Ericsson Review

No 3
1937

ERICSSON REVIEW

Responsible Publisher: HEMMING JOHANSSON
Editor: SVEN A. HANSSON
Editor's Office: Döbelnsgatan 18, Stockholm
Subscriptions: one year \$ 1:50; one copy \$ 0:50

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Printed in Sweden, Esselte ab., Stockholm 1937

Technical Bases of the Automatic Operation of Rural Networks

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Automatic operation of telephone exchanges is constantly increasing throughout the world. To begin with city exchanges were automatised, but now much consideration is being devoted to the automatisation of rural exchanges. The practical solution of the great technical and economic problems represented by rural automatic operation is therefore exercising the attention both of telephone makers and of telephone administrations in most countries. At the 5th congress of Scandinavian Electrical Engineers at Copenhagen in August 1937, one of the chief subjects for discussion was the automatisation of the telephone services in the Nordic lands, with contributions by representatives of the telephone administrations of the countries concerned. The opening paper consisted of the following exposition of the basic technical principles of the automatic operation of rural networks.

Life in rural districts has undergone considerable change in the last ten or twenty years. Electric power has been made more and more available and the isolation formerly a characteristic feature of rural districts has been broken as a result of the rapid development of broadcasting, motoring and bus traffic. These have served for good or ill to bring the rural populations into contact with the conditions and cultural life of the cities and larger communities in a manner which previously had been undreamt of. Progress has therefore been of unexampled rapidity. The ease of acqusition, the reliability, the high quality and comparative cheapness which characterise present-day broadcasting and bus services has had the result that the rural populations are justified in making corresponding demands for expansion in other means of communication. This is no less true in most countries in regard to the telephone, which in respect of number of stations has been far outdistanced by wireless. To expand the telephone service so that it is possible for the greatest number of people, both in town and in country, to communicate with one another by telephone is a problem quite as important as the development of, *e. g.*, power distribution, broadcasting and road communications.

The technical conditions for such expansion are available. As is known, the telephone has during the last decades undergone revolutionary changes, as regards trunk telephony through the introductions of repeaters and as regards local telephony through automatisation. While to begin with automatisation comprised city exchanges only, particularly in the large cities, where the greatest economic gain could be attained with automatic operation, it is now being extended more and more to comprise rural exchanges also. Here the economic advantages are not so obvious, but by means of automatisation it is possible to make even the rural telephone service into a modern and efficient means of communication and raise it to the level of the urban service, since it enables the fundamental principle to be realised of providing telephone facilities throughout the 24 hours of the day with great reliability and completely conserving the secrecy of speech. Thus it is that the great technical economic problem has arisen, briefly named rural automatic operation, on the practical solution of which both telephone manufacturers and the telephone administrations of most countries are engaged.

Extent of Automatic Operation

The term rural automatic operation covers first and foremost naturally such automatisation of the rural exchanges as provides for automatic establishment of connections between subscribers connected to the same exchange. This part of the matter offers no particular complication; it conforms to a great degree with the automatisation of a telephone exchange in a town, with the difference that in the country it is a question of smaller exchanges. With the simple and satisfactory technical construction and the low prices which nowadays characterise even small automatic exchanges in comparison with manual, with the constantly rising cost of wages for operators and the difficulty in obtaining suitable staff for the small exchanges of rural districts, there is no question that in building new telephone exchanges in the country these should be made as automatic ones. Rural automatisation, however, covers also the question of automatic operation of traffic *between* rural exchanges, and it is this phase of the problem which is incomparably the most weighty and at the same time the most difficult to survey. In this case the various geographic, demographic, economic, social and political conditions obtaining in different countries play the greatest part.

The question is, how far shall automatisation be carried out: shall it be restricted to the least possible, *i. e.*, the execution of the small rural exchanges on a semi-automatic system where the automatic connections within the exchange itself are not established by the subscribers themselves, but by operators located at certain main exchanges, who also handle the traffic between the rural exchanges and between these and the urban exchanges; or shall connections within the rural exchanges be allowed to be automatic while traffic between these exchanges is handled semi-automatically by operators; or shall even the last-named traffic be automatised and, in such case, shall it be to a small extent or such that it will gradually comprise the whole trunk traffic of the land? Installations executed in different lands display examples of all these kinds of rural automatic operation.

Seeing that automatisation of urban areas has shown the greatest advantages, economically and from the traffic point of view, in those large towns with several interworking local exchanges, it seems most reasonable to suppose that such would also be the case if automatic interconnection were arranged between a number of rural exchanges. Such a conclusion, however, cannot be drawn too hastily. The traffic conditions are indeed quite distinct in the two cases. In the urban areas it is a question of large exchanges with some thousands, even several tens of thousands subscribers. The exchanges are situated at comparatively short distances from each other and traffic between them is heavy, so that the junctions form large bundles with good efficiency of the individual lines. Rural exchanges on the other hand are small, from some ten subscribers upwards, and are located at great distances from each other. The junctions are therefore long and expensive and in view of the small traffic between the exchanges the bundles only contain a few lines, which on no-delay traffic give but low efficiency in comparison with that when traffic is handled by manual recording.

Full automatic operation, however, allows of quite a different arrangement of the junction layout network than does manual operation, enabling the junctions to be assembled in larger bundles. Moreover, greater decentralisation of the exchanges can be carried out, thus cheapening the subscriber lines. In this manner a more rational construction of the network is obtained, and this outweighs the lower efficiency of the individual junction with automatic direct connection than with manual recording. Now, the junction network constitutes incomparably the major part of the cost of a telephone plant, as a rule at least the half, and twice as much as exchange equipments. It must therefore be made clear to what extent the different manners of automatisation influence the planning of the junction network and its utilisation and how automatisation can be made possible without expensive extension of the junction network.

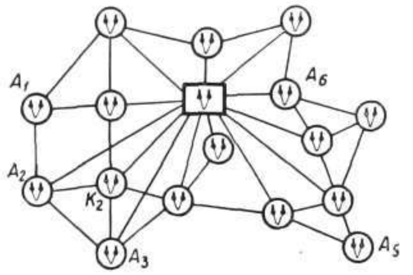

Fig. 1 X 3749
Area with manual local and area traffic

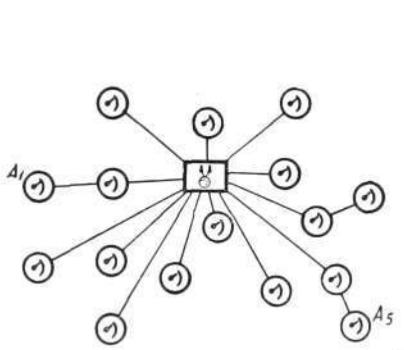

Fig. 2 X 3750
Area with automatic local traffic and manual area traffic

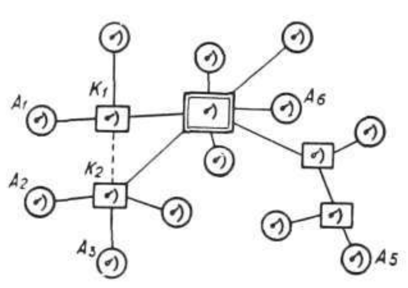

Fig. 3 X 3771
Area with automatic local area traffic

manual main exchange
manual sub-exchange
automatic main exchange
automatic centre exchange
automatic terminal exchange

Rural Telephone Areas

Areas with Manual Local and Area Traffic

Fig. 1 shows an area with a number of manual telephone exchanges, *i. e.*, a manual area, consisting of rural exchanges grouped around a larger main exchange. Direct junctions exist both between the sub-exchanges and the main exchange and between adjacent sub-exchanges. Connections between the exchanges are handled by recording and most of the connections require the intervention of only two operators, those of the outgoing and the incoming exchanges, see Fig. 4. The junction network, therefore, is *diamond-shaped,* made up of a large number of bundles with few lines in each, especially between sub-exchanges. Often one line alone suffices between two adjacent sub-exchanges.

Areas with Automatic or Semi-Automatic Local Traffic and Manual Area Traffic

When on automatising an area only the *local traffic* of the various exchanges is automatised, while the traffic between the exchanges, area *traffic,* is retained as manual, the operators required for this may be concentrated at the main exchange. But few operators are required and night service may be organised without too great expense, thus providing 24 hours' operation for the whole area. The network will then be made up as shown in Fig. 2. The automatic sub-exchanges have direct junctions to the main exchange, while the tie lines between the sub-exchanges are mostly dispensed with. The number of bundles is thus smaller than in the manual area and as the same amount of traffic as before will be proceeding in the area, it is obvious that the traffic in each bundle will be increased correspondingly; partly for this reason and partly because of the lower grade of efficiency with automatic direct traffic to the main exchange a larger number of lines in the bundles is required. No appreciable improvement in the efficiency of the junctions is obtained. On the other hand it is possible to distribute the traffic over a large number of exchanges by arranging periphery exchanges, such as *A1* and *A5*, with junctions only to the nearest exchange.

Local calls are established by subscribers themselves with the dial in the usual way, see Fig. 5. Each exchange has subscriber numbers which are governed only by the size of the exchange. When a call to another exchange is desired, a certain number is dialled, usually *0*, by which connection to an operator at the main exchange is obtained. After recording the operator connects herself over a free junction to the required exchange and, by means of dial or of keybords, operates the selectors at said exchange for the called subscriber. The main exchange may be either manual or automatic: in either case, however, operators are required for area traffic and for the trunk traffic. Such rural automatic operation has been regularly employed to a large extent in Germany and England and other places.

The sub-exchanges may also be made *semi-automatic* instead of automatic. The junction network is made up in the same manner as for automatic sub-exchanges, as per Fig. 2. The operators at the main exchange then deal with the connection of local calls as well, and the subscribers therefore do not have automatic instruments but retain their old LB instruments. The expense for new material in such an automatisation is consequently smaller and this, together with lower electric demands made by the LB fed instruments on the subscriber lines, in certain cases obviating reconstruction of the network which would otherwise be necessary, is the reason why this system has been employed.

Call from a subscriber is connected automatically over a disengaged junction to the main exchange, see Fig. 6. The operator there takes the order and if a call to another exchange is required she makes the connection in the manner

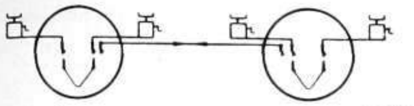

Fig. 4 X 3772
Rural exchanges with manual local and area traffic

already described. If, however, it is a question of a local connection she operates, over the same junction, the selectors at the calling station, so that connection with the required subscriber is made. The operator and the junction are then disconnected and the call remains completely locally connected within the rural exchange. However, as the calling and establishing of the local connections are done on the junction, traffic on these becomes so much the greater. Still, to avoid the necessity of increasing the junctions the semi-automatic exchanges are often made with waiting device, by means of which calls which cannot get through immediately to the main exchange are stored up to be further connected when one junction line will be disengaged. Such rural automatic operation has been largely employed in France.

The semi-automatic exchanges can, however, be made for CB instruments, as can the automatic for LB instruments, which are then supplemented by dials.

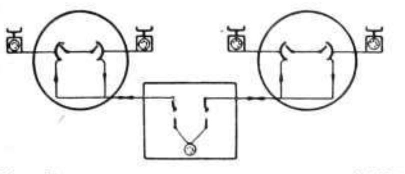

Fig. 5 X 3773
Rural exchanges with automatic local traffic and manual area traffic

Automatic or semi-automatic exchanges with manual area traffic often occur as the first stage of automatisation in manual areas. If a rural exchange requires reconstruction because it is worn out or if a new exchange is to be provided to make the telephone available in a district where it was formerly lacking, but for financial or other reasons more extensive automatisation is not to be carried through, then one must limit oneself to making the new exchange as an *isolated* automatic exchange in the otherwise manual area and connect it to a suitable manual main exchange. If this latter is not organised for 24 hours service then the subscribers of the automatic exchange will only have such service in respect of local connections, or not at all if their exchange is semi-automatic.

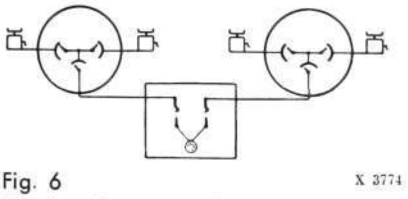

Fig. 6 X 3774
Rural exchanges with semi-automatic local traffic and manual area traffic

Area with Automatic Local and Area Traffic

Considerably better utilisation of the junction network is obtained if the whole area traffic be automatic. The network is arranged in that case as shown in Fig. 3. The direct junctions to the main exchange are retained only in respect of the nearest sub-exchanges but are dispensed with for those on the periphery and in between these. The periphery exchanges are instead linked with the nearest exchange that has direct junctions to the main exchange. There is in this way obtained the characteristic *radial* or *star-shaped* arrangement of the junction network. Such an area comprises a number of *centre exchanges* and radial *terminal exchanges* connected to them. The centre exchanges in turn are as a rule connected to a centre exchange in the traffic centre, the *main exchange* of the area. Occasionally two centre exchanges may be in series with each other.

As may be seen, the number of bundles in the star-shaped area is considerably reduced in comparison with those of the manual area, in the case presented to the half. As the total amount of traffic remains the same as before, the traffic in each bundle will be appreciably increased. A larger number of lines in the bundles involves therefore, though not in proportion to the increase in traffic, so much the better efficiency of each circuit. If the loss on automatic direct traffic is 1 %, for instance, the efficiency in a bundle consisting of only two lines is 5 min per line, rising to 20 min per line with 10 lines.

Fig. 7 X 3775
Rural exchanges with automatic local and area traffic

Now, the requisite number of junctions for the star-shaped area may in most cases be obtained without necessity of making new lines to any great extent. The junctions, in fact, do not take the shortest path between the exchanges, as Fig. 1 indicates, but are more or less radially carried together in open line or cable routes. Thus, for example, the junctions from exchanges *A2* and *A3* do not take the direct path to the main exchange, but proceed with the junctions to exchange *K2* and thence with its junctions continue on to the main exchange. Nor do the junctions between *A2* and *A3* take the direct way but proceed via exchange *K2*. In the manual areas therefore the junctions are to a large extent in respect of line routing already brought together in radial bundles, which however for traffic purposes are broken up into small bundles to avoid a large number of the connections being handled with the intervention of 3, 4 or 5 operators.

In an area with automatic area traffic, on the other hand, there is nothing to prevent the routing of traffic from different exchanges in large common bundles with better efficiency of the individual junctions, since the area traffic may without inconvenience be directed over a number of selectors located at different exchanges. A number of junctions, running direct between sub-exchanges, are either dispensed with or may be employed as *tie lines* between the said exchanges. By using automatic area traffic it is possible also to distribute the traffic over a larger number of exchanges, each covering a small area, thus appreciably reducing and consequently cheapening the subscriber lines. Such entirely automatic operation was first carried out in Bavaria and has since been adopted, *inter alia*, in Switzerland, Italy, Holland and to some extent in the Nordic countries.

Numbering

It is therefore by making both the local and the area traffic of the area automatic that the most rational arrangement of the network is obtained. On the other hand, the automatic exchanges themselves are not so simple as when the area traffic is dealt with manually, since special equipment is required at the automatic exchanges to provide for automatic interworking in the star-shaped area. These are governed by the traffic conditions to be fulfilled, in the first place the question of the *system of numbering* to be employed.

For an isolated automatic exchange, whether urban or rural, or for an urban network with several local exchanges having direct junctions among them, the numbering of subscribers gives rise to no trouble. The subscriber numbers are determined by the size of the exchange or the total capacity of the urban exchanges. With a star-shaped area, however, a call to a subscriber may be connected over a *varying number* of exchanges, according to the exchange to which the caller belongs. For instance, a connection from a subscriber in exchange *A1* to a subscriber in exchange *A6* goes over four exchanges, while a connection to *A6* from a subscriber in the main exchange passes over only two. Special measures are therefore required to enable connection in both cases to be made by using the same subscriber number.

The system of numbering should be as simple as possible and as easy to understand and convenient for the subscriber as possible. The best arrangement in this connection is that every subscriber to whom automatic connection can be made shall always be reached by a certain number given in the directory, irrespective of the exchange from which the call comes, *i. e.*, that subscriber numbers are comprised in a *uniform* numbering. That part of an automatic area in which such holds good we designate as a number area.

Number Areas

The size of the uniform number area should be such that the greatest benefit from the uniform numbering is derived both by subscribers and by the telephone administration. It should cover that portion of the automatic area where large community of interest and heavy traffic between subscribers exist and for which consequently uniform numbering is natural from the subscribers' point of view. The arrangement of the network within the number area may therefore vary considerably in character. The number area may thus consist of a single exchange as is the case with one city exchange, or of several exchanges with direct junctions between as in the larger cities, or of a simple centre area, *i. e.*, one centre exchange with terminal exchanges connected to it, or a more complex star-shaped area as shown in Fig. 3. These different kinds of areas may occur together in one large automatic area. Often the number area will vary in size and type according as automatisation proceeds. Isolated automatic terminal exchanges, which may be the first to be provided, will to begin with form their own number areas to constitute on the automatisation of the main exchange a larger number area in conjunction with same, this larger area at a more distant stage of automatisation comprising the whole of the star-shaped area. Automatic operation, however, involves a certain limitation respecting the type and size of the number areas, and in this connection the various systems present different possibilities. The different principles which may be employed can be shown by their application to an area as in Fig. 8.

Direct-Controlled System

If the *automatic* system employed in the area is *directly controlled, i. e.*, the selectors are actuated direct by the subscribers' dial impulses, each numerical selection movement corresponds to a digit in the number and obviously it must be arranged that an equal number of selector stages is taken in the chain, irrespective of the exchanges from which the call comes. This means that the numerical selecting must proceed from the main exchange and all calls from all the exchanges of the network are automatically connected to the main exchange before answering tone is received and the subscriber can dial the number. The subscriber numbers would be the top ones of those shown beside each subscriber' instrument in Fig. 8.

