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STAFF, DEPARTMENT HEADS AND OFFICE FORCE OF
TELEFONAKTIEBOLAGET L. M. ERICSSON IN STOCKHOLM AT AN INFORMAL GATHERING ON
NEW YEAR'S EVE IN ONE OF THE FACTORY DEPARTMENTS.

ENGLISH EDITION

THE L. M. ERICSSON REVIEW

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Look forward!

The past year has for the Ericsson concern been characterized by substantial gains within all fields of operation. Orders received and deliveries executed by the manufacturing and sales organizations as well as the number of subscribers of the operating companies have shown a powerful increase. The greatly increased amount of work has required the straining of every nerve. I can state with the utmost satisfaction that every member of our organization has to the best of his ability been instrumental in the achievement of this excellent result. There is reason to believe that our gains during the coming year will be still greater.

I want to express my appreciation of the work that has been accomplished and at the same time extend my best wishes for

A HAPPY NEW YEAR

to every member of this organization.

Stockholm, January 1st 1928.



ANDERS LIGNELL,
Superintendent of Telephones,
Stockholm



R 660

Member of the International
Consultative Committee for Long
Distance Telephone Commu-
nications

Suburban Telephone Traffic in a Large City.

By A. Lignell, Superintendent of Telephones, Stockholm.

In foreign countries, a certain fee is almost always charged for telephone calls between the larger cities and their immediate surroundings, i. e. such calls are subject to a special tariff rate and are consequently not included in the regular subscription rate for local telephone service.

Another method is to extend the zone for the purely local traffic to include the outlying districts as well, calls within this zone being handled in exactly the same manner as city calls and being metered together with these latter. With regard to the traffic, this is possible only if a sufficient number of lines for suburban traffic are available, these lines necessarily being of sufficient number to prevent an excessive busy percentage during the busy hour. Otherwise, the advantages of a direct traffic are lost and the local service will be weighted down with ineffectual work.

It is now quite a number of years since Stockholm established direct service within a so-called 'free service zone' without any extra charge for rural or suburban calls — the suburban exchange was opened for traffic in 1923 —, consequently a more detailed description of how this traffic is handled and of the importance of this type of service to the telephone administration as well as to the subscribers may be of interest.

Stockholm's free service zone comprises at present 158 exchanges outside of the city limits with a total of 27,626 subscribers, plus 115,176 subscribers within the city.

The map on page 6 shows the extent of the area included in this zone.

The number of subscribers at the various exchanges

varies from 2500 down to about 50, most of these exchanges being provided with direct city lines.

For some thirty of the smaller and most distant exchanges the traffic is transited over some other exchange with a direct city line. In such cases the transit exchange is provided with a sufficient number of direct lines to permit the effectuation of city calls without delay.

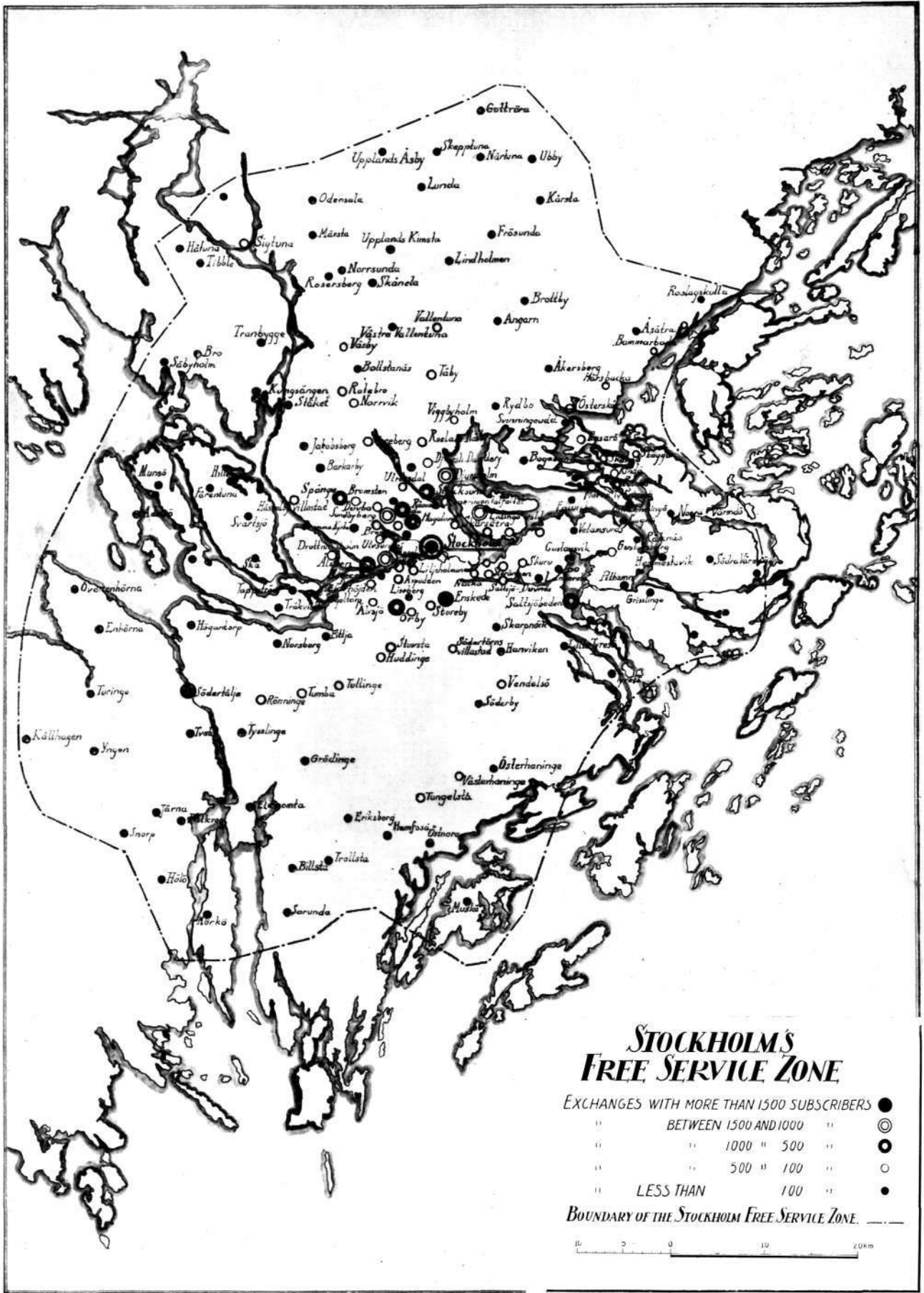
The total number of direct city lines is now 2172, 1139 of these being reserved for outgoing traffic from Stockholm and 1033 for traffic to Stockholm.

The suburban traffic is handled in Stockholm by a specially arranged *suburban traffic exchange* which comprises two main divisions — one for incoming and one for outgoing calls — as well as reference boards for toll traffic with the suburban net, junction boards for junction traffic between exchanges within the free service zone whose calls in some cases must pass over Stockholm, arrangements for carrying the outgoing traffic over the call order service division during temporary reductions in the number of lines on account of trouble, and a supervision room.

Wherever the requirements of the traffic call for direct lines of communication between the suburban exchanges such lines have been provided, thereby avoiding as much as possible the routing of the traffic over Stockholm.

Outgoing traffic.

The outgoing traffic from Stockholm is handled over a 7-panelled B-board at the suburban traffic exchange. The multiple is built up of 20-line lamp and jack strips, the lamp strip lying above and being se-



**STOCKHOLM'S
FREE SERVICE ZONE**

- EXCHANGES WITH MORE THAN 1500 SUBSCRIBERS ●
- " BETWEEN 1500 AND 1000 " ⊙
- " " 1000 " 500 " ○
- " " 500 " 100 " ◦
- " LESS THAN 100 " •

BOUNDARY OF THE STOCKHOLM FREE SERVICE ZONE. - - -



parated from the jack strip by means of a designation strip. The lamps in the multiple serve both as calling and clearing lamps. On a line with the designation strips are located the test buttons, the buttons used for testing an adjoining group of five lines always belonging to the same exchange. In order to test the lines, the operator depresses the test button, a disengaged line being indicated by the glowing of the lamp above the jack of this line. If a line is engaged, the corresponding lamp remains dark.

On making a call, a city subscriber gives the name of the desired suburban exchange after which the A-operator gets a disengaged operator at the suburban traffic exchange by means of an order wire provided with a selector, this last operator establishing the connection over an idle suburban line by means of the trunk multiple, after previously having tested the lines. On receiving an answer from the suburban exchange, the calling subscriber himself requests the desired number.

A clearing signal is obtained on the test lamp over the line jack in the multiple as well as on the lamp of the trunk cord. The glowing of the lamp in the multiple contributes towards a speedy disconnection at the end of the conversation, a very important factor for the effective utilization of the suburban lines. Besides, loss of time through slow disconnections would result in an increased busy percentage and this, in turn, would unfavourably influence the service at the local exchanges.

The extent of the outgoing traffic from Stockholm is given in the following table:

1927	Number of calls during whole day (including toll calls)	Average number of suburban calls during week day		Number outgoing suburban lines	Average calls per suburban line including toll calls, 8 to 21 o'clock
		8 to 21 o'clock	and per operator-hour, 8 to 21 o'clock		
January	2,116,603	69,852	332	1109	66
February ...	1,963,358	68,483	330	1112	65
March	2,215,428	70,237	343	1117	67
April	2,266,889	75,981	347	1122	71
May	2,465,304	79,691	341	1126	74
June	2,546,489	87,077	333	1121	82
July	2,546,657	82,158	318	1129	77
August	2,691,663	84,931	330	1135	79
September...	2,533,586	83,001	330	1134	77
October.....	2,367,254	72,540	327	1134	70
November...	2,235,906	70,403	333	1134	68
December...	2,350,202	72,417	338	1139	69
Total	28,289,339				
Average		76,398	333	1126	72

As will be seen, the number of calls from Stockholm to the 158 exchanges within the free service zone amount to over 2 million per month with an average of 76,398 calls per week day between 8 and 21 o'clock. During the same hours, the average number of calls per operator hour is 333. Seventy-two calls per line — including toll calls — took place between 8 and 21 o'clock over the mean number of suburban lines (1126) available during the year. This figure must be judged with due consideration for the fact that a large number of the suburban exchanges have so-called season traffic. Over line groups to exchanges with a constant yearly traffic load, the average number of week day calls during the same hours is considerably greater, amounting to between 130 and 140. The busy percentage of the suburban lines has varied between 1 and 1.9 % during different parts of the year. The salary cost per outgoing suburban call has amounted to .004 Swed. crowns, or about the same as for local calls handled over B-positions. Thus, one may say that the service cost in Stockholm for an outgoing suburban call (during the entire day) is the same as for a purely local junction call to any other city exchange. The increase in cost over a local call is for the work which takes place at the suburban exchange for completing the connection.

The distribution of the outgoing traffic over the hours between 8 and 21 o'clock and the adjustment of the number of operators to the traffic curve is indicated in the graph on page 8, in which the required number of operators is based on 330 connections per operator hour, this figure being easily exceeded during the busy hours between 10 and 13 o'clock, however, without inconveniencing the service. The average value for the curve is 334 connections per operator hour, the total number of operators required for handling the traffic between 8 and 21 o'clock amounting to thirty-three, with a maximum of nineteen occupied positions. That the personnel curve lies over the traffic curve during lighter traffic is due to the fact that one must have good selecting possibilities from the different local exchanges.

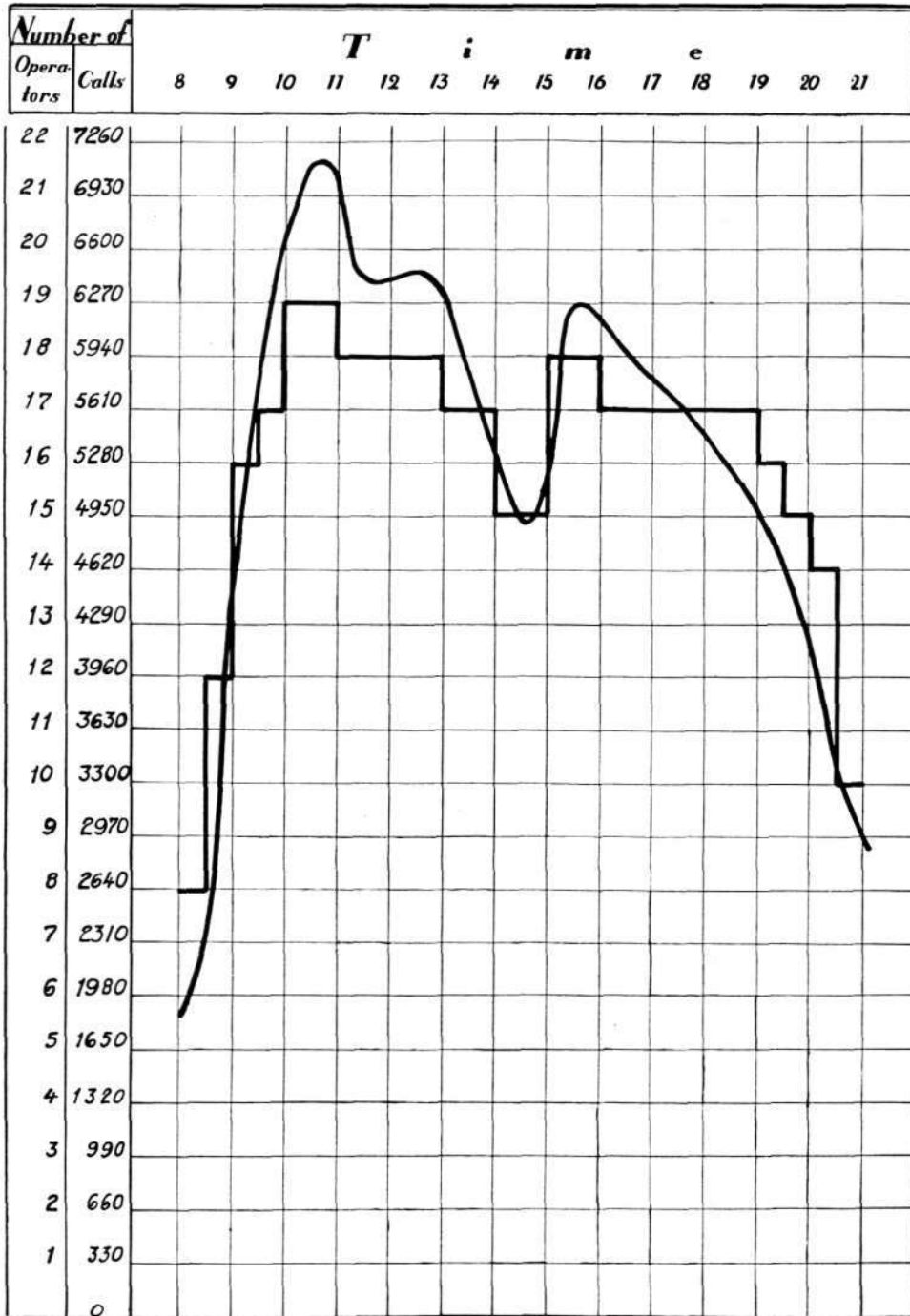
The service is supervised by keeping continuous records of the answering and disconnecting times at the suburban traffic exchange as well as at the suburban exchanges. The answering times on the order lines from the local exchanges to the suburban traffic exchange have an approximate length of one second, 1.5 % of the waiting times exceeding five seconds. The disconnecting times at the suburban traffic exchange amount to about 1.5 seconds, none of them overrun-

OUTGOING SUBURBAN TRAFFIC

STOCKHOLM

8 TO 21 O'CLOCK (AVERAGE 6 WEEK DAYS)

TRAFFIC CURVE
SERVICE CURVE (number of operators) 
 based on 330 connections per operator hour.



ning ten seconds. The answering times at the suburban exchanges during 1927 were as follows:

Number of answering times under supervision	18,303
Average disconnecting time	8.3 seconds
» answering time	4.3 »
Percentage of answering times exceeding ten seconds	8.9

Incoming Traffic.

The traffic coming in to Stockholm from the exchanges within the free service zone is handled over sections, each section comprising nine operators' positions. Each section accomodates 160 incoming lines, the answering jacks (with the calling lamps over each jack) for each line being multiplied so as to be within the reach of all nine operators in the same section. The calling lamps are of different colours, red, green or white, these colours being distributed over the multiple in such a manner that the lamps within the reach of each operator are to an equal number red, green or white. The answering lamp of a line which is red in the three first positions, is green in the next three positions and white in the last three. When answering a call, the operator takes a red lamp as first choice, a green lamp as second and a white lamp as third. Before plugging in to answer a call with a green or white lamp (auxiliary lamps), the operator should glance up to ascertain that no other operator is just about to answer the same call.

This arrangement has resulted in exceptionally good answering times, and there have been no difficulties in getting this type of auxiliary service to function properly. During 1927 the average answering time was 4 seconds, with 7.2 % of the answering times exceeding 10 seconds; the average disconnecting time was 5.5 seconds with 15.6 % exceeding 10 seconds.

A suburban call to Stockholm is handled in the following manner.

The suburban subscriber asks for Stockholm, the number of lines usually being so large that no waiting is required. The operator connects the subscriber to a disengaged Stockholm line (at the larger suburban exchanges these lines are provided with visual testing) and gives a calling signal. Any of the nine operators at the section in which this line terminates in Stockholm can answer the call. The answering operator gives the number of her position, for instance 32. The subscriber requests the desired Stockholm number and the operator at the suburban traffic exchange gets in

touch with the B-operator at the corresponding local exchange over an order wire with selector. The connection is then effectuated over the trunk multiple.

A double clearing signal is received at the suburban traffic exchange on the lamps of both the answering and calling cords, the operator breaking the connection after both lamps have registered the clearing signal. When only a single clearing signal is received, the operator cuts in on the connection before breaking the same.

The pulling down of the calling cord results in the giving of a clearing signal in the B-position at the desired exchange.

The figures in the following table give an idea of the extent of this traffic.

Incoming Suburban Traffic 1927.

1927	Number of calls during entire day	Average calls per week day		Number of incoming lines	Average calls per incoming line, 8 to 21 o'clock
		8 to 21 o'clock	and operator-hour 8 to 21 o'clock		
January	2,163,498	74,695	124	995	75
February ...	2,032,544	74,614	119	997	75
March	2,248,371	75,305	126	1000	75
April	2,245,071	78,818	127	1008	78
May	2,421,308	80,987	124	1012	80
June	2,583,417	91,894	125	1018	90
July	2,593,963	87,535	121	1021	85
August ...	2,733,638	90,580	125	1022	88
September...	2,500,323	84,861	121	1028	83
October.....	2,303,432	76,776	123	1028	75
November...	2,189,286	74,938	123	1028	73
December...	2,295,892	77,048	126	1033	75
Total	28,310,743				
Average		80,671	124	1016	79

Summer season

As indicated above, there was an average of 80,671 calls per week day between 8 and 21 o'clock, the average number of effectuated connections per operator-hour during the year amounting to 124. In judging these figures one must not forget that all of these calls are trunked.

The average number of calls per incoming line between 8 and 21 o'clock amounted to 79, which can be regarded as an exceptionally good utilization of the lines, especially as a considerable number of the suburban exchanges have season traffic, as previously mentioned. The distribution of the traffic over the different hours of the day as well as the adjustment of the number of operators to the traffic curve is shown in the graph on page 10.

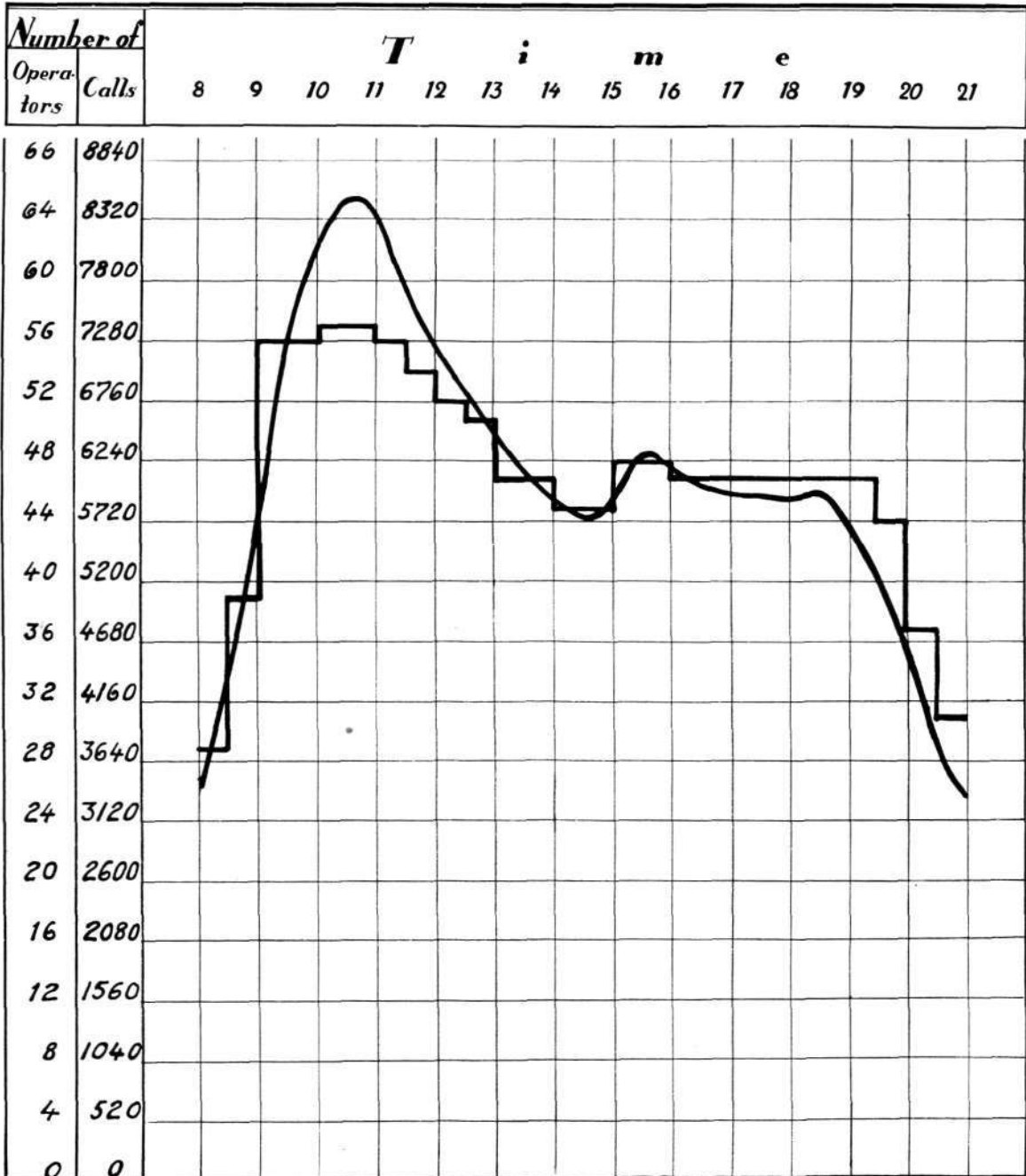
L. M. Ericsson

INCOMING SUBURBAN TRAFFIC

STOCKHOLM

8 TO 21 O'CLOCK (AVERAGE 6 WEEK DAYS)

TRAFFIC CURVE
SERVICE CURVE (number of operators) 
 based on 130 connections per operator hour.



Comparison between call order service and direct service.

Let us now regard this traffic as subject to a special tariff rate, the calls being effectuated in turn after the placing of an order and the service being placed under supervision the same as for toll service. In the first place, a much larger number of positions and operators would be required, as well as increased exchange space. Besides, the subscribers would lose the advantages provided by the direct service since the calls would be subject to waiting times, not to mention the added nuisance of the ordering process.

It may be of interest to make a rough estimate of the requirements for a traffic amounting to 76,400 outgoing calls — the average week day traffic between 8 and 21 o'clock — with call order service as compared with direct service.

First, we must determine the number of operators required to handle the traffic, not forgetting to take into consideration that we must do without the possibility — afforded by the use of B-positions — of easily adapting the number of operators to the varying traffic loads, this being due to the necessity of distributing the lines over a large number of positions between which there is a minimum of coöperation, since the suburban lines are restricted to certain positions.

With call order service — in which the order for the call must first be received and noted down (either at an order service section or by the respective operators), then dispatched in turn, the subscriber connected over a B-position when his turn has arrived, the length of the conversation registered and noted down — an operator who also receives the call orders can dispatch from thirty to thirty-five calls per single hour.

The variation in the traffic loads during the various hours of the day and over different traffic routes does not permit the distribution of the lines in such a manner as to make it possible to maintain this number of calls as a daily average, however. There is no doubt but that an average of twenty-five calls per hour and operator is a liberal figure.

For the 76,400 calls this would require 3056 operator hours or — with 6.5 effective working hours per operator and day — a total of 470 operators. With 7150 calls during the busy hour (see on graph page 8) and figuring on 30 calls per operator during this hour, this would mean that not less than 238 operators would have to be on duty at the same time, requiring a minimum of 238 positions.

From the table on page 7 we find that with direct

service the average number of calls per line is 72. With advance order service, the lines might possibly — the waiting times on these short distances during periods of intense traffic must not be too long — accommodate 80 calls, which would mean that with call order service the number of lines could be reduced to 1012, a reduction of 127 lines.

Consequently, a comparison gives the following figures for 76,400 calls:

	Direct Service	Advance order Service	Difference	
			to the detriment of call order service	in favour of call order service
Calls per operator hour	330	25	305	
Number of operators ...	33	470	437	
Maximum occupied positions	19	238	219	
Number of connections over B-positions at local exchanges	—	76.400	76.400	
Number of lines	1.139	1.012	—	127
Exchange space required			Abt. 15 times more space	

And just what do these differences signify in yearly expenses? The 437 operators required for handling the call order traffic — naturally on condition that the orders are received and registered by the regular operators on duty, and not by a special order service section — in excess of those required for direct traffic must be better qualified than the B-operators for the simple direct service and consequently receive better salaries. However, if we disregard this difference in salaries and assume the yearly cost per operator (salary, vacation and other remunerations) to be 2200 Swedish crowns — a low figure according to Swedish standards — the increased cost for the call order service would amount to 961,400 crowns

The difference in the number of operators' positions — 219 — gives an increased first cost of abt. 800,000 crowns. 10 % for interest and amortization, plus maintenance, gives a yearly cost of abt. 135,700 »

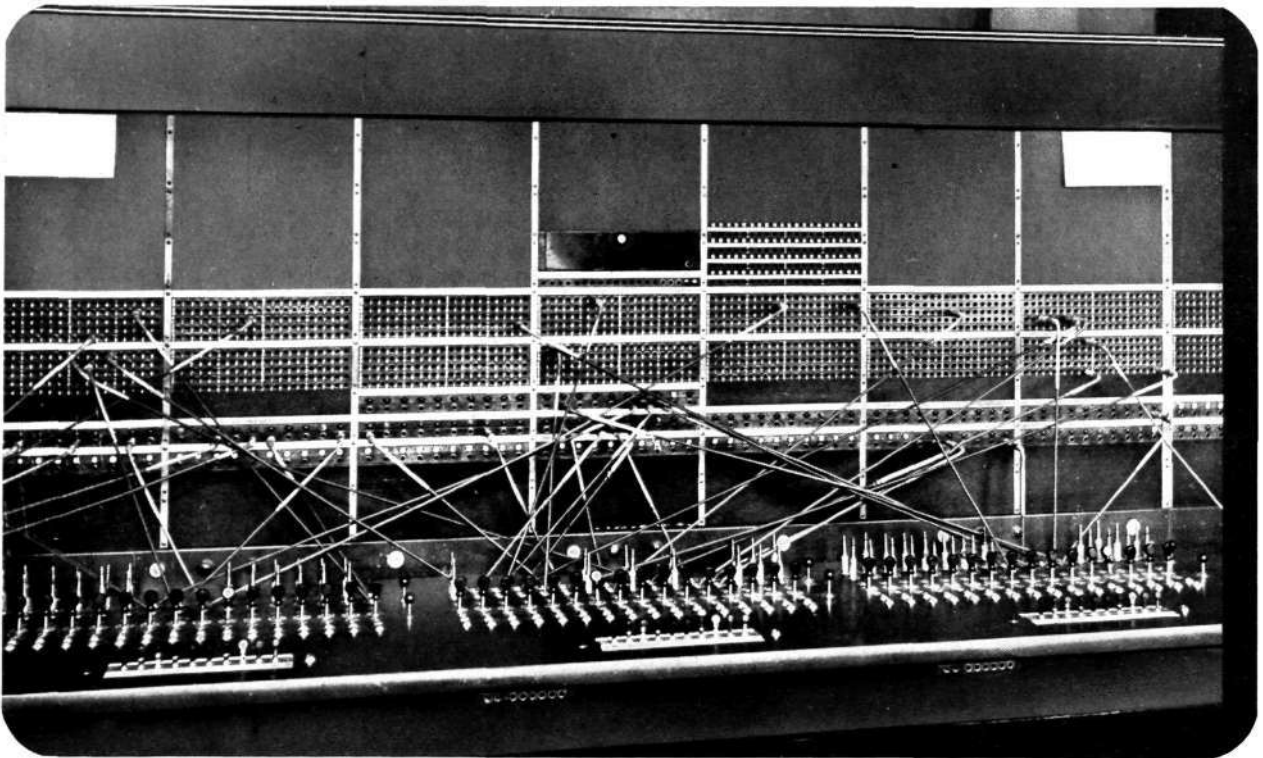
The connections over B-positions at the local exchanges at .004 cr. for a yearly traffic of 22,900,000 calls 91,600 »

Fifteen times more space than for
direct service (rentals, heat,
cleaning, light, etc.) abt. 50,000 crowns
Total 1,238,700 crowns

Thus we arrive at an increased cost of approximately 1.24 million crowns for call order service as compared with direct service. In addition to this, however, we have the cost of sorting and filing the call order tickets, making out of bills, collection of fees, etc., all of which amounts to considerable sums. We do not

more clear we will investigate its aspects with regard to call order service.

According to our experience, the cost for such short distance calls with call order service is so great that the tariff rate which could reasonably be imposed would not compensate it, the sole reason for this high cost being the large sums required for salaries. These conclusions are confirmed in a most interesting article in the May 1927 number of *Archiv für Post und Telegraphie*, entitled *Die neue Fernsprechordnung*, in which are given the costs for toll calls over various



R 857 Seven-Panelled Switchboard for Incoming Suburban Traffic. (The upper part of the multiple contains junction lines to the various local exchanges.)

think it necessary, however, to go any further into these details in this connection.

Against this enormous increase for call order service stands only the cost of the 127 lines with which the suburban net for call order service might possibly be reduced. At the present prices for telephone cable and maintenance, the corresponding reduction in the yearly cost will be comparatively insignificant and can be estimated at 40,000 crowns at the most.

Compensation for direct service.

In what manner shall a reasonable compensation for the service be levied? In order to make this question

distances in Germany. The article shows that for distances under 5 kms., between 5 and 15 kms. and between 15 and 25 kms., the toll service occasions the administration a direct loss.

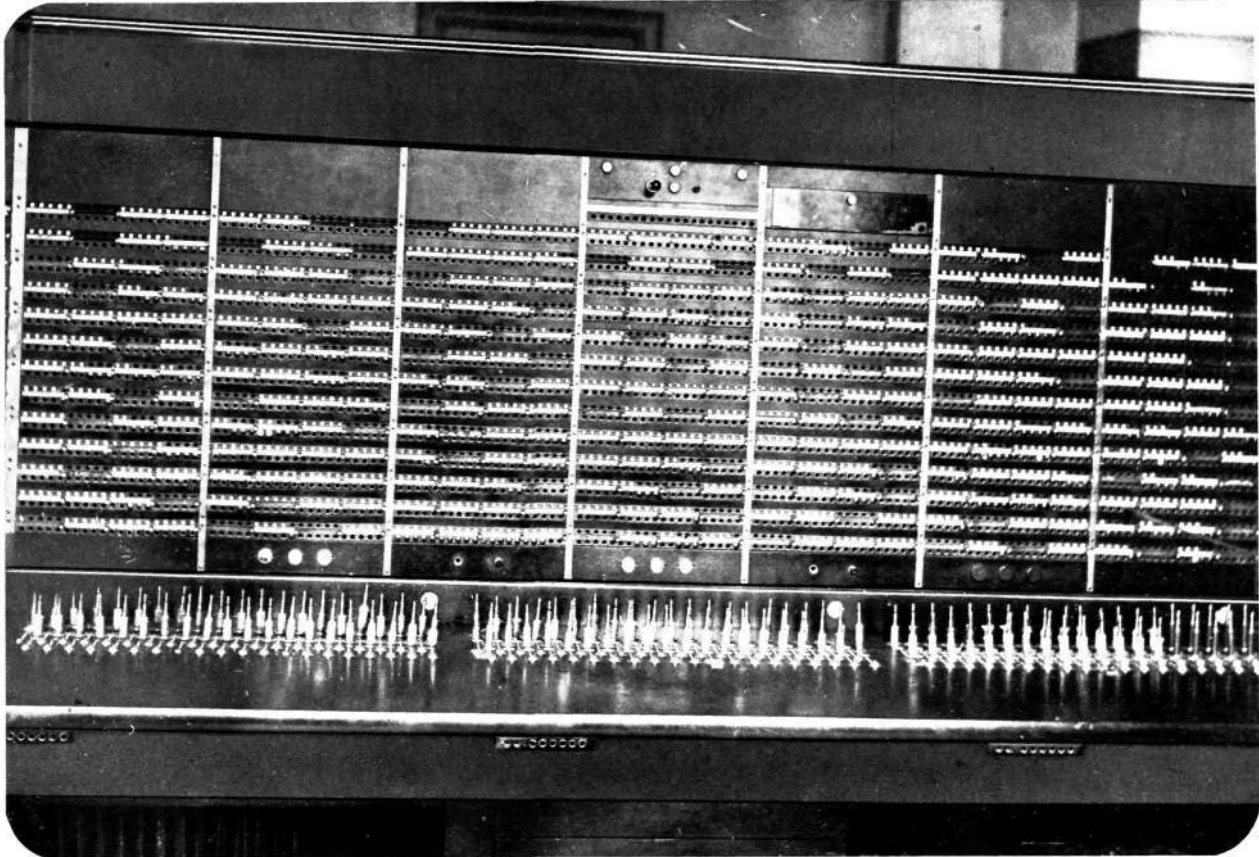
For distances under 5 kms., the cost of a call — not including a reasonable profit and other charges — is given as 32 pfennig, 25 of which went to salaries. The tariff rate was only 15 pfennig.

For distances between 5 and 15 kms. the corresponding costs were 37 pf. and the rate 30 pf. For distances between 15 and 25 kms. the cost is 42 pf. and the rate 45 pf., thus giving a surplus of 3 pf., which becomes a deficit of 6 pf., however, if the

reasonable profit and other charges are taken into consideration. Since the rate is figured per 3-minute period while the costs are figured per call, the actual loss decreases in the same proportion as a call is extended beyond the 3-minute period, but the total loss on this category of calls within Germany is stated to be about 22 million reichsmarks.

With the above described direct service, the net cost for an outgoing suburban call has been reduced

Since the total costs for suburban calls, including the cost of the lines, would be amply covered if these calls were metered twice instead of once on the local subscribers' meters, this would be a simple method of solving the tariff question provided the technical arrangements required for such a change in the metering of the calls would not prove too expensive. In Sweden, this problem has been solved by raising the yearly subscription rate for service within the larger free ser-



R 858

Multiple of Seven-Panelled B-board for Outgoing Suburban Traffic.

to the cost for a junction call to another city exchange, plus the cost of completing the connection at the suburban exchange, this latter being extremely low. The cost of the service which lies within the city net should be included in the local subscription rate. The problem, therefore, is to cover the expenses for service at the suburban exchange and the cost of the lines themselves in a simple and effective manner.

For an incoming suburban call from the free service zone, the cost of service within the city is the same as for a local junction call, to which must be added the cost of service at the suburban exchange plus the cost of the suburban lines.

vice zones, not only for the local city subscribers but also for the suburban subscribers.

The object of this article has been to show in a general way how unsuitable call order service is for traffic over short distances, with low cost of lines and high overhead. The call order service is accompanied by a much greater amount of work, the only result of which is a greatly increased cost for which no special advantages are obtained. The service is handled in a roundabout way, which not only is an expensive proposition in itself but also burdens the traffic with waiting times and the subscribers with increased inconvenience, besides which the rates for such short

distance calls — requiring special registration — cannot be set high enough to give a reasonable profit. Furthermore, the entire system puts a restraint on the development of the traffic. With the introduction of automatic switching, further measures for reducing the personnel required for handling the outgoing as well as the incoming traffic can be devised.

The suitable size of the free service zone must in each special case be determined with due consideration for existing local conditions. The large size of the Stockholm zone is due solely to the intense competition which existed here during the first development of telephone communications in Sweden.

R 735



Call Order Service at the Stockholm Toll Exchange.

By Chief Inspector M. Agrell.

Unlike a number of other large toll exchanges, the Stockholm exchange is not provided with a central order section to which the various call orders placed by the subscribers are directed for subsequent distribution to the different toll positions. Instead the toll call orders are received direct from the subscriber by the toll operator who will effectuate the connection.

This method of handling the service has been in use ever since the time when Stockholm did not have more than two telephone exchanges — one local exchange with a rural service section and one toll exchange. The necessary equipment, however, has undergone successive changes and modernizations along with the growth of the net and the building of new exchanges.

Originally, the ordering lines entering the various toll positions were admitted directly to the multiple of the local exchange and identified with designations consisting of the abbreviated names of the exchanges whose toll calls were handled over the corresponding toll positions; also, these lines were arranged alphabetically according to the names of the exchanges.

At the toll exchange each ordering line was provided with a drop indicator — which was actuated as soon as the connection was completed to the corresponding line at the local exchange — and a key by means of which the operator could get in on the line in order to receive the subscriber's order.

In 1909, the Telegraph Administration opened a number of smaller local exchanges in Stockholm, originally intended for subscribers with residence 'phones. These exchanges were not provided with direct ordering lines to the toll exchange, a connection for a toll call order from a subscriber at one of these exchanges being carried over the ordering multiple of the central exchange. This traffic was handled in exactly the same way as the junction traffic between a sub-exchange subscriber and a central exchange subscriber.

In 1916 the toll exchange was removed to a new location. The switchboards which now came into use were built on the same principle as the former ones, it is true, but at the same time they displayed a number of rather important dissimilarities, of which only those that have a direct bearing on the ordering lines will be here described.

Each operator's position in the new toll exchange was provided with two ordering lines with calling lamps, placed on the vertical part of the board, and keys, placed on the keyboard. In order to make it possible for the operators to help each other with the receiving of orders, the ordering lines were multiplied in the nearest adjoining positions on each side. For this purpose, each position was provided with six order keys, the two to the left for making a connection over the ordering lines of the adjoining left position, the two middle keys for connections over the own lines, and the two to the right for connections over the ordering

lines of the adjoining position to the right. The ordering line lamps, on the other hand, were not multiplied, but were provided with extra large lenses so as to be readily observed from the adjoining positions.

Thus — by means this arrangement, which is still being used — if a signal is given over an ordering line and the corresponding operator is busy with a toll connection or the like, either the operator to the left or the one to the right of her can receive the order.

In addition to this relief service, intended to exert an equalizing influence on the answering times, the manner in which the ordering wires at the local exchange were connected up underwent a change for the very same purpose.

In the multiple of the central exchange these lines were mutually arranged in the same manner as at the toll exchange, i. e. the two jacks corresponding to the ordering lines for a certain toll position were flanked by jacks for the ordering lines belonging to the toll positions adjoining the one first mentioned. In this manner the local operator was able — in case both ordering lines to a certain toll position were busy — to establish a connection over one of the nearest two lines on either side of the busy lines.

In this manner a sort of distribution of the order receiving service among five toll operators was obtained, i. e. if a local operator desired to make a connection over either of the ordering lines belonging to toll position number 3 and these were busy, she could make the connection over the lines leading to positions 2 or 4. An order signal to position 2 could also be answered by either of the operators at positions 1, 2 or 3 and — if a line leading to position 4 had been chosen — by an operator at position 3, 4 or 5.

Since the arrangement of the toll lines at the toll exchange quite naturally could not be in alphabetical order according to the names of the exchanges, it follows that neither could the multiple jacks of the ordering lines be designated as formerly with the names of the respective exchanges alphabetically arranged.

Consequently — as well as for other reasons — the name designations in the local multiple were removed and instead the jacks were provided in pairs with the number of the corresponding position at the toll exchange. At the same time, a special *Information Section* was organized, its duty being to give the local operators information as to the number of the ordering line for a given exchange, since it stands to reason that the many local operators could not be expected to memorize the numbers of the various ordering lines,

neither was there space on the multiple boards for the setting up of the necessary instructions.

The information operators, however, — which did not number more than five to each relay and whose only duty it was to give information as to the numbers of the ordering lines — could easily be trained to memorize these numbers. As an aid to the information operators, however, lists over all the central exchanges and larger distributing exchanges with the numbers of the corresponding ordering lines were set up on the switchboards.

The numbers were inscribed on removable number pegs, thus facilitating a change if called for through the moving of lines at the toll exchange. Besides, the information operators were provided with lists of all the telephone exchanges in the country with the names of the governing central exchanges.

Thus, when a subscriber desired to place an order for a toll call, the local operator depressed a button for an order wire to the information section, causing a disengaged information operator to be selected. The local operator then repeated the name of the desired exchange, receiving in reply from the information operator the number of the corresponding ordering line, after which the local operator connected the calling subscriber to either of the two lines with this number or to one of the two adjacent lines on either side of the same.

As concerns the call order traffic from the other local exchanges, the procedure differed from the above insofar that it was no longer directed over B-positions at the central exchange but over special B-positions arranged especially for this purpose and at the same time functioning as information positions. For this purpose, these boards were furnished with the same lists etc. as the information boards, besides being equipped with a necessary number of cords and plugs and with the same reference multiple as the central exchange.

The increase in the number of subscribers at the sub-exchanges and the building of new sub-exchanges, however, were responsible for a considerable increase in the call order traffic over the above-mentioned reference boards during the following year, at the same time as the call order traffic from the central exchange decreased on account of the removal of subscribers' lines from this exchange to the sub-exchanges.

This necessitated an extension of the reference boards, at which time it was deemed wise to adopt a uniform type of call order service for this traffic from all the local exchanges. As a result, the information

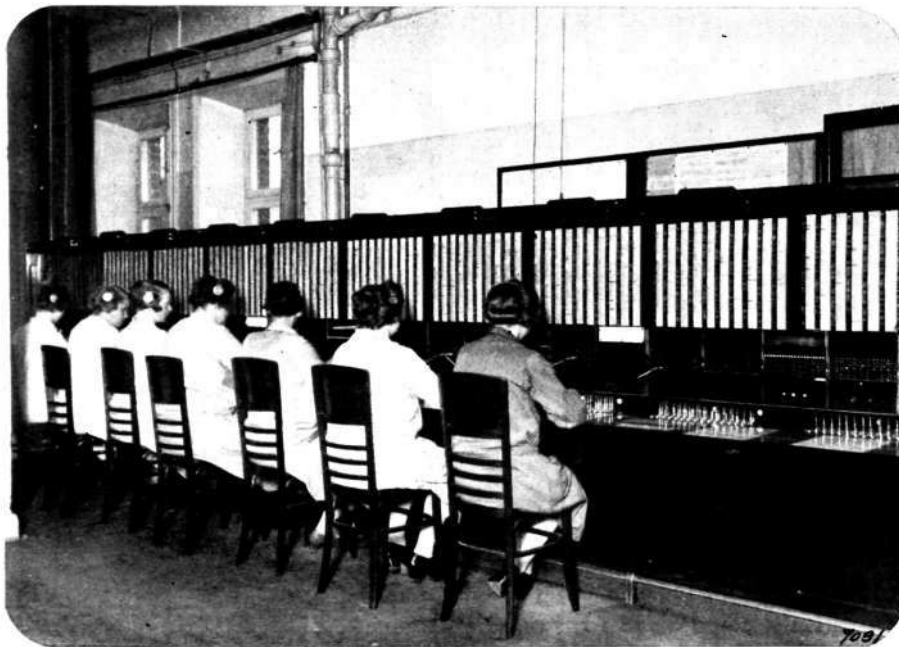
section was in 1919 replaced by reference boards and the reference multiple of the central exchange was changed to a common multiple for junction lines to this reference board.

This type of service for the call order traffic from the local exchanges has been retained unchanged since 1919.

The existing call order reference board with its fourteen positions is shown in fig. 1, only ten of these positions being fully equipped at the present time, however, and not more than seven of them being occupied by operators during the busy hour. As may be

connections with the respective ordering lines without having to refer to either the lists of names over the multiple or the complete list of exchanges. Consequently, it is possible for a well trained reference operator to effectuate as many as 600 reference connections per hour.

The following method has been adopted for handling call orders from automatic subscribers. The subscriber dials the digit 9 and is connected to a first group selector which hunts for a disengaged junction line to the call order reference board. When such a line has been found, the corresponding lamp in the



R 829

Fig. 1.

seen, the keyboards are arranged as for regular B-positions. The multiple contains the jacks of the ordering lines, numbered in pairs similar to the operators' positions at the toll exchange. Above the multiple are the lists containing the names of all the central exchanges in the country and those of the larger distributing exchanges, with — to the left of each name — the number denoting the position which handles the toll call to the exchange in question. These numbers are inscribed on removable number pegs, making them easily exchangeable in case a toll line should be moved over from one position to another. The reference boards are also provided with an easily accessible list of all the existing telephone exchanges in the country together with the names — in certain cases — of the central exchanges over which the calls are handled.

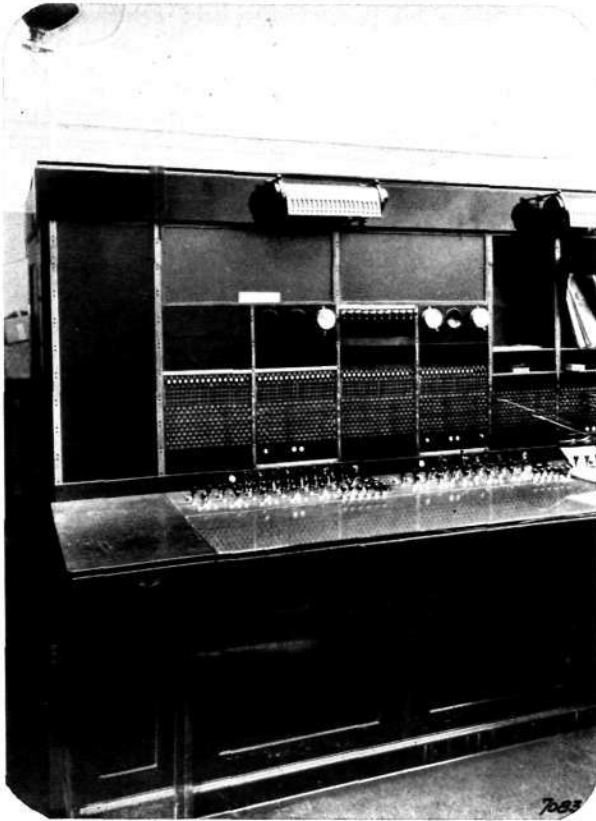
As has already been mentioned, however, the trained reference operators can in most cases effectuate the

reference board glows at the same time as the reference operator is connected to the cord. When this operator answers "9", the subscriber requests "Gothenburg", for instance, and after having answered "Just a moment, please", the operator connects the subscriber to the desired ordering line.

The toll operators themselves have recourse to the call order reference service in those cases when — with transfer calls — they wish to communicate with one another. The service is then fully analogous to what has previously been described.

In fig. 2 we see the keyboard of a toll switchboard at the toll exchange. In front of the toll switching devices and to the front may be seen the six keys for an equal number of ordering lines. The calling lamp for the own ordering lines of the position — corresponding to the two middle keys — are located on the vertical panel.

The arrangement of the ordering lines from a technical point of view is so simple as to require no special detailed description. It is sufficient to state that the pressing down of an order key connects the operator to the line in question and at the same time disconnects her from the rest of the equipment in her position. Thus, if the speaking and ringing key of a toll line is in speaking position, the operator will be disconnected from the toll line on the depression of an order key. Although the decentralization of the call order service



R 828

Fig. 2.

in Stockholm is believed to have been accompanied by more advantages than disadvantages, this does not mean that this system in all cases is preferable to a centralized service.

A choice between the two systems must be made with due consideration for the special conditions ruling at different toll exchanges, such as to what degree it is possible to utilize the lines, the efficiency of the personnel, whether several kinds of calls shall be permitted, the existence of cancellations, number of requests for information concerning ordered calls, linguistic conditions, etc.

The existence or nonexistence of these and other

conditions will influence the value of those qualities that are characteristic for the two systems and which sometimes make the one preferable, sometimes the other.

The decentralized call order service has the following advantages.

The subscribers come in direct contact with the operator who will later on effectuate the desired connection and are therefore able to obtain from her any desired information, such as concerning waiting times, traffic conditions, etc.

Since subscribers often have their toll traffic concentrated to certain localities and certain persons there, it is of advantage to the subscribers to be able to give their call orders to operators who not only are well acquainted with traffic conditions over the line of communication in question but who also possess a wide knowledge as to which subscribers can be regarded as daily users of the various traffic routes. This is of special advantage for the international traffic where the language problem must be considered.

Information as to previously ordered toll calls may be obtained and calls cancelled much more conveniently with decentralized call order service than with the other type.

During the time a line stands idle, incoming orders can be more quickly effectuated than with centralized service with all its intricacies.

Finally, the toll boards are not encumbered with all the expensive pneumatic dispatch paraphernalia which accompany centralized service arrangements, designations required to enable the operators to give the subscribers desired information as to waiting times, etc., as well as arrangements for communications between the centralized service operators and the toll operators or for giving the subscriber a through connection to the toll boards when it may be necessary to obtain information direct from the toll operator.

The greatest advantage which centralized service possesses over the decentralized call order service lies undoubtedly in the possibilities it offers for a better distribution of the work and for the adjustment of the personnel to the intensity of the traffic resulting in shorter and more uniform answering times. With the arrangements at the Stockholm exchange, however, enabling three or even five toll operators to cooperate in the receiving of order calls it has been possible to so restrict the length of the answering times as to make them entirely free from criticism on the part of the public.

L. M. Ericsson

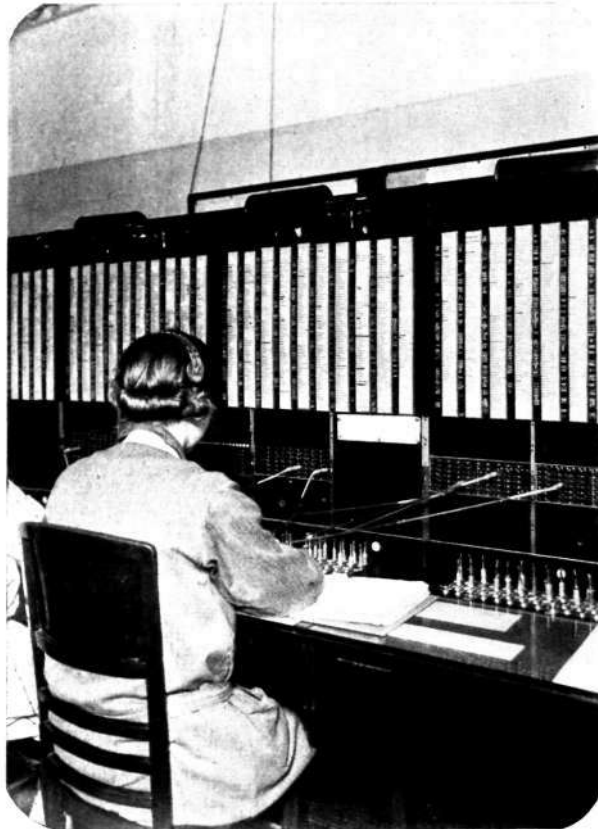
Whether or not the better utilization of the personnel obtainable with centralized call order service means a direct saving in the total expenses for the toll service naturally depends on to what degree the total amount of work is increased by the sorting and distribution operations etc. which accompany centralized service, and also to what degree the decrease in work

for the toll operators — resulting from their not having to receive the call orders — can be compensated by other work.

In most cases it is more than probable that a centralized call order service will not result in any financial saving.

Stockholm, December 1927.

Mauritz Agrell.



Making Register Connections by Means of Cord Circuit Finders.

By Prof. R. Trechcinsky, of the Warsaw Institute of Technology.

Since a register belonging to an automatic system is engaged only during the dialling of the number and the setting of the switches, and not during the conversation, the number of registers provided for a certain number of cord circuits is smaller than this latter and is determined by the existing traffic conditions. A disengaged register is connected to a certain cord circuit by means of a line finder. Either the cord circuits or the registers can be provided with line finders, these latter then being termed register finders or cord circuit finders respectively.

There are two alternatives for the connecting of a register to a cord circuit by means of a cord circuit finder. According to the first alternative, all the cord circuit finders belonging to disengaged registers are set in motion as soon as a call enters a given group, and do not stop until the right cord circuit has been found. In the second alternative, the cord circuit finders of all the disengaged registers — or of only a certain number belonging to the group in question — are actuated and successively come in contact with all the cord circuits within the group until under certain conditions a permanent contact with one of the cord circuits is established. This last alternative is dealt with in the following.

An example illustrating this principle is given in fig. 1, which shows this method as applied to the Ericsson automatic system — called 'Salme' on the diagram — and to junction lines between the same and the Strowger system of Siemens & Halske — called 'S & H' on the diagram.

A. With the Ericsson system, the registers are connected up by means of cord circuit finders according to the method in question and in the following manners, depending on the varying traffic conditions.

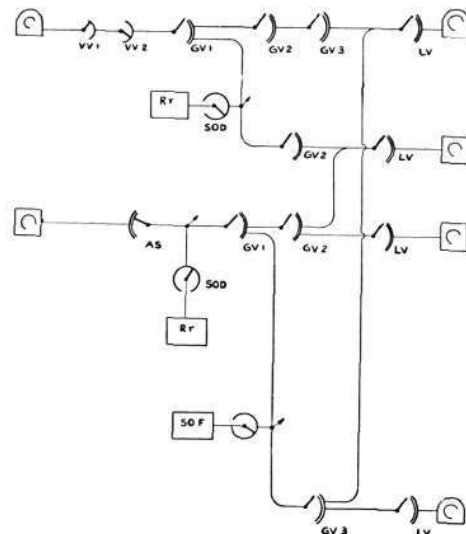
I. The number of cord circuits required for a certain group of subscribers' lines can be calculated with sufficient precision by means of the following formula:

$$x = 0.17 \times SM \times \sqrt[3]{C^2}$$

where S equals the number of calls per subscriber during the busy hour, M is the average gross length of calls in minutes and C is the number of subscribers' lines in the group.

Assuming that $S = 1.5$, $M = 2$ and $C = 500$ we obtain the following:

$$x = 0.17 \times 3 \times \sqrt[3]{500^2} = 32.$$



SALME
 S & H
 R 766

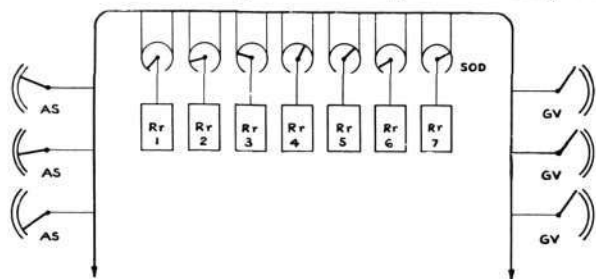
Fig. 1.

These cord circuits require a certain number of registers which is obtained by means of the formula:

$$R_n = 0.07 S \sqrt[3]{C^2} = 0.07 \times 1.5 \times \sqrt[3]{500^2} = 7.$$

Each register is provided with a sequence switch SOD adapted as a cord circuit finder and with thirty-six contact positions. During the rotary movement of this cord circuit finder, the register is successively connected up to the thirty-two cord circuits. The cord circuit finder stops as soon as it has found a disengaged cord circuit, the register being then connected to this cord circuit and to its line finder AS. When a call enters the five-hundreds group, only such idle

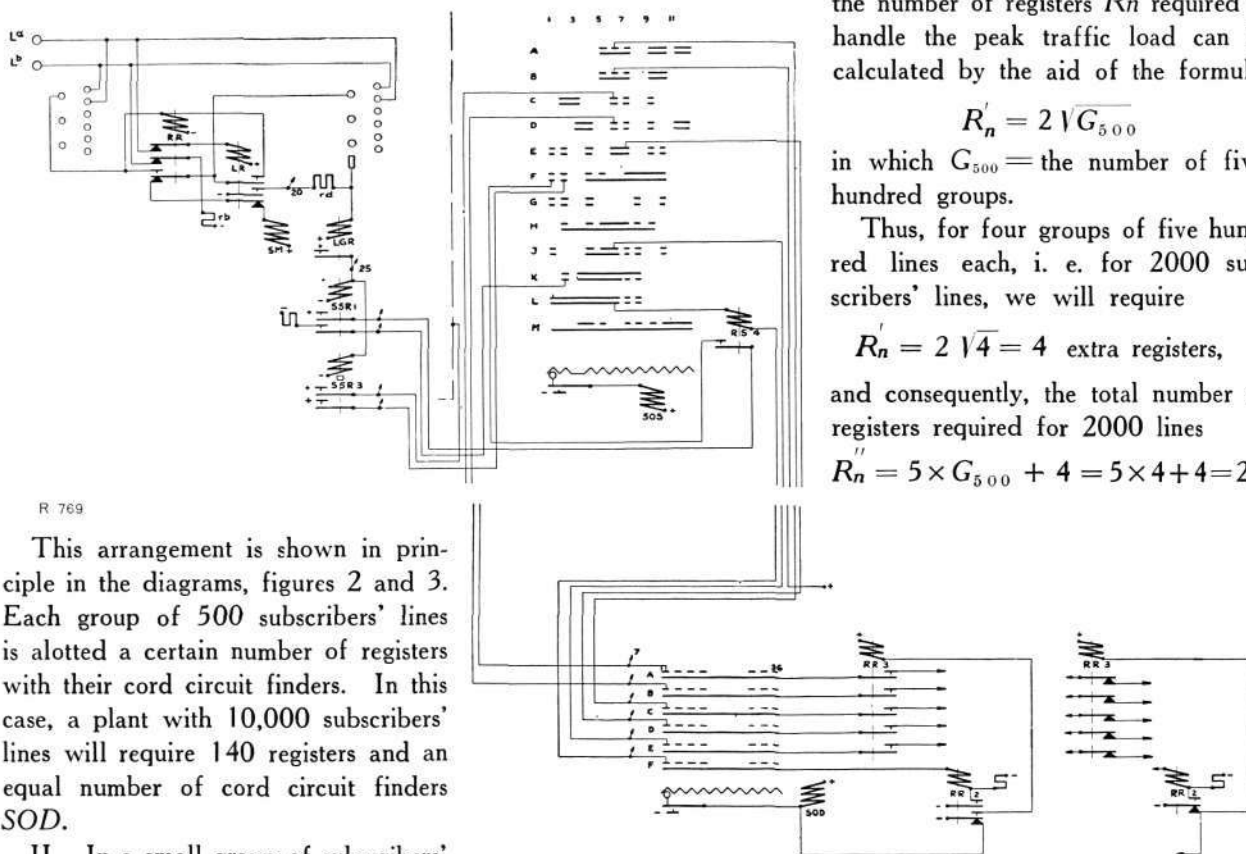
line finders as are connected to idle registers are actuated in order to find the calling subscriber's line. If all seven registers are simultaneously connected up to idle cord circuits, an incoming call entering this



R 767

Fig. 2.

group will consequently actuate seven line finders. After the register has completed its various functions, its cord circuit finder *SOD* continues to function until a new idle cord circuit which is not already connected to a register has been found, and so forth.



R 769

R 768

Fig. 3.

This arrangement is shown in principle in the diagrams, figures 2 and 3. Each group of 500 subscribers' lines is allotted a certain number of registers with their cord circuit finders. In this case, a plant with 10,000 subscribers' lines will require 140 registers and an equal number of cord circuit finders *SOD*.

II. In a small group of subscribers' lines, the peak traffic loads are more noticeable than in a large group on account of the varying demands of the subscribers on the service, due consideration having been taken to this fact in the above-mentioned formula. In order to lessen the influence of these peak loads on the required number of

registers, i. e. to lessen their number, the subscribers' lines are suitably brought together in larger groups with common registers.

In such a case the connection is made as indicated in the diagram shown in fig. 4.

Under identical conditions, the above formula gives a smaller number of registers for *one* group of 1000 lines:

$$R_n = 0.07 \times 1.5 \times \sqrt[3]{1000^2} = 10.$$

Assuming that the peak loads in a group of 1000 lines are of no practical importance, this result indicates that five registers is sufficient to handle the normal traffic within each five-hundred group. The two registers required — according to the previous calculation — for an additional five-hundred group can therefore be considered necessary to handle the above-mentioned peak traffic loads. If several five-hundred groups are assembled so as to form one large group,

the number of registers R_n required to handle the peak traffic load can be calculated by the aid of the formula:

$$R'_n = 2 \sqrt{G_{500}}$$

in which G_{500} = the number of five-hundred groups.

Thus, for four groups of five hundred lines each, i. e. for 2000 subscribers' lines, we will require

$$R'_n = 2 \sqrt{4} = 4 \text{ extra registers,}$$

and consequently, the total number of registers required for 2000 lines

$$R''_n = 5 \times G_{500} + 4 = 5 \times 4 + 4 = 24.$$

Since the cord circuit finders — as has already been stated — have thirty-six contact positions, it is possible — in the present case — for a register to make a connection to only $\frac{36}{4} = 9$ of the thirty-two lines

in each of the four sets of cord circuits for the four groups.

In order to prevent all the registers from being connected up to the same set of thirty-two cord circuits, thus depriving the other three sets of the necessary register connections, the number of registers which can be connected to the same set of cord circuits is limited. An arrangement of this kind is shown in fig. 5, in which the number of registers which can be connected to one set of cord circuits is limited to four. Each cord circuit is provided with an indicator relay *MR* and each set of thirty-two cord circuits with a similar relay *GMR* and three control relays *KR*. When relay *GMR* energizes, this indicates that the entire set of cord circuits is busy. This occurs when any four of the relays *MR* are energized, i. e. as soon as four registers have been connected to the same. Thus, out of twenty-four registers, only sixteen are

to provide some arrangement whereby a disengaged register will obtain a connection with the set which for the moment has the least number of registers. This

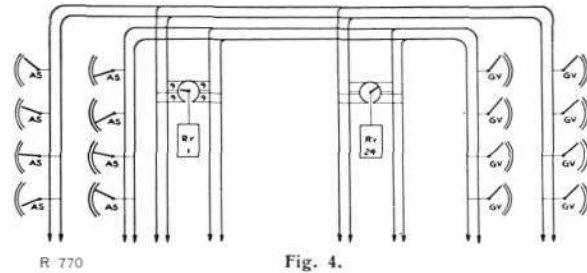


Fig. 4.

function is filled by the control relays *KR*. A set with no registers is indicated by the relay KR_{10} , one connected register by KR_{11} and two connected registers by KR_{12} . In the above example, therefore, sets 1, 2 and 3 are indicated as not fully occupied by means of the relay *GMR* only, all the control relays

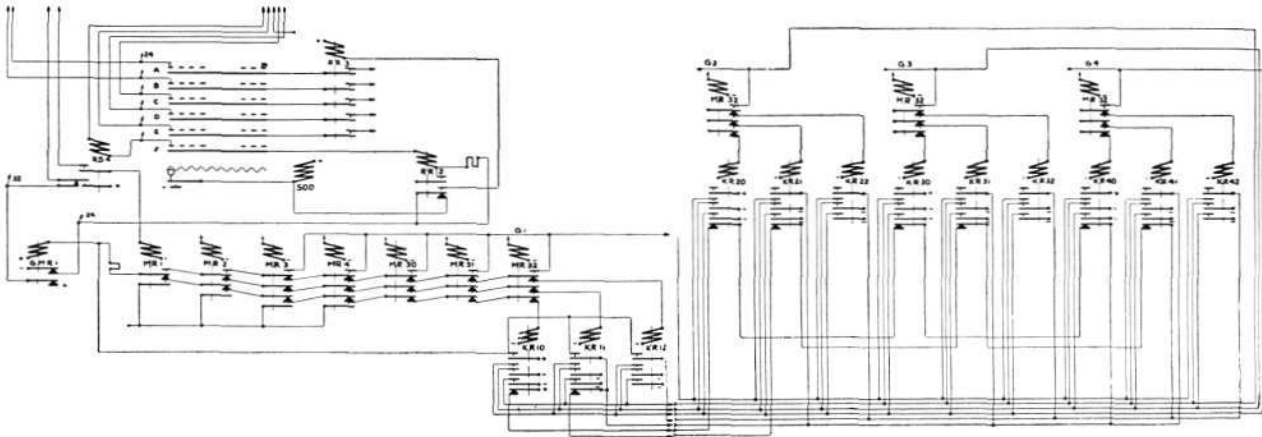


Fig. 5.

connected up, the other eight remaining in their rest positions. As soon as one of the four connected registers begins to function — resulting in the setting of the sequence switch of the cord circuit in question from position 1 to position 2 — the indicator relay *MR* is de-energized. This causes relay *GMR* also to de-energize, upon which the cord circuit finds *SOD* of all the disengaged registers are set in motion for the purpose of finding a disengaged cord circuit in this set.

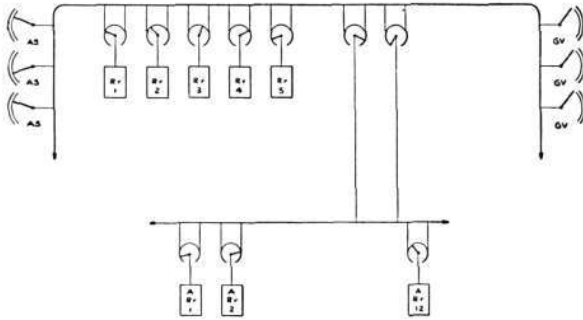
Even though the traffic may be heavy, it is possible that none of the cord circuit sets are indicated as busy, for instance if three sets occupy three registers each and the fourth set only one register. It might now be possible for the first disengaged register to connect itself to a line in a set that already has three registers at its disposal, the fourth set still having but one register at its disposal. For this reason, it is necessary

for this set of cord circuits remaining de-energized. In the fourth set, on the other hand, KR_{11} is energized, causing negative to be connected to the indicator lines *G1*, *G2* and *G3* of the first, second and third sets respectively. These three sets of cord circuits with three registers each are now indicated as occupied, causing the next disengaged register to be connected to the fourth set instead of to one of the other three.

Still another example is given by way of illustration. If the cord circuit set no. 2 had only two connected registers at its disposal, KR_{22} would also energize, and the line *G4* be connected to negative. However, this connecting takes place only when this set of cord circuits has three connected registers at its disposal, and consequently it does not influence the fourth. Since relay KR_{11} is energized, the circuit from positive to all the relays KR_{12} , KR_{22} , KR_{32} and KR_{42} is broken at contact *a*. As a result, relay

GMR_2 is not short-circuited, but remains energized, causing set no. 2 to be indicated as occupied.

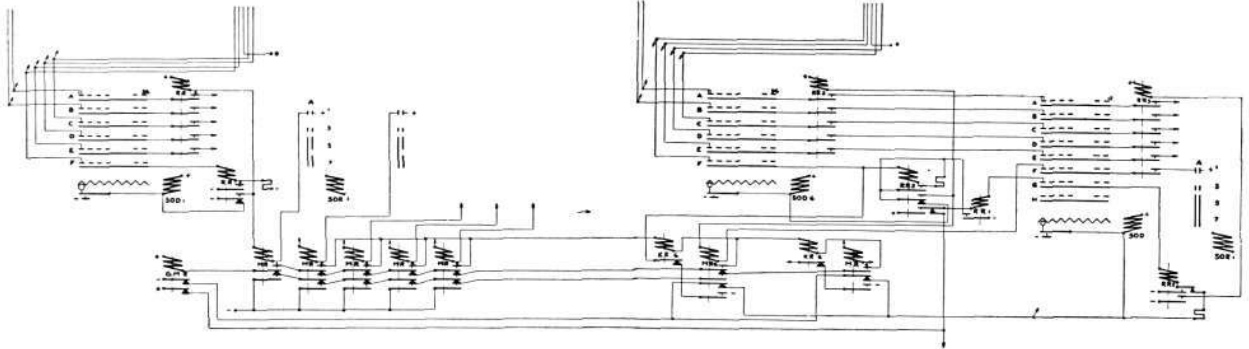
If each of the sets nos. 1, 2 and 3 have only two



R 773

Fig. 6.

connected registers at their disposal, the relays GMR_1 , GMR_2 and GMR_3 are energized over KR_{12} , KR_{22} and KR_{32} respectively, since positive has been disconnected at contact a in KR_{11} . This condition will arise even if the fourth set of cord circuits has no



R 771

Fig. 7.

connected register at all at its disposal. In such a case the first three sets are indicated as occupied and the next disengaged register will be connected to set no. 4.

Since each register, as already mentioned, can only be connected to a certain limited number (9) of cord circuits, it might even happen — with intense traffic — that these cord circuits are all busy when the register becomes disengaged. Such a condition would unnecessarily delay or even paralyze the functioning of the cord circuit finders. In order to increase the chances of the register finding a disengaged cord circuit among the nine of the set, it is necessary to increase their number according to the formula

$$x' = \frac{x \times G_{500}}{R_n} \times \left(\sqrt[3]{\frac{x \times G_{500}}{R_{kn}}} - 1 \right)$$

where R_{kn} is the number of contact positions of the

cord circuit finder. After inserting the values for this special case we get

$$x' = \frac{32 \times 4}{24} \times \left(\sqrt[3]{\frac{32 \times 4}{36}} - 1 \right) = 3.$$

The number (x_s) of cord circuits is therefore

$$X_s = x + x' = 32 + 3 = 35.$$

With systems where an insufficient number of switching devices is responsible for lost calls or for the giving of a premature busy signal, the necessary increase in the number of cord circuits is much greater and cannot be figured with the aid of the foregoing formula, as it sometimes can amount to three times as much. In the present case, the saving achieved through the reduced number of registers is ample to cover the increase in the number of cord circuits. At the same time, it illustrates the importance of using good judgement in the choice of ways and means to reduce the first cost. They can often lead to the very opposite.

