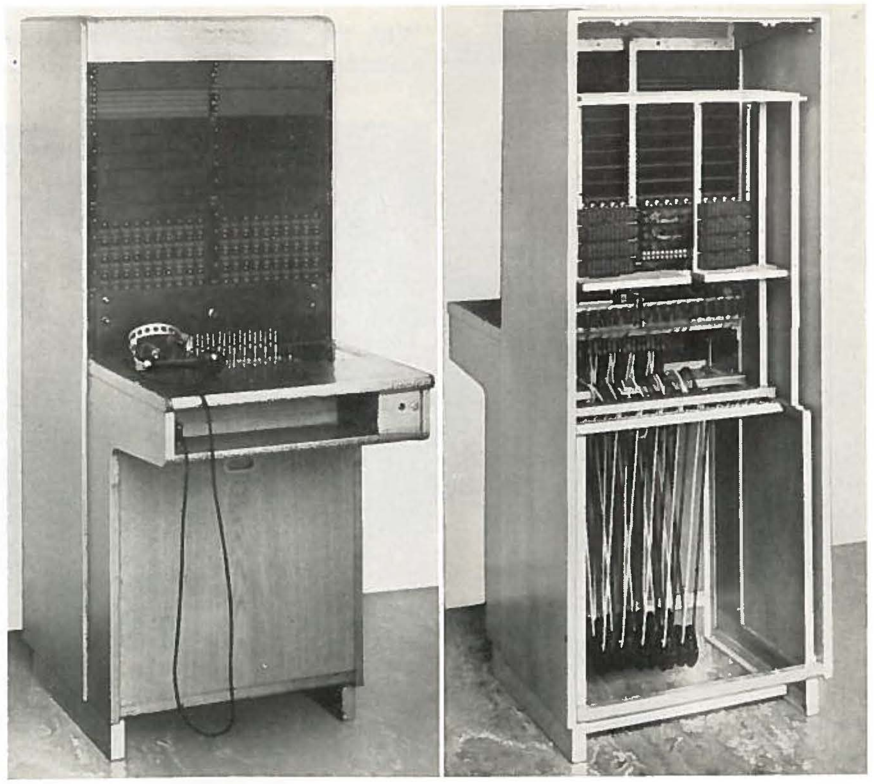

Fig. 1 X 6296
Initial section ABK 6521
right, back view with rear door removed

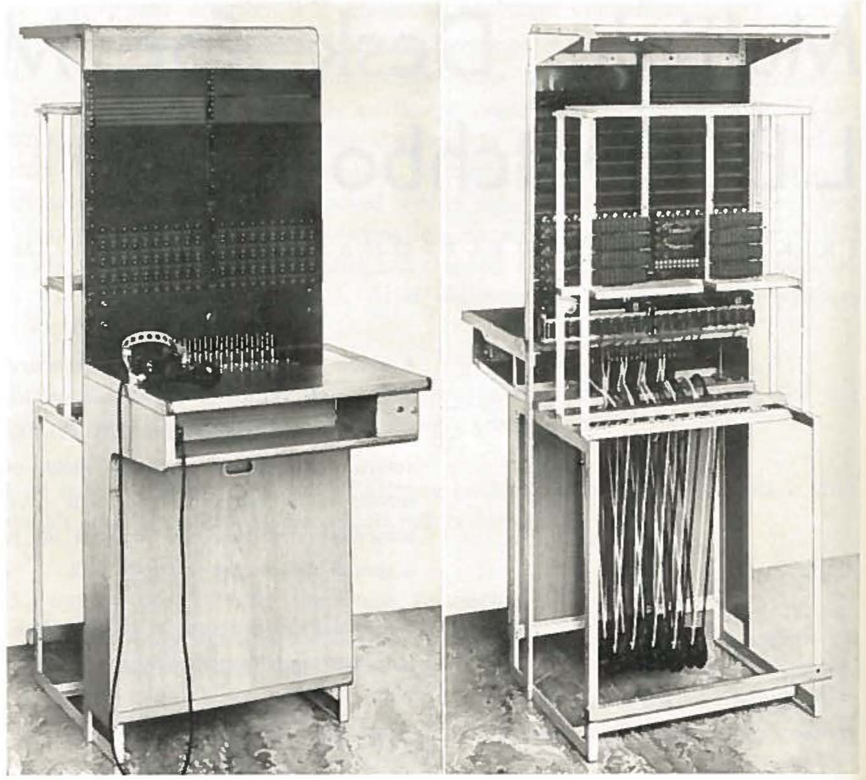

Fig. 2 X 6297
Extension section ABK 6522
right, back view

The key shelf provides space for a max. of 20 cord pairs. The space in the vertical field has been disposed as follows. Right at the bottom is the position unit, containing the equipment common to the cord pairs, then comes the answering field for up to 200 lines and at the top the multiple field is located, this holding 400 lines when employing 20 number jack strips. Thus with four-panel multipling the capacity will be 800 lines. Behind the answering field are the terminal blocks for connection of the lines. Owing to the large number of wires per line — 4 to 5 — it is necessary to use soldering tags instead of screws. Behind the multiple field a shelf is provided for supporting the multiple cables. The terminal blocks and the multiple cables are easily accessible from the rear of the desk.

With the object of facilitating stock-keeping and ordering LM Ericsson's multiple desks will be available in two executions, viz: as initial section and

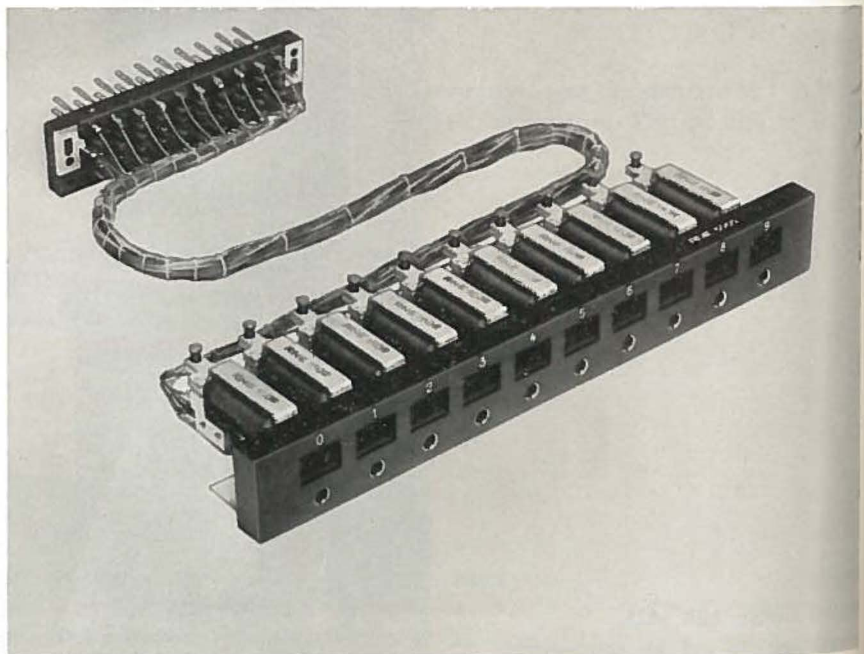

Fig. 3 X 6287
Line unit

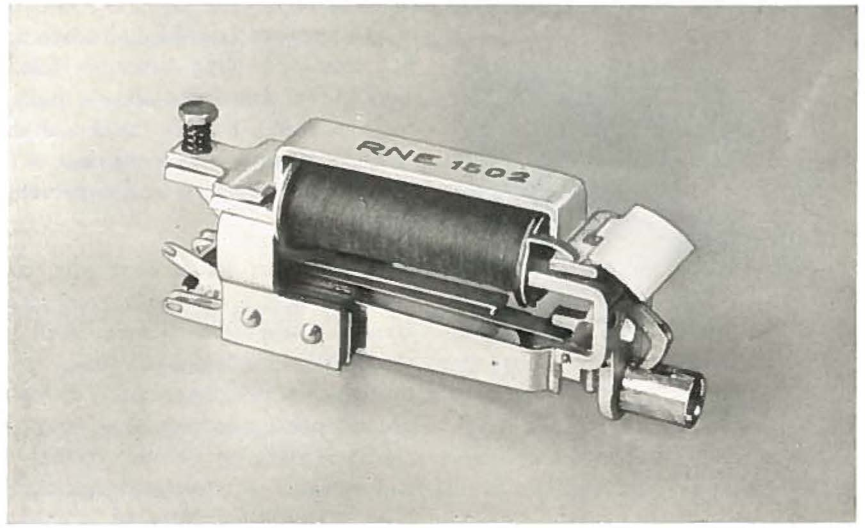

Fig. 4 X 6215
Drop indicator jack, type RNE 15

as extension section. An initial section, the construction of which may be seen from Fig. 1, is in all respects a complete desk. An extension section on the other hand is a desk without cover plates on either side and without end piece on the one side of the key shelf, as shown by Fig. 2. Thus the first desk put in for a plant will consist of an initial section while all enlargement will consist of extension sections, when one cover plate and possibly one end piece will be moved out to the new extension desk.

The new multiple desk has been given the designation *ABK 65*. The dimensions are: height 1514 mm, width 574 mm, depth 885 mm. The net weight for a fully fitted switchboard is:

initial section *ABK 6521* app. 115 kg, extension section *ABK 6522* app. 100 kg.