For example, when a subscriber *22 34* at terminal exchange *A2* wishes to call a subscriber at terminal exchange *A6*, he is connected over a switch at his own exchange to a free junction for centre exchange *K2*, over a switch at this exchange to a free junction for the main exchange and from this last he receives answering tone. Thereupon he dials the number *58 18*, consisting of the *exchange digits* — 58 — the first of which selects the centre exchange *K3* and the second the terminal exchange *A6*, followed by the *subscriber's digits* — 18 — how many of which there are being determined by the size of the exchange, in this case assumed to be 100 numbers; the number thus is four-digit. If on the other hand a connection is desired to a subscriber of the main exchange, which is usual larger, and in this example is assumed to be not more than 10 000 numbers, the subscriber digits will amount to four and the whole number consist of six digits, *e. g., 10 12 34*.

If connection is required to a subscriber *22 56* of the caller's own terminal exchange *A2* then the exchange digits *22* are dialled, the first of which selects the centre exchange *K2* and the second the terminal exchange *A2*, followed by the two subscriber digits *56*. The junctions into the main exchange not used by the call, being disconnected. This is done through the equipment at exchanges *A2* and *K2* being provided with simple marking switches, known as discriminators which are actuated by the impulses from the exchange digits at the same time as the selectors. When the first exchange digit has indicated that the call shall remain within the centre area of *K2*, the discriminator at exchange *K2* disconnects at this exchange the junction to the main exchange and when the second exchange digit shows that the call will be confined to the terminal exchange A2 the discriminator at this exchange disconnects the junction to *K2*, so that the call remains connected locally within the terminal exchange. This occupation of junctions during the process of connection not employed for the call itself we call *advance occupation*.

For a call to subscriber *45 21* at terminal exchange *A5* the selection must be made over two series-connected centre exchanges *K4* and *K5*, that is over still another selector stage, the number of exchange digits required on this account being augmented by one more for subscribers in the centre area *K5*. Recently, however, there has been introduced a method of connection by means of which this disadvantage is avoided. All exchanges within the two centre areas have two-digit exchange numbers, the first digit being *4*. This digit selects the centre area *K4*. The second digit, for centre exchange *K5* may be

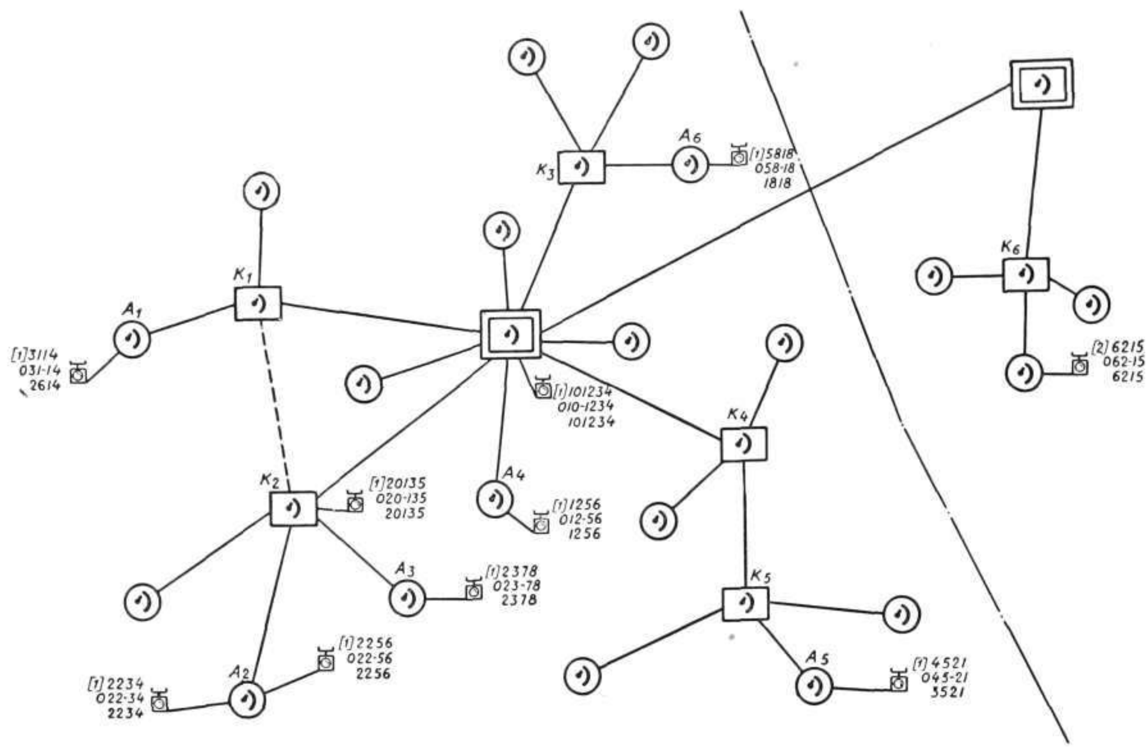

Fig. 8 X 7120

Area with automatic local and area traffic

automatic main exchange

automatic centre exchange

automatic terminal exchange

[1]2256 direct-controlled system with closed numbering

022-56 direct-controlled system with open numbering

2256 register-controlled system with closed numbering

3 and for terminal exchange *A5* it may be *5*. On dialling either of these digits, the connection is made to centre exchange *K5*, but following this selection an operating signal is transmitted automatically from *K4* to *K5*, the nature of which is governed by whether the selected digit was *3* or *5* and which either localises the connection to *K5* or switches it on to the terminal exchange *A5*. Thereupon the selectors at the selected exchange are actuated by the digits *21* in the ordinary manner.

It has been assumed that direct junctions existed between centre exchanges *K1* and *K2* at the time the area was manual. These may be utilised as *tie lines* for traffic between these two centre areas. When on a call to a subscriber *31 14* at terminal exchange *A1* the first exchange digit determined that the call was for the centre area *K1* the discriminator at centre exchange *K2* disconnects the junction to the main exchange and connects the junction from exchange *K2* to exchange *K1*.

If traffic is to proceed automatically with other areas as well, the two exchange digits are supplemented by still another digit, which fixes the required area, *e. g.*, *1* for the area concerned and *2* for the adjacent area, comprising the centre area *K6*, as may be observed from the figures in brackets in Fig. 8.

As may be seen, a system such as that described means that the subscriber numbers will contain a large number of digits. Each centre area requires a first exchange digit, even if the exchanges in the centre area do not amount to ten. Consequently there is limitation right from the start in respect of numbering and the number series must contain a large reserve. Moreover, the advance occupation involves unnecessary taking up of the expensive junctions to the main exchange for calls which should be confined to their own centre area or terminal exchanges. To avoid these inconveniences in the direct controlled system, there is employed a method with *open* numbering or a prefix system instead of the *closed* numbering used in the above-described system. In the system with prefixes the uniform-number area does not cover the whole rural area, but each exchange forms its own number area and for local calls within the exchange numbers are used which contain only subscriber digits, being thus determined by the size of the exchange; they are thus two-digit for terminal exchange *A2* and four-digit for the main exchange. The call remains within the exchange of origin. When a connection to a subscriber at another exchange is required a prefix is first dialled, usually *0*, thus indicating that the call is for outside the exchange, and then the two digits indicating the exchange and the two digits indicating the subscriber. Subscriber numbers will then be as shown by the middle numbers beside each subscriber's instrument in Fig. 8.

When *o* is dialled the call is connected automatically to the main exchange, after which the numerical selection by the exchange and subscriber digits proceeds as previously. Thus dialling differs for the subscriber according to whether the call is for his own exchange or another, and he must therefore always make sure what exchange he is calling from. The directory must give directions regarding the dialling.

For main exchange subscribers, whose chief traffic is within their own exchange, and in general for subscribers at exchanges with considerable internal traffic, the system with prefixes is preferable, since fewer digits are required for the majority of calls than with closed exchange digits. Advance occupation is avoided for all calls within the originating exchange, but continue as regards calls to other exchanges in the same centre area. Both systems, with closed and open numbering may be used together in one area. For example, the main exchange subscribers may make calls within the exchange with only four-digit numbers and with prefixes for the other exchanges, while subscribers to these exchanges employ closed numbering.

It does not always happen that the uniform-number area consists of such a complex network as here described. Often the junctions may be so arranged that the area consists of a few centre areas with direct junctions between them, *e. g.*, if the area consists of the main exchange together with the centre exchanges *K1* and *K2* and terminal exchanges. In such case with a direct controlled automatic system advance occupation need only occur up to the nearest central exchange.

Register-Controlled System

By introducing *registers* for controlling the connections between the exchanges, the disadvantages of advance occupation and less convenient subscriber numbers may be removed. Such registers must not be confused with the translators required in automatic systems employing non-decade, machine-driven selectors. They find employment just as well in systems using decade selectors, *e. g.*, the Strowger system, as in the machine-driven system. We call them *area registers* and their purpose is to make the number of exchange digits independent of the number of stages in the selector chain, *i. e.*, to take care of the translation of the exchange digits' dial impulses to impulse series which actuate the selectors in conformity with the construction of the network.

There are two kinds of area registers, direct acting registers and repeating registers. With the *direct-acting registers,* when the exchange digits have been registered a number of impulse series is sent out, each of which actuates a selector of an exchange, exchange after exchange being selected until the one required is reached. With the *repeating registers* also impulse series are sent out when the exchange digits are registered, but after each series the receiving exchange sends an answering impulse which indicates whether the impulse series represents that exchange or whether the series shall be repeated to act on the selectors of a succeeding exchange. This repetition proceeds until the required exchange is reached.

The area registers will constitute a part of the automatic exchange equipment, which consequently will be more complicated. Still, in a register-controlled system all exchanges do not need to be provided with registers, but only those where traffic demands require it. If all exchanges, even the terminal exchanges, be provided with registers, the whole area forms a uniform number area with the smallest number of digits in the subscriber numbers and there is no advance occupation of junctions at all. The call remains in its own exchange and when the exchange digits or all digits of the number have been registered, the register controls the selection to the called subscriber, after which it is disconnected and ready to deal with the next call. The exchange figures are two-digit and may be chosen entirely at will, as shown by the bottom numbers against each subscriber's instrument in Fig. 8. Thus the exchanges in centre area *K3* may have the same first exchange digit as the main exchange, *viz:* *1*, while in the direct controlled system the digits are *1* and *5* respectively. The numbering system is thus exceptionally flexible and does not demand any special reserves of numbers. Connection to an exchange in another area may be carried out quite automatically without any special area digit preceding the exchange digits. The first exchange digit determines the centre area even in the case of adjoining areas, *e. g.*, digit *6* for a subscriber in the area *K6*.

Terminal exchanges as a rule, however, are small exchanges and the provision of registers for them constitutes an expense which should only occur when in a number area advance occupation to the nearest centre exchange may not be allowed. This would, however, usually be possible so that provision of area registers would only be done for the very few centre exchanges employed for the whole traffic of the centre area. The same subscriber numbers would apply as formerly. If advance occupation may be done right up to the main exchange, the area registers are located at the main exchange.

Prefixes may be used also in a register-controlled system. If it is not wished to have advance occupation to the centre exchange nor to equip the terminal exchanges with registers, the advantage derived from one uniform numbering for the whole area must be dispensed with and recourse made to the prefix system.

Rates and Metering

An important problem arising on automatic operation of traffic between different exchanges is how these calls shall be charged. In a manual area or an automatic area with manual area traffic, the operator supervises the calls and can record those calls which have to be specially debited. In an automatic area this charging must be done automatically, and it is therefore done on the subscriber's meter. This means that all automatic traffic, whether within one number area or between areas, can only be charged in the form of a number of metering impulses on the subscriber's meter. The number of impulses is governed by the time occupied and the distance between the exchanges. To determine these, the automatic exchanges are provided with *time-zone meters*, which on the basis of the number dialled transmit to the meter the number of impulses, corresponding to the distance, at each unit of time, usually 3 min. The charging of subscribers in such a system will as a rule consist of a certain flat rate independent of the number of calls and of a charge for each local call metered by an impulse to the meter and a charge for each connection within the automatic area representing a certain multiple of the local rate. In this way means is provided for great differentiation in respect of charges for inter-exchange connections. With manual operation it has often been necessary to allow an exceedingly large flat-rate area because it did not pay to debit specially such connections, as the recording expenses were too high. With the automatic time-zone meter, however, it is possible to charge the subscriber in a simple and cheap manner according to the cost of his connection in respect of occupation of lines and switches, thus obtaining a rate policy which is fairer and more economic both for the administration and for the subscriber. Developments in conjunction with rural automatic operation may be expected therefore to proceed on the lines of the flat rate area, in which connections only represent one rate irrespective of time consumed, being more and more restricted to comprise solely the subscriber's own exchange.

Rural automatic operation provides, in addition to the above, a number of problems, exceedingly interesting both technically and from a traffic point of view, *e. g.*, attenuation in the rural networks and the employment of amplifiers, various methods of dialling over junctions with DC and AC, for trunk disconnection, etc. The purpose of this article, however, being only to give a guide to the more basic technical principles of rural automatic operation, such questions cannot be dealt with here.

Maintenance Statistics for the Stockholm Automatic Exchanges

I. NORBERG, ROYAL TELEGRAPH ADMINISTRATION, STOCKHOLM

Superintendence of automatic telephone exchanges calls for more or less extensive operation control, based on operation statistics compiled in suitable manner. These are divided into maintenance statistics providing indications for the estimating of the exchange's running in the best manner from the technical and economic points of view, and traffic statistics comprising investigation and supervision of circuit requirements for different traffic routes etc.

The article below, constituting an abridged summary of two papers published in the »Technical Bulletin of the Swedish Royal Board of Telegraphs» No 11—12, 1936, and No 1—3, 1937, gives a description of the general features of the maintenance statistics for the Stockholm automatic exchanges and questions related to them.

Maintenance Work

The Stockholm automatic exchanges, all of which are built on the Ericsson automatic telephone system, are at present divided into two areas: the Stockholm inner area consisting of Stockholm proper, and the Stockholm suburban area comprising the outer parts and the suburbs of Stockholm, etc. The local exchanges at present consist of Centralen, Södra Vasa, Norra Vasa, Söder, Kungsholmen and Östermalm. The automatisation of the suburban area is only in its early stages and of the exchanges comprised in it Äppelviken is included for comparison with those of the local area.

The subscriber network of a local exchange, Fig. 1, consists of the subscriber instruments and subscriber cables and is maintained by a central institution, the fault office. The exchange consists of distribution frames, selector bays and manual trunk positions, which last are not found in the automatised suburban exchanges where trunk calls are connected over trunk selectors.

The staff of an exchange consists in general of superintendent for general service, certain supervision work etc.; trunk operators (with manual positions); cleaning staff for cleaning floors and the premises generally; staff

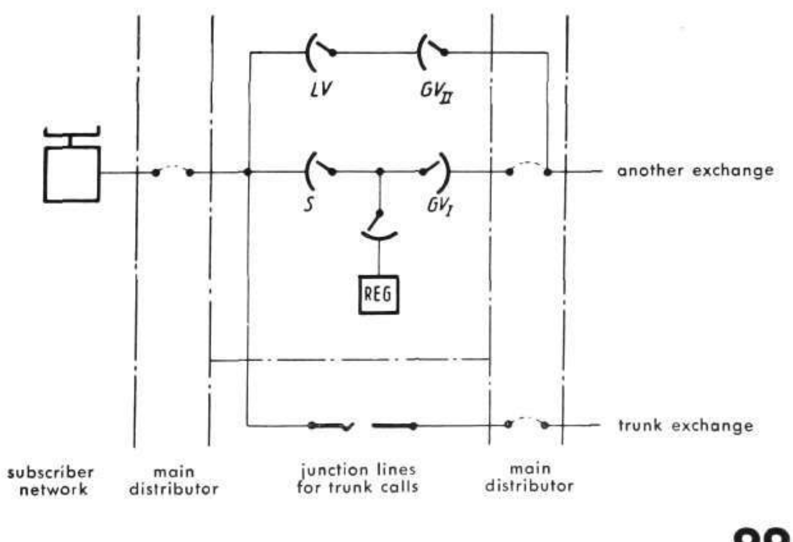

Fig. 1 X 5390
Trunking diagram of telephone exchange with subscriber network

GV_I first group selector
GV_{II} second group selector
LV final selector
S line finder

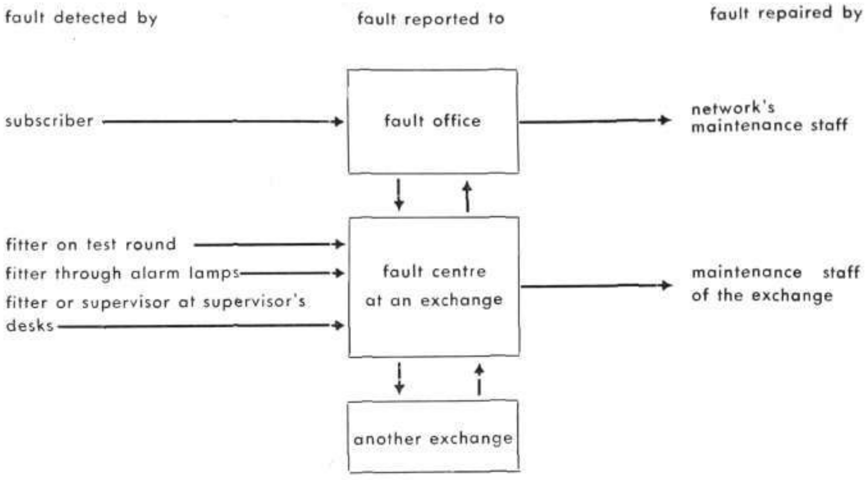

Fig. 2
Diagram of fault notification process

for work on the distribution frames; and maintenance staff in the true sense of the term. The distribution and maintenance staffs of the local exchanges are in charge of a foreman, while the suburban exchanges are supervised by a fitter dwelling on the premises.