Another solution intended to eliminate the above-mentioned drawbacks is shown in the diagram in fig. 6.

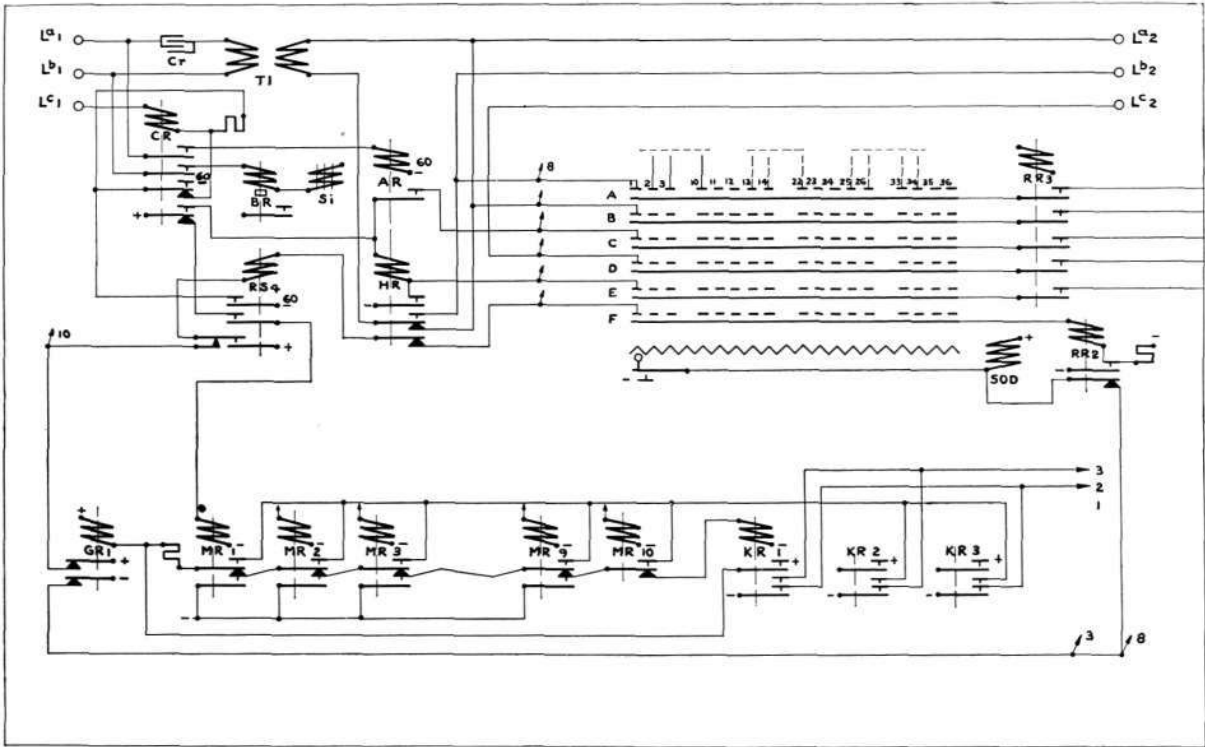
In accordance with the previously given method of calculation, each group of five hundred lines is provided with five registers which can be connected to any one of the cord circuits in the same set. The excess traffic is taken care of by registers which are common for several sets of cord circuits and which can be connected to every line in all the sets by means of double cord circuit finders. As already mentioned, two registers per group are required for this purpose. Thus, an exchange with 3000 subscribers' lines, i. e. six five-hundred groups and six sets of cord circuits, would require twelve additional registers. In order to reduce this number as much as possible, two register lines per group or $2 \times 6 = 12$ lines and twelve cord circuit finders are reserved for this purpose.

These lines connect the respective finders with a group of common registers ARr , whose number (R_n''') is calculated by the aid of the formula

$$R_n''' = 0.44 \times S \times \sqrt[3]{x^2} = 0.44 \times 1.5 \times \sqrt[3]{x^2}$$

which — under the former conditions — gives six registers, or a total of thirty-six instead of forty-two. According to this principle, an exchange of 10,000 lines will require 120 registers and 160 cord circuit finders. The schematic diagram for such a plant is shown in fig. 7. The control relays KR prevent the connecting of the registers ARr to a set of cord

desired number, the register must be ready to start functioning and only those lines — in a ten cord circuit set — to which a register is already connected shall be indicated as occupied. These are the three above-mentioned registers and it is only between these three that a first group selector in an S & H exchange can choose. When the selecting process is finished, this cord circuit is indicated as occupied. As soon as the connection between the subscribers is completed, the register leaves this cord circuit and seeks another idle one to which no register has yet been connected.



R 774

Fig. 8.

circuits which already has five registers at its disposal, i. e. when the set in question is fully occupied.

B. Traffic from the Siemens & Halske automatic Strowger system to the Ericsson automatic system.

I. This connection passes over the first group selector of the S & H exchange, by means of which — with a 5-digit system — the desired ten-thousand group is selected. The first group selector hunts for the first idle cord circuit in a set of ten. The required number of registers for a set of ten cord circuits is obtained from the following:

$$R_n = 0.44 \times S \times \sqrt[3]{x^2} = 0.44 \times 1.5 \times \sqrt[3]{10^2} = 3.$$

Since an S & H exchange subscriber can immediately dial the second and remaining digits of the

II. A set of ten cord circuits seems to be rather insufficient. With a standard construction of cord circuit finders it is possible to group together three ten-circuit sets, these thirty cord circuits then being connected to common registers. The necessary number of common registers will then be

$$R_n''' = 0.44 \times 1.5 \times \sqrt[3]{30^2} = 7$$

instead of nine. Such a connection is shown in the diagram in fig. 8. Two registers for each set of ten cord circuits is maximum, the seventh register being held in reserve to handle the excess traffic loads in the various sets, the right of precedence being given by means of the relay KR to that set of cord circuits which for the moment has the least number of connected registers at its disposal.

Time Recording.

Paper read by Mr. H. Josephsson at the regular fall meeting of the Swedish Cotten Mfrs. Association held at Borås December 10, 1927.

In the same measure as working hours have become shorter and wages higher, so also has it become more and more necessary to replace the rather primitive methods of bygone days with other and more efficient ones for supervising the times of arrival and departure of the employees.

Probably the most primitive method to have found application was to close the factory gates at the beginning of working hours so that those workers who arrived late were forced to return home. Formerly, when working hours were longer and wages lower than they are now, a system of this sort might be tolerated; at the present day, however, it is altogether condemnable. Already the loss of a few minutes time at the beginning of the day is expensive and to be avoided as far as possible, but to willingly forego a half or probably a whole days work is much worse. The excuse that the worker receives no pay for this time most certainly does not justify the adoption of such a system, since it is the factory itself that suffers most from a reduced output, less effective utilization of machines etc.

Notwithstanding, the method of closing the factory gates is still to be found among some of our smaller industrial plants. The day can not be far distant, however, when it will be substituted by something better; if not before, so at least when the owner awakens to the fact that this system, which seems so simple and cheap, in reality is very costly.

Another system — also condemnable, but more generally used than the one just mentioned — is the well known arrangement with numbered brass checks.

The check system can be used in a number of ways. The most common is to let the workers on their arrival hang their checks up in a cabinet placed at the factory entrance, the cabinet being closed and locked when the whistle blows. Those workers who arrive late must hand in their checks to the time-keeper, who writes down their numbers. This system has many disadvantages, one of them being all the writing which it occasions and in which mistakes may occur; another disadvantage is the fact that this method gives no information as to the exact length of the working time. Also, the worker is at the mercy of any ill feeling on the part of the time-keeper and may be subjected to unfair treatment.

It is now more than twenty years since time clocks were introduced in an attempt to remedy these various disadvantages. One or more such time clocks by means of which a record of the workers' times of arrival and departure was obtained on a list or card were set up within a factory, the workers themselves making this

record by punching the clock on their arrival at and departure from the factory. The introduction of time punching constituted a considerable advance towards the ultimate goal — an accurate and absolutely impartial recording system.

The first apparatus that came into use were for the



R 786 Time Recorder and Card Files for Registration of Times of Arrival and Departure.

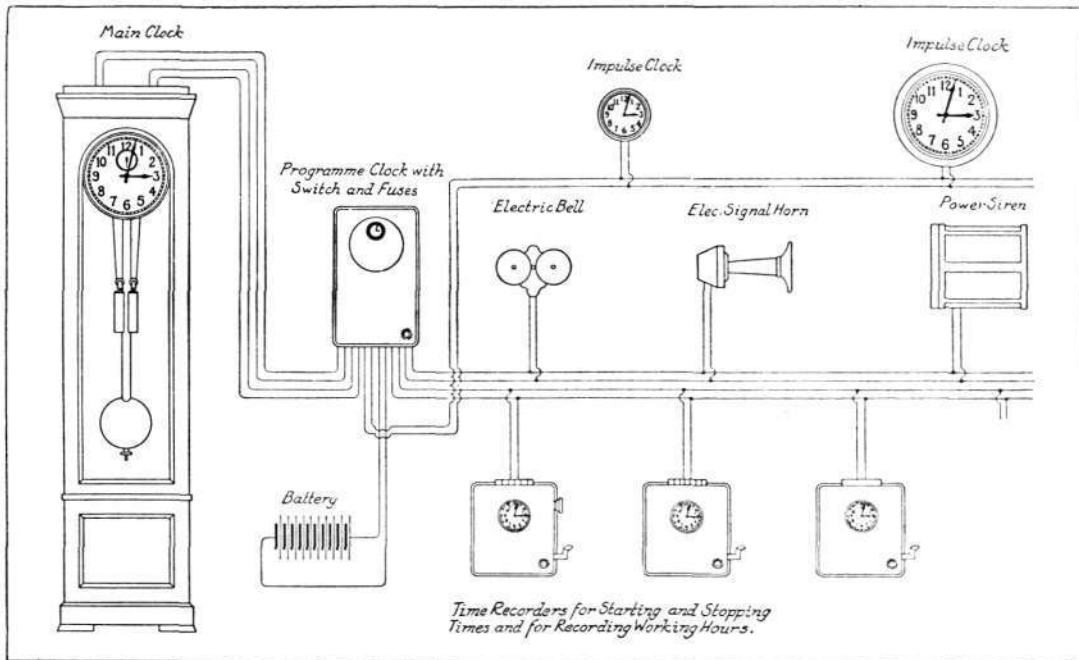
punching of lists and were so constructed that the worker — by the manipulation of a lever handle — stamped the time in a certain column on the list.

A reversing device permitted the apparatus to be set for the stamping of either time of arrival or time of departure.

Before making a closer investigation of the developments in this branch, we will make an abstract of the various requirements which, from a point of view of organisation, must be met by the system which is to provide an absolutely satisfactory solution of the time recording problem.

The above-mentioned time clocks for recording the time on lists were equipped — this being the next step in their development — with bi-coloured inked ribbons with an automatic switching device arranged so that tardiness as well as time off was stamped in red, other time figures being stamped in blue, an arrangement which facilitated the inspection and calculation of the working times.

The next step was to introduce cards instead of the previously mentioned lists so that every worker had his own card. In this way all the various working times for a worker during a one week period were grouped



Schematic Diagram for Time Recording Plant with Signalling Devices.

In the first place the system shall function with perfect accuracy. Since each worker's time as well as eventual irregularities, such as tardiness, time off, overtime etc., are based on the data obtained by means of the time clock, it is an imperative necessity that these data are absolutely correct and do not become incorrect and misleading through any fault in the functioning of the time clock.

Further, it shall be required that the punching can be done quickly and simply so as to eliminate all mistakes. The stamped figures shall be arranged so as to permit the quick and accurate calculation of required data, such as working time, etc., for the pay roll as well as for statistical purposes. In addition, the time clock shall be so constructed as to permit the recording of time of arrival as well as time of departure, time off or overtime, without having to be 'reset' either by the worker himself or by the shop foreman.

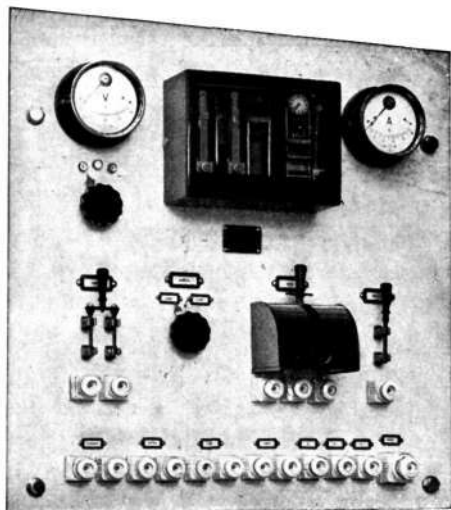
together on a single card, this latter being subsequently used to figure out the total working time and also — in many cases — the wages.

In the beginning, it was customary to place the time clocks close to the factory entrance; now, however, it is becoming more and more customary to place them in the respective shop departments. In the former case more or less time must elapse between the punching of the clock and the moment when work can actually begin at the workbench or machine, these being often at quite some distance from the factory entrance.

The aim, therefore, is to place the time clock as near as possible to the spot where the work is actually carried on and to let the stamping of the cards take place — wherever practicable — after the completion of various preliminaries, such as change of clothing, etc. In this way the recorded time will correspond to the actual working time. If, when the punching takes place at

the factory entrance, an average of five minutes is lost, this means ten minutes per man and day, which, with a force of 200 men, will amount to a loss of 10,000 working hours per year.

When such a tremendous loss of time can ensue merely from the unsuitable placing of the time clock, the importance of paying close attention to this detail is apparent enough without having to be additionally accentuated.



Switchboard for a Large Time Recording Plant.

The workers do not suffer any inconvenience by having to record their time near the spot where their work is accomplished instead of at the factory entrance, but — as already pointed out — this method can be of the utmost importance to the company. In this connection it may be of interest to point out that the replacement of the old check system by a modern time recording system is of just as great advantage to the workers as to the employer. It must quite naturally be equally satisfactory to both parties that the time recording takes place without friction and in such a manner that all chance of unfairness will be eliminated. With a system of this kind every worker becomes his own timekeeper and there is no occasion for disputes.

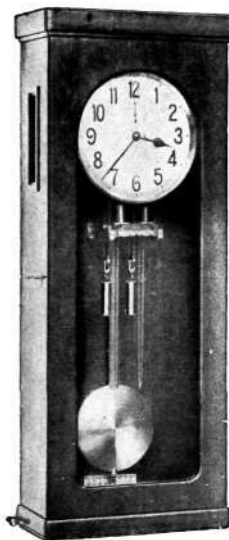
As a result, the use of time clocks is being more and more appreciated by the workers themselves and there are several instances when, during negotiations between labour and employers, the workers have come with direct proposals for the introduction of time recording in the factory where they were employed.

We will now return to the time clocks themselves and their construction, and see to what extent existing types meet the enumerated requirements.

To begin with, it is rather interesting to follow the

development of the time clock with reference to its reliability.

The first time clocks were pendulum-clocks combined with a mechanism which permitted the recording of the time. Such time clocks are still being manufactured, in spite of their many disadvantages, one of these being the serious strain to which the clock works — always more or less delicate — are subjected by the constant jarring resulting from the recurrent punching. Another disadvantage is that in a factory in which a number of time clocks are installed, it is extremely difficult to make them all keep exactly the same time, this — in turn — giving rise to other disadvantages. For instance, let us assume that a whistle or siren sounds when work is to start. The punching of the clock should have taken place before the whistle blows. If one of the time clocks goes say two minutes ahead of the one by which the whistle is blown, the condition can arise that the workers who punch this clock *before the whistle blows* — consequently *in time* — still may have a time card which shows a tardy arrival.



Main Clock with Automatic Electric Winding.

In order to remedy these two disadvantages — the damage to the clock-works and the difficulty in making several clocks run exactly alike — a system with central control was finally devised.

This system is provided with but one real clock with clock-works, a so-called main or control clock. Electric impulses, which actuate electromagnets in the various time recording instruments connected to the system, are sent out from the main clock at the rate of one per minute. The time recorders are not regular clocks with delicate clock-works but instruments pro-

vided with a simple but sturdy stamping device and directly actuated by the impulses from the main clock.

The desired uniformity in the time indicated by the various recorders is also obtained, since there is but one set of clock-works.

It has been claimed that electric time recording systems are combined with a certain degree of uncertainty due to the danger of broken circuits and line trouble between the main clock and the time recorders. In actual practice, however, this danger has been found to be negligible, as trouble of this kind very rarely occurs. Also, electric time recording systems are becoming increasingly popular.

With reference to the speed and accuracy with which the recording operation is performed, it is characteristic for the majority of systems that the time card must be inserted in the recording apparatus with the reverse side turned outwards, in some cases upside down as well. This must be considered as a decided disadvantage, partly because the time card — if the worker forgets to turn it around — is easily stamped on the wrong side.



Impulse Clock.

The entering of the recorded time in the correct column usually takes place in the following manner. That portion of the card which will receive the stamped time records is divided into six vertical columns and seven horizontal spaces. These latter are one for each day of the week, three vertical columns being for arrivals and three for departures. The vertical setting is automatic in that on each consecutive day the card is stamped in the space below that of the preceding day. For the horizontal setting, the apparatus is adjusted by hand so that the first record in the morning is stamped

in the first column to the left. Before stamping the second time record for the day, the apparatus is set so that the time record shall come in the second column, and so forth.

In some concerns, this setting of the apparatus is done by the worker himself, but more generally by the foreman. In the former case numerous mistakes occur, while in the latter it is necessary that the foreman pay close attention to the setting of the apparatus at the



Automatic Time Recorder.

right times. If a worker is granted time off, the foreman must accompany the worker to the time recorder in order that the worker be able to stamp his card, and when he returns to work the foreman's presence is again necessary for the stamping of the card. This condition holds good also with regard to overtime. In those cases when the work is carried on in shifts the disadvantages are even greater, since it can occur that time cards must be stamped alternately for arrival and departure in the same time clock.

The ideal time recorder would naturally be one with automatic vertical as well as horizontal setting.

It was just such an apparatus that L. M. Ericsson set out to design when it was decided, some ten years ago, to take up the manufacture of time recording instruments. The construction was completed and approved a few years ago, enabling L. M. Ericsson to place a full automatic time recording system on the market.

The problem of automatic setting in a horizontal as well as a vertical direction had been solved in a both simple and efficient manner. The time card was divided into seven vertical columns and eight horizontal spacings, the former for the seven days of the week and the latter for four sets each of times of arrival and of departure. The horizontal setting takes place automatically at midnight. The vertical setting is taken care of by means of a hole which is punched in the card simultaneously with the stamping of the time,

this hole determining the position of the card for the next stamping.

The result of this arrangement is that each card is handled individually by the time recorder. Thus, the same recorder can stamp a card 'In' the moment after



Electric Signal Horn.

having stamped another one 'Out' or a third for 'Time off', etc. Also, the manner in which the card is spaced gives such a clear arrangement of the time records that the calculation of the working time is greatly facilitated.

The recording apparatus constructed for coöperation with the main clock are enclosed in a casing of lacquered sheet iron and are comparatively small, requiring much less wall space than the old fashioned time clocks. The face of the recorder is provided with a clock dial, an indicator behind a small aperture showing whether the inked ribbon is set for blue or red stamping. The colour shifting device is constructed so that the shifting of the ribbon on Saturdays can take place at a different time than on the other week days.

These recorders differ from older types also in that the card is stamped on the front side without having to be reversed during the stamping operation.

The card files are made in sections, each section for twenty-five time cards; thus the files can easily be extended for twenty-five cards at the time.

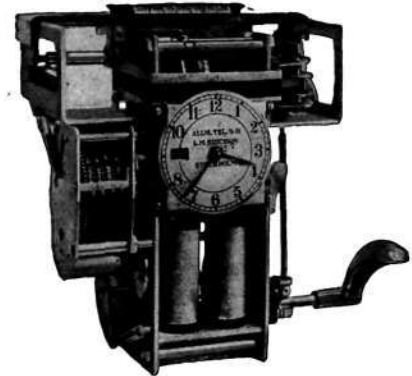
In addition to the above described time recorders, apparatus for actuating automatic signal devices at the beginning and end of working hours, secondary or impulse clocks for indicating the time, time recorders for piece work and watchmen's tell-tale clocks can be connected to the main clock.

The automatic signal device consists of either an impulse signal clock or a program clock. It is possible to set the signals for different Saturday times with either the one or the other of these devices.

Signals are given by means of electric bells, horns or sirens, these devices being adjusted to conform with the desired volume of sound.

The impulse clocks are driven by means of minute-

impulses, in the same manner as the time recorders. The works are of a simple and very sturdy construction, and consist of an electromagnet placed between two permanent magnets and provided with two arma-



Automatic Time Recorder with Cover Removed.

tures which are actuated by the current impulses from the main clock and which drive the hands with a perfectly silent movement. The movement is transferred from the driving magnet to the hands of the clock by means of a worm gear, thus doing away with the large number of gear wheels which are usually to be found in clock works and ensuring a smooth movement in spite of the generously proportioned bearings.

The number of time recorders and impulse clocks which can be actuated by the same main clock is practically unlimited, although one or more relays are necessary with larger numbers.

The standard types are designed for 24-volt direct current, power being obtained from a storage battery.

The charging instruments, meters, fuses and program clock — if such a one is used — for the entire plant are all mounted on a common switchboard.

From what has here been said, it is apparent that a modern time recording plant functions with such accuracy that it must be a most effective aid to the employer, whose chief aim it always is to operate his factory in the most efficient manner.

The accompanying table shows how long time it takes for a time recording plant for a factory with two-hundred employees to pay for itself through time saved.

The first cost is assumed to be 3500 Swedish



The Clock in the Tower is Actuated by the Same Main Clock as Some Ten Time Recorders.

L. M. Ericsson

crowns and the value of the time saved to be one crown per hour and employee.

Calculated time saved in minutes per day & employee	Value per year at 1 crown per hour	First cost of time recording plant calculated at 3500 crowns; with 200 employees this amount is saved in
1	1000 crowns	3 1/2 years
2	2000 »	2 »
3	3000 »	1 1/2 »
4	4000 »	1 »
5	5000 »	3/4 »

There certainly is no exaggeration in the assumption that five minutes per man and day are lost in a factory that cannot boast an efficient time recording system.

Moreover, we must not forget that the values given in the table do not include anything except the direct loss or saving in time. The indirect gains which accompany the use of modern time recording methods must also be taken into consideration, and these are often of no small importance. We allude to the fore-

mens time, which can be put to better use than to keep track of the arrivals and departures of the employees, to the elimination of time disputes between the foremen and the workers, to the absolutely reliable statistical information obtained, etc.

In this connection it may be well to point out that it is of no less importance to keep accurate records of time used on piece work than for regular time work. Here we are up against the fact that shorter working hours mean reduced production. The total cost of production is not diminished, consequently it becomes greater per manufactured unit or figured in percentage of the value of the article.

In addition to the manufacture of time recording apparatus, L. M. Ericsson executes the work of installation, the plants being delivered under the company's guarantee. Also, L. M. Ericsson is in a position to prepare complete projects for time recording installations, special attention being given existing local conditions in order to obtain the highest possible degree of efficiency. Industrial concerns who are desirous of obtaining more detailed information or advice on this subject are requested to apply at our nearest agency, a step which incurs no obligations but may lead to most profitable results.



During What Length of Time and with how Large a Capacity shall a Manual Exchange be Retained in an Otherwise Automatic Telephone Net?

There is no doubt but that it is practically impossible to answer this question in a general way, since each separate case has its own individual and local factors, which must be taken into consideration and which are of the utmost importance.

These factors — among others — are as follows:

1. The desire to retain P. B. X. and other subscribers with a heavy outgoing traffic at the manual exchange.
2. The age of the manual exchange.
3. The possibilities for obtaining the capital required for a sufficiently speedy automatization.
4. The restriction of the cost of junction traffic between manual and automatic subscribers and the possibility of installing the equipment and switchboards necessary for the junction traffic.
5. The possibility of using the special junction traffic equipment for subsequent automatic traffic.
6. The growth of the net.
7. The number of subscribers which can be simultaneously cut over from the manual to the automatic exchanges.

In order the better to illustrate the viewpoints to which this article desires to call special attention, the following fictitious example from a city with a manual telephone exchange will be treated.

An approximate layout of the city is given in fig. 1.

All of the city's telephone subscribers are at the beginning of 1928 connected to a manual exchange in the centre of the city. The exchange has a capacity of 54 000 lines, the present number of subscribers being 44 000. The exchange comprises 320 local positions.

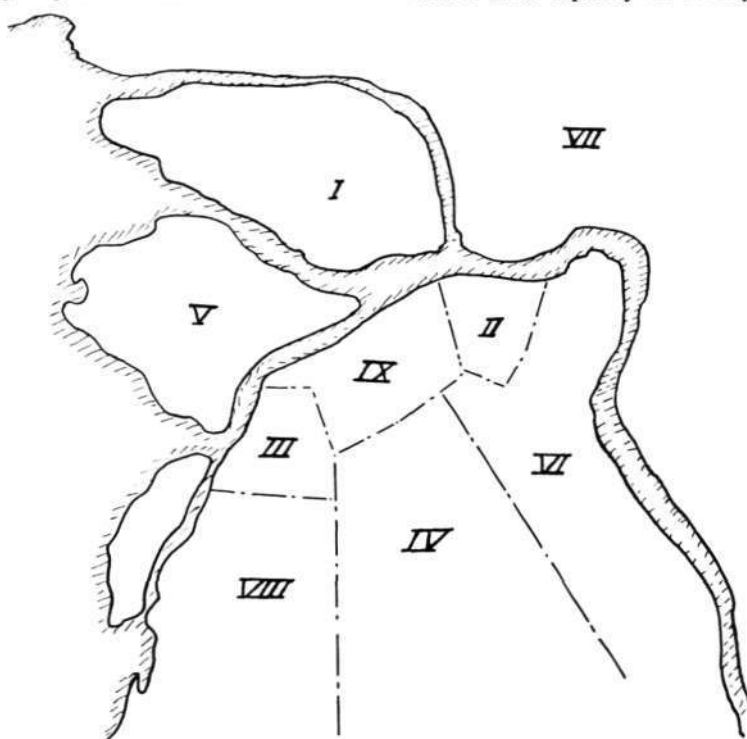
It is taken for granted that automatic exchanges will be provided for handling the future development of the net. For projecting these exchanges, the city is divided into nine sections (see fig. 1), each section with a final capacity of twenty to forty thousand subscribers' lines.

The manual exchange has recently been completely renovated and modernized with respect to all the relays, cables and switchboards, so that the telephone administration is desirous of retaining the same as long as possible.

The call frequency is 1.5 per subscriber during the busy hour. Of this number, 1.1 calls result in conversations with a net average duration of two minutes, 0.4 calls being lost on account of busy subscribers' lines.

The requirements and formulae necessary for the analysis of the problem in hand are given in the following.

The growth of the number of subscribers in the city is studied by means of the graph in fig. 2. The straight line represents an increase of 6000 subscribers per annum.



R 837

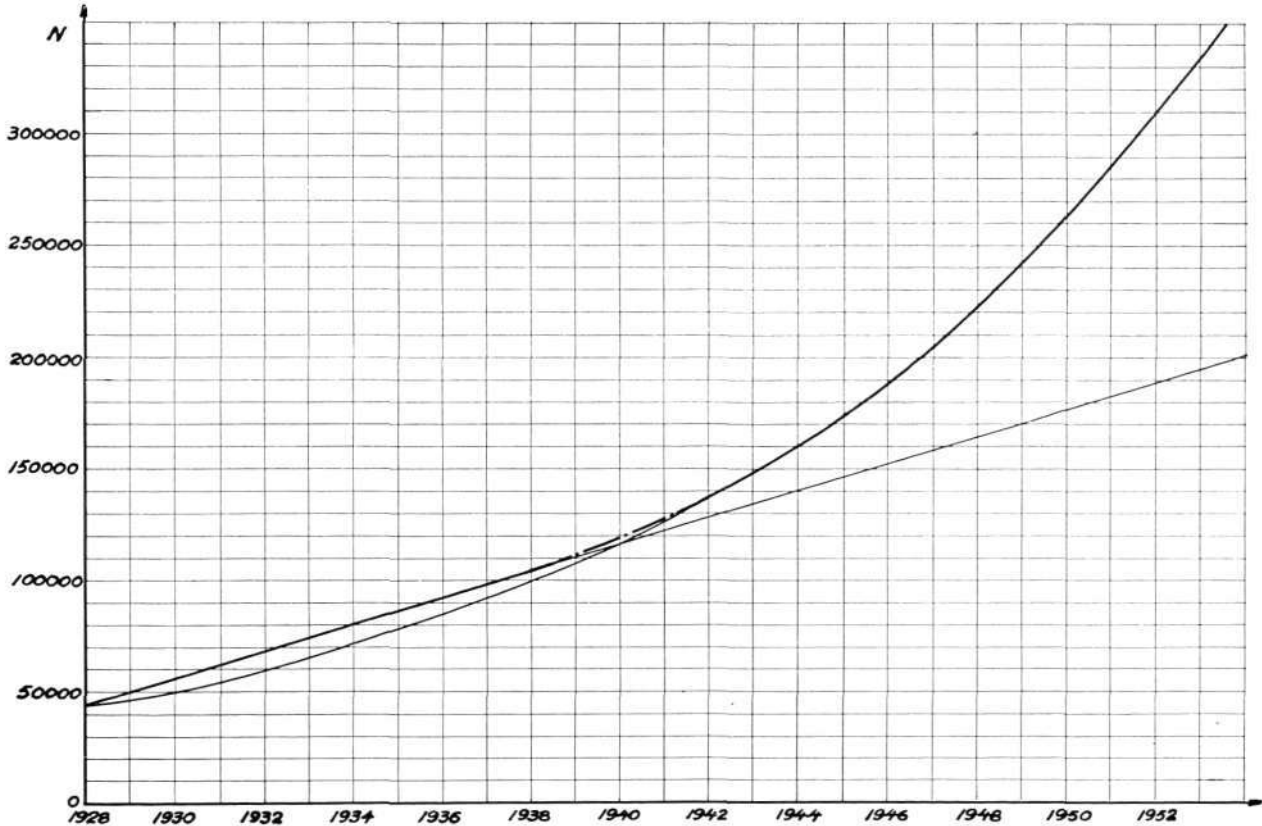
Fig. 1.

The full-drawn curve represents an increase of 50 % in the number of subscribers during a five year period. This curve probably represents the actual growth more accurately, but — in order to simplify the proposition — the increase curve is assumed to coincide with the straight line until the beginning of the year 1938, after which it follows the dot-and-dash line until it meets and coincides with the full-drawn curved line.

available through the discontinuance of a subscription cannot immediately be given to a new subscriber. This is taken into consideration in the following formulae.

By factor of interest is meant that number with which the traffic, divided in proportion to the number of subscribers, shall be multiplied in order to obtain the actual traffic in a given direction.

For traffic from *automatic* to *manual*, a factor of interest of 1.23 is assumed, while for traffic from



R 838

Fig. 2.

In the following diagrams the years are denoted in a corresponding manner.

A call to an engaged subscriber is assumed to take $\frac{1}{10}$ of a minute.

For the junction traffic from the manual exchange to the automatic exchanges the switching devices and junction lines are assumed to be engaged during 3 minutes for the establishing and disconnecting of one connection.

The corresponding time for the traffic from the automatic exchanges to the manual exchange is assumed to be .125 minutes.

In a well planned telephone net, at least 10 % of the total capacity of the exchanges should always be in reserve, since a telephone number which has become

manual to *automatic* the corresponding value is assumed to be .9, the traffic from the outlying districts to the more central parts of the city being proportionately greater than that in the opposite direction.

The capacity of the manual exchange is represented by M , that of the combined automatic exchanges by A , while the total capacity of the entire net is represented by N .

The traffic from *manual* to *automatic* is assumed to be TMA speaking minutes and the traffic from *automatic* to *manual* TAM speaking minutes.

For the manual subscribers, the number of speaking minutes per subscriber during the busy hour is

$$1.1 (2 + .3) + .4 (.1 + .3) = 2.69,$$

the number of speaking minutes for all the manual subscribers being

$$.9 \times M \times 2.69;$$

while with proportional division

$$\frac{A}{A+M} \times .9 \times M \times 2.69$$

speaking minutes go to the automatic exchanges.

Therefore:

$$TMA = .9 \times \frac{A}{A+M} \times .9 \times M \times 2.69$$

or

$$TMA = 2.18 \times \frac{AM}{A+M}.$$

Analogously, we obtain

$$TAM = 2.69 \times \frac{AM}{A+M}.$$

Further,

$$N = A + M.$$

Each operator at the manual exchange is allotted a certain number of jacks for the junction traffic to the automatic exchanges. A certain number of these are individual for a certain operator and consequently need not be provided with test circuits; the remainder, on the other hand, are multiplied over several positions, wherefore testing is necessary.

In this manner each operator is allotted K junction lines, on an average. We figure here with 31.2 useful minutes per junction line during the busy hour, which — with 320 operators — gives us

$$K = \frac{2.18 \times AM}{31.2 \times 320 (A+M)} \text{ or}$$

$$K = 2.18 \times \frac{M}{10000} \times \frac{A}{A+M}.$$

We can assume ten B-operators (with key sets) per two hundred lines for the traffic from *manual* to *automatic*. (How we arrive at this figure is of no interest in this connection.) The number of B-operators is therefore

$$B = K \times 320 \times \frac{10}{200} \text{ or}$$

$$B = 16K.$$

The traffic from *automatic* to *manual* is assumed to pass over connectors at the manual exchange. If we assume 108 500-groups for the manual exchange we obtain

$$\frac{TAM}{108} = 2.49 \times \frac{M}{100} \times \frac{A}{A+M}$$

speaking minutes per group.

The number of connectors LV is obtained by means of Erlang's curves (see *The L. M. Ericsson Review*, Vol. I, nos 5—6: "Calculation of the Required Number of Switches for Automatic Telephone Exchanges") with an assumed grade of service of 3 ‰.

As a second alternative, it is assumed that the traffic from *automatic* to *manual* is handled over call indicator positions by operators at the manual exchange. The number of operators LAT is determined on the basis that each operator can handle 600 calls during the busy hour.

The number of incoming calls during the busy hour is

$$1.66 \times \frac{AM}{A+M}$$

and

$$LAT = \frac{1.66}{600} \times \frac{AM}{A+M} = 2.77 \times \frac{M}{1000} \times \frac{A}{A+M}$$

In the following table I the values of K , B , LV , LAT , A and N are based on the assumption that the manual exchange has a constant capacity of 54 000 lines.

An auxiliary factor $= f \frac{A}{A+M}$ has been used for calculating the values in the table.

The corresponding curves for K , B , LV and LAT are plotted in fig. 3 with the total number of subscribers N as an independent variable, therefore

$$\begin{aligned} K &= F(N) \\ B &= F(N) \\ LV &= F(N) \\ LAT &= F(N) \end{aligned}$$

We see from both table I and fig. 3 that if the manual exchange is retained at a constant capacity, the required number of switching units and positions increases with the total number of subscribers.

Already with an equal number (54 000) of subscribers at the manual and automatic exchanges, $94 + 75 = 169$ positions are required for the junction traffic if this traffic is handled by operators in both directions.

With twice as many (108 000) automatic as manual subscribers (54 000), the required number of positions for the junction traffic is $126 + 100 = 226$, and with three times as many automatic as manual subscribers $113 + 142 = 255$ positions.

Table I.

$f = \frac{A}{A+M}$	$A = \frac{54000}{\frac{1}{f} - 1}$	$N = 54000 + A$	$K = 11.77 f$	$B = 188.3 f$	Speaking minutes for calculating LV $1345 \times f$	LV	$LAT = 149.6 \times f$
$\frac{1}{20}$	2800	56800	0.6	9.4	67	5	7.5
$\frac{1}{10}$	6000	60000	1.2	19	135	7.2	15
$\frac{1}{5}$	13500	67500	2.4	38	269	11	30
$\frac{1}{3}$	27000	81000	3.9	63	448	16	50
0.4	36000	90000	4.7	75	538	17	60
0.5	54000	108000	5.9	94	673	21	75
0.6	81000	135000	7.1	113	807	25	90
0.7	126000	180000	8.2	132	942	29	105
0.8	216000	270000	9.4	151	1076	32	120
0.9	486000	540000	10.6	170	1211	36	135
1	∞	∞	11.8	188	1345	40	150

Thus, it is plain that in the long run it cannot be economical to retain the manual exchange with a capacity of 54 000 lines after the city net has attained such proportions that almost as many junction positions are required as A-positions, especially since the arrange-

ments and equipment for the junction positions are quite expensive.

How then shall the capacity of the manual exchange be reduced?

If the method with call indicators had been chosen,

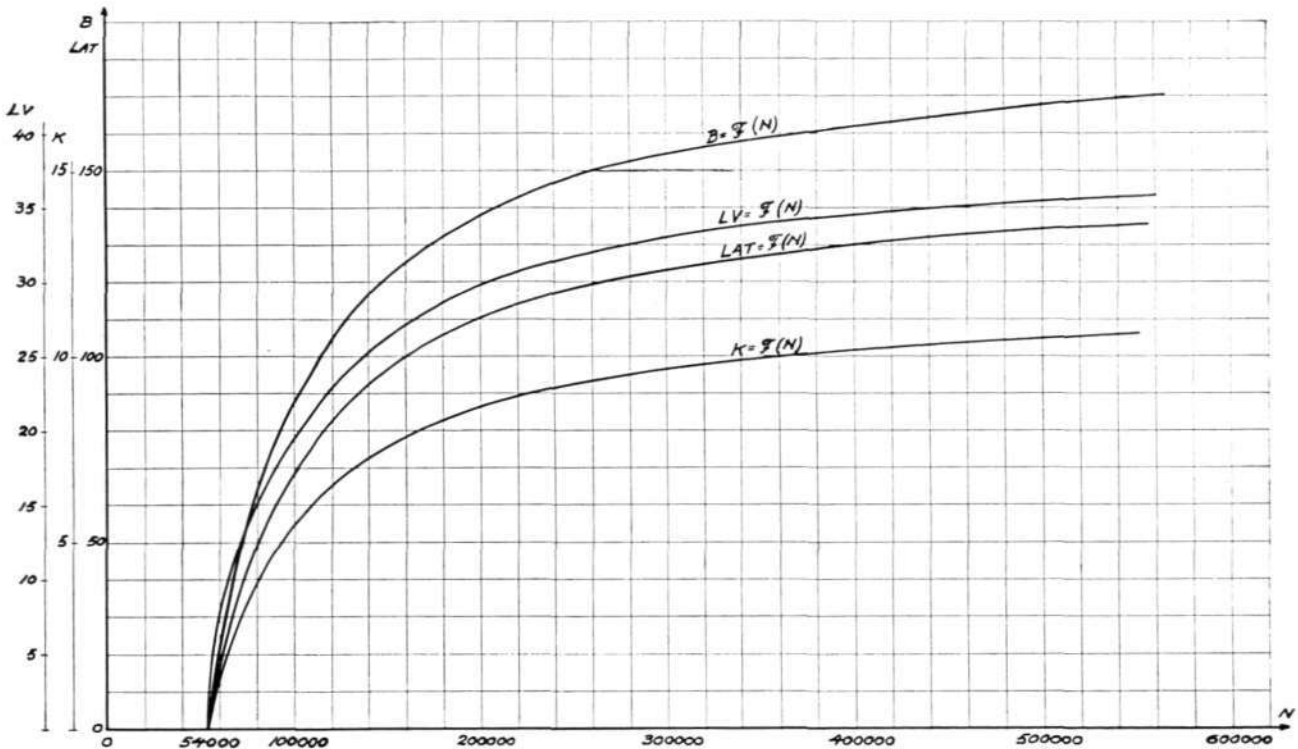


Fig. 3.

it is plain that the sum of the number of A-positions, CA, and the number of call indicator positions, LAT, could not exceed the total number of available positions.

The number of B-positions need not be treated in this connection since they contain no subscribers' multiple and can consequently be placed in an entirely separate room or building than the A-positions.

If all the A-positions are in use already at the beginning of the automatization, it is necessary to be able to set up a certain number of call indicator positions in order to begin the automatization.

To begin with, let us assume that 54 000 subscribers can be given service by 300 positions CA — corresponding to 180 lines per operator — and that an additional 60 call indicator positions can be erected.

We then have

$$CA + LAT = \frac{M}{180} + 27.7 \times \frac{M}{10000} \times \frac{A}{A + M} = 3.60,$$

from which we obtain

$$M \left(2 + \frac{A}{A + M} \right) = 130000$$

or

$$M(2 + f) = 130000.$$

By assuming different values for f we arrive at the following table II.

f	M	A	$A + M$	CA	LAT
0.41	54000	37000	91000	300	60
0.50	52000	52000	104000	289	71
0.60	50000	75000	125000	278	82
0.70	48000	113000	161000	267	93
0.80	46500	186000	233000	258	102
0.90	45000	403000	448000	249	111

However, if it is found that 320 CA positions are required for 54 000 subscribers — which means 169 subscribers' lines per A-operator — only 40 call indicator positions can be erected.

This proposition presents itself in the following form:

$$CA + LAT = \frac{M}{169} + 27.7 \times \frac{M}{10000} \times \frac{A}{A + M} = 360,$$

from which we obtain

$$M(2.14 + f) = 130000.$$

By means of this formula we obtain table III.

f	M	A	$A + M$	CA	LAT
0.26	54000	19500	73500	320	40
0.40	51000	34000	85000	303	57
0.50	49000	49000	98000	292	68
0.60	47500	71500	119000	281	79
0.70	46000	107000	153000	271	89
0.80	44000	177000	221000	262	98
0.90	43000	385000	428000	253	107

As a third alternative we will assume that 320 A-positions are required for 54 000 subscribers at the manual exchange and that it is not possible to increase the number of multiple positions above 320.

From this we obtain the formula

$$CA + LAT = \frac{M}{169} + 27.7 \times \frac{M}{10000} \times \frac{A}{A + M} = 320$$

or

$$M(2.14 + f) = 115500,$$

which gives the following table IV.

f	M	A	$A + M$	CA	LAT
0	54000	0	54000	320	0
0.20	49500	12500	62000	292	28
0.40	45500	30500	76000	270	50
0.50	44000	44000	88000	259	61
0.60	42000	63500	106000	250	70
0.80	39500	157000	197000	233	87
0.90	38000	342000	380000	225	95
0.94	37500	588000	626000	222	98

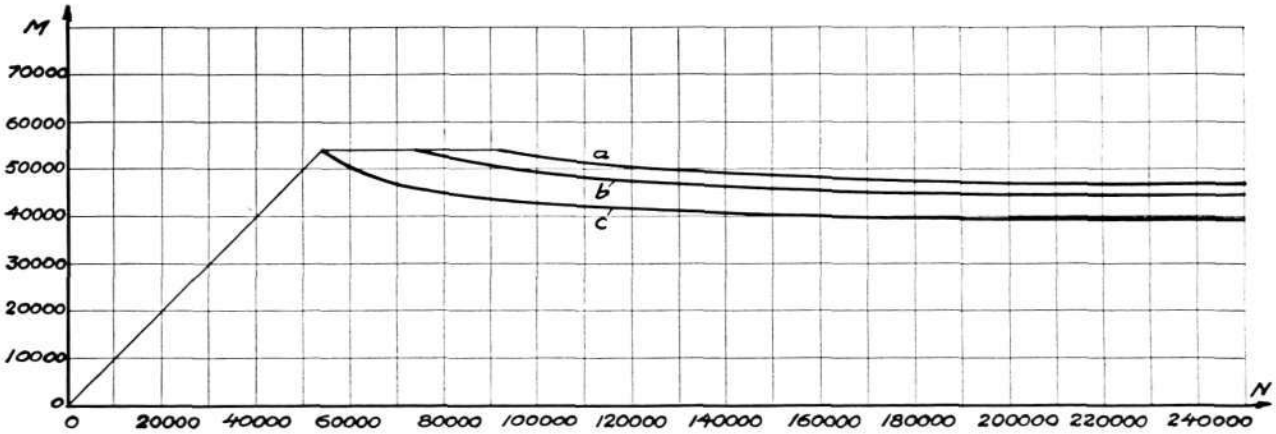
If a maximum value for the sum of the operators' positions ($CA + LAT$) is given, it is an easy matter to determine the theoretical curve representing the gradual reduction of the capacity of the manual exchange.

This is shown in fig. 4, the three curves a , b and c corresponding to the above tables II, III and IV respectively.

These curves give the number of manual subscribers M as a function of the total number N of subscribers in the entire net.

Let us now consider the second case with table III.

We will assume that the manual exchange will remain in existence for another fifteen years; also, that the total capacity of the net by that time will be about 150 000 subscribers.



R 840

Fig. 4.

By that time 88 call indicator positions would be required and the manual exchange would have about 46 000 subscribers.

However, it is impossible from a practical point of view to put a manual exchange with 46 000 lines out of commission at one stroke, but the cutting over of the subscribers to the automatic exchanges must take place successively in groups of not more than four to five thousand lines per half or whole year.

At this rate the evacuation of the manual exchange would take at least five or ten years for 54 000 lines.

During this time the junction traffic will be considerably reduced as compared with the calculated figures; consequently, it would be very uneconomical to install the large calculated number of call indicator positions, which would soon be of no value.

Thus, we must determine the maximum number of call indicator positions that we wish to install.

If connectors are used for the traffic from *automatic* to *manual*, the same restrictions must be observed with regard to them also.

With regard to call indicator positions as well as connectors, economical reasons prevent their being installed in unlimited numbers merely for the sake of retaining the manual exchange as long as possible, since these organs for the greater part become valueless when the manual exchange finally is bound to disappear.

We will now consider the capacity of the manual exchange as a function of the capacity of the automatic exchanges, ignoring the special assumptions on which the tables II, III and IV and the curves in fig. 4 are based.

Both in the case with a determined maximum number of *call indicator positions*, and with a determined number of *connectors* for each 500-group, a certain maximum value for the junction traffic obtained.

The previously derived formula

$$TAM = 2.69 \times \frac{AM}{A + M}$$

gives a certain relation between A and M for every value of TAM .

This function can be expressed.

$$A \times M - \frac{TAM}{2.69} \times A - \frac{TAM}{2.69} \times M = 0.$$

This equation evidently signifies a number of hyperbolic curves whose axes form angles of 45° with the axes A and M . The locus for the vertices of these hyperbolic curves is the line

$$A = M.$$

We then obtain

$$A = M = 2 \times \frac{TAM}{2.69}.$$

In the following table V A is calculated for different values of M after having determined a certain value for TAM .

The table gives also the corresponding values for N , LAT , TMA , K , B and LV .

TAM	M	A	$N = A + M$	
30 000	11 150	∞	∞	$LAT = 31$
	13 000	80 000	93 000	$TMA = 24300$
	15 000	43 500	58 500	$K = 2.4$
	20 000	25 000	45 000	$B = 39$
	22 300	22 300	44 600	$LV = 11$
	25 000	20 000	45 000	
	43 500	15 000	58 500	
	54 000	14 000	68 000	
	80 000	13 000	93 000	
		∞	11 150	∞

TAM	M	A	N=A+M	
40 000	14 900	∞	∞	LAT = 41
	20 000	58 000	78 000	TMA = 32400
	25 000	37 000	62 000	K = 3.2
	29 800	29 800	59 600	B = 52
	37 000	25 000	62 000	LV = 14
	54 000	20 500	74 500	
	58 000	20 000	78 000	
	∞	14 900	∞	
50 000	18 600	∞	∞	LAT = 52
	20 000	263 000	283 000	TMA = 40500
	25 000	73 000	98 000	K = 4.1
	30 000	49 000	79 000	B = 65
	35 000	39 700	74 700	LV = 16
	37 200	37 200	74 400	
	39 700	35 000	74 700	
	49 000	30 000	79 000	
	54 000	28 500	82 500	
	73 000	25 000	98 000	
	263 000	20 000	283 000	
∞	18 600	∞		
54 000	20 100	∞	∞	LAT = 56
	25 000	102 000	127 000	TMA = 43800
	30 000	61 000	91 000	K = 4.4
	32 000	54 000	86 000	B = 70
	36 000	45 400	81 400	LV = 17
	40 200	40 200	80 400	
	45 400	36 000	81 400	
	54 000	32 000	86 000	
	61 000	30 000	91 000	
	102 000	25 000	127 000	
∞	20 100	∞		
60 000	22 300	∞	∞	LAT = 62
	25 000	207 000	232 000	TMA = 48600
	30 000	87 000	117 000	K = 4.9
	33 000	69 000	102 000	B = 78
	40 000	50 400	90 400	LV = 18
	44 600	44 600	89 200	
	50 400	40 000	90 400	
	69 000	33 000	102 000	
	87 000	30 000	117 000	
	207 000	25 000	232 000	
∞	22 300	∞		

TAM	M	A	N=A+M		
40 000	27 900	∞	∞	LAT = 80	
	30 000	295 000	425 000	TMA = 60800	
	40 000	93 000	133 000	K = 6.1	
	45 000	73 500	118 500	B = 92	
	54 000	57 700	111 700	LV = 22	
	73 500	45 000	118 500		
	75 000	93 000	40 000	133 000	
	∞	395 000	30 000	425 000	
75 000	∞	27 900	∞		

In fig. 5 A is drawn as a function of M for four different values of TAM , viz., 30 000, 40 000, 60 000 and 75 000 speaking minutes.

We assume a number of junction switching possibilities corresponding to $TAM = 40 000$ speaking minutes. We see from the corresponding curve that the manual exchange can be retained with a capacity of 54 000 lines if the capacity of the automatic exchanges does not exceed 20 500, or the total capacity does not exceed 74 500.

This is represented by point C in fig. 5.

When the total number of lines now increases, the capacity of the manual exchange must be reduced in order to avoid an increase in the number of junction lines.

For instance, if we reduce the capacity of the manual exchange by 9000 lines, we cannot increase the automatic exchanges by more than about 2000 lines, and if we reduce the manual exchange by 20 000 lines we can only increase the automatic exchanges by about 6000 lines.

Thus, the total number of subscribers' lines would suffer a reduction, since the limited number of junction lines makes it necessary that the gradual reduction of the manual exchange take place faster than the extension of the automatic exchanges.

This condition brings us to point D on the curve.

The total number of subscribers' lines has now been reduced from 74 500 at C to 59 000, however. Not until we reach E does the total capacity come up to 74 500, the capacity of the manual exchange then having gone down from 54 000 to 20 500 lines.

In order to increase the total capacity of the exchanges above 74 500 lines it would therefore be necessary to make a jump from C to E , after which the curve $TAM = 40 000$ could again be followed.

Consequently, if we have restricted the possibilities for junction traffic and wish to retain the manual ex-

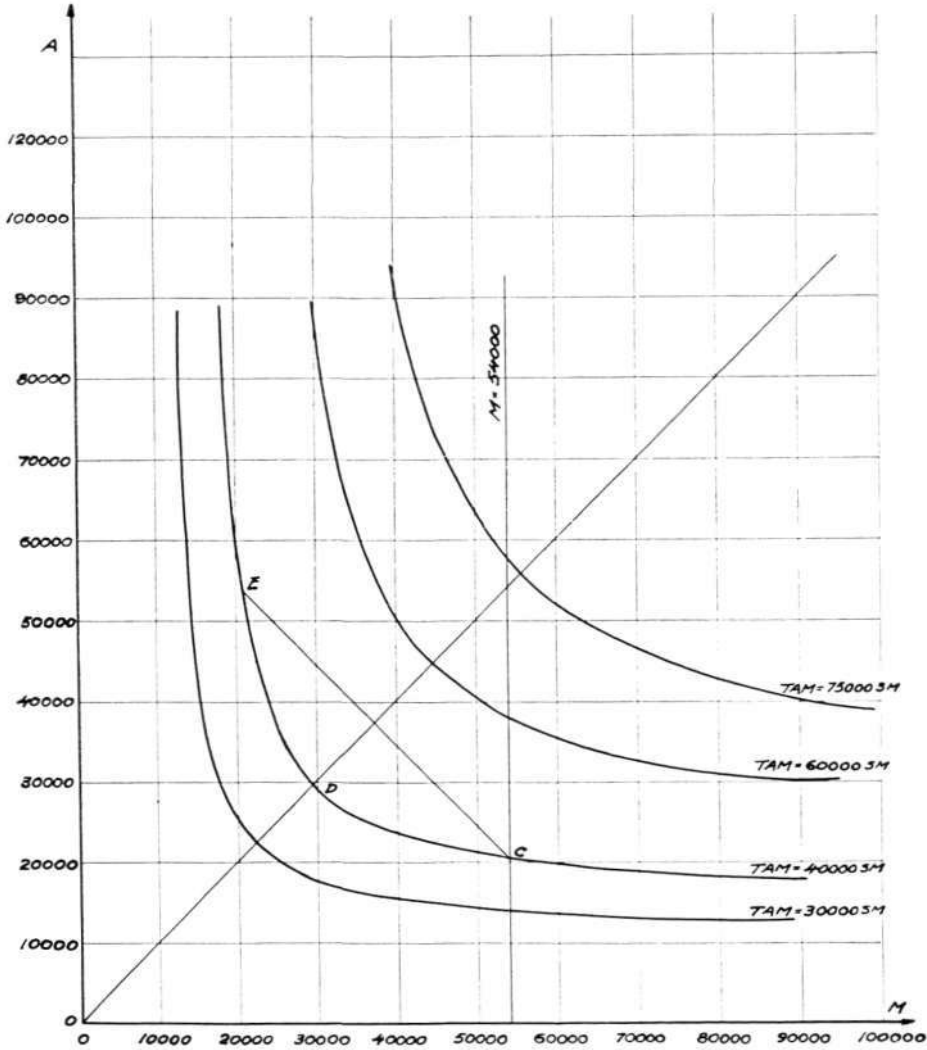
change as long as possible, the number of subscribers which must be cut over at the same time from the manual to the automatic exchanges will be so large as to make this operation practically impossible.

In the case we have chosen for discussion it would be necessary to simultaneously cut over 54 000 — 20 500 = 33 500 subscribers.

Here we also obtain hyperbolic curves.

The line OF intersects the curves in those points through which the tangents to the curves are vertical.

Thus, it is plain that the intersection between OF and a certain curve will give a point from which one may follow the curve in either direction, the total number of subscribers' lines increasing in either case.



R 831

Fig. 5.

In order to be able to carry out this operation in successive stages, junction lines must be provided in sufficient number for a traffic corresponding to a hyperbolic curve whose vertex lies in the intersection between the lines $A = M$ and with $M = 54\ 000$.

In the present example this would mean that $TAM = 72\ 500$ speaking minutes.

The above discussion is probably still better illustrated by fig. 6 which shows how the capacity of the manual exchange varies with the total number of subscribers N for different values of TAM .

Analogously with the method depicted in fig. 5, we find that if the manual exchange is retained with a capacity of 54 000 lines along the line PA and with TAM restricted to 40 000 speaking minutes we are forced to cut over at one time from the manual to the automatic exchanges a number of lines corresponding to AB (abt. 33 500) since, after having reached A , an increase in the total number of subscribers' lines cannot take place without entering the area for higher TAM than 40 000.

Another factor to be taken into consideration is the

speed with which the cutting over of subscribers from the manual to the automatic exchanges can take place.

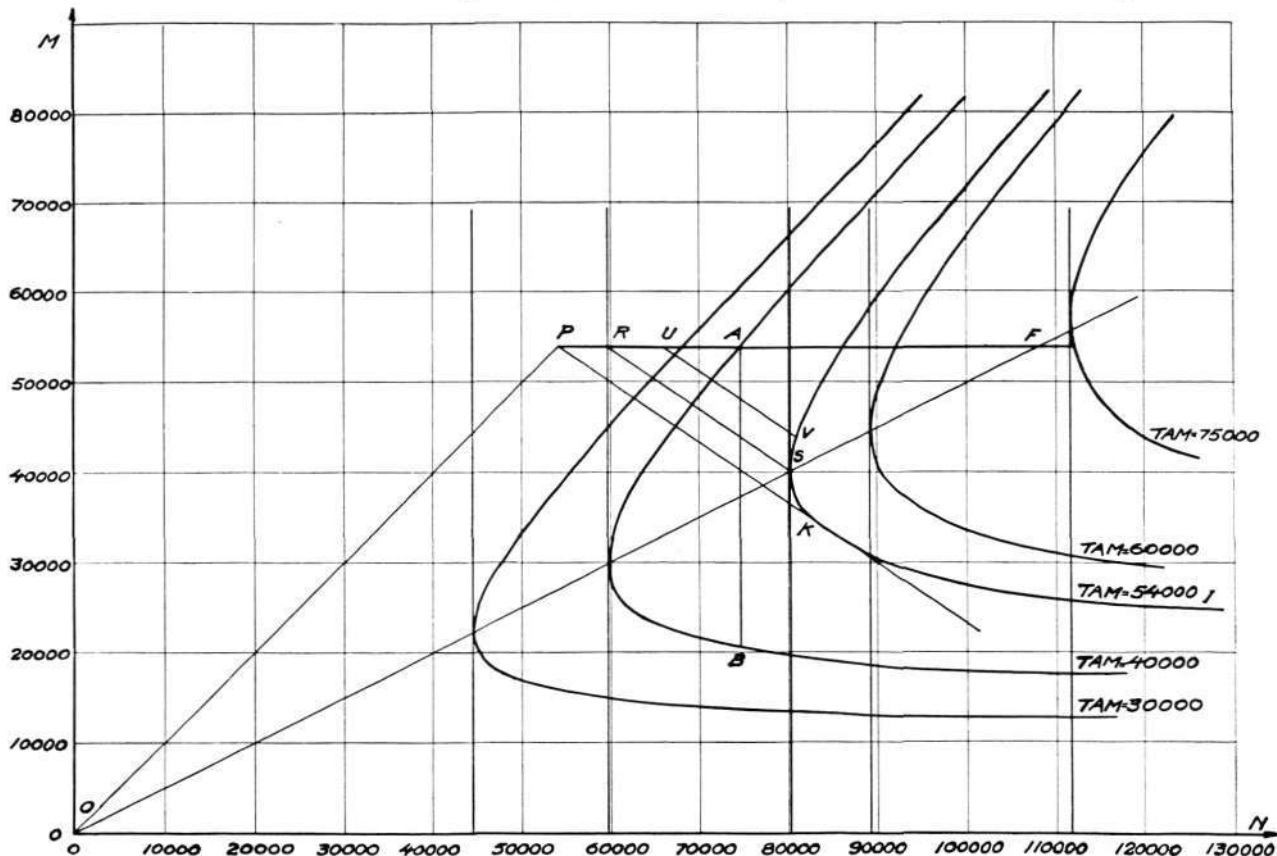
The line *PK* in fig. 6 represents a cut over of 4000 subscribers per year, which value for all practical purposes can be taken as a maximum value for a plant of this size.

As will be noticed, *PK* is tangent to the curve which represents $TAM = 54\ 000$ speaking minutes or fifty-six call indicator positions. Therefore, if we reduce the number of manual subscribers along *PK I*, we

most complete loss — for the extension of junction lines, or else a cut over of such magnitude would have to be made as to be practically impossible from a technical point of view or, if cut overs take place in successive stages, the existing traffic possibilities will be the cause of serious losses or congestions.

We will now consider fig. 7 in which the curves in figures 4 and 6 have been combined.

We will suppose that the telephone administration is of the opinion that the manual exchange is in such



R 842

Fig. 6.

would be certain not to overstep the given maximum speed for cutting over and that the junction traffic would never exceed a value corresponding to fifty-six call indicator positions.

Should it be found desirable at some certain time to risk the cutting over of a larger number of subscribers, there is naturally nothing to prevent ones following the line *RS* or *VV*, for instance.

According to the author, it is most important that a manual exchange be not retained for too long a time at its full capacity. Should the manual exchange be retained for long time at maximum capacity, it will result in the expenditure of an unreasonably large amount of capital — which will later on be an al-

good condition that it can well be retained at full capacity (54 000 lines) for at least eight years.

Instead, we let the number of subscribers at the manual exchange grow up to 54 000 and after that decrease successively so that after sixteen years (Jan. 1, 1944) it is 0. From fig. 7 and table V we find that this can be done without increasing the number of call indicator positions above fifty-eight or, say, sixty.

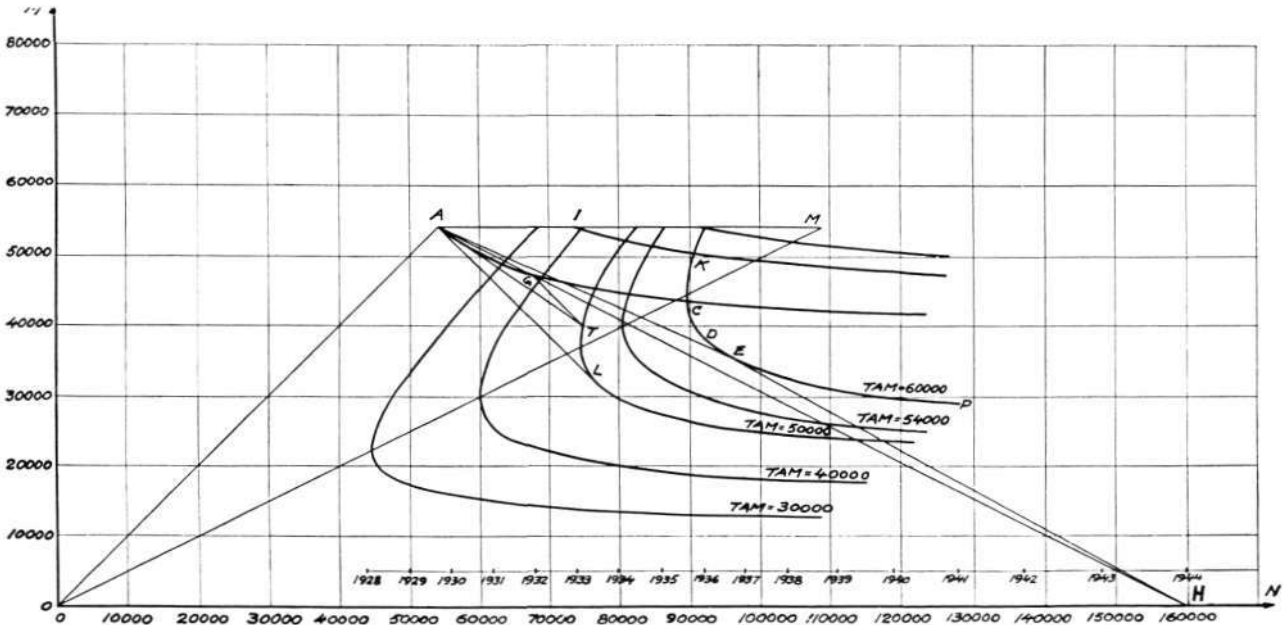
For example, if we should decide to cut over the manual subscribers along the line *AEH*, corresponding to a maximum number of sixty call indicator positions, the entire number of such positions would be of use for but a very short time.

Furthermore, it must be accentuated that if the junction traffic is handled over call indicator positions with a maximum of 320 positions, it is not possible to follow the line *AE* from the start, but the curve *AGC* must then be followed.

In order to increase the effective service time for the sixty call indicator positions and also the effective utilization of the manual exchange, it is apparent that the curve *AGC* can be followed up to *C* and that we then continue along the curve *CDE*. However, this would result in the cutting over of 6000 subscribers in 1935.

multiple is to be extended, the line *AGCDP* will no doubt serve the purpose to equal advantage.

This problem is treated in a similar manner if call indicator positions are not taken into consideration but instead the number of jacks and junction lines from the manual positions to the automatic exchanges, or the fact that there is room for but a limited number of connectors for the incoming traffic at the manual exchange if this traffic is to be handled altogether automatically without call indicators. In such a case one is not so restricted, since no consideration need then be taken to the curves *AGC* and *IK*, or the like, but



R 843

Fig. 7.

Naturally, it is possible to get along with fewer call indicator positions, say fifty-two, for instance — corresponding to $TAM = 50\,000$ — if one follows the line *AL*, *AT* or *ATG*, depending on the speed with which one is willing to effectuate the cutting over.

In such a case, the number of manual subscribers decreases rapidly and this exchange is not put to effective use. On the other hand, it can be retained in operation much longer, if desired, but it will in all probability be uneconomical in the long run to give manual service to only a small percentage of subscribers.

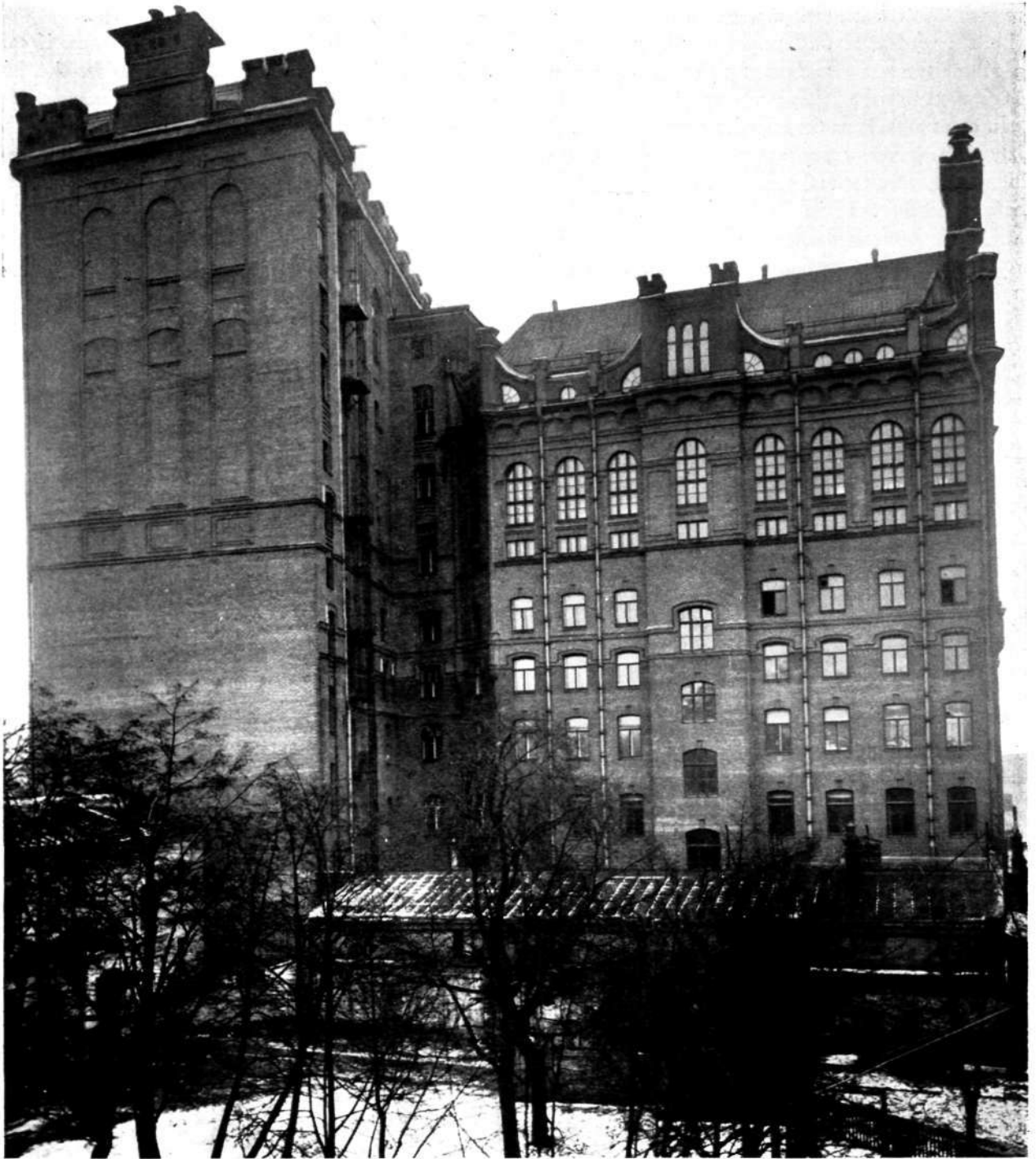
If it were possible to erect forty call indicator positions in addition to the 320 positions required for the local traffic, the cutting over could be effectuated along the line *AIKCDP* or something similar, which would permit a much better utilization of the manual exchange. To what extent this would pay depends on the cost of the extra positions. If the entire mul-

only to the speed with which the cutting over of the lines is to take place and to the absolute maximum of junction traffic.

In the foregoing we have discussed only the practical aspects of the problem. In addition to these, however, we have the previously mentioned economical aspects, such as the difficulty of raising the necessary capital, the possibility of getting new exchanges delivered and installed in sufficiently short time, etc., all of which lie outside of the bounds of the present article.

As a conclusion of the above, it is apparent that the natural desire to retain a good manual exchange for the longest possible time and at its full capacity within an automatic net must not only meet with difficulties of a purely practical nature but also lead to serious and unfavourable consequences from an economical point of view.

H. T—i.



F 1

Exchange Buildings in Moscow Erected by the Swedish-Danish-Russian Telephone Company.

CONTENTS: Suburban Telephone Traffic in a Large City. — Call Order Service at the Stockholm Toll Exchange. — Making Register Connections by Means of Cord Circuit Finders. — Time Recording. — During What Length of Time and with how Large a Capacity shall a Manual Exchange be Retained in an Otherwise Automatic Telephone Net?

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VIEW OF THE STOCKHOLM TAXICAB EXCHANGE.

ENGLISH EDITION

The Telephone as an Aid in the Organization of the Taxicab Service in large Cities.