Details

The purely telephone technical equipment in the multiple desk is built up in the form of easily manipulated units, with bakelite as the predominating

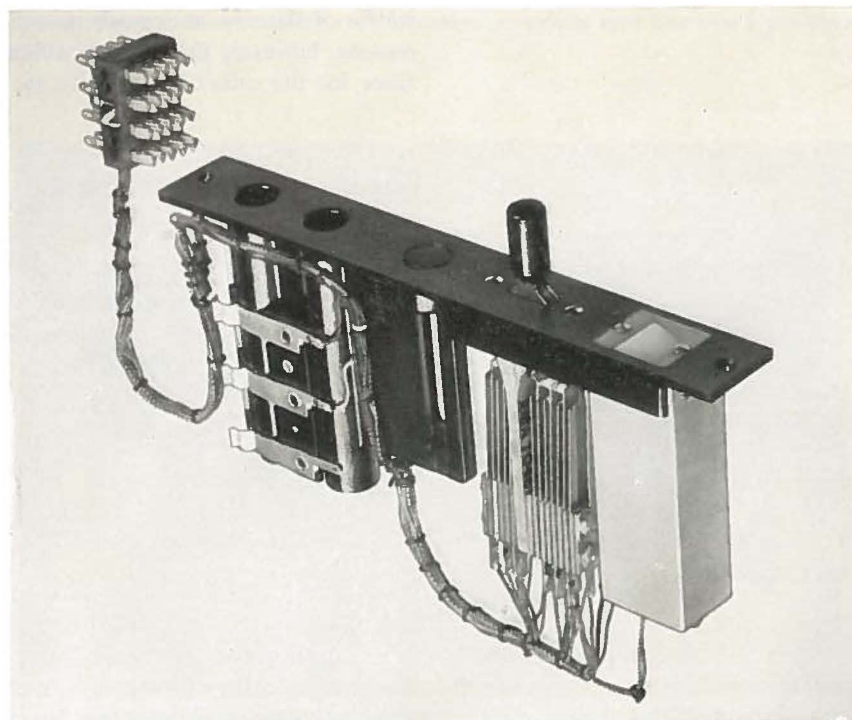

Fig. 5 X 6223
Switching set

Fig. 6 X 4448
Cord (above) and plug RPR 3526

material in the bearing constructions. Thus the calling and connecting devices for 10 lines are assembled to a line unit, see Fig. 3. The equipment for a single line consists of drop indicator jack, the appearance of which may be seen in Fig. 4. Ten such drop indicator jacks are mounted on a strip of bakelite which, together with a terminal block and an S-shaped cable, forms a complete 10-line unit. A multiple desk comprises a maximum of 20 line units which are all alike, both as regards shape of cable and numbering of the strip.

The equipment for a cord pair, comprising a key, a clearing signal drop indicator and a couple of cord clamp blocks, has also been built up on a frame of bakelite to a unit called the switching set, see Fig. 5. The cable terminates in a multi-pole plug, providing quick attachment of the unit to the desk. A complete cord pair comprises, in addition to the switching set proper, two cords with plugs and a pair of cord weights. Fig. 6 shows the cord and the plug as used in the multiple desk. The plug is of new design and consists of a molded plug tip and a plug shaft with protective spiral. Nevertheless the calibre is as usual, i. e., 5.76 mm. The cord weight, too, Fig. 7, is of new design. It consists of two halves of die-cast zinc alloy and a cord wheel of light metal.

All devices common to the lines and the cord pairs, except the hand generator, are assembled to form a position unit, in which therefore are included all coils and condensers for the telephone circuit, relays, rectifiers etc. for the ringing circuit and relay and bell for the alarm circuit. In addition the position unit contains a number of press button keys for operating these circuits. Finally there is on a position unit a row of multi-pole jacks by which the switching sets is connected to the desk. Each multiple desk is equipped with LM Ericsson's new operator's head set type *RLF 20* which is connected to the desk by a 4-way plug and jack.

The Multiple Annex

The multiple annex, Fig. 8, is intended as end section for rows of desks made up of a number of multiple desks. Its chief object is to make possible the extension of the multiple field, one panel in each direction, so that the operators at the end of the row of desks have the same facilities as operators in the middle of the row as regards accessibility of the multiple field. For practical reasons, however, the multiple annex has been arranged so that it also has space for the cables incoming to the multiple field.

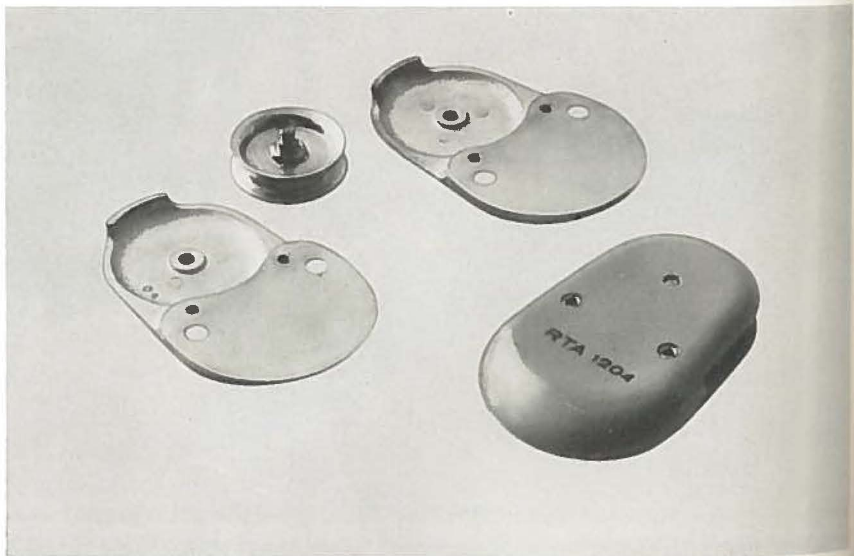

Fig. 7 X 6288
Cord weight RTA 1204

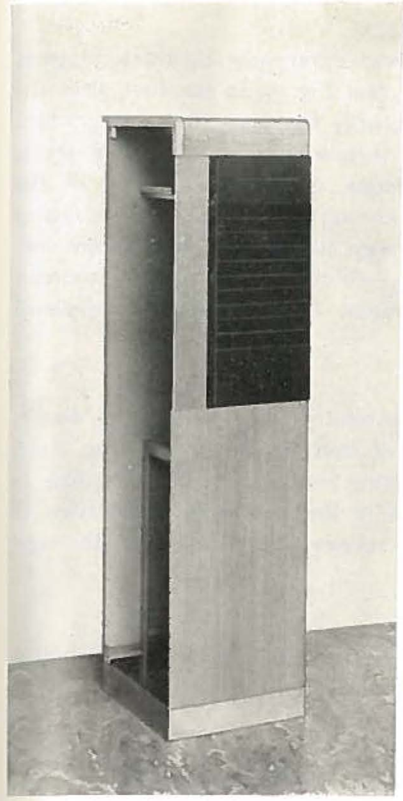

Fig. 8 X 4515
Multiple annex BAR 16

Like the multiple desk, the multiple annex has a frame of iron to which the woodwork is screwed. Otherwise the shape is such that annex and desk match when they are placed alongside each other in a row of desks. The multiple annex may be had in both right and left hand execution.

The multiple annex, which has been given the type designation *BAR 16*, has a width of 400 mm and a net weight of app. 26 kg.

Multiple Equipment

The multiple is built up of multiple mats type *TSE 83*. The multiple mat consists of a number of 20 number jack strips type *RNR 80*, joined up in parallel by a specially sewn flat cable. The distance between the strips is normally such that a given jack is repeated in each fourth jack panel. As each mat comprises 20 lines, the number of multiple mats required will be 1/20 the total number of lines.

To facilitate orientation in a multiple field thus built up, which extends over 4 jack panels, the jacks must be numbered in some simple manner. In the case considered the figures for 100s and 10s are on the covers that stretch over a block of 5 jack strips, the jack strips themselves being engraved with the unit figures only. In this way we get all jack strips engrave alike 0—9, 0—9, which is of great importance from the standpoint of standardisation.

Rows of Desks

Of the above-named components, the multiple desk and the annex plus multiple mats, it is possible to make up rows of desks with any desired number of positions. Such a row of desks comprises in the main the following material:

1 annex, left, *BAR 1601*,
1 initial section *ABK 6521*,
the requisite extension sections *ABK 6522*,
the requisite multiple jack strips and mats *TSE 83*,
1 annex, right, *BAR 1602*.

Fig. 9 shows such a complete row of desks, providing four operator's positions and a total of 400 lines.

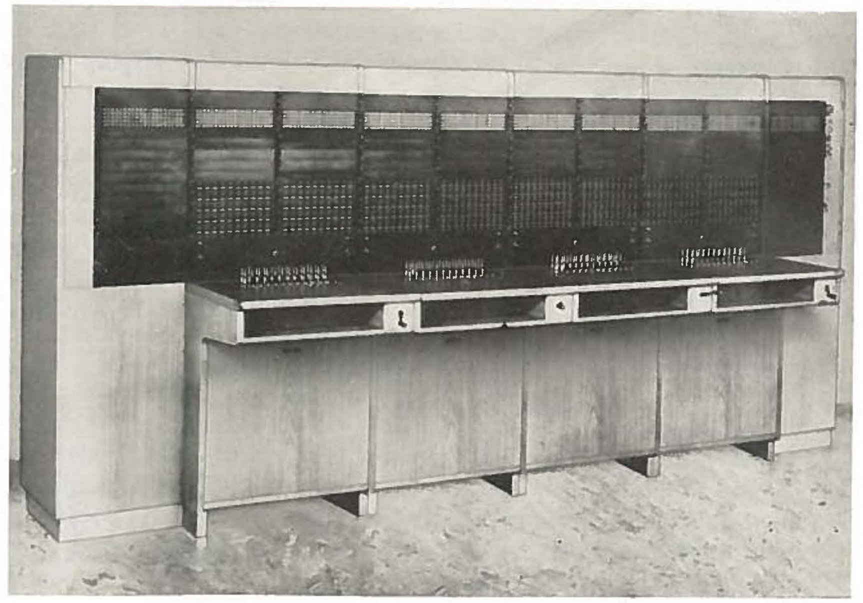

Fig. 9 X 6286
Row of desks
consisting of four multiple desks and two multiple annexes

Connecting Diagram

As regards diagram our new multiple desks differ only in a few respects from our earlier types, see connecting diagram Fig. 9. In the first place the busy test system normal for C.B. switchboards has been introduced, which though it necessitates the employment of three-way plugs and cords yet is counterbalanced by considerable simplification of the construction of the multiple jacks. Moreover, facility for call metering has been provided, a system being adopted that demands very small energy consumption. Finally the operator's speaking set has been furnished with feed coils in the transmitter circuit so that a common battery may be employed for multi-position telephone switchboards.

The call meter used in conjunction with this multiple desk is of special design, in that the core of the electro-magnet is of steel instead of soft iron. Such a meter has after relatively brief magnetising the property of remaining in attracted position owing to the remanence in the steel core. Restoration of the meter is caused by a short impulse in reverse direction, so that the steel core is demagnetised.

Alt. A shows the connection for the call meter and alt. B shows the connection when the call meter is not in the circuit.

