Ericsson Review

No 1
1937

ERICSSON REVIEW

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

CONTENTS

Printed in Sweden, Esselte ab., Stockholm 1937

CCIF Recommendations for the Handling of Trunk Calls

A. LIGNELL, DIRECTOR OF TELEPHONES, STOCKHOLM

In Europe telephone operation is mostly in the hands of State administrations, though there are private telephone undertakings in a number of countries. To ensure satisfactory International joint working, therefore, uniform provisions for the establishment of calls are an indispensable necessity. With this object the International Consultative Committee for Telephony (CCIF) has drafted certain recommendations and working instructions intended for application to international telephone traffic. The contents of these recommendations are discussed from the point of view of operation.

Long international telephone circuits are expensive installations and require to be fully utilised if the rates for calls are to be kept within reasonable limits. Circuits which are badly utilised in respect of actual charged time of calls, due to unsatisfactory operating devices and service, naturally involve higher rates for calls if they are to return interest and redemption on the capital engaged and provide for operating and other expenses than do circuits in which the quality of the operating devices and the service are such as to ensure full utilisation of the circuits.

With present international rates for calls, losses of time in establishing connections, apparently insignificant in themselves, may represent appreciable amounts in the long run when traffic is extensive. In international as in national trunk operation distinction must be made, both for economic reasons and for the handling of the traffic, between short and long circuits. Short circuits in view of the small cost of the lines are comparable with purely local traffic and can thus, like them, be arranged for automatic operation on zone and time bases for charging calls. In such case the expense of operators is eliminated, which in short distance connections with manual ordering of the calls plays a greater part than do the costs of lines and exchanges. In the longer circuits on the other hand the cost of lines is the most important economically, the costs of exchanges and operators being in comparison of less importance. The utilisation of the circuits, *i. e.*, the utilisation of the lines for actual charged duration of call is therefore of predominating importance.

CCIF in its recommendations has therefore emphasised the importance of devices at the local and trunk exchanges being of such quality that they allow of speedy establishment of international calls and increased yield on the international lines. All technical devices which facilitate the work of the operator and make it possible for her to reduce the time of service between calls are therefore to be recommended.

An international call makes use of the subscriber's line, the exchange equipment at both ends and one or more international lines, as well as two or more operators for making the connections. On the other hand, a local call only takes up two subscribers' lines and the exchange equipment concerned, the connecting of the lines taking place automatically or with little work on the part of the operator.

Besides the great difference in cost for technical devices necessary for the two types of call, the international call is more difficult to deal with than the local call, both in respect of the time occupied and the handling. The local call may be connected without any particular work or consumption of time while the international call, if it cannot be established because the called subscriber's line is busy with a local call, must be held in abeyance thus entailing considerable loss both as regards utilisation of the line for charged call units and consumption of operator's time. Moreover it may be asserted without any great fear of contradiction that an international call is as a rule of greater importance than a purely local connection.

Basing on these considerations, CCIF in its recommendations has declared that a local call ought to be cut off to allow of an international call and in »Instruction pour les opératrices du service téléphonique européen» has prescribed such cutting off, if the exchange technical equipment permits. The condition for not requiring that a subscriber's line engaged by a local call be cut off in favour of an international call would be that the international lines were so inexpensive that diminution in their utilisation would not have so much effect on the fixing of the rates. At present, however, the cutting off of local calls in favour of long distance communications is a necessity for economic operation.

The time elapsing between the ending of one call and the starting of another is dependent on two different operations: the time taken up on the trunk line for the necessary service communications between the exchanges — provisions regarding this are to be found in »Instruction pour les opératrices du service téléphonique européen» — and the time taken up in putting the two subscribers into connection with each other. The work during this latter period does not affect the trunk lines but it is the most troublesome and time consuming and the possibility of arriving at good utilisation of the lines depends mainly, therefore, on what can be done at the close of one call to establish communication rapidly between the caller and the called for the next call. To achieve this end requires that the trunk operator's work in setting up the call be facilitated as much as possible and that the time occupied by her in speaking with the subscriber should be as short as possible. It is with a view to this that the CCIF service instructions respecting the blocking of the subscriber's line and the preparation of the call have been drafted.

By blocking the subscriber's line is meant, according to the »Vocabulaire téléphonique international» published by the CCIF, to *reserve* the subscriber's line for completing an international — or trunk — call. The subscriber's line should, therefore, after connection to the trunk position be marked »trunk engaged», whereupon operators with other calls for that subscriber's number, can see without loss of time that the line is reserved. Blocking in conjunction with preparation, by which the subscriber is advised of a forthcoming international or trunk call is, according to CCIF, desirable for fixed calls (person to person call or call with prior advice to a given instrument) which constitute about 50 % of international calls. By prior advice there is the advantage that the wanted person can get ready to speak, it is not necessary for him to be sought at the moment the call is ready for connection and the time taken in establishing the call is reduced. Blocking is also necessary to expedite the service when a waiting call is on the line and can proceed with or without notification. Even blocking without notification tends to accelerate establishment of the call.