By A. Lignell, Superintendent of Telephones, Stockholm.

The manner in which taxicab service in a large city is organized is a matter which intimately concerns the convenience of the public, and constitutes a problem which cannot be satisfactorily solved without the aid of the telephone.

Now that the telephone has become an all-powerful factor in our everyday life, there is no reason why this means of communication should not be used for the ordering of taxicabs as well as for the transaction of any other kind of business, and a well-arranged cooperation between the taxi and telephone companies enables a telephone subscriber to secure transportation by automobile at a much cheaper rate and at least as quickly as if he had a car of his own at his constant disposal.

An effective centralisation of the ordering facilities enables the taxicab company to keep the traffic under constant supervision, thereby making possible an efficient utilization of the fleet of taxicabs, which is of decisive importance for the economical operation of the business.

A description of the taxicab service in Stockholm and its relation to the Telegraph Administration will, we feel sure, prove of general interest.

The Cab Owners' Association: its organization and manner of cooperation with the Telegraph Administration.

The original taxi telephone exchange with the name-call "Droskstation" — meaning "cab exchange" —, which has been in existence since 1901 and is operated by the Swedish Telegraph Administration, provides order service for the Stockholm Cab Owners' Association only. The members of this association are individual taxicab owners who have been authorized by the police authorities to operate taxicabs, the chauffeur having permission to pick up chance fares along the streets or to await passengers or telephone orders at special cab ranks.

In addition to the above-mentioned association there is another organization of cab owners with a telephone exchange of its own. This exchange has the name-call "AB" and is built and maintained by the Telegraph Administration although the personnel is in the employ of the association. This association has the same privileges and obligations with respect to the operation of public conveyances as the one previously mentioned.

These two are the only organizations in Stockholm who have been granted privileges of this kind.

The number of licenses granted by the police authorities is based on the requirements of the traffic and is kept within certain bounds in order to maintain the service on a sound economical basis and so as to satisfy the demands of the public with respect to safety, comfort, the quality and appearance of the vehicles and the responsibility and discipline of the drivers. Also, the authorities reserve the right to issue certain orders as to the disposition of the vehicles so as to eliminate any danger of an inadequate supply during certain less lucrative times of the day or that certain sections of the city be favoured at the expense of others. This stand on the part of the authorities with regard to the granting of licenses has given the cab owners a relatively strong position and created a high standard for the vehicles as well as for the drivers and has made it possible to build central taxi exchanges with widespread telephone nets. As a result of the foregoing, it is natural that the number and location of the cab ranks is determined by the police authorities in collaboration with the cab owners. The city ordinance which covers this form of public service also provides for the use of horse drawn vehicles, but these have entirely disappeared from the streets of Stockholm since many years back.

The Cab Owners' Association subscribes to a number of junction lines, sufficient to provide for the traffic between the cab exchange and the local city exchanges, a connection to the former being obtained

over any local exchange by merely asking for "Droskstation", meaning "Cab Exchange".

In addition to this the Association has special lines to six of the largest restaurants and hotels, over which direct calls to the cab exchange can be made.

At the present time, the Association subscribes to 92 branch exchange instruments — for the most part mounted on posts at the cab ranks — together with the respective lines between the same and the cab exchange.

The junction as well as the branch lines enter a common switchboard at the cab exchange, which is operated by the Telegraph Administration. The entire cost for this service is paid to the Telegraph Administration by the Association. All questions of an economic nature touching on the taxicab telephone plant are settled between the Telegraph Administration and the executive board of the Cab Owners' Association, the Telegraph Administration having no dealings whatever with the individual members of the Association.

Some special features of the service.

The intensity of the traffic over the cab exchange is extremely variable. It can be forecast to a certain extent, but since a great part of it is influenced by unforeseen conditions which may arise at a moment's notice, it is necessary — in order to be able to handle the same — to have recourse to one or more adjacent departments from which operators, familiar with the work in the cab exchange and possessing an excellent knowledge of the city, may temporarily but immediately be requisitioned.

The operators and other personnel of the number records office in the same building are first of all employed for this purpose.

The traffic curve for a normal week-day is more or less constant, the regular fluctuations being caused by the departures and arrivals of trains and passenger boats, lunch time, the close of office hours, opening and closing of theatres and cinemas and the closing of the restaurants. In addition to this we have temporary fluctuations in the traffic which can be foreseen, such as week-end congestions of the traffic, theatre first-nights, sporting events and the like. For traffic fluctuations of such a nature it is the duty of the exchange manager to make suitable arrangements by requisitioning the necessary extra help. In this she is guided by statistics from previous years, besides which she is well informed as to which special week-days, holidays and yearly recurring events require a large number of operators at the cab exchange.

On such often recurring occasions, when the cab exchange is suddenly swamped with orders, it often happens that there is a shortage of taxicabs. In this connection it has been deemed wiser to connect the calling parties to the cab exchange where they receive the information that no cabs are available than to let the local exchange answer "Busy" only to have the same party call again and again in an effort to get the cab exchange. It is for this reason that an ample number of junction lines between the local exchanges and the cab exchange have been provided.

From what has here been said, it should be evident that a balanced distribution of the personnel is possible only when there is a nearby source of supply for extra help. Without this source it is necessary either to get along with a force based on normal traffic conditions and consequently with no possibility of an immediate increase — which is often necessary during a very short time —, or else to have on the pay roll a force which is entirely too large for normal traffic conditions and which will prove altogether too expensive in the long run still without being able to cope with unforeseen emergencies when these occur.

The Cab Owners' Association has about 600 cars in traffic at present, with a reserve of about 200 cars, the average number of orders effectuated each day by the aid of the taxi telephone exchange amounting to 7700. The other association has about 300 cars with a reserve of 100 cars at its disposal. The number of orders which it effectuates per day amount to about 1350.

In addition to an easily accessible reserve of operators and an ample number of junction lines between the local exchange and the taxi exchange, the following requirements must be taken into consideration when planning a taxi telephone exchange.

1. Each order must be dealt with by a telephone operator; consequently, the ordering party must not be given a through connection to the chauffeur at the cab rank. The reasons why this rule must be observed are manifold. In the first place, the lines to the cab ranks would be engaged all too frequently if the conversations — often unnecessarily lengthy — were carried on between the patrons and the chauffeurs instead of the orders being relayed by experienced operators. It would be difficult to prevent unauthorized calls which did not concern the taxi service. It is important for quite a number of reasons that a record be kept of the orders as well as of the chauffeurs' numbers, for instance to afford a certain amount of protection against false orders being given with mischievous

intent, for the searching for lost effects, for investigating complaints and drives to faulty addresses, for police investigations etc. These records can be kept by the exchange personnel much more accurately than by the chauffeurs. Further, it is to much greater advantage that the chauffeur receives the order from an experienced operator who speaks distinctly than from a patron who is often unable to understand the difficulties of the chauffeur — on account of the street noises — to correctly understand the given order. The operator at the taxi exchange answers a call with the words "Taxi Exchange". The ordering party gives his street number and name and awaits the operator's answer: "Taxi coming". If there should be no taxi standing at the nearest cab ranks, the operator informs the ordering party of the nearest cab rank from which a taxi can be obtained, and it is then up to this party to decide if he wants to pay the higher charge dictated by the greater distance from the cab rank to the given address. It shall be possible to make connections between the cab rank 'phones and certain telephone instruments in the local net, such as the office of the Cab Owners' Association, the police, etc. Further, the chauffeur shall be able to call up the taxi exchange.

2. There shall be a reliable indicating signal arrangement by means of which the operator can see at a glance where taxicabs are stationed, thereby eliminating the nuisance of having to call up several cab ranks at random. The indicating signals shall function for each cab rank as soon as a chauffeur drives up to the same, and shall cease when the last taxi has left the rank.

3. Naturally, the operator should possess such an accurate knowledge of the city as to enable her — in the majority of cases, at least — to immediately get in touch with the cab rank nearest to the given address, but for more difficult and exceptional cases she must have access to complete tables enabling her to immediately locate the address in question.

Switchboard and indicating arrangements.

The Stockholm taxi exchange is equipped with a switchboard comprising 24 operators' positions. Both the junction lines to the local exchange as well as the cab rank telephone lines are multiplied in the positions and are consequently accessible to *all* the operators on duty, thus enabling them to answer any incoming order call and to call any cab rank in order to effectuate the order. The chief operator's desk is provided with

complete equipment for the supervision of the service. Here the jacks and lamps for the junction lines and the jacks for the cab rank lines are multiplied, thus enabling the chief operator to supervise the traffic and if necessary answer any incoming call.

The arrangements whereby the operators can signal the chief operator are so constructed that they may be used for communications between the above-mentioned persons. The indicating arrangements consist of a large wall map of the city, placed so as to be within the range of vision of each operator. On this map all the cab ranks are indicated by lamps, the circuit for each lamp being carried to the corresponding cab rank. A number on the map beside the lamp denotes the number of the cab rank and corresponds to the number in the multiple of the lines leading to this cab rank. The chauffeur of the first taxicab to enter a cab rank must have a shorting plug — which he always carries about with him in his pocket — introduced in a special short circuiting jack in the cab rank telephone instrument. This closes the lamp circuit and causes the corresponding lamp on the wall map to glow. When there is no taxi at the cab rank there must not be any plug in the aforementioned jack and the lamp on the wall map is consequently dark. As soon as an operator introduces a cord plug in a multiple jack belonging to a cab rank line, the corresponding lamp on the wall map glows with a flickering light, this arrangement having been provided instead of the usual testing devices which, in the present case, would not be adequate. In the present case a glance at the map informs the operator that at least one taxi is available at the cab rank which for the moment is represented by a flickering lamp, but that the line to this cab rank is engaged by another operator. In order to save current, arrangements have been made so that the map is in circuit only when an operator needs to consult it. By depressing a push button, the operator closes the circuit for the lamp within the district she specially wishes to investigate. One such push button is situated at each end of each of the jack strips for the cab rank lines, each strip containing twenty jacks with the correspondingly designated lamps and representing one or two districts. These lamps are interconnected with the indicator lamps on the wall map, an arrangement which enables the more trained operators to judge the available supply of taxicabs without having to consult the map. In order to make the existing situation clear at a glance, each position is equipped with a self-restoring push button by means of which the operator is able to close the circuit to all the lamps on the map,

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the lamps of the cab rank lines in the multiple not being affected by this manipulation, however. When the traffic is congested, the current for the map lamps of

vacant, this procedure being resorted to whenever a line is faulty or a chauffeur leaves a cab rank without removing his signal plug. Signals to and from the



R 922

Map of Stockholm, Showing Cab Ranks.

all the districts are kept in circuit over a key in the chief operator's desk, this fact being indicated by a special observation lamp placed in the upper left hand corner of the wall map. In boxes in front of the operators' positions are special jacks, one for each of the cab rank lines. By introducing a plug in one of these jacks the corresponding cab rank is indicated as

cab ranks can be given regardless of whether the special jack is plugged or not.

The indicating arrangements are shown on the diagram in fig. 1.

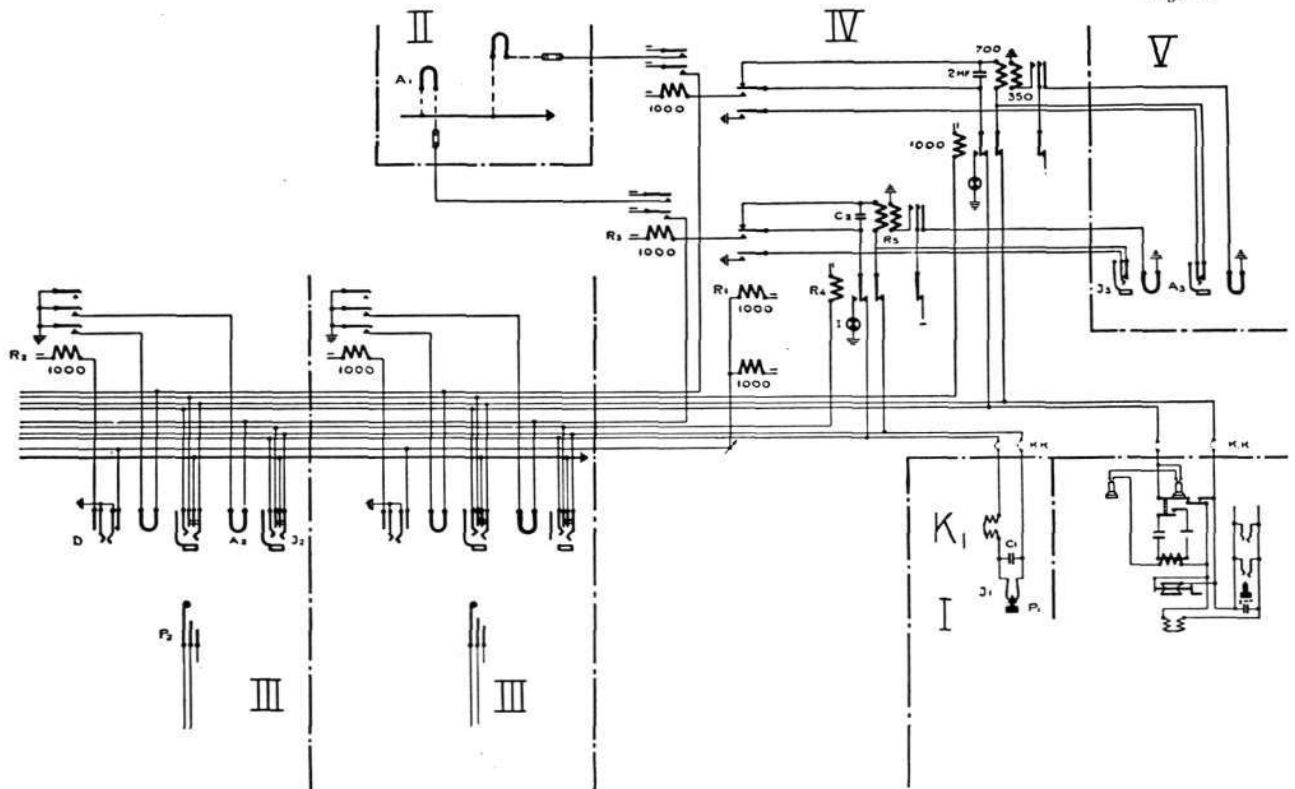
The office of the Cab Owners' Association is provided with a wall map similar to the one at the taxi exchange — the lamps in both of these maps being

Street	House Numbers	Number of Cab Rank	House Numbers	Number of Cab Rank	House Numbers	Number of Cab Rank	House Numbers	Number of Cab Rank	House Numbers	Number of Cab Rank
Tegnérsgatan	16 to 34	61	47 to 61	67	36 to 48	67				
Tegnérlunden	2 to 14	67								
Teknologgatan	1 to 11	67								
Telegrafgränd	1 to 5	2								
Tempeltrappan		102								
Thorildsvägen		14								
Thorildsplan		14								
Timmermansgatan	1 to 33	33	2 to 40	30	35 to 51	34	42 to 52	34		
Tjärhovsgatan	1 to 11	28	2 to 30	28	13 to 71	27	32 to 58	27		
Tomtebogatan	2 to 13	104	14 to 53	102						
Torbjörn Klockaresgata		103								
Torkel Knutssonsgata	2 to 35	33								
Torsgatan	1 to 19	100	2 to 30	69	21 to 51	103	32 to 48	100	50 to 80	103
Torsplan	1 to 3	103								
Torstenssonsgata	2 to 15	82								
Tre Liljors plan	1 to 8	110								
Triewaldsgränd	1 to 3	1		5						
Tryckerigatan	2 to 8	4								
Trängsund	2 to 14	4								
Trädgårdsgatan, Staden	1 to 7	2								
Trädgårdsgränd		35								
Trädgårdstvärgänd		2								
Tulegatan	1 to 13	70	2 to 8	70	15 to 47	107	10 to 34	107	49 to 55	108
Tulegatan	36 to 44	108								
Tullgränd		5								
Tunnelgatan	1 to 13	68	2 to 18	68	15 to 29	69	20 to	69		
Tyrgatan	1 to 13	72								
Tyska brinken	19 to 36	1								
Tyska brunn		1								
Tyska skolgränd		1								
Tyska stallplan		1								
Tyskbagaregatan	1 to 14	90								
Tysta gatan	1 to 18	84								
Uggelgränd	1 to 4	23								
Uggleviksgatan	1 to 15	72								
Ulrikagatan	1 to 7	81								
Upplandsgatan	1 to 7	69	2 to 10	69	9 to 31	67	12 to 26	67	33 to 37	64
Upplandsgatan	28 to 32	64	39 to 71	105	34 to 64	105	73 to 79	110	66 to 96	110
Uppsalagatan	1 to 22	104								
Urvädersgränd, Söder..	1 to 13	7								
Wahrendorffsgatan	1 to 10	44								
Valhallavägen	1 to 38	108								

connected in parallel — and with arrangements for the supervision of the junction and cab rank lines as well as of the service. Each operator has before her a miniature replica of the wall map mounted in the switchboard — on which the cab ranks are designated by numbers — as well as reference tables giving the number of the cab rank nearest to the different house numbers. One of these miniature maps is reproduced in fig. 2 and a reference table in fig. 3. The taxi exchange switch boards are shown in fig. 4. The

cal and a horizontal position can be substituted for the above. A condenser C_1 (see section 1 of the simplified diagram of the cab rank telephone instrument) is connected in series with the signal bell K_1 . If there is no plug P_1 in any of the jacks, the D. C. from the 24 volt exchange storage battery cannot pass over the telephone line. The insertion of a plug makes a bridge past the condenser, giving an unbroken telephone circuit for direct current. In order to investigate the number of available taxis within a cer-

Fig. 1.



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cab rank telephones are generally mounted on cast iron posts and are specially designed L. B. instruments provided with a condenser, a handmicrotelephone and the necessary shortcircuiting jacks. The entire apparatus is contained in a moistureproof cast-iron box.

Some remarks with reference to the diagram for the indicating arrangements and cab rank telephone instrument. (See fig. 1.)

Each cab rank telephone is provided with three parallel indicator jacks in which the taxi chauffeurs insert metal plugs on their arrival at the cab rank. An arrangement with small metal flags with a verti-

tain district, the operator depresses the district key D (III), causing relays R_1 (IV) and R_2 (III) to energize. The energizing of R_1 causes relay R_3 (IV) to be connected to one branch of the cab rank line while the other branch is grounded. If a plug is inserted in the jack J_1 (I) relay R_3 (IV) will energize, thereby closing a circuit over the signal lamp A_1 on the wall map (II). A circuit through the multiple lamp A_2 (III) for the cab rank lines is simultaneously closed over contacts in the relays R_2 and R_3 .

As soon as an operator plugs up her calling cord P_2 in order to call a cab rank in the usual manner, these signal lamps flicker instead of giving a steady light if the district key D is depressed. The insertion of the ringing plug P_2 closes a contact in the

jack J_2 , thereby energizing relay R_4 (IV) and causing the current over relay R_3 (IV) to pass through the impulse machine I (IV), the pulsating current thereby obtained causing the lamps A_1 (II) and A_2 (III) to flicker when D is depressed. The energizing of R_4 causes the indicating arrangements at the exchange to be simultaneously disconnected from the telephone line.

When a chauffeur calls up the taxi exchange, the magneto current which is produced when he turns the crank of the cab rank telephone actuates the relay R_5 (IV) between the two branches of the line, causing the calling lamp A_3 to glow. These lamps are mounted in the same box as the previously mentioned jacks J_3 (V) for the cutting out of faulty cab rank lines. The condenser C_2 (IV) which is connected in series with relay R_5 (IV) bars the direct current from relay R_3 .

If there should occur such serious trouble on a cab rank line as to make it unserviceable, the signal lamps for this line should be disconnected until the line has been repaired so as not to cause any unnecessary delay in the service through useless calls. This is accomplished by inserting a wooden plug in the jack J_3 (V) thereby breaking the earth connection of relay R_3

(IV) and causing this latter to be deprived of current when an operator depresses the district key. If the last chauffeur to leave a cab rank forgets to remove his plug from the indicating jack, the signal lamp will glow but the operator will receive no answer from the telephone instrument. Consequently, the line will appear to be faulty, is so reported and its signal lamp is put out of function and remains so until another chauffeur enters the same cab rank, calls up the exchange and gives the information that a plug has been forgotten in the jack, or until a trouble man reports the same condition. This seemingly small detail forces the chauffeurs to carefully mind the signaling, which quite naturally is of fundamental importance for the correct functioning of the system.

The successive fluctuations in the traffic during the month of December 1927 are shown in fig. 5, where the total number of orders as well as the number of orders which could not be effectuated on account of an insufficient number of taxicabs are given. The increase on Saturdays as well as during the Christmas holidays and at New Year's is very noticeable. In judging the insufficiency of taxicabs as compared with the number of orders one must bear in mind that on occasions when the demand is greatest taxis are hailed

Month	8 to 15 o'clock		15 to 22 o'clock		22 to 8 o'clock		Total for entire day		Total number of orders received	Blind-drives
	Effectuated orders	Orders not effectuated	Effectuated orders	Orders not effectuated	Effectuated orders	Orders not effectuated	Effectuated orders	Orders not effectuated		
January	73,047	1,121	105,545	10,425	47,182	517	225,774	12,063	237,837	785
February	63,406	629	96,390	8,989	42,746	177	202,542	9,995	212,537	724
March	73,520	261	109,627	11,211	46,094	184	229,241	11,656	240,897	797
April	77,312	3,421	108,645	26,648	47,624	826	233,581	30,895	264,476	830
May	82,605	3,868	103,165	8,191	41,826	272	227,596	12,331	239,927	812
June	87,182	12,896	82,447	19,028	29,592	305	199,221	32,229	231,450	735
July	76,324	8,010	71,818	12,914	27,097	448	175,239	21,372	196,611	688
August	72,453	4,051	77,573	4,134	26,457	208	176,482	8,393	184,875	709
September ...	76,505	3,458	94,455	14,603	34,057	458	205,017	18,519	223,536	833
October.....	77,076	5,293	110,732	18,085	42,511	673	230,319	24,051	254,370	880
November ...	75,260	554	108,270	6,231	44,565	113	228,095	6,898	234,993	921
December ...	86,290	11,315	114,308	33,962	53,250	7,877	253,848	53,154	307,002	949
Total	920,980	55,077	1,182,974	174,421	483,001	12,058	2,586,955	241,556	2,828,511	9,663
Average per month	76,748	4,590	98,581	14,535	40,250	1,005	215,579	20,130	235,709	815
Average per day	2,523	151	3,241	478	1,323	33	7,087	662	7,749	26

on the streets or are awaited at the cab ranks to a far greater extent than when conditions are normal.

Personnel.

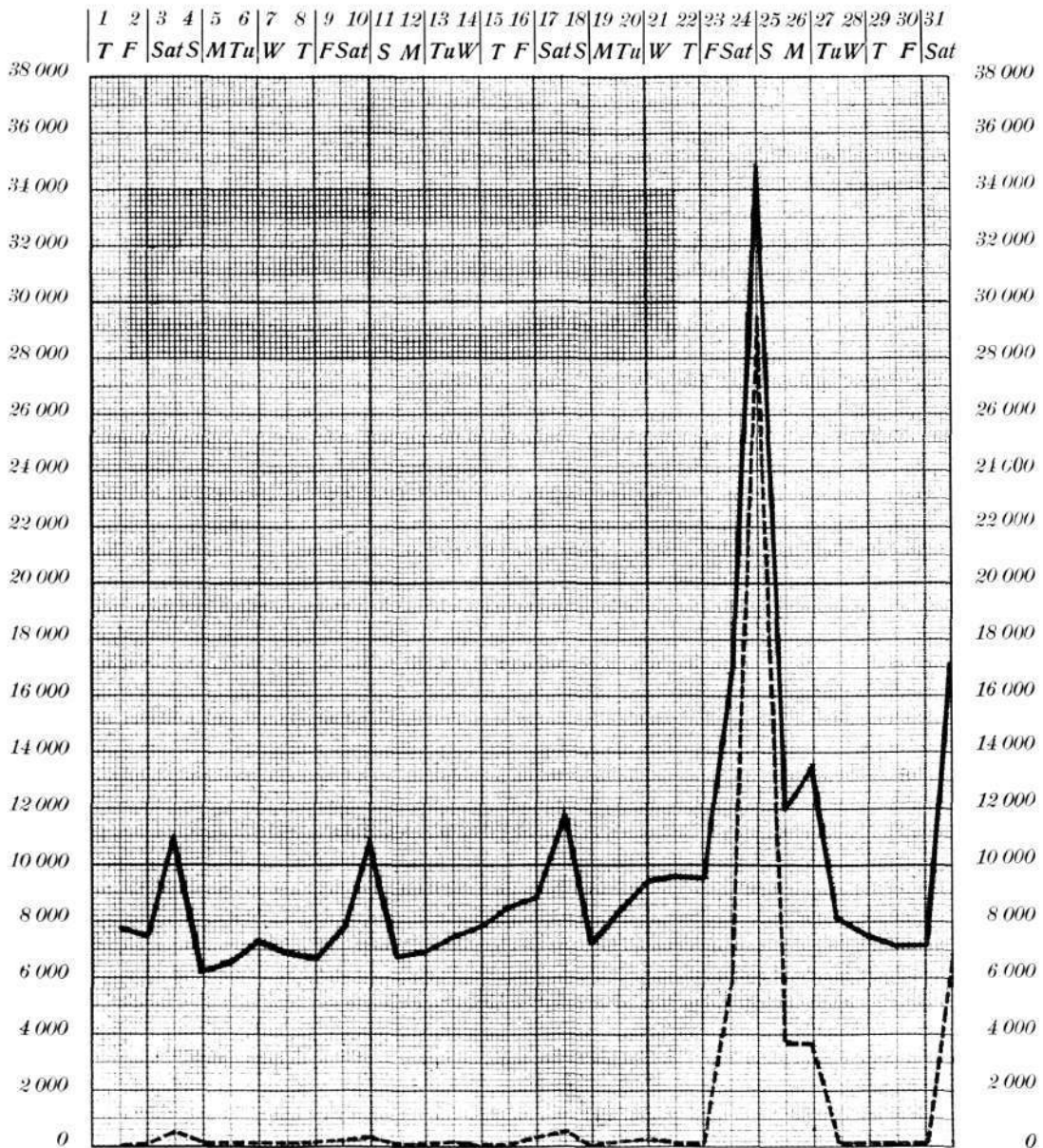
The regular staff of the taxi exchange consists for the present of two exchange superintendents — who

also act as superintendents for the number records of office located in the same building — and twenty-four local operators with an effective working day of 6.5 hours on week days and on every other Sunday. At certain definite times the force is increased with operators from another exchange. The number of operators on duty as well as the distribution of traffic dur-

Supplement 5.

Number of Orders at the Stockholm Taxicab Exchange.

December 1927.

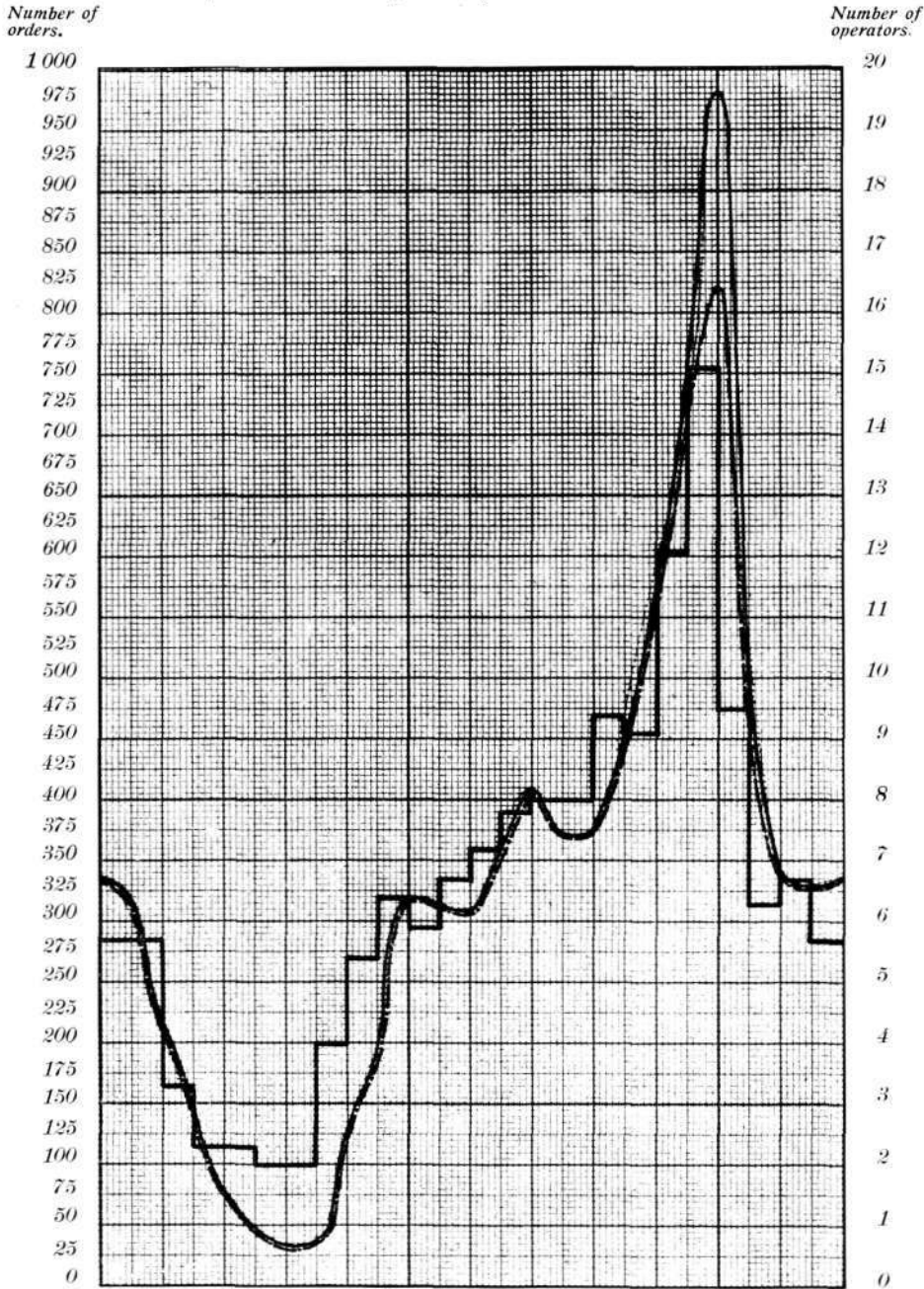


— Total number of orders.

- - - - - Orders not effectuated for lack of a sufficient number of taxicabs.

Average number of orders received (total and number effectuated) at the Stockholm Taxi-cab Exchange and average number of operators during the various hours of the day for the week ending March 4th 1928.

1 Operator-hour during the busy hour = 50 handled calls.



Time 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

Average number of operators 5.7 5.7 3.3 2.3 2.3 2 2 4 5.4 6.4 5.9 6.7 7.2 7.8 8.0 8.0 9.4 9.1 12.1 15.1 19.5 6.3 6.7 5.7

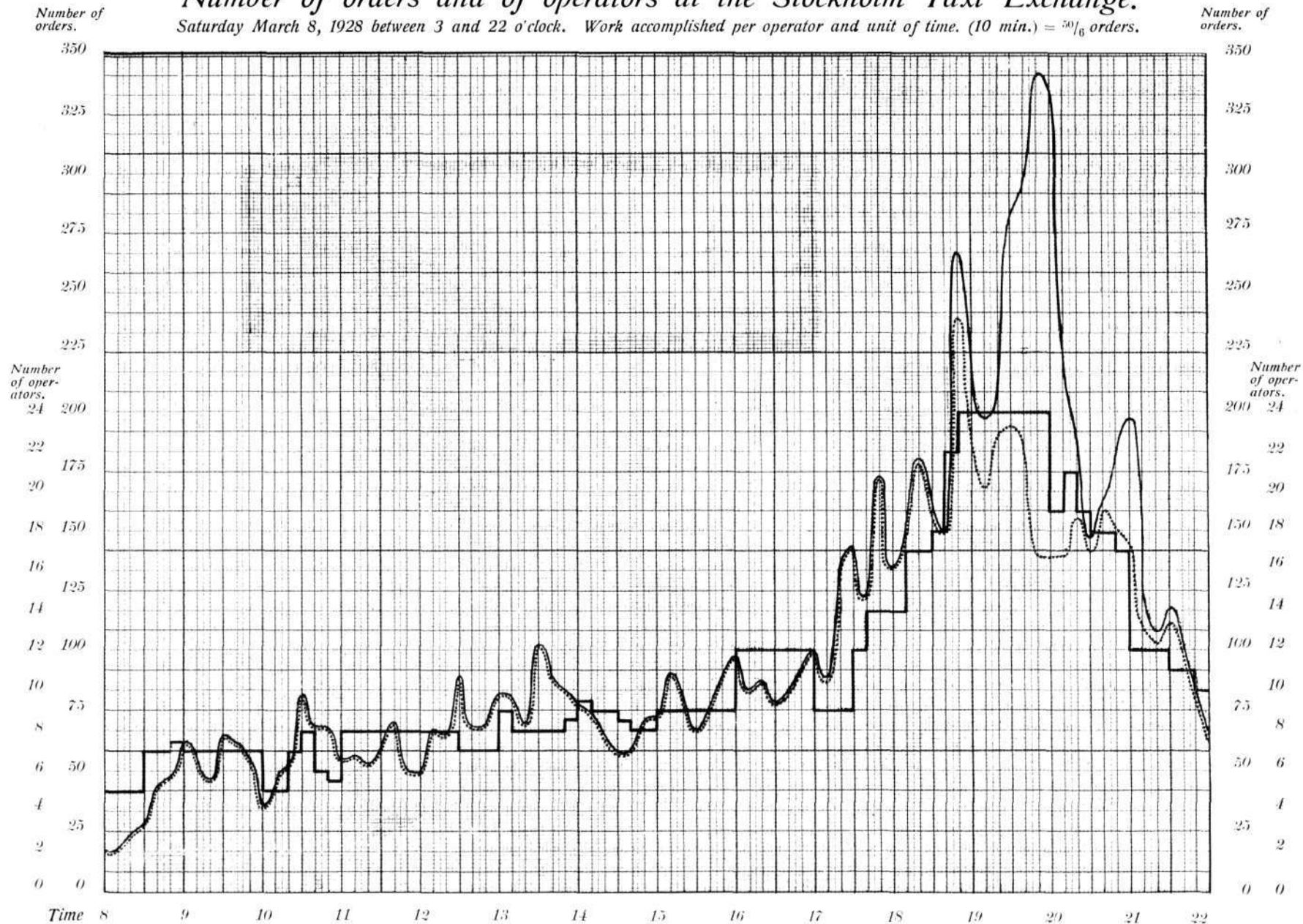
Number of operators.
 Total number of orders.
 Number of effectuated orders.




Note! 0 to 1 o'clock: Closing time of restaurants.
 8 to 10 » : Arrival of suburban trains and opening of office hours.
 13 to 14 » : Lunch time.
 17 to 18 » : Close of office hours and departure of suburban trains.
 19 to 21 » : Opening of theatres and cinemas.

Number of orders and of operators at the Stockholm Taxi Exchange.

Saturday March 8, 1928 between 3 and 22 o'clock. Work accomplished per operator and unit of time. (10 min.) = $\frac{50}{6}$ orders.

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 Number of operators.
 Total number of orders.
 Number of orders effectuated.

ing the various hours of the day is shown in fig. 6. On Saturdays and on days preceding holidays the traffic quite naturally is much heavier than during other week days, this condition being shown in fig. 7, which gives the number of orders received and operators on duty on Saturday March 3rd 1928. The average number of effectuated orders per operator-hour is rather difficult to state since there are two different categories to take into consideration, i. e. such that result in drives and such that cannot be effectuated on account of a lack of taxicabs within suitable distance to the ordering party. However, it may safely be stated that under normal conditions an operator can effectuate fifty orders per hour.

Charges paid by the Taxi Owners' Association to the Telegraph Administration.

The Taxi Owners' Association pays certain stipulated charges for main lines, extension lines, extension telephone instruments and supervision equipment at the office of the Association, these charges being sufficient to cover the expenses of the Telegraph Administration for maintenance and amortization and to give a reasonable interest on the invested capital.

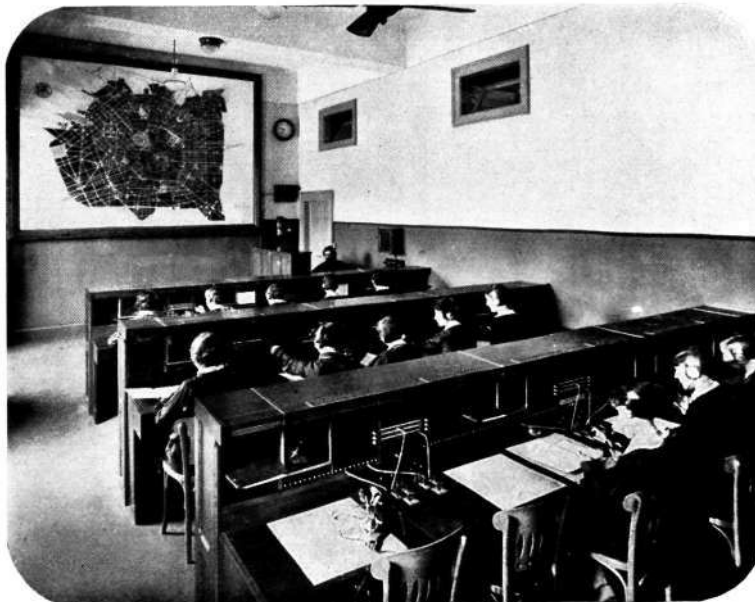
Expenses for salaries for the exchange staff are calculated for each quarter and are based on the personnel engaged during that time, both regular and extra, according to predetermined rates.

Since the solution of the taxi service problem is a matter of important civil interest, the rates have been set just high enough to cover the actual costs of the Telegraph Administration plus the necessary interest on the invested capital.

During 1927 the number of effectuated orders amounted to 2,586,955. The telephone service for each order with positive results cost the Association .0362 Swedish crowns.

No special fee is levied from the telephone subscribers for the placing of orders for taxi service, such an order call being counted as a regular local call. As a general rule the ordering party has a taxi at his disposal within five minutes after the placing of the order.

As far as it is possible to judge there should be no obstacle to this system of telephone taxi order service being introduced in the large metropolises of the world, in which case a subdivision of the city into districts with an order exchange for each district would probably be found necessary.



R 813

The Milan Taxi Exchange.

The Swedish Radio Company.

By Managing Director I. Wibom.

In september 1919 a number of Swedish firms interested in wireless telegraphy and telephony decided to form a company — The Swedish Radio Company — for the promotion of their interests, more specifically for the purpose of carrying on investigations and doing experimental work in the radio branch. This experimental work soon developed into manufacturing, however, a development which did not prove very profitable on account of the adverse post-war conditions. Furthermore, the company could not boast of a very favourable posi-

tion as concerned the use of valuable patents — due to a lack of cooperation with the leading corporations of international repute —, this condition eventually leading to an agreement with the Marconi company whereby this latter became a shareholder in the Radio Company in August 1921 in conjunction with a reorganization of the last mentioned company. The desired position with regard to the use of patents was thus obtained, in addition to which the possibilities of being able to keep abreast of the times were considerable increased.



R 907

Radiola M. 60.



R 908

3-Valve Receiving Set M. 55.

L. M. Ericsson

The advent of broadcasting presented the company with a new field of activity, which has also become the principle one during latter years.

In the fall of 1927, the shares in the hands of Swedish owners were acquired by Telefonaktiebolaget L. M. Ericsson, this company thus obtaining a controlling majority in the Radio Company, a minority amounting to not quite one half of the total number of shares being owned by the Marconi concern. As a

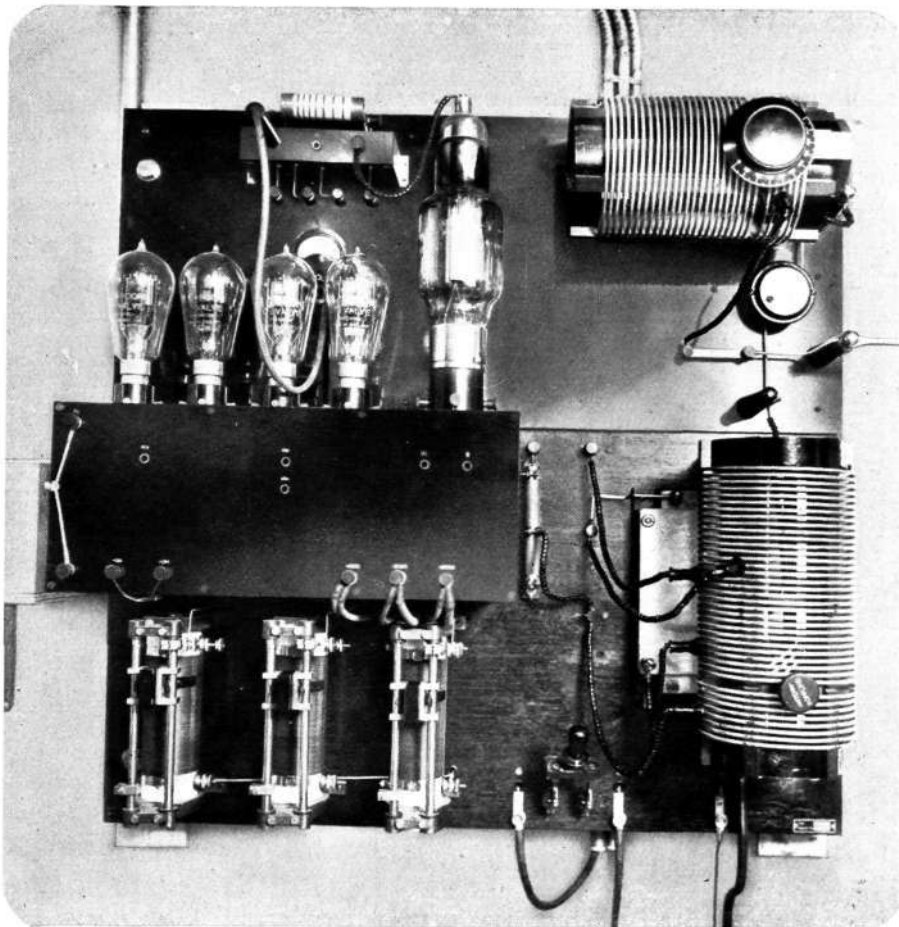
result of its incorporation with the Ericsson concern, the Radio Company is devoting itself more to



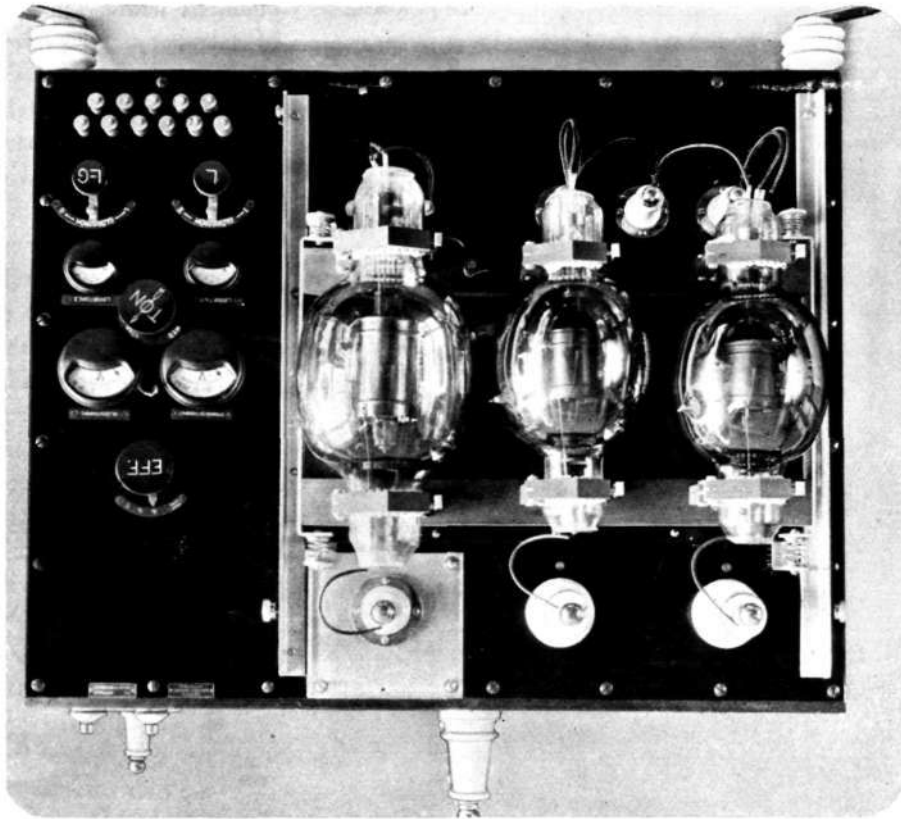
R 902 3-Valve Receiving Set M 55.

questions within the field of telephony, its present activities comprising a department for wireless telephony, a marine department and one for wire telephony.

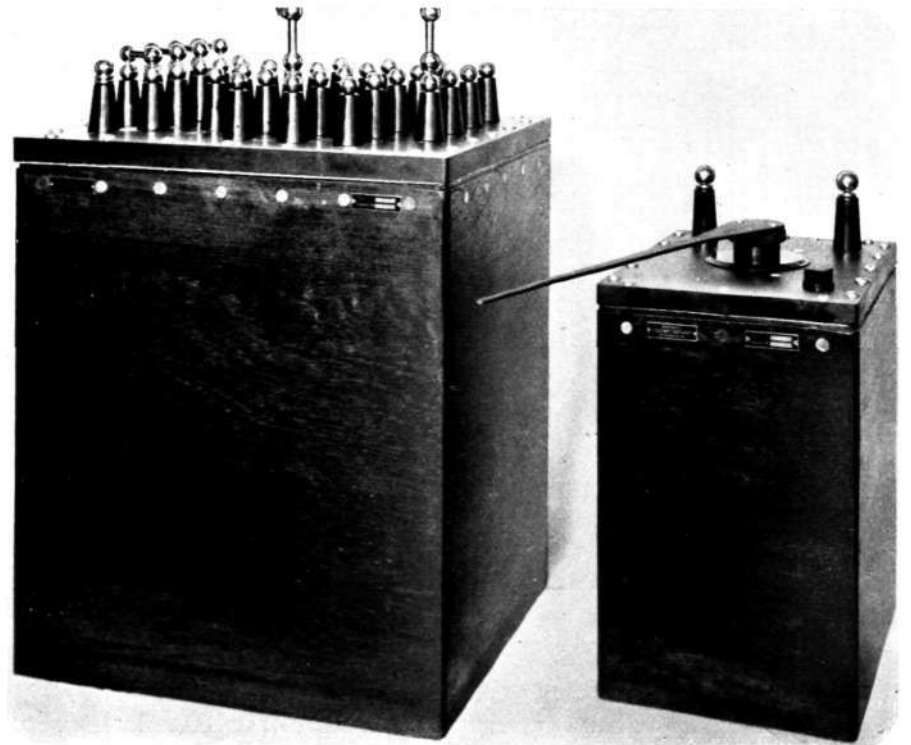
The wireless department has been occupied chiefly with the manufacture of complete receiving sets and transformers. The company's receiving sets — known under the name *Radiola* — have earned a widespread popularity for their excellent workmanship, the ease with which they are manipulated and "tuned in" and their reasonable prices. As far as receiving sets are concerned, there is no doubt



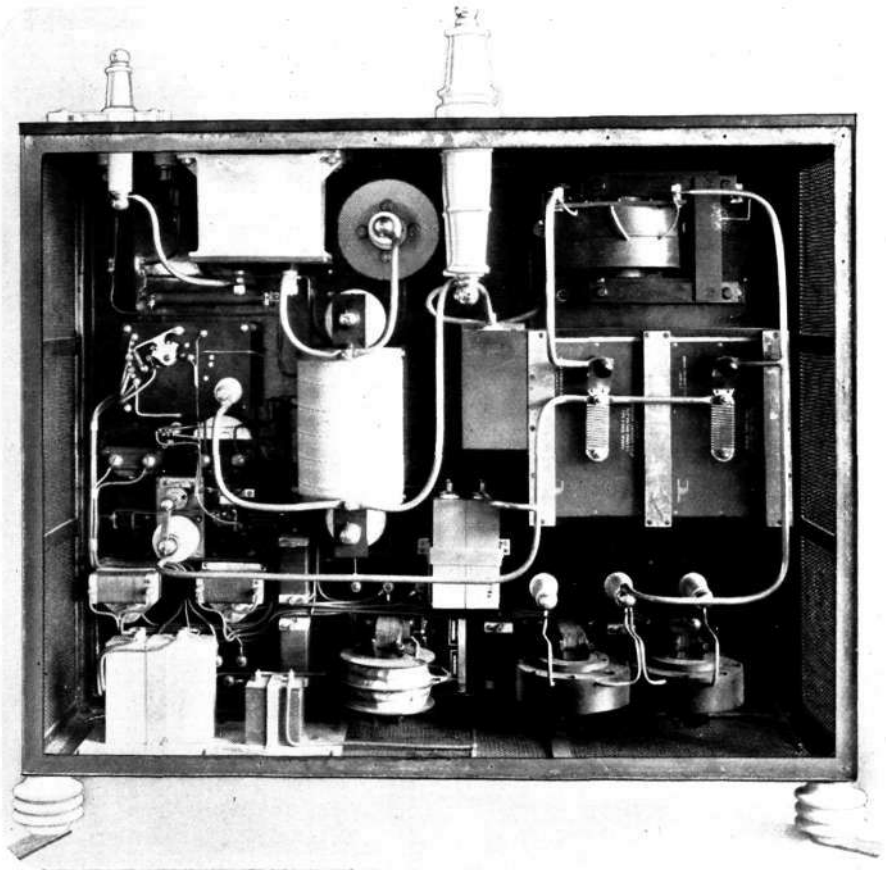
R 904 Relay Sending Station AT 100, Exterior View.



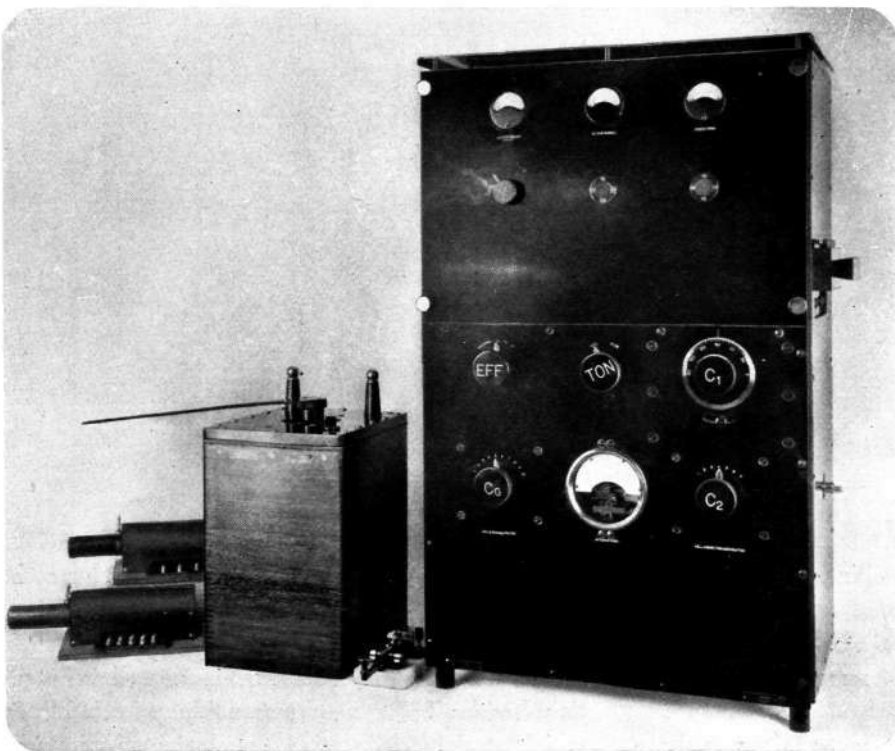
R 901 1 Kw. Sending Station. At 1000 VI G Generator Cabinet. Exterior View.



R 910 1 Kw. Sending Station. Connecting Coil and Variometer.



R 901 a 1 Kw. Sending Station, Generator Cabinet At 1000 VI G. Interior View.



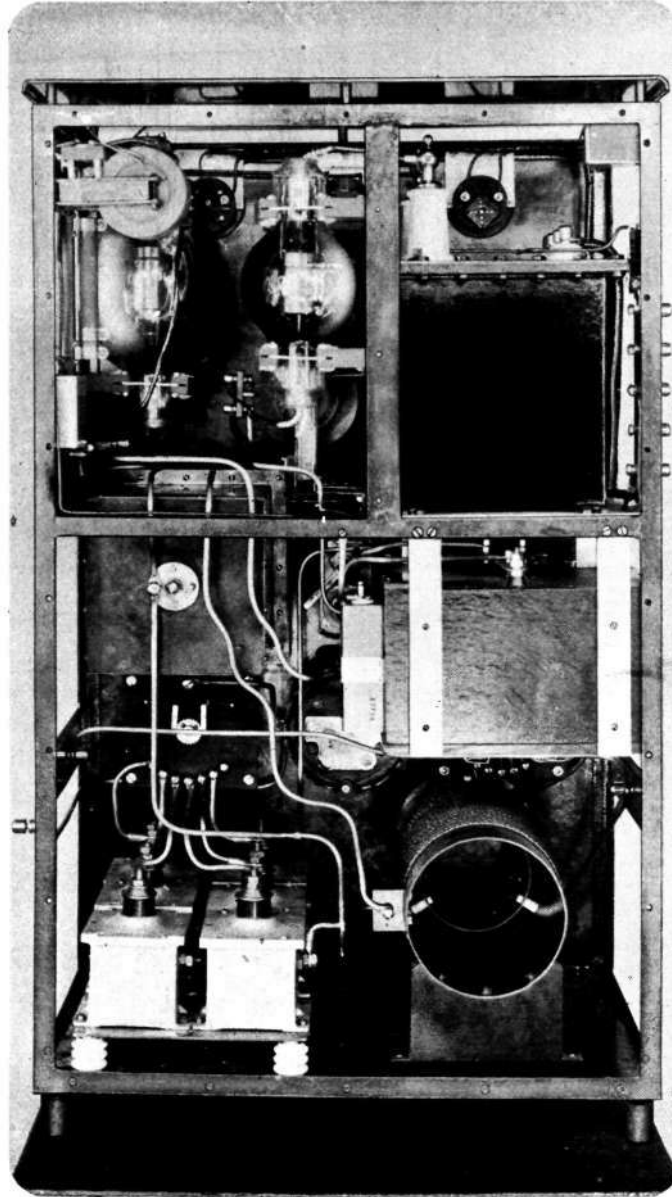
R 905

Sending Station AF 500.

but that the Radio Company is the most important manufacturing concern in Sweden, if not in all Scandinavia, comprising Sweden, Norway and Denmark.

As yet the company has not been in a position to manufacture for export to any great extent, all its ef-

doubt quite well known through the instructions for building radio sets issued by the Baltic company — another Swedish concern occupied with the manufacture of radio material — in which these transformers are highly recommended.



R 906 b Sending Station AF 500. Rear Interior View.

forts having been centered on filling the demands of the domestic market. The two valve set Radiola M 60 and the three valve set Radiola M 55, which were introduced during the past season, are shown in the accompanying illustrations.

The company's low frequency transformers have been extensively sold outside of Sweden and are no

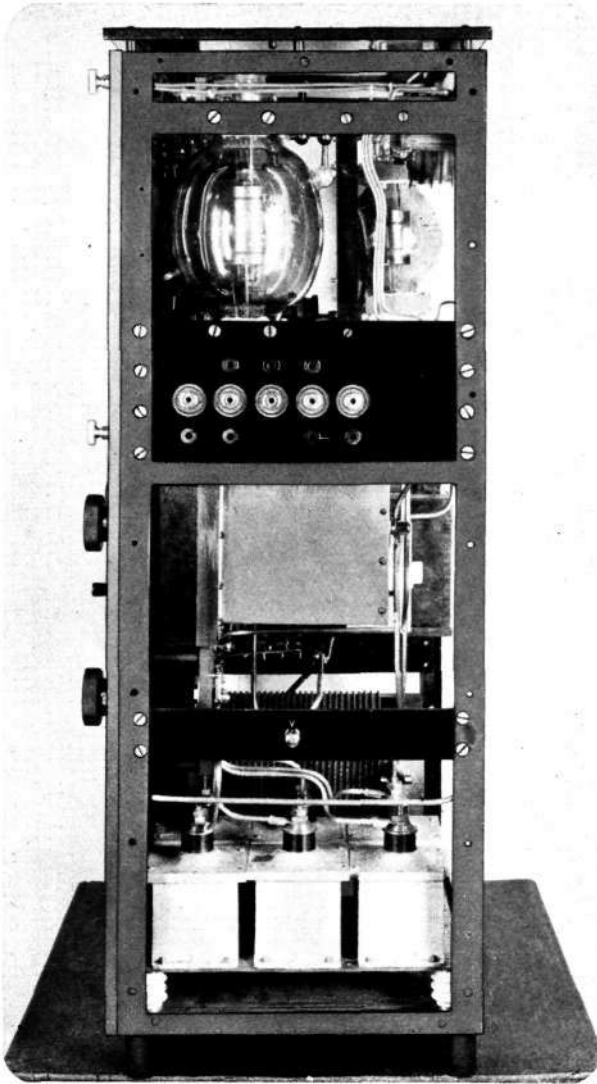
Some twenty relay sending stations have been delivered to different parts of Sweden and Finland by the Radio Company. These relay sending stations are extremely simple in construction as well as in operation besides being very reasonably priced, all facts which explain their wide popularity. We wish to call attention to the fact that all of the relay sending

stations operating in Sweden and purchased complete from the manufacturers are of the Radio Company's make except three, two of these having been furnished by AEG-Telefunken and one by Western Electric. The illustration shows the sending board without amplifier for one of these stations.

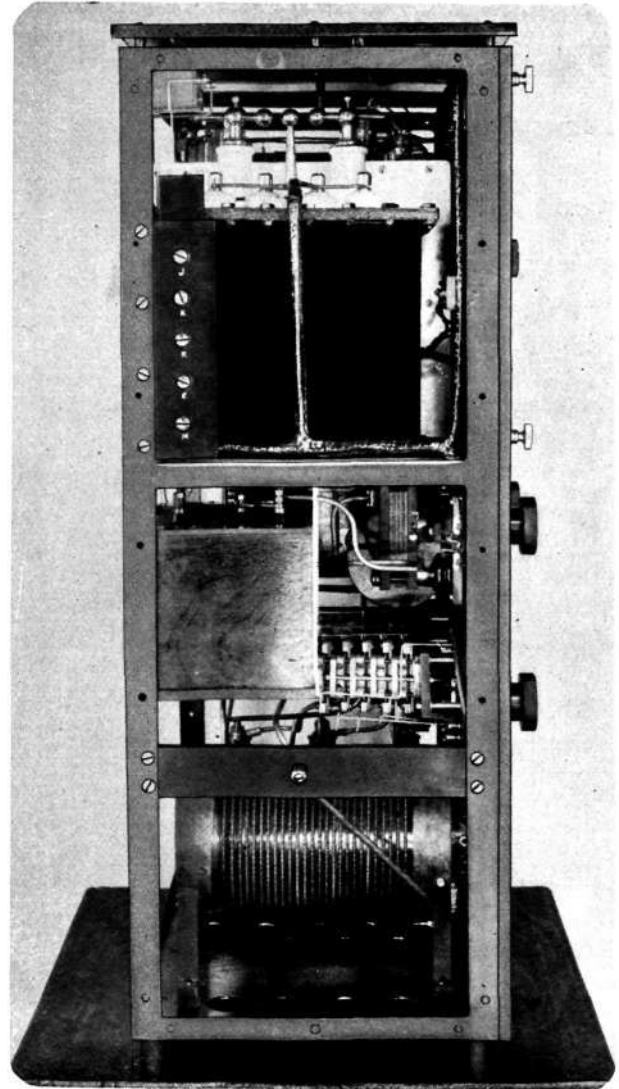
with or without telephone facilities and intermediate circuit.

Marconi's sending valves are used in all of these stations.

A 1 kw. single circuit sending station of the type used in nearly all of the Swedish coastal and inland



R 906 a
Sending Station AF 500. Interior View seen from Right.



R 906
Sending Station AF 500. Interior View seen from Left.

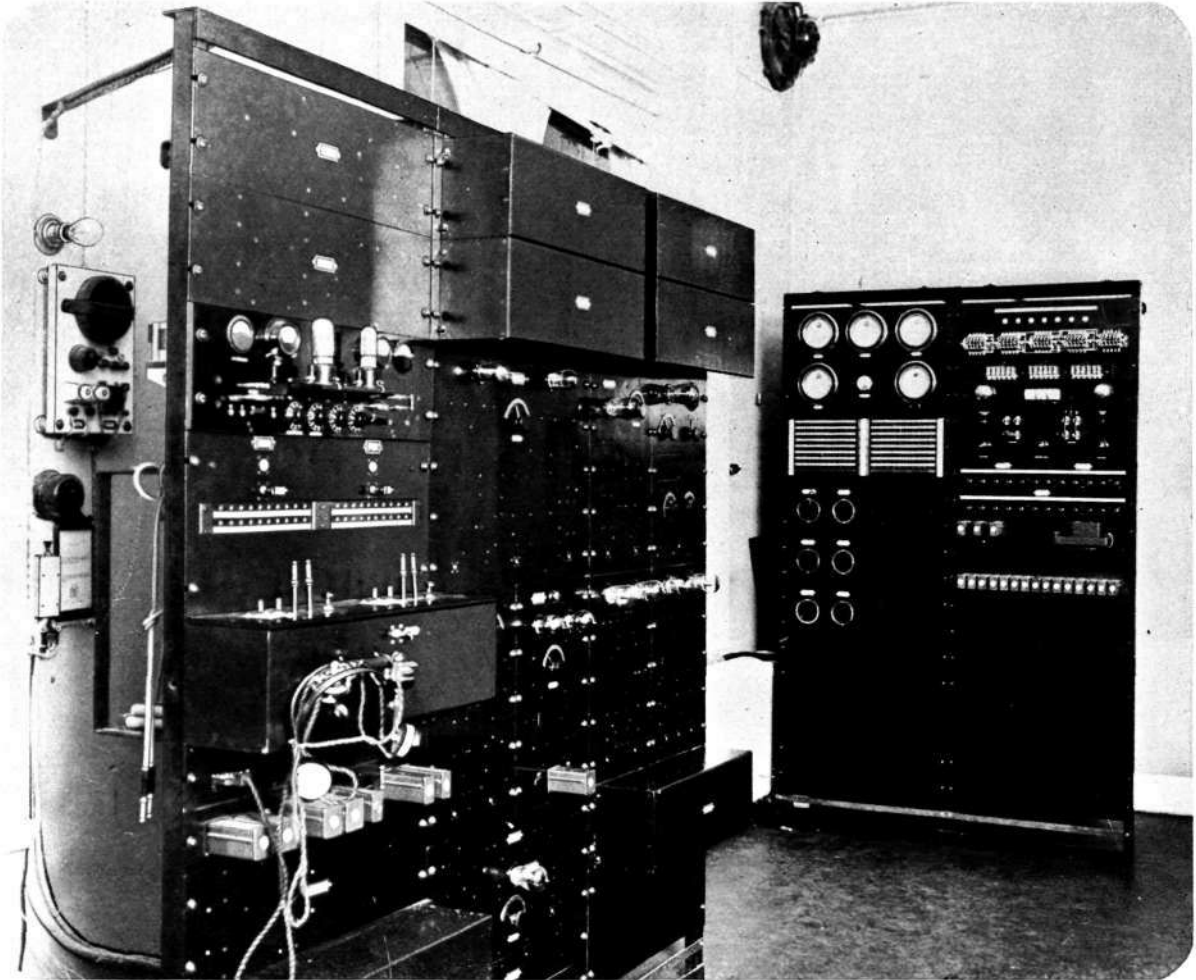
The marine department has been occupied chiefly with the manufacture of wireless stations for the Swedish navy and merchant marine. Sending stations have been of the valve type only, and practically all of the valve sending stations now in use in the Swedish navy and merchant marine have been furnished by the Radio Company. The antenna input of the sending stations varies between 1 kilowatt and 200 watts,

stations and on the liners of the Swedish American line, as well as a 500 watt sending station for the Swedish merchant marine with intermediate circuit and device for producing short waves are shown in the accompanying illustrations.

The 1 kw. sending station is designed for sending telegraphic messages with or without a tone, and for wireless telephony, in which case a special attach-

ment is required, the wave lengths ranging from 500 to 3000 m. The $\frac{1}{2}$ kw. sending station is intended for telegraphy only, with or without tone, and works with a wave length varying between 550 and 850 m. and — with special attachment — between 25 and 50 m. This station requires a 500 cycle alternating current of 2.5 to 3 kw. or 1.6 kw. respectively.

The department for apparatus used in wire telephony has for a number of years been occupied with the manufacture of apparatus for high frequency telephonic and telegraphic communication. Quite a number of installations for this purpose have been delivered within Sweden and to Finland, the most recently built plant — ordered by the Swedish Tele-



R 909 a

Multiplex High Frequency Telephone Communication Stockholm—Umeaa.
The Umeaa Station.

A standard type of wireless receiver — type M 29, covering a range from 17 to 20,000 m. — has been constructed for the Swedish merchant marine. This receiver is equipped with an emergency crystal detector (see illustr.).

It is to be observed that the Swedish Telegraph Administration has a monopoly for the installation of radio equipment on Swedish merchant ships, the above administration consequently being the only channel through which apparatus of this kind can be sold.

graph Administration for the 850 km. long line between Stockholm and Umeaa and with an amplifier at Aange — being shown in the accompanying illustrations. At present this department is occupied with the manufacture of high frequency telephone equipment for the toll service of Empresa de Teléfonos Ericsson, Mexican subsidiary of the Ericsson concern.

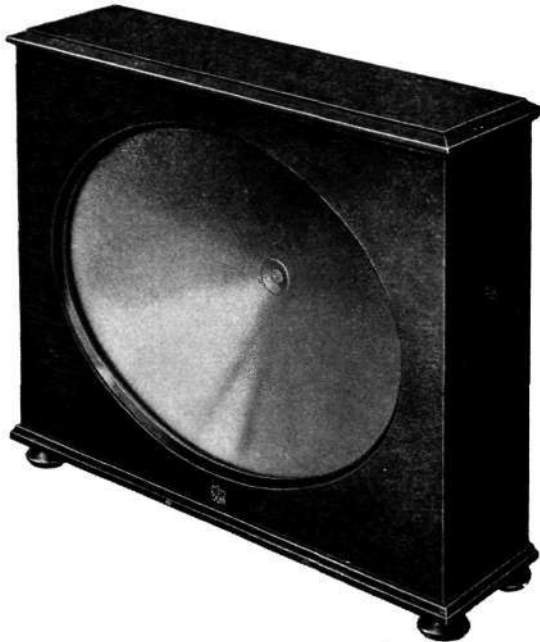
Another important article of manufacture is telephone amplifiers for the Ericsson telephone company, an intimate cooperation having been established between these two companies.



R 903 Receiving Set M 29.

Although the deliveries from the marine department are restricted to Sweden and neighbouring countries on the Baltic sea, the wireless and telephone departments are not thus handicapped.

The existing relations between the Swedish Radio



R 940 Radiola Loudspeaker.

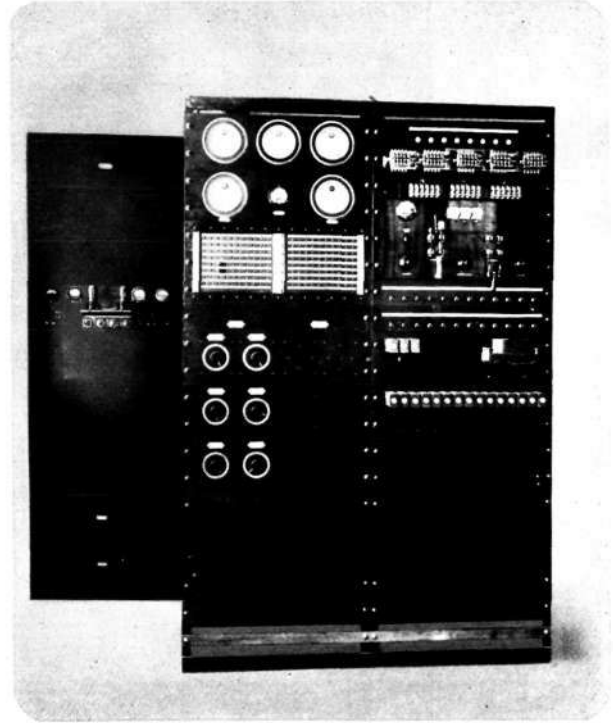


Fig. 13. Multiplex High Frequency Telephone Communication Stockholm—Umeaa. The H. F. Amplifying Station at Aange.