The connecting process in establishing a call is in the main as follows:

A subscriber calls the telephone switchboard in the usual way by means of the hand generator. The call indicator *CI* falls and gives the operator a clear visible signal. The call indicator alarm contact makes and the call meter *SM* attracts at the same time the pilot relay *BR* and starts the bell *B* if it is connected in. The operator answers the call by throwing the key *SK—RK*

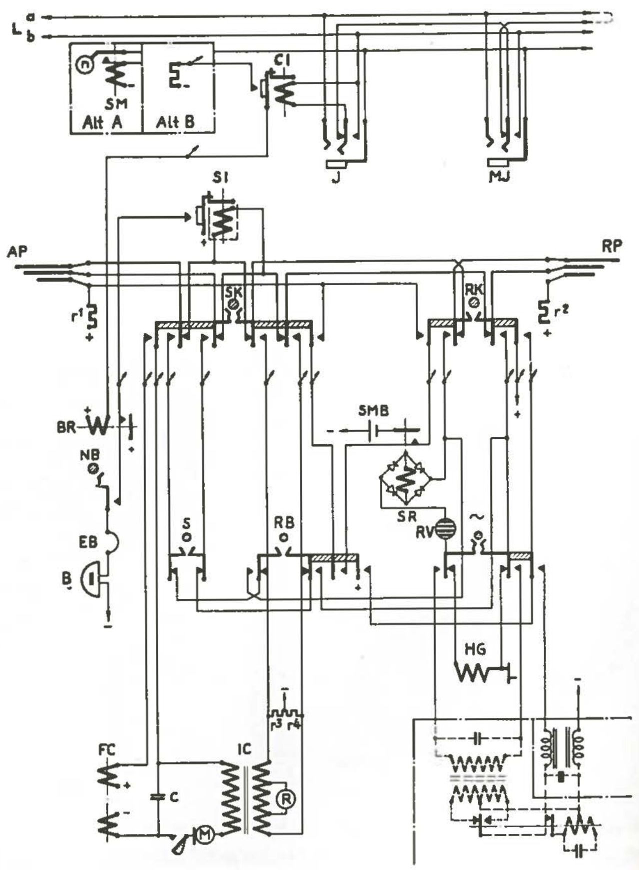

Fig. 10 X 6279

Connecting diagram for L.B. telephone switchboard

with multiple

- a, b subscriber line speaking wires
- AP answering plug with cord
- B bell
- BR pilot relay
- C condenser
- CI call indicator
- EB extra bell
- FC feed current coil
- HG hand generator
- IC induction coil
- J answering jack
- L subscriber line
- M microphone
- MJ multiple jack
- NB key for night bell
- r^1, r^2 sleeve resistance
- r^3, r^4 test resistance
- R receiver
- RB ringing-back key
- RK ringing key
- RP ringing plug
- RV ringing pilot visual
- S splitting key
- SI clearing signal indicator
- SK speaking key
- SM call meter
- SMB auxiliary battery for call metering
- SR call metering relay
- ~ key for pole changer

of an unoccupied cord pair to position *SK* and inserts the answering plug *AP* in the calling line's answering jack *J*. Insertion of the plug restores indicator *CI* automatically. The alarm contact is broken, but the call meter remains attracted owing to the remanence in the steel core.

After the operator has been told the wanted number by the calling subscriber she finds out the situation of the wanted line by putting the tip of ringing plug *RP* against the sleeve of the multiple jack *MJ* of the line in question. If she hears a click in her receiver then the line is busy with another call. The operator has then only to inform the calling subscriber and disconnect. If nothing is heard when testing as above, the line is unoccupied and connection can proceed. The operator then inserts ringing plug *RP* in the multiple jack *MJ* and moves key *SK—RK* into position *RK*. If the pole changer is connected, which would be the rule in a multiple desk, ringing signal is emitted automatically as long as the key is thrown. The ringing pilot indicator attracts giving the operator visible signal that the ringing current has really been transmitted to the line. Relay *SR* attracts moreover and transmits tension back via key *RK* and answering plug *AP* to the calling line's call meter *SM*. This tension is directed in such a manner that the call meter is demagnetised and restored. The call metering is then completed and, when the called subscriber has answered, the conversation may begin.

Throughout the conversation the clearing signal indicator *SI* is connected over the speaking wires of the cord pair. Thus, when one of the speakers at the close of the conversation rings off, the indicator falls, giving the operator a visible and if necessary also an audible signal. The operator then has only to throw key *SK—RK* to position *SK* (this automatically restoring indicator *SI*), make sure by listening that the conversation is really terminated and then take down the connection.

The above is the normal connecting process. In some cases the operator may need to talk with the B-subscriber without the A-subscriber hearing. To make this possible there is a splitting key *S* in the common equipment. It may happen that the operator requires to send a ringing signal back to the A-subscriber. This is possible by means of key *RB*. Finally, if the common ringing current source should fail, there is a reserve at each operator's position in the form of an ordinary hand generator.

Accessories

A telephone switchboard consisting of one or more multiple desks of the kind described above requires a certain amount of common equipment for its operation, mainly power sources of various kinds. First there is required a 6 V battery, an accumulator being appropriate, for the feeding of transmitters signal circuits and pole changers, as also for attraction of the call meters. In addition there is required a smaller battery of 1.5 to 3 V consisting of dry cells, for restoration of the meters. Finally a telephone swichboard of this size should be equipped with a ringing current source, consisting either of a pole changer or a small rotary converter. If the switchboard comprises more than two desks, then a complete multiple of the lines should of course be added to the row of desks.

When call meters are to be included in the plant these are mounted in a separate rack, located outside the switchboard proper.

A telephone plant of the size requiring the use of multiple desks should naturally also be furnished with proper distribution. All current types of main distribution frames are suitable for this. Nevertheless, if one of the types *BAB 12—15* or *BAB 22—23* is chosen, there is also space available for the necessary protector devices and easily accessible test jacks for line tests.

Power Plants for Telephone Exchanges

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After a short review of the development of power plants for L M Ericsson telephone changes the article goes on to describe the L M Ericsson system of full float service specially with reference to latest design with transductor regulated metal rectifiers. A special step regulated system developed by engineers of the Swedish Telegraph Administration for the parallel operation of rectifier banks is described in detail. The use of an automatic end cell switch is discussed followed by a description of standard power boards. Salient points for the dimensioning of batteries and rectifiers are finally mentioned and views are presented.

Brief Survey

Ever since the first C.B. exchange was delivered by LM Ericsson at the beginning of the present century, the standard power supply for public telephone exchanges has been two accumulators.

In the earlier plants, the power board was so arranged that the charging equipment could only be connected to the battery if the latter were disconnected from the exchange. Consequently the batteries had always to be switched alternately for charging and discharging. Around 1912 a choke coil was inserted between the charging set and the battery, and at the same time the power board equipment was altered to enable float charging to be done. The batteries still had to be charged and discharged alternately but the float operation enabled longer intervals to take place between each charging. As the life of a battery is governed by the number of times it is charged and discharged, this enabled the life of the battery to be prolonged and also in certain cases allowed of decreased battery size.

When the first automatic exchanges began to be delivered around 1920 there was no alteration in principle regarding the power plants.

Up to 1930, D.C. shunt machines were the only charging appliances used. The machines were generally of the supplier's standard make but there were also machines with low disturbance level for telephone frequencies. As a rule two charging converters were supplied to each exchange. Each converter had an output sufficient for charging an exchange battery in 7—8 hours. At an early stage, electric generators driven by internal combustion engines were installed as emergency power supply at places with unreliable electric supply mains.

It was about 1930 that LM Ericsson installed the first metal rectifiers of Westinghouse copper oxide type. They were put in at small telephone exchanges in the concession regions of Italy and the Argentine. In 1932 two rectifiers each with an output of 45 A at 24 V were installed at the Lidingö telephone exchange, Stockholm. These were in uninterrupted service for 12 years, after which they became too small and were therefore dismantled in conjunction with the moving of the whole exchange. At the time of dismantling these rectifiers were still in full working order. The regulation of the first rectifiers, as also those constructed during the next 10 years, was done by on-load tap changing switches connected to the transformer windings.

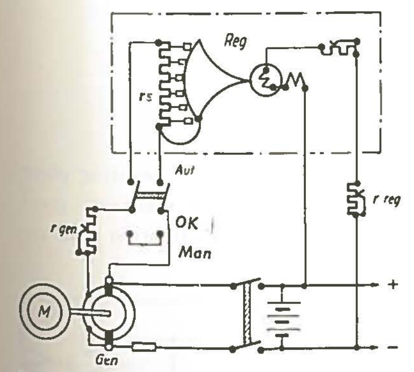


Fig. 1 X 4527

Skeleton diagram of voltage regulator regulating shunt generator

Aut automatic operation
Gen generator
M motor
Man manual operation
OK switch
Reg regulator
r gen shunt rheostat
r reg regulator adjustment resistance
rs regulator rheostat

In the above mentioned float operation, the aim was as far as possible to adjust the charging current so that it was of the same magnitude as the discharging current. This had to be done manually by the man on duty at the exchange. Often a contact voltmeter was installed which gave alarm if the battery tension varied beyond certain limits. Attention to the charging equipment naturally took up a great deal of time and, if it was to be efficiently carried out, required a man on duty the greater part of the day, which was only convenient at very large telephone exchanges. Nor was the upkeep of the battery ideal, as renovation or replacement of plates had to be done every 7—10 years.

The Principle of Full Float Service

Better charging methods were called for and proposals were not lacking. From America in particular there came the idea of the full float charging system, this being introduced in Sweden after trial and improvements by the Swedish Telegraph Administration. In 1938 the first telephone power plant on this system was put in service by the Administration.

The principle of the full float system is to aim at the ideal condition of automatically adjusting the output current of the charging equipment to the exchange load, so that the previously fully charged batteries, floating on the exchange bus bars, only receive a trickle charge sufficient to make up for the internal losses of the batteries, thus keeping them in best possible condition and ready with their full capacity for service during an eventual discharge due to mains failure. It is also essential that this trickle current is supplied uninterrupted even when there is no load.

Experiments have been carried out by battery manufacturers to ascertain the proper rate of trickle charge for different sizes of batteries, and it has been found that 0.9—1.0 milliamps per amphour capacity of the battery (at 10 hour discharge rate) is a suitable value. This value corresponds to a voltage of 2.15 volts per cell of a lead battery and further investigation has revealed that this voltage can be varied between 2.15—2.18 volts without changing the trickle current appreciably. All charging equipments for full float service are therefore now arranged so that the voltage on the exchange bus bars is automatically kept at the above mentioned value of 2.15—2.18 volts per cell, no matter how the exchange load varies.

Naturally charging equipments may be made on various principles, and either motor generators or rectifiers may be employed. The shunt generator, which is used as charging unit as stated above, is in general easy to arrange for automatic voltage regulation by inserting a voltage regulator in the field circuit of the generator.

Full Float Plants with Motor Generators

Reconstruction of existing plants with motor generators to full float service seemed therefore indicated. As early as 1938 old power plants of telephone exchanges in the Argentine were rebuilt by LM Ericsson who was responsible for the running of these exchanges. Good operating results were obtained with full float service, and consequently several power plants at telephone exchanges in the Mexican concession area were reconstructed. New full float plants with motor generators and voltage regulators have also been supplied, some to places with D.C. mains.