The work of the distribution and maintenance staffs may be divided up in different ways according to the size of the exchange. In the smaller exchanges the staff must share in all the duties, while in the larger ones a certain amount of specialisation may occur. The following working duties may be particularised:

work on *distribution frames* is largely governed by changes in the subscribers; in the Stockholm exchanges the staff required for this purpose normally amounts to from $^1/_2$ to 2 men;

the *fault centre* constitutes the centre of reception for all fault reports to and from an exchange, and the fault tracing work is largely directed from it, see Fig. 2; there all faults reported are entered in fault books of various kinds, to be collated later into fault statistics. The fault centre is generally located near the distribution frames, and the fitters of the distribution frames and the fault centre collaborate in their work; the staff normally required in the fault centre consists of $^1/_2$ to 1 man;

work in the *selector bays* may be divided into two groups, *viz:* supervision of the instruments and watch duty; supervision of instruments comprises periodic inspection, cleaning and adjustment of automatic devices, and systematic testing of the instruments, junction lines etc. all in accordance with a plan laid down and as far as possible employing female staff; the watch duty consists in supervising the faults that may arise during the run of the automatic exchange and comprises fault-tracing and fault-clearing indicated by pilot and alarm lamps of various kinds, fault reporting etc.;

care of the *power plant* comprises supervision of charging and discharging of batteries, regulation of operating tension as well as care of the exchange batteries, electric machines and rectifiers;

the exchanges should furnish each month certain *statistical reports*, mainly fault statistics and traffic statistics, compiled from fault books, traffic figures noted, etc.

Besides the above-mentioned routine maintenance work, the maintenance staff carries out a number of smaller jobs, consisting of making connections required by additions to subscriber and junction circuits and various other alterations at the exchanges. More comprehensive work of this nature, however, is dealt with by a special new-construction department. In addition to what is stated above, it should be observed that certain of the male staff are on fixed duty lists which provide the necessary stand-by staff for exchanges, *e. g.*, in the evenings, at night and on Sundays and holidays. The duty lists are to a certain extent standardised and made out for 3 to 8 men. Should an exchange require to increase its staff above that noted on the duty list, »permanent day-men» are appointed.

Operating Reliability and Faults

Supervision of the operating reliability of the exchanges is carried out at supervisor's position connected to the automatic registers of the exchange. The supervisor follows up a certain number of connections taken at random on all the registers and records the defects observed. In a month of such supervision the number of calls checked usually amounts to one per thousand of the total number of calls.

The checked calls are divided into *faultless connections* (including busy, no reply and the like), *subscriber faults* and *technical faults*. The number of technical faults detected in percentage of the number of calls checked constitutes the technical fault percentage p. The admissible value of p will be a figure dictated by experience, depending to a certain extent on how exacting the subscribers may be; in general it may be said that the technical fault percentage should be small in proportion to the percentage of faults caused by the subscribers themselves. An exchange where the maximum for p amounts to 0.5 % may nowadays be considered sufficiently good from the point of view of reliability; the mean figure for p for the Stockholm exchanges in 1936 was 0.14 %. As the subscribers themselves in the corresponding period were responsible for about 1.5 % faults on the average, it appears that the above requirement is well fulfilled.

To provide further check of the functioning of the exchange from the technical point of view, each month all faults notified are brought together into a fault report which indicates the distribution of the localised faults over the various connecting devices and other exchange equipment, and also the nature of the fault. The number of faults unlocalised is also given so that care may be taken that this does not become disproportionately large. Faults unlocalised are further divided into »no fault» meaning that the fitter found nothing indicating a fault and »clear during test» intimating that the fitter saw that a fault had occurred but could not be sufficiently certain of the source of the fault.

With the aid of the fault statistics it is possible to form a good idea of the nature of the faults which arise at the exchanges. The technical faults arising may be divided into permanent defects from the erection of the exchange, such as defects in construction, defects due to workers, defects in material; *tempo-*

	Centralen	Södra Vasa	Norra Vasa	Söder	Kungsholmen	Östermalm[2]
registers	330	234	144	287	162	266
localised register faults	348	137	38	105	132	159
localised register faults per register	1.05	0.59	0.26	0.37	0.81	0.60
millions of calls	87.04	40.24	14.33	51.19	34.00	44.79
millions of calls per register	0.264	0.173	0.100	0.178	0.210	0.168
p[1] %	0.28	0.04	0.08	0.05	0.22	0.17

[1] p here represents technical fault percentage for the calls which proceed from the different exchanges to all exchanges, both automatic and manual; the above figures for p therefore are practically speaking equal to technical fault percentage for the different exchanges

[2] the relatively high fault percentage for Östermalm, compared with Söder, Södra Vasa and Norra Vasa, is due to certain defects persisting from the time of erection of the exchange not having yet been removed

Table I

Operating statistics for registers of Stockholm automatic exchanges 1935

Table II
Faulty calls as function of technical fault percentage

p %	S/day	S_f/day	S/day	S_f/day
0.10	40 000	40	250 000	250
0.30	40 000	120	250 000	750
0.50	40 000	200	250 000	1 250

rary faults, such as faults due to variations in tension, faults due to work and faults due to injury; and *wear faults,* such as contact faults, winding faults due to overheating and electrical break-down, mechanical faults due to friction and the like.

There is obviously a certain relation between operating reliability and the number of faults, as is also seen in the statistical reports. If the operating reliability decreases it is due to augmentation of the number of faults developing. Thanks to existing alarm devices and the rational arrangement of tests these new faults are rapidly detected and the number of faults investigated as also the number of localised faults increase.

To make an elementary investigation of the relation between faults and operating reliability it may be assumed that the defective devices cause faults in calls at regular intervals until they are localised. This assumption may be regarded as an acceptable average of actual conditions. In certain cases there may arise a defect of such a nature that all calls subsequently passing over the device in question will be faulty. Other faults, such as constructive weaknesses and the like, cause faults in connections in certain combinations or in certain circumstances. A third kind of defect, such as dirty contacts and the like, appear first at long intervals and then more and more frequently.

As an application of the relation presented, an investigation is made in some cases of the operating reliability of the registers at the Stockholm exchanges during 1935, Table I. The registers lend themselves better to such an investigation than do the selectors, among the reasons being that the technical fault percentage p, strictly speaking, only applies to faults of establishing of connections, to which all register faults belong, while selector faults may also be connected with the restoring of a connecting device. Moreover the traffic on the registers is so large that defects in them are more noticeable.

The following designations are introduced:
p = percentage technical faults during a short period t,
S = calls during period t,
S_f = faulty calls during period t.
It is obvious that

$$p = \frac{S_f}{S}$$

In this equation p is known from the above with sufficient accuracy while S is obtained from traffic statistics; thus S_f may be calculated. Even though p be small, the absolute number of faulty calls at an exchange with heavy traffic may be large, as can be seen in Table II. An exchange with 40 000 calls a day corresponds to Norra Vasa at present and one with 250 000 calls to Centralen.

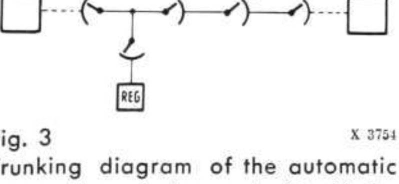

Fig. 3 X 3754
Trunking diagram of the automatic connecting devices at Stockholm telephone exchanges
GV$_I$ first group selector
GV$_{II}$ second group selector
LV final selector
S line finder

Since a certain number of the faulty calls are notified by subscribers or observed through the alarm lamps in the register or traffic supervision positions, it may be understood that the fault-tracing work at an exchange with heavy traffic may be considerable, even if operating reliability be good.

Now to determine the relation between the number of faulty calls S_f and the defective devices at an exchange, we turn to the trunking diagram of an automatic exchange, Fig. 3. We assume that defects, existing or in course of deve-

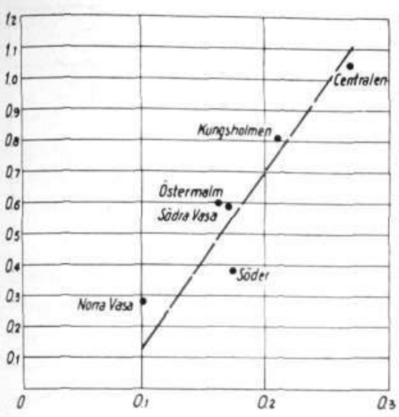

Fig. 4 X 3755

Localised faults as function of million calls per register, 1935

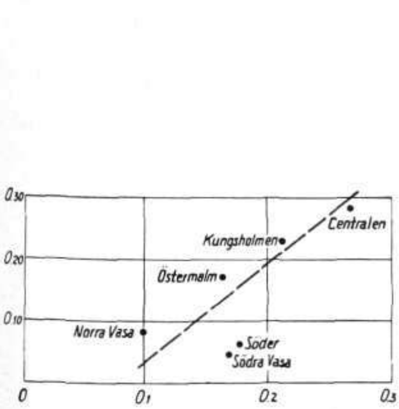

Fig. 5 X 3756

Technical fault percentage as function of million calls per register, 1935

loping, in a device give rise to fault every nth time a call passes over the device in question. The connecting devices contained in the system are merged together in groups, the devices in one group being equivalent from a traffic point of view. For the sake of simplicity it is assumed that all selector stages have the same value, which means that they would have the same number of devices and that these are utilised to the same extent; there is therefore no question of grading. In this manner there are obtained two distinct groups, namely registers and selectors. Further it is assumed that a faulty call is never caused by more than one defective device. The following designations are introduced:

R = registers connected at the exchange during a certain short period t,
V = selectors connected at the exchange per selector step during period t,
R_f = faulty registers at the exchange during period t,
V_f = faulty selectors at the exchange during period t,
n = a faulty device causes fault each nth time it is used.

It is obvious that S_f is the number of calls on the faulty device multiplied by $\frac{1}{n}$, from which we get

$$p = \frac{S_f}{S} = \left(\frac{R_f}{R} + \frac{V_f}{V}\right) \cdot \frac{1}{n}$$

This equation gives the relation of p to the number of faulty devices at a certain moment. Let us investigate this somewhat more closely. If R and V are assumed to be constant and an exchange has only permanent faults, say of a constructive nature, this would mean that R_f and V_f are constant. Then p would also be constant and independent of the traffic intensity.

If we go on to assume that the device faults R_f and V_f are exclusively due to wear and as such a function of the number of calls per device, we get

$$p = f\left(\frac{S}{R} + \frac{S}{V}\right)$$

Other conditions being equal, it thus holds good that a part of the fault percentage due to wear is a function of the number of calls per device, which means that exchanges with heavier traffic per connecting device display a higher fault percentage than the others. This assumption seems to accord very well with actual conditions, see Fig. 4 and 5, where the tendency in the relation of the measured points is clear; still it is a matter of chance that the figures should lie so close together.

Naturally, it should not be supposed from what has been stated above that the differences obtaining in fault percentage between the exchanges of Stockholm are entirely due to the traffic on the connecting devices. A certain part of the technical fault percentage consists also of faults persisting from the erection of the exchange as well as of temporary faults. This portion is, as pointed out above, to a great extent constant and thus independent of the traffic flowing. An appreciable difference may naturally exist between exchanges, *e. g.*, because of censtructive dissimilarity, difference in the number of fitters and so on, but one cannot disregard the differences in technical fault percentages which are a direct result of traffic intensity.

The equation also indicates how the fault percentage is related to the distribution of faults over automatic devices of varying importance. We take, for example, that an exchange with 200 registers and 1 000 selectors per selector stage has altogether 20 faulty devices. Table III shows various figures for p, according as the 20 faults are to be found in the registers, in the selectors or in both. The importance of the registers being maintained with care is brought out by this with all the clearness one might wish.

Table III
Technical fault percentage for different fault distributions

R_f	V_f	p %	p %
		$n = 1$	$n = 10$
20	0	10	1.0
0	20	2	0.2
10	10	6	0.6

If each faulty device were localised and put right the first time a fault arose, the technical fault percentage would be obtained direct from the fault reports and the particulars of the number of calls. The exchange could then be regarded as free from fault, that is without permanent fault; some defect arises from time to time but this never succeeds in causing fault in more than one call before it is removed. Here then applies the following relation

$$p = \frac{S_f}{S} = \frac{\text{number localised faults}}{S}$$

In order to discover how near we are to the above ideal case, Table IV has been drawn up, showing the number of localised faults in the connecting devices (selectors and registers with accessory equipment) during 1935 in percentage of the number of calls a, fault percentage p during the same period and the ratio of p/a. If all faults had been localised and remedied the first time they appeared, p/a would be equal to *1*. The reasons that p/a in the table is so much higher are two: first, the number of remedied faults is considerably larger than the number of localised faults given by the fault statistics (certainly all faults met with are entered in the fault statistics, but numerous defects which were not found disappear through the cleaning and adjustment of the devices etc.; thus the figure for a above is too small); second, a faulty device may succeed in causing a number of faults in calls before the fault is detected, localised and remedied.

Size of Maintenance Staff

To compare the different exchanges in respect of efficiency of attendance, it is advisable to draw up staff requirement forms, based on work and time studies for the type of exchange concerned. From these are derived the requisite number of working hours that should be put in by the maintenance staff.

Recalling what has been stated regarding maintenance work at the Stockholm automatic exchanges, it may be seen that the requisite maintenance time for these exchanges may be distributed over the following four work groups, see Fig. 6: care of the exchange, comprising inspection, testing, cleaning, repair etc. of the automatic exchange devices; watch duty (fault tracing) during the period of the day with comparatively heavy traffic; stand-by duty during low traffic times, and finally work in the fault centre, entering of statistics and sundry work.

Care of the exchange demands a number of working hours largely proportional to the number of connecting devices. In order to find the necessary time, a

Table IV
Localised faults in connecting devices in percentage of number of calls and technical fault percentage in Stockholm telephone exchanges 1935

	a %	p %	p/a
Centralen	0.0018	0.28	155
Södra Vasa	0.0020	0.04	20
Norra Vasa	0.0017	0.08	47
Söder	0.0019	0.05	26
Kungsholmen	0.0029	0.22	76
Östermalm	0.0016	0.17	106

Fig. 6 X 5392
Distribution of work at a telephone exchange in Stockholm

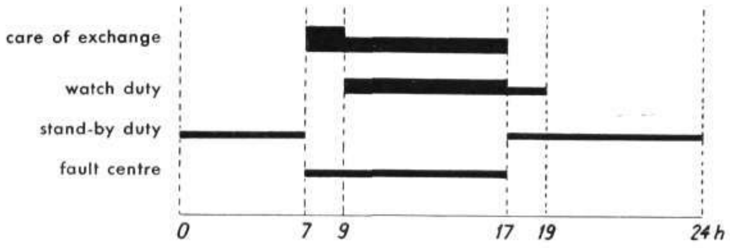

table has been drawn up covering all the routine tests, all rounds of inspection, adjustment and cleaning for the various devices, together with the time required for same during a year. An investigation of this kind made in the Stockholm automatic exchanges gave the result that each year on an average there is taken up maintenance time of:

2.3 hours per selector with sequence switch
1.6 hours per selector with relay set instead of sequence switch
18.0 hours per register
1.2 hours per relay repeater at the suburban exchanges.

In these times are included the maintenance of the devices referred to, along with maintenance of accessory shafts, motors, alarm devices and also maintenance of devices common to the exchange, such as battery and machine rooms, supervisors' positions etc., the times for which are divided proportionately among the connecting devices.

Watch duty comprises the work devoted to fault tracing caused by the traffic of the exchanges. The number of faults, inclusive of blocked circuits, is about proportional to the number of calls, as may be seen in Table V. In what follows it is taken that watch duty during ordinary weekdays normally falls between 9 o'clock and 17 o'clock (Saturdays between 9 and 13 o'clock), but that when working staff is required at an exchange beyond the fitter intended for stand-by duty, that working staff shall be counted in the regular duty.

Let us now take approximately that all calls fall within the time watch duty is proceeding, and that all faults arise during that time and are dealt with by the duty man. An investigation has shown that the number of hours of watch duty per year may be placed at 10^{-4} times the number of calls in the respective exchanges per year. That means that one hour's duty is reserved for 10 000 calls. According to Table V, the number of faults notified per 10 000 calls is on the average 2.5, for which therefore one hour's duty is taken up. Blocking constitutes one quarter to a half of these faults.

Stand-by duty means that a fitter shall be present at an exchange on duty for the event anything special occurs. The duty-man will naturally deal with faults that arise etc., but his working hours will not normally be taken up by such work. Only one man at a time is stand-by duty-man and he attends at the exchange before 7 and after 17 o'clock on weekdays, before 7 and after 13 o'clock on Saturdays and the days before holidays, and the whole of the 24 hours on Sundays and holidays. Table VI shows the stand-by duty-man's hours of attendance at the Stockholm inner exchanges. These times are constant for a certain duty list and are governed by the necessity of having someone in attendance at the exchange at certain periods. The Stockholm inner exchanges have permanent attendance, so that the stand-by duty times per year for them is in round figures 6 000 h. The outer exchanges for the present do not have night and Sunday and holiday duty men. An exchange like Äppelviken has at present a stand-by duty time of about 1 400 h per year.

Table V
Reports entered per 10 000 calls

	Centralen	Södra Vasa	Norra Vasa	Söder	Kungsholmen	Östermalm	average
1935	2.4	2.7	3.0	2.1	2.4	2.5	2.5
1936	2.4	2.4	2.9	2.2	2.8	2.2	2.5

Table VI
Stand-by time for exchanges with constant attendance

	period of stand-by duty h	days (average)	total period stand-by duty h
ordinary weekdays	0—7 and 17—24=14	250	3 500
saturdays and eve of holidays	0—7 and 13—24=18	54	872
sundays and holidays	0 — 24=24	61	1 464

In the formula sought there comes finally a constant time for *duty in the fault centre* and for *statistical work*. Even though work in the fault centre to a certain extent is proportional to the number of fault notifications, yet it is most frequently not of an extent to constitute full utilisation of the time. Keeping the fault books, attending the switchboard, compiling fault and traffic statistics demand within a wide range the same time at different exchanges. The above work is reckoned to take a man's whole time of duty between 7 and 17 o'clock (Saturdays 7—13) at the larger exchanges; at the smaller exchanges half this time is estimated. The total time taken for such work is therefore 1 400 h for Norra Vasa and the outer exchanges, and 2 800 hours for the other automatic exchanges.