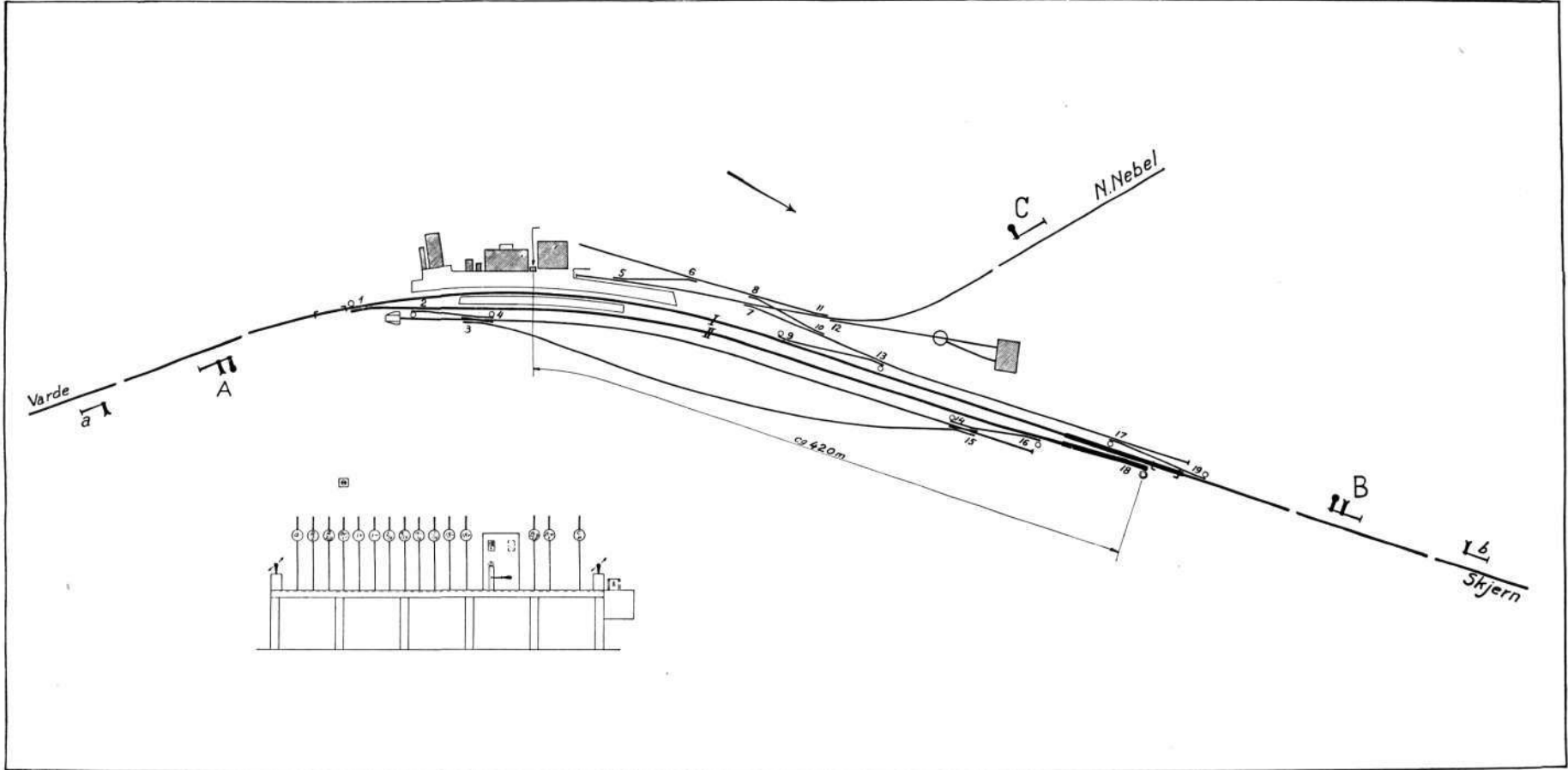
Company on the one hand and the Marconi Wireless Telephone Company and L. M. Ericsson on the other, as well as the reliability and efficiency of the appa-



Radiola Detector.

ratus manufactured speak well for the future popularity and world wide use of the Radio Company's products.

Other branches than those already mentioned are also being developed by this young and enterprising concern, a subject to which we will revert in a subsequent issue.



R. 923

Fig. 1. Track Plan at Tarm, on the Danish State Railways.

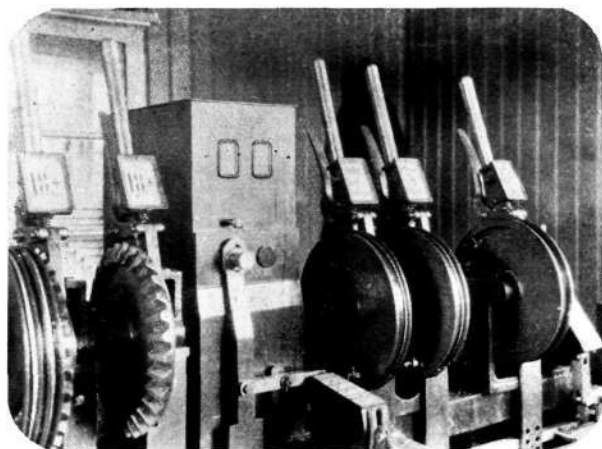
L. M. Ericsson

The smallest electric Interlocking Machine.

In 1925 the mechanical interlocking machine at the Tarm station on the Danish State Railways in Jutland was rebuilt. Formerly, the plant consisted of two interlocking machines, one in each end of the station yard, interconnected by means of electric lock-and block apparatus. On the rebuilding of the plant, which was undertaken for the direct purpose of lowering the operating expenses through a reduction in personnel, these two machines were replaced by a

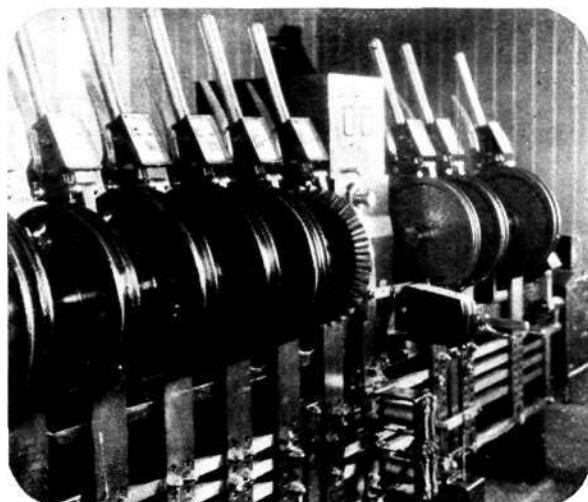
signal lamps of the incoming semaphores. In order to reduce the consumption of 30 volt current as much as possible it was proposed that this current be supplied only when needed and that the closing of the circuit should take place over a pedal contact placed in the floor in front of the lever for the manoeuvring of this point.

With the above requirements in view Signalbolaget prepared complete estimates for the project which



R 924

Fig. 2.



R 925

Fig. 3.

single one located in a new signal cabin near the station building. The distance between the interlocking machine and the most distant point controlled by the same was found to be so great and local conditions were of such a nature that the advisability of manoeuvring this point by means of purely mechanical means became extremely doubtful. This gave rise to the idea of providing electric control for the point in question together with local setting of the same according to the patented L. M. Ericsson system. Power was available for this purpose in the form of a 220 volt direct current, this current being deemed suitable for direct operation of the apparatus without a storage battery. The necessary supervisory current could be obtained from a 30 volt storage battery, which would also supply the energy required for the

were accepted and an order for the plant placed by the Danish State Railways.

This switch, which has been provided with a standard switching machine whose motor is driven by the 220 volt current, is manoeuvred by the aid of a small table type electric interlocking machine (figs. 2 and 3) placed on the top of the mechanical interlocking machine. This small interlocking machine is provided with only one lever, the usual point supervision and point locking magnets and a solenoid for the local setting of the point according to the above-mentioned system. A corresponding track lever in the mechanical interlocking machine is provided with locking magnets and contacts in order to obtain the required cooperation between the electric and the mechanical interlocking machines. When all the devices are in normal

position the system is dead and the track lever in the mechanical interlocking machine is locked in normal position. When the circuit is closed over the pedal contact, the lever magnets become energized, thus permitting the setting of the point lever on condition that the insulated track section nearest the point is free from rolling stock. The point is then set, the track lever being retained in normal position by the above-mentioned locking magnets. After the point has been set, the closing of the pedal contact will energize the locking magnet of the corresponding track lever, thereby releasing the same and permitting this track lever to be set to a position corresponding to that of the point. After the setting of the track lever, the point is locked through the breaking of the circuit over the points lock magnet and the simultaneous breaking of the circuit over the solenoid for local setting of the point, thus also preventing the point from being set locally.

As an added precaution this point is provided with a locking wheel for the mechanical locking of the

same in similarity with the other points in the station area. This provides the added advantage of being able to admit trains to the station by signal in case the current supply from the local power plant should be cut off. If this should happen, the point must be set by hand by the aid of the crank for the point setting mechanism.

The mechanical cross locking gear provides such a mutual cooperation between the points lever in the electric interlocking machine and the two lever arms (+ and —) for the mechanical safety locking that the points lever cannot be set unless the other two lever arms are in normal position i. e. the point is unlocked; neither can a lever arm be moved unless the points lever is in the corresponding position.

This plant is an excellent example of how simply and efficiently serious problems attending mechanical interlocking can be solved by means of electric devices and auxiliary apparatus, and has won the unqualified approval of the personnel who make constant use of the same.

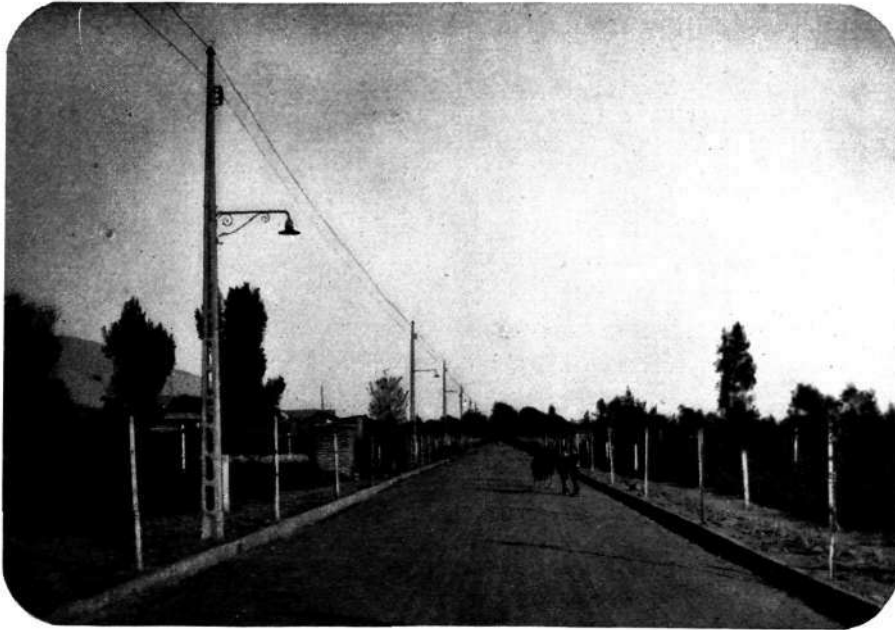
C. P.

Telephone Poles of reinforced Concrete.

The difficulty of obtaining wooden telephone poles at reasonable prices and of suitable durability and length of life is becoming more and more apparent from year to year. Of course, this condition is not so noticeable in timber producing countries like Sweden, for instance, but is all the more seriously felt in those countries that are dependent upon imported material.

sary to adopt the use of more permanent material. The use of reinforced concrete for this purpose has become more and more popular and can well be said to have successfully passed the experimental stage for poles with a length of 12 to 15 metres. Concrete poles of greater length are generally too cumbersome and difficult to transport.

The choice between poles of reinforced concrete



R 926

Fig. 1.

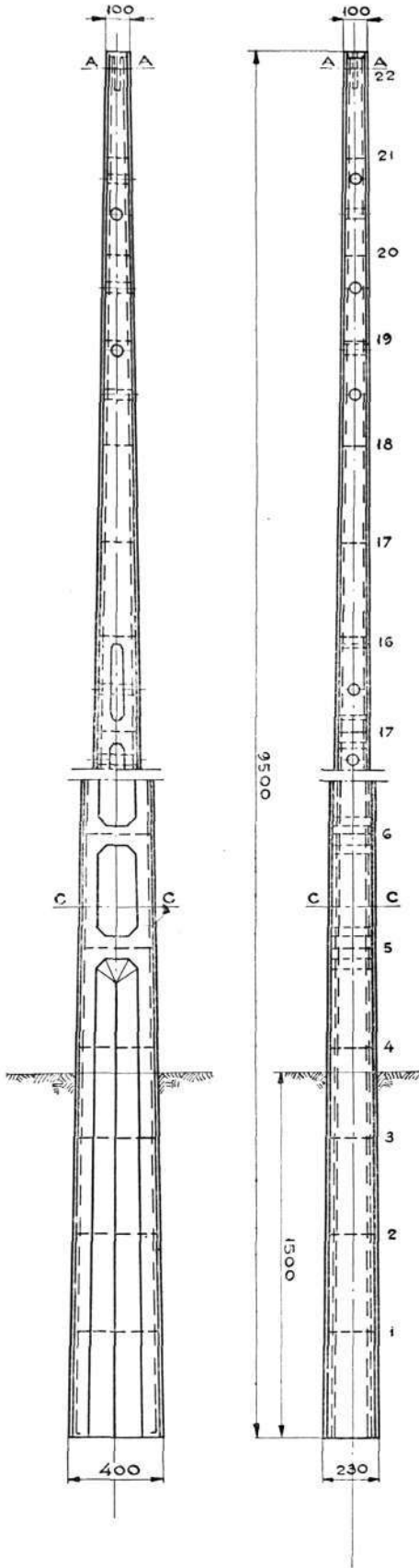
During latter years protectionism has caused this condition to become more and more aggravated, the majority of countries having adopted measures intended to encourage the domestic lumber producing interests and consisting in the levying of more or less prohibitive duties. This often leads to a serious devastation of the forest growth, a condition not easily remedied for lack of efficient legislation. The existing forest lands are dwindling rapidly and nothing is being done for their reclamation.

The prohibitive prices of timber have led to the use of timber of inferior quality, such as eucalyptus, certain species of palms etc., which do not last more than four or five years in damp localities, sometimes even less.

The above cited conditions have so increased the cost of amortization and maintenance of wood pole lines, that in many localities it has been found neces-

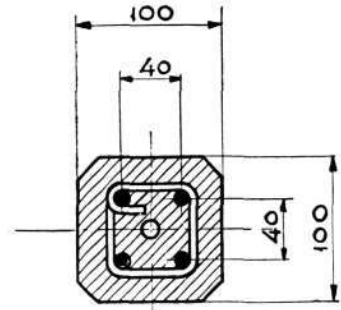
and of wood is largely a matter of economy and due consideration must be given the period of amortization, existing rates of interests, etc. A presentation of the financial aspects of the question would be all too lengthy, however, especially as no general rules are applicable. One must in each separate case choose that alternative which will prove most economical in the long run.

The writer has been in a position to study the construction of reinforced concrete poles by a large Chilean power company, "Compañía de Tracción y Alumbrado de Santiago", which has solved the pole maintenance problem in a most satisfactory manner by the extensive use of concrete. Since the experience which the writer has acquired on this subject may be of interest for the readers of this journal, a short description will be given of the pole design used as well as of the method of construction.



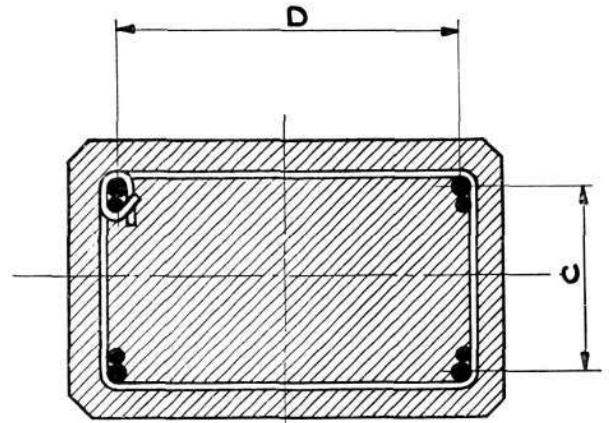
R 939

Fig. 2.



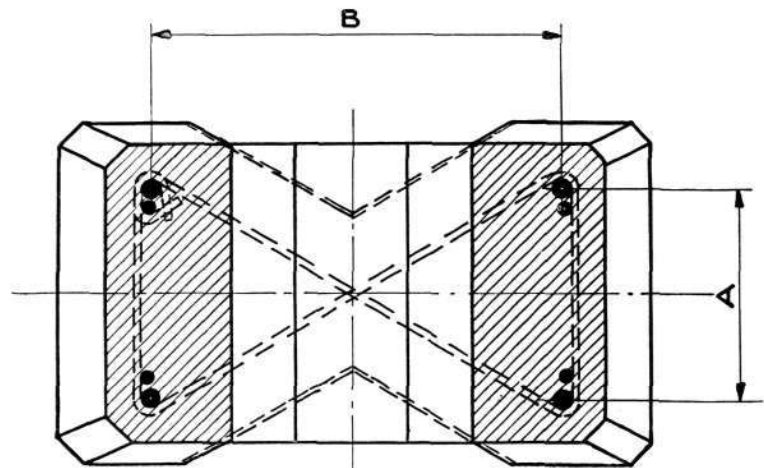
R 938

Section A-A.



R 937

Section B-B.



R 936

Section C-C.

Section B—B

No.	C	D
6	150	272
7	144	257
8	138	242
9	132	229
10	126	216
11	120	203
12	115	190
13	110	177
14	105	164
15	100	151
16	95	138
17	90	125
18	85	113
19	80	101
20	75	89
21	70	77
22	65	65

Section C—C

No.	A	B
1	180	347
2	174	332
3	168	317
4	162	302
5	156	287

quiring 283 kg. of cement per cubic meter of concrete. On this particular job American "Ferrocrete" cement was used.

The pouring of the poles took place in six tanks, one for each working day of the week and each tank accomodating six poles with their respective forms.

The forms are placed in the bottom of an empty tank, each form being built up on a 2" plank. The sides are of sheet steel and are held together by means of strong iron clamps. The openings between the



R 927

Fig. 3.

If the manufacture of concrete poles is to be at all profitable the work must be carried on uninterruptedly. Ordinary portland cement is not very suitable for this purpose on account of its slow setting qualities which necessitate the use of a large number of forms as well as extensive space, making the entire process both lengthy and expensive. The new quick-setting grades of cement are therefore to be preferred, and it can well be said that it is thanks to these that the economical manufacture of concrete poles has been at all possible.

Figure 1 shows the construction of the poles used in Santiago de Chile. As will be seen in fig. 2, they are used for supporting the power lines as well as for street lighting purposes, but there is nothing to prevent their being used to equal advantage for the erection of telephone and telegraph lines. They have a total length of 9.5 m. and weigh 769 kg.

The mix consists of 1 part cement, 2.5 parts river sand and 5 parts crushed stone, these proportions re-

diagonal members are obtained by inserting wood blocks of a suitable shape.

During the pouring operation the reinforcement is held in position by means of 1 m/m iron wire, the protruding ends of which are cut off after the removal of the formwork.

The comparatively thin mix is poured into the forms and left to set until the next morning, when the forms are removed and used for new poles. The poles with their underlying planks remain undisturbed and the tank is immediately filled with water so as to completely submerge the poles, which should remain under water for six days. The setting process is then completed and the poles are ready for immediate use.

The method here described requires no expensive plant. With only six forms and six very simple tanks an output of 150 poles per month can be reached. As a rule the poles can be manufactured on the site, this being an important factor for the elimination of unnecessary transportation.



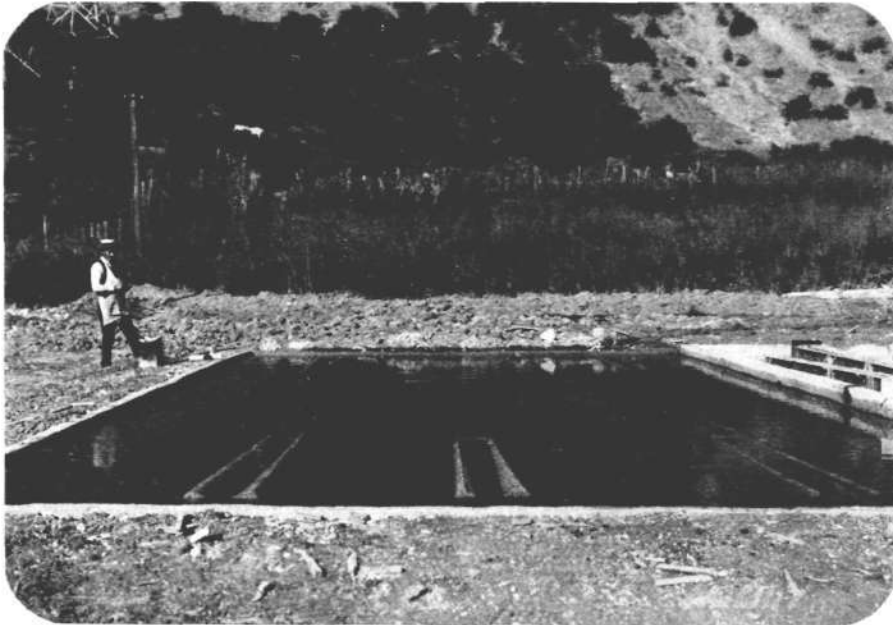
R 929

Fig. 4.

A gang of four men is sufficient for an output of the above-mentioned magnitude. No mixer is required, as one man can easily handle this part of the work, together with the transportation of the mix to the forms.

is required for the transportation and erection of six poles per day.

In order to facilitate the calculation of the cost of manufacture for concrete poles it may be mentioned that the aforementioned Chilean power company fi-



R 928

Fig. 5.

The experience gained on the Santiago job proves that the poles are easily transported and that there is practically no danger of breakage. A four-wheel trailer hauled by a common automobile truck or lorry is best suited for this purpose. A gang of ten men

figures that each pole, including erection and overhead, cost them about four pounds sterling. With the above information and a knowledge of the cost of materials and local labour, however, it should be comparatively easy to arrive at a fairly exact figure. *B. Koch.*

Some Hints on Track Circuit Calculation.

By *Ture Hård*,

Chief Engineer for Signals, Swedish State Railway, Stockholm.

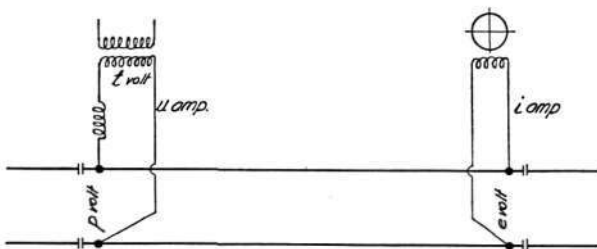
The solving of track circuit problems by considering the circuit as a series-parallel circuit with uniformly distributed constants is not a new idea. The method of calculation described by Harold Mc Ready in his book "Alternating Current Signalling" is based on this principle and is now generally used for practical purposes.

The method presented below is also based on this same principle but differs essentially from the former method with respect to the practical treatment of the problem.

The newer method is practicable for both direct and alternating currents and allows a mathematical treatment to be used throughout. The comparison of different track conditions and apparatus is easier, and the effect of shunting can be more readily calculated. A method of calculating the rail impedance and the ballast resistance from practical tests on track circuits can be based on the same fundamental principles and is described in the following.

General assumptions.

A track circuit, the general arrangements of which are shown in fig. 1, may be considered as a power



distribution system in which the line wires are the rails which transmit power from the track transformer or the battery to the track relay.

The leakage resistance of the ballast is considered equally distributed over the whole length of the track.

The capacity between the two rails is considered negligible as compared with the ohmic leakage. At

every point of the track, therefore, the current through the ballast is in phase with the voltage across the rails at that point.

The self inductance of the rail must be taken into account by using values obtained from actual measurements on track circuits.

In the equations and formulæ presented below the following notations will be used. A letter in bold-faced type signifies a vector or complex quantity. When such a letter is met with in an equation or formula, the phase angle must be taken into consideration. If regular type is used, this means that only the magnitude of the vector or quantity is to be considered. Phase angles are denoted by capital letters.

z = Rail impedance in ohms per 1000 feet of track.

r = Ballast resistance in ohms per 1000 feet of track.

Z = Phase angle of the rail impedance z .

l = Length of track circuit in thousands of feet.

e = Volts between rails at relay end.

i = Ampères in rails at relay end.

p = Volts between rails at feed end.

u = Ampères in rails at feed end.

F_e, F_p and F_u = Phase angles of e, p and u with respect to i , which is taken as the axis of reference.

In the equations and diagrams below, the angles are reckoned positive in the counter-clockwise direction. The phase angle of an impedance is considered positive when the current lags after the voltage.

General equations and formulæ.

With the foregoing assumptions the following equations can be shown to represent the conditions prevailing in the track circuit

$$u = \left(i + e \frac{b}{a} \right) c \dots\dots\dots(1)$$

$$p = (e + i a b) c \dots\dots\dots(2)$$

where

a , b and c are complex quantities, whose magnitudes a , b and c , and phase angles A , B and C , can be calculated from the following formulæ

$$a = \sqrt{rz} \dots\dots\dots (3)$$

$$A = \frac{Z}{2} \dots\dots\dots (4)$$

$$b = \sqrt{\frac{\cosh 2m - \cos 2n}{\cosh 2m + \cos 2n}} \dots\dots\dots (5)$$

$$B = \text{arctg} \frac{\sin 2n}{\sinh 2m} \dots\dots\dots (6)$$

$$c = \frac{1}{\sqrt{2}} \sqrt{\cosh 2m + \cos 2n} \dots\dots\dots (7)$$

$$C = \text{arctg} (\text{tgh } m \times \text{tg } n) \dots\dots\dots (8)$$

where

$$m = l \sqrt{\frac{z}{r}} \cos \frac{Z}{2} \text{ and } n = l \sqrt{\frac{z}{r}} \sin \frac{Z}{2}.$$

From the formula (3) it is clear that the value of a is independent of the length of the track circuit, and for a given track proportional to the square root of the ballast resistance.

Further, from formula (4) we find that for a given track the phase angle A is constant and equal

to the half of the phase angle Z of the rail impedance.

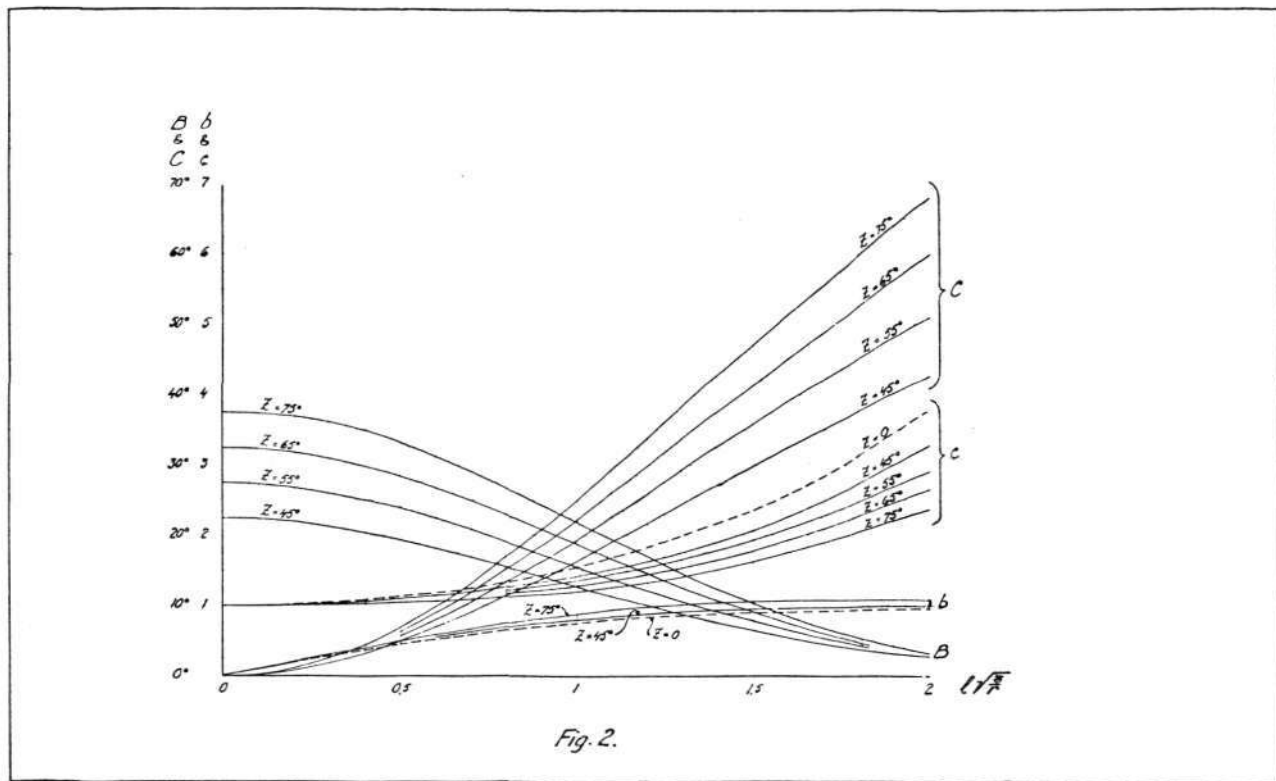
From the formulæ (5), (6), (7) and (8), lastly, we find that b , B , c and C are functions of the quantity $l \sqrt{\frac{z}{r}}$ and the phase angle Z . With the values of l , r , z and Z given, the values of b , B , c and C can be calculated with the aid of tables for trigonometric and hyperbolic functions available in most engineering handbooks.

To illustrate the variations of the quantities b , B , c and C , the curves in fig. 2 have been plotted in the following manner.

The values of b , B , c and C have been calculated for a series of values of $l \sqrt{\frac{z}{r}}$ and Z . For each angle Z curves representing b , B , c and C have then been plotted by using the values of $l \sqrt{\frac{z}{r}}$ as abscissæ and the corresponding values of b , B , c and C as ordinates.

The curves for b and c for $Z = 0$ apply to direct current. With $Z = 0$ the value of B and C is zero.

If plotted with sufficient accuracy, the curves can be used to determine the values of b , B , c and C for



any value of $l\sqrt{\frac{z}{r}}$ and Z by seeking the ordinates corresponding to the given abscissa $l\sqrt{\frac{z}{r}}$ and phase angle Z . When the given angle Z lies between two of the phase angle values for which curves have been plotted, the proper ordinates b , B , c and C may be determined by means of interpolation.

Example 1.

Track circuit, 5000 feet long.

Ballast resistance, 6 ohms per 1000 feet.

Rail impedance, .31 ohms per 1000 feet of track at $\cos Z = .68$.

Hence $l = 5$; $r = 6$; $z = .31$; $Z = 47^\circ$.

Then $l\sqrt{\frac{z}{r}} = 1.14$; $a = \sqrt{rz} = 1.36$; $A = \frac{Z}{2} = 23.5^\circ$.

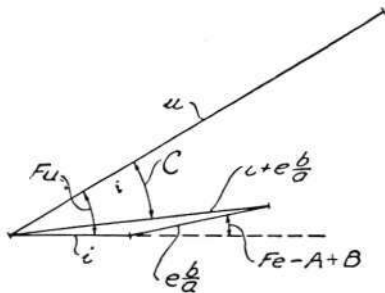
From the formulæ (5), (6), (7) and (8) or from the curves in fig. 2, we obtain

$b = .86$; $B = 11.5^\circ$; $c = 1.53$; $C = 21^\circ$.

Calculation of the current and voltage at the feed end.

When the magnitudes of a , b and c , as well as the phase angles A , B and C , are known, it is possible from the equations (1) and (2) to determine the voltage and current to be used at the feed end of the track circuit in order to maintain a given current and voltage at the relay end.

The determination may be accomplished either graphically by plotting vector diagrams, or analytically by means of vector algebra.



R 880 Fig. 3.

The graphical solution of equation (1)

$$u = \left(i + e \frac{b}{a} \right) c$$

is shown in fig. 3.

The current i is laid off along the axis of reference ($Fi = 0$). The vector representing the expression

$i + e \frac{b}{a}$ is then found by adding a vector of the length $e \frac{b}{a}$ to the current vector i so as to form an angle $Fe - A + B$ with the axis of reference.

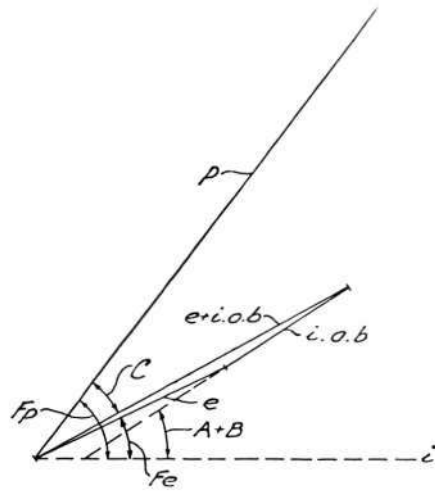
The magnitude of the current vector u is obtained by multiplying the length of $i + e \frac{b}{a}$ with the factor c .

The phase angle Fu of the vector u is determined by revolving the vector $i + e \frac{b}{a}$ the angle C .

The graphical solution of equation (2)

$$p = (e + i a b) c$$

is shown in fig. 4.



R 881 Fig. 4.

The vector e is drawn at an angle Fe to the current vector i , which, as in fig. 3, is the axis of reference.

The second component $i a b$ of the expression $e + i a b$ is laid off at an angle $A + B$ to the reference axis.

By multiplying the length of the resultant vector $e + i a b$ with the factor c , and revolving this vector the angle C , the vector p is determined as to magnitude and phase.

The magnitudes p and u and their phase angles Fp and Fu may also be determined by solving the vector equations (1) and (2) analytically. For this purpose the equations should be written in the following forms where the letter j signifies the imaginary component of a complex quantity and E the base of the Napierian logarithms.

$$u E^{jFu} = \left[i + e \frac{b}{a} E^{j(Fe-A+B)} \right] c E^{jC} =$$

$$= \left[i + e \frac{b}{a} \cos(Fe-A+B) + \right.$$

$$\left. + j e \frac{b}{a} \sin(Fe-A+B) \right] c E^{jC}.$$

$$p E^{jFp} = [e E^{jFe} + i a b E^{j(A+B)}] c E^{jC} =$$

$$= [e + i a b E^{j(A+B-Fe)}] c E^{j(C+Fe)} =$$

$$= [e + i a b \cos(A+B-Fe) +$$

$$+ j i a b \sin(A+B-Fe)] c E^{j(C+Fe)}.$$

Hence

$$u = c \sqrt{\left[i + e \frac{b}{a} \cos(Fe-A+B) \right]^2 +$$

$$+ \left[e \frac{b}{a} \sin(Fe-A+B) \right]^2} =$$

$$= c \sqrt{i^2 + \left(e \frac{b}{a} \right)^2 + 2 i e \frac{b}{a} \cos(Fe-A+B)} \dots(9)$$

$$p = c \sqrt{[e + i a b \cos(A+B-Fe)]^2 +$$

$$+ [i a b \sin(A+B-Fe)]^2} =$$

$$= c \sqrt{e^2 + (i a b)^2 + 2 i e a b \cos(A+B-Fe)} \dots(10)$$

$$Fu = \arctg \frac{e \frac{b}{a} \sin(Fe-A+B)}{i + e \frac{b}{a} \cos(Fe-A+B)} + C \dots\dots\dots(11)$$

$$Fp = \arctg \frac{i a b \sin(A+B-Fe)}{e + i a b \cos(A+B-Fe)} + C + Fe \dots(12)$$

Example 2.

Let us use the track circuit described in example 1, and assume the current through the relay to be 1 amp. at 1.78 volts between the rails, and lagging 25° behind this voltage.

We have then $i = 1$ volt; $e = 1.78$ volts; $Fe = 25^\circ$; $a = 1.36$; $A = 23.5^\circ$; $b = .86$; $B = 11.5^\circ$; $c = 1.53$; $C = 21^\circ$; $Fe - A + B = 25^\circ - 23.5^\circ + 11.5 = 13^\circ$; $A + B - Fe = 23.5 + 11.5 - 25 = 10^\circ$.

Hence, from the formulæ (9), (10), (11) and (12)

$$u = 1.53 \times \sqrt{1 + \left(1.78 \times \frac{.86}{1.36} \right)^2 + 2 \times 1 \times 1.78 \times$$

$$\times \frac{.86}{1.36} \cos 13^\circ} = 3.22 \text{ amp.}$$

$$p = 1.53 \times \sqrt{1.78^2 + (1 \times .86 \times 1.36)^2 + 2 \times 1 \times$$

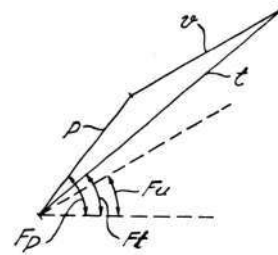
$$\times 1.78 \times .86 \times 1.36 \times \cos 10^\circ} = 4.50 \text{ volts.}$$

$$Fu = \arctg \frac{1.78 \times \frac{.86}{1.36} \times \sin 13^\circ}{1 + 1.78 \times \frac{.86}{1.36} \times \cos 13^\circ} + 21^\circ = 28^\circ.$$

$$Fp = \arctg \frac{1 \times 1.36 \times .86 \times \sin 10^\circ}{1.78 + 1 \times 1.36 \times .9 \times \cos 10^\circ} +$$

$$+ 21^\circ + 25^\circ = 50^\circ.$$

If the voltage t at the track transformer secondary is given, the voltage drop v in the limiting resistance or impedance between transformer and track can be obtained as shown in fig. 5.



R 882 Fig. 5.

After plotting the vector p at an angle Fp to i , the vector v representing the voltage drop is laid off at the proper phase angle to the current u and is extended so that the resultant of p and v becomes equal to the given transformer voltage t .

Influence of a shunt between rails.

It is now easy to determine the influence on the track circuit of the application of an impedance of any sort across the rails. Let us assume an impedance of the magnitude d and with a phase angle D to be connected across the rails at the relay end.

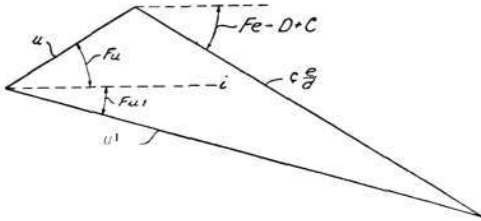
The current u_1 and voltage p_1 necessary at the feed end to maintain the voltage e at the relay end after applying the shunt d may be expressed by the following vector equations

$$u_1 = \left(i + \frac{e}{d} + e \frac{b}{a} \right) c = \left(i + e \frac{b}{a} \right) c + \frac{e}{d} c = u + \frac{e}{d} c \dots(13)$$

$$p_1 = \left[e + \left(i + \frac{e}{d} \right) a b \right] c = (e + i a b) c + \frac{e}{d} a b c =$$

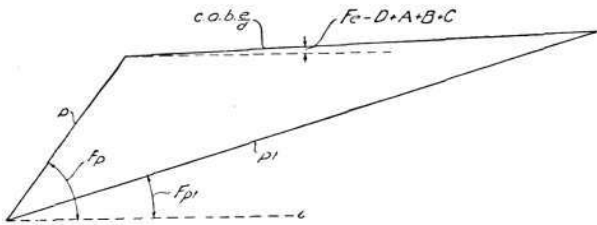
$$= p + \frac{e}{d} a b c \dots\dots\dots(14)$$

From the expressions (13) and (14) it follows that the current u_1 is obtained by adding to the current vector u a vector of the magnitude $\frac{e}{d} c$ making an angle $Fe + C - D$ with the reference axis i . The graphical construction of equation (13) is shown in fig. 6.



R 883 Fig. 6.

Likewise, the voltage p_1 can be found by adding to the voltage p a vector of the magnitude $\frac{e}{d} a b c$ making an angle $Fe + A + B + C - D$ with the reference axis i . The graphical solution of equation (14) is shown in fig. 7.



R 884 Fig. 7

The solution of equations (13) and (14) may also be carried out analytically. The equations should then be written in the following forms

$$u_1 E^{jF_{u_1}} = u E^{jF_u} + \frac{e}{d} c E^{j(Fe+C-D)}$$

$$p_1 E^{jF_{p_1}} = p E^{jF_p} + \frac{e}{d} a b c E^{j(Fe+A+B+C-D)}$$

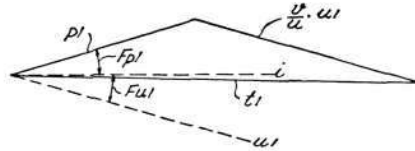
Hence

$$u_1 = \sqrt{\left[u \cos F_u + \frac{e}{d} c \cos (Fe + C - D) \right]^2 + \left[u \sin F_u + \frac{e}{d} c \sin (Fe + C - D) \right]^2} \dots (15)$$

$$p_1 = \sqrt{\left[p \cos F_p + \frac{e}{d} a b c \cos (Fe + A + B + C - D) \right]^2 + \left[p \sin F_p + \frac{e}{d} a b c \sin (Fe + A + B + C - D) \right]^2} (16)$$

$$F_{u_1} = \arctg \frac{u \sin F_u + \frac{e}{d} c \sin (Fe + C - D)}{u \cos F_u + \frac{e}{d} c \cos (Fe + C - D)} (17)$$

$$F_{p_1} = \arctg \frac{p \sin F_p + \frac{e}{d} a b c \sin (Fe + A + B + C - D)}{p \cos F_p + \frac{e}{d} a b c \cos (Fe + A + B + C - D)} (18)$$



R 885 Fig. 8.

In fig. 8 is shown the graphical determination of the hypothetical transformer voltage t_1 corresponding to the voltage p_1 , the current u_1 and the given limiting impedance $\frac{v}{u}$ between transformer and track.

After plotting the vector p_1 the voltage drop $\frac{v}{u} u_1$ in the limiting impedance is laid off at the proper angle to the current u_1 . The resultant of p_1 and the drop vector represents the hypothetical voltage t_1 .

If u , p and t are values actually existing with the track clear, it is obvious that p_1 , u_1 and t_1 cannot be the real values to be expected on applying the shunt d . Since the voltage t at the track transformer secondary remains practically unchanged after the application of the shunt, it is obvious that the voltages and currents actually existing in the track circuit with the impedance d connected across the rails will be found by reducing the values p_1 , u_1 , e and i in the proportion of $\frac{t}{t_1}$.

Calculation of the rail impedance and the ballast resistance from "short circuit" and "open circuit" values.

Let us consider a case where the relay end is short circuited, so that the voltage between the rails is zero. From equations (1) and (2) we obtain

$$u_s = i_s c$$

$$p_s = i_s a b c$$

where u_s and p_s are the current and the voltage at the feed end and i_s is the current at the relay end when this latter is short circuited. Dividing the equations we obtain

$$\frac{p_s}{u_s} = a b \dots\dots\dots (19)$$

If S is the phase angle between p_s and u_s , then $S = A + B$.

Assuming that the circuit is broken at the relay terminals so that no current passes through the relay end, then $i = 0$.

From equations (1) and (2) we then obtain

$$u_o = e_o \frac{b}{a} c$$

$$p_o = e_o c$$

where u_o and p_o represent current and voltage at the feed end, and e_o the voltage at the relay end when the track circuit is open at the relay end.

Dividing the equations, we obtain

$$\frac{p_o}{u_o} = \frac{a}{b} \dots\dots\dots (20)$$

If O is the phase angle between p_o and u_o , then $O = A - B$.

From equations (19) and (20) the following formulæ can be derived

$$a = \sqrt{\frac{p_s p_o}{u_s u_o}} \dots\dots\dots (21)$$

$$b = \sqrt{\frac{p_s u_o}{u_s p_o}} \dots\dots\dots (22)$$

$$A = \frac{S + O}{2} \dots\dots\dots (23)$$

$$B = \frac{S - O}{2} \dots\dots\dots (24)$$

From formula (4) we get $Z = 2A$.

Hence $Z = S + O$, which means that the phase angle of the rail impedance is equal to the sum of the phase angle between current and voltage at the transformer end when the track circuit is opened at the relay end, and the phase angle between current and voltage at the feed end when the track is short circuited at the relay end.

The formulæ (5) and (6) may be written

$$\cos 2n = \frac{1 - b^2}{1 + b^2} \cosh 2m$$

$$\cosh 2m = \sqrt{1 + \cot^2 B - \cot^2 B \cos^2 2n}$$

By putting $\frac{1 - b^2}{1 + b^2} = k$ and solving the equations we obtain

$$\cosh 2m = \frac{1}{\cos B \sqrt{k^2 + \text{tg}^2 B}} \dots\dots\dots (25)$$

$$\cos 2n = \frac{k}{\cos B \sqrt{k^2 + \text{tg}^2 B}} \dots\dots\dots (26)$$

With the aid of the formulæ (25) and (26) the values of m and n can be calculated if the values of k and B are known.

Previously, we had

$$m = l \sqrt{\frac{z}{r}} \cos \frac{Z}{2} \quad \text{and} \quad n = l \sqrt{\frac{z}{r}} \sin \frac{Z}{2}$$

Therefore,

$$\text{tg} \frac{Z}{2} = \frac{n}{m}$$

$$\sqrt{\frac{z}{r}} = \frac{m}{l \cos \frac{Z}{2}} = \frac{n}{l \sin \frac{Z}{2}}$$

Further, from the general formula (3) we know that $\sqrt{rz} = a$.

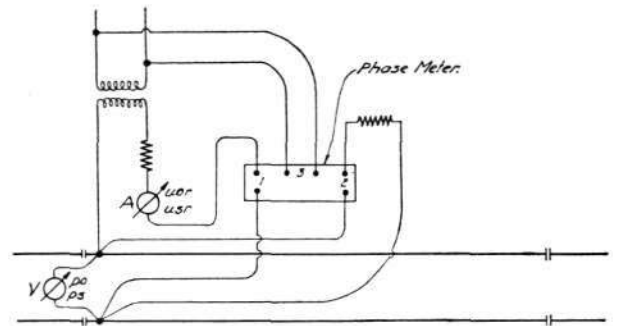
The following formulæ will, therefore, give the values of the rail impedance and the ballast resistance.

$$z = \frac{a m}{l \cos \frac{Z}{2}} \quad \text{or} \quad \frac{a n}{l \sin \frac{Z}{2}} \dots\dots\dots (27)$$

$$r = \frac{a l \cos \frac{Z}{2}}{m} \quad \text{or} \quad \frac{a l \sin \frac{Z}{2}}{n} \dots\dots\dots (28)$$

Method of testing.

In fig. 9 is shown a method of obtaining the values of p_o , u_o , p_s and u_s and the phase angles O and S with the aid of an ammeter, a voltmeter, and an instrument for measuring phase angles between currents.



R 886 Fig. 9.

For measuring the phase angles, a power factor meter of special design has been employed. The instrument has two separate current coils, one of which (number one) has an impedance of .6 ohms at 50 cycles and is connected in series with the ammeter.

The other current coil (number two), which has an impedance of 16 ohms at 50 cycles, is connected across the rails in series with an ohmic resistance of about 100 ohms. To each one of the current coils belongs a tension coil (number three). Both of these tension coils are connected to the same auxiliary voltage, for instance the primary of the track transformer.

The instrument has two scales showing the phase angle between the auxiliary voltage and each of the two currents. The difference between the indicated phase angles will give the phase angle between the currents passing through the current coils. As the phase difference between the current and the total drop in the branch consisting of coil 2 and a resistance in series is known, it is also possible with the aid of this instrument to determine the difference in phase between the current through the ammeter and the voltage across the rails.

In order to obtain the correct values of u_s and u_o the ammeter readings u_{sr} and u_{or} should be corrected so as to allow for current passing through the voltmeter and the phase meter coil in parallel with the voltmeter. Likewise, it will be necessary to correct the phase meter reading S_r , as shown in the following example.

Example 3.

Test made on a track circuit fed with a 50 cycle alternating current.

Length of track circuit, 5000 feet.

Weight of rails, 40.5 kg. per metre.

Length of each rail, 10 metres.

Bonding by means of copper wires welded to the rail head.

Measurements with track circuit open.

Readings,

$p_o = 8$ volts (resistance of voltmeter = 500 ohms).

$u_{or} = 2.60$ amp.

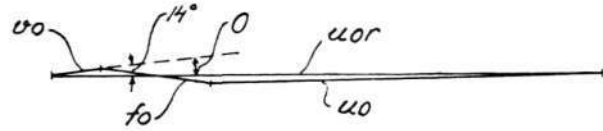
$O = 6^\circ$ (impedance of phase meter coil and resistance connected in series across the rails = 110 ohms at a phase angle of 14°).

Current taken by voltmeter $v_o = \frac{8}{500} = .016$ amp.

Current taken by phasemeter $f_o = \frac{8}{110} = .073$ »

Corrected according to the diagram in fig. 10,

$$u_o = 2.60 - .016 - .073 = 2.51 \text{ amp.}$$



R 887

Fig. 10.

Measurements with the track short circuited at relay end.

Readings,

$p_s = 3.90$ volts (resistance of voltmeter = 100 ohms).

$u_{sr} = 3.75$ amp.

$S_r = 54.5^\circ$ (impedance of phase meter coil and resistance = 110 ohms at a phase angle of 14°).

Current taken by voltmeter, $v_s = \frac{3.90}{100} = .039$ amp.

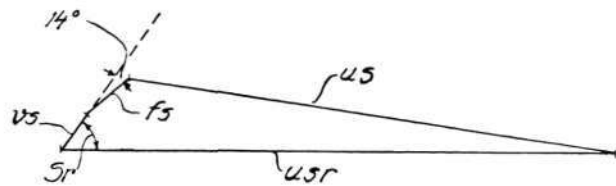
Current taken by phase meter, $f_s = \frac{3.90}{110} = .035$ amp.

Corrected according to the diagram in fig. 11.

$$u_s = 3.75 - .04 \times \cos 54.5^\circ - .035 \times \cos (54.5^\circ - 14^\circ) = 3.70 \text{ amp.}$$

$$S = 54.5 +$$

$$+ \frac{.04 \times \sin 54.5^\circ + .035 \times \sin 40.5^\circ}{3.70 \times 3.14} \times 180 = 55^\circ$$



R 888

Fig. 11.

Hence, from the formulæ (21), (22), (23) and (24)

$$a = \sqrt{\frac{3.90}{3.70} \times \frac{8.00}{2.51}} = 1.84$$

$$b = \sqrt{\frac{3.90}{3.70} \times \frac{2.51}{8.00}} = .575$$

$$A = \frac{55 + 6}{2} = 30.5^\circ$$

$$B = \frac{55 - 6}{2} = 24.5^\circ$$

Further, $k = \frac{1 - b^2}{1 + b^2} = \frac{1 - .33}{1.33} = .50$ and from the formulæ (25) and (26)

$$\cosh 2m = \frac{1}{.91 \times \sqrt{.25 + .21}} = 1.62$$

$$\cos 2n = .50 \times 1.62 = .81$$

$$2m = 1.06; m = .53.$$

$$2n = 35.45^\circ = .62; n = .31.$$

$$\text{tg } \frac{Z}{2} = \frac{.31}{.53} = .59; \frac{Z}{2} = 30.5^\circ. \quad Z = 61^\circ.$$

This value of Z coincides with the value of Z which is obtained by adding up the phase angles $S = 55^\circ$ and $O = 6^\circ$.

Finally, from the formulæ (27) and (28) we obtain

$$z = \frac{1.84 \times .53}{5 \times \cos 30.5^\circ} = .23 \text{ ohms}$$

$$r = \frac{1.84 \times 5 \times \cos 30.5^\circ}{.53} = 15 \text{ ohms.}$$

Example 4.

Track circuit, 5000 feet long, fed with direct current.

Open circuit test.

$p_o = 1.10$ volts (voltmeter resistance = 690 ohms).
 $u_{or} = .450$ amp.

$$\text{Correct } u_o = .450 - \frac{1.10}{690} = .448 \text{ amp.}$$

Short circuit test.

$p_s = .43$ volts (voltmeter resistance = 690 ohms).
 $u_{sr} = 2.50$ amp.

$$\text{Correct } u_s = 2.50 - \frac{.43}{690} = 2.50 \text{ amp.}$$

Hence,

$$a = \sqrt{\frac{.43}{2.50} \times \frac{1.10}{.448}} = .65.$$

$$b = \sqrt{\frac{.43}{2.50} \times \frac{.448}{1.10}} = .265.$$

$$k = \frac{1 - .07}{1.07} = .87.$$

Since $B = 0$, $\cos B = 1$ and $\text{tg } B = 0$.

$$\text{Hence, } \cosh 2m = \frac{1}{k} = 1.15$$

$$2m = .54; m = .27$$

$$z = \frac{.65 \times .27}{5} = .035 \text{ ohms per 1000 feet.}$$

$$r = \frac{.65 \times 5}{.27} = 12 \text{ ohms per 1000 feet.}$$

CONTENTS: Carl Edward Nilsson †. — The telephone as an aid in the organization of the taxicab service in large cities. — The Swedish Radio Company. — The smallest electric interlocking machine. — Telephone poles of reinforced concrete. — Some hints on track circuit calculation.

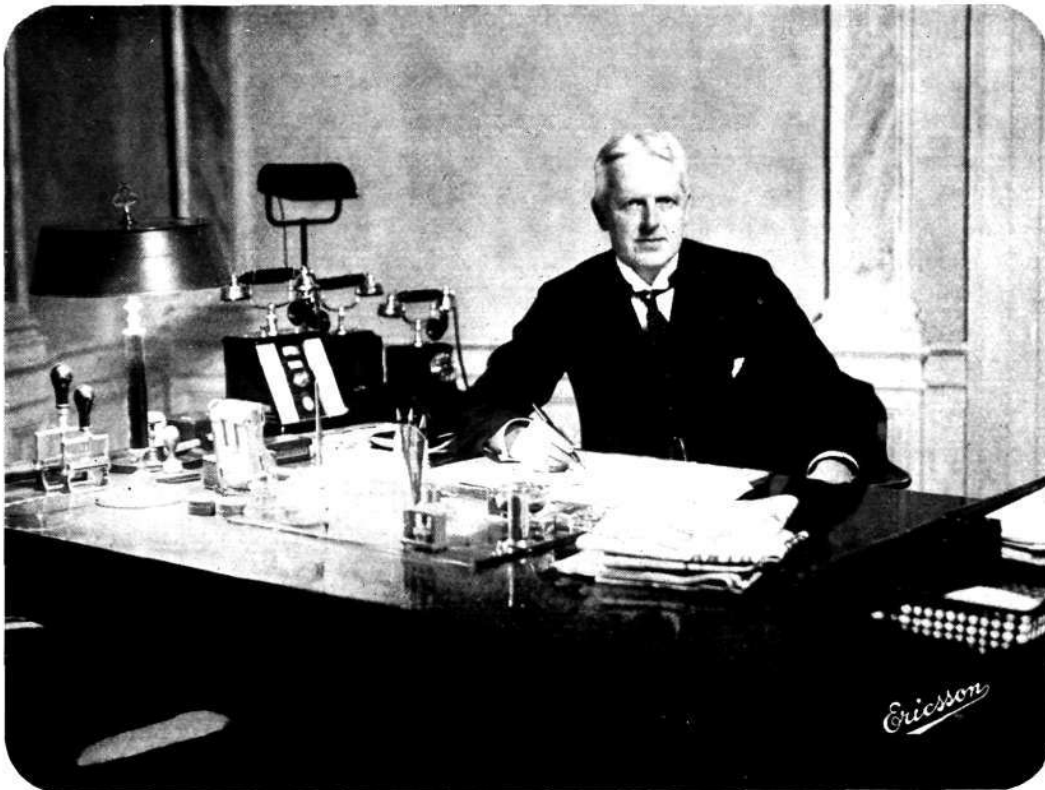
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THE SEVENTYFIFTH ANNIVERSARY OF THE ROYAL SWEDISH TELEGRAPH ADMINISTRATION WAS CELEBRATED ON THE 1ST NOVEMBER 1928 OF THIS YEAR. ABOVE: PRESENT HEAD OF THE TELEGRAPH ADMINISTRATION, COUNT A. HAMILTON, AT HIS WRITING DESK.

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Subtraction Meter with Load Balancing Switch.

By Axel Widström.

Engineer of the Electric Power Works, Stockholm.

A constant mean load in the plant is obtained through the switching on and off of heat accumulating devices.

Recently the form of tariff based on a fixed yearly rate increased with a certain rate per consumed kilowatt-hour has again been made the subject of much interested discussion. Although originally intended to stimulate the consumption of lighting energy as well as the increased use of various household conveniences such as irons, vacuum cleaners and the like, this tariff is now considered suitable also for the sale of electrical energy for cooking, on condition that the kilowatt-hour rate is set sufficiently low, preferably under .10 Swed. crowns.

However, if a consumer who has already been using electrical energy for cooking purposes with a direct acting range according to this tariff wishes to have the added convenience of a heat accumulating water heater, he will generally consider the rate of .08 or .09 crowns per kilowatt-hour for water heating purposes to be rather high, while on the other hand the power companies are generally satisfied with a lower rate for energy used for this purpose, on condition, however, that the consumption takes place during suitable hours of the day. Such an arrangement requires a regulating clock, which switches the water heater on and off at certain pre-determined times, however, and generally also a special meter for the energy consumed by the water heater. This complicated equipment means a higher cost of installation

which — specially for smaller hot-water installations — also means a considerable increase in the cost of energy.

A much simpler and cheaper method of solving this problem is generally found by using the household tariff meters manufactured by L. M. Ericsson* for D. C. as well as A. C. and which have been in use for several years and in such large numbers that their reliability and efficient service can well be vouched for.

The Ericsson Household Tariff Meter.

This meter is an ordinary ampere-hour meter with total and excess recording trains. Also, it is provided with a small (sealed) mercury switch which breaks a circuit or closes the same depending on the load.

A skeleton diagram of the meter is shown in fig. 1. The water heater is connected between neutral and the outer pole over the mercury switch 39; the other devices, such as lamps, direct acting cooking range etc. being connected direct between neutral and the outer pole. To the left is shown the regular magnet motor meter 3 with shunt 4, armature 8, brake mag-

* The idea of using the household tariff meter for installations with direct heating electric ranges and water heaters originated with chief engineer N. Forssblad.

nets 7 and recording train 16 for registering the total amount of energy consumed by the entire plant, since all the consumed energy passes through either the

This last force is transmitted over the gears 19—20 and 21—22 to the clockwork which is set in motion on condition that the tension of the spring is correctly adjusted.

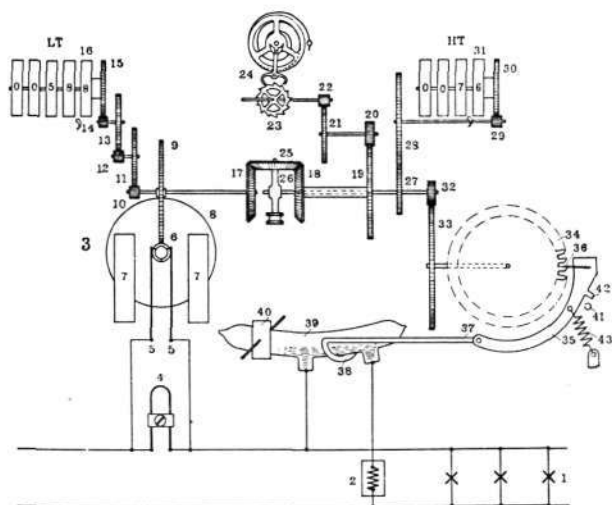


Fig. 1. Skeleton Diagram Showing Construction of Meter and Manner of Applying Loads.

meter shunt or the armature. The mechanical element which provides the constant speed which corresponds to the subscribed or subtraction limit is represented by the clockwork 23, 34. The movements of the clockwork and of the armature of the meter are mechanically transmitted to the gear wheels 17 and 18 of a differential gear, the planet wheel 25 of which imparts its movements to the excess recording train through the shaft 26, 27. Consequently, the speed with which this shaft rotates is proportional to the difference between the variable speed of the armature and the constant speed of the clockwork, i. e. the excess recording train registers the effect which — in a load diagram — lies over the load limit corresponding to the speed of the clockwork. The meter is adjusted to different values of subscribed effect by exchanging one of the gear wheels in the transmission 19, 20.

The necessary impulse required to start the clockwork is obtained in the following manner. If the armature 8 begins to rotate and we assume the clockwork and consequently also the planet wheel 18 to be at a standstill, the shaft 26—32 of the planet wheel rotates an angle equal to one half of the angle of rotation of the mitre wheel 17. This movement is transmitted to the ratchet wheel 34 which lifts the control lever 35 up from the rest 41, thus bringing about a tension in the spiral spring 43. The tension in the spring acts as a cog pressure between the gear wheels 17 and 25 and an equal pressure on wheel 18.

Functioning of the Meter.

Three different cases may occur depending on whether the load is less, equal to, or greater than the bulk limit.

In the first-mentioned case, with a small load—meaning that the speed of rotation of wheel 17 is less than the constant speed of wheel 18, which latter corresponds to the speed of the clockwork —, the ratchet wheel moves clockwise and the control lever with the ratchet tooth is lowered towards the rest 41, thus depriving the clockwork of its driving force and causing it to come to a standstill. After the armature 8 has made a few more revolutions the lever arm is again raised and the clockwork again starts to function, the entire procedure being repeated. For loads which do not reach the bulk limit, therefore, the clockwork works intermittently, the length of the pauses being inversely proportional to the size of the load, i. e. the smaller the load, the longer the pauses.

In the second case, with a load equal to the bulk limit, the ratchet wheel remains at rest after the clockwork has started to function, the wheels 17 and 18

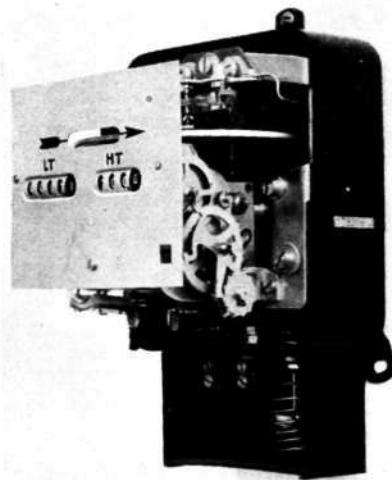


Fig. 2. Subtraction Meter for D. C. with Protecting Cover Removed.

having the same speed of rotation in opposite directions. In the first as well as in the second case the ratchet tooth 36 rests against the same tooth on the ratchet wheel, no consumption being registered by the excess recording train 31.

In the third case, with a load exceeding the bulk limit, wheel 17 is constantly rotating with greater speed than wheel 18; consequently, the ratchet wheel 34 rotates counter-clockwise, lifting the control lever. The excentric hanging of this lever in relation to the ratchet wheel causes the ratchet tooth 36 to finally trip off of the tooth of the ratchet wheel against which it is resting and to fall down upon the next one. This takes place about opposite the number 34 on the circumference of the ratchet wheel. (In fig. 1 the control lever is merely schematically pictured, in reality it extends around about half of the circumference of the ratchet wheel, the point about which it pivots being on the same level as the shaft which carries the wheels 33 and 34.) The resisting moment on the ratchet wheel which is necessary in order to provide the motive force for the clockwork is still provided by the ratchet tooth.

In the respects heretofore mentioned the meter functions in exactly the same manner as a common subtraction meter, merely with the modification that the clockwork is driven by the meter instead of by a separate source of energy.

We now come to the switch 39. This is a (sealed) mercury switch which, among the special features which make it suited for this purpose, embodies what may be termed a certain dead or idle movement; when, at a break, the mercury separates, the surface tension of the liquid metal causes the two parts of mercury to quickly contract so that a certain separating space is immediately formed between them. Thus, the switch must be tilted a certain angle from make to break position and vice versa. The make and break tilting angles for the same mercury switch are always the same; in varying designs the switching angle may vary between the limits 1.5° and 3° . The mercury is connected to the control lever so that its angle movement is always proportional to that of the ratchet wheel and consequently also proportional to that of the planet wheel shaft as long as the ratchet tooth remains in position against the same tooth of the ratchet wheel. The switch is in make position when the control lever is resting against the rest 41. When the total load exceeds the bulk limit, the ratchet wheel rotates counter-clockwise, bringing with it the control lever 35 which — by means of the rigidly attached arm 37 — tilts the mercury switch about the shaft 40 until it breaks the circuit and disconnects the water heater.

The mean load in the plant is regulated by the meter in the following manner. In fig. 3, B re-

presents that part of the load which cannot be disconnected, A is the bulk limit, while C is the load which can be disconnected by the mercury switch. If B minus C , is greater than A , the ratchet wheel — as already mentioned — will rotate counter-clockwise until the load C has been disconnected. If the remaining load B is smaller than A the movement of the ratchet wheel will be reversed and after it has rotated clockwise a certain angle, C will again be brought in circuit, after which the ratchet wheel will again reverse. When the ratchet wheel has rotated the same angle counter-clockwise, C is again brought in circuit, and so forth. A certain angle of rotation of the shaft 26—27—32 of the planet wheel corresponds to a certain effect above or below the bulk limit, and since in the present case the angle of rotation clockwise is equal to the angle of rotation counter-

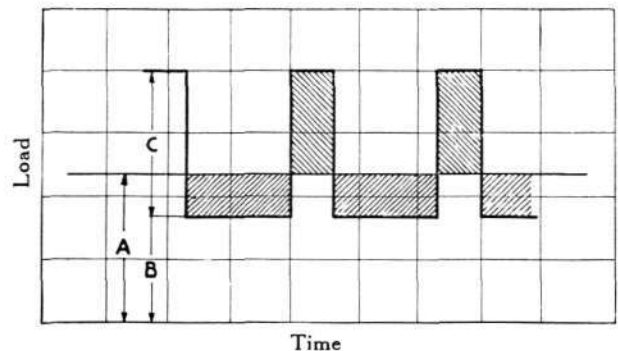


Fig. 3. The Load C is Automatically Switched On and Off. Thereby Maintaining the Average Load of the Installation at the Subscribed Effect A .

clockwise, we arrive at the conclusion that the excess effect during the time that both B and C are in circuit is compensated by an equal deficiency during the time that B alone is in circuit. The cross-hatched portions in fig. 3 above and below the bulk limit A are therefore equal and the meter regulates the load to a mean value equal to the bulk limit by the alternate connecting and disconnecting of C . If the constant load B is greater than the bulk limit A it is no longer possible for the meter to accomplish such a regulation. In this case the load of the water heater is permanently switched off and the excess recording train starts registering the consumption of effect which exceeds the bulk limit.

Tariff Rates and Charges.

When determining rates to be applied in conjunction with this meter, the manner in which the meter functions must be given due consideration. Let us take a concrete example and assume that a customer

consumes 300 kilowatt-hours for lighting etc. and 1500 kilowatt-hours for cooking, paid for at the rate of 60 Swed. crowns per year (calculated according to the number of rooms) plus an effect fee of .09 crowns per kilowatt-hour. The customer wishes to install a water heater for 300 watts and the energy which this requires is to be paid for at the rate of .05 crowns per kilowatt-hour. The household tariff meter should then be adjusted for a bulk limit of 300 watts. The total recording train registers the total amount of energy consumed by the plant while the excess recording train registers that part which exceeds the bulk limit of 300 watts. When the load for cooking, lighting etc. exceeds 300 watts the water heater is constantly switched off.

The charges are best calculated so that a fee of .05 crowns per kilowatt-hour is charged for the energy registered by the total recording train, with an additional charge of $.09 - .05 = .04$ crowns for the energy registered by the excess recording train. However, in this way the customer might obtain that part of the cooking and lighting load which lies below the bulk limit at a lower rate than before, i. e. at .05 instead of .09 crowns per kilowatt-hour.

The value of the compensation which, for this reason, should go to the power company, may suitably be figured as follows. Investigations show that a direct acting electric range is switched on an average of 3.5 hours per day. The amount of energy used for cooking purposes which lies below the bulk limit is therefore $3.5 \times A$ kilowatt-hours per day, if A represents the bulk limit in kilowatts, or, figuring with 330 days, $330 \times 3.5 \times A$ kilowatt-hours per year. If the additional fee amounts to a crowns per kilowatt-hour, the total charges should include a yearly fee of

$$330 \times 3.5 \times A \times a \text{ crowns.}$$

If we insert the values given in the above example we obtain

$$330 \times 3.5 \times A \times .04 = 46 \times A \text{ crowns,}$$

or, in round figures, a tariff rate of 50 crowns per subscribed kilowatt-hour and year. The greater part of the lighting energy, estimated at two thirds or about 200 kilowatt-hours, also falls below the bulk limit, thereby giving cause for an increase of $200 \times .04 = 8$ crowns. Also, a certain rental should be paid for the expensive meter, say about 7 crowns. The metering fee as well as the increase for light energy may suitably be included in the set yearly fee.

The tariff rate would consequently include the following items:

1. A set yearly fee of $60 + 8 + 7 = 75$ crowns;
2. A yearly fee of 50 crowns per each subscribed kilowatt;
3. A fee of .05 crowns per kilowatt-hour registered by the total recording train;
4. An additional fee of .04 crowns per kilowatt-hour registered by the excess recording train.

A circumstance which should be accentuated in this connection is that the bulk limit of the individual consumer is not increased on account of the water heater, but quite naturally the condition that a small part of the water heaters take part in the excess load of the company's power plant is unavoidable.

In any case, the above-described meter provides a comparatively simple and cheap solution to the problem of obtaining long consecutive loading which does not heavily tax the service net of the power company and increases its maximum load in but a very small degree.

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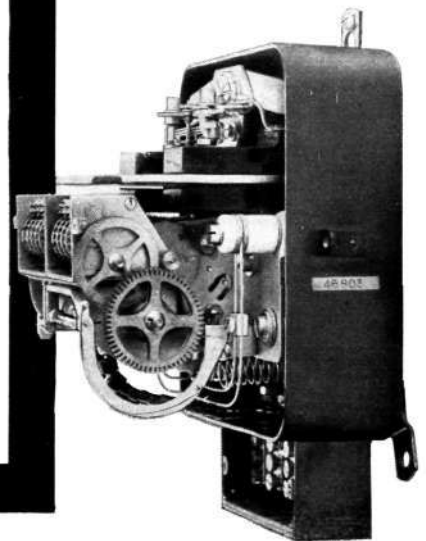
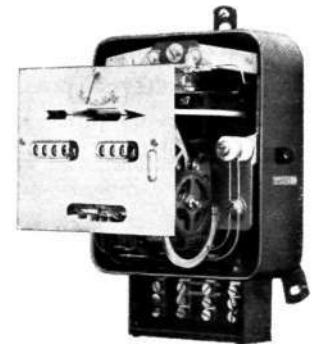
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On Junction Telephone Traffic Automatic to Automatic, or Manual to Automatic.

by Professor R. Trechcinski, of the Warsaw Institute of Technology.