The voltage regulator employed has in all cases been the Brown Boveri type of regulator, which has proved very suitable and reliable. The diagram which is very simple may be seen in Fig. 1.

In principle the regulator consists of a rheostat regulated by a voltmeter. The voltmeter system itself is built up of a fixed and a movable coil, which are connected to the battery discharge side. The electro-dynamic force of the moving coil is counteracted by the tension of a flat spiral spring. By inserting additional small spiral springs it has been possible to make the spring tension constant for the whole movement range of the regulator.

Rheostat, *rs*, is made up of wire-wound resistance spirals connected between the bars of a circular contact bank. On the inner side of the contact bank there is a movable sector of conducting material with a radius smaller than the contact bank. This sector is pressed against the contact bank by a sector pressure spring attached to the moving coil. When the moving coil rotates the sector rolls along the contact bank. The resistance spirals are connected or disconnected according to the direction of movement. The position taken up by the movable system is governed by the amount of regulator resistance necessary for keeping the battery voltage at its right value. Thus the position of the system is dependent on the load. When the load increases the system rotates counterclockwise.

If the generator is to be employed for full float service, switch *OK* is thrown to position *Aut*, this connecting rheostat *rs* into the generator field circuit. The voltage to be held constant (= battery voltage) is set by resistance *rreg*. This resistance is connected in series with the moving coil of the regulator. The higher the resistance in this circuit, the higher the voltage will be.

If switch *OK* is thrown to position *Man*, the generator may be regulated in the ordinary way by means of the shunt field rheostat, *rgen*.

The over-all efficiency of a motor generator decreases with decreasing load due to the increasing importance of the no load losses. As the exchange load is small during the night this means that the over-all efficiency will be low when a motor generator is used in full float service. This will be especially the case when large converters capable of taking the busy hour load are used, such as often occurs when an old power plant is reconstructed for full float service. To improve the over-all efficiency, small night service converters may be put in to take care of the service during periods of low traffic. This, however, means increased cost for plant and often for staff as well, as switching over from large to small converters must be done after working hours at the exchange. Of course, purely automatic operation can be arranged but this is rather expensive besides involving many uncertain factors when it is a question of switching on and off such converters. Here a night rectifier is the best solution as its no load losses are much smaller and being stationary it needs no supervision.

Full Float Plants with Rectifiers

For new full float plants it therefore seems advisable from the operating point of view to use rectifiers instead of converters. These have relatively good efficiency at small loads, are quiet and require little or no attention and are easy to arrange for automatic operation.

Constant Voltage Rectifiers

For 5 years LM Ericsson has been using a regulating system for full float service rectifiers, in which the Brown Boveri regulator referred to above has been used. The diagram for a 3-phase rectifier of this kind is shown by Fig. 2.

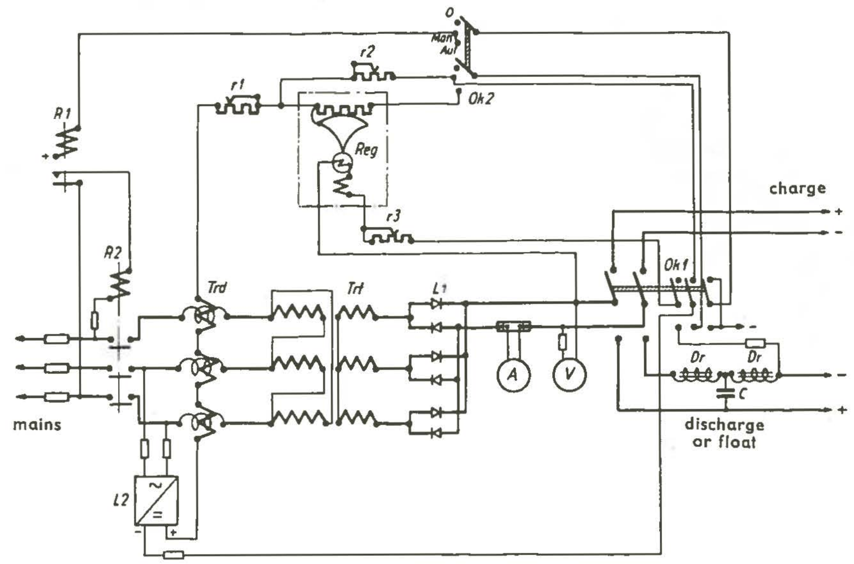
Before going on to describe the functioning we shall briefly refer to some of the components.

The voltage regulator, *Reg*, briefly described above, actuates 3 groups of D.C. saturable chokes, *Trd*, known as transductors. Each transductor consists

Fig. 2 X 6309

Skeleton diagram of constant voltage rectifier

A	ammeter
Aut	automatic operation
C	condenser
Dr	chokes
L1	metal rectifier
L2	auxiliary rectifier
O	off position
OK1	rectifier switch
OK2	change-over switch
r1—r3	resistances
R1 R2	relays
Trd	transductor
Trf	transformer
V	voltmeter



of two transformer cores, each with an A.C. and a D.C. winding. The A.C. windings are connected in parallel and the D.C. windings in series opposition. This ensures that no A.C. passes over to the D.C. circuit. Thus each pair of transductors is connected as shown in Fig. 3. In a transductor the ampère turns of the A.C. windings and the resulting ampère turns of the D.C. windings are practically of equal magnitude at every moment. Thus the transductor will in principle work as a current transformer. The current in the A.C. winding will, for a certain input A.C. voltage, be proportional to the current in the D.C. winding. This property has been utilised to limit the output current of the rectifier.

If at constant mains tension the D.C. saturation of the transductor is limited then its A.C. output will likewise be limited, as there is proportionality between the A.C. and D.C. side of the rectifier. If the mains tension varies, however, a fluctuation will be observed in the rectifier output, although the D.C. in the transductor circuit is constant. To avoid this fluctuation, the auxiliary rectifier, *L2*, is so made that its D.C. output varies inversely with the mains tension in such a way that the transductor's A.C., and consequently the output of the rectifier, will be constant.

The metal rectifier, *L1*, is made up of one or more rectifier units connected in 3-phase Graetz circuit. The units are generally air-cooled. For tropical areas they may also be supplied in oil tanks similar in type to those used for transformers. They are of the Westinghouse selenium compound or Westalite type. LM Ericsson has for some 20 years been in uninterrupted collaboration with The Westinghouse Brake & Signal Co Ltd. in connection with metal rectifiers. The transformer, *Trf*, is of standard air-cooled 3-phase type. The primary side may be connected either in star or delta connection for 380 or 220 V.

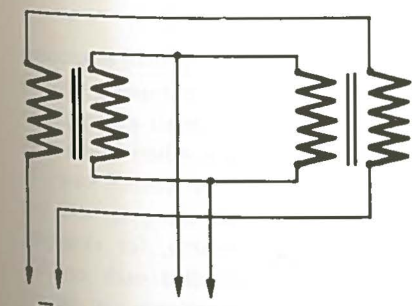


Fig. 3 X 4528

Skeleton diagram of transductor

The filter circuit consists of 2 chokes, *Dr*, each with a voltage drop of 0.5 V at the maximum output of the rectifier, and an electrolytic condenser, *C*. As may be seen from the diagram, the filter is connected in the bus bar system for full float service. Consequently the extra voltage drop produced by the filter is avoided when charging a battery separately.

Rectifier switch, *OK 1*, is provided with 3 extra auxiliary contacts over which the rectifier starting circuit and the D.C. circuits of the transductors are closed when the switch is thrown to charging or full float service position. In the latter case the moving coil circuit of the voltage regulator is closed over one of the contacts. By means of these circuits extra check of the operation of the rectifier is obtained.

Description of Operation

Automatic Regulation

If the rectifier is to be employed in full float service, rectifier switch *OK 1* is first moved to full float service position. Switch *OK 2* is then put in position *Aut*, causing relay *R1* to attract and pulling up contactor *R2*. The mains tension will then be connected to the auxiliary rectifier *L2* and to the transductor and transformer circuits *Trd* and *Trf* respectively. The transductor's D.C. circuit is closed over an auxiliary contact on switch *OK1*, over position *Aut* of switch *OK2* and then over the voltage regulator rheostat and the variable resistance *r1*. The moving coil of the voltage regulator is also switched in over its auxiliary contact on switch *OK1* to the bus bar system for full float service.

Regulator *Reg* will now rotate and take up a position corresponding to the setting of resistance *r3* and to the exchange load. If the battery voltage is too high resistance *r3* must be increased; if the voltage is too low then the resistance must be decreased. If now the exchange load increases, the battery voltage will fall. The regulator's electromagnetic field is weakened, which causes the system to move counterclockwise. Resistance spirals in the regulator will then be short circuited one after the other causing the resistance in the D.C. circuit of the transductors to diminish. The D.C. through the transductors will naturally increase, which means that the A.C. current through them also increases. As stated earlier, proportionality prevails between the A.C. and D.C. circuits of the transductor so that the rectifier's charging current must also increase and consequently the battery voltage. Should the load continue to increase, more and more spirals in the regulator rheostat are short circuited and finally the rheostat is entirely shunted. The rectifier will then be delivering maximum current. The value at which current limitation is to take place may be adjusted by resistance *r1*. If the load increases still more, the rectifier current will be limited to its max. value, but the voltage will drop.

Regulation with Regulator Disconnected

If the regulator is disconnected, the rectifier can be operated manually. Switch *OK1* is then turned to position *Man*, thus disconnecting the regulator rheostat and switching in resistance *r2*. By means of this resistance, constructed as a dial rheostat, the rectifier may be regulated by hand.

Manual Regulation

If the rectifier is to be used for separate charging of a battery, rectifier switch *OK2* is thrown to charging position, after which switch *OK2* is put in position *Man*. Also in this case regulation is done by resistance *r2*.