The formula of staff requirements at an automatic exchange on the Ericsson system in Stockholm is thus made up of four components: the number of connecting devices, the number of calls and two constants representing stand-by duty and duty in the fault centre etc. We introduce the following designations:

A = maintenance time in working hours per year
V_s = selectors with sequence switches
V = selectors without sequence switches
R = registers
T = relay repeaters
S = calls originated per year
K_b, K_f = constants

The formula then takes the following appearance

$$A = 2.3 \cdot V_s + 1.6 \cdot V + 18 \cdot R + 1.2 \cdot T + 10^{-4} \cdot S + K_b + K_f$$

The formula does not take into account circumstances such as an exchange with larger traffic per device than another reasonably requiring inspection and testing more frequently than the latter, nor has any account been taken of the nature of the exchange building. It is obvious, *e. g.*, that an exchange on three floors is more troublesome to look after than an exchange on one floor. Still these and other considerations do not seem to have any decisive influence on staff requirements on the whole. Should, however, the actual

Table VII **Estimated and actual maintenance time**

	Centralen	Södra Vasa	Norra Vasa	Söder	Kungsholmen	Östermalm	Äppelviken
$2.3 \cdot Vs + 1.6 \cdot V + 18 \cdot R + 1.2 \cdot T$	21 050	14 610	7 570	17 650	12 440	15 630	4 640
$10^{-4} \cdot S$	9 380	4 200	1 460	5 040	3 710	4 820	1 060
Kb (stand-by duty)	6 000	6 000	6 000	6 000	6 000	6 000	1 400
Kf (fault centre etc.)	2 800	2 800	1 400	2 800	2 800	2 800	1 400
estimated number maintenance hours A	39 230	27 610	16 430	31 490	24 950	29 250	8 500
actual number maintenance hours in 1936 incl. foreman's time	37 066	30 665	18 969	29 997	31 296	31 042	
difference between actual and estimated maintenance hours	— 2 164	+ 3 055	+ 2 539	— 1 493	+ 6 346	+ 1 792	
ratio between actual and estimated maintenance hours	0.94	1.11	1.15	0.95	1.25	1.06	

number of maintenance hours for an exchange deviate to any appreciable extent from the number estimated, the reason for this would naturally require to be investigated in each individual case. Nor is foreman's time reckoned in the formula, where a foreman is employed. Certain of the jobs included are such as would normally fall to a foreman, *e. g.* compiling statistics etc., but the greater part of a foreman's time would still, however, fall outside the estimated maintenance time.

Let us now see what the formula shows in respect of the Stockholm exchanges. In Table VII a comparison is made of the estimated times and the actual times occupied for the year 1936. The estimated time is divided into its components, by which one may see the influence of each portion. The difference between actual time and estimated time should in accordance with what has just been pointed out be normally about 2 000 h, representing the foreman's time. From the table it appears that Centralen and Söder had too few maintenance hours during the year. Both these exchanges consequently had their staffs increased at the beginning of 1937. Kungsholmen displays a certain excess of maintenance hours. This is due to the fact that the exchange was in a phase of expansion, by which transition was made from a duty schedule of 6 to one with 8 men. This caused a temporary surplus of staff. As the exchange is continuing to undergo strong development the surplus is, however, only apparent and should soon be absorbed. In respect of the other inner exchanges, Södra Vasa, Norra Vasa and Östermalm, the actual, number of maintenance hours would seem to accord well with the estimated number.

As regards Äppelviken the number of maintenance hours worked in the year 1936 could not be obtained, partly because the exchange was first opened in the spring of that year and partly because working conditions on a new exchange are not completely stabilised for some time. It would appear, however, as if the estimated maintenance hours will show good agreement with the actual number during the present year 1937. With reference to the requisite maintenance time for Äppelviken particular notice should be taken of the gain arising from the facility of restricting the night duty as also the Sunday and holiday duty, thus reducing stand-by duty to a minimum.

The number of hours obtained from the above formula includes also the time devoted to cleaning the connecting devices, generally undertaken by female labour. Female labour can, of course, in many cases replace or supplement male labour, so that the formula of requirements would be most correct with the combining of the working times of male and female staff. The necessary number of cleaning women should, however, be determined separately, and this is easily done since their work is fairly constant. Cleaning women clean the selectors and sequence switches at all exchanges. At certain exchanges they also help in the cleaning of registers. Moreover, they are employed to a certain extent for the compiling of statistics. The requisite number of hours for cleaning women may be set at

$$A_p = 1.2 \cdot V_s + 0.65 \cdot V + 4.0 \cdot R$$

Maintenance Statistics

Out of the statistic particulars furnished by the exchanges there is drawn up each year a summary for the control of the exchanges and comparison between them, mainly in the manner described above. Tables VIII—XI show such annual summaries for the Stockholm automatic exchanges for 1936. No complete statistics can yet be obtained from exchanges in the suburban area; still statistics from Äppelviken for the second half of 1936 have been included.

Table VIII — **Traffic data[1]**

	Centralen	Södra Vasa	Norra Vasa	Söder	Kungs-holmen	Östermalm	Äppelviken
exchange connected	spring 1929	spring 1932	spring 1924	spring 1931	spring 1928	spring 1933	spring 1936
numbers in 1936	20 000	30 000	10 000	40 000	27 000	25 000	9 000
500-line groups in 1936[2]	40	60	20	80	54	50	18
average subscribers connected during the year	16 200	20 707	6 733	26 604	18 710	19 514	5 580
outgoing calls during the year	93 813 914	42 009 808	14 569 517	50 041 716	37 086 599	42 223 075	5 305 806[3]
call minutes per busy hour[4] for outgoing calls	69 200[5]	37 455	17 045	50 435	32 530	43 485	12 030
call minutes per busy hour[4] for incoming calls	28 490	31 350	13 815	42 790	24 670	37 340	11 110
average of connected registers	330	234	144	287	161	266	89
average of connected line finders[6]	2 000 (2 000)	1 350 (1 350)	595 (595)	1 625 (1 625)	1 115 (1 115)	1 420 (1 420)	390 —
average of connected first group selectors[6]	2 000 (2 000)	1 350 —	595 (595)	1 625 —	1 115 (790)	1 420 —	390 —
average of connected second group selectors[6]	1 250 (1 250)	1 260 —	470 (470)	1 570 —	1 075 (640)	1 290 —	275[7] —
average of connected final selectors	1 305 (1 305)	1 355 (1 355)	505 (505)	1 585 (1 585)	1 075 (1 075)	1 410 (1 410)	460[8] —
average of connected repeaters	—	—	—	—	—	—	520

[1] figures are derived from traffic statistics of the exchanges and are designed to give a picture of the sizes and traffic flow of the exchanges

[2] indicates subscriber equipment capacity at close of year, not selector equipment capacity

[3] this figure would be about double for the whole year, as Äppelviken statistics only apply to half the year 1936

[4] the number of conversation minutes for call finders and final selectors during busy hours is determined for each exchange at least once a month; if the 10 000 line groups of the exchanges cannot be measured simultaneously, the maximum conversation minutes for each group are added together, thus giving the total number of conversation minutes for the exchanges; deduction is made from the twelve maximum monthly figures of the three lowest, representing certain months of low traffic; the means of the remaining nine figures are entered under above headings; determination of the number of conversation minutes is a factor of the traffic statistics; these figures are employed in the maintenance summary for comparison with maintenance costs

[5] outgoing traffic from Centralen is appreciably larger than incoming, proceeding mainly to name-call exchanges and group number exchanges

[6] the figures in brackets represent the average number of sequence switches attached to the connecting devices in question

[7] group selectors for local traffic from the Stockholm urban area as also trunk group selectors

[8] including trunk final selectors

Table IX **Size of distribution, maintenance and cleaning staff**

	Centralen		Södra Vasa		Norra Vasa		Söder		Kungsholmen		Östermalm		Äppelviken	
	male	female	male	female	male	female	male	female	male	female	male	female	male	female
foreman	(1)[1]		1		1		1		1		1		—	
main distributor	2		2		1		2		2		2		1/2	
fault centre	1		1		1/2		1		1		1		1/2	
apparatus room and trunk positions	11		8		5 1/2		8		8		8		3	
cleaning of automatic devices		3		3		1		3		3		3		(1)[2]
cleaning of premises		2		1		1		2		2		2		1
total	15	5	12	4	8	2	12	5	12	5	12	5	4	2

[1] at Centralen there is a head linesman replacing the foreman; he is also in charge of the maintenance staff at the trunk exchange etc.

[2] female staff for apparatus cleaning do not attend permanently at the suburban exchanges; the necessary number of cleaners move about from one exchange to another

Table X **Operating reliability and faults[1]**

	Centralen	Norra Vasa	Södra Vasa	Söder	Kungsholmen	Östermalm	Äppelviken
technical fault percentage p (outgoing calls)	0.41	0.05	0.05	0.06	0.19	0.09	0.03
localised faults in connecting devices (incl. clear on test)	2 093	758	346	1 153	960	760	220[3]
localised faults in other exchange devices (incl. clear on test)	535	267	96	423	342	298	53[3]
total localised exchange faults per subscriber	0.16	0.05	0.06	0.06	0.07	0.05	0.05[3]
total localised exchange faults per 10 000 calls	0.28	0.24	0.30	0.31	0.35	0.22	0.51
total of faults entered in exchange books[4]	22 570	10 011	4 289	11 172	10 413	10 406	2 587[3]
total of faults entered in exchange books per 10 000 calls	2.4	2.4	2.9	2.2	2.8	2.2	4.9

[1] figures derived from fault and operating statistics of exchanges

[2] these figures would be double for a full year

[3] in these are included faults in subscriber relays, strips and main distributor, excluding faults in manual trunk positions

[4] in these totals are included all localised and partly localised faults in the exchange itself, at other exchanges and by subscribers of the exchange including handset left off, as also all unlocalised faults

Table XI Maintenance times and maintenance costs[1]

	Centralen	Södra Vasa	Norra Vasa	Söder	Kungsholmen	Östermalm	Äppelviken
working hours in apparatus rooms and manual trunk positions incl. foreman's time	27 330	21 846	15 436	21 692	21 780	21 732	
working hours in fault centre[2]	2 400	2 400	1 200	2 400	2 400	2 400	
working hours for cleaning automatic devices	7 336	6 419	2 333	5 905	7 116	6 910	
total maintenance hours	37 066	30 665	18 969	29 997	31 296	31 042	
estimated number maintenance hours A[3]	39 230	27 610	16 430	31 490	24 950	29 250	8 500
maintenance hours per subscriber[4]	0.94	1.11	1.15	0.95	1.25	1.06	1.0
wages for maintenance staff[5]	59 147: —	48 643: —	31 449: —	47 894: —	49 175: —	48 898: —	
costs of material and repairs etc. in the automatic system	2 618: —	392: —	418: —	727: —	693: —	663: —	
total maintenance costs U[6]	61 765: —	49 035: —	31 867: —	48 621: —	49 868: —	49 561: —	14 000: —
total maintenance costs per subscriber[7]	3.81	2.37	4.74	1.83	2.66	2.54	2.5
total maintenance costs per 10 000 outgoing calls[8]	6.59	11.67	21.90	9.73	13.45	10.28	13.2
total maintenance costs per outgoing call minute and incoming call minute in busy hours[9]	0.63	0.71	1.03	0.52	0.87	0.61	0.61
total maintenance costs per A[10]	1.57	1.77	1.94	1.54	2.00	1.69	1.65

[1] figures are derived from time-cards and collation of costs
[2] estimated time
[3] obtained by formula $A = 2.3 \cdot V_s + 1.6 \cdot V + 18 \cdot R + 1.2 \cdot T + 10^{-4} \cdot S + K_b \cdot K_f$
[4] the ratio between executed and estimated maintenance hours would normally lie between 1.00 and 1.10
[5] hours worked at each exchange have been multiplied by the mean cost per hour for all exchanges, *viz*: S. Kr. 1.76 for men and S. Kr. 0.93 for women; the mean cost has been calculated in such a way that all wages paid to maintenance staff at Stockholm automatic exchanges, including overtime, holiday and sick payments but excluding pension contributions, have been divided by the total number of hours worked
[6] sundry costs falling outside maintenance costs for the automatic system are not included in the annual statistics so as not to spoil the comparison between the exchanges; these sundries include among other things replacement of an exchange battery and certain administrative costs
[7] maintenance cost per subscriber is evidently a rather uncertain basis of comparison; in general it is found that the more subscribers an exchange has the cheaper is the cost per subscriber
[8] maintenance costs referred to the number of outgoing calls show great variation; were the number of incoming calls known the comparison would be better
[9] by dividing the maintenance costs by the number of call minutes per busy hour for outgoing and incoming traffic the costs are referred to the amount of traffic on the exchange concerned during busy hours; this would seem to be the safest basis for general comparison between different exchanges; if the tending of the exchange is the same at the exchanges concerned, the comparison per call minute brings out the differences between exchanges arising from dissimilarities in system and construction, attendance etc.; in respect of the Stockholm exchanges the replacement of sequence switches by relays, *e. g.*, constitutes an appreciable improvement from the maintenance standpoint
[10] the cost per number of estimated maintenance hours A varies approximately as the ratio between executed and estimated number of hours, which is natural since material costs may be ignored in considering labour costs

The Worlds Northernmost Automatic Telephone Exchange

E. WESTER, TELEFONAKTIEBOLAGET L.M. ERICSSON, STOCKHOLM

The city of Oulu in Finland has recently had an automatic telephone exchange delivered and installed by Telefonaktiebolaget L.M. Ericsson. The exchange is the only one in the world situated above latitude 65° N. The installations, consisting of a local exchange on the Ericsson automatic system with 500-line selectors and manual exchanges for the rural and trunk traffic, were put into service on the night of August 28th to 29th 1937.

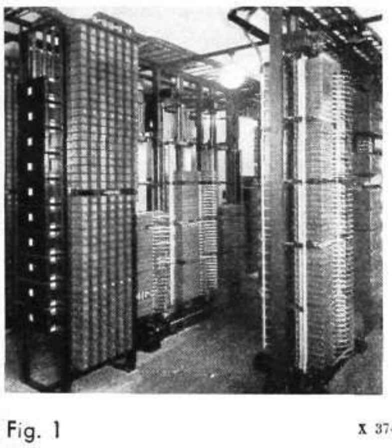

Fig. 1 X 3745
Automatic exchange room

The local automatic exchange is built for 2 500 subscribers but at present only about 1 500 of them are connected. Some 30 lines are routed to public telephone cabins provided with Ericsson telephone coin boxes for automatic cashing, described in the Ericsson Review No 2, 1937.

From a technical point of view the facilities for establishing trunk calls are of the greatest interest. The Finnish Post and Telegraph Administration, which handles all trunk connections in the country, after close study stipulated last year the facilities to be provided by Finnish telephone exchanges regarding the establishing of trunk calls. The installations in Oulu answer in every respect to the stipulations in question. The trunk connections are set up automatically and some 40 junction lines to the automatic exchange are available. The trunk operator, connected over a disengaged junction, dials the calling number wanted and is informed by different signals whether the subscriber is disengaged, locally engaged or trunk engaged. In the first case the subscriber is immediately marked engaged for local as well as trunk calls and the operator can transmit ringing signals. This facility also remains after answer by the called subscriber. If the subscriber wanted is engaged by a local conversation the operator is warned but is not connected in parallel on the conversation. On the other hand cutting in can be done by the operator and a weak warning buzzer informs the subscribers that a third person is listening. The operator then can cut off the subscriber not concerned.

In a country such as Finland, where the number of trunk lines is comparatively limited, it is advisable to increase the utilization of the lines by setting up the connections in advance of the calls. Pending the arrival of the trunk call the subscriber is able to make outgoing calls, although he is barred for incoming calls. For subscribers having several lines and a common calling number, *i.e.*, PBX subscribers, the system installed offers the advantage that the final selectors handling trunk calls can hunt twice over the bundle of lines. Should no disengaged line be obtainable during the first movement, the selector is started again and the line locally engaged first reached is connected.

Odense Telephone Exchange

J. VON LINSTOW, DIRECTOR OF TELEPHONES, FYNS KOMMUNALE TELEFONSELSKAB, ODENSE

On April 4th, 1937, the new Odense telephone exchange was put into service. The exchange delivered by Telefonaktiebolaget L.M. Ericsson replaces a manual CB-exchange and is designed in accordance with a system commonly adopted in Denmark, e.g., the automatic distribution system.
The following description of the new exchange is a report of a lecture held at the 5th congress of Scandinavian Electrical Engineers at Copenhagen in August 1937.

The concession of the Municipal Telephone Company of Fyn covers the diocese of Fyn, Fig. 1. The largest city, Odense, has a central position among the other 94 central exchanges. The situation of Odense and the fact that 90 000 of the 360 000 inhabitants of the diocese live in the Odense exchange area contribute to make Odense the main city of the diocese from the telephonic point of view, as in many other respects. This importance is further illustrated by the fact that 9 000 of the 27 000 subscribers of the Company belong to the Odense exchange, to which 40 % of the 11 000 000 interexchange calls of the Company are connected, and 17 000 000 local calls out of a total of 32 000 000 take place in Odense.

The main exchange at Odense, connected over direct junctions with 9 sub-exchanges, consists of two sections of approximately the same size, *e.g.*, a section for interexchange calls and a local exchange. Since the local exchange is of the greatest general interest, attention will be devoted chiefly to this exchange and only the main principles for establishing interexchange calls will be dealt with.

Choice of System

The calculations preceding the determination of the system for the local exchange made it clear that the two systems under comparison, *i.e.*, the full automatic system and the automatic distribution system were equivalent from the economic point of view. In respect of economy an entirely automatic system is not superior to an efficient manual system in cities not requiring more than one exchange for the telephone service. If a city is of such size that several exchanges are needed the conditions might not be the same, which does not, however, apply in this case.