When establishing junction traffic between two or more telephone exchanges, it is usually stipulated that all signals shall be given in exactly the same manner as for connections between subscribers within the same exchange area, i. e. calling signals shall be suited to the systems of the respective exchanges, either the call is made between two subscribers within the same exchange area or belonging to different exchange areas. Should one of the exchanges serve in the capacity of sub-exchange, the signals at this exchange should be normal while at the central exchange they need not be influenced by manipulations made at the sub-exchange.

When referring to junction traffic between automatic exchanges, we differentiate between main exchanges which are inter-connected according to the compound system, and satellite exchanges, whose main characteristic is that their first group selectors and registers are placed at the main exchange. The connections between a satellite and the main exchange can be either direct or over an intermediate exchange (tandem connections). Certain main exchanges can serve as switching centres or junction points for the different exchange groups within an automatized area.

Special arrangements are required for junction traffic between automatic exchanges of different systems. Some of these arrangements will be described in the following.

The term 'small automatic' is here used to designate installations in which the number of subscribers' lines or of cord circuits is restricted by the very nature of the system, while the term 'large automatic' refers to installations in which the number of lines as well as of cord circuits can be extended at will by increasing the number of switching contacts or of switching devices.

By cord circuit is here meant the combination of switching devices required to establish a connection between two subscribers belonging to the same ex-

change. In addition, a connection to a compound, tandem or satellite exchange includes a junction line.

In the following we will touch especially on the apparatus at an automatic exchange which receives the trains of impulses sent out by a subscriber's calling dial and which transmits them to another automatic exchange.

These trains of impulses correspond to the decimal system, which does not mean, however, that the automatic exchanges must operate on the decimal system.

Slow acting relays are used to separate the different trains of impulses at the automatic exchange. While normal acting relays actuate within a space of ten to thirty thousandths of a second, in slow acting relays the space of time required for this operation can be increased to as much as 300 thousandths of a second with the aid of various devices. An even longer space of time can be obtained with special types of relays.

In one very common type of slow acting relay the iron core is surrounded by a copper sleeve.

For relays with an iron core 8 mm. in diam, which has been magnetized to an induction of 5000 gauss, the time — expressed in milliseconds — during which the relay remains actuated after the breaking of the circuit, can be calculated by the aid of the following *approximate formula which — as well as the following ones — is intended merely to give a clearer conception of what is meant.*

$$T_a = (100 \sqrt{D} - 8) \text{ ms,}$$

in which D = outer diam. of copper sleeve in mm.

The sensitiveness, i. e. the strength of current required to actuate normal relays provided with a contact spring group with a contact pressure — in normal as well as actuated position — of 20 gr. may be approximately calculated by means of the formula

$$I_a = \frac{120}{\sqrt{R}} \text{ mA (milliamperes)}$$

in which R = resistance of winding in ohms.

As soon as the relay energizes there is a reduction of the magnetic resistance in the magnetic circuit. The strength of current required to hold the armature is then obtained from the formula

$$I_k = \frac{60}{\sqrt{R}} \text{ mA.}$$

where P = contact pressure in grams and R = resistance of winding in ohms.

In automatic exchanges with cord circuits so arranged that two subscribers obtain a direct connection with each other without any condensers or with only one condenser in one of the line branches, the necessary

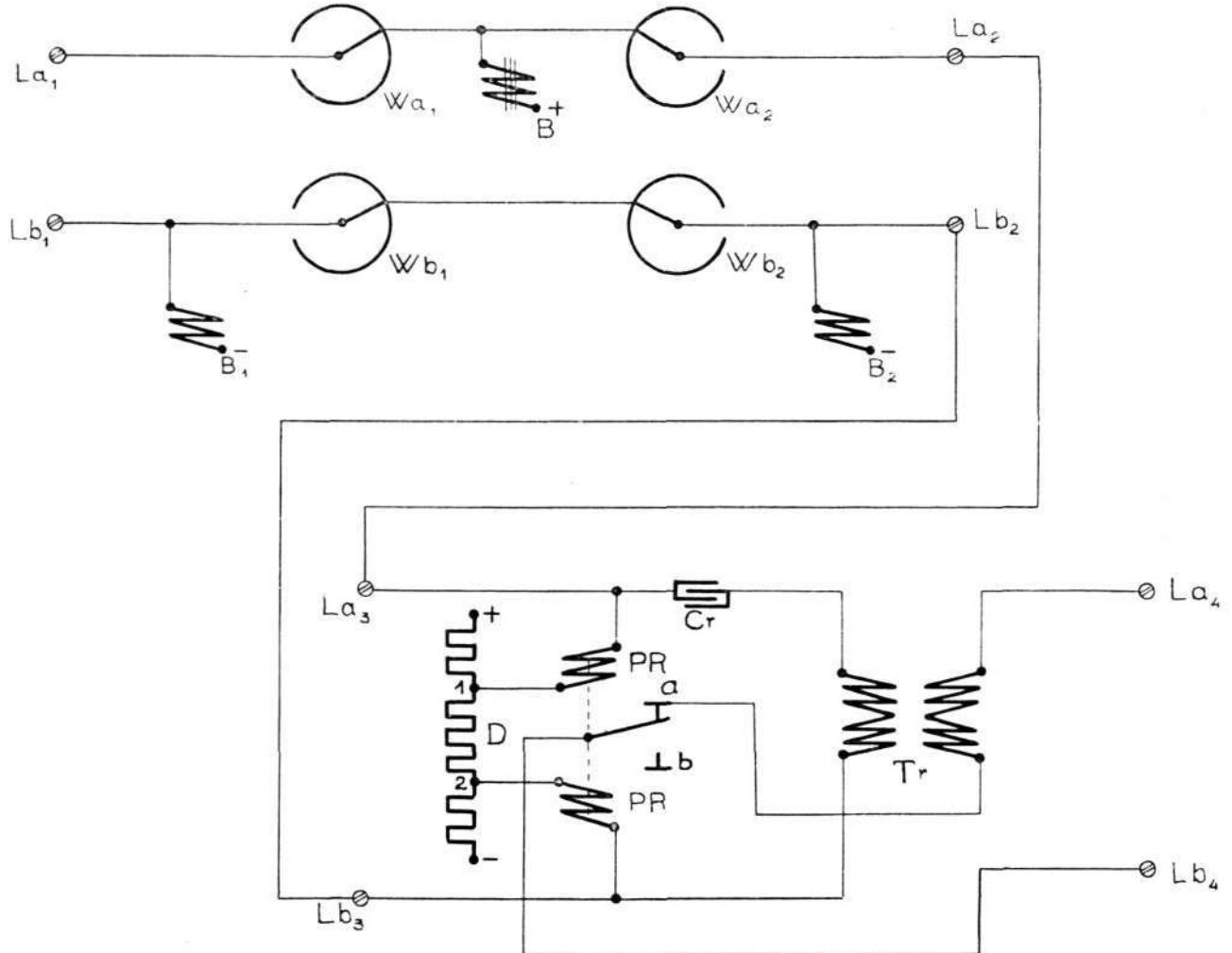


Fig. 1.

The maximum strength of current at which the armature with certainty will return to normal can, under similar conditions, be calculated from the formula

$$I_p = \frac{30}{\sqrt{R}} \text{ mA.}$$

The sensitiveness of the polarized relay is obtained by using the formula

$$I_a = \frac{4P}{\sqrt{R}} \text{ mA,}$$

translation of impulses may be accomplished by means of the cord circuit translator shown in fig. 1.

The upper part of the diagram represents the cord circuit in a small automatic exchange. $B1$ och $B2$ are the subscribers' line relays, B a common feed induction coil, while Wa and Wb are selectors on the lines La and Lb respectively.

The lower portion of fig. 1 represents the diagram for the translation of impulses over the above-mentioned cord circuit. PR is a polarized relay, on the one side connected to the line branches and on the other side to a current splitting device D . This lat-

ter may be substituted by a battery with lower tension than the feed battery for the exchange. The automatic exchange which receives the impulses is connected to the terminals *La4* and *Lb4*.

As soon as the calling subscriber at the exchange in question has dialled the number of the line to which the impulse translator is connected the following circuit is closed.

Positive, *B*, *Wa1*, *La1*, the subscriber's instrument, *Lb1*, *B1*, negative, and also in parallel *Wb1*, *Lb1*, *B2* to negative.

If we assume, for instance, that the induction coil *B* has a resistance of 150 ohms and each of the relays *B1* and *B2* a resistance of 300 ohms, which, when connected in parallel, makes 150 ohms and that the feed battery for the automatic exchange has a tension of 24 volts; also, that the voltage between the positive pole of the current subdivider and point one is 2 volts, between points 1 and 2 the voltage is 20 volts and between point 2 and negative it is 2 volts, the resistance of the polarized relay being assumed to be 2×100 ohms. With a contact pressure $P = 10$ gr., the sensitiveness of the polarized relay will then be

$$I_a = \frac{4 \times 10}{\sqrt{200}} = 2.85 \text{ mA.}$$

In order to permit a current of this strength to pass through *PR*, the difference in voltage between point *D1* and the line branch *La* must amount to

$$\frac{2.85 \times 100}{1000} = .285 \text{ volts.}$$

The voltage drop in coil *B* is then 2.285 volts, the strength of the current passing through the coil being 15.1 mA. This value together with the strength of the current passing through the polarized relay gives us a strength of line current equal to 17.95 mA.

Since voltage and current conditions for the b-branch are analogous with those for the a-branch, the voltage between the terminals *La1* and *Lb1* is

$$24 - 2 \times 2.285 = 19.4 \text{ volts,}$$

corresponding to a total resistance in the subscriber's line and telephone instrument of

$$\frac{19.4 \times 1000}{15.1} = 1280 \text{ ohms}$$

If the resistance of the telephone instrument is about 280 ohms, the line resistance will be about 1000 ohms. With a lower line resistance, there is an in-

crease in the strength of the current passing through the induction coil *B* and the polarized relay, a maximum value being obtained when the line resistance = 0, i. e. when the telephone is connected direct to the exchange. Since the line resistance varies between the above-mentioned values, the relay *PR* energizes and closes the upper contact *a* with a contact pressure of 10 gr. or more.

When the subscriber replaces the microtelephone on the cradle rest the following circuit is formed,

Positive over *B*, *Wa2*, *La2*, *La3*, *PR* to *D1*, with a strength of

$$\frac{2 \times 1000}{250} = 8 \text{ mA.}$$

A current of this same strength passes through the two parallel relays *B1* and *B2*, giving each one 4 mA.

According to the above formula the current required to keep relays *B1* and *B2* actuated is

$$I_k = \frac{60}{\sqrt{300}} = 3.45 \text{ mA.}$$

From this we find that the current is of sufficient strength to hold relays *B1* and *B2* in their energized positions and that both relays remain actuated during the breaks in the circuit occurring in the telephone instrument. The current of 8 mA now passes through the polarized relay in another direction than previously and the armature of the polarized relay is reset to the lower contact of this relay due to the fact that the strength of current depasses the degree of sensitiveness of the relay.

If the circuit is closed in the telephone instrument, everything is restored to its previous condition and the upper contact of the relay is again closed. Thus it is clear that the position of the armature of the polarized relay depends on whether the circuit through the telephone instrument is closed or broken.

Since the transmission of impulses causes a making and breaking of the current through the telephone, the armature of the polarized relay moves back and forth resulting in makes and breaks in the circuit to the automatic exchange connected to the terminals *La4* and *Lb4*, as shown in fig. 1.

When the calling subscriber replaces his microtelephone at the termination of the call, the armature of *PR* returns to the lower contact *b* causing a clearing signal to be sent out to the other automatic exchange.

The speaking circuit between the two subscribers is as follows:

Subscriber's instrument, $La1$, $Wa1$, $Wa2$, $La2$, $La3$, Cr , Tr , $Lb3$, $Lb2$, $Wb2$, $Wb1$, $Lb1$, and subscriber's instrument, and

from the other automatic exchange to $La4$, Tr , upper contact of PR , $Lb4$, back to the exchange and from there to the other subscriber.

We will illustrate the above principle by means of an example, assuming telephone traffic between a private automatic exchange A and another private or city exchange B . The principle of the switching process is shown in fig. 2. The direction of the traffic is indicated by arrows, 'TLIM 500/1000' representing the impulse translating device schematically shown in fig. 3.

In exchange A the connection in question differs from a standard connection in that the feed contact springs for generator current are insulated, due to the fact that a signal current is not necessary for the starting and functioning of the translator.

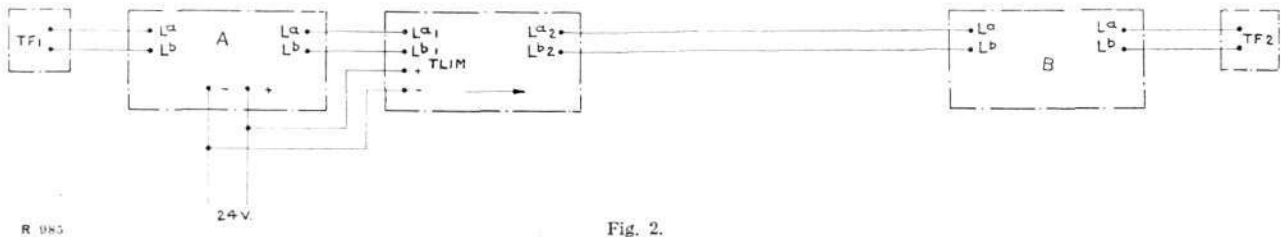


Fig. 2.

In the following we will designate the contacts of a relay by the letters a , b , c etc. counting from the top.

When the subscriber dials the number of the line to which the impulse translator is connected the following circuit is formed:

Positive, VRa , ERa , PR , $La1$ (1)
and in parallel,

Positive, B (fig. 1), $La1$, over the calling subscriber's telephone to the two relays in parallel and to negative.

RR energizes and closes the following circuit,

Positive, RRa , ER to negative (2)

The relay ER energizes and closes the following circuits,

Positive, VRa , ERb , ER to negative (3)

Positive, ERf , DW , ERc to negative (4)

$La1$, ERd , PR , DW (5)

$Lb1$, ERe , PR , DW (6)

Circuit (1) is broken and RR de-energizes. The current starts to pass through PR , whose armature is attracted, closing contact PRa and the following circuit,

Positive, ERg , PRa , IR to negative (7)

IR energizes and closes the circuit of the called exchange over $La2$, $T11$, IRa and $Lb2$.

If the called exchange sends out a buzzer signal, this signal reaches the calling subscriber over the circuit (see figs. 1 to 3)

$T11$, $Cr1$, $La1$, Wa , La , $TF1$, Lb , Wb , $Lb1$, and back to $T11$ (8)

When the calling subscriber receives a tone denoting that the connection to the called exchange is clear, he dials the desired number just like any subscriber belonging to the net of the called exchange. PR transmits impulses while circuit (7) is alternately

broken and closed. IR alternately de-energizes and energizes, causing makes and breaks to occur in the impulse relay circuit of the called exchange, thereby establishing the desired connection.

The pulsating of PR causes the following circuit (9) to be closed over contact PRb ,

Positive, ERg , PRb , VR , Li to negative .. (9)

During this transmission of impulses, however, circuit (9) is closed for so short a time that the slow acting relay VR , which is connected in series with the induction coil Li , does not have time to energize. When the subscriber replaces his microtelephone, VR energizes and circuit (3) is broken. ER de-energizes, thereby breaking circuits (4), (5) and (6) and disconnecting PR from $La1$ and $Lb1$. Also, circuit (7) is broken, IR de-energizes and breaks the current circuit to the other exchange, a clearing signal being simultaneously sent out to this exchange. The condenser $CR2$ and the series connected resistance of 500 ohms prevent the forming of sparks at PRa in circuit (7).

Terminals $L1$ and $L2$ as well as $T12$ serve for

the connecting up of an amplifier if such a one should be found necessary.

If still another impulse translator is inserted between the second exchange and a third one, it is possible for a subscriber belonging to the first exchange to obtain a full-automatic connection over the second exchange to a number at the third one.

Furthermore, there is nothing to prevent a sub-

From the foregoing it is evident that the called exchange receives a clearing signal from the translator between the calling and the called exchanges as soon as the calling subscriber has replaced his microtelephone. When the called subscriber also replaces his microtelephone the called exchange receives a double clearing signal and breaks the cord connection.

It may happen, however, that the called subscriber

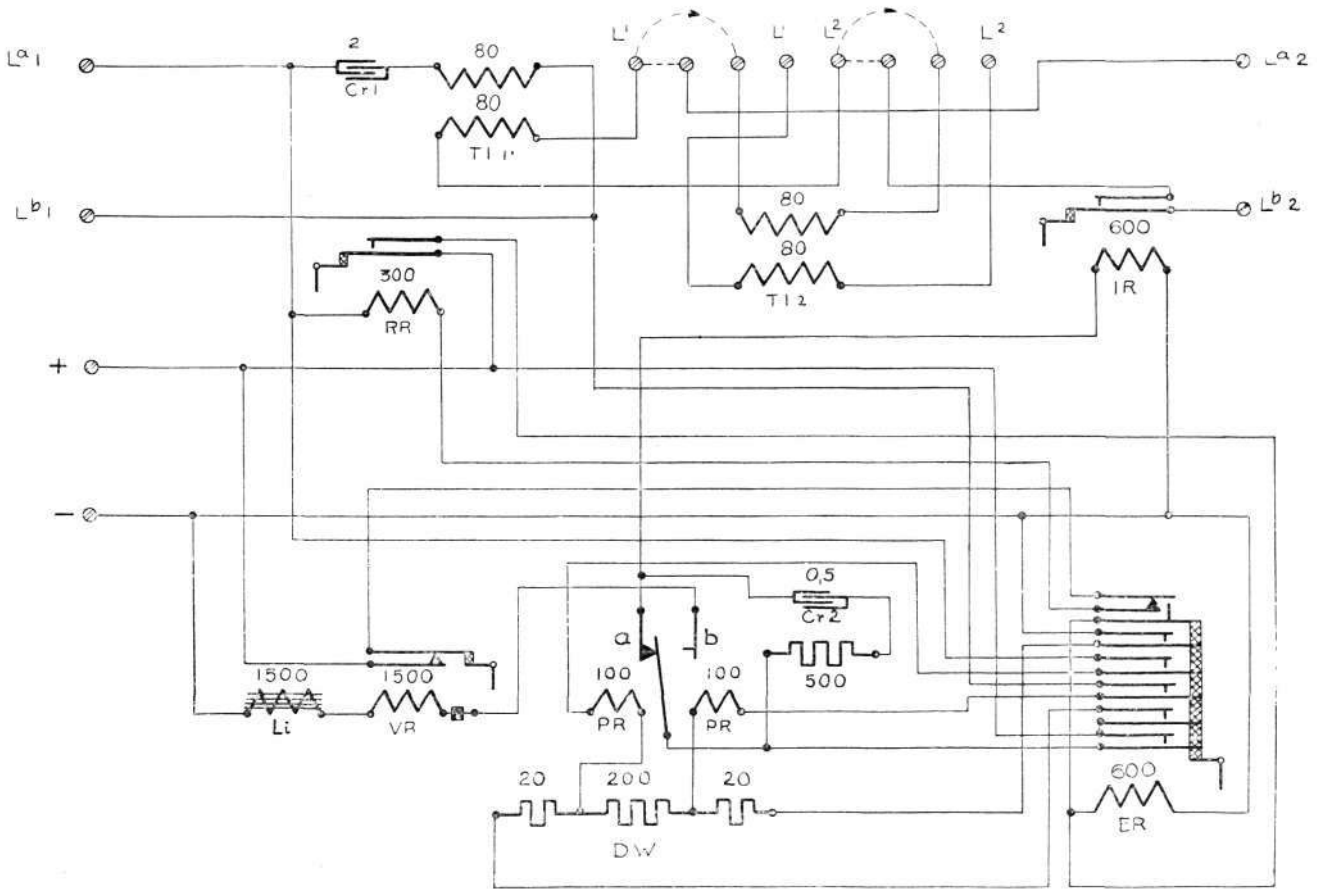
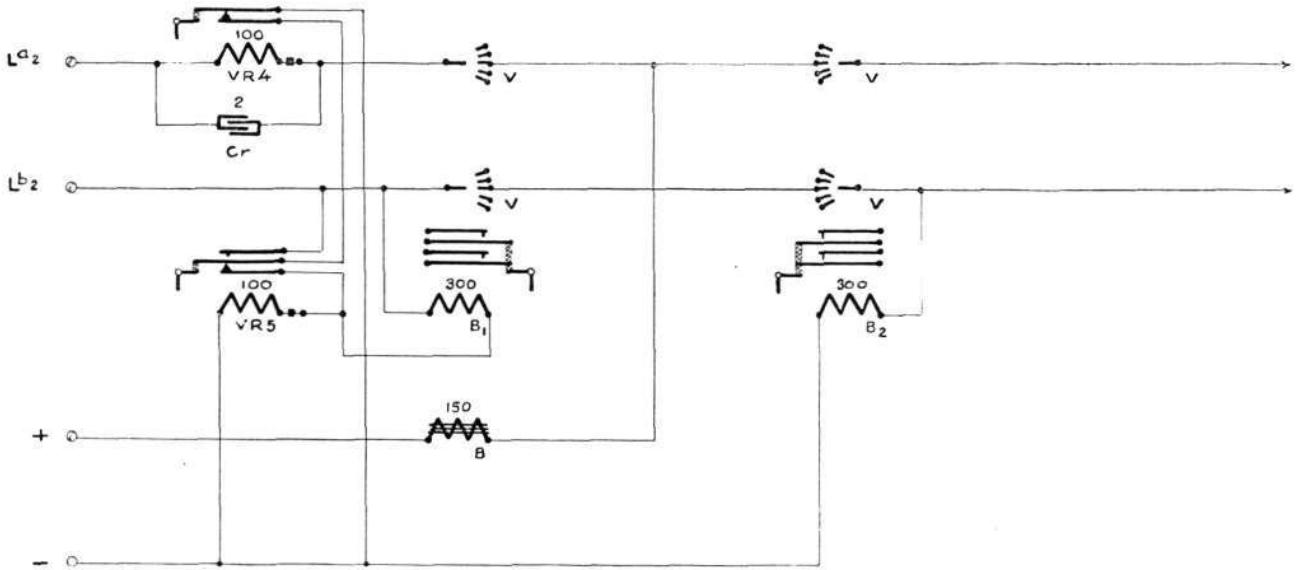


Fig. 3.

scriber from obtaining automatic connections in this manner over several automatic exchanges. To accomplish this the calling subscriber must dial the number of each exchange in turn, each time awaiting the dial tone from the called exchange, finally dialling the desired subscriber's number after having reached his exchange. It is of importance that the calling subscriber does not dial more than one exchange number at the time and he must know the number of intermediate exchanges over which the connection is to pass.

for some reason or other does not replace his microtelephone, causing the cord circuit translator to be blocked for further calls from the calling exchange, and a subscriber at this first exchange is unable to obtain a connection to the same called subscriber. For this reason it is desirable that the cord circuit at the called exchange becomes disengaged as soon as the conversation is ended, for which purpose a special arrangement for the release of the cord circuits is required.

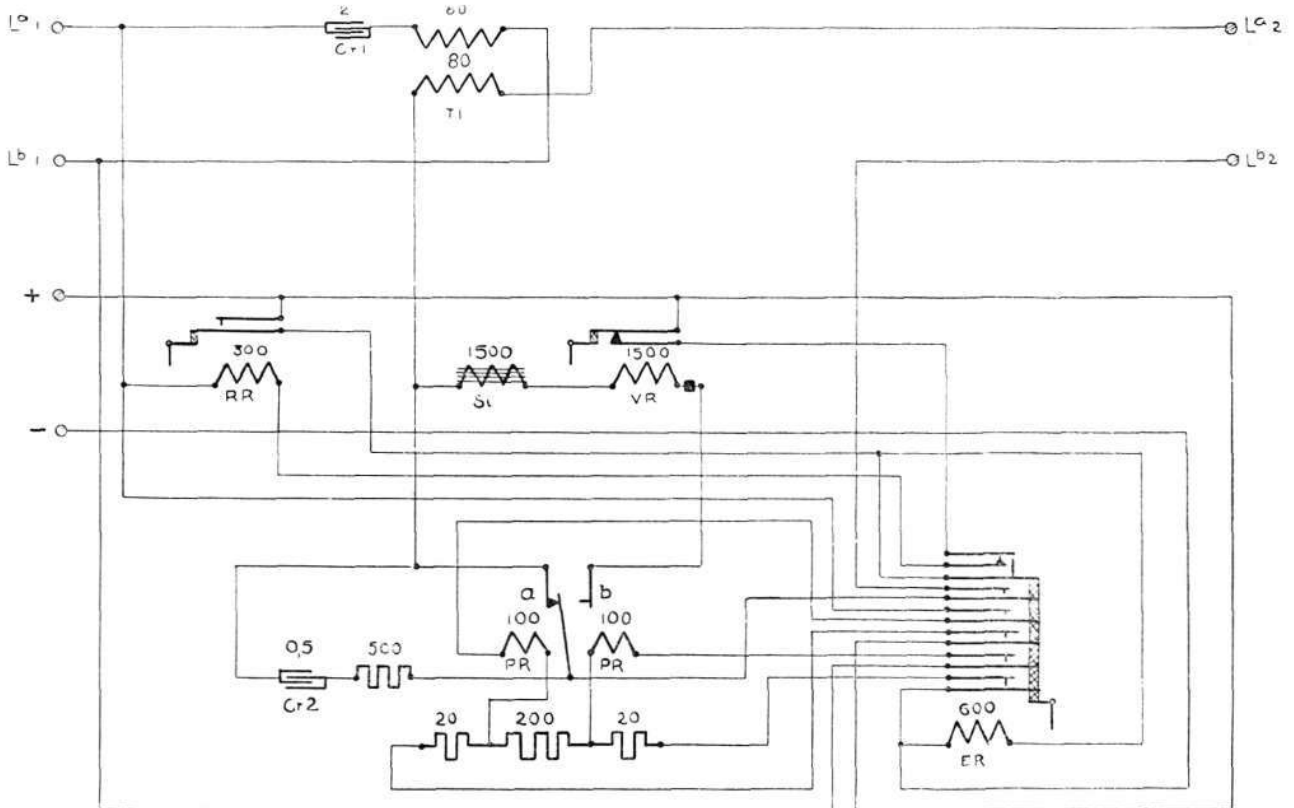


R 986

Fig. 4.

Fig. 4 shows a circuit diagram for an arrangement of this kind and the method of connecting the same in relation to relays *B1*, *B2* and *B* in fig. 1. The slow acting relay *VR4* inserted in the line branch *La*

Positive, *B*, *VR4*, *La2*, *T11*, *IRa*, *Lb2*, *B1*, *VR5a*, *VR4b* to negative (10)
B1 and *VR4* energize, breaking circuit (10) and at the same time closing a new circuit,



R 989

Fig. 5.

and the slow acting relay *VR5* is connected up between negative and one of the line relays *B*. Simultaneously with the closing of the contact of *IR*, the following circuit is formed,

Positive, *B*, *VR4*, *La2*, *T11*, *IRa*, *Lb2*, *B1*, *VR5* to negative (11)
 After a disengaged cord circuit has been found the following circuit is closed,

Positive, *VR4*, *La2*, *T11*, *IRa*, *Lb2*, *B2*, *VR5* to negative, and from *Lb2* in parallel over the resistance that causes the energizing of *B1* during the transmission of the impulses, to positive (12)

VR5 is kept energized over circuit (12), the selecting taking place as usual. The speaking currents circumvent *VR4* through the condenser, which is connected in parallel with *VR4*. When the calling subscriber replaces his microtelephone but the called subscriber neglects to do this, *VR5* and *B_i* remain actuated while *VR4*, on the contrary, de-energizes. The following circuit is closed,

$$Lb2, VR5a, VR5, B1, Lb2 \dots\dots\dots (13)$$

resulting in the short circuiting of the two relays *B1* and *B2*, which de-energize, thereby releasing the cord circuit. Also *VR5* de-energizes, causing the relay *B2* of the called subscriber (who has not replaced his microtelephone) to energize again, the disengaged cord circuit being sought out as usual. At a subsequent call from the cord circuit translator, *B1* is already de-energized but is now actuated again and the disengaged cord circuit is sought out as usual.

In certain cases, when the impulse translator connects two exchanges, and the line resistance between one of the exchanges and the subscribers' stations is not greater than 2×150 ohms, the impulse relay in this exchange can be so adjusted as to be less sensitive and to surely de-energize at 6 mA, in which case a simpler connection, as in fig. 5, can be used. A polarized relay *PR* which momentarily breaks the current circuit of the called exchange serves as a direct impulse relay at the calling exchange, this current circuit being again closed by the connecting up of *VR* and *Si* with a total resistance of 3000 ohms. The current is completely cut off for a moment by the regular impulse relay at the called exchange, after which it passes through a resistance of 3600 ohms (*VR*, *Si* and the impulse relay at the called exchange), or at 22 volts with a current of about 6 mA. With such a strength of current it is impossible — according to our assumptions — for the regular impulse relay to remain energized. In the same moment as the calling subscriber replaces his microtelephone at the end of the conversation the armature of *PR* moves over to contact *b* and closes the following circuit,

From the called exchange, positive, *B*, *Wa*, *La2*, *T1*, *Si*, *VR*, *PRb*, *ERc*, *Lb2*, over the two paralleled relays *B1* and *B2* at the called exchange to negative (14)

Since we have assumed that the line resistance from the called exchange to a subscriber's station is not greater than 2×150 ohms and the subscriber's telephone is assumed to have a resistance of 200 ohms, the subscriber's line including *B*, line, telephone instrument, line and *B2* will have a resistance of not more than 800 ohms and the tension between the terminals *La2* and *Lb2* will not exceed 15 volts. This corresponds to about 5 mA through relay *VR*, which is adjusted so as to energize for a current of this strength. When the calling subscriber only replaces his microtelephone, the cord circuit as well as the cord circuit translator at the exchange are not released.

Should a new call from the first calling exchange be made to the same cord circuit translator, the calling subscriber will receive a busy signal from his own exchange. It is not until the called subscriber has replaced his microtelephone that the relay *VR* receives more current on account of the fact that the voltage between *La2* and *Lb2* is increased. *VR* energizes and the feed circuit for *ER* is broken. *ER* de-energizes and releases the cord circuit translator as well as the cord circuits in both exchanges.

If the junction line between two exchanges has a resistance between 2×400 ohms and 2×900 ohms, the junction traffic can be handled by the aid of an intermediate' translator placed so that the resistance between the first exchange and the intermediate translator is not greater than 2×500 ohms, and between the intermediate translator and the other exchange not greater than 2×400 ohms, a 24 volt battery and feed coils being required for the intermediate translator. The connections are made according to the diagram in fig. 6.

If feed coils with higher resistance are used, together with a special impulse translator, the line resistance — with a tension of 24 volts — between the first exchange and the intermediate translator can be increased to 2×1000 ohms. On the same conditions, but with a tension of 48 volts, this resistance may be increased to 2×1600 ohms. With such long lines, however, it is advisable to use amplifiers for the speaking current. An amplifier can be connected up while the cord circuit translator is working to obtain a connection.

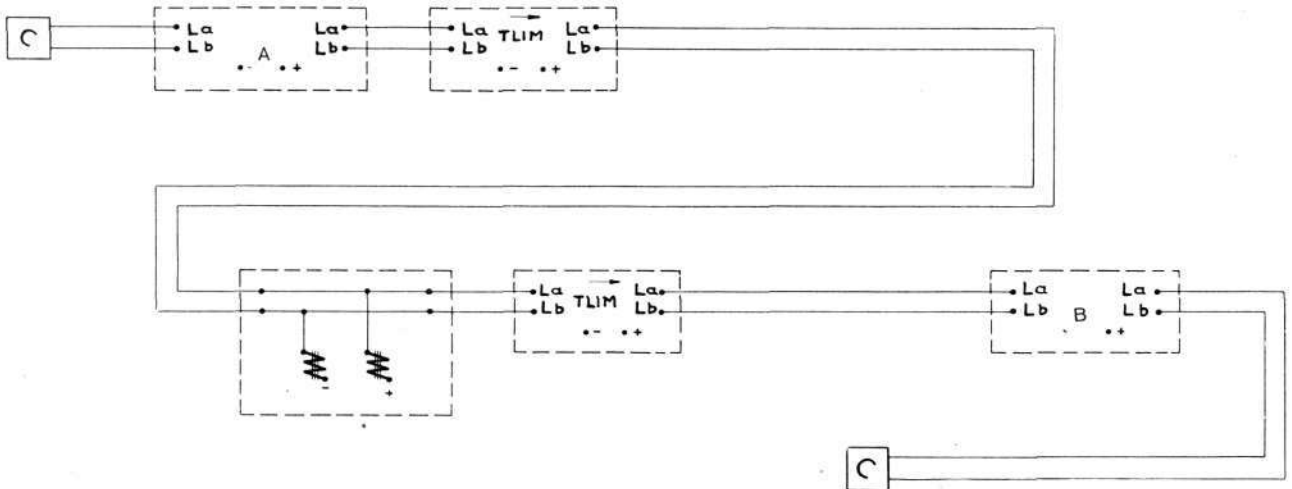
Should the line resistance remain between 2×100 ohms and 2×200 ohms, the polarized relay in the first impulse translator may be replaced by a com-

mon relay. The circuit diagram for an arrangement of this kind is shown in fig. 7.

All telephones with a line resistance of less than 2×100 ohms should be provided with an extra re-

to obtain a connection through the translator to the other exchange for outgoing calls.

As will be seen from the foregoing, a cord circuit translator of the type here described will work only



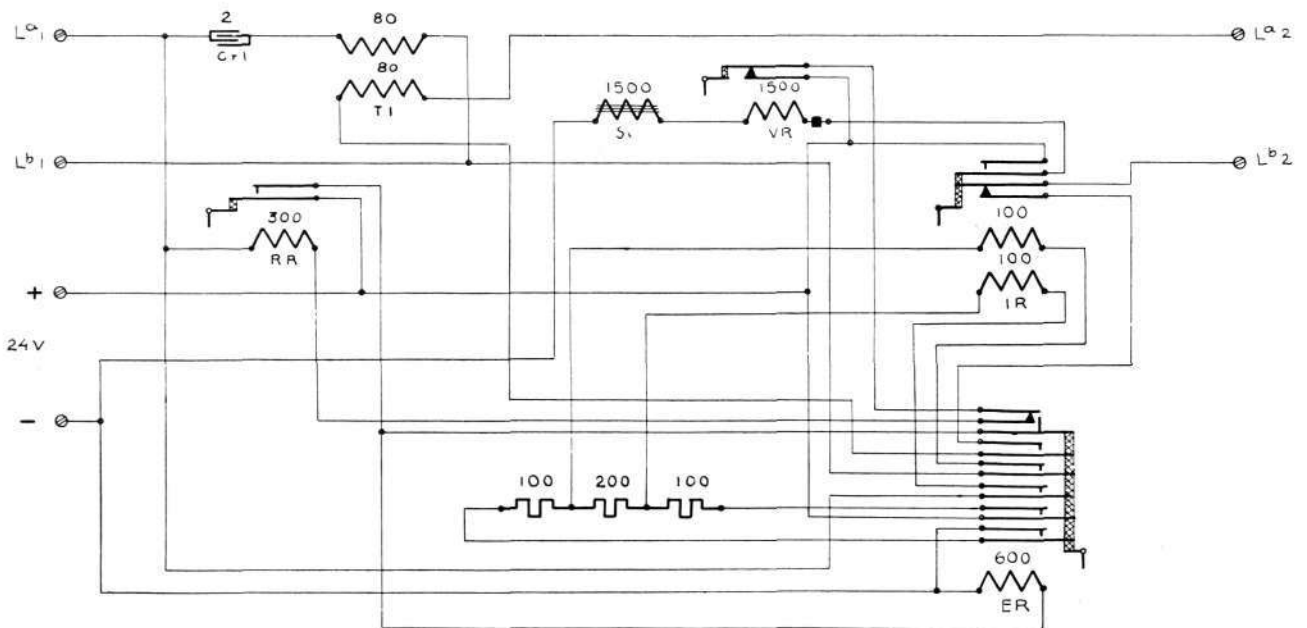
R 988

Fig. 6.

sistance in order to be able to use a translator of this kind.

A telephone with a line resistance of less than 2×50 ohms cannot use this translator arrangement

with one way impulses, i. e. impulses can be transmitted in one direction only, from terminals $La1$ and $Lb1$ to $La2$ and $Lb2$. The speaking currents, on the other hand, can travel in both directions, from the



R 991

Fig. 7.

with an additional resistance, and cannot be used at all when the line resistance exceeds 2×300 ohms. Consequently, this arrangement can be used for the blocking of telephones which do not have permission

subscriber in the first exchange to the one in the second exchange and vice versa.

If there is but one junction line between two exchanges, it is possible to place a translator at each

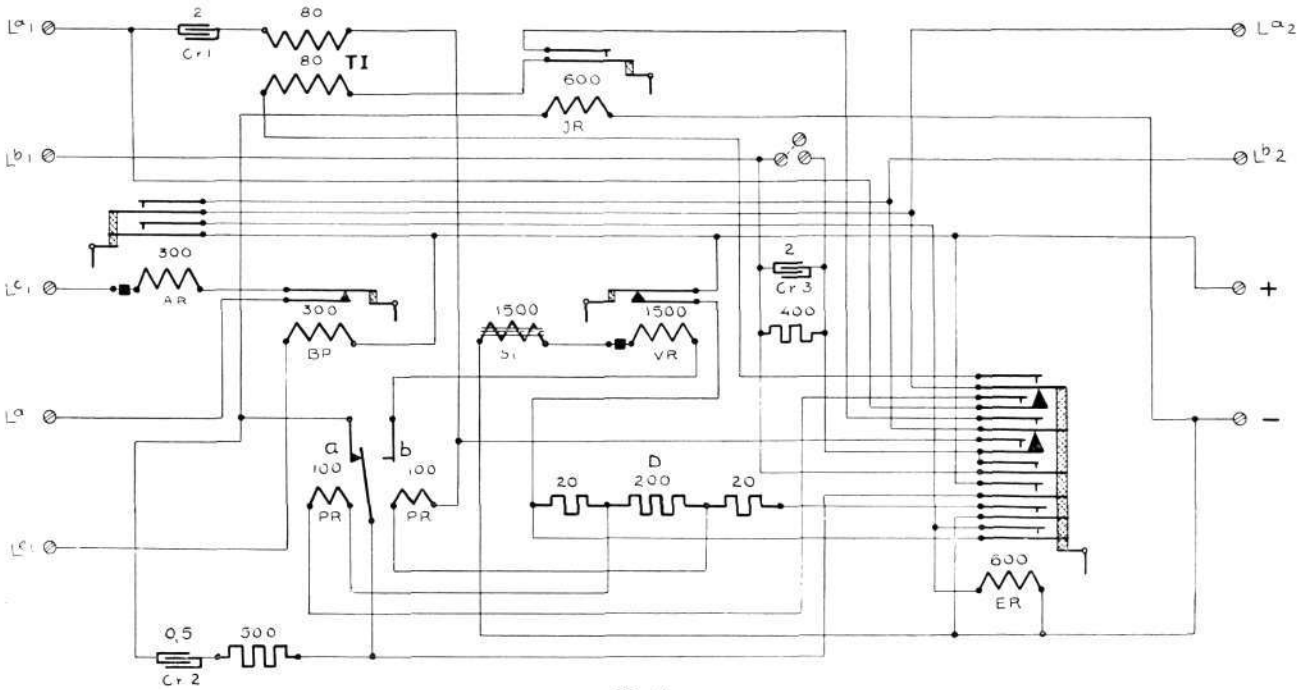


Fig. 8.

end of the junction line. Each of these translators will work in one direction only.

Fig. 8 shows the diagram for such a translator and in fig. 9 are shown the connections between a translator and a junction line between two exchanges.

the difference in voltage between the two batteries should be so small that the strength of the equalizing currents — when it is at rest — is never sufficient to energize any of the relays.

When a subscriber at the first exchange dials the

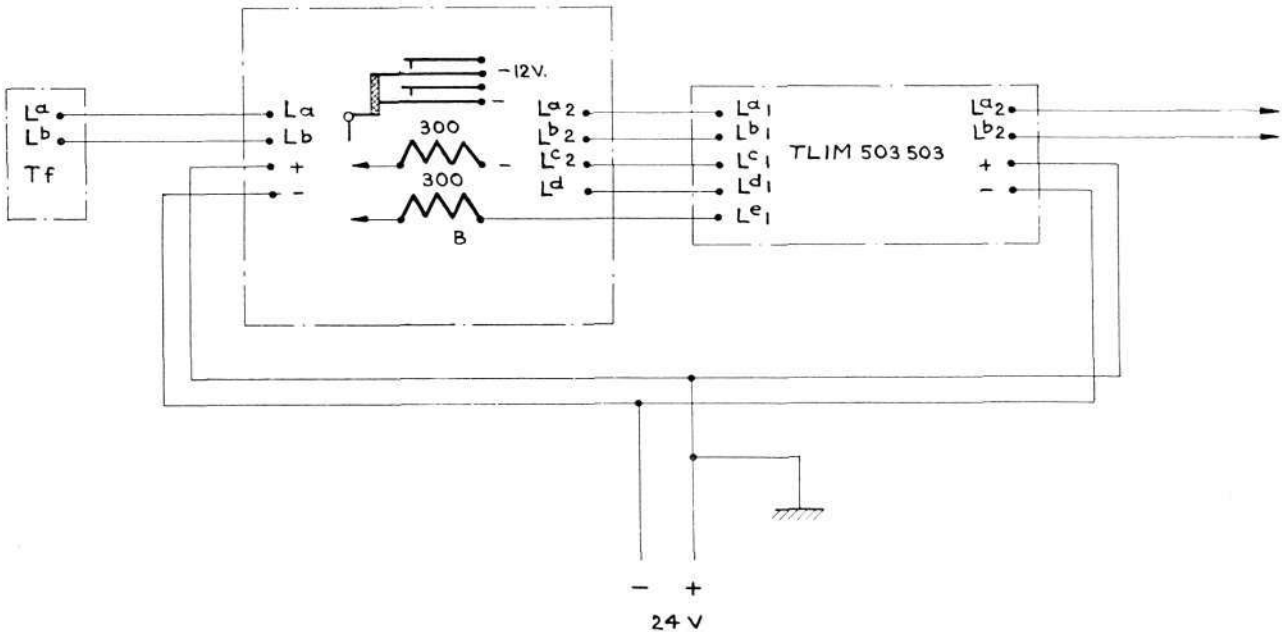


Fig. 9.

In this case a closed circuit is formed over both the exchanges, the line relay and the junction lines, for which reason it is necessary that the feed batteries for both exchanges have the same voltage. In any case

number to which the translator is connected, the following circuit is formed at the same time as a ringing signal is sent out,

Positive, relay and relay contacts at first exchange,

Ld1, BRa, AR, Lc1, relay contacts and relay at first exchange to negative (15)

AR is energized and closes a circuit — over contact *ARa* — to the second exchange and simultaneously closes the following circuit,

Positive, *ARB, ER* to negative (16)

ER energizes and closes the circuit

Positive, *VRa, ERk, ER* to negative (17)

ER now receives a holding current and remains energized, although *AR* de-energizes after the sending out of the calling signal.

The following circuits are closed when *ER* energizes,

Positive, *ERh, PRa, IR* to negative (16)

Positive, *VRa, D, ERj* to negative (19)

D, PR, ERc, La1 (20)

D, PR, ERf, ERg, Lb1 (21)

IR obtains current over circuit (18) and the circuit to the second exchange is now closed over *IRa* after first having been closed over *ARa*. As soon as *AR* de-energizes the dial tone can be sent out from the second exchange to the calling subscriber over *TI*,

La2, ERa, TI, IRa, ERd, Lb2 (22)

The calling subscriber dials the desired number and *IR* transmits the impulses to the second exchange.

Relays *AR* and *BR* prevent two subscribers at different exchanges from obtaining simultaneous connections to the same junction line. When a subscriber belonging to the first exchange dials the exchange number and the register at this exchange sends out a current over the number line, relay *AR* energizes and occupies the junction line as long as the selector for a line provided with a translator hunts for the cord circuit to which the selector of the calling subscriber is connected. At the same moment as the junction line is seized from either one side or the other, *BR* in the exchange at the other end of the junction line is energized and closes the following circuit,

Positive, *BR, Le1, B2, junction line, La2, ARa, Lb2, junction line, B2* to negative (23)

BR energizes and breaks the circuit between *Lc1* and *Ld1*, thereby preventing the subscriber at the second exchange from obtaining a connection to the translator, a busy signal being sent out instead.

A diagram for such a cord circuit translation between exchanges of different automatic systems is shown in fig. 10.

After the subscriber has dialled the exchange number, *AR* energizes over the following circuit,

Positive from the register of one of the exchanges, *Lc1, AR, Ld1* over contact and through relay at this exchange to negative (24)

Relay *AR* closes the circuit,

Positive, *ARa, ER* to negative (25)

ER energizes and closes the following circuits,

Positive, *VR1a, ERa, ER* to negative (26)

Positive, *ERe, D, ERf*, to negative (27)

La1, ERd, PR, D (28)

Lb1, ERc, PR, D (29)

Lb2, ERb, ARc to earth (30)

The circuit (24) is presently broken and *AR* de-energizes, while circuit (26) keeps *ER* energized. As long as *AR* remained energized, *Lb2* was earthed through circuit (30), whereby a calling signal was sent out to the other automatic exchange.

The armature of the polarized relay *PR* is in the upper contact position, *PRb*. When the calling subscriber dials a number and impulses are sent out from the first exchange, the armature of *PR* moves to *PRa* and closes the following circuit,

Positive, *ARB, PRa, IR, ERf* to negative .. (31)

IR energizes and connects *La2* to earth over circuit

La2, IRb to earth (32)

The second exchange now receives the train of impulses. Each energizing of *IR* closes the circuit

Positive, *IRa, VR2* to negative (33)

Since *VR2* is a slow acting relay, it remains energized during the transmission of the entire train of impulses for each digit and closes the following circuit,

Positive, *VR3, VR2b* to negative (34)

VR2 de-energizes as soon as the impulses for a digit have been transmitted. However, since *VR3* is a slow acting relay, its armature remains attracted a little longer and connects *Lb2* to earth by closing the circuit

Lb2, ERb, ARd, VR2a, VR3a to earth .. (35)

VR3 de-energizes, breaking the connection from *Lb2* to earth and again connecting it to *TI*.

A signal is sent out to the second exchange over circuit (35) between the dialling of each digit. The switching process may be repeated as often as there are digits in the numbers of the second exchange.

After the dialling of all the digits in the desired

number, the following circuit is closed from the second exchange,

Negative, through the feed coil, $La2$, IRc , TI , $VR3b$, $VR2a$, ARd , ERb , $Lb2$, to negative (36)

When the subscriber at the first exchange replaces his microtelephone the following circuit is formed,

Positive, ARb , PRa , Si , $VR1$, ERf to negative (37)

This circuit was closed already on the transmission of the impulses, but it was impossible for $VR1$ to

RR energizes and closes the following circuit,
Positive, RRa , ER to negative (39)

Relay ER energizes and closes the following circuits,

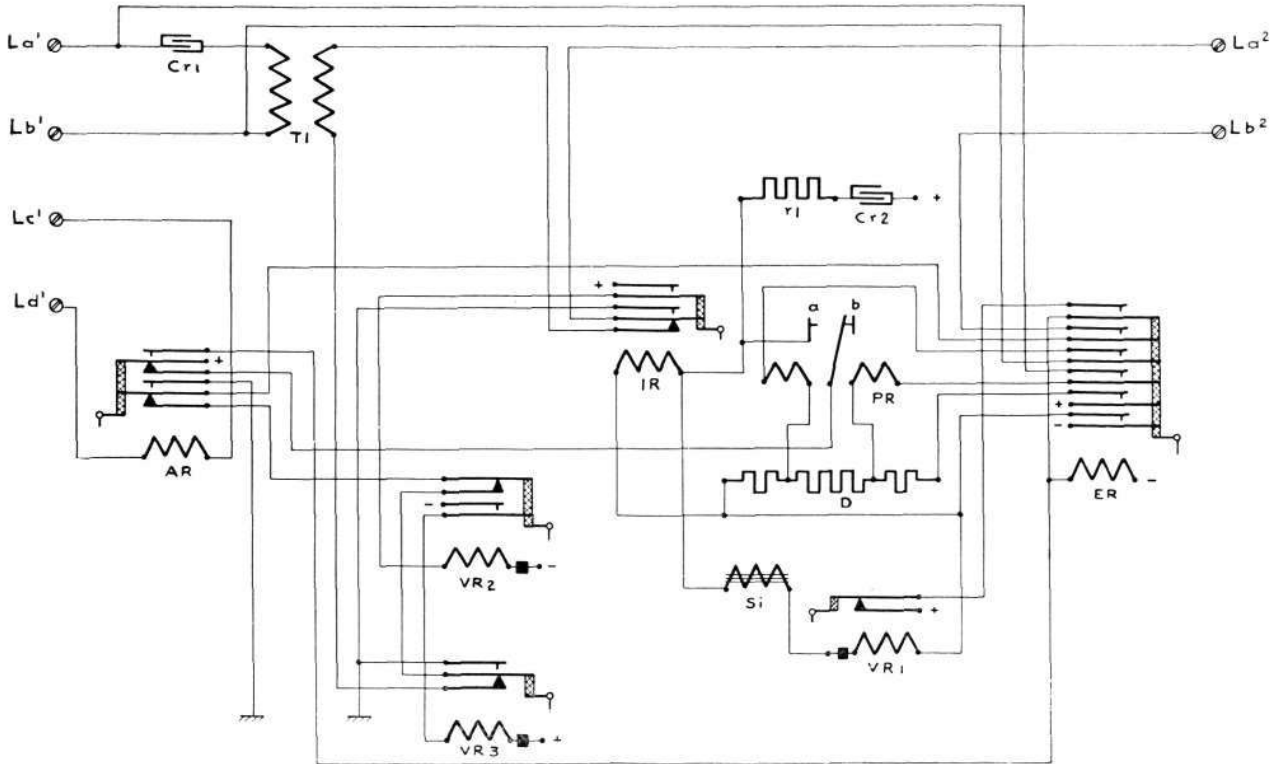
Positive, VRa , ERb , ER to negative (40)

$La1$, ERc , PR , D (41)

$Lb1$, $Si1$, ERe , D (42)

Positive, ERf , D , ERg to negative (43)

Circuit (38) was broken when ER energized; ER



R 993

Fig. 10.

energize at that time since the circuit was closed for so short a time and $VR1$ is a slow acting relay connected in series with a self induction coil. $VR1$ now energizes and breaks circuit (26), thereby de-energizing ER and causing $La2$ to be connected from $Lb2$. In this manner the other exchange receives a clearing signal.

In exchanges with one condenser in one of the line branches and a common feed coil in the other the cord circuit translator is connected as shown in fig. 11.

As soon as the subscriber has dialled the exchange number a plunger key is depressed and the following circuit is obtained, on condition, however, that the line to the translator is disengaged,

Positive, VRa , ERa , RR , $Lb1$, through a resistance to negative (38)

is slow-acting, however, for which reason the armature is not released until after a certain time has elapsed, during which relay PR energizes and the following circuit is closed,

Positive, RRb , ERd , PRb , IR to negative (44)

Relay IR energizes. If the other exchange is of another type, a calling signal may be sent out over the following circuit,

$La2$, TI , IRa , $Lb2$ (45)

A dial tone is received by the calling subscriber at the first exchange, after which he can dial the desired number, on condition, however, that his calling dial is identical with those used by the called exchange. When the current is broken in the telephone instrument of the calling subscriber, the armature of PR is moved to contact PRa , thereby breaking circuit

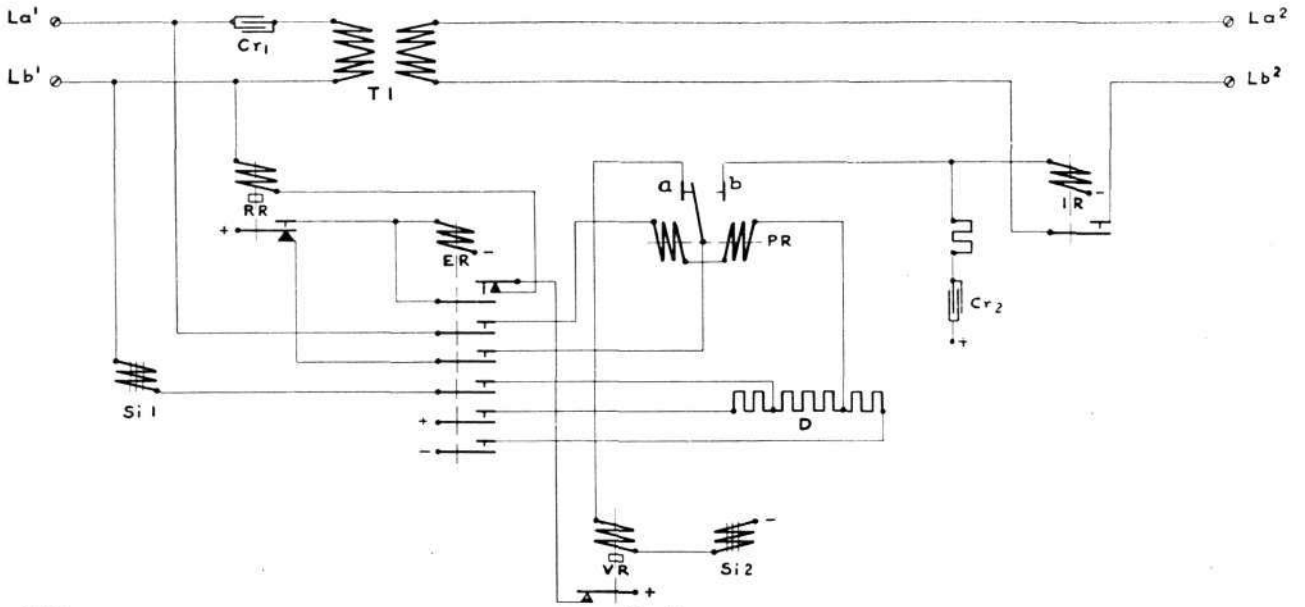


Fig. 11.

R 004

(44). *IR* de-energizes and breaks the circuit to the other exchange. When the current is again closed, *IR* energizes and circuit (45) is again closed. In this manner the trains of impulses are transmitted to the other exchange.

current impulses to energize, but is now actuated. This results in the breaking of circuit (40), causing all the relays to de-energize and the other exchange to receive a clearing signal.

When the junction traffic is between two exchanges

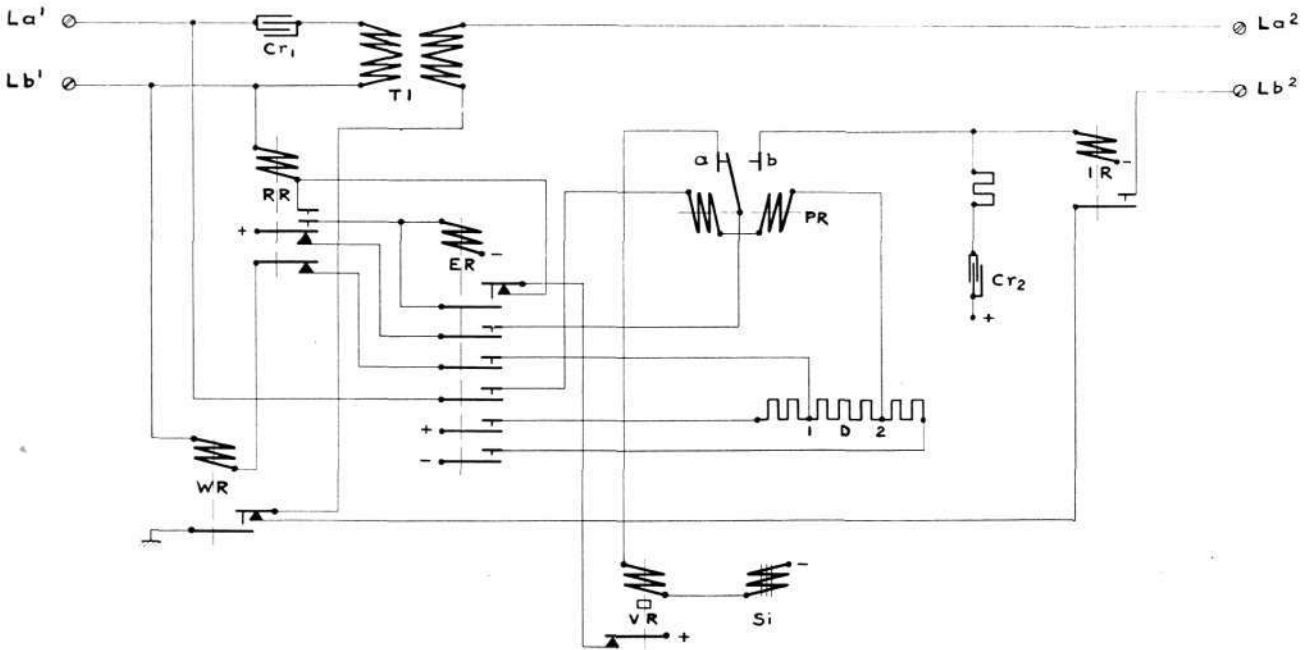


Fig. 12.

R 005

After the subscriber at the first exchange has replaced his microtelephone on the cradle rest, the armature of *PR* moves over to contact *PRa*, where it remains, thereby closing the following circuit,

Positive, *RRb*, *ERd*, *PRa*, *VR*, *Si2* to negative

Relay *VR* has not previously received long enough

of the same above-mentioned type, the connections will be according to the circuit diagram in fig. 12.

As in the previous case, the subscriber dials the exchange number and depresses a push button, closing the following circuit,

Positive, *VRa*, *ERa*, *RR*, *Lb1*, through a resistance coil to negative

RR energizes and closes the following circuits,
 Positive, *RRa*, *RR*, *Lb1*, through a resistance coil to negative (48)
 Positive, *RRb*, *ER* to negative (49)
ER energizes and breaks circuit (47), although *RR* remains energized over circuit (48) until the subscriber depresses the button.
 Relay *ER* closes the following circuits,
 Positive, *VRa*, *ERb*, *ER* to negative (50)
La1, *ERe*, *PR* to *D* (51)
 Positive, *ERf*, *D*, *ERg*, to negative (52)

La2, *TI*, *WRb* to earth (56)
 The *Lb* line of the called subscriber is connected to negative over a resistance coil causing the sending out of a calling signal. The called subscriber removes his handset, thereby closing the following circuit,
La2, *TI*, *WRa*, *IRa* to *Lb2* (57)
 If two such exchanges are to have junction traffic with cord circuit translation, this can be obtained according to the diagram shown in fig. 13.
 After the dialling of the exchange number and the

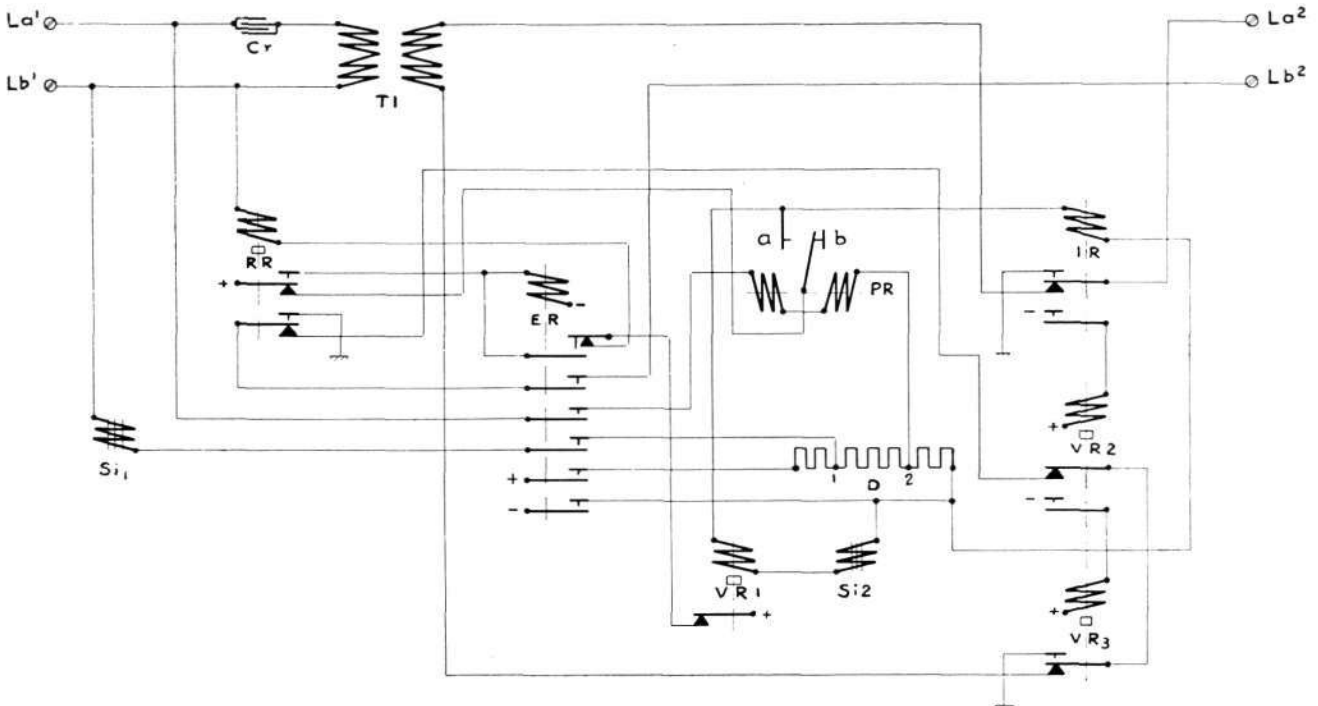


Fig. 13.

The following circuits are closed after *RR* de-energizes,
 Positive, *RRc*, *ERc*, *PRb*, *IR* to negative (53)
Lb1, *WR*, *RRd*, *ERd*, *D* (54)
WR cannot energize because the current between *Lb1* — which is connected to positive — and *D1* is too weak.
 When the calling subscriber at the first exchange has dialled the number of the desired subscriber at the other exchange, he depresses the plunger key on his telephone, causing *Lb1* to be connected to negative over a resistance coil and *WR* receives a current over the following circuit,
 Positive, *ERf*, *D1*, *ERd*, *RRd*, *WR*, *Lb1* over a resistance coil to negative (55)
WR energizes, whereby *La2* is earthed over the following circuit,

depressing of the plunger key, the following circuits are formed,
 Positive, *VR1a*, *ERa*, *RR*, *Lb1*, over a resistance coil to negative (58)
 Positive, *RRa*, *ER* to negative (59)
 Relay *ER* energizes and closes the following circuits,
 Positive, *VR1a*, *ERb*, *ER* to negative (60)
 Earth, *RRc*, *ERc*, *Lb2* (61)
La1, *ERd*, *PR*, *D2* (62)
Lb1, *Si1*, *ERe*, *D1* (63)
 Positive, *ERf*, *D*, *ERg* to negative (64)
 Shortly thereafter *RR* de-energizes, thereby breaking circuit (61). The trains of impulses are now transmitted over the following circuits
 Positive, *RRb*, *PRa*, *IR*, *ERg* to negative (64)
La2, *IRa* to earth (65)

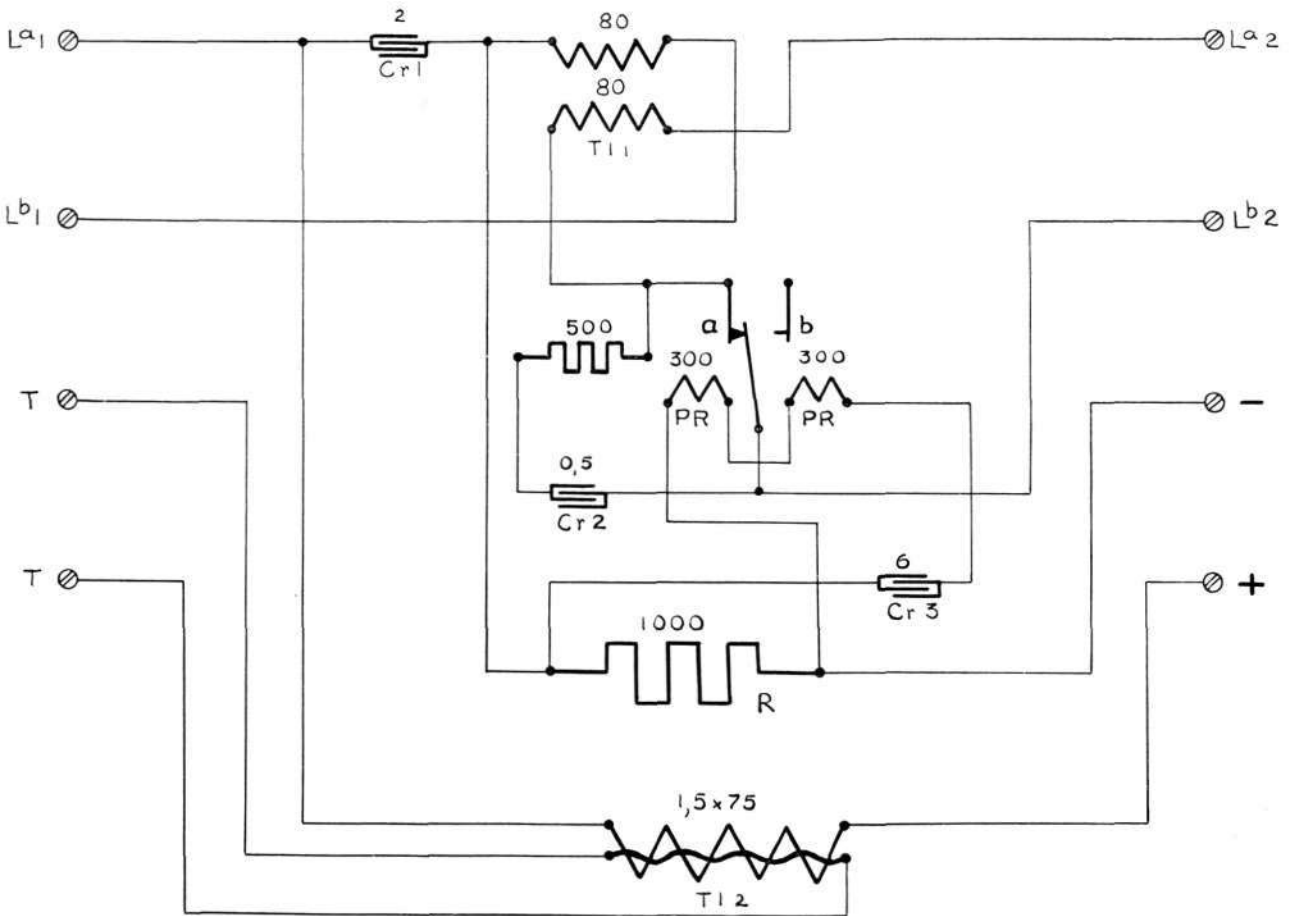


Fig. 14.

R 997

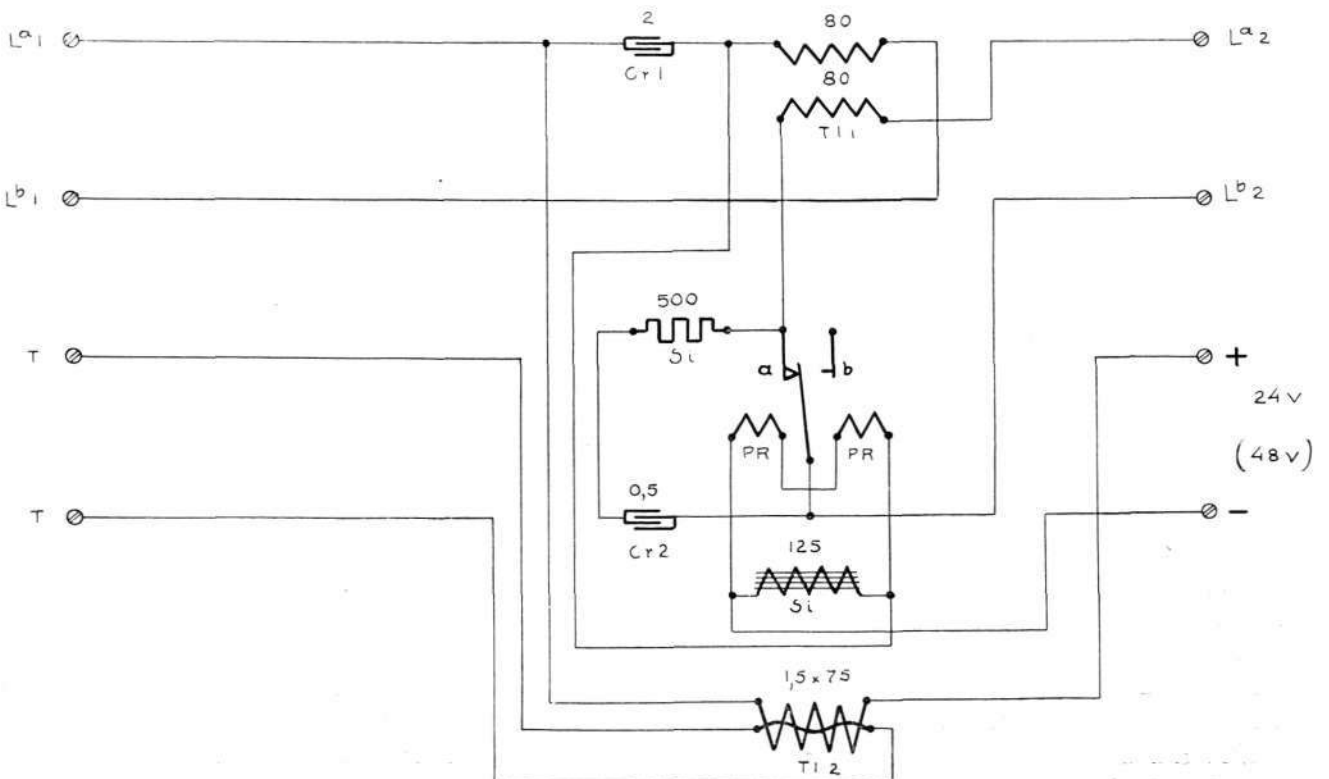


Fig. 15.