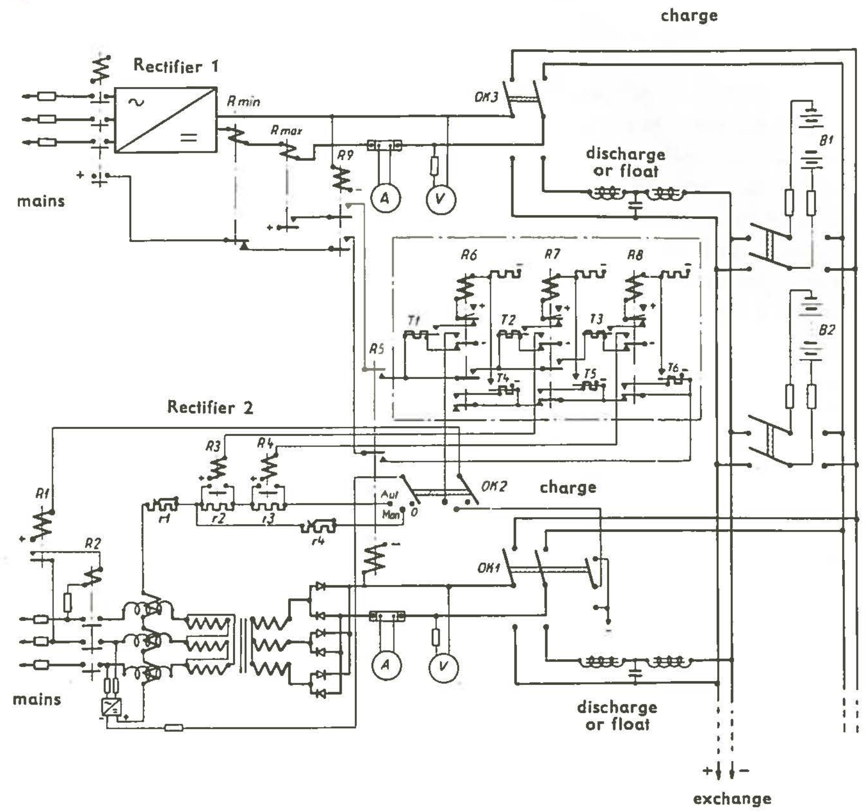
Step-regulated Rectifier

In fixing the outputs of the charging units for a telephone exchange, account must be taken of the final capacity of the exchange and how rapidly growth may be expected to take place. Sometimes it may be considered advisable to calculate the rectifiers for the final capacity of the exchange, whereas in other cases an extension later of the rectifier is reckoned on. In neither case, in view of necessary reserve, is it advisable to install a single charging unit but division into several units is preferred. For complete reserve, for example, two equally large full float service rectifiers may be installed each capable of driving the whole exchange alone. If the reserve requirements can be reduced, two smaller rectifiers may be put in, both of which must be in service during periods of heavy traffic. In this case also two full float service rectifiers

Fig. 4 X 6307

Skeseton diagram for step-regulated rectifier

A	ammeter
Aut	automatic operation
B1 B2	batteries
Man	manual operation
OK1	rectifier switch
OK2	switch
OK3	rectifier switch
r1—r4	resistances
R1—R9	relays
T1—T6	thermo-contacts
Rmin	minimum current relay
Rmax	maximum current relay
V	voltmeter



are employed, as these can very well work in parallel. If, as often happens, there is some difference in their characteristics, the result is of course uneven distribution of load, but owing to current limitation neither of the rectifers will be overloaded.

It has already been pointed out that when the load is low the efficiency of rectifiers is better than that of motor generators. Nevertheless with very low load even the efficiency of the rectifiers diminishes rapidly, so that obviously it will be uneconomical during the night to run two parallel connected rectifiers, both delivering a small amount of current. Manual connection and disconnection of one of the rectifiers may be considered but, as suggested above, the time for disconnection often does not conform with normal times of duty.

The Swedish Telegraph Administration has indicated a method for fully automatic tandem running, which gives good efficiency and has the advantage that cheaper rectifier units may be employed. Good operating results have been obtained with plants constructed on this method. LM Ericsson has built such plants for the Swedish Telegraph Administration and for telephone administrations in other countries and these are described below.

A somewhat simplified skeleton diagram is shown in Fig. 4. The upper *Rectifier 1*, only partially shown, is automatically voltage regulated in the manner described above. To this rectifier have been added two relays connected in series in the charging circuit, the maximum current relay *Rmax* and the minimum current relay *Rmin*. The lower *Rectifier 2* is transductor controlled and may be switched in three steps, at 1/3, 2/3 and 1/1 load. It is also current limited on the principle indicated above. Its switching is controlled by the voltage regulated rectifier via relay set *R6—R8*.

The manner of operation will be seen from the following detailed description of function.

Description of Function

Full Float Service

Rectifier 1 is assumed to be in full float service in the manner already stated. Relay *R9* will then be attracted. In order that *Rectifier 2* shall be switched automatically the full float service switch *OK1* must be put in full float position and switch *OK2* in position *Aut.* Relay *R5* will then attract. After these manoeuvres the rectifier will be connected to the exchange battery but not to the mains. So far it is delivering no charging current.

Let us now assume that the voltage regulated rectifier becomes full loaded. The maximum relay *Rmax* then attracts and circuit is made to thermo-contact *T1*. If *Rectifier 1* is full loaded more than about 30 s (or any shorter time for which the thermo-contact is set) the thermo-contact spring will bend to its end position. Relay *R6* will then be connected in and held. From a contact on the relay, negative polarity is transmitted to relay *R1* which attracts and closes the circuit for contactor *R2*. *Rectifier 2* will then be connected to the mains and will deliver a charging current that is 1/3 of its maximum.

As the load will now be distributed over two rectifiers, the charging current from *Rectifier 1* falls. The maximum relay's release value is so set that the relay releases for this change of current in *Rectifier 1*.

Should *Rectifier 1* again become fully loaded the process is repeated. This time, however, it is thermo-contact *T2* and relay *R7* that come into operation. A circuit is made to relay *R3* which attracts and shortcircuits resistance *r2*. The D.C. through the transductors will then increase to such an extent that *Rectifier 2* delivers 2/3 of its maximum charging current. The process described may be repeated once more, with thermo-contact *T3* and relay *R8* connected in and current impulse being given to relay *R4* which shortcircuits resistance *r3*. *Rectifier 2* will now be fully loaded.

If the exchange load sinks the charging current will decrease owing to the voltage regulated rectifier, *Rectifier 1*, coming into operation in the manner above described. Should the output current of *Rectifier 1* now sink to app. 20 % of its maximum value the minimum relay *Rmin* will release (*Rmin* can also be adjusted to release for other values). A circuit is then closed to thermo-contact *T6* which heats and bends to end position if the circuit remains closed for app. 30 s. By this relay *R8* will be shunted and will release, thus breaking the circuit of relay *R4*. When relay *R4* releases, resistance *r3* is no longer shunted. The D.C. saturation of the transductor is thereby reduced to such an extent that the rectifier only delivers 2/3 of its maximum current. *Rectifier 1* will then take over that part of the charging current of which *Rectifier 2* is relieved. The minimum current relay *Rmin* is then again energized and the circuit to the step connecting relays is broken.

Next time the charging current from *Rectifier 1* falls to 20 % of its maximum value, thermo-contact *T5* is connected in and shunts relay *R7*, whereupon relay *R3* also releases. The D.C. saturation of the transductor decreases so that *Rectifier 2* becomes loaded with 1/3 of its maximum load. At the last disconnecting step thermo-contact *T4* is actuated and releases relay *R6* which in turn breaks the circuit to relay *R1*. Contactor *R2*, the holding circuit of which goes over a contact on *R1*, releases and breaks the circuit to the mains. Thus *Rectifier 2* is entirely cut off.

Manual Regulation

If switch *OK2* is put to position *Man.* *Rectifier 2* may be regulated by hand with resistance *r4*. This may be done both in charging and full float service positions.

Advantages

The system described above works with good efficiency over a wide range of current and is very flexible in respect of increasing the charging current. By providing the step relay set with more relays, further step-regulated rectifiers may be easily connected to the bus bar system and controlled by the voltage regulated rectifier. If a telephone plant is expected to grow slowly then only the battery and distribution panels of the Power Board need be dimensioned for the final capacity, while only rectifier units covering requirements för 2—3 years ahead need be installed to begin with. Not until it becomes necessary need additional rectifiers be installed later on.

Cell Switch

LM Ericsson constructs automatic exchanges for 3 different battery voltages, *viz.*: 24, 36 and 48 V, the indicated voltage being the nominal voltage. Automatic exchanges work reliably with a voltage varying approximately + 15 % and — 10 % around the nominal value. In this connection it should be remembered that between the battery and the switch racks there will be a voltage drop of app. 3 %. With full float service, as stated, the battery voltage is held at 2.15—2.18 V/cell.

If, for a 24 V plant, 11 lead cells are used the battery voltage with full float service will be around 23.6—24.0 V. The battery voltage will then coincide with the nominal exchange voltage.

In the event of an interruption in the mains, however, the battery voltage falls rapidly to 22 V. Already at this voltage the reliability of the automatic exchange is affected and if the interruption continues for any time the battery voltage will become so low that the exchange will not work properly.

If instead 12 lead cells are used in the exchange battery, a bus bar voltage of 25.8—26.2 V is obtained with full float service. This voltage figure lies well within the tolerance limits so that the automatic exchange may well work on this voltage.

On failure of the mains, the battery voltage will rapidly fall to 24 V and the automatic exchange will not be affected and it will only be after a lengthy period of emergency operation that the battery voltage becomes so low that the automatic exchange does not function to satisfaction.

Full float service with a 12 cell battery will thus be possible under all circumstances. The disadvantage, in addition to the readjustment of certain relays, is however that the power consumption will be unnecessarily large. When resistance is constant it holds good for a D.C. circuit that the power varies with the square of the voltage. Thus with a 12 cell battery the power consumption of the exchange will be $\left[\left(\frac{26.2}{24}\right)^2 - 1\right] = 19\,\%$ larger than if 11 cells were used.

The ideal solution would seem then to be to use 11 lead cells for normal full float service and 12 lead cells during mains failure. This method of operation is possible of achievement by introducing a cell switch which on mains failure automatically switches in an extra cell to the exchange battery.

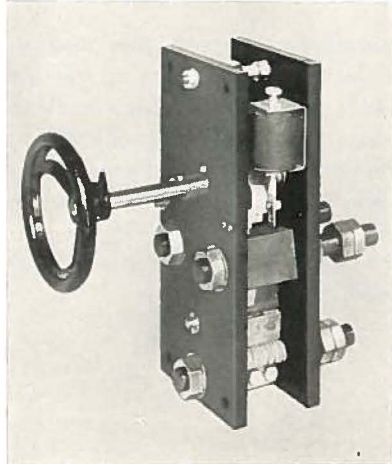


Fig. 5 X 4526
Cell switch

Fig. 5 shows the construction of such a cell switch for max. 800 A. The principle will be seen from the diagram, Fig. 6.

The cell switch itself is shown in the rectangle *C*. The arm *1* can move between contact *2*, connected to the battery's 11th cell, and contact *3* which is connected to the 12th cell. Switching over from contact *2* to contact *3* takes place on mains failure by contactor *K* falling and connecting in magnet coil *4* of the cell switch. The pawl *5* is then released, whereupon the strong spiral spring *6* pulls the arm over to contact *3*.