The gain of a cheap 24 hours' service may affect the choice of the system to the advantage of the automatic system, a consideration not, however, applicable to Odense, as this city is surrounded by a manual network unlikely to be discarded for years. Consequently the night traffic between Odense and the remaining part of Fyn would have to be handled manually even with a full automatic exchange at Odense. The small increase of manual staff required in order to handle the local traffic simultaneously during the night was made clear by an investigation that was carried out, the result of which estimated for 1937 is shown in Fig. 2. Basing on this investigation it was decided that all night traffic, whether interexchange, local or trunk traffic, should be handled by a special small exchange, called the night exchange, working between 9 p.m. and 7 a.m. The fact is that the total night traffic can be handled by one or two operators, and it does not seem likely that this number could be further reduced, even if the local exchange was an automatic one.

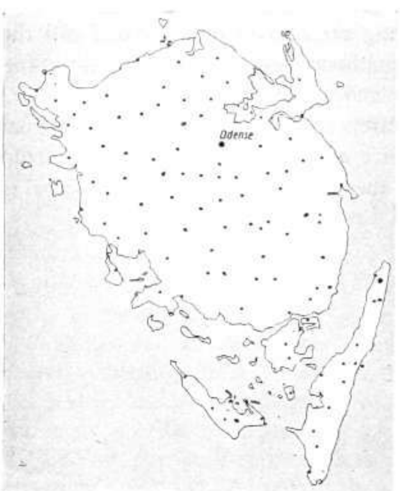

Fig. 1 X 3769
Map of Fyn

The company had consequently no reason to choose an automatic system, since the latter would not involve lower running costs or additional ease in arranging 24 hour service.

From the subscribers' point of view it can hardly be denied on impartial consideration that there is no comparison between a really up-to-date manual system and on automatic system. In the former system the subscriber under any conditions — good as well as bad — has only to lift his handset, get a quick answer, give the number wanted and at the end of the conversation he gets immediate clearing. Besides, the presence of the multiple and the elasticity introduced by the latter renders it possible to grant further advantages to the subscribers as far as reference calls to the inquiry desk and correct calls in spite of change of number, are concerned.

In the automatic system the subscriber takes the place of the operator and in order to get the connection wanted he has to carry out the work that otherwise the operator is supposed to do. This fact does not add to the convenience of subscribers but just the contrary. Further it must be taken into consideration that under certain conditions the dial cannot be used, *e.g.*, in bad light or complete darkness, if spectacles are mislaid, when age or illness render the use of the telephone instrument difficult, and during other events of life; consequently from the subscriber's point of view a system offering skilled assistance under all conditions is to be preferred — provided that the two systems work with the same speed and reliability. As to speed, any desired degree can be attained. In manual systems it is merely a question of the service and staff available and depends in both systems on the number of switches. As regards reliability nobody can say that the number of faulty connections is smaller when a thousand individuals, all having different interests, have to set up for themselves the connections wanted, as against a well skilled staff of operators establishing the connections. That self-done as a rule is well-done but other people's faults are catastrophes is another point of view having no influence on the fitness of the system. From the social point of view it is unreasonable to reduce employment, when no economical advantage for the undertaking or the telephone subscribers is to be gained.

Fyns Kommunale Telefonselskab decided in view of these circumstances to install the new telephone exchange at Odense on a system giving the greatest possible efficiency and obtained the necessary license from the State Control Office for licensed telephone companies.

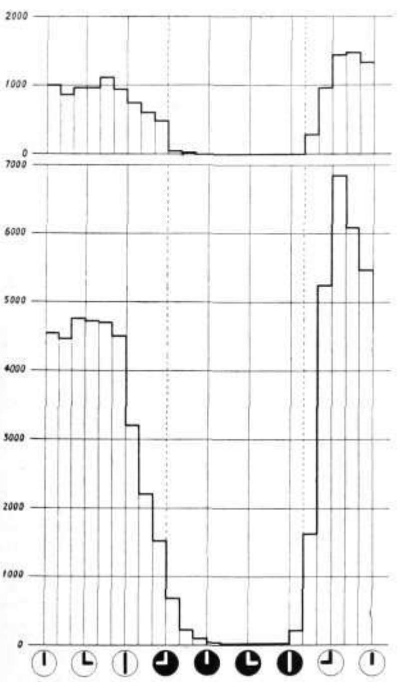

Fig. 2 X 3748

Number of connections per hour during the day

for interexchange traffic (above) and local traffic (below)

Charges

The constitution of the company requires that the same rates should be applied to all subscribers. The rates are therefore the same throughout the area, whether the subscriber is connected to a small rural exchange, a town exchange of medium size or the Odense exchange and also irrespective of whether the subscriber is located close to or remote from the exchange.

In considering the design of the Odense exchange it must be noted that two categories of subscribers are connected to the exchange; we will call them A and C-subscribers. The A-subscribers are entitled to have calls over the whole area while the C-subscribers are not entitled to calls beyond their own exchange area, *i.e.*, an area comprising subscribers connected to exchanges within a distance of 10 km from their own exchange. A subscriber belonging to either category may contract for an unlimited number of calls or else for a number limited to 1 200 calls per year. In the latter case all excess calls have to be paid at a rate per call, this rate, however, not being the same for the two categories.

When ordering calls beyond their own exchange area, in the following denoted as interexchange calls, those A-subscribers who have an unlimited number of calls at their disposal have not to be noted with a view to charging, and the A-subscribers having a limited number of calls only have to be charged with a call, since the destination of the call is of no importance. Such metering can take place in the local exchange and consequently as regards charging no A-subscribers are of interest to the exchange from which the interexchange calls are established. This exchange is called the interexchange office in the following.

As all C-subscribers have to pay a certain charge for all calls routed beyond the Odense exchange area, all their calls have to be recorded at the interexchange office for charge. Since these subscribers as well as the A-subscribers are charged with a call by ordering an interexchange call, the number of local calls on the quarterly bill is reduced by the number of interexchange calls. Consequently a subscriber having many interexchange calls does not contract at C-rate. This is the reason why the number of interexchange calls originated by the C-subscribers is only a very small part of the total number of interexchange calls.

With regard to the establishment of the calls, all calls are recorded at the interexchange office, whether ordered by an A- or a C-subscriber. If, however, on ordering an interexchange call it were possible to inform the operator at the interexchange office that the calling subscriber is an A or a C-subscriber, the calls could be divided into two groups, *e.g.*, those of the predominating A-group which after establishment of a call are of no more interest for bookkeeping, and those of the smaller C-group, which have to be entered in the books for charging purposes. This arrangement would cause an immense simplification of the metering department. The problem is solved by having different calling signals for calls originating from A and C-subscribers. The junction lines to the interexchange office are provided with an A and a C-jack and a call causes a white or a green lamp at the interexchange office to light up indicating an ordering call from an A or a C-subscriber respectively. By using two separate calling signals it is possible to add a third one, *viz.*: alternate flashing of the white and the green lamps. This signal is provided for the trunk exchange of the State, indicating subscribers who on account of arrears are barred for trunk calls. Such subscribers when calling the State trunk exchange are connected over a separate junction to the supervisor at the trunk exchange.

Design

Before inviting tenders, the company worked out circuit diagrams and descriptions of every category of lines and the properties required of them,

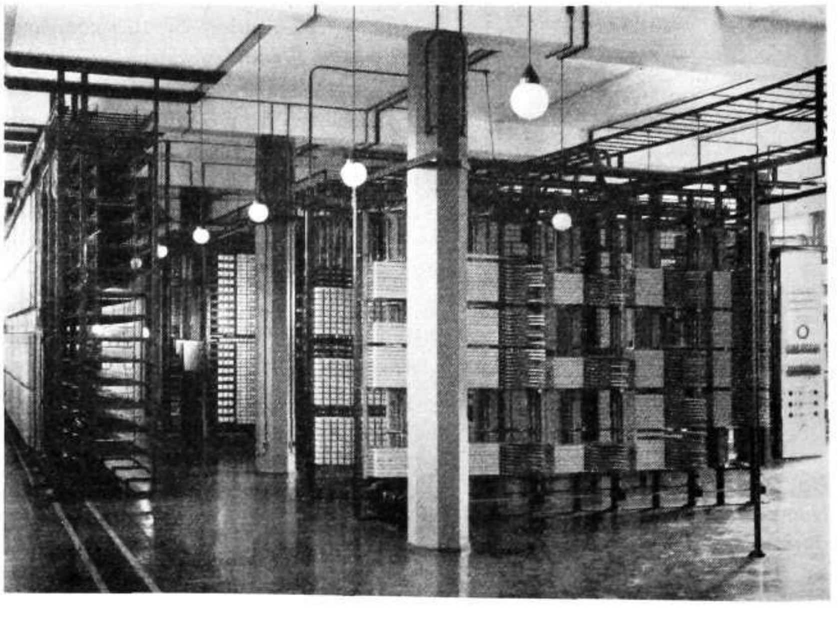

Fig. 3 X 5386
Automatic equipment room of Odense telephone exchange

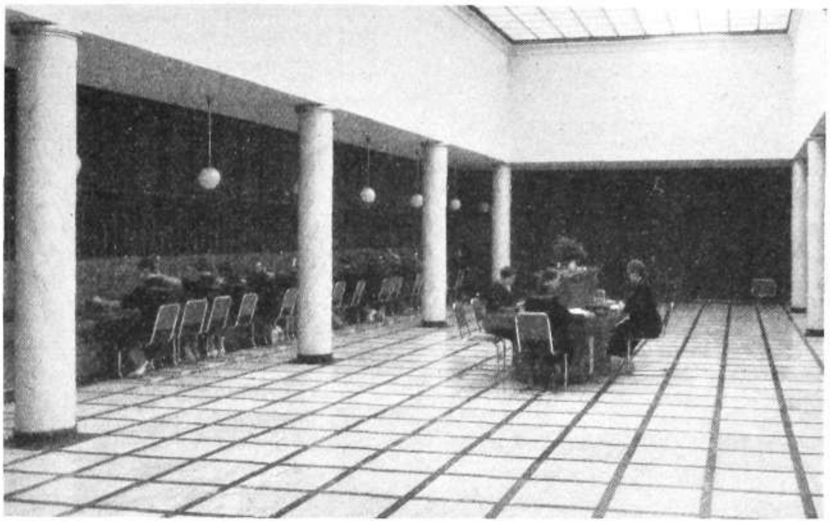

Fig. 4
Odense manual exchange

X 5387

stipulations that in all main respects remained unchanged apart from modifications suggested by Telefonaktiebolaget L.M. Ericsson which secured the order to build the exchange and which on its part, in view of its vast experience, did a great deal of good work in rearranging and improving the circuits proposed, to the advantage of the system and its reliability. Right from the beginning of the delivery of material and the erection it was a pleasure to see with what care and sense of fine installation work the exchange grew, so that it now illustrates the fact that complicated technics and beauty can very well be combined, see Fig. 3 and 4.

As already mentioned the system is an automatic distribution system, *i.e.*, a system that at any moment automatically distributes all incoming calls from subscribers and sub-exchanges as smoothly as possible to the attended manual positions. The staff of operators may therefore throughout the fluctuating traffic conditions during the day be adapted to the actual traffic flow, since a single attended position forms a complete exchange.

Automatization is carried out to the extent that the operators only have to receive a number and insert a plug. Thus the automatic devices have to hunt for the calling subscriber, connect him to a disengaged manual cord at a disengaged operator, light the calling lamp, connect the operator to the cord automatically, transmit answering signal, busy test and ringing signal and at the end of the conversation clearing signal. This last facility makes it possible for the two subscribers to make a new call immediately after replacing their handsets, whether the cord over which they were connected be taken down or not.

The selectors used for the connection of calling lines are the Ericsson 500-line selectors and the multiples belonging to the selectors contain four wires per subscriber's line to provide for the double calling signal. Every operator position is divided into two half-positions, each of which can receive a call. The first call is visible but the second one only when the first has been established. As already mentioned, the calling signals are different if A or C-subscribers are calling, *viz.*: a white or a green lamp. The automatic answering signal of the exchange consists of two parts, at first a continuous weak buzzer tone transmitted from the connection of the half-position to the moment the calling signal becomes visible, and then three stronger tone signals, the last of which is also heard by the operator.

The operators are not provided with microphones and are consequently debarred from conversation with the subscribers. This arrangement is made in order to ensure rapidity in establishing calls by precluding the possibility of calling the operator's attention to other matters than giving the calling

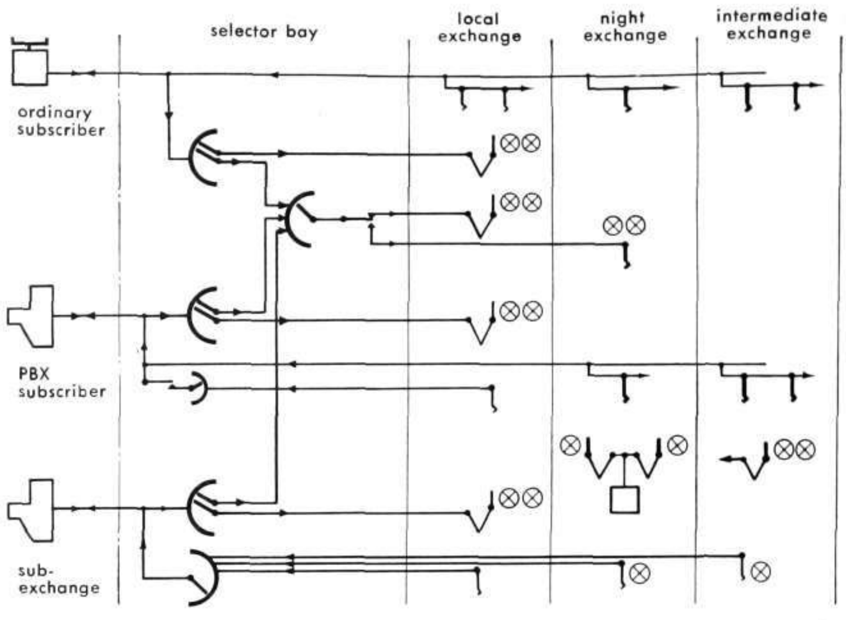

Fig. 5 X 5385
Trunking diagram of Odense telephone exchange

number. Another reason is to prevent discourteous answer being given on repeated call after, *e.g.*, a faulty connection, and possible impoliteness by subscriber to the operator who has to deal with the repeated call but in all probability was not the operator who established the first connection. If after the transmission of the answering signal the number wanted is not distinctly heard, the three signals can be repeated as a request to the subscriber to give the number again. In difficult cases the call can be routed to an auxiliary position, at which an operator can speak with the subscriber and forward his call. After receipt of the number wanted the connection is established without test. If the called subscriber is busy, the exchange transmits an interrupted buzzer tone; if he is disengaged, ringing signal is heard at intervals of a few seconds.

At the end of the conversation clearing takes place automatically. The operator is informed by a single clearing lamp that does not light up until both subscribers have replaced their handsets. The fact that both the subscribers must transmit clearing signal, coupled with the design of the selectors in the system, makes it possible without special technical devices to catch calling subscribers, who abuse the telephone with insulting or criminal intention. A subscriber reporting that he has been troubled is requested not to replace his handset if he again receives such a call. In this case the switches over which the call is routed give alarm, and the selector that has connected the caller as well as his number can thus be located.

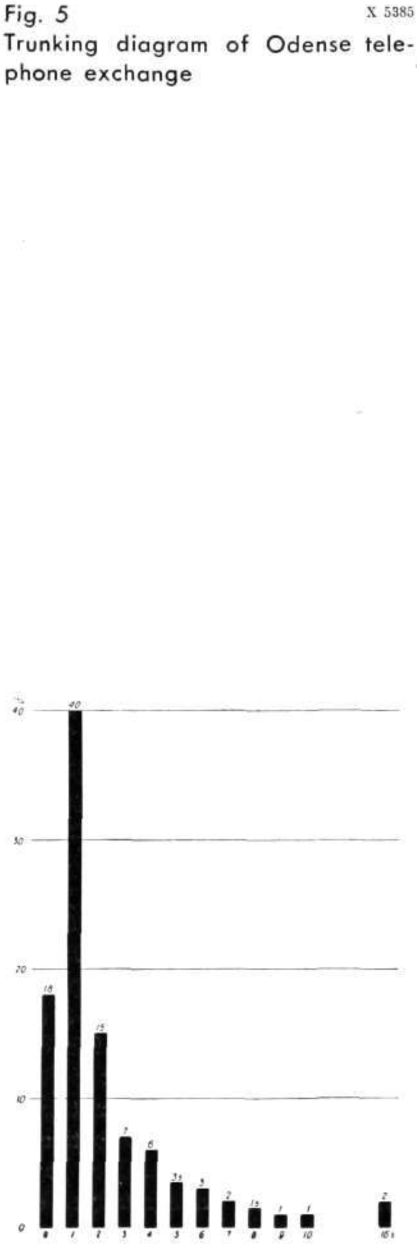

Fig. 6 X 3770
Diagram of the answering time
the diagram shows the percentage of calls having an answering time of 0, 1, 2, 3 . . . 10 s; the average answering time is 2.3 s

The local exchange contains ordinary subscribers as well as PBX subscribers, *i.e.*, subscribers having 2, 3, 4 or 7 lines with common calling numbers and junction lines to the sub-exchanges including State trunk exchange and the interexchange office. The main routes of the local exchange appear from Fig. 5, showing an ordinary subscriber, a large subscriber, and a subexchange junction line. As may be seen each 500-line group has a number of ordinary selectors directly connected to the manual cords and also a few supplementary selectors routed to a multiple of a number of second selectors allotted to a bundle of supplementary cords. As long as a 500-line group contains a disengaged ordinary selector, no supplementary selectors can be started. The latter constitutes a common reserve for the whole exchange and is provided to deal with the traffic peaks, wherever such a peak may arise. The supplementary selectors are not only routed to the supplementary cords at the local exchange, but are also connected in parallel to jacks and lamps at the night exchange in such a manner that when the local exchange is put out of service and the night exchange is working, all ordinary selectors are disconnected and only the supplementary ones in function. The connections are

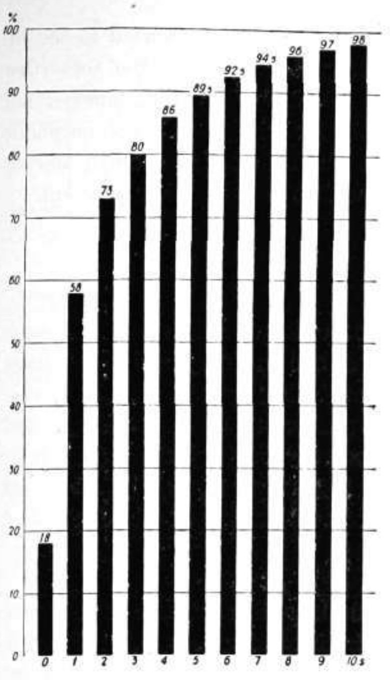

Fig. 7 X 3768

Diagram of the answering time

the diagram shows the percentage of calls handled in a given answering time

established by means of cord pairs of such design that the inserting of an answering plug corresponds to the lifting of a single cord at the local exchange. The putting into service of the night exchange takes place quite automatically as the operators successively leave their places in the local exchange and the night attendants take up their positions. On answering the word »Odense» is used by the night operators.