R 998

During the transmission of the impulses the slow acting relays *VR2* and *VR3* are energized over the circuits

Positive, *VR2*, *IRc* to negative (67)

Positive, *VR3*, *VR2b* to negative (68)

After a train of impulses has been transmitted, the following circuit is momentarily closed,

Earth, *VR3a*, *VR2a*, *RRd*, *ERc*, *Lb2* .. (69)

The speaking circuit passes from *La2* over *IRb*, *TI*, *VR3b*, *VR2a*, *RRd* and *ERc* to *Lb2*.

At the close of the conversation, *VR1* energizes, circuit (60) is broken and all the relays de-energize, causing a clearing signal to be sent out to the other exchange.

Cord circuit translation between exchanges wired according to the cord circuit system with two condensers takes place according to other principles. The diagram for an installation of this kind is shown in fig. 14. *R* represents a resistance in the circuit. A polarized relay *PR* — in series with a condenser *Cr3* — is connected up in parallel with the same.

When the line circuit for the calling exchange is closed, *R* receives current and there is a certain difference in voltage between the terminals of *R*. This furnishes the condenser *Cr3* with a loading current which passes through *PR* and sets the armature of this relay to contact *PRa*. As soon as the current in the circuit is cut off the difference in tension between the terminals of *R* ceases, *Cr3* is subject to a discharge and the discharge current passing through relay *PR* moves the armature of this relay to contact *PRb*. Thus each closing of the circuit sets the armature to *PRa* and each break to *PRb*.

Still another circuit diagram is shown in fig. 15. Here *Si* is a self-inductance coil with comparatively high self-inductance and low resistance. In parallel with this coil is a polarized relay *PR* with high resistance and low self-inductance. When a circuit is closed over *La1* and *Lb1*, *Si* immediately makes a very high although merely apparent resistance which causes almost all of the current to pass through *PR* and sets the armature to contact *PRa*. During the following moment almost all of the current passes through *Si* and only a very small part through *PR* on account of the high resistance of the coil *Si*. When the current is cut off, self-inductance in *Si* creates a reversed current which passes through *PR* and causes the armature to be set to contact *PRb*.

Thus, for an exchange with two condensers, cord

circuit translation can take place according to the diagrams in figs. 14 and 15. For exchanges with long, loaded lines or with lines having large, variable leakage line translation should be provided.

Fig. 16 shows a diagram for cord circuit translation between a manual exchange and an automatic exchange. A special switching device is arranged in the manual exchange for junction service to the automatic exchange. When a manual subscriber wishes to call an automatic subscriber, the local operator at the manual exchange connects the subscriber to a junction board where another operator plugs up the answering cord *ASt* in the corresponding jack *G1* and throws the speaking and ringing key *KSr*. She can now communicate with the calling subscriber over the transformer *Tr1* and the following circuit,

Tr1, *KSrc*, *CR1*, *TR2*, *T*, *KSrf*, *KSrb* to *Tr1* (70)

After the operator has been told the desired number, she inserts the distributing plug *WSt* in the jack *G2* of the corresponding junction line, thereby closing the following circuit,

Positive, *RRb*, *La1*, junction line, *La*, *KSrc*, calling, dial, *KSrc*, *Tr1*, *KSrb*, *Lb*, junction line, *Lb1*, *Tr*, *Si* and relay *PR*, *RRa* to negative (71)

The armature of *PR* is set to contact *PRa*, closing the following circuit,

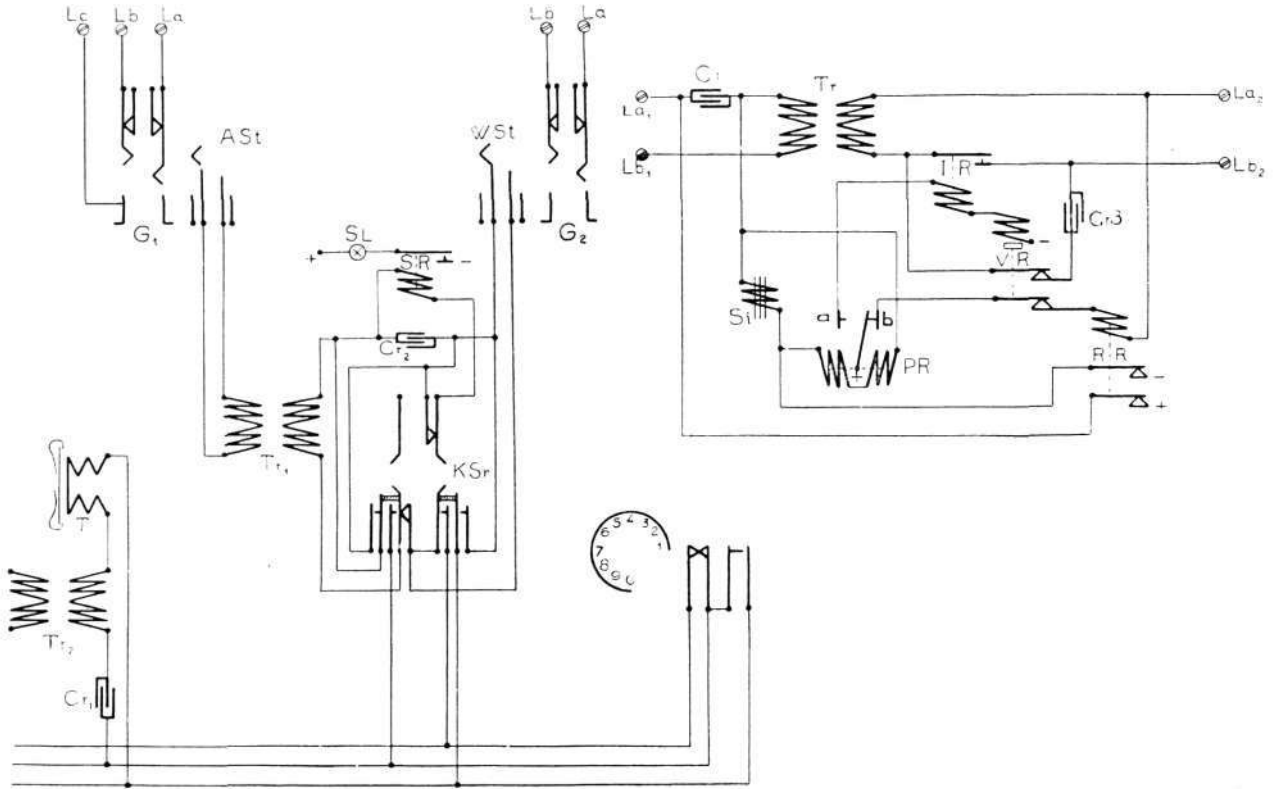
Positive, *PRa*, *IR*, *VR* to negative (72)

IR energizes and closes the following circuit,

La2, *Tr*, *IRa*, to *Lb2* (73)

The automatic exchange now receives a calling signal and the selector hunts for a disengaged cord circuit. When a register connection has been obtained, which is indicated by means of a buzzer signal, the operator can dial the desired number. The breaks in the current occasioned by the impulses cause — by means of the armature of relay *PR* — breaks in circuit (72), whereby *IR* de-energizes and circuit (73) is broken. The automatic exchange now receives the impulses sent out by means of the calling dial and selects the desired number. If this number is disengaged the operator receives the calling tone and must wait on the line until the called subscriber answers, after which she places the speaking and ringing key in speaking position, thereby breaking circuit (71). The armature of *PR* moves to contact *PRb* and breaks circuit (72). *IR* and *VR* de-energize. Instead, the following circuit is closed,

Positive, *PRb*, *VRb*, *RR*, *La2*, over the cord



R 999

Fig. 16.

circuit of the called automatic exchange and the telephone instrument of the called subscriber to negative (74)

RR energizes and disconnects the battery from the junction line. The air pump causes the speaking and ringing key to return to normal after a certain determined time, thereby closing the following circuit,

Lb, KSra, SR, Tr1, KSrd, La (75)

Since the battery is disconnected, however, *IR* remains de-energized. The speaking circuits are now as follows:

Tr1, KSrd, La, junction line, La1, Cr, Tr, Lb1, junction line, Cr2 and Tr1 (76)

La2, Tr, VRa, CR3 to Lb2 (77)

When the automatic subscriber replaces his handset, *RR* de-energizes and the poles of the battery are connected to the junction line, closing the following circuit,

Positive, *RRb, La1, junction line, Lb1, Tr, Si* in parallel with *PR, RRa* to negative (78)

IR energizes and closes the following circuit,

Positive, *SL, SRa* to negative (79)

The clearing lamp *SL* glows after which the operator pulls down the connection.

If it be undesirable that the operator wait until the called subscriber has answered, both clearing lamp and supervisory lamp will be required in the junction position, in which case the connections will be as shown in fig. 17.

The throwing of the speaking and ringing key *KSr* closes the following circuit,

Positive, *KL, KR, KSrf* to negative (80)

KR is energized and the supervisory lamp *KL* glows on account of the low resistance of *KR*. After the automatic subscriber has been given a calling signal by the operator — verified by means of a signal tone —, *KSr* is thrown in speaking position and *KR* de-energizes. The throwing of *KSr* to speaking position ends the short-circuiting of *SR* and *SR* energizes quicker than *KR* de-energizes, this latter being a slow acting relay. The following circuit is now closed,

Positive, *KL, KR, KRa, SRa* to negative .. (81)

During the calling of the desired number, the following circuit is closed,

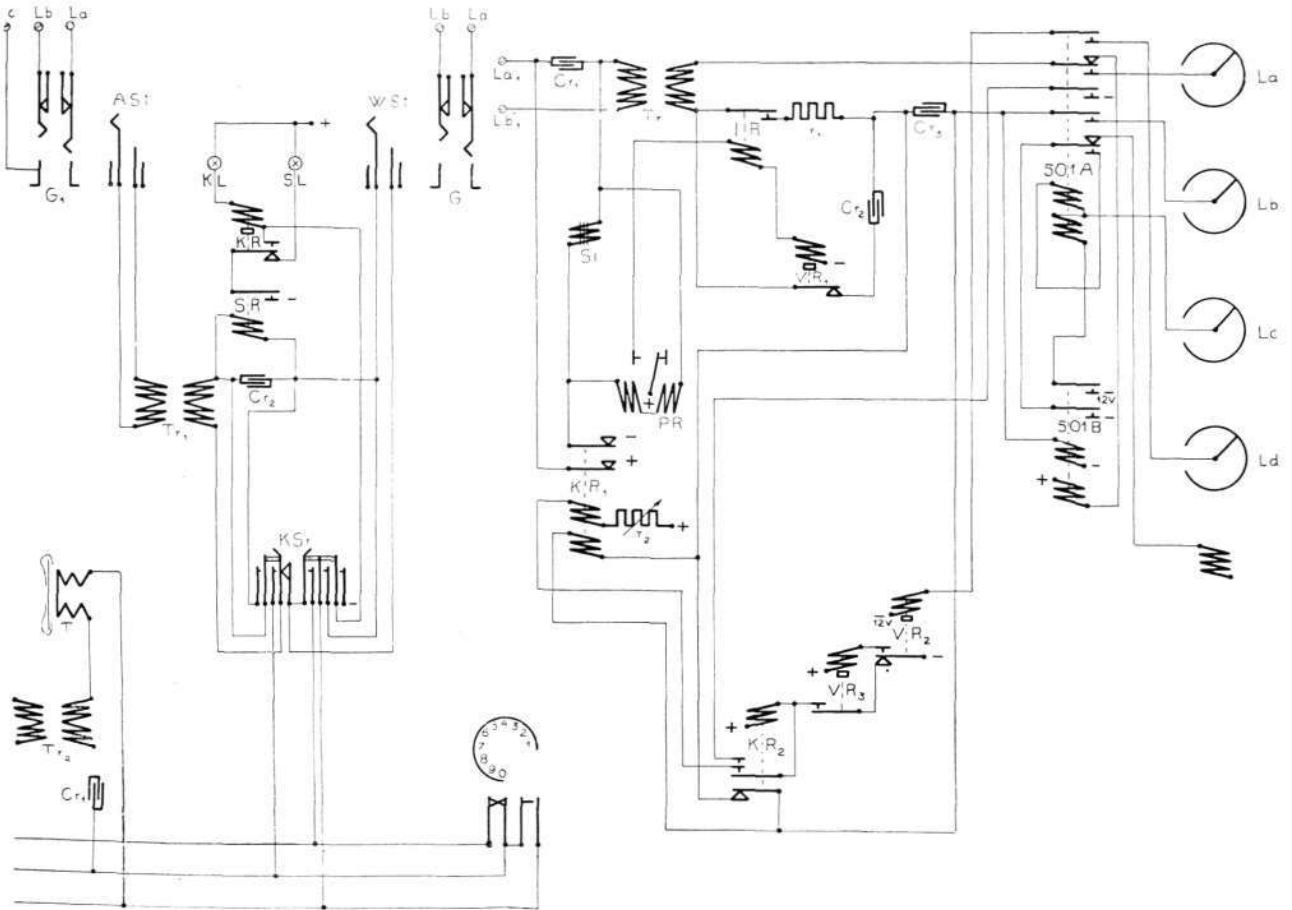
Positive, $Ld, Aa, VR2$ to negative (82)

$VR2$ energizes and closes the following circuit,

Positive, $VR3, VR2a$ to negative (83)

At the end of the calling signal circuit (82) is broken and $VR2$ de-energizes. Since $VR3$ is slow acting, the following circuit will be momentarily closed,

The resistances $r1$ and $r2$ are so calculated that the number of ampere turns in both windings of $KR1$ are alike. Since these two windings counteract one another, $KR1$ remains de-energized. At the same moment the called subscriber removes his microtelephone, the amount of current passing over circuit (87) is reduced, $KR1$ energizes and cuts off the current supply to the junction line. This causes SR to de-



R 1000

Fig. 17.

Positive, $KR2, VR3a, VR2b$ to negative (84)

When $VR3$ de-energizes, the closing of the following circuit keeps $KR2$ energized,

Positive, $KR2, KR2a, Ad$ to negative (85)

The following circuit is also formed,

Positive, $r2, Kr1, KR2b, Ad$ to negative .. (86)

after which the current of the automatic exchange passes through the following circuit,

Positive, $Ac, Tr, IRa, r, KR1$, over two B 's in parallel to negative (87)

energize, whereby KR de-energizes and KL cease to glow.

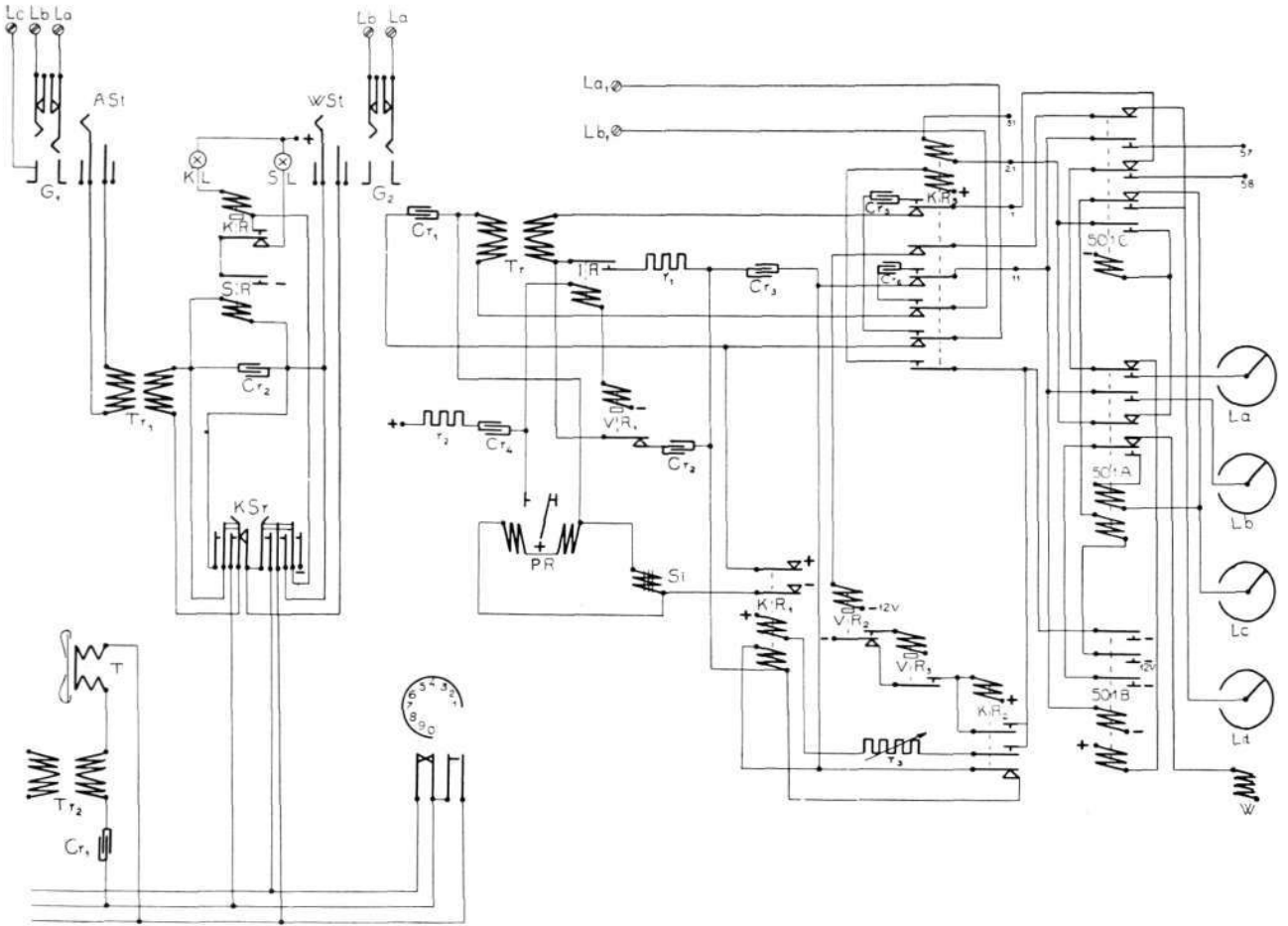
When the called subscriber replaces his microtelephone, $KR1$ again de-energizes and battery is connected to the junction line.

SR is energized and closes the following circuit,

Positive, SL, KRb, SRa to negative (88)

SL glows, whereby the junction board receives a clearing signal.

The problem of obtaining two-way traffic with but one junction line may be solved on the aforementioned principles, the diagram for such a plant



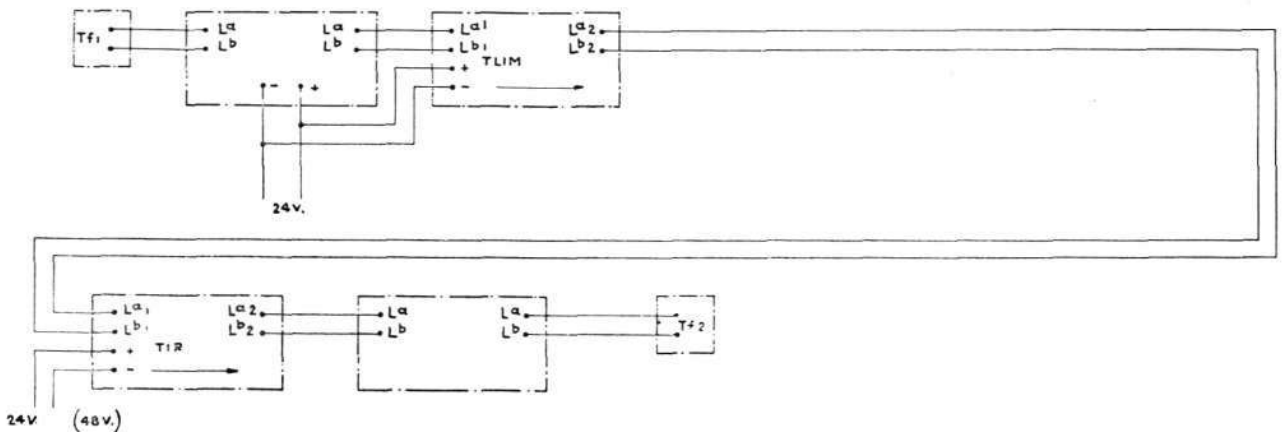
R 1002

Fig. 18.

being shown in fig. 18. (An additional supervisory relay must be included in the diagram, fig. 17.)

When two automatic exchanges are inter-connected

Impulses can be transmitted from a 48-volt line battery over a cable with a resistance of 6000 ohms, a total capacity of 3 mF and an inductance of up to



R 1001

Fig. 19.

by means of loaded cables or long aerial lines, cord circuit translation is provided at the exchange which transmits the impulses and so-called line translation at the receiving exchange, as shown in fig. 19.

5 Henries. The battery must be individual for the line and be well insulated from earth. The diagram shown in fig. 14 can be used to advantage for aerial lines with considerable and irregular leakage.



R 890

Air-view of a forest fire.

On Forest Fires and Forest Fire Protection.

The Telephone as an Effective Agent in the Prevention of Forest Fires.

by Folke Johansson, of the Swedish Government Forestry Service.

The tentative estimates which now and again are being made of the world supply of those raw products — iron ore, petroleum, gold, coal and timber — which constitute a dominating factor in our modern commercial life often lead to the prediction that these supplies will soon be exhausted. Prophecies of this sort generally result in the appearance of more or less irresponsible statements in publications of a professional character as well as in the daily press. Thus, an English prediction that the world supply of pine timber would be completely depleted within a space of 37 years recently found its way to all corners of the world. The truth of this prophecy — which was avidly taken up by publications of all sorts — is a matter which we will not bother to discuss at the present moment, but the intense interest evoked by this “cry of distress” proves that many were fully aware of the importance of our pine forest reserves — not only on account of the importance of this product for various household uses, but also in its property of raw product for a number of exceedingly important industries, i. e. the lumber, wood pulp and paper industries — as well as of the necessity of adopting rational methods for the working up of the forests and for the utilization of the timber supply. Consequently, the assumption that a realisation —

even though more or less superficial — of the necessity for the care and protection of existing pine forests has permeated circles which are not directly interested in forestry or any of the above-mentioned industries cannot be taken as an exaggeration.

Ever since time immemorial catastrophical and rapid changes in the nature and condition of the forests has been caused by fire, this scourge having later on found a serious competitor in man, however. In the present case we will not touch on the human efforts of a purely selfish character whose sole aim is the ruthless devastation of our forest reserves for personal gain only and without a thought for the future, these efforts falling outside the scope of this article, but will devote ourselves solely to forest fires. It is true that — due to more effective protective measures and better fire fighting methods — the losses caused by fire have been restricted in the same proportion as the forest supply is undergoing a gradual reduction, but the actual economical losses caused by fire are nevertheless more and more keenly felt. In spite of all our most modern and advanced technical resources the forest fire remains to this day a largely uncontrollable and most important agent of destruction. Seen from a geographical point of view, this is especially true in Russia, Siberia, Canada and

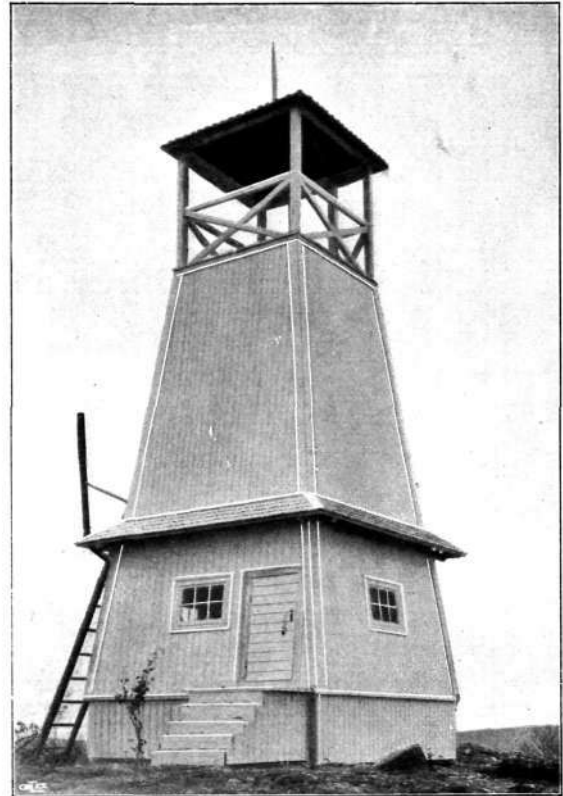
the United States, whose climatic conditions tend to considerably increase the fire risk, although countries with such favourable climates as Sweden, Finland, Germany, Norway etc. also suffer great losses each year on account of forest fires.

A few figures taken at random will suffice to prove this statement. In Finland, for instance, during the summer of 1925, about 25,500 hectares (abt. 63,000 acres) of government forest land were laid waste by fire, the financial loss being estimated at 4 million finmarks. (The Finnish government forest reserves cover about one third of the total area of the country.) The devastated area of forest land in Sweden is estimated at about 8500 hectares (abt. 21,000 acres) per year during the last fifty years, corresponding to a monetary loss — including value of timber, cost of extinguishing fires etc. — of about 2 million Swedish crowns; in Sovjet Russia the destroyed area amounts to about 600,000 hectares (1,484,000 acres), in the United States 7,000,000 hectares (abt. 17,300,000 acres) and in Canada 1,000,000 hectares (abt. 2,471,000 acres), all per year. In the two last mentioned countries the losses are estimated at 30 and 14 million dollars respectively. No additional comments are necessary.

Just as cities and other communities have been forced to adopt various measures in order to protect life and property from destruction by fire, so also has this been found necessary as regards forests, for in our present age with its enormous consumption of paper the forest supply is altogether too valuable to be allowed to merely go up in smoke before ever having had the chance of being utilized in some form or other. We will not here discuss the rather common temporary and more loosely organized forest fire brigades or other organizations which serve the same purpose; what we once for all want to establish is that the most important part of an organization for the fighting of forest fires — no matter how local conditions may affect the same — always is a combination of patrol duty and fire signalling, the purpose of which is to quickly discover and locate a starting forest fire and to report the same to the nearest headquarters from which aid may be obtained. At the outbreak of a fire every minute counts; a fire which at one moment may be extinguished by a child with a tuft of pine branches and a pail of water may, at the next, defy the efforts of hundreds of well equipped men. The most destructive forest fires have always had a very insignificant beginning.

The most effective alarm system for forest fires —

it might almost be called automatic, for reasons which we will touch on in the following —, combining both patrol duty and fire alarm, is the so-called fire tower system, used with excellent results since many years back. Experience shows that the fire tower, placed on a mountain top or other rise in the ground from which an unobstructed view of the surrounding country is obtained, is the safest method of detecting the outbreak of forest fires in sparsely inhabited, desolate

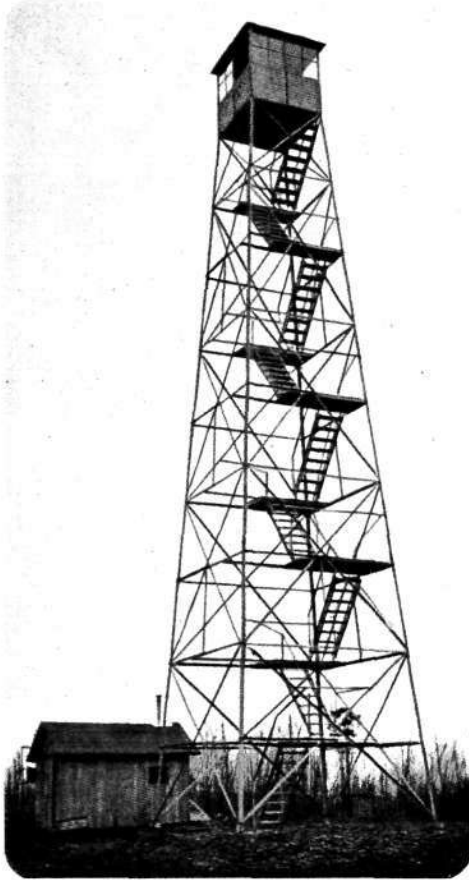


Swedish Fire Tower from the Province of Härjedalen.

and hilly tracts of land. Even the aeroplane is considered inferior in this respect to the fire tower, since for reasons of safety it can only be used in regions with numerous lakes; also, patrol duty is exercised only while the machine is in the air, the entire district lying unprotected between flights. Such is not the case with fire towers, however, in which special guards are stationed during the summer whose sole duty it is to keep a sharp lookout from break of day until nightfall (and who may, in a sense, be compared to the thermo-contact or sensitive organ of the automatic fire alarm) for any suspicious looking smoke, which is then located on the map in the tower by means of a diopter, after which a tele-

phone report is made to headquarters from which a force may be sent out for the extinguishing of the fire. Thus, every fire tower must be able to communicate with headquarters and preferably also with

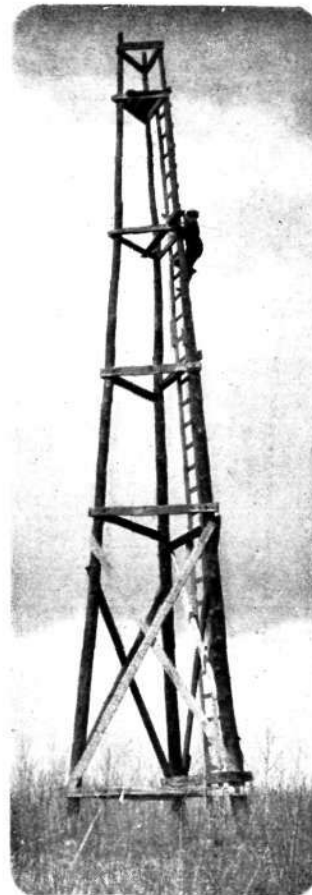
with the most modern apparatus are organized etc. But if the signalling system is inadequate or does not function properly, what good is then derived from all this wonderful fire extinguishing apparatus? Intervention at the right moment, i. e. at the very outbreak of a fire, is of much greater value than a whole arsenal of fire engines and many large bodies of water; consequently, a campaign against forest fires should not be begun by the acquiring of all the latest models of fire engines and other paraphernalia. On the contrary, the only efficient method is to intervene immediately on the outbreak of a fire and thereby prevent it from doing serious damage, and this can be done only if a report of the fire is sent in quickly and accurately, in other words if the alarm system is in



R 890 American Fire Tower of Steel. The house at the foot of the tower contains the fire guard's living quarters.

other towers and points of observation within the same district. At the present time the desired communications are almost exclusively obtained by means of permanent telephone lines; formerly optical signals were used as well.

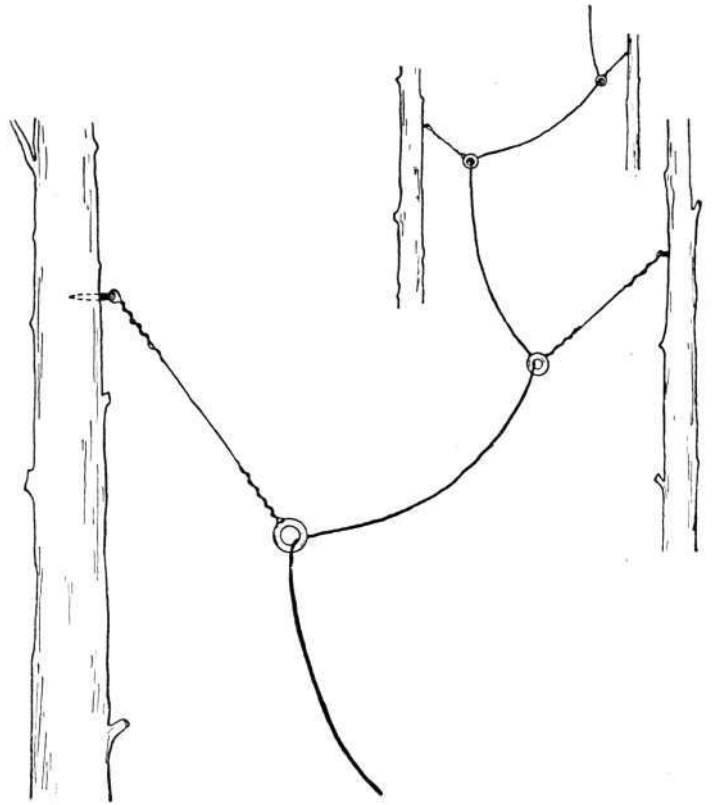
Just as the fire fighting equipment in our towns and cities has undergone successive improvements and become many times more effective than, let us say, only ten years back, so also has the equipment used for fighting forest fires been improved upon and perfected to a surprising degree. There are at present portable motor fire engines in which lightness of weight is combined with a most surprising efficiency, light types of fire hose in kilometer lengths which are easily transported to the site of the fire, in many localities horse, automobile or railway patrols equipped



R 892 Temporary Wooden Fire Tower. Canada. (Foto. Can. Forest Service.)

good working order. In fact, it actually is better to have a reliable alarm system and antiquated fire extinguishing apparatus — naturally on condition that the latter is serviceable — than vice versa.

The duty of the fire guard up in the tower, therefore, is to turn in an alarm in the shortest possible time. Since, as has already been mentioned, minutes are precious and it is generally necessary to simultaneously make a short report, there is practically but one way in which this can be done, and that is with the aid of the telephone. Thanks to simple yet adequate telephone communications the alarming of forest fires has been made as quick and reliable as can well be desired; consequently, it cannot be regarded in the light of an exaggeration to emphasize that fire towers without telephone communications cannot even approximately fill present day requirements. In fact, the telephone can well be said to constitute the solid foundation for modern forest fire protection and what has here been stated should make clear the fact that the greatest responsibility born by any inert matter in this organisation rests upon the telephone alarm system. The fact that no fire towers are now erected without being provided with a telephone gives ample proof that this means of communication has stood the test, and proved its fitness for this purpose.



R 801 a
Schematic Drawing showing Construction of Telephone Line Using Live Trees as Poles. The wire is run through the shackle insulators.



R 808
The tops of the trees are cut off but a few branches are left to prevent the tree from dying.
(From the annuals of the Swedish Forest Preservation Society.)

One can be practically certain that no two telephone plants for forest service are exactly alike in all respects. It often happens that unskilled labor is used for line construction and other similar work, and under such conditions the result cannot be satisfactory. In other instances, however, men specially trained in this kind of work are employed for the purpose, the result being a plant which is first class in every respect.

West-European conditions have not, as a general rule, required the construction of such extensive fire protection telephone nets as are to be found in North America, for instance. In proceeding to describe a fire alarm telephone plant for the purpose of giving a clear idea of its outer contours and method of functioning, therefore, the writer prefers to choose an example from the new world, in this case from Canada, where colonization, climate and other conditions are such as to have developed the technic of forest fire protection to such a degree that it may well be held forth as an example for the world at large. The plant chosen for this purpose was made the object of a protracted stay on the part of the writer while travelling in North America some two years ago for purposes of study and does not presume to be

constructed in every detail according to the most advanced theories in the field of applied low tension electricity, but in the writer's opinion it represents a satisfactory and instructive practical solution — both as to design and construction — of the problem of providing telephone communications at a reasonable

from each tower slightly overlap. As is generally customary, the telephone net consists of single lines, earth being used for the return. This is also general practice in Scandinavian forestry, where, for the sake of economy, single lines are always used for fire alarm, lumber camp and forest guard telephone communications, a practice in which no special difficulties are encountered due to the comparatively short lines and the general absence of troublesome high tension transmission lines.

The company has about 300 km. of single lines with a double line about 50 km. long following a railway track, making a total of 350 km. of telephone lines. Both single and double lines proceed from the headquarters' administrative building and are run as straight as possible between the towers, branch lines being provided at two or three places. A total of twenty-four telephone instruments are connected to the single line, twenty-one of these being constantly connected up during the warm season while the remaining three — which are situated at the branching points — are used only now and then for trouble shooting by the line inspectors, for ordering repair material, and similar purposes. At headquarters another thirteen telephones are installed which can all be connected to the single line over a telephone switchboard. Another switchboard equipped with three vacuum protectors, one resistance coil, one transformer and two keys permits the establishing of connections between the single and double line through the transformer. Since each station has been given a separate calling signal it is possible — with the above arrangements — to speak between any two stations.

The lines of the Abitibi plant are almost without exception aerial lines passing through vast, uninhabited forest lands; between the Upper and Lower Abitibi Lakes, however, is a sound about 300 m. wide across which a 1¼" submarine cable has been laid. A 'pass' from 2.5 to 3 m. wide has been cleared through the forest for the erection of the lines, the trees along the edge of the 'pass' serving as poles. The insulators are large porcelain rings or shackles provided with a groove on the outside for receiving a 50 cm. long spliced stranded wire cord by means of which the insulators are hung to the tree. The wire cord is fastened to the trunk of the tree at a height of about 6 m. from the ground by means of strong 4" staples, light scaling ladders or specially built pole climbers being used. The hole in the insulator is sufficiently large to give the line wire — 2.5 to 3 mm. diam. phosphorbronze wire — free play.



R 898

Saddle for Carrying Reels of Telephone Wire used for transportation through forest wilds.
(Foto. Can. Forest Service.)

cost in the district in question. Consequently, it has been considered worthy of serving as an illustrative example.

The forest domains of the Abitibi Power and Pulp Co. are so extensive that it was considered wise to establish a special guard system in order to provide protection against forest fires. Nine fire towers have been erected, each one with an effective radius of 60 to 80 km. and placed so that the areas surveyed



R 894

Canadian Line Erection Gang on the March.
(Foto, Can. Forest Service.)

The line is erected so that every other insulator is hung on one side of the pass and every other on the

clearance for the wire and keeps it away from the tree trunks, thus eliminating all danger of short circuits



R 893



R 895

Telephone Cabinet for Fire Alarm Use.
(Foto, Can. Forest Service.)

other side, the wire being run in zig-zag fashion with a distance of about 30 m. between the points of support. This method of construction provides ample

in wet weather. The wire is not stretched very tightly, neither is it fastened at any point along the line, but is allowed to run freely through the insulators with



R 897
Portable Telephone for use in Trouble Finding on Fire Alarm Telephone Lines. Canada. (Foto. Can. Forest Service.)

practically no fixed points except at the two extreme ends. This manner of erecting lines, which possesses the advantage that a tree falling over the line does not break the wire but merely presses it down against the ground, does not seem to be in use outside of the United States and Canada, but the idea is undoubtedly a good one and deserves to be taken up for consideration in other countries as well. Experience shows that in dry weather there is almost no danger at all for short circuiting through an accident of this kind, and the trouble is easily remedied; the fallen tree is merely cut in two and the wire freed, after which it automatically rises up in the air again.

During the entire forest fire season while the telephone alarm system must be in perfect condition, the lines are inspected at regular intervals, each line inspector being responsible for a stretch of 40 to 50

km. Besides the necessary tools etc., the line inspectors are provided with portable telephones which can easily be connected up on the line. The previously mentioned telephone instruments at the branching points can also be used to advantage for trouble finding.

Of course, there is no denying the fact that the transmission of speech over a single line of such great length must be subject to the deleterious influences of currents caused by variations in the potential of the ground and by the polarization of the ground plates, giving rise to disturbing noises in the telephone receivers. In order to remedy this condition and eliminate these noises as much as possible the Abitibi



R 889
Canadian Forest Service Emergency Communication Kit in Use. The set contains in the smaller compartment 1 extension bell, 1 protector, 1 howler, 1 condenser. The larger compartment is fitted with 2 binding posts, from which wires lead to the external connections in the set and a portable telephone. There is also room for tools, etc.

line has been provided with some twenty 'Lavite' discharge coils with a resistance of about 38,000 ohms each, vacuum lightning protectors being mounted in the same boxes as the discharge coils as an added precaution. These coils have proved so efficient in the stopping of undesirable extra currents, that the line is being successively equipped with more and more of them, although a too liberal use of the same may do more harm than good.

The parallel telephone instruments erected in the fire towers and elsewhere are all wall instruments of standard type with 5-magnet generators and 2500-ohm bells, permitting the actuation of the signal bells of all the telephones on the same line with about the same degree of effectiveness. The telephones on the single line are equipped with a condenser — the six most distant ones with two each — and a key by means of which the telephone can be disconnected from the circuit while looking for faults. A Chapman protector has been mounted on the fourth pole from the headquarters' station building and the cable terminal box on the 'intake' pole.

The functioning of the fire alarm system is briefly as follows. If any suspicious looking smoke is observed from the fire tower, the guard sights the same through the diopter on the map table, notes the bearing in degrees of the spot with reference to the North point of the compass, calls up the man on duty at headquarters by giving the headquarters station signal and turns in his report about as follows, — "This is Smith in the tower. Light smoke at 235." As soon as Smith has submitted his report, he makes haste to get off the line in order to permit guards in other towers to report their observations as quickly as possible. The information thus obtained makes it possible for headquarters to locate the site of the fire on a general map covering the entire district and to take suitable steps for extinguishing the same.

There is no doubt but that the alarm system with fire towers or other similiar points of observation equipped with telephone communications should be more extensively adopted in the entire northern pine forest belt than has hitherto been the case. In Sweden, for instance, whose forestry is considered to have reached a very high standard and whose wood pro-

ducts are of vital importance not only for home consumption but also as one of the country's most valuable sources of income, — representing, as it does, more than one half the value of the country's entire exports — large forest tracts for which this type of alarm system would be exceptionally suitable are still without effective fire protection, and this in spite of the fact that large rebates are allowed off premiums on forest fire risks when suitable precautions are taken, i. e. the use of one fire tower entitles the policy holder to a rebate of 10 %, this being increased to 15 % where two fire towers are used. In Norway some fifty stationary points of observation have been established but many more are yet needed before the forest fire protection can be regarded as fully adequate. In Finland, where what has been said of Sweden holds true to an even greater extent, a severe yearly loss is occasioned by forest fires. Russia and Siberia are still more or less unknown quantities when it comes to forestry, depending on the inaccessibility of their forests and the attendant difficulties of timber cutting, due to which the standing timber in extensive forest areas has been considered almost valueless. In the same degree as the world demand and consequently also lumber prices experience an increase so also will these Russian and Siberian forest lands be subject to development and there will be a large demand for equipment for the purpose of fire protection. In the United States and Canada the forest areas protected by the fire tower system are rapidly increasing from year to year.

From the above statistical data it is evident that there still remains much to be done in this line. Existing conditions all seem to indicate serious future difficulties within pine timber production, due chiefly to the enormous yearly increase in the world-consumption of paper, and if the future needs of the paper industry as well as of other wood-consuming industries are to be provided for the rational development of the forest lands is an imperative necessity. But what permanent benefits are obtained from all the work spent on forest reclamation as long as the risk of losing in some few hours' time the fruits of many years' labour and of invested capital is forever imminent? It is very probable that the forest fire is an inevitable evil, but its effects can most certainly be kept within bounds through efficient fire protection.

On Subscribers' Meters.

The problem of making the operation of a telephone plant a paying proposition presented itself simultaneously with the planning of the first installation of this kind. The solution nearest at hand was naturally that those persons who had financed the undertaking should be the ones to use the plant and derive benefit therefrom. This matter was arranged in the same manner as at the present time, i. e. so that those

at the telephone exchange was determined by the number of effectuated connections per time unit, however, and consequently it became necessary to devise a means for the registration of the completed calls. Quite naturally, an attempt to let the operators themselves take care of this registration proved a failure and this task was then assigned to persons specially employed for this purpose. Even this arrangement



R 911

Fig. 1.

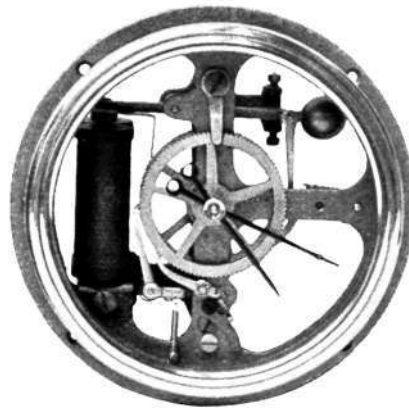


Fig. 2.

persons who had a telephone instrument connected to the net in question paid a certain yearly fee as rental for their telephone instruments. This system proved satisfactory in the beginning, but by degrees, as the telephone became more popular and more generally used, the steadily increasing traffic soon necessitated the extension of the exchanges as well as of the nets. In this connection it soon became apparent that only a comparatively small number of subscribers created this necessity through their frequent use of their telephones and since it did not seem more than fair that just these subscribers should stand for the increased costs there arose the problem of determining to what extent the different subscribers used their telephones.

First, an attempt was made to determine the total length of time per day during which the telephone instrument was in use; that is to say, what might be termed the service time was of minor importance since the cost of the plant proved to be considerably smaller than the cost of operation. The size of the staff

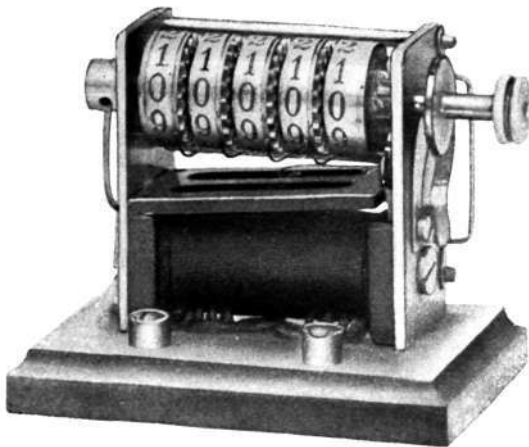
met with serious difficulties, however, at the same time proving to be all too expensive. Finally, there remained no other alternative but to design apparatus which would automatically register the calls, thus bringing into existence the problem of subscribers' meters.

To simply construct an instrument which could register the number of calls did not meet with any serious difficulties. However, a subscriber's meter intended for a telephone plant with several thousand subscribers — each one of whom must have his own meter — must have certain other properties as well; it must have a low cost of production and require a minimum of attention and maintenance. The first subscribers' meters did not meet these requirements, consequently it was not possible to manufacture them in such quantities as to permit of every subscriber's line being equipped with one of them.

The operating companies soon had another problem to face on account of the steady increase in the traffic.

As soon as an exchange reached such proportions as to require the services of more than one operator it was found necessary to divide the work equally among them or so as to correspond to the efficiency and capacity for work of each one.

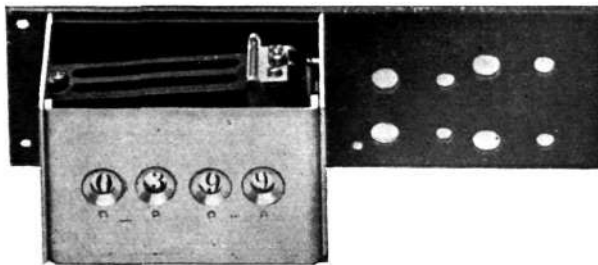
For this purpose it was necessary to obtain information as to the number of calls per time unit



R 912

Fig. 3.

effectuated by each operator and it was found that this could be accomplished with a comparatively small number of meters. Consequently, the first cost did not play such an important role and even the rather expensive apparatus already to be found on the market could be used for this purpose. Thus, one of the first duties of the subscriber's meter was to



R 913

Fig. 4.

provide the statistical information which served as a basis for the distribution of the service among the different operators.

Subscribers' meters of this type — the appearance of which is shown in figs. 1 & 2 — were first manufactured by L. M. Ericsson & Co. in about 1893.

The mechanism consists of an armature which is attracted by an electromagnet and is restored to normal by means of a counterweight. The armature actuates two ratchet wheels on whose shafts are two

hands, one of which indicates units and tens while the other one indicates hundreds and thousands. The meter has a capacity of 10,000. Both illustrations show front views of the meter, but in fig. 2 the dial has been removed in order to show the driving mechanism.



R 914

Fig. 5.

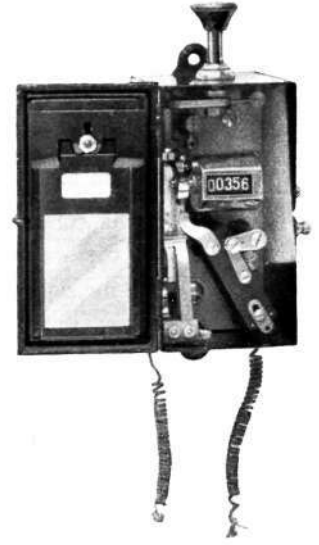


Fig. 6.

nism. In spite of the fact that these subscribers' meters were a decided improvement on those previously used they were quite bulky and expensive.

Fig. 3 shows a more recent construction of meter for the same purpose as the foregoing but much smaller as well as more accurate in its functioning. The circular face or disc with its gradations and in-

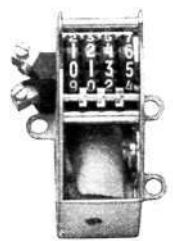


R 915

Fig. 7.



Fig. 8.



indicator hand, which often was the cause of mistaken readings, is here replaced by the rotating recording train now in general use; also the meter is of a much neater and less bulky construction, an important feature when it comes to the mounting of the meters as well as with regard to the cost of production and transportation.

Fig. 4 shows still another type in which the registering mechanism is similar to that generally to be found in gas meters. This type is also of an older design

L. M. Ericsson



R 916



Fig. 10.



Fig. 11.



Fig. 12.

and has never gained any great amount of popularity, probably for the reason that it is not considered reliable.

The meter illustrated in figs. 5 and 6 is the first one constructed by L. M. Ericsson for use in conjunction with a subscriber's telephone instrument. The meter is sealed and is mounted beside the telephone instrument. It is wired so as to register a call on the pressing down of the button with the microtelephone removed from the cradle rest. The button is depressed after the desired number has answered and at the request of the operator, who is also able to tell whether the calling subscriber actually depresses the button or not.

Figs. 7 and 8 show a subscriber's meter of a type similar to the foregoing although of a more modern design. This type is intended to be incorporated in the telephone instrument in the manner illustrated in fig. 9, and can be used for manual as well as automatic installations.

The meter is wired so as to register only outgoing calls for which the connection has been effectuated. It is not difficult to see the advantage for a subscriber who is entitled to a certain limited number of calls per year to always be able to see the number of calls already made. This is probably one of the surest ways of eliminating all controversies between the subscribers and the telephone company.

It is only in exceptional cases, however, that subscribers' meters are placed anywhere except at the telephone exchange. Still, a number of telephone companies and administrations do practice this method, and it is to satisfy their demands that L. M. Ericsson manufacture the above described type.

The subscribers' meters described in the following and which are all intended for mounting at the exchange may therefore be regarded as of standard design. However, here also there are a number of varying designs.

Figures 9, 10 and 11 show three different designs of the hand and dial type for 500, 1000 and 10,000 calls. The driving mechanism for all three consists of an electromagnet which drives a worm gear by

means of a ratchet wheel. The wheel of the worm gear is mounted on the same shaft as the indicator hand of the meter. This construction is unusually simple and functions with great accuracy.

These meters are very well adapted for a special type of subscription. The telephone subscriber purchases a card entitling him to, say 500 calls. His meter is then set to 500 and adjusted to go back-



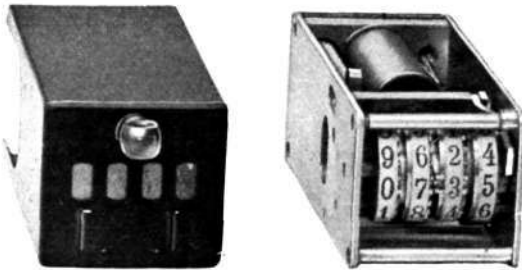
R 920

Fig. 9.

wards, one unit for each call. When the meter is nearing the zero mark he is apprized of this by the operator who asks if he does not wish to purchase a new card. If the subscriber does not comply with this request his telephone is shut off. This system can

be modified so that the subscribers are kept under surveyance from a special bureau equipped with automatic devices which give notice when a subscription has run out. Also, an arrangement can be made by means of which the subscriber is notified — with a special buzzer tone — when only a small number of calls remain to his credit.

A type of subscriber's meter which has been manu-



R 917

Fig. 13.

factured by L. M. Ericsson since many years back and of which great numbers have been sold to all parts of the world is shown in fig. 12. It is of an unusually sturdy and simple construction and functions with accuracy and precision in our northern Swedish climate as well as in damp tropical countries or in desert tracts with their dust laden atmosphere.

Nothing is so perfect, however, but that something



R 918

Fig. 14.

better can be imagined. Our modern times have set up requirements of a much too rigorous character to be filled by these meters of an older construction, a condition which has resulted in the construction by L. M. Ericsson of a new type of subscriber's meter which represents all that is most modern and most perfect in this line.

The meter shown in fig. 13 is a direct development of the one previously mentioned. The principle is the same, but the design has been considerably simplified, a number of details having undergone modifications and improvements in order to make the meter perform its work with still greater precision and reliability. It may seem almost inconceivable that

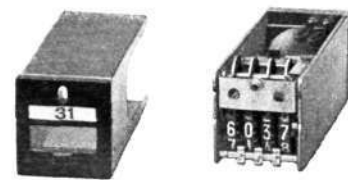
such a small device as this one can be provided with so many intricate details, but they will be recognized by the trained eye of the expert, some of them seemingly insignificant but still of considerable importance for the perfect functioning of the meter.

What we have said about the meter in fig. 13 is also true for the one in fig. 14. This one, however, has been provided with a little arrangement which



R 919 Fig. 15.

permits of its being quickly and simply cleared and restored to its O-position, a characteristic which — under certain conditions — is of the utmost importance. For instance, if a subscriber is entitled to a certain number of calls during a given time period, the work of supervision is made considerably simpler if the meter can be cleared after each reading. If this were not possible it would be necessary to keep



R 919 b

Fig. 16.

a special record for each meter and, at each reading, to deduct the figures obtained at the previous one, a procedure in which unnecessary and annoying mistakes often occur.

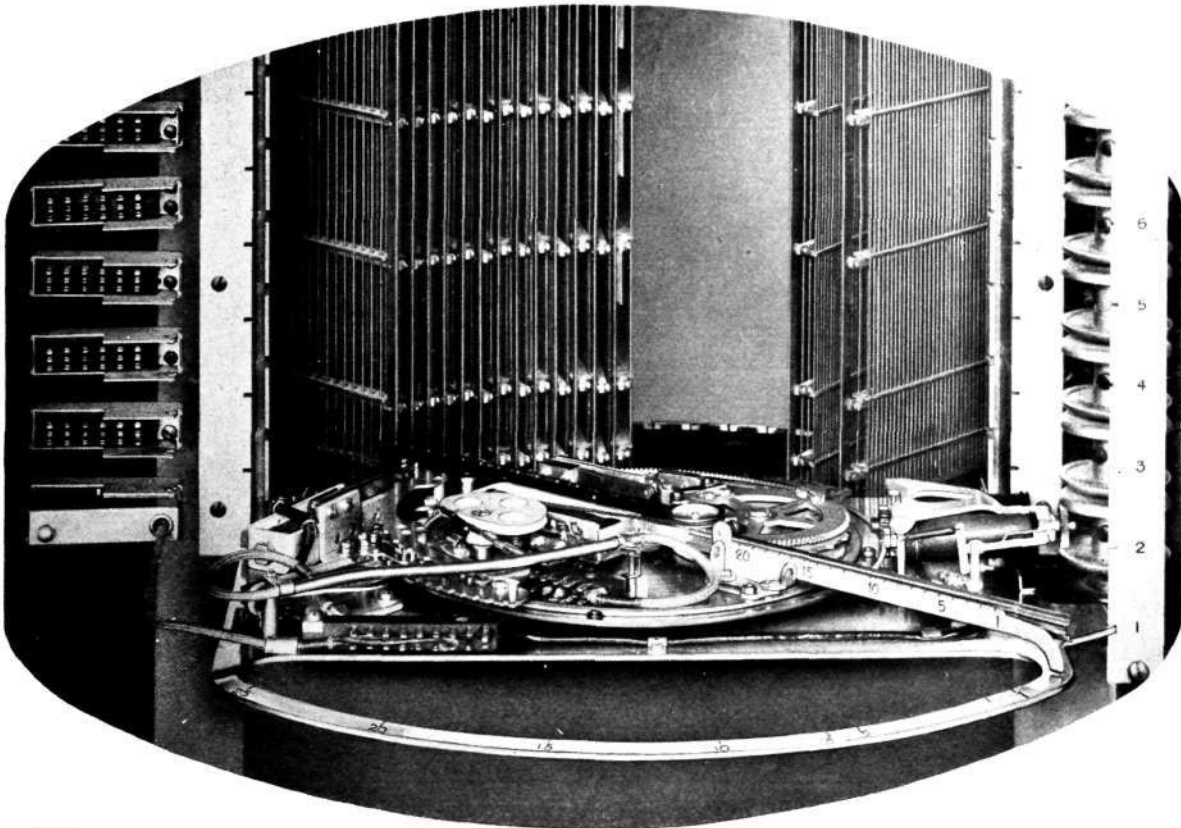
In the foregoing we have stated that it is the meter which is placed beside the telephone instrument which gives the subscriber the greatest amount of satisfaction, since it puts him in a position to see for himself how large a number of the calls to which he is entitled have been made or — if the conditions of the subscription are such — the number of calls for which he will be charged. A meter of this type does not serve the telephone company as well, however. In the first place, an employee must be sent out to read

L. M. Ericsson

the meter. He makes out a bill for the number of calls made, but it often happens that the subscriber is unable to pay his bill just then, necessitating a second visit on the part of the collector.

When all the meters are placed in the exchange, a great saving of time is obtained in the reading of the

same; also, the telephone bills can be made out in advance and sent to the subscribers with information as to the date on which the collector will call. This system is without doubt much more economical for the telephone company as well as for the subscribers.



R 572 a

Automatic Warning Signals at the Railway Crossing near the Henriksdal station on the Stockholm—Saltsjön Railway.

In an attempt to reduce operating expenses, the Stockholm—Saltsjön Railway has decided to replace the guards at the grade crossings with an automatic signalling system. The cost for protecting the crossings with guards — at least two men being re-

signals. Since this crossing is quite close to the tunnel entrance, thereby cutting off a clear view of the crossing from the road, it is especially dangerous for the heavy automobile traffic. On account of this the requirements to be filled by the signalling system were



R 906

Fig. 2.

quired per crossing and day — is relatively high on account of the heavy traffic, trains being run at close intervals during both day and night except during a very few hours. A comparison between the operating and amortization costs for an automatic signalling system on the one side, and the cost of maintaining crossing guards, on the other, proved the advantage of adopting automatic signal protection. A grade crossing just East of the tunnel near the Henriksdal station has now been provided with automatic warning

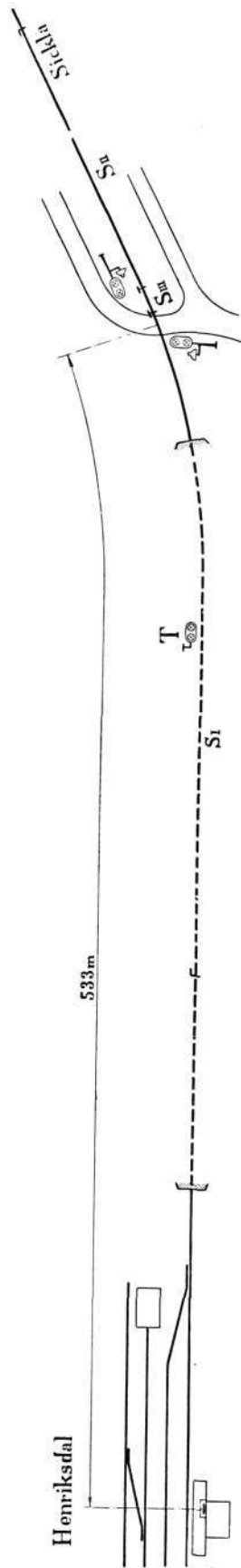


R 904

Fig. 3.

exceptionally strict and it was decided to use intermittent flashing signals combined with warning bells. The light signals — one on each side of the tracks — show a white flashing light which changes to red on the approach of a train, when vehicles and pedestrians are not permitted to cross the tracks. The warning bell is mounted on the same pole as the light signal. One of the signal poles, bearing the crossed sign required by law, is shown in fig. 2.

»Signalbolaget» was entrusted with the work of

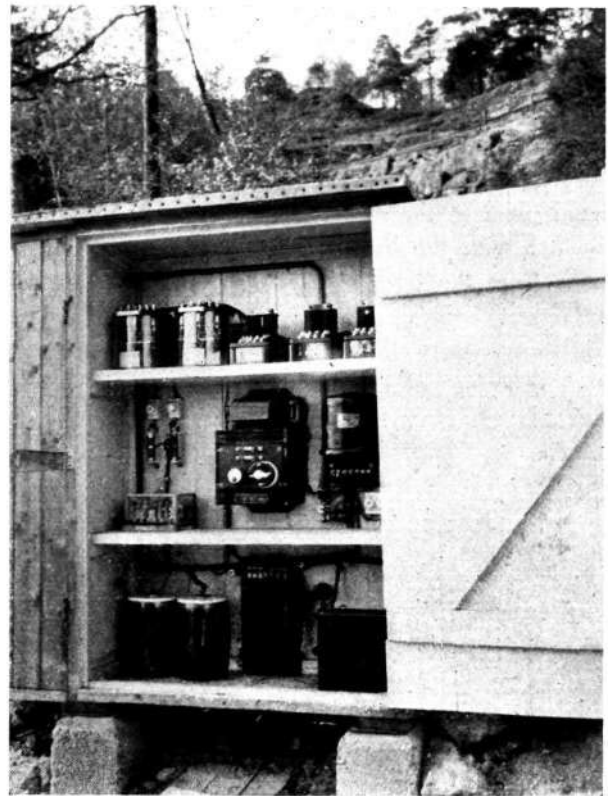


R 962 Fig. 1.

preparing estimates for the plant, the project being based on constant and uninterrupted track circuits (S_I and S_{II} in fig. 1). It was necessary, however, to take into consideration the fact that the railway was electrified, the traction current having a tension of 1300 volts D. C. and the rails serving as return conductors. For this reason single phase A. C. was adopted as feed current for the track circuits. Only one of the rails has been used for this purpose and been divided into insulated sections, one for each of the track circuits S_I , S_{II} and S_{III} , the other rail having been left unchanged to serve as return for both traction and signal current.

The crossing being situated so near to the station, and since it was found desirable that the warning signals should not be made to function during normal switching movements when the train does not go up to or pass over the crossing, it was found impossible to make track section S_I of sufficient length for the automatic switching on of the warning signals within the time prescribed by law (at least thirty seconds before the train reaches the crossing) to give warning of the approach with normal speed of a train just leaving the Henriksdal station. This problem has been solved by installing a plunger key in the signal cabin at Henriksdal, in which the interlocking ma-

chine is housed, by means of which — with the aid of a relay — the signal plant can be switched on for the giving of a warning signal within the prescribed time even though no train has entered on track section S_I . In order to make it possible for the locomotive engineer of such a train to verify that the warning signals have been switched on at Henriksdal, a light signal — T in fig. 1 — has been set up in the tunnel, the lamps of this signal being connected in series with the signal lamp at the crossing so as to show a white flashing light when the warning signals show red,



R 965

Fig. 4.

and an orange flashing light when the warning signals show white. As soon as the train reaches the track section S_I , the auxiliary relay co-operating with the plunger key in the signal cabin is disconnected and the system functions quite automatically. Thus, the signals again show a white flashing light and the warning bells cease to ring as soon as the train leaves track sections S_I and S_{III} . When the train has also left section S_{II} , the entire system is restored to normal. If the engineer of a train leaving Henriksdal should observe an orange coloured light signal at T , he must cut down the speed of the train to 25 km. per hour as soon as the train enters on track

section S_I and the warning signals are automatically switched on in order that the length of the time which elapses before the train reaches the crossing shall fill the requirements of the law. When a train approaches from the other direction the signal system functions quite automatically, the warning signals being switched on as soon as the train enters section S_{II} and switched off when the train has completely left sections S and S'_{II} .

In order to be able to verify at the Henriksdal station that the warning signals at the railway crossing are in good working order, the same board on which the above-mentioned plunger key is mounted (see fig. 3) has been provided with supervisory lamps in series with both the white and red crossing signal lamps, while in the office of the station master a lamp and a buzzer have been mounted in series with the red signal lamps. Besides supervising the condition of the signal plant at the crossing, the last mentioned lamp together with the buzzer announce the approach of trains from the East in a most satisfactory manner. All the supervisory lamps are provided with a shunt resistance, thereby eliminating any danger of the warning signals at the crossing being extinguished in case a supervisory lamp is removed or has become broken.

The relays for this plant are mounted in a cabinet (fig. 4) which has been placed close to the railway crossing. The track circuits S_I and S_{II} — as already mentioned — are fed by single phase alternating current, the relays which serve this purpose and which are mounted on top and to the left in the cabinet being specially adapted therefore. The remaining ones are all D. C. relays. The necessary A. C. is obtained from the existing service net and is transformed down to a suitable voltage for the track circuits and signal lamps. Direct current for the other relays and the warning bells is obtained from a storage battery which is under constant charging from the A. C. net by means of a rectifier mounted in the middle of the cabinet in fig. 4. This is a so called metallic rectifier, noted for its sturdy construction, absence of moving parts and lamps, and for the fact that it requires no attention whatever after once having been correctly adjusted; also, it functions with such precision that the well-known saying 'install and forget' may well be applied to the same.

This plant has been in service since the beginning of 1928 and has given entire satisfaction with respect to the manner in which it has functioned as well as from an economical point of view.



CONTENTS: Subtraction Meter with Load Balancing Switch. — On Junction Telephone Traffic Automatic to Automatic, or Manual to Automatic. — On Forest Fires and Forest Fire Protection. — On Subscribers' Meters. — Automatic Warning Signals at the Railway Crossing near the Henriksdal Station on the Stockholm—Saltsjön Railway.

The *L. M. Ericsson* *Review*



VOL. V

1928

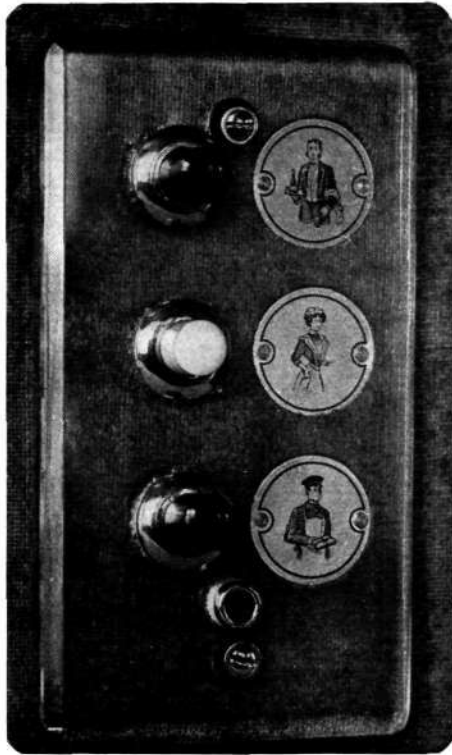
Nos. 10 to 12

The inauguration of the new telephone plant of Naples took place on October 28th, 1928.

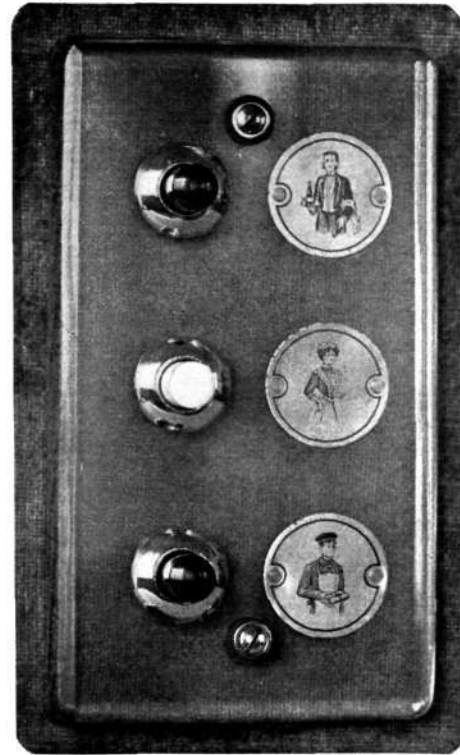


INTERIOR OF ADMINISTRATION BUILDING ON THE PIAZZA NOLANA.

ENGLISH EDITION



R 973 Fig. 1. Room Push Button Set.



R 972 Fig. 2. Cut-out Switch.

a figure representing the corresponding kind of service. The push button sets can be made either for table use or for mounting on the wall, in which latter case they may be placed directly against the wall or else made to fit into a recess and covered with a glass plate.

Cut-out switch.

The cut-out switch is mounted just outside of the room, on the wall of the ante-chamber or corridor. This switch is provided with one, two or three push buttons corresponding to those of the room set. Below this switch the switching relays are mounted in a box. When a push button in the room set is depressed, the corresponding relay is actuated and puts the corresponding room signal lamp in circuit. On the arrival of the called servant, he or she pushes the corresponding button of the cut-out switch, thereby extinguishing the glowing room signal lamp. If he so wishes, a hotel guest may push several buttons in order to call several servants, thereby also causing several room signal lamps to glow. In order to avoid all confusion when disconnecting the signals, the cut-out buttons are also made in red, white and green and provided with engraved designation plates. The

cut-out switch with relay box is furnished for mounting against the wall or, if preferred, for placing in a recess, flush with the wall and with a glass cover plate.

Room lamps.