To avoid interruption in the battery circuit, a resistance *7* is inserted in the usual way over the 11th and 12th cells during the switching period.

Restoration of the cell switch to contact position *2* (11th cell) must be done by hand after the mains tension has returned.

By means of the simple rectifier *L*, a trickle charging current is directed through the 12th cell to make up for idle losses. The charging current is adjusted by resistance *8* and checked on the ammeter *9*. If switch *10* is closed, the cell may be charged with a higher current.

For full float service plants there are usually installed two accumulators which are normally connected in parallel to the bus bar system and it is therefore advisable, if cell switches are used, to fit a cell switch for each accumulator. This, however, is not a necessity as one cell switch may be used for two accumulators, as was done in 1938 for the full float power plants in the Argentine exchanges referred to above. Operation at these exchanges has all the time proceeded without any trouble with this arrangement.

Whether cell switches are to be installed or not is partly an economical and partly a technical question. As usual the cost of installation of the cell switch should be compared with the saving in energy cost. Moreover one has to consider if a smaller number of switching faults may be expected to arise by the battery voltage being kept practically the same under all operating conditions and nearly equal to the nominal exchange voltage.

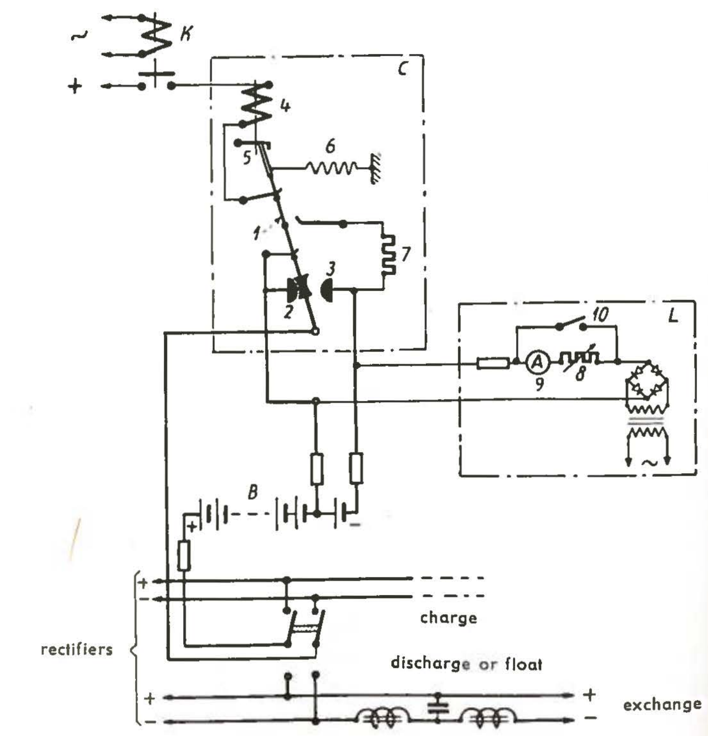


Fig. 6 X 6308
Skeleton diagram of cell switch
A ammeter
B battery
C condenser
K contactor
L rectifier set

Mechanical Construction

During the first 25 years of this century, power boards made by LM Ericsson were of white marble with all instruments, switches, fuses, etc. on the front. The copper bus bars and wiring were however on the back side. About 1926 larger knife switches, overload and reverse current switches were mounted on the back side with only their handles on the front. All other small switches, fuses, etc. were, however, still left unprotected on the front. Suitable apparatus were then lacking in order to achieve the aim of a power board with a real dead front. When in 1938 power boards of sheet iron were introduced it therefore became a necessity to make these missing apparatus and now all power boards consist of panels with a dead front throughout.

These sheet iron panels are made self-bearing by folding and welding them into shallow boxes. Their width is 600 millimetres, which has proved to be sufficient for power boards of this kind. A standard height of 2200 millimetres has also proved to be suitable. The material used consists of 3 millimetre thick cold rolled steel sheets. Side panels, where necessary (see Fig. 7), are usually of the same size and construction. Also side doors on hinges can be made of the same panels. The surface is first antirust treated and then sprayed with aluminium coloured cellulose, with a final coating of transparent cellulose on the front side making it easier to keep panels clean.

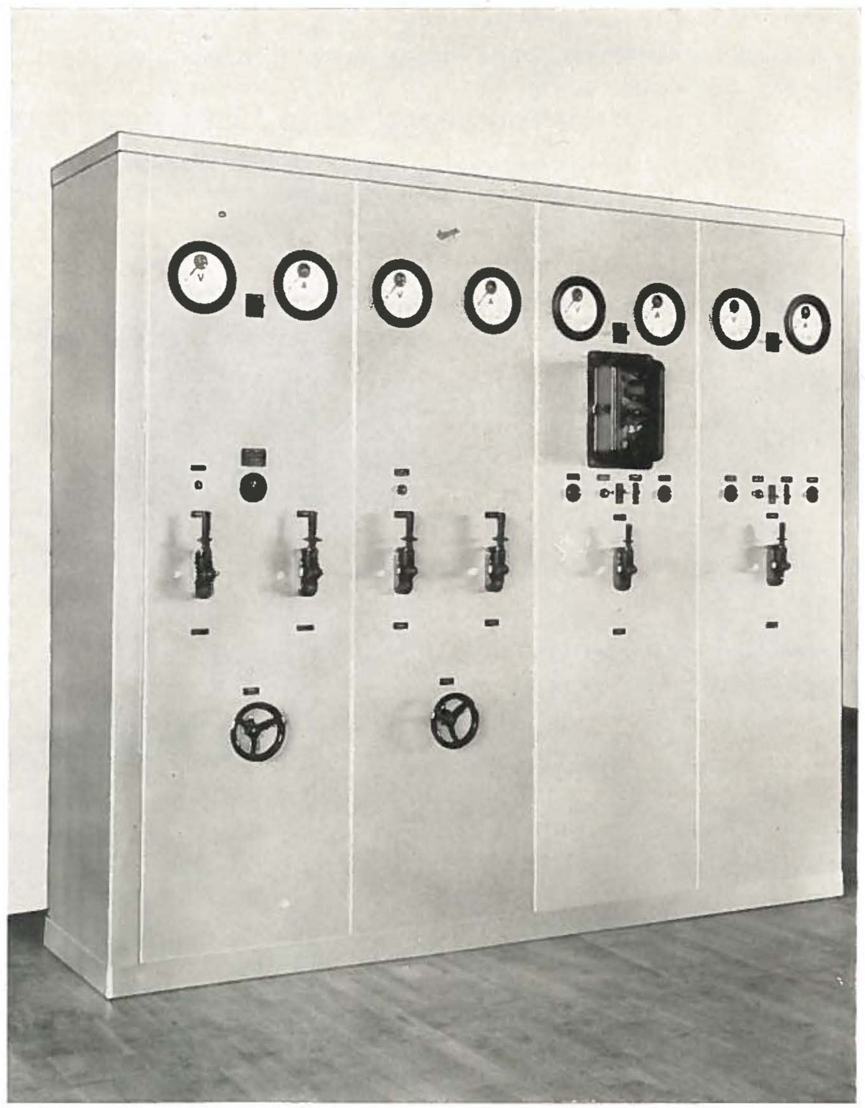


Fig. 7 X 6306
Power board for an automatic exchange
From left to right: battery panel with switches and cell switch, emergency generator panel with overload switch and field resistance, rectifier panel with voltage regulator and switches, rectifier panel for step or manual operation

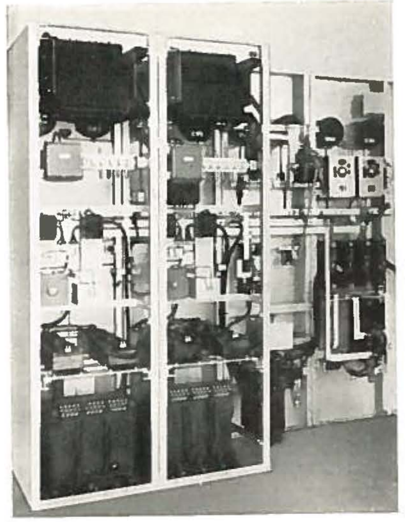


Fig. 8 X 4528

Power board

back view; from left to right: step-regulated rectifier, automatic rectifier, emergency generator panel and battery panel

For battery, distribution and converter panels etc. the equipment is mounted on the back of the panel. Thus no angle iron frames are required. The equipments for the rectifier units, however, are built into a cubicle of angle-iron that is attached to the rectifier control panel. Transductors, rectifier units and auxiliary rectifiers etc. are assembled in units that can easily be drawn out.

In building the power boards, particular attention has been given to making them easy to pack and transport.

Fixing Dimensions of Batteries and Rectifiers

Computation Basis

In computing the number of telephone switches necessary for an automatic exchange, traffic figures are taken as basis. These figures are usually stated for busy hours, and may be expressed either in TU (traffic units) for the whole exchange or in SM (call minutes) for each subscriber. In addition there must be given in either case the mean length of each call and the traffic concentration in the busy hour. On the basis of these particulars it should naturally be possible also to compute the energy requirement for an automatic exchange, if the constant for energy consumption per connected call is known.

For the setting up and disconnection of a call between two subscribers the energy consumed, expressed in Ah, has been determined by planimetering the current oscillogram for each switching process. The energy consumption during the call itself has been determined by multiplying the current consumption with the mean length of the call.