The ordinary subscribers are provided with multiples at the local exchange and at the intermediate exchange for interexchange and trunk calls and the night exchange. For large subscribers the first mentioned of these multiples is replaced by a special provision facilitating automatic connection without busy test to a disengaged line. This is done, by large subscribers with 2 or 3 lines being provided with one local jack (PBX subscriber's calling number) at each position and large subscribers with 4 and 7 lines with two local jacks. These jacks are wired to the contact segments of 25-point selectors, the number of which corresponds to the number of lines of the subscriber. By plugging in a local jack at any position, the disengaged selectors belonging to a bundle of lines are started and hunt for the calling position. The selector that first finds this position connects the line and the connection is established. Should all lines be occupied with calls to or from the subscriber or possibly in both directions, the inserting of the plug into any local jack would cause busy signal to be transmitted to the caller.

At the intermediate and the night exchanges, both of which require busy test, every line in the bundles of large subscribers is provided with multiple jacks in view of the requirement that interexchange and trunk calls shall have access to a certain line. These multiple jacks are mounted in vertical rows for each bundle of lines in order to point out clearly the lines belonging to the same subscriber.

The junction lines to the nine sub-exchanges belonging to the Odense area and the lines to the State trunk exchange are arranged in the same way as the large subscribers, but with considerably more lines and consequently a greater number of local jacks, up to six per position. These lines are provided with local jacks not only in the local exchange but also in the intermediate exchange and the night exchange, because at the latter two exchanges, at which busy tests as a rule have to be carried out, it would be too much waste of time to test on the large number of junction lines to the sub-exchanges. The only difference is that at the intermediate and the night exchanges each bundle of local jacks is provided with a lamp that lights up only when all junctions to the subexchange concerned are busy. If the lamp is not glowing any disengaged jack can be taken without test and a line finder will find a disengaged line of the subexchange. Due to the large amount of local jacks the selectors of these groups are of the common 500-line type, the movement of which, however, is restricted to a limited number of multiple frames. Calls from the subexchanges are routed to the Odense exchange as ordinary subscriber's calls.

Among other special facilities may be mentioned that the exchange can announce the time when a call is made to »time» and that a separate posi-

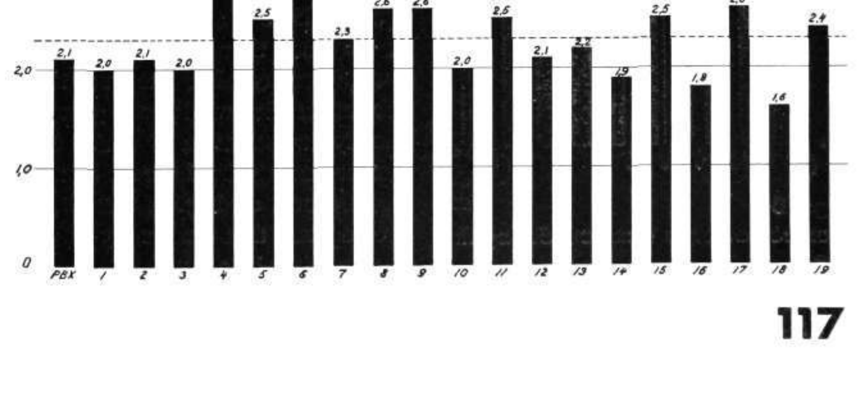

Fig. 8 X 5388

Average answering time within the 500-line groups

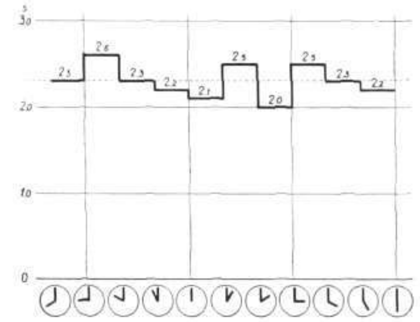

Fig. 9 X 3751
Fluctuation of the answering time during the day

tion serves public coin boxes. Further subscribers can be connected to the information office. For this purpose the exchange equipment of the subscriber is connected to the position in question and his line to a calling number not known by him, in order to make it possible for him to use his telephone instrument for calls, if he is at home for a short time, for example during holidays. Further the exchange is provided with a routine test equipment.

Traffic Results

The initial capacity of the exchange is 10 000 ordinary subscribers and 1 000 large subscribers and its ultimate capacity 22 000 ordinary and 2 000 large subscribers. The intention with such a distributing system was to *ensure quick answer* to a call by distributing the total work of the exchange and avoiding accumulation of calls to positions already busy by the reduction of the manual work due to the automatization, and *to increase the efficiency of the operating staff, i.e.* to obtain a suitably increased number of calls established per operator and hour.

In considering the traffic results now to be dealt with it must be remembered that the exchange has only been working for three months, so that the staff is not yet trained to perfect operation of the new system which in several respects differs from the system formerly in use, and that the final distribution of switching devices and junction circuits could not be fixed before the above traffic results were known. With the distribution of switches and junction circuits, the Ericsson system offers great advantages in respect of elasticity. This is gained by the fact that selectors as well as junction circuits constitute loose apparatus to be connected to the system by means of jacks, thus rendering is possible to shift them from one group of subscribers to another at any time wanted.

Checking of the answering time, *i.e.*, the time elapsing between the moment a subscriber is ready to order a call and the answering tone being transmitted from the exchange, covers 20 000 calls and shows an average answering time of 2.3 s. However, such an average figure is no guide to the quality of the service unless its composition is known, especially the number of long answering times. On the diagrams, Fig. 6 and 7, the answering times are collected in groups of full seconds so that the answering time of 0 s contains all answering times up to 0.4 s, the answering time of 1 s all answering times between 0.5 and 1.4 s etc. Fig. 6 shows the percentage of calls corresponding to answering times 0, 1, 2, 3 .... 10 s. As may be seen 18 % were answered immediately, 40 % after 1 s etc. 2 %, however, having an answering time of more than 10 s with an average of 16 s. Fig. 7 shows the percentage of calls handled within a certain answering time indicating that 58 % were established within 1 s, 73 % within 2 s etc. up to 98 % within 10 s.

However, even these particulars regarding the composition of the average answering time are still insufficient. We require to know whether every subscriber connected to the exchange is well served. Fig. 8 shows the average answering time within the different 500-line groups of the exchange. The group marked PBX indicates the large subscribers group. As may be seen the highest average is 3.0 s, *i.e.*, 0.7 s above the total average. For the remainder the variations are comparatively small. Recognizing that the groups *4* and *6* have a somewhat too high average value and the groups *16* and *18* at the same time have a low one, we can make use of the elasticity of the system and equalize the variations by increasing the number of switching devices in the two former groups with switches taken from the latter ones. Finally investigation is made, as to whether the service is to some extent similar during the different hours of the day. The result of this investigation is, as shown on Fig. 9, that the fluctuations of the average answering times are so small that the quality of the service can be considered as homogeneous during the whole day.

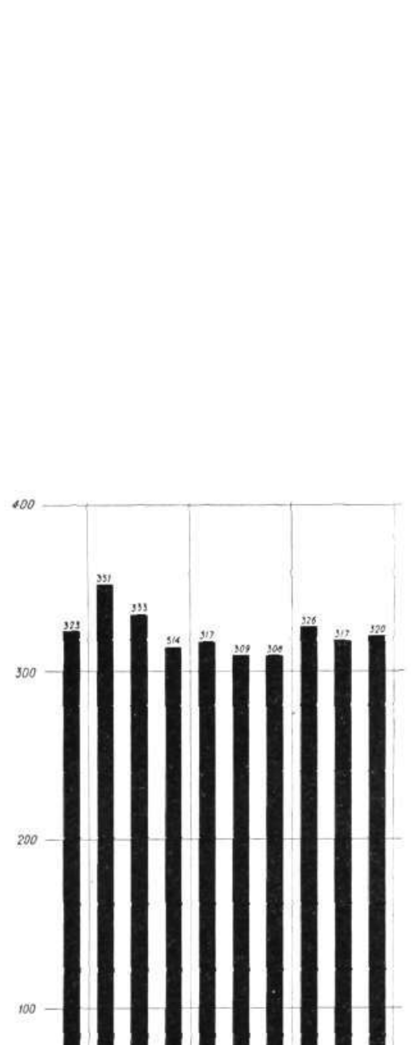

Fig. 10 X 3752
Number of calls handled during the day

Turning to investigation of the utilisation of the staff, Fig. 10, indicates that during the day, *i.e.*, from 8 a.m. to 6 p.m., the number of connections established per operator and hour was 308 to 351, an average of 323. This figure ought to be increased but for that purpose not only has the staff to be more practised, but the subscribers themselves must get accustomed to answering more rapidly and distinctly in order to reduce the number of repeated answering signals. In that respect, however, the greater slowness of the inhabitants in a provincial city, as compared with those of a large city, must be taken into consideration. On Fig. 11 are also shown the fluctuations around the average value of curves for the number of calls and connections established. Obviously the strongly fluctuating call curve is transformed into a considerably more even working curve. Being thus informed about these fluctuations it is possible to equalize the peak between 9 and 10 a.m. by increasing the number of operators, whereas the staff may be reduced to some extent between 1 p.m. and 3 p.m. Finally, Fig. 12 indicates the number of connections made by each of the positions. The deviations from the average figure 323 are not great except with regard to a few positions, but the system facilitates correction by transferring some junction circuits from the positions *6* and *9* to the positions *18* and *22* in the junction circuit intermediate field.

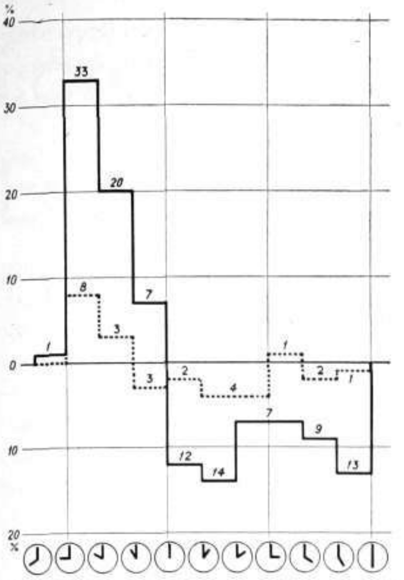

Fig. 11 X 3753
Fluctuation around the average value of the number of calls and the number of connections handled
— call curve
---- connection curve

Connections beyond the Exchange Area

The interexchange calls coming in to Odense are twice as many as the outgoing interexchange calls from Odense. For the main part of the incoming calls a separate section is installed. This section is provided with the Odense subscribers' multiple and with the interexchange lines directly routed to the positions of this section in such a way that the greater part of the incoming interexchange calls can be handled as if they were local calls. Thus the cheapest possible operation is ensured. This section is called the intermediate exchange. The outgoing interexchange calls from Odense are established by a separate interexchange office without the subscribers' multiple. The interexchange lines as well as the ordering lines for interexchange calls from Odense subscribers are designed on the lamp-multiple system, causing all calls to be indicated by a row of signals distributed among the positions of the exchange. One third of the exchange staff is able to answer every call but only the operator who first inserts the plug can be connected. The calls ordered are recorded out by the operators, who forward the calls. When establishing connections the operators reach the Odense subscribers over a

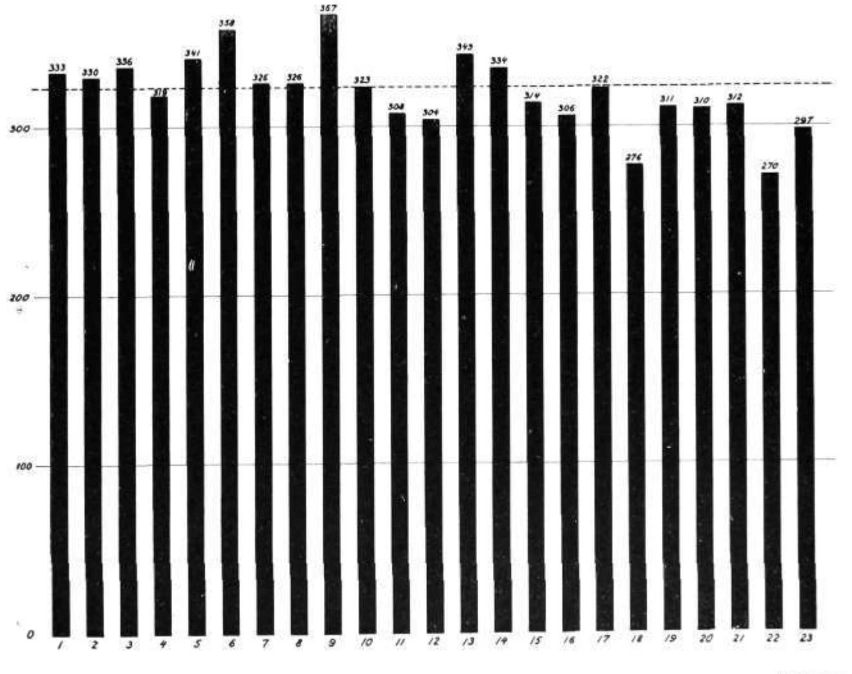

Fig. 12 X 5389
Number of connections handled by the different positions

bundle of junctions to the same intermediate exchange to which interexchange lines for *incoming* calls are routed. Automatic line finders hunt for disengaged junction lines. The State trunk exchange at Odense finds disengaged lines for the establishing of trunks calls in the same way.

Transit Connections

As may be seen from the map of Fyn, Fig. 1, and the situation of Odense, a not insignificant number of calls has to be routed transit over Odense. In the old exchange it was impossible in spite of all efforts, to reduce the waiting time for these calls to a reasonable value compared with calls to and from Odense. The reason evidently is to be found in the fact, that — consciously or not — the operators made a distinction between »own subscribers», *i.e.*, Odense subscribers, and »foreign subscribers» to the disadvantage of the latter. In order to eliminate this purely psychological factor, a separate branch exchange is detached from the interexhange office, to deal exclusively with the transit connections. The result of this arrangement is that the waiting time of the transit calls now is of the same value as that of interexchange calls to and from Odense subscribers. All calls, even those with transit destination, are routed to the interexchange office. When »transit» is asked for, the operator at the interexchange office has only to push a button, whereby the call lamp signal from the interexchange office will be forwarded to the transit exchange. The interexchange office as well as the transit exchange are provided with conversation time control devices on every line. This control is carried out as follows: When a plug is inserted in order to forward an interexchange call, a green lamp connected to the manual cord pair flashes. When the conversation is established, a button has to be pushed and the lamp goes out; when the 3 min. conversation period is over, the green lamp glows continuously again.

Large Private Automatic Branch Exchanges

E. WESTER & E. NILSSON, TELEFONAKTIEBOLAGET L.M. ERICSSON, STOCKHOLM

During the last few years a variation of the Ericsson automatic telephone system with 500-line selectors has been developed, which is called OS PABX, and is intended for large private automatic branch exchanges. This new system has already been put on the market. In the Ericsson Review No 4, 1935, a description was given of such an installation as delivered to the Victorian Railways in Melbourne. Below are given descriptions of the series of exchanges manufactured by Ericsson on this system, with particular reference to the provision for fulfilling all the demands which may be made on an up-to-date telephone exchange.

A telephone installation is nowadays considered an absolute necessity for any undertaking of importance and the facilities offered have become more and more comprehensive. The first requirement is the possibility of quickly and easily establishing internal telephone connections between persons within the undertaking as well as external connections over the public networks for a number of these persons. It was soon realised as automatisation progressed that it would be an advantage to arrange the internal traffic automatically in order to increase speed and reliability. At first separate telephone instruments were installed for internal connections and those requiring to make external calls were provided with a second instrument, connected directly or over a manual exchange to the public network. It was thus possible while carrying on an external call to make an enquiry call over the other instrument to persons within the undertaking. As it would hardly be necessary to converse simultaneously over the internal extension line and with the public exchange subscriber, it was proposed to introduce a switching device by which the one instrument could be connected for an internal or an external call as required. In this way the desk was relieved of one of the two instruments. At first these alternative connections were carried out by means of a switch on the instrument requiring two lines to be wired to the desk instrument, which had the disadvantage of making the instrument rather complicated.

In an up-to-date telephone installation on the OS PABX system these disadvantages are entirely removed while at the same time a number of additional facilities of considerable value are provided. Thus it is possible to originate outgoing calls automatically, to make inquiry calls over the branch exchange as well as the public exchange, to transfer a public call to another extension etc. All these connections are made by means of the dial of a quite ordinary subscriber's instrument, the manipulation of which is quite simple to grasp.

Normal Traffic Facilities

Internal Calls

To originate an internal call, the receiver is lifted and on receipt of dialling tone the required number is dialled. If the extension is disengaged ringing current will be transmitted. This current is cut off when the call is answered, and the connection is then established. The caller hears ringing tone as the ringing current is transmitted. If the called extension is busy the caller receives busy tone. Replacement of the handset causes disconnection and the switches are restored.