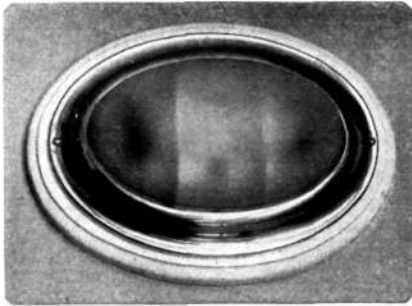
One, two or three signal lamps of different colours, corresponding to the one, two or three push button sets, are mounted in the hall or corridor, above the



R 969 Fig. 3. Room Lamp.

door of the room. These lamps are mounted on a common base board of wood behind an oval or round cover of cut or frosted glass, held in a frame of

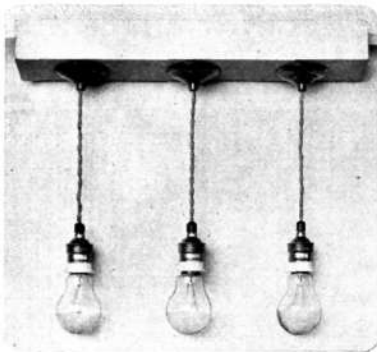
brass. These covers may be made in any desirable finish or design to suit the architecture or interior decorations.



R 988 Fig. 4. Room Lamp.

Pilot lamps.

In buildings with long corridors or where these form angles, it is not always possible to observe the lamp of a room from which a signal has been given, and in such a case it is most suitable to combine the room lamps into groups, each group being provided with pilot lamps placed so as to be discernible from as many directions as possible and repeated in as many places as the layout of the building may require. These pilot lamps also serve the purpose of notifying any of the servants who may be in the corridor that a service signal has been given. When so desired, they can be executed in any suitable finish



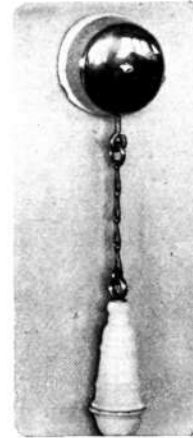
R 970 Fig. 5. Pilot Lamps.

or design, either as drop lights or for mounting on the wall.

Bath-room signal device.

A signal from a bath room can often mean an accident or a case of illness, and the servants are therefore required to answer such calls in preference to all others. For this purpose it is necessary that a bath-room signal be easily distinguished from the

others, this being accomplished by installing blue bath-room lamps and blue pilot lamps. The sig-



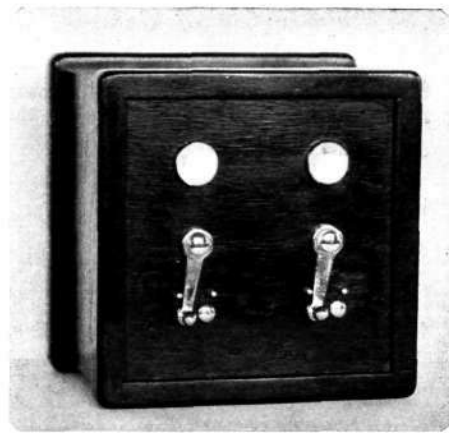
R 667

Fig. 6. Bath-room Signal Device.

nalling device consists of a pull contact mounted on a porcelain base and actuated by means of a chain with handle. This device is provided with a suitably placed cut-out switch.

»On duty» indicator lamp.

In order to provide a better supervision of the service, a special indicator lamp may be mounted in the



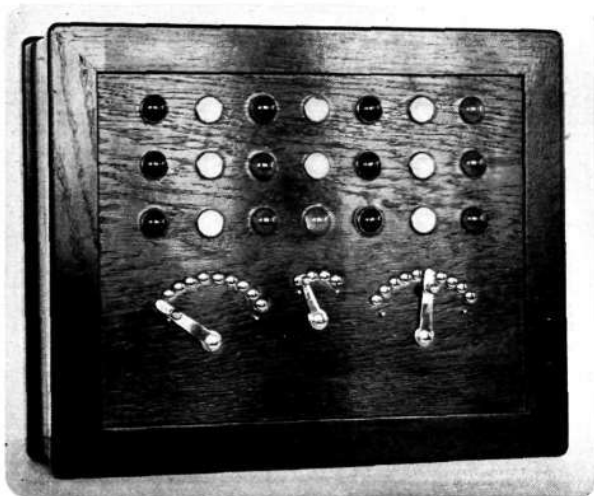
R 971 Fig. 7. Annunciator Board with Buzzer for the Servants' Room.

hall, beside the room door. If any of the servants are on duty in the room, this fact is made known by their introducing a plug in the jack of the room push button set, thereby lighting the afore-mentioned »on duty» lamp.

Annunciator board for servants room.

The servants are apprized of the given signals by means of an annunciator board mounted at some suit-

able place in the servants' room, this annunciator board being provided with signal lamps wired in parallel with the pilot lamps and equal in number to that of the room lamp groups. On the giving of a signal from a room, the corresponding signal lamp on the annunciator board will glow simultaneously with the room and pilot lamps. If there are separate rooms for chambermaids, waiters and porters, each category of servants must have its own annunciator board. Small single-stroke bells or buzzers, which give a continuous signal until the button of the cut-out switch outside of the room of the guest in question is pushed, are connected up in parallel with the lamps on the annunciator board. These acoustic signals are used only when really necessary — especially for night service — and are switched on by means of the lever



R 974 Fig. 8. Supervision Board.

switches shown in fig. 7. The signals are adjusted so as to make the sound clearly audible within the room without being heard outside of the same. If desired, annunciator boards can be provided without switches, the acoustic signals being permanently connected in parallel with the lamp signals.

Supervision board.

In order to provide efficient supervision of the service, the above annunciator boards are repeated at the hotel clerk's desk or other suitable place. By observing this board it is possible to check up on the time which expires between the lighting and the extinguishing of a signal lamp — i. e. between the giving of a signal and the moment when the called servant arrives at the room from which the signal has been given. If desired, this supervision may be combined

with a recording device by means of which the waiting times of the guests are registered on a paper band. If special supervision is desired, an acoustic signal may be switched on in parallel with a lamp signal by means of the switches shown in fig. 8.

Night signal board.

The above supervision boards can also be used as night annunciator boards for establishments with a very light night service which can easily be handled by one man, for instance the night clerk or other specially appointed person.

Current feed arrangements.

The necessary current for an installation of this kind may be obtained from the public service net. Since the system works with a tension of only twenty-four volts, however, suitable devices, such as transformers or pendulum or rotary rectifiers must be used. The most suitable arrangement, however, is a couple of storage batteries, one of which is held in reserve or is being charged while the other is in use, thereby eliminating all danger of depriving the signal plant of current should trouble arise in the public service net. The capacity of the storage batteries may be figured so as to be sufficient for providing necessary lighting current in case of emergency. Charging sets of some approved type are used for charging the storage batteries.

Storage batteries, charging sets, instrument and power distribution board etc. should be installed on the ground floor.

Standards for electric light wiring shall be followed when installing feed and distribution lines, due consideration being taken to the tension required for the relays.

Functioning of an optical annunciator system.

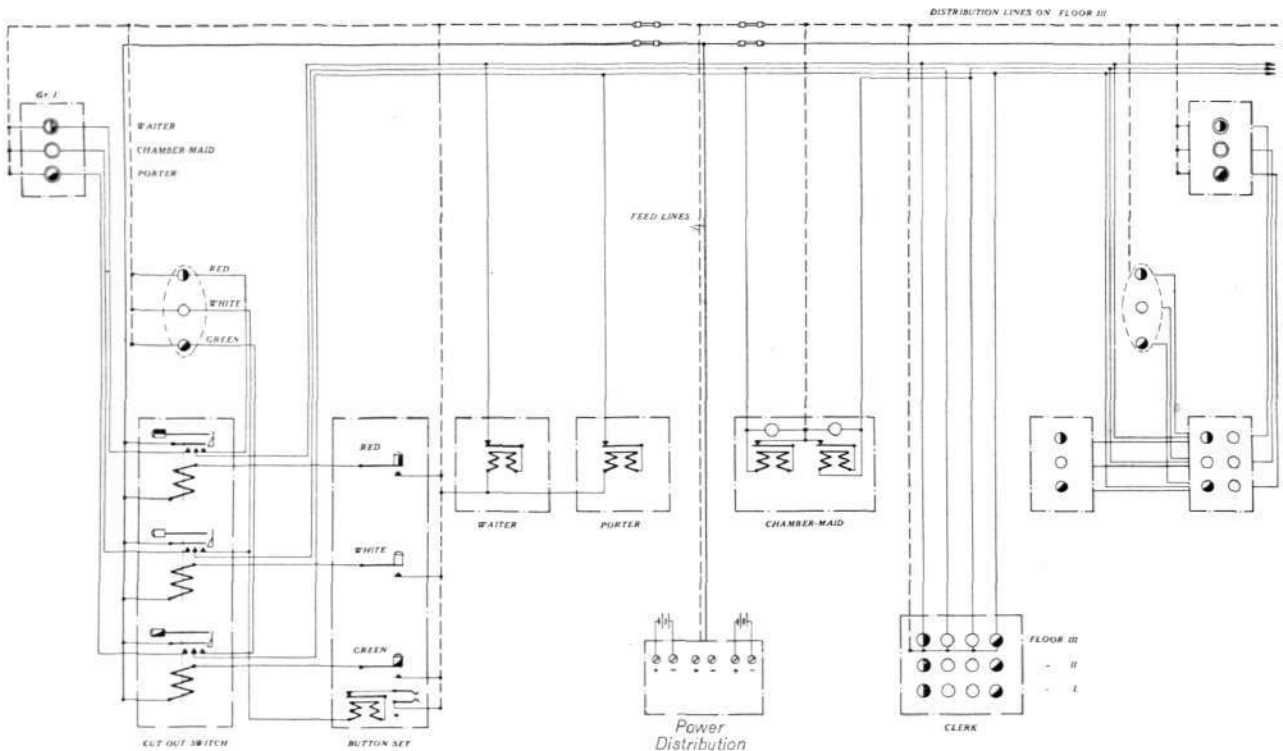
The accompanying diagram represents an optical annunciator system, the wiring for one floor only being shown and the room lamps being divided into two groups. Each room is provided with a room lamp in three colours, one push button set and a cut-out switch. Each group of room lamps has a three-coloured pilot lamp. The chamber-maids' room has an annunciator board with two lamps and two buzzers, while the waiter's and porter's rooms each have but one buzzer. The hotel clerk is provided with a lamp signal supervision board.

This installation functions in the following manner.

A guest in one of the rooms of the left group desires the services of a chambermaid and therefore pushes the white button of the set *RT1*, thereby energizing the middle relay of the cut-out switch *AT1*. This relay is actuated and closes its contacts, the relay being provided with mechanical holding. The right hand contact closes the circuit for the white room lamp, the one to the left closes the circuit for the white lamp in the pilot lamp *Gr1*, while the middle contact puts the left lamp and left buzzer on the chambermaid's annunciator *TM*, as well as the corres-

When requesting estimates the following information must be submitted.

1. Complete plans.
2. How many and which rooms on each floor are to be provided with chambermaid, waiter or porter service?
3. The room groups shall be denoted on the plans.
4. Information as to the servants' rooms and sleeping quarters.
5. Information as to whether or not the night clerk is stationed at the clerk's desk.



R 975

Fig. 9.

ponding lamp on the clerk's supervision board, in circuit. If the chambermaid is in her room, she both sees and hears that her services are wanted; if she happens to be in the corridor, she is made aware of the signal by means of the pilot and room lamps; if she is occupied in one of the guest rooms, she plugs in her buzzer in the jack on the push button set, after which this buzzer notifies her if any signal is given from another room. When the chambermaid has received her orders from the guest, she pushes the button of the cut-out switch for this room, thus causing the contact springs of the relay to be mechanically released and all of the lamps in circuit cease to glow. The switching operations take place when a service signal is given for a waiter or porter.

6. Is the night clerk required to provide the guests with night service or are other persons detailed for this purpose and if so which rooms do these latter occupy?
7. Are the push button sets to be for wall or table use, or both, and in which rooms? This should be indicated on the plan.
8. Type of available current as well as tension of same must be given. Room or location where storage batteries, machines, power board etc. — in other words, the power plant — may be placed should be denoted on plan.
9. All the above information should be noted on floor plans.

Ericsson



HOTEL ANNUNCIATORS

L. M. Ericsson

Plan of the new General Motors Plant
at Hammarbyleden in Stockholm.

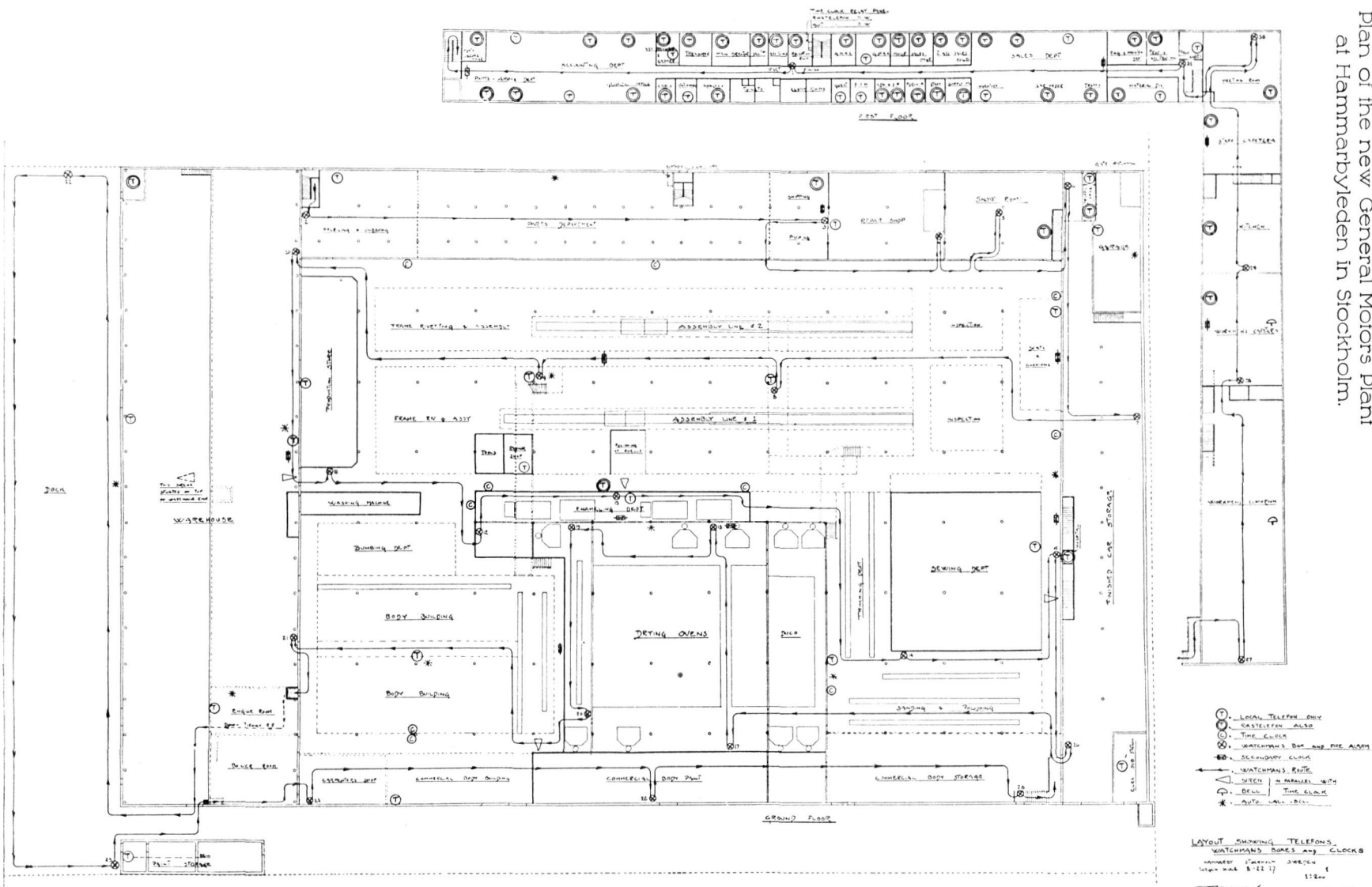


Fig. 1.

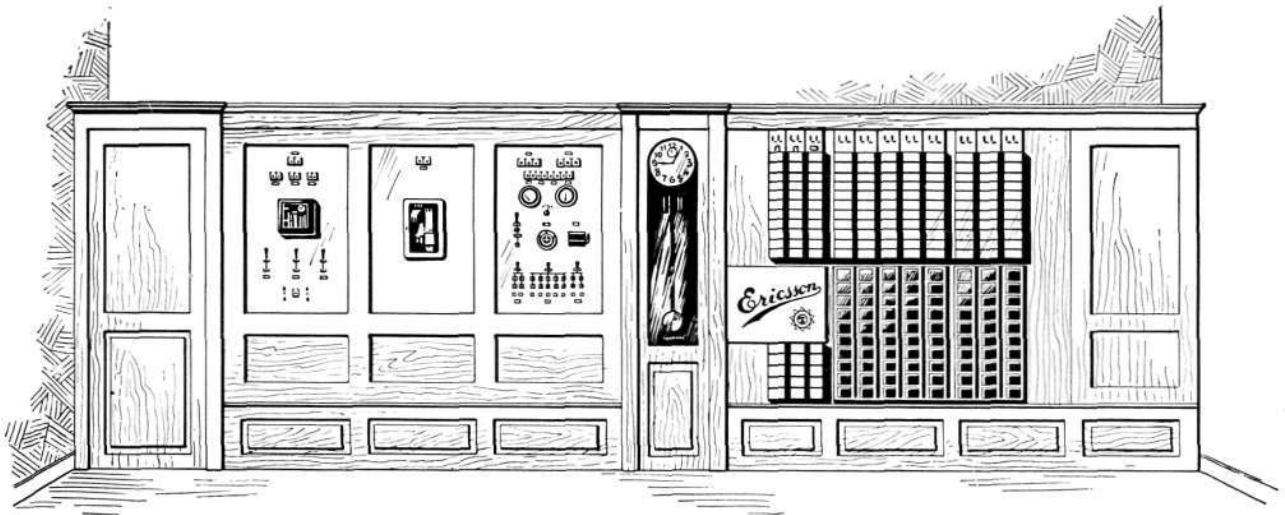
Low Tension Installations in a Modern Industrial Plant.

By H. Josephsson.

General Motors may well be classified among the most successful industrial enterprises in the world. In addition to its extensive plants in the United States and Canada, this corporation has a number of factories in Europe — in England, Belgium, Germany and Denmark. To this chain has now been added still another link — General Motors

Personal locating system;
Automatic fire alarm combined with sprinkler system.

A plan of the factory is shown in fig. 1. This is a one-story building except for those portions in which the various offices are located, the building here being two stories high. The offices, cloak rooms and lunch room are on the second floor along the East and



R 832 B

Fig. 2.

new factory buildings on the Hammarby channel in Stockholm.

One reason for the phenomenal success of the General Motors Corporation is without doubt its excellent organization. We are convinced that it will interest our readers to get a little look »behind the scenes» of the newest General Motors plant and see how various commodities in our own special branch have been made use of in the organizing of the same.

At the time of the opening of the new factory in Stockholm during February last, the following installations by the Ericsson company were put in service: Private Automatic Telephone Exchange.

Electric clock system with which are combined the following installations:

- Automatic time signals;
- Employees time recording system.

South sides of the building. The placing of the apparatus for the above-mentioned installations is indicated on the plan. With the exception of the fire alarm board — which is located in the janitor's room at the southeast corner of the lower floor — the switch-boards and control apparatus for all of these systems have been placed in a room adjoining the session room for the board of directors on the second floor.

Fig. 2 shows how the various units have been erected. To the right is the OL 500 P. A. X. Switchboard with two registers and a capacity of 80 local lines. Seventy-six of these were installed already on the opening of the plant.

Next to the telephone switchboard is the Master Clock which directs the movement of a number of



Fig. 3.

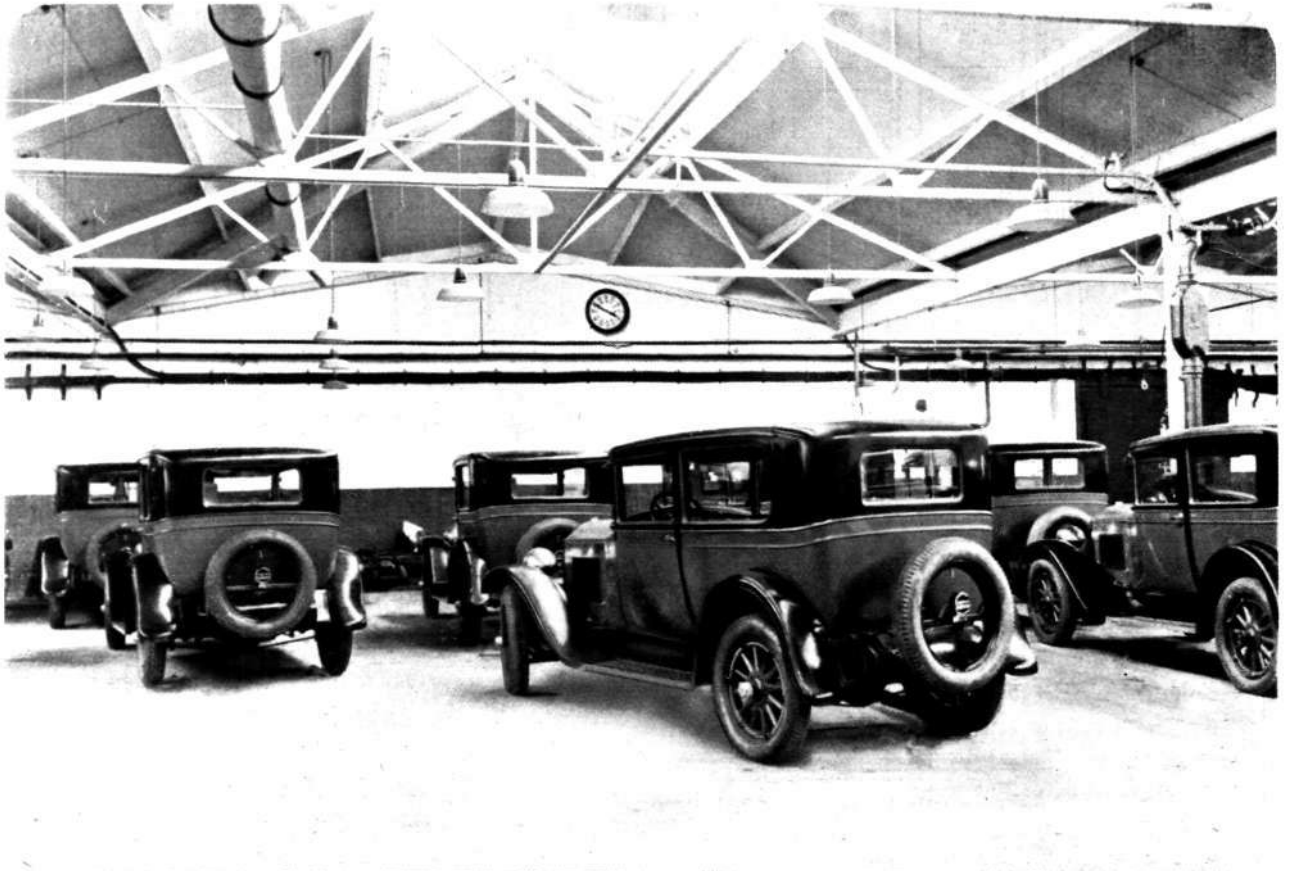


Fig. 4.

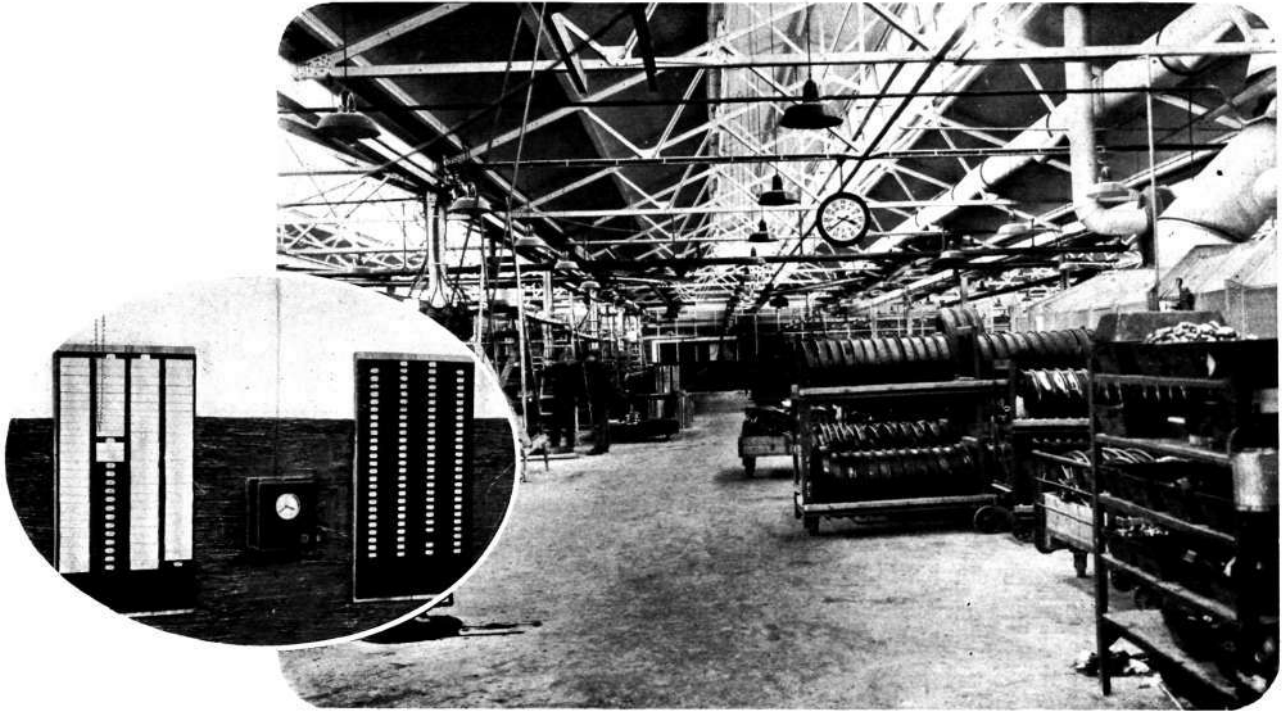


Fig. 5.

secondary clocks placed so that one of them is visible from almost any spot in the shops or offices.

Fig. 3 is a partial view of one of the office rooms, showing a clock finished so as to harmonize with the interior finish of the room.

Figs. 4 and 5 are views from different parts of the shop, showing a one and two faced clock respectively. A program clock has also been provided to work in conjunction with the master clock. This is shown at the extreme left and is arranged so as to give automatic signals at the opening and close of working hours, before and after lunch etc., by means of powerful gongs and signal horns.

Further, this program clock controls the movements of some ten time recorder clocks for registering the times of arrival and departure of the employees. The time recorders are of the full automatic type.

Just to the right of the program clock may be seen the night watchman's time recorder, which is connected to the master clock. The stamping is directed from thirty-five different contact boxes distributed over the entire building. When the night watchman inserts a master key in a contact box, a circuit is closed through the time recorder so that this latter stamps the time as well as the number of the contact box on a band of paper with automatic feed. This band can be torn off each day for inspection.

To the left of the master clock is an instrument board for the charging of the storage batteries which provide current for all of these systems. On this board are also mounted voltmeters and ammeters as well as the necessary protectors and fuses.

The battery room is shown in fig. 6.

The alarm board for the automatic fire alarm system (fig. 7) is connected to four sprinkler valves, one for each of four sections. As soon as a sprinkler begins to function a relay in one of the above-mentioned sprinkler valves is energized, thereby lighting an indicator lamp on the alarm board and closing an alarm bell circuit. The alarm board is connected up with a city fire alarm box from which an alarm is simultaneously sent in to the fire department. The entire wiring system of the automatic fire alarm is under constant supervision provided by a special supervisory control current, all faults in the system being immediately and automatically signalled on the alarm board. The locating system comprises a little switchboard placed beside the manual P. B. X. telephone switchboard for city service, and a number of signal bells mounted throughout the building. (This system uses the same wiring system as the night watchman's time recording system.)

When the telephone operator wishes to locate some department head who does not happen to be in his

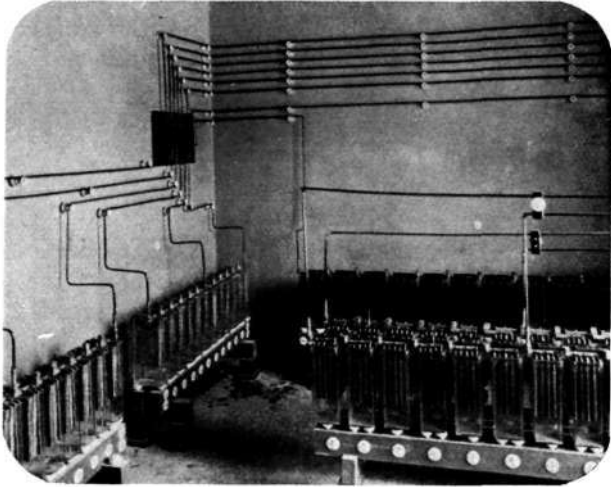


Fig. 6.

private office, she sends out his individual signal by closing the corresponding switch in the switchboard and starting a clockwork which repeats the signal eight times on all the signal bells.

In connection with the time recording system it may be of interest to note how the employee's dressing rooms — grouped on the second floor, as shown in fig. 1 — are arranged and from which the employees make their way to the different departments where the time recorders are punched. The result of this arrangement is that the registered time corresponds almost exactly with the net working time, no time being included for the changing of clothing or for walking from the dressing rooms to the place of work.

The above-described installations as well as the entire plant may be regarded as exemplary in more ways than one. Also, it has been planned and organized by General Motors' own American experts,



R 993

Fig. 7.

who naturally possess a very wide experience on this subject. So much the more gratifying is it to ascertain that, in the planning of the various installations here described the choice has fallen on Swedish systems and material of Swedish manufacture, their superiority over similar systems of other makes having previously been established by thorough and impartial investigations.

An efficient organization

of public or private commercial and manufacturing institutions *of all kinds requires*

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TELEFONAKTIEBOLAGET L. M. ERICSSON
STOCKHOLM, SWEDEN

or any of their representations over the whol world.

On Cross-Talk and other Problems of a Kindred Nature.

By *Torben Laurent.*

I. Introduction.

The difficulty of finding an absolutely satisfactory definition for cross-talk is due to the necessity of compromising between the two following points of view.

On the one hand, there is a desire to obtain as correct a conception as possible of the magnitude of the disturbances caused by cross-talk, for which purpose all the secondary factors, such as transmission levels, the characteristic line impedances, the sensitiveness of the ear for disturbances caused by cross-talk etc., must be taken into consideration. On the other hand, it is of interest to judge the quality of the lines with reference to cross-talk, and for this purpose it is necessary to have a definition for cross-talk based as much as possible on those primary factors, such as unbalance and the like, which one endeavours to reduce as much as possible.

Other desirable features are that it shall be possible to easily measure the cross-talk and to treat it mathematically in a clear and simple manner and on as general a theory as possible.

The simplest solution to this problem is, in all probability, to use two different definitions for cross-talk, the one for judging the character of the disturbances and the other for judging the quality of the lines, thus making it possible to satisfy each condition separately.

The paper here presented constitutes an attempt to give a mathematical treatise on cross-talk — considered as a form of impedance termed “mutual impedance” — chiefly for the purpose of judging the quality of the lines, and is part of a treatise written by the author and published in “Elektrischen Nachrichten Technik” for 1928. The theories of the homogeneity of lines has also been published in “Tekniska Meddelanden från Kungl. Telegrafstyrelsen” (Technical Information from the Royal Telegraph Administration) for 1924. Compare “Allmänna egenskaper hos ett system parallella ledningar med variabla konstanter” (General properties of a system of parallel lines with

variable constants) by H. Pleijel (1917) and “Über das Nebensprechen in mehrfachen Fernsprechkabeln und seine Verminderungen” (1923) and “Über neue Fehlermessverfahren an pupinisierten Leitungen” (1922) by K. Küpfmüller.

The mathematical operations which occur in the above-mentioned treaties are made according to the symbolical method.

II. Definition for currents and tensions in the three telephone circuits of a twisted four-wire line.

The tensions and currents occurring in side circuits I and II and the phantom circuit are designated with V_I, V_{II}, V_d and J_I, J_{II} and J_d respectively. If $V_{12}, V_{13}, V_{14}, V_{23}, V_{24}, V_{34}$ and J_1, J_2, J_3 and J_4

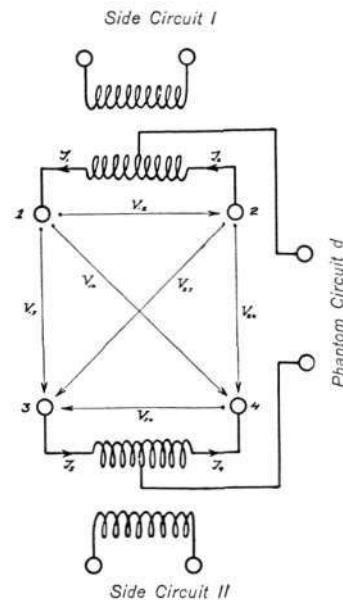


Fig. 1.

represent the tensions and currents in a cross-section of the twisted four-wire line taken at the line terminals of one set of phantom transformers, as shown in fig. 1, we clearly obtain the following relations for a line free from cross-talk,

$$\left. \begin{aligned}
 V_I &= V_{12} = V_{14} - V_{24} = V_{13} - V_{23} \\
 V_{II} &= V_{34} = V_{13} - V_{14} = V_{23} - V_{24} \\
 V_d &= \frac{1}{2}(V_{13} + V_{24}) = \frac{1}{2}(V_{14} + V_{23}) \\
 J_I + \frac{1}{2} J_d &= J_1 \\
 J_I - \frac{1}{2} J_d &= J_2 \\
 J_{II} + \frac{1}{2} J_d &= J_3 \\
 J_{II} - \frac{1}{2} J_d &= J_4
 \end{aligned} \right\} (1)$$

We will take equations (1) as definition for tensions and currents in the three telephone circuits in an arbitrary cross-section of the twisted line. It is true that equations (1) do not apply to lines with cross-talk, but the deviation in current may be considered as cross-talk current from another line.

III. *The law of reciprocity.*

In an arbitrary line system *A* (see fig. 2), for which linear relations between currents and tensions

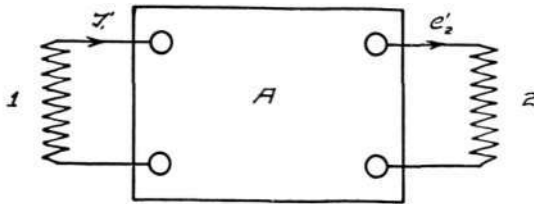
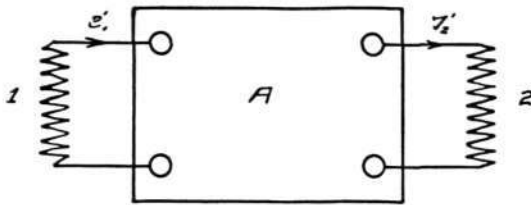


Fig. 2.

can be assumed, we have lines 1 and 2. If an electromotive force e_1 is admitted to line 1, we obtain in line 2 a current J_2 according to the relation

$$J_2' = \frac{e_1'}{k_{12}}$$

On the other hand, if we admit an electromotive force e_2 to line 2, we obtain in line 1 a current J_1' according to the relation

$$J_1' = \frac{e_2'}{k_{21}}$$

k_{12} and k_{21} are constants, and according to the law of reciprocity

$$k_{12} = k_{21}.$$

We will now consider a line system to which three electromotive forces have been admitted (see fig. 3).

In lines 1, 2 and 3 we have the electromotive forces

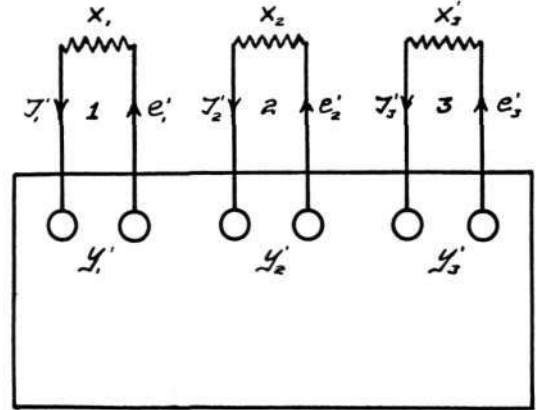


Fig. 3.

e_1' , e_2' and e_3' , currents J_1' , J_2' and J_3' external impedances x_1' , x_2' and x_3' , and, finally the internal impedances y_1' , y_2' and y_3' respectively.

According to the law of reciprocity and the principle of superposition we obtain

$$\left. \begin{aligned}
 J_1' &= \frac{e_1'}{x_1' + y_1'} + \frac{e_2'}{k_{12}} + \frac{e_3'}{k_{13}} \\
 J_2' &= \frac{e_2'}{x_2' + y_2'} + \frac{e_1'}{k_{12}} + \frac{e_3'}{k_{23}} \\
 J_3' &= \frac{e_3'}{x_3' + y_3'} + \frac{e_1'}{k_{13}} + \frac{e_2'}{k_{23}}
 \end{aligned} \right\} (a)$$

The mutual influence between the lines can also be represented by the E. M. F:s E_1' , E_2' and E_3' , so that

$$\left. \begin{aligned}
 J_1' &= \frac{e_1' + E_1'}{x_1' + y_1'} \\
 J_2' &= \frac{e_2' + E_2'}{x_2' + y_2'} \\
 J_3' &= \frac{e_3' + E_3'}{x_3' + y_3'}
 \end{aligned} \right\} (b)$$

giving

$$\left. \begin{aligned}
 \frac{e_2'}{k_{12}} + \frac{e_3'}{k_{13}} &= \frac{E_1'}{x_1' + y_1'} \\
 \frac{e_1'}{k_{12}} + \frac{e_3'}{k_{23}} &= \frac{E_2'}{x_2' + y_2'} \\
 \frac{e_1'}{k_{13}} + \frac{e_2'}{k_{23}} + \frac{E_3'}{x_3' + y_3'} &= \dots
 \end{aligned} \right\} (c)$$

If we solve equations (c) with respect to e_1' , e_2' and e_3' we obtain

$$\left. \begin{aligned} 2e_1' &= -E_1' \frac{k_{12}k_{13}}{(x_1' + y_1')k_{23}} + E_2' \frac{k_{12}}{x_2' + y_2'} \\ &\quad + E_3' \frac{k_{13}}{x_3' + y_3'} \\ 2e_2' &= -E_2' \frac{k_{13}k_{23}}{(x_2' + y_2')k_{13}} + E_1' \frac{k_{12}}{x_1' + y_1'} \\ &\quad + E_3' \frac{k_{23}}{x_3' + y_3'} \\ 2e_3' &= -E_3' \frac{k_{13}k_{23}}{(x_3' + y_3')k_{12}} + E_1' \frac{k_{13}}{x_1' + y_1'} \\ &\quad + E_2' \frac{k_{23}}{x_2' + y_2'} \end{aligned} \right\} (d)$$

Inserting these values for e_1' , e_2' and e_3' in equations (a) we obtain the following expressions

$$\left. \begin{aligned} J_1' &= \gamma_1 E_1' + \eta_{12} E_2' + \eta_{13} E_3' \\ J_2' &= \gamma_2 E_2' + \eta_{12} E_1' + \eta_{23} E_3' \\ J_3' &= \gamma_3 E_3' + \eta_{13} E_1' + \eta_{23} E_2' \end{aligned} \right\} (e)$$

If we use equations (e) to compute E_1' , E_2' and E_3' expressed in terms of J_1' , J_2' and J_3' we obtain expressions of the following form

$$\left. \begin{aligned} -E_1' &= z_1' J_1' + M_{12} J_2' + M_{13} J_3' \\ -E_2' &= z_2' J_2' + M_{12} J_1' + M_{23} J_3' \\ -E_3' &= z_3' J_3' + M_{13} J_1' + M_{23} J_2' \end{aligned} \right\} (f)$$

By inserting the tensions at the net terminals

$$\left. \begin{aligned} V_1' &= e_1' - J_1' x_1' \\ V_2' &= e_2' - J_2' x_2' \\ V_3' &= e_3' - J_3' x_3' \end{aligned} \right\} (g)$$

we finally obtain from equations (b), (f) and (g) the following equations

$$\left. \begin{aligned} V_1' &= (y_1' + z_1') J_1' + M_{12} J_2' + M_{13} J_3' \\ V_2' &= (y_2' + z_2') J_2' + M_{12} J_1' + M_{23} J_3' \\ V_3' &= (y_3' + z_3') J_3' + M_{13} J_1' + M_{23} J_2' \end{aligned} \right\} (2)$$

which are of fundamental importance for the following mathematical deductions.

The intimated derivation of equations (2) which has here been given should be sufficient, as the following will provide us with ample proof of their accuracy.

IV. Line impedance and mutual impedance.

We will assume that no E. M. F:s are inserted in the conductors on one side of an arbitrary cross-section through a twisted line. We will call this side the "impedance side". According to equations (2) we then obtain

$$\left. \begin{aligned} V_I &= y_I J_I + M_{II} J_{II} + M_{I_d} J_d \\ V_{II} &= y_{II} J_{II} + M_{II} J_I + M_{II_d} J_d \\ V_d &= y_d J_d + M_{I_d} J_I + M_{II_d} J_{II} \end{aligned} \right\} (3)$$

where the coefficients for the currents have reference to the impedance side, y_I , y_{II} and y_d representing the impedances of the three circuits measured from the cross-section towards the impedance side in such manner that while one circuit is being measured the two others are open at the cross-section. The impedances are termed "line impedances". M_{II} , M_{I_d} and M_{II_d} also have the dimensions of impedances and represent the relation between the apparent electromotive force in one circuit and the current in another, the third circuit being open at the cross-section. Apparently, this same relation exists between the apparent electromotive force in the second circuit and the current in the first one. M_{II} , M_{I_d} and M_{II_d} are values of the cross-talk between the side circuit *I* and the phantom circuit and side circuit *II* and the phantom circuit respectively. These coefficients will be termed "mutual impedance".

V. Unbalance of lines.

The impedance side of a cross-section can be replaced by an impedance cross with mutual impedances between the arms as shown in the first section in fig. 4. The voltage between the conductors will then be

$$\left. \begin{aligned} V_{12} &= J_1 y_1 + J_2 M_{12} + J_3 M_{13} - J_4 M_{14} \\ &\quad + J_2 y_2 + J_1 M_{12} + J_4 M_{24} - J_3 M_{23} \\ V_{34} &= J_4 y_4 + J_3 M_{34} + J_2 M_{24} - J_1 M_{14} \\ &\quad + J_3 y_3 + J_4 M_{34} + J_1 M_{13} - J_2 M_{23} \\ V_{13} &= J_1 y_1 + J_2 M_{12} + J_3 M_{13} - J_4 M_{14} \\ &\quad + J_3 y_3 + J_4 M_{34} + J_1 M_{13} - J_2 M_{23} \\ -V_{21} &= J_2 y_2 + J_1 M_{12} + J_4 M_{24} - J_3 M_{23} \\ &\quad + J_4 y_4 + J_3 M_{34} + J_2 M_{24} - J_1 M_{14} \end{aligned} \right\} (a)$$

According to equations (1)

$$\left. \begin{aligned} V_{12} &= V_I \\ V_{34} &= V_{II} \\ \frac{1}{2}(V_{13} + V_{24}) &= V_d \\ J_1 &= J_I + \frac{1}{2} J_d \\ J_2 &= J_I - \frac{1}{2} J_d \\ J_3 &= J_{II} + \frac{1}{2} J_d \\ J_4 &= J_{II} - \frac{1}{2} J_d \end{aligned} \right\} (b)$$

and if we insert these expressions in the equations (a) we obtain the expressions

$$\left. \begin{aligned}
 V_I &= J_I (y_1 + y_2 + 2 M_{12}) \\
 &\quad + J_{II} (M_{13} + M_{24} - M_{14} - M_{23}) \\
 + J_d \cdot \frac{1}{2} (y_1 - y_2 + M_{13} + M_{14} - M_{23} - M_{24}) \\
 V_{II} &= J_{II} (y_3 + y_4 + 2 M_{34}) \\
 &\quad + J_I (M_{13} + M_{24} - M_{14} - M_{23}) \\
 + J_d \cdot \frac{1}{2} (y_3 - y_4 + M_{13} + M_{23} - M_{14} - M_{24}) \\
 V_d &= J_d \frac{1}{4} [y_1 + y_2 + y_3 + y_4 \\
 &\quad + 2 (M_{13} + M_{14} + M_{23} + M_{24} - M_{12} - M_{34})] \\
 &\quad + \frac{1}{2} J_I (y_1 - y_2 + M_{13} + M_{14} - M_{23} - M_{24}) \\
 &\quad + \frac{1}{2} J_{II} (y_3 - y_4 + M_{13} + M_{23} - M_{14} - M_{24})
 \end{aligned} \right\} (c)$$

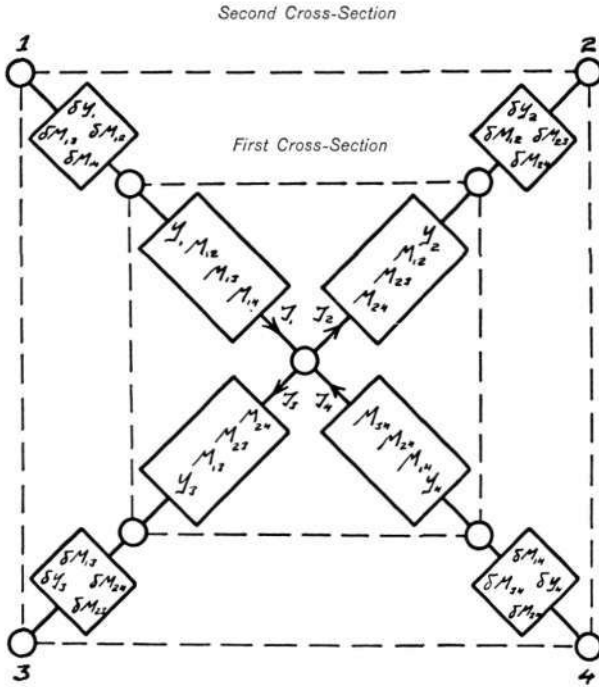


Fig. 4.

After inserting the values

$$\left. \begin{aligned}
 x_I &= y_1 + y_2 + 2 M_{12} \\
 x_{II} &= y_3 + y_4 + 2 M_{34} \\
 x_d &= \frac{1}{2} (y_1 + y_2 + y_3 + y_4) \\
 &\quad + \frac{1}{2} (M_{13} + M_{14} + M_{23} + M_{24} - M_{12} - M_{34}) \\
 m_{II} &= M_{13} + M_{24} - M_{14} - M_{23} \\
 m_{Id} &= \frac{1}{2} (y_1 - y_2 + M_{13} + M_{14} - M_{23} - M_{24}) \\
 m_{II d} &= \frac{1}{2} (y_3 - y_4 + M_{13} + M_{23} - M_{14} - M_{24})
 \end{aligned} \right\} (d)$$

the equations (c) become as follows

$$\left. \begin{aligned}
 V_I &= x_I J_I + m_{II} J_{II} + m_{Id} J_d \\
 V_{II} &= x_{II} J_{II} + m_{II} J_I + m_{II d} J_d \\
 V_d &= x_d J_d + m_{Id} J_I + m_{II d} J_{II}
 \end{aligned} \right\} (e)$$

which conform with equations (3).

Considering a new cross-section of the twisted four-wire line, located at a short distance from the former cross-section, and assuming that portion of the twisted line between the cross-sections to be free from leak impedances, increases in the arms of the impedance cross are clearly obtained, as shown in fig. 4. These increases consist of line resistance and self inductance in the single conductors.

If the increases in impedance are designated as in fig. 4, we then obtain for the latter cross-section

$$\left. \begin{aligned}
 y_I &= x_I + (\delta y_1 + \delta y_2 + 2 \delta M_{12}) \\
 y_{II} &= x_{II} + (\delta y_3 + \delta y_4 + 2 \delta M_{34}) \\
 y_d &= x_d + \frac{1}{4} (\delta y_1 + \delta y_2 + \delta y_3 + \delta y_4) \\
 &\quad + \frac{1}{2} (\delta M_{13} + \delta M_{14} + \delta M_{23} + \delta M_{24} \\
 &\quad \quad - \delta M_{12} - \delta M_{34}) \\
 M_{II} &= m_{II} + (\delta M_{13} + \delta M_{24} - \delta M_{14} - \delta M_{23}) \\
 M_{Id} &= m_{Id} + \frac{1}{2} (\delta y_1 + \delta y_2 + \delta M_{13} + \delta M_{24} \\
 &\quad \quad - \delta M_{23} - \delta M_{24}) \\
 M_{II d} &= m_{II d} + \frac{1}{2} (\delta y_3 - \delta y_4 + \delta M_{13} \\
 &\quad \quad + \delta M_{23} - \delta M_{14} - \delta M_{24})
 \end{aligned} \right\} (f)$$

We will adopt the following terms and expressions for the increases:

$$\left. \begin{aligned}
 \text{Increase in "line impedance",} \\
 S_I &= \delta y_1 + \delta y_2 + 2 \delta M_{12} \\
 S_{II} &= \delta y_3 + \delta y_4 + 2 \delta M_{34} \\
 S_d &= \frac{1}{4} (\delta y_1 + \delta y_2 + \delta y_3 + \delta y_4) \\
 &\quad + \frac{1}{2} (\delta M_{13} + \delta M_{14} + \delta M_{23} + \delta M_{24} \\
 &\quad \quad - \delta M_{12} - \delta M_{34})
 \end{aligned} \right\} (4)$$

$$\left. \begin{aligned}
 \text{Increase in the "unbalance of the line",} \\
 T_{II} &= \delta M_{13} + \delta M_{24} - \delta M_{14} - \delta M_{23} \\
 T_{Id} &= \frac{1}{2} (\delta y_1 - \delta y_2 + \delta M_{13} + \delta M_{14} \\
 &\quad \quad - \delta M_{23} - \delta M_{24}) \\
 T_{II d} &= \frac{1}{2} (\delta y_3 - \delta y_4 + \delta M_{13} + \delta M_{23} \\
 &\quad \quad - \delta M_{14} - \delta M_{24})
 \end{aligned} \right\} (5)$$

This makes equations (f) as follows

$$\left. \begin{aligned} y_I &= x_I + S_I \\ y_{II} &= x_{II} + S_{II} \\ y_d &= x_d + S_d \\ M_{II} &= m_{II} + T_{II} \\ M_{Id} &= m_{Id} + T_{Id} \\ M_{II d} &= m_{II d} + T_{II d} \end{aligned} \right\} \quad (6)$$

which show how the impedances x change into y and the mutual impedances m change into M on account of the increases S and T in line impedance and line unbalance respectively.

From equations (5) we obtain the familiar condition that cross-talk between the side and phantom circuits is due to the difference between the resistance and self inductance in the line branches, which is not the case with cross-talk between the two side circuits.

VI. Unbalance of leakage.

Each conductor in a twisted four-wire line has a certain capacity as well as leakage to the other conductors and to earth. The capacities and leakances to earth, which are represented by an impedance cross as in

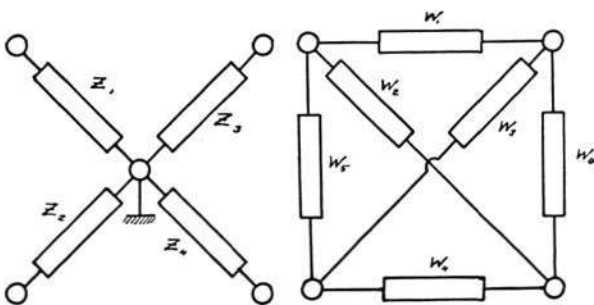


Fig. 5.

fig. 5 with the impedances Z_1, Z_2, Z_3 and Z_4 , are equivalent to an impedance diagram with the impedances W_1, W_2, W_3, W_4, W_5 and W_6 as shown in fig. 5.

K. K upfm uller has derived the relations

$$\left. \begin{aligned} W_1 &= Z_1 Z_3 g \\ W_2 &= Z_1 Z_4 g \\ W_3 &= Z_2 Z_3 g \\ W_4 &= Z_2 Z_4 g \\ W_5 &= Z_1 Z_2 g \\ W_6 &= Z_3 Z_4 g \\ g &= \frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3} + \frac{1}{Z_4} \end{aligned} \right\} \quad (a)$$

Consequently, we may always consider capacities and leakances as being merely capacities and leakances between the conductors. For the rest we will ignore earth as well as other neighbouring conductors.

The following relations apply in the cross-section of a twisted line

$$\left. \begin{aligned} V_I &= i_I x_I + i_{II} m_{II} + i_d m_{Id} \\ V_{II} &= i_{II} x_{II} + i_I m_{II} + i_d m_{II d} \\ V_d &= i_d x_d + i_I m_{Id} + i_{II} m_{II d} \end{aligned} \right\} \quad (b)$$

In this section we will introduce leakances between the conductors as shown in fig. 6 with the complex

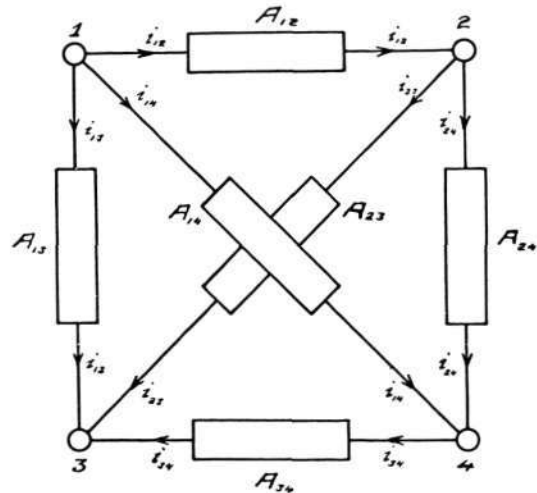


Fig. 6.

values $A_{12}, A_{13}, A_{14}, A_{23}, A_{24}$ and A_{34} for the conductance. According to equations (1) the voltages between the conductors are

$$\left. \begin{aligned} V_{12} &= V_I \\ V_{34} &= V_{II} \\ V_{13} &= V_d + \frac{1}{2} (V_I + V_{II}) \\ V_{24} &= V_d - \frac{1}{2} (V_I + V_{II}) \\ V_{14} &= V_d + \frac{1}{2} (V_I - V_{II}) \\ V_{23} &= V_d - \frac{1}{2} (V_I - V_{II}) \end{aligned} \right\} \quad (c)$$

from which follows that the leakage currents are

$$\left. \begin{aligned} i_{12} &= A_{12} V_{12} & i_{34} &= A_{34} V_{34} \\ i_{13} &= A_{13} V_{13} & i_{14} &= A_{14} V_{14} \\ i_{23} &= A_{23} V_{23} & i_{24} &= A_{24} V_{24} \end{aligned} \right\} \quad (d)$$

If we designate the portions of these currents belonging to the side circuits I and II and the phantom circuit with J'_I, J'_{II} and J'_d respectively, we then obtain from equations (1)

$$\left. \begin{aligned} J_I' + \frac{1}{2} J_d' &= i_{12} + i_{13} + i_{14} \\ J_I' - \frac{1}{2} J_d' &= i_{12} - i_{23} - i_{24} \\ J_{II}' + \frac{1}{2} J_d' &= i_{13} + i_{23} + i_{34} \\ J_{II}' - \frac{1}{2} J_d' &= -i_{14} - i_{24} + i_{34} \end{aligned} \right\} \quad (e)$$

which may be transposed to

$$\left. \begin{aligned} J_I' &= i_{12} + \frac{1}{2}(i_{13} + i_{14} - i_{23} - i_{24}) \\ J_{II}' &= i_{34} + \frac{1}{2}(i_{13} + i_{23} - i_{14} - i_{24}) \\ J_d' &= i_{13} + i_{14} + i_{23} + i_{24} \end{aligned} \right\} \quad (f)$$

If the expressions (c) for the voltages V_{12} , V_{34} etc. are inserted in equations (d) and the expressions thus obtained for the currents i_{12} , i_{13} etc. are then inserted in equations (f) we obtain the equations

$$\left. \begin{aligned} J_I' &= \frac{1}{4}(4A_{12} + A_{13} + A_{14} + A_{23} + A_{24})V_I \\ &+ \frac{1}{4}(A_{13} + A_{24} - A_{14} - A_{23})V_{II} \\ &+ \frac{1}{2}(A_{13} + A_{14} - A_{23} - A_{24})V_d \\ J_{II}' &= \frac{1}{4}(4A_{34} + A_{13} + A_{14} + A_{23} + A_{24})V_{II} \\ &+ \frac{1}{4}(A_{13} + A_{24} - A_{14} - A_{23})V_I \\ &+ \frac{1}{2}(A_{13} + A_{23} - A_{14} - A_{24})V_d \\ J_d' &= (A_{13} + A_{14} + A_{23} + A_{24})V_d \\ &+ \frac{1}{2}(A_{13} + A_{14} - A_{23} - A_{24})V_I \\ &+ \frac{1}{2}(A_{13} + A_{23} - A_{14} - A_{24})V_{II} \end{aligned} \right\} \quad (g)$$

We will now introduce the following terms and expressions,

$$\left. \begin{aligned} \text{Increase in "complex leakage"} \\ A_I &= \frac{1}{4}(4A_{12} + A_{13} + A_{14} + A_{23} + A_{24}) \\ A_{II} &= \frac{1}{4}(4A_{34} + A_{13} + A_{14} + A_{23} + A_{24}) \\ A_d &= (A_{13} + A_{14} + A_{23} + A_{24}) \end{aligned} \right\} \quad (7)$$

$$\left. \begin{aligned} \text{Increase in "unbalance of leakage"} \\ B_{II} &= \frac{1}{4}(A_{13} + A_{24} - A_{14} - A_{23}) \\ B_{Id} &= \frac{1}{2}(A_{13} + A_{14} - A_{23} - A_{24}) \\ B_{II d} &= \frac{1}{2}(A_{13} + A_{23} - A_{14} - A_{24}) \end{aligned} \right\} \quad (8)$$

Equations (g) may then be written as follows

$$\left. \begin{aligned} J_I' &= A_I V_I + B_{II} V_{II} + B_{Id} V_d \\ J_{II}' &= A_{II} V_{II} + B_{II} V_I + B_{II d} V_d \\ J_d' &= A_d V_d + B_{Id} V_I + B_{II d} V_{II} \end{aligned} \right\} \quad (h)$$

These leakage give us a new impedance side with the currents

$$\left. \begin{aligned} J_I &= i_I + J_I' \\ J_{II} &= i_{II} + J_{II}' \\ J_d &= i_d + J_d' \end{aligned} \right\} \quad (i)$$

If we eliminate J_I' , J_{II}' and J_d' between equations (h) and (i), the following expressions are obtained,

$$\left. \begin{aligned} i_I &= J_I - A_I V_I - B_{II} V_{II} - B_{Id} V_d \\ i_{II} &= J_{II} - A_{II} V_{II} - B_{II} V_I - B_{II d} V_d \\ i_d &= J_d - A_d V_d - B_{Id} V_I - B_{II d} V_{II} \end{aligned} \right\} \quad (j)$$

and if we insert these values for the currents i_I , i_{II} and i_d in equations (b) we obtain

$$\left. \begin{aligned} x_I J_I + m_{II} J_{II} + m_{Id} J_d &= k_I V_I + k_{II} V_{II} + k_{dI} V_d \\ x_{II} J_{II} + m_{II} J_I + m_{II d} J_d &= k_{II} V_{II} + k_{II} V_I + k_{dII} V_d \\ x_d J_d + m_{Id} J_I + m_{II d} J_{II} &= k_d V_d + k_{Id} V_I + k_{II d} V_{II} \end{aligned} \right\} \quad (k)$$

where

$$\left. \begin{aligned} k_I &= 1 + x_I A_I + m_{II} B_{II} + m_{Id} B_{Id} \\ k_{II} &= 1 + x_{II} A_{II} + m_{II} B_{II} + m_{II d} B_{II d} \\ k_d &= 1 + x_d A_d + m_{Id} B_{Id} + m_{II d} B_{II d} \\ k_{II} &= x_{II} B_{II} + m_{II} A_I + m_{II d} B_{Id} \\ k_{II I} &= x_I B_{II} + m_{II} A_{II} + m_{Id} B_{II d} \\ k_{Id} &= x_d B_{Id} + m_{Id} A_I + m_{II d} B_{II} \\ k_{dI} &= x_I B_{Id} + m_{Id} A_d + m_{II} B_{II d} \\ k_{II d} &= x_d B_{II d} + m_{II d} A_{II} + m_{Id} B_{II} \\ k_{dII} &= x_{II} B_{II d} + m_{II d} A_d + m_{II} B_{Id} \end{aligned} \right\} \quad (l)$$

From equation group (k) we can figure the voltages V_I , V_{II} and V_d expressed in the currents J_I , J_{II} and J_d .

If we adopt the following designations

$$\left. \begin{aligned} P_1 &= k_d k_{II} - k_{dII} k_{II d} \\ P_2 &= k_d k_I - k_{dI} k_I d \\ P_3 &= k_{II} k_I - k_{II I} k_I II \\ R_1 &= k_{II d} k_{dII} - k_{II I} k_{Id} \\ R_1' &= k_{II d} k_{dII} - k_{dI} k_{II} \\ R_2 &= k_{Id} k_{dII} - k_{II} k_{Id} \\ R_2' &= k_{Id} k_I II - k_{dII} k_I \\ R_3 &= k_{II} k_{II d} - k_{Id} k_{II} \\ R_3' &= k_{II I} k_I d - k_{II d} k_I \end{aligned} \right\} \quad (m)$$

then

$$\begin{aligned}
 V_I &= J_I \frac{x_I P_1 + m_{II} R_1 + m_{Id} R_1'}{k_I P_1 + k_{III} R_1 + k_{Id} R_1'} \\
 &+ J_{II} \frac{m_{III} P_1 + x_{II} R_1 + m_{II d} R_1'}{k_I P_1 + k_{III} R_1 + k_{Id} R_1'} \\
 &+ J_d \frac{m_{Id} P_1 + m_{II d} R_1 + x_d R_1'}{k_I P_1 + k_{III} R_1 + k_{Id} R_1'} \\
 V_{II} &= J_{II} \frac{x_{II} P_2 + m_{II} R_2 + m_{II d} R_2'}{k_{II} P_2 + k_{III} R_2 + k_{II d} R_2'} \\
 &+ J_I \frac{m_{III} P_2 + x_I R_2 + m_{Id} R_2'}{k_{II} P_2 + k_{III} R_2 + k_{II d} R_2'} \\
 &+ J_d \frac{m_{II d} P_2 + m_{Id} R_2 + x_d R_2'}{k_{II} P_2 + k_{III} R_2 + k_{II d} R_2'} \\
 V_d &= J_d \frac{x_d P_3 + m_{Id} R_3 + m_{II d} R_3'}{k_d P_3 + k_{dI} R_3 + k_{dII} R_3'} \\
 &+ J_I \frac{m_{Id} P_3 + x_I R_3 + m_{III} R_3'}{k_d P_3 + k_{dI} R_3 + k_{dII} R_3'} \\
 &+ J_{II} \frac{m_{II d} P_3 + m_{III} R_3 + x_{II} R_3'}{k_d P_3 + k_{dI} R_3 + k_{dII} R_3'}
 \end{aligned} \quad (n)$$

and in equations (n) we have the desired equations for the new cross-section (i. e. the original cross-section with equations (b) plus the leakances). These equations are, however, altogether too awkward for all practical purposes, and we will therefore make a few approximations.

We will assume that the mutual impedances can be ignored as compared with the line impedance, this being possible for all cases occurring in actual practice, as will be shown in the following. This assumption means that m may be ignored as compared with x , and B may be ignored as compared with A , on condition, however, that A is not so small as to be negligible (see equations (b) and (h)). Equations (1) may therefore be written as follows,

$$\left. \begin{aligned}
 k_I &= 1 + x_I A_I \\
 k_{II} &= 1 + x_{II} A_{II} \\
 k_d &= 1 + x_d A_d
 \end{aligned} \right\} \quad (o)$$

and

$$\left. \begin{aligned}
 k_{III} &= x_{II} B_{III} + m_{III} A_I \\
 k_{II} &= x_I B_{II} + m_{II} A_{II} \\
 k_{Id} &= x_d B_{Id} + m_{Id} A_I \\
 k_{dI} &= x_I B_{Id} + m_{Id} A_d \\
 k_{II d} &= x_d B_{II d} + m_{II d} A_{II} \\
 k_{dII} &= x_{II} B_{II d} + m_{II d} A_d
 \end{aligned} \right\} \quad (p)$$

Further, k_I , k_{II} and k_d are plainly of a higher order than k_{III} , k_{II} , k_{Id} , k_{dI} , $k_{II d}$ and k_{dII} , giving

$$\left. \begin{aligned}
 P_1 &= k_d k_{II} = (1 + x_d A_d)(1 + x_{II} A_{II}) \\
 P_2 &= k_d k_I = (1 + x_d A_d)(1 + x_I A_I) \\
 P_3 &= k_{II} k_I = (1 + x_{II} A_{II})(1 + x_I A_I)
 \end{aligned} \right\} \quad (q)$$

and

$$\left. \begin{aligned}
 R_1 &= -k_{III} k_d \\
 &= -(1 + x_d A_d)(x_I B_{III} + m_{III} A_{II}) \\
 R_1' &= -k_{dI} k_{II} \\
 &= -(1 + x_{II} A_{II})(x_I B_{Id} + m_{Id} A_d) \\
 R_2 &= -k_{II} k_d \\
 &= -(1 + x_d A_d)(x_{II} B_{II} + m_{II} A_I) \\
 R_2' &= -k_{dII} k_I \\
 &= -(1 + x_I A_I)(x_{II} B_{II d} + m_{II d} A_d) \\
 R_3 &= -k_{Id} k_{II} \\
 &= -(1 + x_{II} A_{II})(x_d B_{Id} + m_{Id} A_I) \\
 R_3' &= -k_{II d} k_I \\
 &= -(1 + x_I A_I)(x_d B_{II d} + m_{II d} A_{II})
 \end{aligned} \right\} \quad (r)$$

It is obvious that P_1 , P_2 and P_3 are of a higher order than R_1 , R_1' , R_2 , R_2' , R_3 and R_3' , and for this reason — according to equations (o) and (q) — all of the numerators in equations (n) may be written

$$= (1 + x_I A_I)(1 + x_{II} A_{II})(1 + x_d A_d) \quad (s)$$

and the denominators

$$\left. \begin{aligned}
 x_I P_1 + m_{II} R_1 + m_{Id} R_1' &= x_I(1 + x_{II} A_{II})(1 + x_d A_d) \\
 x_{II} P_2 + m_{II} R_2 + m_{II d} R_2' &= x_{II}(1 + x_I A_I)(1 + x_d A_d) \\
 x_d P_3 + m_{Id} R_3 + m_{II d} R_3' &= x_d(1 + x_I A_I)(1 + x_{II} A_{II}) \\
 m_{III} P_1 + x_{II} R_1 + m_{II d} R_1' &= m_{III} P_2 + x_I R_2 + m_{Id} R_2' \\
 &= (1 + x_d A_d)(m_{III} - x_I x_{II} B_{III}) \\
 m_{Id} P_1 + m_{II d} R_1 + x_d R_1' &= m_{Id} P_2 + x_I R_3 + m_{III} R_3' \\
 &= (1 + x_{II} A_{II})(m_{Id} - x_I x_d B_{Id}) \\
 m_{II d} P_2 + m_{Id} R_2 + x_d R_2' &= m_{II d} P_3 + m_{III} R_3 + x_{II} R_3' \\
 &= (1 + x_I A_I)(m_{II d} - x_{II} x_d B_{II d})
 \end{aligned} \right\} \quad (t)$$

Using the expressions (s) and (t), equations (n) finally assume the form

$$\left. \begin{aligned}
 V_I &= J_I y_I + J_{II} M_{II} + J_d M_{Id} \\
 V_{II} &= J_{II} y_I + J_I M_{II} + J_d M_{II d} \\
 V_d &= J_d y_d + J_I M_{Id} + J_{II} M_{II d}
 \end{aligned} \right\} \quad (u)$$

where

$$\left. \begin{aligned} y_I &= \frac{x_I}{1 + x_I A_I} \\ y_{II} &= \frac{x_{II}}{1 + x_{II} A_{II}} \\ y_d &= \frac{x_d}{1 + x_d A_d} \end{aligned} \right\} \quad (9)$$

and

$$\left. \begin{aligned} M_{II} &= \frac{m_{II} - x_I x_{II} B_{II}}{(1 + x_I A_I)(1 + x_{II} A_{II})} \\ M_{Id} &= \frac{m_{Id} - x_I x_d B_{Id}}{(1 + x_I A_I)(1 + x_d A_d)} \\ M_{II d} &= \frac{m_{II d} - x_{II} x_d B_{II d}}{(1 + x_{II} A_{II})(1 + x_d A_d)} \end{aligned} \right\} \quad (10)$$

In analogy with equations (6), equations (9) and (10) show how the impedances x are changed into y and the mutual impedances m are changed into M on account of the increases A and B in complex leakage and of the unbalance of leakage respectively.

As will be noticed, equations (9) are simply the expressions for parallel connections.

VII. Influence of a homogeneous and cross-talk free line before the point of unbalance.

We will assume the twisted line to be homogeneous and free from cross-talk between two cross-sections. The equations

$$\left. \begin{aligned} v_I &= i_I x_I + i_{II} m_{II} + i_d m_{Id} \\ v_{II} &= i_{II} x_{II} + i_I m_{II} + i_d m_{II d} \\ v_d &= i_d x_d + i_I m_{Id} + i_{II} m_{II d} \end{aligned} \right\} \quad (a)$$

are applicable to one of these sections and equations

$$\left. \begin{aligned} V_I &= J_I y_I + J_{II} M_{II} + J_d M_{Id} \\ V_{II} &= J_{II} y_{II} + J_I M_{II} + J_d M_{II d} \\ V_d &= J_d y_d + J_I M_{Id} + J_{II} M_{II d} \end{aligned} \right\} \quad (b)$$

to the other.