Such measurements have been made for the standard circuits of the OS system and for various switching stages, e. g., for finders and final selectors, for finders, group selectors and final selectors etc. On the basis of these measure-

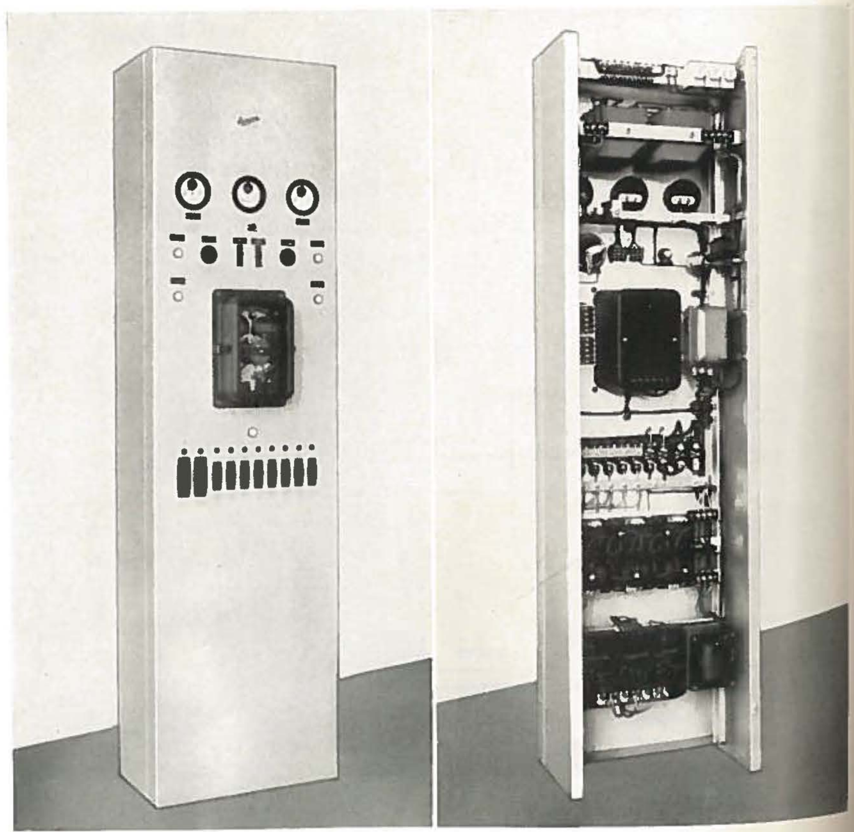


Fig. 9 X 6305

Power panel for private branch exchanges

with constant voltage rectifier, battery and distribution fuses and auxiliary rectifier for calls to public exchange

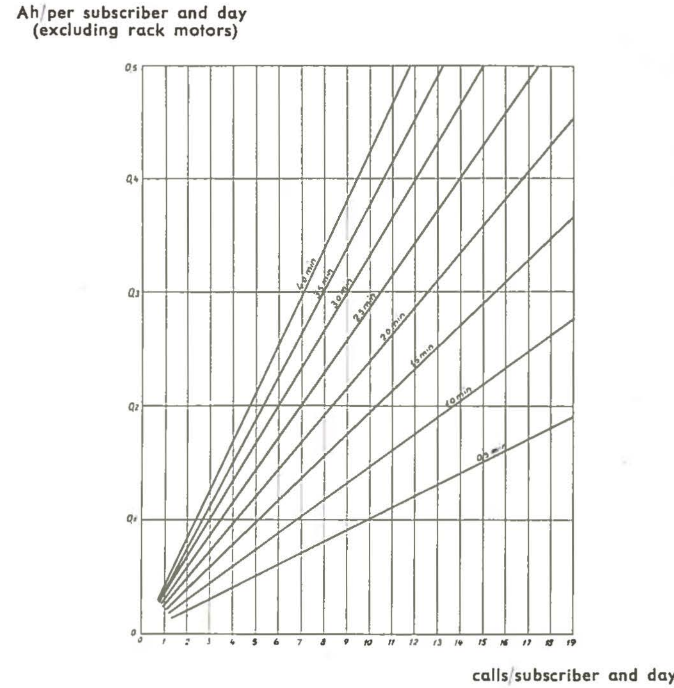


Fig. 10 X 6312

Chart

showing the relation between traffic figures and energy consumption per call

ments charts have been made up indicating the relation between the traffic figures and the energy consumption per call.

Such a chart is shown by Fig. 10.

To show how the chart is used an example will be given: assume that switches for 100 *TU* are required to handle the traffic for 2400 subscribers. The mean length of each call is 2 min and the concentration = 1/8.

Per subscriber and busy hour there is then obtained

$$\frac{100 \cdot 60}{2400} = 2.5\ SM$$

As the length of each call is 2 minutes, the number of calls per subscriber and busy hour will be

$$= \frac{2.5}{2} = 1.25$$

The number of calls per subscriber and day

$$= 8 \cdot 1.25 = 10$$

We then get from the corresponding curve that the current consumption per subscriber and day will = 0.24 Ah.

Assume further that the power plant is to be constructed for a final capacity of 9000 subscribers. The telephone switches are to be fitted in 9 racks, each with a rack motor consuming 40 Ah per day.

The whole energy consumption of the automatic exchange will then be

$$9000 \cdot 0.24 + 9 \cdot 40 = 2520\ \text{Ah}$$

If a full float service plant is to be made, we reckon with two accumulators always connected in parallel to the exchange bus bar system. We also select the battery size so that the two batteries together can supply the exchange with current for a whole day.

Each battery in that case would require to be for $\frac{2520}{2} = 1260$ Ah.

The nearest standard size would then be 1296 Ah (at 10 h discharge rate).

The output of the rectifier should be at least equal to the total Ah figure × the concentration $= \frac{2520}{8} = 315$ A.

To provide for emergencies, one voltage regulated rectifier of 150 A and one step regulated of 200 A are selected, or better still two step regulated rectifiers of 150 A each instead of one for 200 A.

Views on the Initial Sizes of Rectifiers and Batteries

In most cases, however, it is not possible to fix the dimensions of the power plant for a given final capacity from the beginning, as was assumed in our example. The growth of the exchange often takes place so gradually that in such case the plant would be unnecessarily large for many years to come. For that reason the power plant is computed for a lower initial capacity, to be progressively increased. Fixing the dimensions of the rectifier units causes no trouble, as we have seen that rectifiers can easily be added when necessary. In the case of the battery, however, a certain hesitation may arise. It is not so easy to enlarge a battery, so that the following questions may arise: is it necessary at the start to give the battery the final capacity or would it be advisable to begin with larger battery containers instead? Can one count on gradually being in a position to rearrange the two existing batteries into one and procure an entirely new battery of their combined size? May one assume that the batteries can in a few years be moved over to another telephone plant, so that larger batteries can then be installed at the present exchange? It is not possible to give general answers to these and similar questions. One must try to judge each case separately. Nevertheless, as a rule, it is advisable to dimension the battery switches, fuse holders, etc. and the bus bar system for the final capacity of the exchange as these items are not easy to enlarge.

Size of the Battery Emergency Reserve

At the beginning of the century, the C.B. exchanges were often provided with batteries so large that each battery could supply the exchange with current for a week. And for the first automatic exchanges supplied by LM Ericsson, a 24 hours period of operation was reckoned for each battery. With the introduction of full float service, however, the battery size has been decreased, as one may generally count on both batteries being constantly fully charged. In the example given, it was assumed that the two batteries in parallel would be able to supply the exchange for 24 hours in case of mains failure. This dimensioning of batteries is very usual. The cost of batteries for an exchange is so considerable that it is generally desired to utilise the advantages of the full float service even in respect of battery size. Nevertheless it should be remembered that the absolute reserve has in reality been lowered thereby. If mains failure were to occur during busy hours just when a battery was temporary out of order, the battery reserve would in the worst case be reduced to 2 or 3 hours. A condition for being able to decrease the battery size must for this reason be that an electric emergency plant is available and that it can come into operation within a couple of hours.

Bomb-wrecked LM Ericsson Material Could Be Put in Working Order

U.D.C. 621.395.722.004.67

A rather fantastic example of how skilled staff can repair the seemingly irreparable and how an automatic telephone exchange of LM Ericsson's make can keep on operating in conditions that might be described as impossible is provided by the repair of the telephone exchange at Palermo in Sicily, after the bombing it underwent on 9th May, 1943.

Fig. 1 X 4523

The building of Società Esercizi Telefonici at Palermo

after the air attack of 9th May, 1943

On that date Palermo was subjected to a violent air bombing which severely damaged the telephone exchange. Half the building, that part housing the trunk exchange, collapsed through all four floors, but the half that contained the automatic exchange stood the ordeal. The trunk positions were overturned and buried under masses of masonry, while the order position was hanging down from the fourth floor, held by the cables from the selector hall.

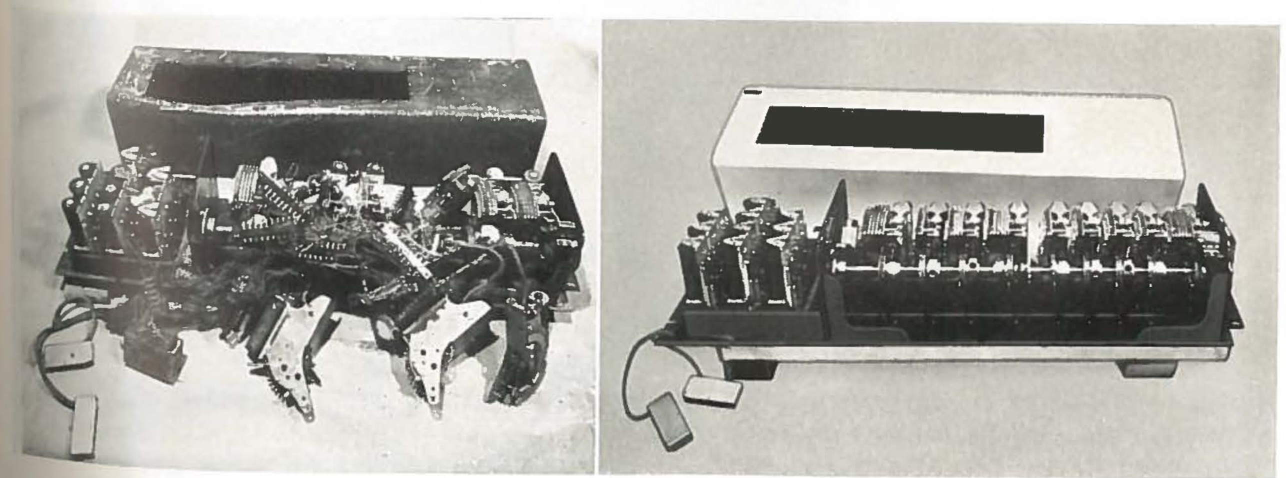
The automatic exchange was damaged by the shaking and the blast from the explosions. Splinters were flying round the premises and masses of building material were cast into the selector hall. The horizontal shafts of the register racks were bent so that they could not rotate, some registers and selectors were hit or smashed by flying pieces and falling bricks and mortar, all connecting devices being buried under a thick layer of dust and mortar. Many of the cable runs were torn from the walls.

Despite the extremely difficult working conditions — both water and light were lacking in the town — Società Esercizi Telefonici decided to attempt to repair the damage, as it was considered that the telephone exchange was not entirely destroyed. Selectors, relays, registers and sequence switches, devices that normally are given the greatest care and attention, were found to operate again after merely being cleaned of mortar and lime and adjusted, bent shafts were straightened and the exchange was made provisionally serviceable. And it kept on working for three years, though the apparatus were without protection against dust and the humidity of the air, aggravated as it was by rain coming through a roof consisting merely of planks and tarpaulins.