Exchange Calls

It may often be desirable to bar some extensions for public exchange calls, for example where a higher annual charge has to be paid for extensions entitled to public exchange calls. Apart from extensions completely barred in this way, it is possible to have extensions connected which have access to the public network only through the private branch operator. The public exchange to which the branch exchange is connected may be of any system, automatic or manual CB or magneto. The private exchange equipment will always be the same, but requires the addition of simple junction line repeaters if connected to an LB-exchange. This method has been adopted to avoid alteration in the branch exchange equipment should the existing LB-exchange be replaced by one on another system.

Outgoing public exchange calls are originated by dialling digit *o*, whereby a disengaged public exchange line is connected automatically. If the public exchange is automatic the PABX extension hears dialling tone from the public exchange and then dials the number of the subscriber wanted. If the public exchange is manual, the private branch extension communicates the wanted subscriber's number to the public operator. If all exchange lines are busy at the time or if the call is attempted from a barred extension, busy tone is heard after dialling *o*.

Incoming public exchange calls are received by an operator who forwards them to the persons wanted. As the OS PABX system is designed for rather large installations, it has been equipped with manual switchboard for incoming exchange calls, this being the best method for large installations. The exchange lines and all extensions not barred for incoming exchange calls are provided with jacks in the manual switchboard, and over these the operator can quickly and accurately connect exchange lines and extensions by means of cord pairs. One reason why cord pairs have been adopted is that any faults arising in the cords may not put exchange lines out of service. With heavy traffic, however, the operator's work may be made much easier by not removing the answering cord from the exchange jack. Connections are then made as in a single cord system.

An incoming exchange line call causes the calling lamp to light up, whereupon the operator answers and, by testing with the ringing plug on the jack sleeve, learns whether the extension required is busy. If the extension is disengaged the operator transmits ringing current. The cords of the manual switchboard may be provided with automatic ringing device. On insertion of such a cord in the jack of a busy extension the conversation proceeding is not disturbed but the call offering is held waiting and ringing current will be transmitted immediately the call ends. Before transmission of ringing current the clearing lamp flashes, informing the attendant that the connection has not yet been established. When the extension answers the lamp goes out but again lights up at the end of the call. The operator then has to restore the cord. If a new call arrives before the operator has had time to remove the cord, the calling lamp lights up in the usual manner but the extension to which the cord is plugged in is not connected to the new call.

As it is desirable that urgent calls, particularly trunk calls, may have access even to busy extensions, the attendant can cut in on calls proceeding, whereby the subscribers are notified by a faint buzzer tone that the operator is listening. The attendant may then disconnect the extension not concerned. If all exchange lines should be busy the trunk operator as usual is able to cut off an exchange line connection. The manual switchboard at the branch exchange is then called by ringing current, the occupied extension is disconnected, after which the operator can forward the new call in the usual manner.

Fig. 1 X 3763

Telephone instrument, Type DBK 11

all instruments are of normal pattern without push button and are connected over two-wire lines without additional wire or earth connection

Connections through Operator

On dialling the digit *9* the manual switchboard will be connected. Such a call cannot be forwarded to other lines and consequently extensions barred for external calls are prevented from obtaining calls in this way. The operator can, however, be requested to call a public exchange subscriber and connect same to a non-barred extension. As the operator can cut in on busy extensions, it is also possible to order the establishment by the operator of a particularly important internal call to a busy extension. The operator warns the two subscribers and cuts the connection, or he may wait intil the conversation going on is completed and then insert a plug in the jack of the wanted subscriber. When the line becomes disengaged, a lamp lights up and the operator can establish the connection ordered.

Call-Back

An extension connected to a public exchange line has the facility of making call-back by dialling the first digit on the dial, *i.e.*, usually the digit *1*. This disconnects the exchange line but clearing signal is not transmitted to the public exchange. The extension is then connected to the automatic equipment over a separate intermediate unit and the internal number wanted may be dialled. Having obtained the required information it is possible to return to the exchange line by again dialling *1*. Provided that the local extension called does not replace the handset, alternate connection with extension and exchange line may be effected by repeatedly dialling the digit *1*. If on the other hand the local extension's handset is replaced, the inquirer on making a new call-back is again connected to the automatic equipment and may make new call-back to any line. Call-back may be made to any line accessible to a normal call over the automatic exchange.

If the line wanted for call-back is already busy and the importance of the exchange call makes it a necessity for the inquirer to have the call-back connection, he calls the operator by dialling *9*. In this case the inquirer is connected with the manual switchboard over a separate junction unit, the exchange line being held busy. If the line wanted is available in the multiple field the attendant can forward the call as desired. To return to the exchange line the inquirer dials digit *1* in the usual way. Call-back can also be made to another exchange line.

Transfer

An exchange line connection may be transferred to another extension provided that this latter is not barred for such calls. After a call-back the inquirer replaces his handset and the connection is automatically transferred to the called extension. The first extension is immediately released and the second one, having now received the call, has in his turn the same facility of making call-back and transferring the call. Thus the transfer of a call is entirely under control of the one passing on the call. Periodic ringing current is then automatically transmitted and if this is not answered in a certain time the exchange line is connected automatically to the operator's position by means of the above-mentioned tie unit. If attempt is made to transfer an exchange call to a barred extension or to another exchange line, the first exchange line is in the same way connected to the manual board. The same also occurs on attempt to transfer the call to a busy extension. Thus the switching process is supervised and any call not correctly dealt with is automatically transferred to the operator. After a call-back forwarded by the operator the connection may also be transferred. As before the originating party has only to replace his receiver.

Night Service

During the times when the operator is not on duty, all or some of the exchange lines may be arranged for night service. If the public exchange is so designed that it is possible to call individual lines of the bundle connected to the PABX concerned, incoming calls can be routed to extensions specially allotted to predetermined exchange lines. Before going off duty the operator throws a number of night switching keys and inserts the plugs of the corresponding cords in the jacks of the lines assigned. An incoming exchange line call is connected thereafter to the appropriate extension automatically. If the extension is disengaged ringing current is transmitted. In the contrary case a warning tone indicates that an incoming call is waiting. The call is answered and if desired may be rerouted on the call-back and transfer method. An extension assigned for night service has the same facilities as others for internal and external calls.

If desired all incoming exchange calls may be routed to one extension. In this case a key is thrown which causes all incoming calls to be routed automatically to the extension in question. It may also be advisable to connect the tie units, by which call-backs and transfers to the manual switchboard are normally effected, to the night service devices. When the manual board is not attended, all calls handled by these tie units are routed to a certain extension, so that it is possible to ascertain whether exchange line connections already established are dealt with correctly. As the number of night service intermediate devices is limited it may occur that some incoming calls cannot be dealt with immediately. The system therefore comprises queue facilities for incoming calls awaiting attention.

Special Traffic Facilities

Conference Calls

The connection of several extensions for a conference is carried out as a rule by the operator. Extensions which may often be engaged in conferences are provided with individual connecting devices at the manual board, these consisting of connecting and ringing keys and a feeding relay that actuates a signal lamp. The device may be fitted with an additional relay making it possible without disturbing an existing conversation to ascertain whether the extension is busy or not. In addition to these special extensions, a limited number of other extensions may be connected by means of ordinary junction cords, provided these extensions are provided with jacks in the manual board.

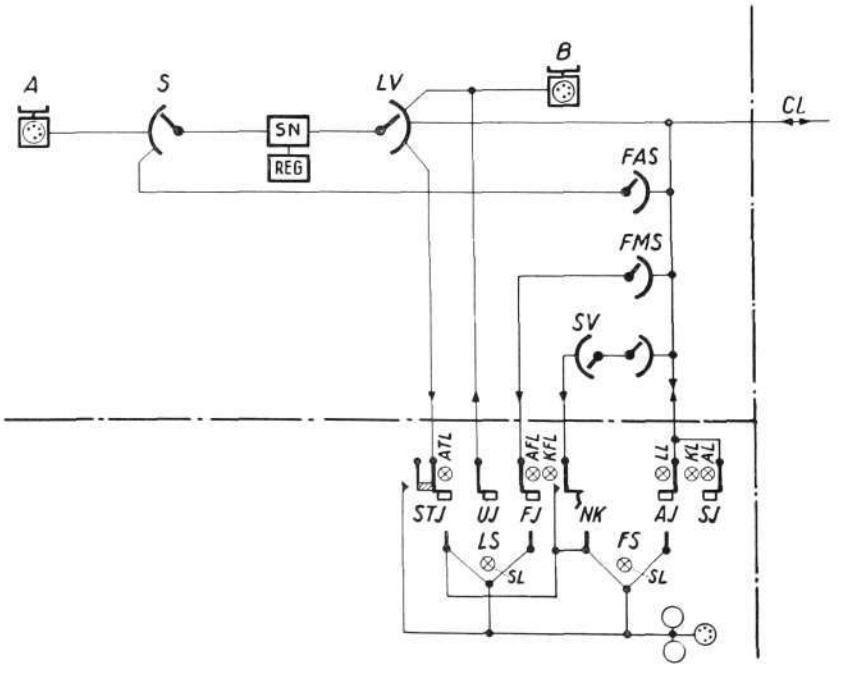

Fig. 2 X 5399

Routing diagram for 400-line branch exchange, System OS PABX

- A, B telephone instruments
- AFL calling lamp for FJ
- AJ calling jack for exchange line
- AL calling lamp for SJ
- STJ calling lamp for STJ
- CL two-direction exchange line
- FAS intermediate unit for automatic call--back and transfer
- FJ jack for call-back to operator
- FMS intermediate unit for manual call-back and transfer
- FS junction cord
- KFL supervisory lamp for FJ
- KL supervisory lamp for SJ
- LL idle indication lamp for AJ
- LS cord for internal connections
- LV final selector
- NK key for night service
- REG register
- S line finder
- SJ answering jack for CL
- SL clearing lamp
- SN automatic link circuit
- STJ answering jack for calls to operator
- SV night service equipment
- UJ multiple jack for non-barred extension

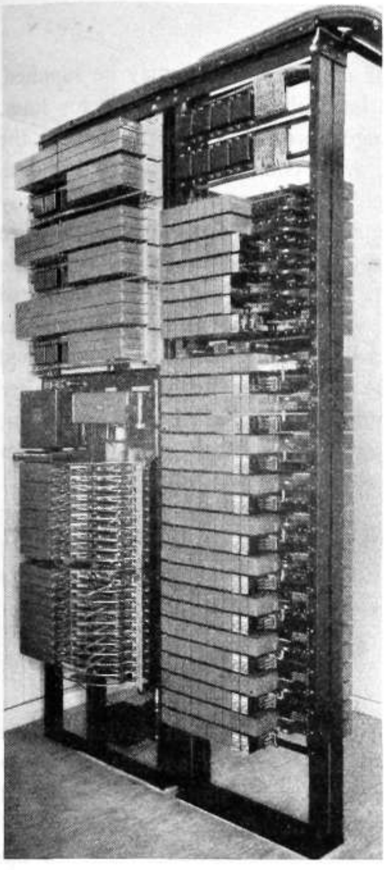

Fig. 3 X 3764

Automatic equipment for 90 lines

with 10 conversation facilities, 20 exchange lines, 2 automatic and 2 manual junction units and 2 night service devices; the bay is 2.4 m high and 1.4 m wide

By the introduction of special circuits in the automatic equipment and complementary units for the extensions concerned, the establishment of conference calls may be effected quite automatically. The extensions for conference are in this case requested to dial a special digit, which causes his line to be disconnected from the exchange equipment. In view of the greater convenience in establishing the connections and for economical reasons it is, however, preferable to have conference calls handled by the operator.

Preference Calls

Provision can be made for certain extensions allotted to the higher staff, whose calls are often of a specially urgent nature, to break in on calls established. As, however the normal design of the system allows of such breaking in with the aid the operator, the supplementary devices for automatic breaking in should only be introduced in exceptional cases.

Extensions provided with automatic preference facilities can listen in on calls proceedings with a view to supervising them. Still for this purpose also a manual supplementary device is preferable.

Staff Locater

Staff locating equipment is installed in order to facilitate the search for a person not available at his own extension. This equipment is connected over two lines to the automatic exchange. It actuates a number of lamp sets located at conspicuous spots in the various departments. For location of 15 persons four lamps per signal set are required and for 70 a maximum of eight lamps. The locating equipment is called in the same way as a normal extension. On hearing dialling tone from the staff locating equipment the originating party dials the special two-digit calling number assigned to the wanted person. The corresponding lamp combination is lighted and at the same time an audible signal is emitted. When the person sought observes the signal he obtains connection with the calling party by dialling the answering number of the locating equipment on the nearest extension. The staff locating equipment is intended for brief important communications. Consequently if a call of any length is necessary it is advisable to make a new call in the usual way, to avoid blocking the equipment.

Often it may be more advisable to have the operator operate the locater equipment. For this purpose a number of keys actuating the lamp sets are installed in the manual board in place of the locater board. The person sought calls the operator to get the necessary information.

Fig. 4 X 5398

Manual Switchboard

the left-hand section contains, reading downwards: alarm lamps, jacks for operator's line and call-back lines, calling jacks for exchange lines, answering jacks for exchange lines; the right-hand section contains, reading downwards: night service keys and multiple field with jacks for non-barred extensions; the horisontal part contains a local cord pair and twelve junction cords with operating keys etc.

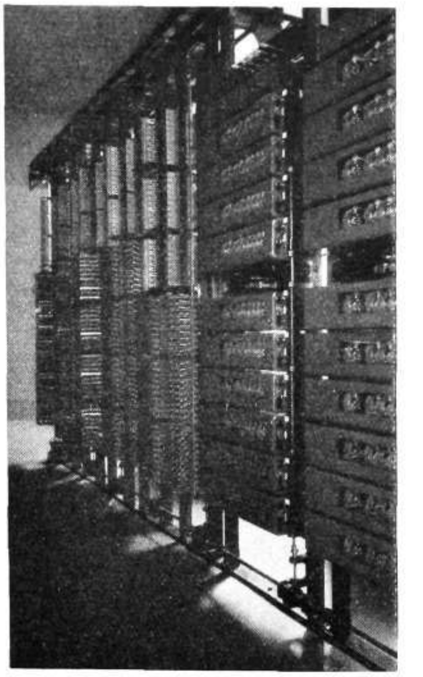

Fig. 5 X 3766

Bay for automatic switching devices for 800 line exchange

with 120 conversation facilities; the bay is 3.1 m high and 6.4 m wide

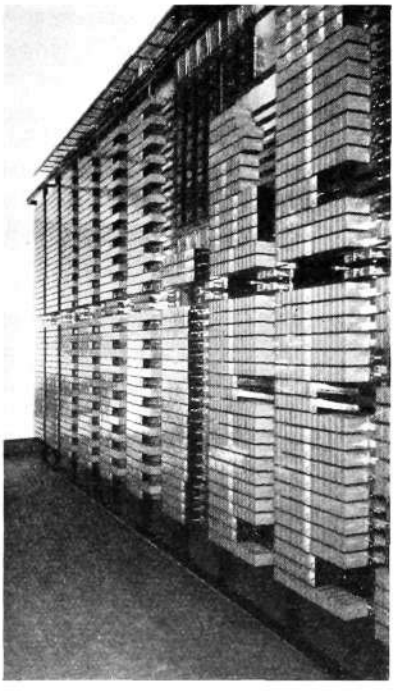

Fig. 6 X 3767

Bay for auxiliary devices for a 800-line exchange

with 80 exchange-line relay sets, 16 automatic and 4 manual junction units and 80 magneto-line relays; the bay is 3.1 m high and 5.8 m wide

Tie-Line Service

Tie lines to provide service between two or more exchanges may be supplied. The method of connection is governed by local circumstances. Selector lines, LB-lines and junctions to remote exchanges are as a rule routed to the manual switchboard. Adjacent exchanges, with common traffic so large as to make the utilization of the lines sufficiently high, are connected directly to the automatic exchange over directed or double direction two or three-wire junction lines. Signalling over the lines can be effected by AC alone, if the lines are loaded or form a phantom circuit, so that DC cannot be transmitted over them. For traffic between exchanges, what are known as open direction digits are used as a rule. This means that the remote exchange is connected by dialling the single digit assigned to the tie line bundle in question, after which the calling number of the wanted line is dialled. All extensions, however, may be given numbers in the same series, if the technical design of the exchange allows. In such case direction digits are omitted.

Lines whose electrical properties are particularly bad may be connected to the automatic exchange, provided they are furnished with separate repeaters as described in the Ericsson Review No 4, 1935.

Call Supervision

A number of extensions can be provided with additional devices in the manual board causing all incoming calls internal as well as external to go first to the operator, who only forwards the call to the person concerned with his consent. In the absence of the operator, however, the calls are routed directly to the extension. Calls from such subscribers are not handled by the operator but are routed to the automatic exchange in the normal way and the telephone instruments are of the normal type.

Telephone Instruments

As stated earlier, one of the most noteworthy features of the Ericsson private branch exchanges is that the multitude of traffic facilities offered are effected by simple manipulation of the dial. Consequently quite normal telephone instruments without push buttons can be used. The instruments are connected to the exchange over two-wire lines and no additional wire, real or fictitious by connection of the instrument to earth, is required. A very suitable instrument for offices is the Ericsson bakelite instrument, Type DBK 11, Fig. 1, described in the Ericsson Review No 4, 1933. This instrument is provided with a buzzer giving a signal that is distinct but fainter than that of a bell. As a rule the instruments are placed on the desk where a strong signal would be too disturbing and therefore undesirable. Where instruments with bells are preferred, the Ericsson instruments, Type DBH11 and DBN11, are suitable. These are described in the Ericsson Review No 1, 1933. Where two instruments have to be connected to the same line, extension sets as described in the Ericsson Review No 1, 1935, should be used.