Further, we will assume that this homogeneous portion without cross-talk forms a part of the impedance side of the latter cross-section and is therefore not to be found in the impedance side of the first-mentioned section. As we already know, the relations between the voltages and currents at the ends of a homogeneous line free from cross-talk are

$$\left. \begin{aligned} V &= J Z \coth \gamma s - i Z \frac{1}{\sinh \gamma s} \\ v &= J Z \frac{1}{\sinh \gamma s} - i Z \coth \gamma s \end{aligned} \right\} \quad (c)$$

and we can therefore write

$$\left. \begin{aligned} V_I &= J_I I_I' - i_I A_I' \\ v_I &= J_I A_I' - i_I I_I' \\ V_{II} &= J_{II} I_{II}' - i_{II} A_{II}' \\ v_{II} &= J_{II} A_{II}' - i_{II} I_{II}' \\ V_d &= J_d I_d' - i_d A_d' \\ v_d &= J_d A_d' - i_d I_d' \end{aligned} \right\} \quad (d)$$

where I and A are $Z \coth \gamma s$ and $Z \sinh \gamma s$ respectively. If we eliminate the voltages between the equation groups (a), (b) and (d) we obtain

$$\left. \begin{aligned} J_I y_I + J_{II} M_{II} + J_d M_{Id} &= J_I I_I' - i_I A_I' \\ J_{II} y_{II} + J_I M_{II} + J_d M_{II d} &= J_{II} I_{II}' - i_{II} A_{II}' \\ J_d y_d + J_I M_{Id} + J_{II} M_{II d} &= J_d I_d' - i_d A_d' \end{aligned} \right\} \quad (e)$$

$$\left. \begin{aligned} i_I x_I + i_{II} m_{II} + i_d m_{Id} &= J_I A_I' - i_I I_I' \\ i_{II} x_{II} + i_I m_{II} + i_d m_{II d} &= J_{II} A_{II}' - i_{II} I_{II}' \\ i_d x_d + i_I m_{Id} + i_{II} m_{II d} &= J_d A_d' - i_d I_d' \end{aligned} \right\} \quad (f)$$

From equations (f) we may now figure the currents i_I , i_{II} and i_d expressed in terms of J_I , J_{II} and J_d . As a result of this operation we obtain

$$\left. \begin{aligned} i_I &= J_{II} A_{II}' k_{II I} + J_d A_d' k_{d I} - J_I A_I' k_I \\ i_{II} &= J_I A_I' k_{I II} + J_d A_d' k_{d II} - J_{II} A_{II}' k_{II} \\ i_d &= J_I A_I' k_{I d} + J_{II} A_{II}' k_{II d} - J_d A_d' k_d \end{aligned} \right\} \quad (g)$$

where

$$\left. \begin{aligned} k_{II I} &= k_{II} = S[(x_d + I_d') m_{II} - m_{Id} m_{II d}] \\ k_{Id} &= k_{d I} = S[(x_{II} + I_{II}') m_{Id} - m_{II} m_{II d}] \\ k_{II d} &= k_{d II} = S[(x_I + I_I') m_{II d} - m_{II} m_{Id}] \\ k_I &= S[(x_{II} + I_{II}') (x_d + I_d') - m_{II d}^2] \\ k_{II} &= S[(x_I + I_I') (x_d + I_d') - m_{Id}^2] \\ k_d &= S[(x_{II} + I_{II}') (x_I + I_I') - m_{II}^2] \\ \frac{1}{S} &= (x_I + I_I') m_{II}^2 + (x_{II} + I_{II}') m_{Id}^2 \\ &\quad + (x_d + I_d') m_{II d}^2 - 2 m_{II} m_{Id} m_{II d} - \\ &\quad - (x_I + I_I') (x_{II} + I_{II}') (x_d + I_d') \end{aligned} \right\} \quad (h)$$

If we then insert these values for i_I , i_{II} and i_d in equations (e) we obtain

$$\left. \begin{aligned} J_I y_I + J_{II} M_{II} + J_d M_{Id} &= J_I (I_I' + A_I'^2 k_I) \\ &\quad - J_{II} A_I' A_{II}' k_{I II} - J_d A_I' A_d' k_{I d} \\ J_{II} y_{II} + J_I M_{II} + J_d M_{II d} &= J_{II} (I_{II}' + A_{II}'^2 k_{II}) \\ &\quad - J_I A_I' A_{II}' k_{I II} - J_d A_{II}' A_d' k_{II d} \\ J_d y_d + J_I M_{Id} + J_{II} M_{II d} &= J_d (I_d' + A_d'^2 k_d) \\ &\quad - J_I A_I' A_d' k_{I d} - J_{II} A_{II}' A_d' k_{II d} \end{aligned} \right\} \quad (i)$$

from which we find that

$$\left. \begin{aligned} y_I &= I_I' + A_I'^2 k_I \\ y_{II} &= I_{II}' + A_{II}'^2 k_{II} \\ y_d &= I_d' + A_d'^2 k_d \\ M_{II} &= -A_I' A_{II}' k_{I II} \\ M_{Id} &= -A_I' A_d' k_{I d} \\ M_{II d} &= -A_{II}' A_d' k_{II d} \end{aligned} \right\} \quad (j)$$

Even these equations become rather complicated, for which reason we will again make certain approximations, i. e. that the mutual impedances may be ignored as compared with the line impedances.

Consequently, the equation group (h) may be written as follows,

$$\left. \begin{aligned} k_{II} &= S(x_d + I_d') m_{II} \\ k_{Id} &= S(x_{II} + I_{II}') m_{Id} \\ k_{II d} &= S(x_I + I_I') m_{II d} \\ k_I &= S(x_{II} + I_{II}') (x_d + I_d') \\ k_{II} &= S(x_I + I_I') (x_d + I_d') \\ k_d &= S(x_{II} + I_{II}') (x_I + I_I') \\ \frac{1}{S} &= -(x_I + I_I') (x_{II} + I_{II}') (x_d + I_d') \end{aligned} \right\} \cdot (k)$$

Inserting these expressions in the equations (j), we obtain

$$\left. \begin{aligned} y_I &= I_I' - A_I'^2 \frac{1}{x_I + I_I'} \\ y_{II} &= I_{II}' - A_{II}'^2 \frac{1}{x_{II} + I_{II}'} \\ y_d &= I_d' - A_d'^2 \frac{1}{x_d + I_d'} \\ M_{II} &= A_I' A_{II}' \frac{m_{II}}{(x_I + I_I') (x_{II} + I_{II}')} \\ M_{Id} &= A_I' A_d' \frac{m_{Id}}{(x_I + I_I') (x_d + I_d')} \\ M_{II d} &= A_{II}' A_I' \frac{m_{II d}}{(x_{II} + I_{II}') (x_d + I_d')} \end{aligned} \right\} (l)$$

Instead of the I and A impedances we will introduce the characteristic line impedances and the propagation constant, designating the former with Z_I , Z_{II} and Z_d and the latter with γ_{sI} , γ_{sII} and γ_{sd} for the side circuits I and II and the phantom circuit respectively.

According to equations

$$I = Z \operatorname{tgh} \gamma s \text{ and } A = Z \frac{1}{\sinh \gamma s}$$

we then obtain the equation group

$$\left. \begin{aligned} y_I &= Z_I \frac{x_I + Z_I}{x_I - Z_I} + e^{-2\gamma_{sI}} \\ &\quad \frac{x_I + Z_I}{x_I - Z_I} - e^{-2\gamma_{sI}} \end{aligned} \right\} (m)$$

$$\left. \begin{aligned} \eta_{II} &= \frac{Z_I Z_{II}}{(Z_I + x_I)(Z_{II} + x_{II})} [1 + \operatorname{tgh}(\gamma_{sI} + p_I + i q_I)] [1 + \operatorname{tgh}(\gamma_{sII} + p_{II} + i q_{II})] \\ \eta_{Id} &= \frac{Z_I Z_d}{(Z_I + x_I)(Z_d + x_d)} [1 + \operatorname{tgh}(\gamma_{sI} + p_I + i q_I)] [1 + \operatorname{tgh}(\gamma_{sd} + p_d + i q_d)] \\ \eta_{II d} &= \frac{Z_{II} Z_d}{(Z_{II} + x_{II})(Z_d + x_d)} [1 + \operatorname{tgh}(\gamma_{sII} + p_{II} + i q_{II})] [1 + \operatorname{tgh}(\gamma_{sd} + p_d + i q_d)] \end{aligned} \right\} (13)$$

$$\left. \begin{aligned} y_{II} &= Z_{II} \frac{x_{II} + Z_{II}}{x_{II} - Z_{II}} + e^{-2\gamma_{sII}} \\ &\quad \frac{x_{II} + Z_{II}}{x_{II} - Z_{II}} - e^{-2\gamma_{sII}} \\ y_d &= Z_d \frac{x_d + Z_d}{x_d - Z_d} + e^{-2\gamma_{sd}} \\ &\quad \frac{x_d + Z_d}{x_d - Z_d} - e^{-2\gamma_{sd}} \\ M_{II} &= \frac{4 Z_I Z_{II}}{\left[\frac{x_I + Z_I}{x_I - Z_I} - e^{-2\gamma_{sI}} \right] \left[\frac{x_{II} + Z_{II}}{x_{II} - Z_{II}} - e^{-2\gamma_{sII}} \right]} \cdot \frac{m_{II} e^{-(\gamma_{sI} + \gamma_{sII})}}{(x_I - Z_I)(x_{II} - Z_{II})} \\ M_{Id} &= \frac{4 Z_I Z_d}{\left[\frac{x_I + Z_I}{x_I - Z_I} - e^{-2\gamma_{sI}} \right] \left[\frac{x_d + Z_d}{x_d - Z_d} - e^{-2\gamma_{sd}} \right]} \cdot \frac{m_{Id} e^{-(\gamma_{sI} + \gamma_{sd})}}{(x_I - Z_I)(x_d - Z_d)} \\ M_{II d} &= \frac{4 Z_{II} Z_d}{\left[\frac{x_{II} + Z_{II}}{x_{II} - Z_{II}} - e^{-2\gamma_{sII}} \right] \left[\frac{x_d + Z_d}{x_d - Z_d} - e^{-2\gamma_{sd}} \right]} \cdot \frac{m_{II d} e^{-(\gamma_{sII} + \gamma_{sd})}}{(x_{II} - Z_{II})(x_d - Z_d)} \end{aligned} \right\} (m)$$

If we introduce hyperbolic functions and the designations

$$\left. \begin{aligned} e^{2(p_I + i q_I)} &= \frac{Z_I + x_I}{Z_I - x_I} \\ e^{2(p_{II} + i q_{II})} &= \frac{Z_{II} + x_{II}}{Z_{II} - x_{II}} \\ e^{2(p_d + i q_d)} &= \frac{Z_d + x_d}{Z_d - x_d} \end{aligned} \right\} (11)$$

equations (m) will appear as follows,

$$\left. \begin{aligned} y_I &= Z_I \operatorname{tgh}(\gamma_{sI} + p_I + i q_I) \\ y_{II} &= Z_{II} \operatorname{tgh}(\gamma_{sII} + p_{II} + i q_{II}) \\ y_d &= Z_d \operatorname{tgh}(\gamma_{sd} + p_d + i q_d) \end{aligned} \right\} (12)$$

and

$$\left. \begin{aligned} M_{II} &= m_{II} \eta_{II} e^{-(\gamma_{sI} + \gamma_{sII})} \\ M_{Id} &= m_{Id} \eta_{Id} e^{-(\gamma_{sI} + \gamma_{sd})} \\ M_{II d} &= m_{II d} \eta_{II d} e^{-(\gamma_{sII} + \gamma_{sd})} \end{aligned} \right\}$$

where

For large values of

$$\begin{aligned} &(\gamma s_I + p_I + i q_I), \\ &(\gamma s_{II} + p_{II} + i q_{II}) \text{ and} \\ &(\gamma s_d + p_d + i q_d) \end{aligned}$$

η_{II} , η_{Id} and η_{Id} , the so-called "reflex coefficients" become.

$$M_{II} = \left[\frac{(m_{II} + T_1) e^{-(\gamma s_I + \gamma s_{II})_1} \cdot \eta_{1I} \eta_{1II} - x_{2I} x_{2II} B_2}{(1 + x_{2I} A_{2I})(1 + x_{2II} A_{2II})} \cdot e^{-(\gamma s_I + \gamma s_{II})_2} \cdot \eta_{2I} \eta_{2II} \right. \\ \left. + T_3 \right] \cdot e^{-(\gamma s_I + \gamma s_{II})_3} \cdot \eta_{3I} \eta_{3II} + \dots \text{ etc.} \quad (a)$$

$$\left. \begin{aligned} \eta_{II} &= \frac{2 Z_I}{Z_I + x_I} \cdot \frac{2 Z_{II}}{Z_{II} + x_{II}} \\ \eta_{Id} &= \frac{2 Z_I}{Z_I + x_I} \cdot \frac{2 Z_d}{Z_d + x_d} \\ \eta_{II d} &= \frac{2 Z_{II}}{Z_{II} + x_{II}} \cdot \frac{2 Z_d}{Z_d + x_d} \end{aligned} \right\} \quad (14)$$

If $Z_I = x_I$, $Z_{II} = x_{II}$ and $Z_d = x_d$, then $\eta_{II} = \eta_{Id} = \eta_{II d} = 1$. (15)

VIII. *Summation of elements of unbalances in a longer stretch of line.*

From the foregoing we find that with the introduction of the quantities for unbalance of line and unbalance of leakance the mathematical treatment is the same for all three telephone circuits in a twisted four-wire line.

Further, the adopted approximations have shown us that the mutual influence between two circuits is independent of the third circuit and therefore also of other neighbouring circuits such as earth, for instance.

Consequently, it is quite sufficient to investigate the mutual influence between any two circuits.

Let us assume two circuits between which exist the consecutive unbalances $T_1, T_3, T_5 \dots$ etc. and between these the unbalances of leakance $B_2, B_4, B_6 \dots$ etc. Between two proximate unbalances we will assume that there are small homogeneous lengths of line free from cross-talk with the sum of the propagation constant for both lengths of line, $(\gamma s_I + \gamma s_{II})_1, (\gamma s_I + \gamma s_{II})_2, (\gamma s_I + \gamma s_{II})_3 \dots$ etc. At each unbalance of leakance, we will assume that the circuits have the impedances x_{2I} and x_{2II} , x_{4I} and x_{4II} , x_{6I} and $x_{6II} \dots$ etc. (towards the impedance side), also assuming that there have been formed complex leakances A_{2I} and A_{2II} , A_{4I} and A_{4II} , A_{6I} and $A_{6II} \dots$ etc.

Lastly, we will assume that unlike characteristic impedances of the various line sections are responsible

for the forming — at each point of unbalance — of reflexes, represented by the reflex coefficients η_{1I} and η_{1II} , η_{2I} and η_{2II} , η_{3I} and $\eta_{3II} \dots$ etc.

According to equations (6), (10) and (12), and after the summation of n unbalances, the mutual impedance is

which expression can also be written

$$M_{II} = \left[\frac{(m_{II}' + T_1') - x_{2I} x_{2II} B_2'}{(1 + x_{2I} A_{2I})(1 + x_{2II} A_{2II})} + T_3' \right] + \dots \\ \text{where} \\ \left. \begin{aligned} T_1' &= T_1 (\eta_{1I} \eta_{1II} \eta_{2I} \eta_{2II} \dots \eta_{nI} \eta_{nII}) \cdot e^{-\sum_1^n (\gamma s_I + \gamma s_{II})} \\ B_2' &= B_2 (\eta_{2I} \eta_{2II} \eta_{3I} \eta_{3II} \dots \eta_{nI} \eta_{nII}) \cdot e^{-\sum_2^n (\gamma s_I + \gamma s_{II})} \\ T_3' &= T_3 (\eta_{3I} \eta_{3II} \eta_{4I} \eta_{4II} \dots \eta_{nI} \eta_{nII}) \cdot e^{-\sum_3^n (\gamma s_I + \gamma s_{II})} \\ &\dots \dots \dots \text{ etc.} \end{aligned} \right\} \quad (16)$$

In case the lines are perfectly homogeneous and provided with end impedances equal to the characteristic impedances Z of the line, all values of $\eta = 1$, all values of $A = 0$, all values of $x_I = Z_I$ and all values of $x_{II} = Z_{II}$. Equations (15) may then be written

$$M_{II} = m_{II}' + T_1' + T_3' + \dots + T_{n-1}' - Z_I Z_{II} (B_2' + B_4' + \dots + B_n')$$

$$\text{wo} \quad \left. \begin{aligned} T_1' &= T_1 e^{-\sum_1^n (\gamma s_I + \gamma s_{II})} \\ T_3' &= T_3 e^{-\sum_3^n (\gamma s_I + \gamma s_{II})} \\ &\dots \dots \dots \\ T_{n-1}' &= T_{n-1} e^{-\sum_{n-1}^n (\gamma s_I + \gamma s_{II})} \end{aligned} \right\} \quad (17)$$

and

$$\left. \begin{aligned} B_2' &= B_2 e^{-\sum_2^n (\gamma s_I + \gamma s_{II})} \\ B_4' &= B_4 e^{-\sum_4^n (\gamma s_I + \gamma s_{II})} \\ &\dots \dots \dots \\ B_n' &= B_n e^{-(\gamma s_I + \gamma s_{II})_n} \end{aligned} \right\}$$

Apparently, equations (16) hold good for any arbitrary line, since, by reducing certain sections of line and certain unbalances etc. to 0, we can obtain any imaginable combinations of unhomogeneity and unbalance.

The reflex coefficients $\eta_{1I}, \eta_{1II}, \eta_{2I}, \eta_{2II}, \dots$ etc. are calculated with the aid of equations (13), (14), or (15).

The calculation of the impedances $x_{2I}, x_{2II}, x_{4I}, x_{4II}, \dots$ etc. is treated more thoroughly in chapters XII, XIII and XIV.

IX. Calculation of the attenuation of cross-talk currents from the line impedances and mutual impedances.

Let us assume that we have summated the unbalances up to that end of the twisted wire from which the cross-talk attenuations are to be determined. The equations for the cross-section at this end

$$\left. \begin{aligned} V_I &= J_I y_I + J_{II} M_{II} + J_d M_{Id} \\ V_{II} &= J_{II} y_{II} + J_I M_{II} + J_d M_{II d} \\ V_d &= J_d y_d + J_I M_{Id} + J_{II} M_{II d} \end{aligned} \right\} \quad (a)$$

are therefore known.

In this cross-section we have line terminals for two phantom transformers whose internal impedances are R_I, R_{II} and R_d , and to the windings of which are linked the E. M. F.s E_I, E_{II} and E_d for side circuits I and II and the phantom circuit respectively. The tensions may then be expressed as follows

$$\left. \begin{aligned} V_I &= E_I - J_I R_I \\ V_{II} &= E_{II} - J_{II} R_{II} \\ V_d &= E_d - J_d R_d \end{aligned} \right\} \quad (b)$$

Eliminating the tensions between equations (a) and (b), we obtain

$$\left. \begin{aligned} E_I &= J_I (y_I + R_I) + J_{II} M_{II} + J_d M_{Id} \\ E_{II} &= J_{II} (y_{II} + R_{II}) + J_I M_{II} + J_d M_{II d} \\ E_d &= J_d (y_d + R_d) + J_I M_{Id} + J_{II} M_{II d} \end{aligned} \right\} \quad (c)$$

1. Assume E_{II} and $E_d = 0$.

Eliminating J_{II} between equations (c) for E_{II} and E_d we obtain

$$\frac{J_I}{J_d} = \frac{(y_d + R_d)(y_{II} + R_{II}) - M_{II d}^2}{M_{II} M_{II d} - M_{Id} (y_{II} + R_{II})}; \quad (d)$$

and after the elimination of J_d between the same equations we obtain

$$\frac{J_I}{J_{II}} = \frac{(y_d + R_d)(y_{II} + R_{II}) - M_{II d}^2}{M_{Id} M_{II d} - M_{II} (y_d + R_d)}. \quad (e)$$

2. Assume E_I and $E_d = 0$.

Eliminating J_d between equations (c) for E_I and E_d we obtain

$$\frac{J_{II}}{J_I} = \frac{(y_d + R_d)(y_I + R_I) - M_{Id}^2}{M_{Id} M_{II d} - M_{II} (y_d + R_d)}; \quad (f)$$

and after the elimination of J_I between the same equations we obtain

$$\frac{J_{II}}{J_d} = \frac{(y_d + R_d)(y_I + R_I) - M_{Id}^2}{M_{Id} M_{II} - M_{II d} (y_I + R_I)}. \quad (g)$$

3. Assume E_I and $E_{II} = 0$.

Eliminating J_{II} between equations (c) for E_I and E_{II} we obtain

$$\frac{J_d}{J_I} = \frac{(y_I + R_I)(y_{II} + R_{II}) - M_{II}^2}{M_{II} M_{II d} - M_{Id} (y_{II} + R_{II})}; \quad (h)$$

and after the elimination of J_I in the same equations we obtain

$$\frac{J_d}{J_{II}} = \frac{(y_I + R_I)(y_{II} + R_{II}) - M_{II}^2}{M_{Id} M_{II} - M_{II d} (y_I + R_I)}. \quad (i)$$

If we approximate these equations [(d), (e), (f), (g), (h), and (i)] with the assumption that the mutual impedances are negligible as compared with the line impedances, the following equations are obtained in order

$$\left. \begin{aligned} \frac{J_I}{J_d} &= \frac{y_d + R_d}{M_{Id}} \\ \frac{J_I}{J_{II}} &= \frac{y_{II} + R_{II}}{M_{II}} \\ \frac{J_{II}}{J_I} &= \frac{y_I + R_I}{M_{II}} \\ \frac{J_{II}}{J_d} &= \frac{y_d + R_d}{M_{II d}} \\ \frac{J_d}{J_I} + \frac{y_I + R_I}{M_{Id}} & \\ \frac{J_d}{J_{II}} &= \frac{y_{II} + R_{II}}{M_{II d}} \end{aligned} \right\} \quad (j)$$

If the cross-talk attenuation is defined from the relation between outgoing and incoming current, we obtain the following expressions for cross-talk attenuation between

$$\left. \begin{array}{l} \text{Circuit I} \\ \text{and} \\ \text{Phantom} \end{array} \right\} \begin{array}{l} \beta s_{Id} = \ln \frac{y_d + R_d}{|M_{Id}|} \\ \beta s_{dI} = \ln \frac{y_I + R_I}{|M_{Id}|} \end{array} \begin{array}{cc} \text{Disturbed} & \text{Disturbing} \\ \text{circuit} & \text{circuit} \end{array} \left. \begin{array}{cc} d & I \\ I & d \end{array} \right\} \quad (18)$$

$$\left. \begin{array}{l} \text{Circuit II} \\ \text{and} \\ \text{Phantom} \\ \\ \text{Circuits} \\ \text{I and II} \end{array} \right\} \begin{array}{l} \beta_{sII d} = \ln \frac{|y_d + R_d|}{|M_{II d}|} \\ \beta_{s d II} = \ln \frac{|y_{II} + R_{II}|}{|M_{II d}|} \\ \\ \beta_{sI II} = \ln \frac{|y_{II} + R_{II}|}{|M_{I II}|} \\ \beta_{sII I} = \ln \frac{|y_I + R_I|}{|M_{I II}|} \end{array} \begin{array}{l} \text{Disturbed} \\ \text{circuit} \\ \\ \\ \text{Disturbing} \\ \text{circuit} \end{array} \begin{array}{l} d \\ II \\ \\ I \\ II \end{array} \quad (18)$$

This plainly gives the familiar condition that another value for the cross-talk attenuation is generally obtained if the source of energy and the receiver change places. In order to obtain a definition for cross-talk attenuation which is independent of the internal impedances R_I , R_{II} and R_d , and of the positions of the source of energy and receiver, we must choose the square root of the relation between the outgoing and the incoming current and make a correction for the reflexes at the receiver.

The cross-talk is then

$$\beta_{sI II} = \ln \sqrt{\frac{J_I V_I}{J_{II} V_{II}}} \frac{2 y_{II}}{y_{II} + R_{II}} \quad (19)$$

Approximately

$$\left. \begin{array}{l} V_I = J_I y_I \\ V_{II} = J_{II} y_{II} \\ \frac{J_I}{J_{II}} = \frac{y_{II} + R_{II}}{M_{I II}} \end{array} \right\} \quad (k)$$

and if we insert these values in equations (19) we obtain

$$\beta_{sI II} = \ln \frac{2 \sqrt{y_I y_{II}}}{M_{I II}} \quad (20)$$

which proves the above statement.

In case the lines are homogeneous and have end impedances equal to the characteristic line impedances Z , then

$$\beta_{sI II} = \ln \frac{2 \sqrt{Z_I Z_{II}}}{M_{I II}} \quad (21)$$

X. Investigation of the negligibility of the mutual impedance as compared with the line impedance.

The definition for cross-talk attenuation as derived from the relation between outgoing and incoming current according to equations (18) is then

$$\beta_{I II} = \ln \frac{|y_{II} + R_{II}|}{|M_{I II}|} \quad (a)$$

If we assume that the mutual impedance $M_{I II}$ may be neglected as compared with the line impedances

when it is 1 % of the line impedance ($y_{II} + R_{II}$) the derived equations for cross-talk attenuation

$$\beta s \geq \ln 100 = 4,6.$$

clearly hold good.

With an attenuation $\beta_{sI II} = 6$, for instance, the mutual impedance $M_{I II}$ is $\frac{1}{4}$ of one percent of the line impedance $|y_{II} + R_{II}|$, and with $\beta_{sI II} = 7$, $M_{I II}$ equals 1 pro mill of the line impedance.

If the phase of the mutual impedance is shifted in relation to the line impedance, conditions are still more favourable.

In any case a good idea of the nature of the cross-talk is obtained from the derived equations, this being the most interesting side of the problem when the cross-talk attenuations are as low as $\beta s = 4,6$.

XI. Relation between mutual impedance und unbalance of capacity.

According to equations (8) the unbalances of leakage are

$$\left. \begin{array}{l} B_{I II} = \frac{1}{4} (A_{13} + A_{24} - A_{14} - A_{23}) \\ B_{I d} = \frac{1}{2} (A_{13} + A_{14} - A_{23} - A_{24}) \\ B_{II d} = \frac{1}{2} (A_{13} + A_{23} - A_{14} - A_{24}) \end{array} \right\} \quad (a)$$

We will assume that the complex leakances to be governed by capacity only, which permits us to write

$$\left. \begin{array}{l} B_{I II} = \frac{1}{4} i \omega (C_{13} + C_{24} - C_{14} - C_{23}) \\ B_{I d} = \frac{1}{2} i \omega (C_{13} + C_{14} - C_{23} - C_{24}) \\ B_{II d} = \frac{1}{2} i \omega (C_{13} + C_{23} - C_{14} - C_{24}) \end{array} \right\} \quad (b)$$

where C_{13} , C_{14} , C_{23} and C_{24} are the capacities between the conductors and ω is the angle frequency. If we introduce the symbols $K_{I II}$, $K_{I d}$ and $K_{II d}$ for the unbalance of the capacities between side circuits I and II, between side circuit I and the phantom circuit, and between side circuit II and the phantom circuit respectively, it is plain that

$$\left. \begin{array}{l} K_{I II} = C_{13} + C_{24} - C_{14} - C_{23} \\ K_{I d} = C_{13} + C_{14} - C_{23} - C_{24} \\ K_{II d} = C_{13} + C_{23} - C_{14} - C_{24} \end{array} \right\} \quad (c)$$

(Compare K. K pfm ller's treatise " ber das Nebensprechen in mehrfachen Fernsprechkabeln und seine Verminderung")

and equations (b) then take on the following appearance

$$\left. \begin{aligned} B_{I II} &= \frac{1}{4} i \omega K_{I II} \\ B_{I d} &= \frac{1}{2} i \omega K_{I d} \\ B_{II d} &= \frac{1}{2} i \omega K_{II d} \end{aligned} \right\} \quad (22)$$

The measuring of unbalance of capacity usually takes place in short lengths of unloaded cable with the circuits open at the far end. Consequently, it may be of interest to investigate the mutual impedance for such lines. According to equations (10) we have

$$\left. \begin{aligned} M_{I II} &= \frac{m_{I II} - x_I x_{II} B_{I II}}{(1 + x_I A_I)(1 + x_{II} A_{II})} \\ M_{I d} &= \frac{m_{I d} - x_I x_d B_{I d}}{(1 + x_I A_I)(1 + x_d A_d)} \\ M_{II d} &= \frac{m_{II d} - x_{II} x_d B_{II d}}{(1 + x_{II} A_{II})(1 + x_d A_d)} \end{aligned} \right\} \quad (d)$$

In this case $m_{I II} = m_{I d} = m_{II d} = 0$ and $x_I = x_{II} = x_d = \infty$. Further,

$$\left. \begin{aligned} A_I &= i \omega C_I \\ A_{II} &= i \omega C_{II} \\ A_d &= i \omega C_d \end{aligned} \right\} \quad (e)$$

where C_I , C_{II} and C_d are the line capacities for the side circuits *I* and *II* and the phantom circuit respectively. By introducing these expressions in equations (c) we obtain

$$\left. \begin{aligned} M_{I II} &= i \frac{K_{I II}}{4 \omega C_I C_{II}} \\ M_{I d} &= i \frac{K_{I d}}{2 \omega C_I C_d} \\ M_{II d} &= i \frac{K_{II d}}{2 \omega C_{II} C_d} \end{aligned} \right\} \quad (23)$$

Thus, the mutual impedance is directly proportional to the unbalance of the capacity and reversly proportional to the angle frequency ω .

XII. Dependence of the line impedance on one un-homogeneity.

We will consider a homogeneous line free from cross-talk and ending with the impedance x . According to equations (11) and (12) the line impedance is then

$$\left. \begin{aligned} y &= Z \operatorname{tgh}(\gamma s + \rho + i q), \text{ wo} \\ e^{2(\rho + i q)} &= \frac{Z + x}{Z - x} \end{aligned} \right\} \quad (a)$$

The amplitude and phase angle for the impedance y is then

$$\left. \begin{aligned} |y| &= |Z| \sqrt{\frac{\cosh 2(\beta s + \rho) - \cos 2(\alpha s + q)}{\cosh 2(\beta s + \rho) + \cos 2(\alpha s + q)}} \\ \varphi_y &= \varphi_z + \operatorname{arctg} \frac{\sin 2(\alpha s + q)}{\sinh 2(\beta s + \rho)} \end{aligned} \right\} \quad (24)$$

We find that for an increasing $(\alpha s + q)$ the impedance y is subject to periodic variances. The geometrical locus for maximum and minimum amplitudes for the same $(\beta s + \rho)$ and for arbitrary values of $(\alpha s + q)$ have the following equations

$$\left. \begin{aligned} |y|_{\max} &= |Z| \sqrt{\frac{\cosh 2(\beta s + \rho) + 1}{\cosh 2(\beta s + \rho) - 1}} \\ |y|_{\min} &= |Z| \sqrt{\frac{\cosh 2(\beta s + \rho) - 1}{\cosh 2(\beta s + \rho) + 1}} \end{aligned} \right\} \quad (b)$$

By introducing the expression

$$n_o^2 = \frac{|y|_{\min}}{|y|_{\max}} < 1 \quad (25)$$

in the relation between the ordinates for the minimum and maximum curve we obtain

$$n_o^2 = \frac{\cosh 2(\beta s + \rho) - 1}{\cosh 2(\beta s + \rho) + 1}, \quad (c)$$

or

$$\beta s + \rho = \frac{1}{2} \ln \frac{1 + n_o}{1 - n_o}. \quad (26)$$

For $x = 0$ we find that

$$e^{2(\rho + i q)} = 1, \text{ i. e. } \rho = 0,$$

and the impedance y is equal to the short-circuit impedance R of the line.

Consequently, if

$$\left. \begin{aligned} \frac{R|_{\min}}{R|_{\max}} &= n_o^2 \end{aligned} \right\} \quad (27)$$

then:

$$\beta s = \frac{1}{2} \ln \frac{1 + n_o}{1 - n_o}$$

For $x = \infty$ we find that

$$e^{2(\rho + i q)} = -1, \text{ i. e. } \rho = 0.$$

and the impedance y is equal to the free impedance I of the line.

$$\left. \begin{aligned} \frac{I|_{\min}}{I|_{\max}} &= n_o^2 \end{aligned} \right\} \quad (28)$$

then:

$$\beta s = \frac{1}{2} \ln \frac{1 + n_o}{1 - n_o}$$

Thus, it is possible to determine the attenuation of the line from the relation between the ordinates of the minimum and maximum curves for the short or free impedance.

From equation (24) it is clear that for $\beta s + \rho = \infty$ the impedance $y = Z$.

This occurs when the line is infinitely long, when βs is infinitely great, or when $x = Z$, making p infinitely great.

We will assume that the end impedance x consists of a leak impedance a and a homogeneous and cross-talk free continuation of the line, with $p + \beta s = \infty$.

Consequently, according to equation (a)

$$\left. \begin{aligned} x &= \frac{Z a}{Z + a} \\ e^{2(p_a + i q_a)} &= \frac{Z + x}{Z - x} = 1 + 2 \frac{a}{Z} \end{aligned} \right\} \quad (29)$$

If, instead, the impedance x consists of a series impedance b and a homogeneous and cross-talk free continuation of the line, with $p + \beta s = \infty$, then

$$\left. \begin{aligned} x &= b + Z \\ e^{2(p_b + i q_b)} &= \frac{Z + x}{Z - x} = - \left(1 + \frac{2Z}{b} \right) \end{aligned} \right\} \quad (30)$$

Lastly, if the impedance x consists of a continuation of the line with another characteristic Z' and with $\beta s + p = \infty$ then

$$e^{2(p_z + i q_z)} = \frac{Z + Z'}{Z - Z'} \quad (31)$$

In those cases where a , b , Z and Z' are pure reals, it is clear that

$$\text{and } \left. \begin{aligned} q_a &= 0, \quad q_b = \frac{\pi}{2}, \quad q_z = 0 \\ p_a &= \frac{1}{2} \ln \left(\frac{2a}{Z} + 1 \right) \\ p_b &= \frac{1}{2} \ln \left(\frac{2Z}{b} + 1 \right) \\ p_z &= \frac{1}{2} \ln \frac{Z + Z'}{Z - Z'} \end{aligned} \right\} \quad (32)$$

In those cases where a and b are governed by inductance or capacity only, and Z is a pure real, then

$$\left. \begin{aligned} q_a &= \frac{1}{2} \operatorname{arctg} \frac{2a}{Z} \\ q_b &= \frac{1}{2} \operatorname{arctg} \frac{2Z}{b} + \frac{\pi}{2} \\ p_a &= \frac{1}{4} \ln \left[4 \left(\frac{a}{Z} \right)^2 + 1 \right] \\ p_b &= \frac{1}{4} \ln \left[4 \left(\frac{Z}{b} \right)^2 + 1 \right] \end{aligned} \right\} \quad (33)$$

If we apply equations (32) and (33) to loaded cables with capacities C and C' and self inductance L and L' respectively per km., and with a surplus

or shortage of capacity δC or of self inductance δL in a coil section, the following equations apply for the lower frequencies

$$\left. \begin{aligned} Z &= \sqrt{\frac{L}{C}}, \quad Z' = \sqrt{\frac{L'}{C'}} \\ a &= \frac{1}{i \omega \delta C} \text{ and } b = i \omega \delta L \end{aligned} \right\}$$

Thus, we obtain

$$\left. \begin{aligned} q_a &= \frac{1}{2} \operatorname{arctg} \frac{2}{k_a} \\ q_b &= \frac{1}{2} \operatorname{arctg} \frac{2}{k_b} + \frac{\pi}{2} \\ q_z &= 0 \end{aligned} \right\} \quad (34)$$

where

$$\left. \begin{aligned} p_a &= \frac{1}{4} \ln \left[\frac{4}{k_a^2} + 1 \right] \\ p_b &= \frac{1}{4} \ln \left[\frac{4}{k_b^2} + 1 \right] \\ p_z &= \frac{1}{2} \ln \frac{1 + \sqrt{\frac{L' C}{L C'}}}{1 - \sqrt{\frac{L' C}{L C'}}} \end{aligned} \right\}$$

and

$$k_a = Z \omega \delta C \text{ and } k_b = \frac{\omega \delta L}{Z}$$

XIII. Dependency of the line impedance on several unhomogenities.

In a certain point on a line we will assume that there is an unhomogeneity consisting in part of a series impedance b or a leak impedance a and in part of a change in characteristic line impedances from Z to Z' . The propagation constant between the above-mentioned point and beginning of the line is designated by γs_1 . In another point, situated further away from the beginning of the line than the first one, we assume an unhomogeneity with the values $p = p_2$ and $q = q_2$. Between these two unhomogenities we have the propagation constant γs_2 . If the resulting values of $p = P$ and of $q = Q$ at the first unhomogeneity, then, according to equations (11) and (12), we obtain

$$\left. \begin{aligned} e^{2(P + i Q)} &= \frac{Z + y + b}{Z - y - b} \\ \text{or } e^{2(\dot{P} + i \dot{Q})} &= \frac{Z + \frac{y a}{y + a}}{Z - \frac{y a}{y + a}} \end{aligned} \right\} \quad (a)$$

there $y = Z' \operatorname{tgh} (p_2 + i q_2 + \gamma s_2)$

If we introduce the following designations

$$\left. \begin{aligned} n_b &= \operatorname{tgh}(\rho_b + i q_b) = 1 + \frac{b}{Z} \\ n_a &= \operatorname{tgh}(\rho_a + i q_a) = \frac{1}{1 + \frac{Z}{a}} \\ n_z &= \operatorname{tgh}(\rho_z + i q_z) = \frac{Z'}{Z} \\ n_2 &= \operatorname{tgh}(\rho_2 + i q_2 + \gamma s_2) \\ n_1 &= \operatorname{tgh} \gamma s_1 \\ N &= \operatorname{tgh}(P + i Q) \\ n &= \operatorname{tgh}(P + i Q + \gamma s_1) \end{aligned} \right\} \quad (35)$$

in which

n = the relation between the impedance and the characteristic Z at the beginning of the line, an investigation shows that

$$N = n_z n_2 + n_b - 1 \quad (36)$$

or
$$\frac{1}{N} = \frac{1}{n_z n_2} + \frac{1}{n_a} - 1 \quad (37)$$

and
$$\frac{x}{Z} = n = \frac{N + n_1}{1 + N n_1} \quad (38)$$

For a line with several unhomogenities, therefore, one commences at the most distant unhomogeneity and calculates the resulting value N at this point by means of equations (36) or (37), after which one recalculates this value to the next furthest unhomogeneity and calculates the resulting value N at this latter unhomogeneity by means of equation (36) or (37), again recalculating this value to the next unhomogeneity by means of equation (38), etc. In this manner one finally obtains the value n at the beginning of the line, and consequently also the impedance $x = Zn$.

XIV. *Approximate equations for small unhomogenities, using the impedance of unhomogeneity analogously with mutual impedance.*

We will introduce the quantities "impedance of unhomogeneity" H , with the following definitions

$$\left. \begin{aligned} H_b &= Z(1 - n_b) \\ H_a &= Z(1 - n_a) \\ H_z &= Z(1 - n_z) \\ H_2 &= Z(1 - n_2) \\ H_1 &= Z(1 - n_1) \\ H_N &= Z(1 - N) \\ H &= Z(1 - n) \end{aligned} \right\} \quad (39)$$

According to equations (35) and (39) we then obtain

$$\left. \begin{aligned} n_b &= 1 - \frac{H_b}{Z} = 1 + \frac{b}{Z} \\ n_a &= 1 - \frac{H_a}{Z} = \frac{1}{1 + \frac{Z}{a}} \\ n_z &= 1 - \frac{H_z}{Z} = \frac{Z'}{Z} \\ n_2 &= 1 - \frac{H_2}{Z} = \operatorname{tgh}(\rho_2 + i q_2 + \gamma s_2) \\ n_1 &= 1 - \frac{H_1}{Z} = \operatorname{tgh} \gamma s_1 \\ N &= 1 - \frac{H_N}{Z} = \operatorname{tgh}(P + i Q) \\ n &= 1 - \frac{H}{Z} \end{aligned} \right\} \quad (a)$$

If we insert these expressions in equations (36) and (37) we obtain

$$\left. \begin{aligned} 1 - \frac{H_N}{Z} &= \left(1 - \frac{H_z}{Z}\right) \cdot \left(1 - \frac{H_2}{Z}\right) + \\ &\quad + 1 - \frac{H_b}{Z} - 1 \\ \frac{1}{1 - \frac{H_N}{Z}} &= \frac{1}{\left(1 - \frac{H_z}{Z}\right) \left(1 - \frac{H_2}{Z}\right)} + \frac{1}{1 - \frac{H_a}{Z}} - 1 \end{aligned} \right\} \quad (b)$$

For small values of H_N , H_z , H_2 , H_b and H_a the latter equation may be written

$$1 + \frac{H_N}{Z} \simeq \left(1 - \frac{H_z}{Z}\right) \left(1 + \frac{H_2}{Z}\right) + 1 + \frac{H_a}{Z} - 1; \quad (c)$$

and after having been duly simplified equations (b) take on the following appearance

$$\left. \begin{aligned} H_N &= H_z + H_2 + H_b - \frac{H_z \cdot H_2}{Z} \\ H_N &\simeq H_z + H_2 + H_a + \frac{H_z \cdot H_2}{Z} \end{aligned} \right\} \quad (d)$$

The term $\frac{H_z \cdot H_2}{Z}$ need plainly no longer be considered and equations (d) may then be written

$$H_N \simeq H_z + H_2 + H_a + H_b. \quad (40)$$

If we introduce the expressions (a) in equation (38) we obtain

$$\left. \begin{aligned} 1 - \frac{H}{Z} &= \frac{1 - \frac{H_N}{Z} + 1 - \frac{H_1}{Z}}{1 + (1 - \frac{H_N}{Z})(1 - \frac{H_1}{Z})} \\ &\simeq 1 - \frac{H_N \cdot H_1}{Z(2Z - H_1)} \end{aligned} \right\} \quad (e)$$

or

$$H \simeq H_N \frac{H_1}{2Z - H_1} \quad (f)$$

According to equations (a), however,

$$1 - H_1/Z = \operatorname{tgh} \gamma s_1 = \frac{1 - e^{-2\gamma s_1}}{1 + e^{-2\gamma s_1}} \quad (g)$$

making

$$\frac{H_1}{2Z - H_1} = e^{-2\gamma s_1} \quad (h)$$

and equation (e) may therefore be written

$$H \simeq H_N \cdot e^{-2\gamma s_1} \quad (41)$$

Further, from equations (a) we find that

$$\left. \begin{aligned} H_a &= \frac{Z^2}{Z + a} \\ H_b &= -b \\ H_z &= Z - Z' \end{aligned} \right\} \quad (42)$$

With equations (40), (41) and (42), therefore (which have been reiterated here below, for the sake of clearness), we are able to handle small unhomogeneities much more conveniently than with equations (35), (36), (37) and (38). These approximate equations must be used with careful judgement, however, since the impedance of unhomogeneity H under normal conditions appears with much greater values than the mutual impedance M .

From equations (40), (41) and (42) we find that the combined impedances of unhomogeneity $(H_Z + H_a + H_b)_I$, $(H_Z + H_a + H_b)_{II}$, $(H_Z + H_a + H_b)_{III}$ etc., — between which unhomogeneities and the measuring end we find the propagation constants γs_I , γs_{II} , γs_{III} etc. — give the resulting impedance of unhomogeneity at the measuring end,

$$H = \left. \begin{aligned} &(H_z + H_a + H_b)_I e^{-2\gamma s_I} \\ &+ (H_z + H_a + H_b)_{II} e^{-2\gamma s_{II}} \\ &+ (H_z + H_a + H_b)_{III} e^{-2\gamma s_{III}} + \dots \end{aligned} \right\} \quad (43)$$

The most unfavourable value of H in relation to αs occurs when

$$H = H_0 e^{i\varphi_z} = \left[\begin{aligned} &[(H_z + H_a + H_b)_I] e^{-2\beta s_I} \\ &+ [(H_z + H_a + H_b)_{II}] e^{-2\beta s_{II}} \\ &+ [(H_z + H_a + H_b)_{III}] e^{-\beta s_{III}} + \dots \end{aligned} \right] e^{i\varphi_{s_z}} \quad (44)$$

and with the value H_0 we are able to fix two limits between which the impedance x at the measuring end will oscillate, i. e.

$$|Z + H_0| > |X| > |Z - H_0| \quad (45)$$

Finally, we have the relation between H and $\rho + \beta s$ derived from the equations

$$\left. \begin{aligned} H &= Z(1 - n) \\ n &= \operatorname{tgh}(\rho + iq + \gamma s) \end{aligned} \right\} \quad (i)$$

Consequently,

$$H = Z[1 - \operatorname{tgh}(\rho + iq + \gamma s)] \quad (46)$$

For small unhomogeneities one may write

$$\operatorname{tgh}(\rho + iq + \gamma s) \simeq 1 - 2e^{-2(\rho + iq + \gamma s)} \quad (j)$$

making

$$\left. \begin{aligned} H &= 2Z e^{-2(\rho + iq + \gamma s)} \\ |H| &= 2Z e^{-2(\rho + \beta s)} \\ \rho + \beta s &= \frac{1}{2} \ln \frac{2|Z|}{|H|} \end{aligned} \right\} \quad (47)$$

XV. Meaning of the value of unhomogeneity $P + \beta s$.

We will now assume that $P + \beta s$ has been calculated for each of the lines on both sides of a two-way amplifier (see fig. 7). The transformers T and T_2 are assumed to be perfect and the balances B_1 and B_2 to be in perfect accord with the mathematical characteristics of the respective lines.

An incoming current from line 1 passes through the amplifier R_1 and out over line 2. At the unhomogeneity P_2 a certain part is reflected, returning to line

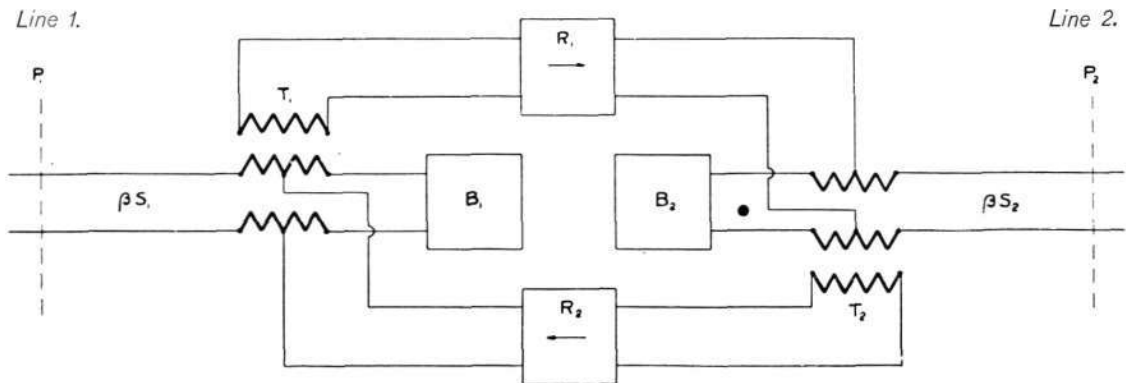


Fig. 7.

I through the translator R_2 . At the unhomogeneity P_1 a certain part is again reflected and returns through the amplifier R_1 , and so forth. The circulating current must therefore pass through a positive attenuation $2(P_1 + \beta s_1) + 2(P_2 + \beta s_2)$ and a negative attenuation equal to the sum of the effective amplification ($b_1 + b_2$) of the two amplifiers.

If $b_1 + b_2$ is not smaller than $2(P_1 + \beta s_1) + 2(P_2 + \beta s_2)$ there is danger that the translator will oscillate.

XVI. Localisation of unhomogenities and unbalances.

From equation (24)

$$\left. \begin{aligned} |y| &= |Z| \sqrt{\frac{\cosh 2(\beta s + p) - \cos 2(\alpha s + q)}{\cosh 2(\beta s + p) + \cos 2(\alpha s + q)}} \\ \varphi_y &= \varphi_z + \arctg \frac{\sin 2(\alpha s + q)}{\sinh 2(\beta s + p)} \end{aligned} \right\} \quad (a)$$

we find that the amplitude and phase angle of the impedance vary periodically with the increasing value of $\alpha s + q$ when we have an unhomogeneity with the values p and q at a distance s from the measuring end.

Furthermore, if equations (17) are applied to two homogeneous lines with $\beta s + p = \infty$ and a mutual unbalance of line T or an unbalance of leakage B , we obtain

$$\left. \begin{aligned} M_T &= T e^{-(\beta s + \beta' s) - i(\alpha s + \alpha' s)} \\ \text{or } M_B &= -Z Z' B e^{-(\beta s + \beta' s) - i(\alpha s + \alpha' s)} \end{aligned} \right\} \quad (b)$$

where s is the distance to the unbalance.

In general, the unbalances T and B are pure reals or purely imaginary, and therefore have a constant phase angle.

Consequently, an increase in $(\alpha s + \alpha' s)$ is also an increase in the phase angle of the mutual impedance.

Now α and α' are functions of the angle frequency ω (velocity of propagation $v = \frac{\omega}{\alpha}$), for which reason we may write

$$\left. \begin{aligned} 2(\alpha s + q) &= 2 \left[f(\omega) + \frac{q}{s} \right] s \\ (\alpha s + \alpha' s) &= [f_1(\omega) + f_2(\omega)] s \end{aligned} \right\} \quad (c)$$

When locating an unhomogeneity or an unbalance, one studies the periodic variations of the line impedance or the increase of the phase angle of the impedance of unhomogeneity or of the mutual impedance respectively, with reference to ω .

Apparently, it is then possible to determine two values of ω , ω_1 and ω_2 , corresponding to the

difference in phase for one period, i. e. a change in $2(\alpha s + q)$ and $(\alpha s + \alpha' s)$ amounting to 2π . According to equations (c) we then obtain

$$\left. \begin{aligned} 2\pi &= 2 \left[f(\omega_2) - f(\omega_1) + \frac{q_2 - q_1}{s} \right] s \\ 2\pi &= [f_1(\omega_2) - f_1(\omega_1) + f_2(\omega_2) - f_2(\omega_1)] s \end{aligned} \right\} \quad (d)$$

$\frac{q_1}{s}$ and $\frac{q_2}{s}$ are small in relation to $f(\omega)$ and may therefore be ignored.

Consequently, equations (d) may be written under the form

$$2\pi = [\psi(\omega_2) - \psi(\omega_1)] s \quad (e)$$

The curve radius of the function $\psi(\omega)$ is generally so large that the function may well be considered as a straight line within the interval $(\omega_2 - \omega_1)$.

The derivatives of the function are then

$$\psi' \left(\frac{\omega_2 + \omega_1}{2} \right) = \frac{\psi(\omega_2) - \psi(\omega_1)}{\omega_2 - \omega_1} \quad (f)$$

and if we introduce this in equation (e) we obtain

$$2\pi = (\omega_2 - \omega_1) s \psi' \left(\frac{\omega_2 + \omega_1}{2} \right) \quad (g)$$

By making a study of an unhomogeneity or an unbalance at a known distance s_1 (for instance a short-circuit or a break at the end of a line or the placing of an artificial attenuation between two lines with $\beta s + p = \infty$) one can figure the function

$$s_1(\omega_2 - \omega_1) = \frac{2\pi}{\psi' \left(\frac{\omega_2 + \omega_1}{2} \right)} \quad (48)$$

for different values of $\frac{\omega_2 + \omega_1}{2}$.

Inversely, the distance to an arbitrary unhomogeneity or unbalance can then be calculated with the aid of the equation

$$s = \frac{2\pi}{\omega_2 - \omega_1} \frac{1}{\psi' \left(\frac{\omega_2 + \omega_1}{2} \right)} \quad (49)$$

When locating unbalances, unhomogenities consisting of true line or leak impedances and unhomogenities consisting of a change of characteristic line impedances which practically do not vary with reference to ω , the distance for homogeneous lines, calculated according to equation (49) will then coincide very well with the actual distance.

When locating purely capacitive and purely inductive line or leak impedance, the neglecting of q in equations (d) means a deviation in distance from the actual distance amounting to

$$A = \frac{s}{\pi} \left[\operatorname{arctg} \frac{2}{Z\omega_1 \delta C} - \operatorname{arctg} \frac{2}{Z\omega_2 \delta C} \right] \quad (h)$$

$$A = \frac{s}{\pi} \left[\operatorname{arctg} \frac{2Z}{\omega_1 \delta L} - \operatorname{arctg} \frac{2Z}{\omega_2 \delta L} \right]$$

[see equations (34)]. We find that A diminishes when δC and δL diminish.

For loaded lines, the conditions become more complicated because αs varies in sudden leaps at the loading coils for increasing values of s .

If we introduce the following symbols

- s_0 = length of one half loading section,
- C_0 = capacity of one loading section,
- L_0 = self inductance in a coil,

$$\omega_0 = \frac{1}{\sqrt{L_0 C_0}} = \text{cut-off frequency,}$$

the small unsymmetrical line element consisting of half of a loading section and half of a loading coil possesses practically the following characteristics

$$\alpha s_0 = \operatorname{arc} \sin \frac{\omega}{\omega_0}$$

$$\left. \begin{aligned} Z_C &= \sqrt{\frac{L}{C}} \sqrt{1 - \left(\frac{\omega}{\omega_0}\right)^2} \quad \text{measured from the capacity side,} \\ Z_L &= \sqrt{\frac{L}{C}} \sqrt{1 - \left(\frac{\omega}{\omega_0}\right)^2} \quad \text{measured from the selfinductance side} \end{aligned} \right\} \quad (i)$$

These line characteristics plainly depend on the capacity and selfinductance of the line per loading section only, and it is therefore chiefly inductive and capacitive unhomogenities and unhomogeneity consisting of deviations in the characteristic line impedances which are of any importance in such a line.

When locating a surplus or deficiency in the n th or $(n+1)$ th half section capacity (in the same loading section), where n is an even whole number, the distance according to equation (49) is then

$$s = ns_0 + \frac{s}{\pi} \left[\operatorname{arctg} \frac{2}{Z_c \omega_2 \delta C} - \operatorname{arctg} \frac{2}{Z_c \omega_1 \delta C} \right] \quad (j)$$

When locating a surplus or deficiency in the self inductance in the $(n-1)$ th and n th half section (in the same loading coil), the calculated distance is

$$s = (n-1)s_0 + \frac{s}{\pi} \left[\operatorname{arctg} \frac{2Z_L}{\omega_2 \delta L} - \operatorname{arctg} \frac{2Z_L}{\omega_1 \delta L} \right] \quad (k)$$

For small unhomogenities the expression between the last brackets may be neglected and it is then possible to determine the respective loading section and loading coil in which the unhomogeneity is located.

When locating an unbalance in the n th or

$(n+1)$ th half section or in the $(n-1)$ th or n th half coil, we find that here also the calculated distance is

$$\left. \begin{aligned} s &= n s_0 \text{ resp. } \\ s &= (n-1)s_0 \end{aligned} \right\} \quad (l)$$

Finally, we have unhomogeneity consisting of a deviation in the characteristics (a deviation of the capacity per km. of the line, of the coils or of the distances between the coils, for instance). If both parts of the line are interconnected in a loading section so that the capacity of this section is equal to the sum of the capacity from each part of the line of a normal half section we get an unhomogeneity consisting of a pure deviation in the characteristic line impedance from Z to Z' at a distance of an even number of half loading sections. If this condition is not complied with, i. e. if we get a small deviation capacity δC within the loading section, then, according to equations (35) and (37)

$$\frac{1}{\operatorname{tgh}(P+iQ)} = \frac{Z}{Z'} + 1 + \frac{Z}{a} - 1$$

or

$$\operatorname{tgh}(P+iQ) = \frac{aZ'}{Z(a+Z')};$$

giving

$$e^{2(P+iQ)} = \frac{ZZ' + a(Z+Z')}{ZZ' + a(Z-Z')} = \frac{(Z+Z') + i\omega \delta C ZZ'}{(Z-Z') + i\omega \delta C ZZ'} \quad (m)$$

Since Z and Z' may be assumed to be true reals, and $\frac{1}{\omega \delta C}$ to be large in comparison with Z and Z' , then

$$\left. \begin{aligned} 2Q &= \operatorname{arctg} \frac{\omega \delta C ZZ'}{Z+Z'} - \operatorname{arctg} \frac{\omega \delta C ZZ'}{Z-Z'} \\ 2P &= \frac{1}{2} \ln \frac{(Z+Z')^2 + (\omega \delta C ZZ')^2}{(Z-Z')^2 + (\omega \delta C ZZ')^2} \end{aligned} \right\} \quad (n)$$

or

$$\left. \begin{aligned} Q &\approx \omega \delta C Z \frac{Z'^2}{Z'^2 - Z^2} \\ P &\approx \frac{1}{4} \ln \frac{Z+Z'}{Z-Z'} \end{aligned} \right\} \quad (o)$$

Thus, we obtain here also unhomogeneity consisting of a pure deviation in the characteristic line impedance from Z to Z' , but the distance to the unhomogeneity will be subject to an apparent deviation from an even number of loading sections, this deviation having the value

$$A = \frac{s}{\pi} \frac{\delta C Z}{2} \frac{Z'^2}{Z'^2 - Z^2} (\omega_1 - \omega_2) \quad (p)$$

The automatic fire alarm system described in this article is furnished by Telefonaktiebolaget L. M. Ericsson.
Editor's note.

The Automatic Fire Alarm.

By Folke Johansson, of the Swedish Forestry Service.
(Reproduced from the forestry magazine »Skogen», No. 12, 1928.)

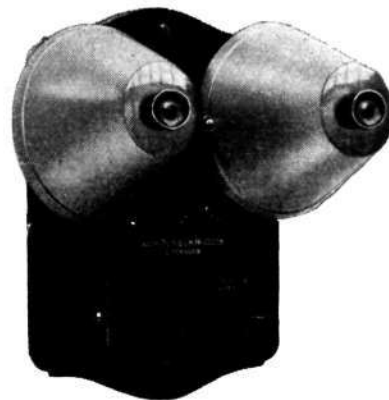
The danger of fire in the woodworking industries can be considerably reduced by the use of automatic fire alarm equipment.

In the lumber and woodworking industries — no matter whether saw-mills, planing mills, finer wood working factories or wood-pulp mills of various kinds

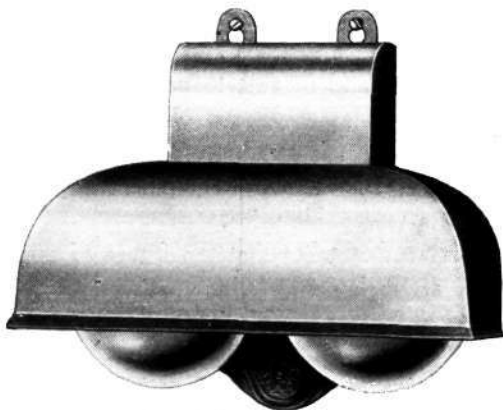
not the cause of the fire remains unknown, the fire having broken out between the night watchman's inspection rounds and having gained such headway by



The Thermo-contact — the «feeler» of the automatic fire alarm — is the first organ to function in case of fire.



Alarm Bell for Indoor Use.



Alarm Bell for Outdoor Use.



Extension Alarm Button, to be used when an automatic alarm signal is to be transmitted direct to the municipal fire department or other protective organization.

Fig. 1.

— the danger of fire is generally extremely great, owing to the construction of the buildings, the character of the machine equipment and of the material handled, the quantities of accumulated sawdust and shavings as well as to many other factors. It is therefore not unusual that fire occurs in factories and mills of this description and every so often the daily press contains notices of such occurrences which have resulted in serious material losses. More often than the time it was discovered that the work of ex-

tinguishing the same proved extremely difficult or even futile. As a rule, the direct material losses as well as those incurred through a crippled production are covered by insurance, at least for all the larger industrial enterprises, but an occurrence of this kind invariably awakens a conviction within us that, economically — from a general as well as from an individual point of view — a much better condition of affairs could be reached if the automatic fire alarm were more universally adopted.

There is absolutely no doubt but that the most important factor in all fire fighting is that the fire is observed at as early a stage as possible, for it is literally true that when, at one moment, a fire may be extinguished with a pail of water, at the next it may defy the efforts of the most modernly equipped fire department. The finding of a method whereby fire could be discovered in its very earliest stages has, therefore, constituted a problem with which fire protection

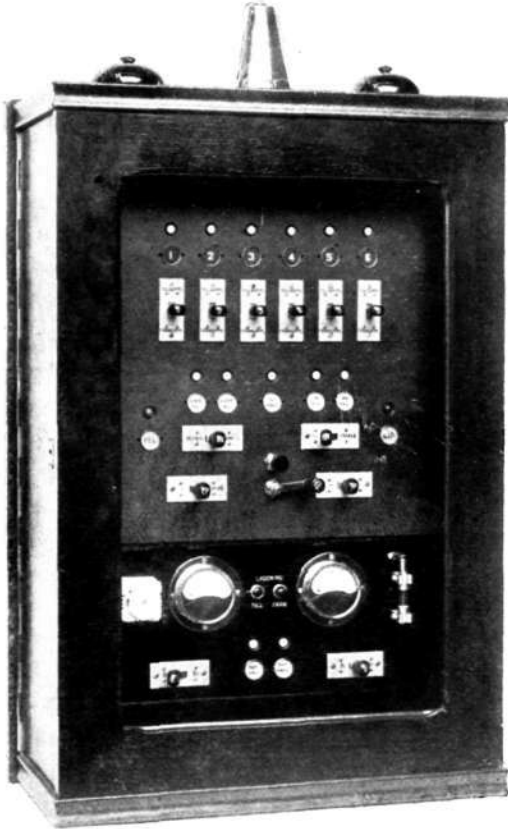


Fig. 2. An incoming impulse from a thermo-contact — transmitted at the outbreak of a fire — is received at the alarm board, which causes the alarm bells to function. That part of the building in which the fire has broken out is indicated on the board. Also, the alarm board indicates at all times the presence of faults in the electric installation, i. e. whether the circuits are in perfect condition or not.

interests have long been occupied. These efforts, aided by modern developments within the field of low tension electrotechnics, have resulted in the construction of the automatic fire alarm, whose function it is to replace the human element with all its defectiveness and to make possible intervention at the earliest possible moment, thereby preventing serious catastrophies.

The automatic fire alarm works on the following principle. The heat engendered by the fire affects contacts which are influenced by a super-normal temperature, so called thermo contacts (fig. 1) — a cer-

tain number of which are mounted on the ceilings of the rooms or premises which are to be protected — thereby closing an electric circuit which actuates an alarm signalling device (gong or siren) placed outdoors, within the building or at any other desired place, as at the local fire department or in the caretaker's quarters, for instance. The thermo-contacts are wired so as to communicate with an alarm board (fig. 2) which denotes from which part of the building the alarm has emanated.

Various such systems have been devised during latter years, but none of them have been absolutely satisfactory in all respects. One unequivocal requirement is that the system shall function with absolute accuracy under all manner of conditions (for instance in the extremely moist air of woodpulp mills) and be unaffected by the ravages of time, and it is in this respect, especially, that earlier constructions have been at a disadvantage. Quite recently, however, developments in this line have taken a great stride forward, thanks to the automatic fire alarm system devised by Mr. H. Ekman, telegraph engineer for the Stockholm Fire Department; a system in which all the faults and deficiencies of previous systems have been eliminated, thereby assuring its accuracy and reliability.

The interest for safety devices of this kind has not been very pronounced within the Swedish lumber and woodworking industries, a condition which must be ascribed in part to a lack of knowledge of the automatic fire alarm and in part to past experience with more or less unreliable systems. Increased enlightenment on this subject is an absolute necessity, so much the more since efficient alarm equipment may now be obtained at a reasonable price.

There is no doubt but that the future of the automatic fire alarm is assured, in woodworking as well as in other industries. This is already suggested by the fact that the insurance companies are giving large reductions off premiums on risks taken by concerns whose plants are equipped with reliable electric and automatic fire alarm systems, and the reductions thus obtained should cover interest for and amortization of the entire installation within a very short time. Another important advantage is that the relative cost of an automatic alarm installation with a small number of thermo-contacts is inconsiderably greater than for one with a large number of contacts, thus making it advantageous for mills and factories of all sizes to install this type of equipment, thereby obtaining increased protection for their production.

Folke Johansson.

Fire Protection in Industrial Life.

By Robert Mossberg.

(Reproduced from "Teknisk Tidskrift" for July 14, 1928.)

Among the many present-day problems, fire protection is without doubt one of the foremost. In all countries, energetically conducted campaigns for the spread of enlightenment on this subject — as seen from a political economic point of view — have caused wider and wider circles to understand the importance of fire protection.

Also, in industrial life, fire protection is being regarded more and more as a purely economic question, as another step in the development of competitive power, although the importance of this does not yet seem to have received as serious consideration in Sweden as in a number of other countries, for example Finland.

To a certain extent, this is undoubtedly due to the opinion — so prevalent in Sweden — that fire protection is something to be taken up between the fire-insurance companies and the industrial enterprises, so that the degree of protection against fire for almost every insurable object would be determined by the risk policy adopted by the insurance companies. In other words, this would mean that the character and financial extent of the fire protective measures would be weighed merely against the larger or smaller reduction off premiums.

A closer scrutiny of this problem will soon reveal, however, that we here have to deal with a far-reaching economic question, in which the risk policy of the insurance companies often plays a comparatively unimportant role.

The aim of insurance against damage by fire is to cover the material value of buildings, equipment and stock. That protection against material losses is but one aspect of the problem is as undeniable a fact as that the insurance companies, through their influence on the design and method of construction of industrial buildings, have largely contributed to a reduction of the risk moments.

A large fire in a factory or mill is generally ac-

companied by a temporary crippling of the production, thereby causing serious reductions in both output and profits. Formerly, it has not been possible to judge the extent of interruption losses caused by fire, but the interruption insurance which has been introduced during latter years and the resulting statistical information on this subject has made it possible to include this factor in the estimates.

The premiums for an interruption insurance are generally double those for regular fire insurance, the fairness of this proportion being proved by the value of paid out interruption insurance, examples taken at random from insurance statistics during the last few years showing that in cases of insurance against interruption in the production, the insurance paid out on such risks has been practically the double of what was paid out for fire insurance in the same cases. In other words, this means that if a reduction off premiums is taken as basis for estimating the extent of fire protective measures, and we designate this reduction with a , then the calculations must be based on a value $3 a$.

A third factor which must be included in the estimates for fire protective measures is the risk of a reduction in the business connections which may be brought about by a fire. It is extremely difficult to make a general estimate of such a risk, conditions being altogether too different within the various industries. This risk is most keenly felt by industries having season production, for instance the textile industry, in which the customer is forced to obtain his supplies from another manufacturer in case a fire should prevent the filling of an order at the time for putting a season article on the market. Other industries, which must at all times be prepared to deliver spare parts to their customers, are more and more beginning to equip their factory buildings in the most favourable manner, seen from a fire protective point of view. An instance of this kind from the S. K. F. company (Swedish Ball Bearing Com-

pany) was recently mentioned in the Swedish journal "Brandskydd" (Fire Protection).

Another important — although not sufficiently considered — side of the industrial fire protection problem is the social one, also with far-reaching economic consequences. In many of our rural districts, the inhabitants as well as the entire community are dependent on some certain industrial enterprise for their livelihood. A destructive fire in such an enterprise generally means more or less unemployment with ensuing increased demands for help from the commonwealth, at the same time as the financial capacity

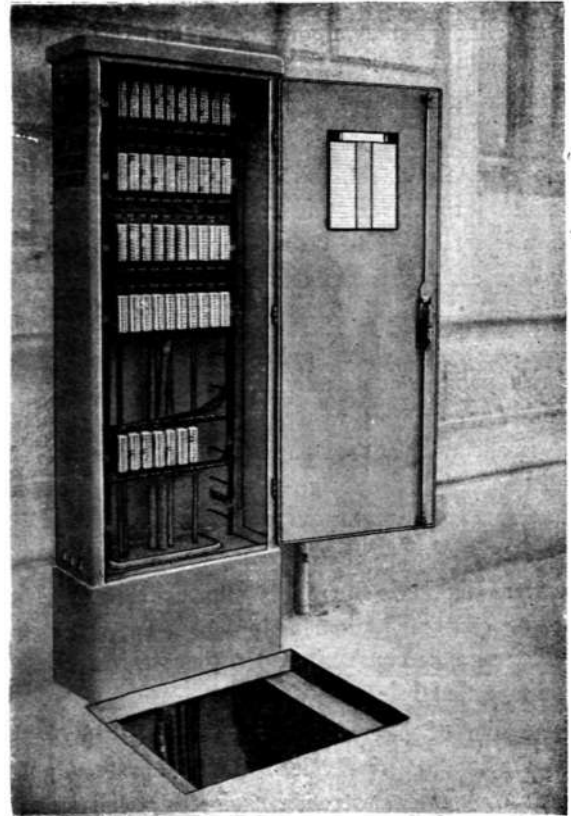
of the principal source of tax income is considerably reduced. This results in higher taxes, which must be borne almost entirely by the enterprise in question, an increase in expenditures which most certainly should be entered on the insurance account.

An industrial fire for which, possibly, but a comparatively insignificant indemnity is paid may thus mean — which it also generally does — many times greater losses of a direct or indirect nature, which might have been avoided or materially reduced had suitable fire protective measures been consistently adopted.

The new Telephone plant of Naples.



View of the Cable-Canalisation.



View of a distribution Cabinet.

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THE
L.M. ERICSSON
REVIEW



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