Fig. 2 X 7454

Register

salved after the bombing of the telephone exchange at Palermo; right, after repair



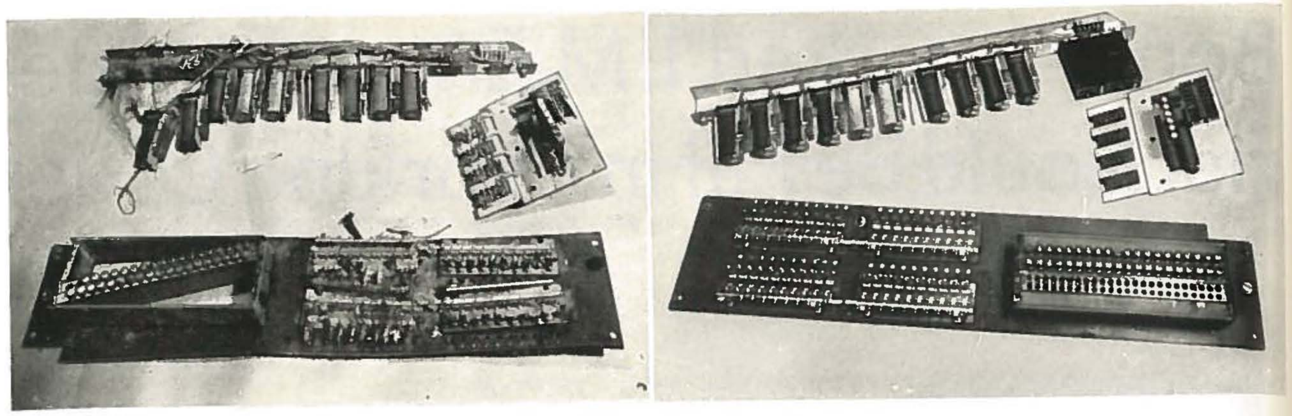


Fig. 3 X 7455

Relay set and terminal strips

from the bombed telephone exchange at Palermo right, before, and, left, after repair

There could be no question of proper cleaning and lubricating, as both cleaning and lubricating materials were lacking. Nevertheless the exchange kept on working to the great wonder, first of the Germans and then of the Allies.

Three years later it was possible to dig out from the debris the material of the trunk exchange, which in the interval had been provisionally restored with the aid of LM Ericsson trunk position desks brought in from Messina. Relays, switches and jacks were, to say the least of it, in a deplorable condition when they were brought to light from under the debris, but they were cleaned and repaired and gradually there were made up from the salved material two complete trunk position desks, enabling trunk traffic to be increased.

The Caltanisetta telephone exchange, comprising two groups 500-line selectors, was put out of operation in July 1943, when a bomb exploded in adjoining premises causing the dividing wall to collapse over the racks. Some selectors and connecting circuit relay sets were damaged and a horizontal shaft was bent. The exchange had been put in service again by September 1943, being operated for some years with a single battery and a rectifier coupled in tandem, as the second battery had been wrecked. The same conditions applied at Trapani, where one of the batteries was smashed.

In Marsala the surroundings of the telephone exchange were badly ravaged by bombardment. The building was shaken to its foundations, but the telephone exchange never ceased to function.

Fig. 4 X 6504

Salving material after the bombardment of Borsa, Naples

U.D.C. 519.2:621.395.34

PALM, C: *Waiting Times when Traffic has Variable Mean Intensity.* Ericsson Rev. *24* (1947) No 4 pp. 102—108.

The article presents a method for computation of the waiting times in non-automatic or semi-automatic traffic, which is applicable to varying mean intensity in the traffic load and which is exceptionally suitable when the intensity exceeds the maximum handling capacity.

U.D.C. 621.395.668

FERNHOLM, E: *Power Plants for Telephone Exchanges.* Ericsson Rev. *24* (1947) No 4 pp. 134—146.

Description of the system of full float service, for the first time used in a telephone power plant, put into service in 1938 by the Swedish Telegraph Administration. Discussion of the use of an automatic end cell switch followed by a description of standard power boards. Salient points for the dimensioning of batteries and rectifiers.

U.D.C. 621.395.26

NILSSON, E: *Centralized Private Branch Exchanges.* Ericsson Rev. *24* (1947) No 4 pp. 109—126.

Telefonaktiebolaget L M Ericsson has constructed a centralized automatic branch exchange system which is advantageous economically and technically meets the demands for small organizations. An account of the economy, design and traffic facilites of the centralized automatic branch exchange.

U.D.C. 621.395.33

ENGQVIST, E: *Multiple Desk for Multi-Position L.B. Switchboards.* Ericsson Rev. *24* (1947) No 4 pp. 127—133.

Description of the multiple desk which fulfils the demands for subscriber multiples and facilities for progressive enlargement. The multiple desk supplements the series of new manual L. B. cord switchboards referred to in Ericsson Review No 3/1944.

The Ericsson Group

Associated and Cooperating Enterprises

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AB Alpha	*Sundbyberg*
AB Ermex	*Solna*
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L M Ericssons Mätinstrumentaktiebolag	*Ulvsunda*
L M Ericssons Signalaktiebolag	*Stockholm 32*
Mexikanska Telefonaktiebolaget Ericsson	*Stockholm 32*
Sieverts Kabelverk	*Sundbyberg*
Svenska Radioaktiebolaget	*Stockholm*, Alströmergatan 12

ASIA

India Ericsson Telecommunication Ltd	*Calcutta*, 167 Lower Circular Road, P. O. B. 2324
Indonesia Ericsson Telefoon-Maatschappij N. V.	*Bandoeng*, Tamblongweg 11

AMERICA

Argentina Cía Sudamericana de Teléfonos L M Ericsson S.A.	*Buenos Aires*, Belgrano 894
Corp. Sudamericana de Teléfonos y Telégrafos S.A.	*Buenos Aires*, Belgrano 894
Cía Argentina de Teléfonos S.A.	*Buenos Aires*, Belgrano 894
Cía Entrerriana de Teléfonos S.A.	*Buenos Aires*, Belgrano 894
Cía Comercial de Administración S.A.	*Buenos Aires*, Belgrano 894
Brasil Ericsson do Brasil Comercio e Indústria S.A.	*Rio de Janeiro*, Rua Moncorvo Filho 50, C. P. 3601
Empresa Sul Americana de Telófonos S.A.	*Rio de Janeiro*, Rua Moncorvo Filho 50, C. P. 4684
Chile Cía Ericsson de Chile S.A.	*Santiago*, Alameda Bernardo O'Higgins 1761, Casilla 2118
Colombia Cía Ericsson Ltda	*Bogotá*, Edificio Bogotá, Apartado Aéreo 4052
Mexico Cía Comercial Ericsson S.A.	*México*, D.F. Ernesto Pugibet 33, Apartado 9958
Empresa de Teléfonos Ericsson S.A.	*México*, D.F. 2:a calle Victoria 55/61, Apartado 1396
Cía de Teléfonos y Bienes Raíces	*México*, D.F. 2:a calle Victoria 55/61, Apartado 1396
Peru Cía Ericsson S.A.	*Lima*, Edificio Sudamerica, Apartado 2982
Cía de Teléfonos de Arequipa y Mollendo S.A.	*Arequipa*
Uruguay Cía Sudamericana de Teléfonos L M Ericsson S.A.	*Montevideo*, Rio Branco 1381
United States of America Ericsson Telephone Sales Corporation	*New York 17*, 101 Park Avenue

Agencies

EUROPE

Belgique Électricité et Mécanique Suédoises	*Bruxelles*, 14 Rue van Orley
Bulgarie M. Chichkoff & D. Kostoff	*Sofia*, 36 Rue Denkoglou
Československo Isolatechna, A. Honig a spol.	*Praha*, Malé náměstí 1
Eire E. C. Handcock	*Dublin C 5*, Handcock House, 17 Fleet Street
Grèce »ETEP», S.A.	*Athènes*, 41 Rue W. Churchill
Österreich Schrack-Ericsson Elektricitäts-Aktiengesellschaft	*Wien 87 (XII)*, Pottendorferstrasse 25—27
Portugal Sociedade Herrmann Ltda	*Lisboa*, Calçada do Lavra 6

ASIA

China The Ekman Foreign Agencies Ltd	*Shanghai*, 185 Yuen Ming, Yuen Road, P.O.B. 855
The Swedish Trading Co. Ltd	*Hongkong*, Prince's Building, Ice House Street
Iran Irano Swedish Company A.B.	*Teheran*, Khiabane Pahlevi Koutche Dr Malek Zadeh
Palestine Jos. Muller	*Haifa*, 37 Kingsway, P.O.B. 243
Philippines Koppel (Philippines) Inc	*Manila*, Boston and 23rd Streets, Port Area
Saudi Arabia Mohamed Fazil Abdulla Arab	*Jeddah*
Siam The Borneo Co., Ltd	*Bangkok*, Chartered Bank Lane
Syrie et Liban C.A. Loisides	*Beyrouth*, Place de l'Etoile, B.P. 931
Türkiey Nebil Baykent	*İstanbul*, Ünyon Han 16-17, Galata P.K. 1455

AFRICA

Congo Belge Société Commerciale & Minière de L'Uélé	*Aketi* (Uélé)
Egypte Swedish Industries	*le Caire*, 25 SH. Adly Pacha P.O.B. 1722
Moçambique J. Martins Marques	*Lourenço Marques*, P.O.B. 456
Union of South Africa and **Southern Rhodesia** Rogers-Jenkins & Co. (Pty) Ltd	*Johannesburg*, Marshall and Nugget Streets, P.O.B. 654

AMERICA

Bolivia Johansson & Cía, S.A.	*La Paz*, Avenida Montes 642, Casilla 678
Costa Rica Tropical Commission Co.	*San José*, Apartado 661
Curaçao N.W.I. S.E.L. Maduro & Sons	*Curaçao*
Ecuador Ivan Bohman y Cía	*Guayaquil*, Almacen Nueve de Octubre 211, Casilla 1317
El Salvador Dada-Dada & Co.	*San Salvador*, Apartado 274
Guatemala Agencia de Fosforos Suecos, S.A.	*Guatemala C. A.*, Apartado 125
Surinam C. Kersten & Co. N.V.	*Paramaribo*, Steenbakkerijstraat 27, P. O. B. 216
Venezuela Electro-Industrial Halven O. L. Halvorssen C.A.	*Caracas*, Esquina de Monroy 28, Apartado 808

AUSTRALIA & OCEANIA

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New Zealand ASEA Electric (NZ) Ltd	*Wellington*, Huddart Parker Building P.O. Square