Design of the Exchanges

The system OS PABX is machine-driven and provided with automatic registers which receive the dial impulses transmitted from the dials and set the selectors to the wanted line. An up-to-date exchange of this kind comprises a number of switching facilities not required in a public automatic exchange. In spite of this fact, in elaborating the system OS PABX it has been possible to make use of the same components, *e. g.*, the 500-line selectors, the registers and the main part of the relay sets, as in the Ericsson system for public installations. The special switching tasks to be fulfilled by exchanges of this kind are concentrated at a few points, *viz.:* the exchange relay sets and a small number of units for call-back, transfer, night service and similar special purposes, see Fig. 2. The maintenance of the exchanges is thus without complication, and they offer the same reliability as the system for public exchanges. The electrical properties also are the same as those of the latter system. The working voltage is 24 V; the feeding coils have a resistance of 2×400 ohms and are consequently calculated for normal Ericsson telephone instruments. The maximum permissible loop resistance of extension lines is 1 500 ohms and the minimum insulation resistance is 20 000 ohms wire-to-wire. The attenuation at 800 c/s does not exceed 0.06 neper and the lowest value of the cross-talk attenuation is 10 neper. Installations may also be furnished with feeding coils of other properties in order to allow of the connection of telephone instruments of other types. The electrical data, however, would then be changed accordingly.

Exchanges for not more than 90 extension lines have two-digit calling numbers. Exchanges for 800 or possibly 900 extensions have three-digit numbers and larger installations four-digit numbers. The digits *0* and *9* are as a rule reserved for calls to the public exchange and to the attendant's board.

The use of 500-line selectors enables 400 or possibly 460 extension lines, in addition to exchange lines and call-back lines, to be connected to the same group. At exchanges of this size the total traffic flow can consequently be handled by a single group of switches, and connections over several further switches are avoided. The total number of switches is exceedingly small and the risk of momentary overloading is reduced to a minimum, because a rush in traffic on a number of lines is likely to be neutralised by a simultaneous decrease in the traffic of some other lines connected to the same group of switching devices. All irregularities due to technical faults are notified by means of alarm circuits connected to the automatic exchange and the manual switchboard.

As a rule the exchanges consist of two parts, *viz:* bays for automatic switching devices and supplementary units, Fig. 3, and a manual switchboard, Fig. 4. At the larger exchanges the automatic equipment is mounted in two bays, the one containing the automatic switching devices, Fig. 5, and the second containing exchange line relay sets, junction units etc., Fig. 6. The various sizes

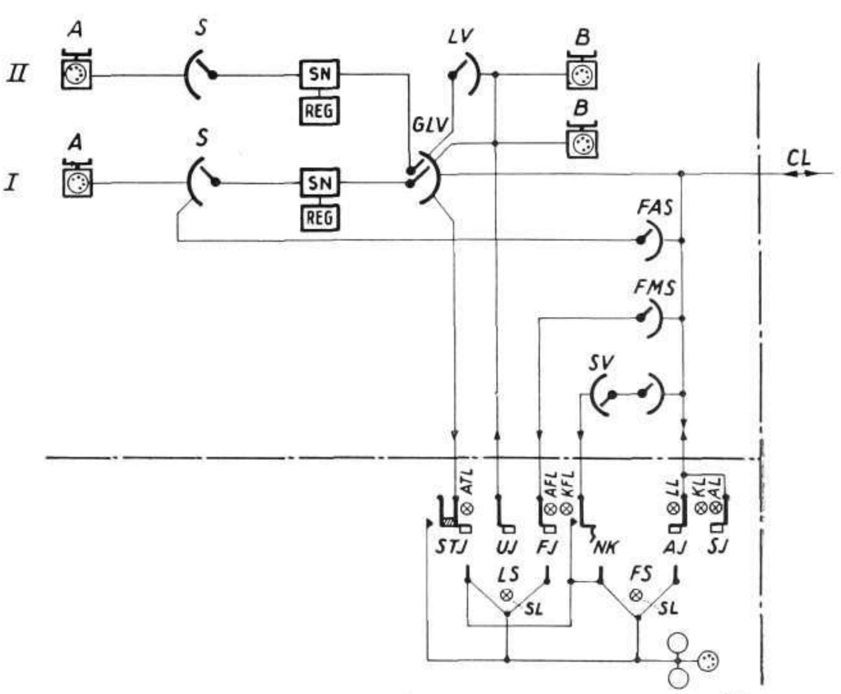

Fig. 7 X 5400

Routing diagram for 800-line branch exchange, System OS PABX

A, B	telephone instruments
AFL	calling lamp for FJ
AJ	calling jack for exchange line
AL	calling lamp for SJ
STJ	calling lamp for STJ
CL	two-direction exchange line
FAS	intermediate unit for automatic call-back and transfer
FJ	jack for call-back to operator
FMS	intermediate unit for manual call-back and transfer
FS	junction cord
GLV	final selector for first group
KFL	supervisory lamp for FJ
KL	supervisory lamp for SJ
LL	idle indication lamp for AJ
LS	cord for internal connections
LV	final selector for second group
NK	key for night service
REG	register
S	line finder
SJ	answering jack for CL
SL	clearing lamp
SN	automatic link circuit
STJ	answering jack for calls to operator
SV	night service equipment
UJ	multiple jack for non-barred extension

of these exchanges always contain the same kind of switching devices, which latter are provided with plugs assigned to corresponding jacks in the bays. Thus when inserting a unit in a rack no soldering is required. Consequently the capacity of an exchange may easily be increased by the addition of switching devices. The normal sizes are for up to 90, 280, 400 (possibly 460) and 800 (possibly 900) extensions.

Exchanges for 800 (900) extensions as maximum, the routing diagram for which is shown on Fig. 7, each consist of two groups but nevertheless no group selectors are required. All traffic relating to the first group is dealt with as in a 400-line exchange, but calls to the second group are led over one connecting stage more. The system OS PABX is also very suitable for installations comprising more than 900 extensions.

The power plant depends on local conditions, and particularly on the reliability of the mains supply. If AC is available, metal rectifiers are installed to convert the current to 24 V DC. Battery charging is operated quite automatically, and the power consumption is very low. The combined driving and signal unit which starts automatically when required consumes 2.5 A at 24 V. Without risk to the good working of the installation, automatic exchange and power plant and all other parts may be left unattended for long periods and only inspected occasionally.

Handset with Dial

E. BERGHOLM, TELEFONAKTIEBOLAGET L.M. ERICSSON, STOCKHOLM

Fig. 1 X 3778
Handset with dial

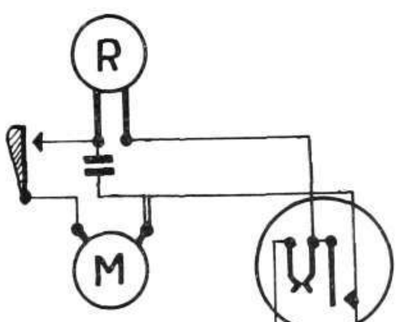

Fig. 2 X 3776
Diagram of handset with dial

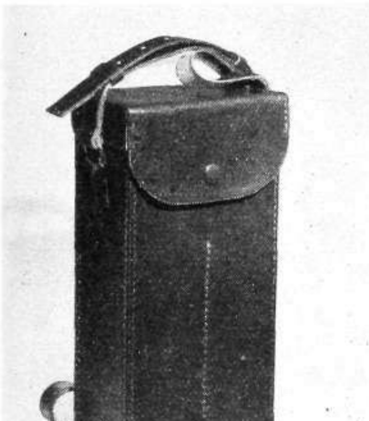

Fig. 3 X 3777
Case for handset with dial

Telefonaktiebolaget L.M. Ericsson has recently designed a portable telephone instrument for use in automatic systems, which in respect of small dimensions and compact construction meets a want long felt. The instrument is chiefly intended for exchange and line testing, but is suitable also for a number of other purposes.

The demands which may be imposed on a simple portable telephone instrument for exchange and line testing in automatic telephone networks are chiefly of a constructive nature; thus the instrument should have the lowest weight possible and small dimensions, it should be made as one unit, greatly facilitating its carrying, and finally standard parts should be used as far as possible, in order to simplify replacement of parts.

In the design of the Ericsson instrument, Fig. 1, these requirements together with convenience in use have been the determining factors. The instrument comprises all necessary parts for a telephone instrument with the exception of signal device for the receipt of calls, see Fig. 2; the signal device may be dispensed with since the instrument is not intended to be permanently connected in on the line. The induction coil also may be eliminated since calls with such instruments do not as a rule need to be transmitted over lines of appreciable length. On the other hand it must be possible for the instrument to be connected to the line without a call immediately taking place; to provide for this a condenser has been inserted in the microphone chamber, while the handset has been furnished with a key. When this key is not pressed the instrument is connected over the line in series with the condenser and it is easy to ascertain by listening whether the line is engaged or not. If the line is disengaged, the key is pressed, whereupon the transmitter is connected and call to the exchange is made. After buzzer tone has been received, impulsing can be done by means of the dial; the key is kept pressed down throughout the conversation.

All parts of the instrument are of normal Ericsson type and easily interchangeable. The connecting cord is normally provided with crocodile clips to facilitate connection to soldering tags, strips of fuses etc., but on request it may be furnished with any other connection, *e. g.*, with plug for connecting up with test jacks.

In view of its small weight, 0.75 kg, and small dimensions it may be carried in the tool-bag. In many cases, however, a special case may be more convenient; for this purpose a leather case has been made, see Fig. 3, its dimensions being $80 \times 120 \times 160$ mm; this case contains a special compartment intended for small tools, spare parts, fuses and the like, and thus constitutes a complement to the lineman's tool equipment. Complete with case the instrument weighs 1.3 kg.

The sphere of employment of the instrument is by no means restricted to testing work. It may be used anywhere that simplicity and mobility is required, *e. g.*, for temporary connection on board ship, and when arranging temporary connection of instruments for military purposes, such as for listening posts at air defence centres connected to automatic telephone networks etc.

Fire and Police Alarm Installation

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In March 1936 the Fire Committee of Kristianstad, Sweden, ordered from Ericsson a fire telegraph installation on the Morse supervisory-current system, which was subjected to final official inspection in July 1937. Prior to this the installation had already been connected up and in operation for a couple of months and also on a few occasions had been employed to alarm the fire brigade on outbreak of fires. The installation presents a novelty, in that it may also be utilised by the public for calling the police.

The installation comprises a central apparatus at the fire station with batteries and charging devices, along with motor alarm set and alarm bells to call the firemen in station quarters, alarm bells at the dwellings of the volunteer firemen and their places of employment in various parts of the town, a telephone instrument at the police station, together with fire and police boxes with lighting fittings set up in the streets of the town. All the material including the circuit network has been delivered by Telefonaktiebolaget L. M. Ericsson, but the erection has been carried out by the staff of the fire brigade. The connecting up of the central apparatus and final testing of the installation was done by a special mechanic.

The central apparatus, Fig. 1, which is of the normal type for this size of installation, consists of two instrument boards and a shelf table on which are two automatic telegraph instruments, Type TI 70, which start automatically on the arrival of signals and stop when the signal comes to an end. One of the boards is equipped with normal instruments for the connection of three circuit loops including the fire-police boxes and alarm bells located at the volunteer firemen's dwellings and places of employment. The other board is equipped with battery switches for stationary charging of the installation's four 24 V, 15 Ah Nife batteries and reserve battery. Above the respective battery switches are battery pilot lamps which light up if interruption occurs in a battery or if the tension falls below the tolerated figure. The board is moreover equipped with an alarm switch; in one position of the alarm switch,

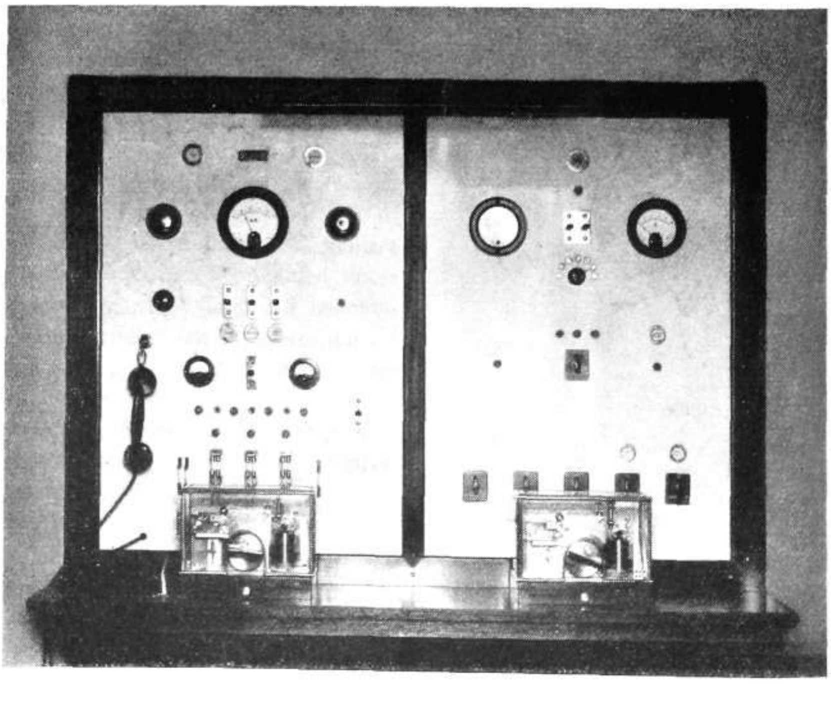

Fig. 1 X 5396
Central apparatus at fire station
connected to the left-hand board are the three alarm loops; the right-hand board contains battery switches and alarm switch

Fig. 2 X 3758
Fire and police box
the pull handle above is used for fire alarm; behind the sealed lower panel the police telephone instrument is mounted

alarm is given to the staff of the station by series connected 2 ohm AC bells, with DC bells as reserve, of which one is a large bell, Type RA 3001, mounted outdoors in the tower. On night alarm emergency lights appear in the quarters, staircases, corridors and garage. When the alarm bells are switched off, the lights continue to burn until a restoring button on the board is pressed, whereupon the pilot lamp above the button also goes out.

When alarm is sent out to the volunteer fire brigade outside the station, the alarm switch is moved over to another position, by which only the alarm set is started. The outgoing lines are then connected one after the other over separate connections to the alarm set, and 16 c/s AC is transmitted over the loops for ringing the 2 ohm AC bells set up in the houses of the members of the volunteer fire brigade.

A device for measuring the insulation and resistance of the outgoing lines is included in the board equipment. The figure obtained on measurement, read on a voltmeter which is also intended for measuring the tension of the batteries, is compared with a calibration curve, whereby the circuit resistance or insulation resistance may be obtained direct.

The central apparatus includes a handset for exchanging communications with the boxes, as also a device for transferring calls via a direct line to the telephone instrument in the police station.

The combined fire and police box, Fig. 2, is a modification of the standard box, Type TH 371, with pull handle for giving the alarm signal. The lower part of the box door has a panel which is normally kept closed and sealed. To call the police the sealed handle is turned, thus breaking the seal, the panel is opened and the handset is exposed. A telephone signal is transmitted automatically to the fire station where the caller on request is transferred to the police station. The speech transmission from all boxes has proved exceedingly good, this being achieved by employment of a special connection.

The placing of the fire boxes has been done in consultation with the fire chief and the object aimed at has been to have them mounted as far as possible at street corners and on posts, so that they may easily be seen. Above the box, on an arm projecting from the wall, red light globes are mounted, which are burning day and night and which further serve to distinguish the positions of the boxes.

The installation has been executed in such a way that it may in simple manner be supplemented by devices making it possible to call policemen on patrol from a signalling set at the police station, by means of flashes of the lamps above the boxes. This addition will probably be made in the near future.

Executed in the manner described, the combined fire and police alarm installation is very little more expensive than a simple fire alarm installation and since it makes it possible for the public to come into communication with the police in case of need, the authorities of various towns have displayed particularly keen interest in this kind of installation.

Precision Time Giving by Telephone

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In the Ericsson Review No 2, 1934, there was described a photo-electric talking machine for verbally communicating the time to telephone subscribers. At the time of the construction of that talking machine there existed no great demand for accuracy in the time given. In a number of cases one was content with statement of the hour and the minutes only, while in other cases the communication of the seconds was required. At the beginning therefore the machine was planned for communicating the time every tenth second, whether the seconds had to be given or not. Later however, a demand arose for great accuracy in the communication of the time. Without any other alteration to the machine than change of a cam disc this new requirement has been met in a simple manner.

The talking machine is normally synchronised every minute by control impulses from a precision clock. As the machine is usually connected to the telephone exchange battery and this is exposed to voltage variations, the synchronisation principle necessarily involved that the machine would be fast or slow in relation to the correct time by a number of seconds, the greater the variation of voltage the greater the deviation. By synchronising at shorter intervals the deviations in the machine's running could theoretically be reduced to any extent. In practice it has been found sufficient to carry out synchronisation every tenth second. In this way there can be attained an accuracy of ± 1 s deviation from the precision clock's impulses with a voltage variation in the exchange battery of from 22 to 26 V.

With this accuracy of running a definition must be given of which part of the time communication uttered may be considered as the correct time. Misunderstanding may easily arise among subscribers and even if directions for interpretation of the time communication were inserted in the telephone directory, it might happen that this latter was not available at the moment. To eliminate all misunderstanding and to give unequivocal time communication, the verbal communication is followed by a short tone emitted from the exchange voice-frequency generator; this does not proceed from the talking machine itself. The generator is connected to the voice-frequency circuit by a relay which in turn is attracted by a current impulse from the master clock. This determines the instant for the emission of the tone direct by the master clock and its accuracy is thus the same as that of the master clock. On account of variations in speed of the talking machine the interval between the word for seconds and the tone is variable. Synchronisation of the talking machine must thus, in view of the unavoidable battery tension variations, take place so often that the speech either with maximum lateness is ended when the tone arrives or with maximum fastness cannot be taken as connected with the preceding tone. Normally it has been found advisable to synchronise the machine every tenth second by which the same impulses from the head clock are used as those controlling the emission of the tone.

This method for the emission of precision time was first employed in Oslo, Norway, where the time communication plant was taken into service 1st April, 1937. The synchronising impulses are sent out from the observatory, which guarantees an accuracy of 0.1 s. In September 1937 a similar plant was delivered to Riga, Latvia. In that delivery a head clock was included, which sends out control impulses. This clock on its part is synchronised with second impulses from the observatory. The accuracy of running is thus determined by the observatory clock. On interruption of the line the clock of the plant continues to run independently so that no interruption of the time communication need take place.

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