It may be of interest to consider more closely the exchange devices most suited to the CCIF recommendations for accelerating the establishment of international calls and increasing the return on international lines. The operating devices at the international positions should, as already stated, be such as save the time of the operator. The process of notification and the connection of the subscriber's line to the international line is facilitated by cord groups, with which the subscriber's line by means of a simple switch can be connected to the international line when the turn of the call comes. The same applies to cordless positions. The trunk operator herself should have the means of breaking in on a local or zone call which is going on. In automatised networks the selection of the subscriber should be by keyset which takes less of the operator's time than a dial. Manipulation of the cords during the operation should as far as possible be avoided, being replaced by a switch.

Handling of Calls

The various cases which may arise in the establishment of an international or a trunk call are indicated below, and for these different cases the devices are indicated which may be considered suitable for carrying out the recommendations of CCIF.

The Wanted Subscriber's Line is Free

The trunk operator should be sure that the line is disengaged if no busy indication is received. If the operator must find this out by calling on the line, the establishment of the call is delayed in every case and a mistake may arise because at the moment there happened to be a temporary pause in the conversation proceeding.

Then the subscriber's line, on connection to the operator's position, should be blocked for other trunk calls. For, if the subscriber's line be not blocked when an international call is awaited or proceeding, other trunk operators wanting that subscriber's number may cause interruption both during a possible blocking time and during the ensuing call. Enquiries by the telephone staff as to what kind of call the subscriber is engaged with, etc., cause confusion in the service both for operators and for callers and moreover they take up the time of operators; operators' enquiries while a call is proceeding will interrupt and confuse the speakers as well as add to the duration of the call, thus increasing the cost to the users. These interruptions entail considerable inconvenience for calls on the longer international and trunk lines. Moreover, in such case international and trunk calls can be heard from any of the exchange trunk positions, which endangers the maintenance of telephone secrecy.

For the above reasons a subscriber's line which is connected for a local call should be marked busy for the trunk operator by a *local* indication, and a subscriber's line which is blocked or busy with an international or a trunk call should be marked busy by a *trunk* indicator. Separate indicators for international and trunk calls on the one hand and local calls on the other are thus a necessity.

The Called Subscriber's Line is Busy with a Local Call

The trunk operator, on connecting the subscriber's line to her position, should be able without delay to decide whether the subscriber is engaged on a local call. Should this not be possible, which is the case when one indication sign is used for both trunk and local calls, then enquiry must be made of the speakers. As in this instance the subscriber is locally engaged, the time occupied in establishing the subscriber's international connection is prolonged. If, on the other hand, the operator can ascertain for herself the nature of the call on which the subscriber is engaged, she should, as a local call is in question in this case, cut off the call after a brief intimation and connect the subscriber's line to the international or trunk line, in full accordance with the CCIF recommendations. Moreover, the subscriber's line on being connected to the operator's position, should be blocked for other trunk calls as stated above.

For these reasons separate indications for trunk and local calls are a necessity and the trunk operator should be in a position to cut off any local call in progress.

The Wanted Subscriber's Line is Busy with International or Trunk Call

The trunk operator should, when she has plugged in the subscriber's line to her position, know for herself whether the subscriber is busy with an international (trunk) call. Should this not be possible, because a common indicator is used for both trunk and local calls, then the subscribers must be asked, with the inconveniences referred to above. In addition the time taken up by the call on the line served by the operator is detrimentally affected by the delay caused in ascertaining from the subscriber that the line is busy with an international (trunk) call.

Person-to-Person Call

As stated earlier a préavis call should be prepared for, after which the subscriber's line should be kept reserved at the operator's position up to the moment for connecting the call. Special trunk engaged indication is therefore necessary..

A Call is Waiting on the Line

The »Instruction pour les opératrices du service téléphonique européen» prescribes that if a call is waiting on the line, it should be possible to set up the new call *immediately* the preceding one comes to an end. For this purpose all operations which can be carried out in advance should be done while the preceding call is going on, in order that caller and called for the new call can be put into connection for the new call without waste of time.

It should be possible to connect the subscriber's line to the operator's position without at the same time signalling the subscriber. If signal goes out automatically on connection of the subscriber's line to the operator's position the subscriber gets a call without being able to converse. If the advance preparation has not been completed then the subscriber is needlessly troubled.

The subscriber's line after connection should also be reserved for the international or trunk call in question for the reasons given.

Consequently signalling from the trunk position should be manual, not automatic on connection. Moreover there should be special trunk indication.

As may be seen from the foregoing, to enable the CCIF recommendations to be fulfilled the following operating devices are necessary:

1. separate indication for trunk and for local calls, which not only accelerates service and reduces work for operators, but also ensures the necessary order in the service, with conversation undisturbed by operator's enquiries;

2. the trunk operator herself should, after brief notification to the subscribers, be able to cut off a local — or possibly suburban — call which may be going on;

3. signalling from the trunk position should be manual, not take place automatically on connecting in.

To avoid the inconvenience which blocking of a subscriber's line may be supposed to cause the subscriber, it is advisable besides to have a device which, during the blocking period, leaves the blocked line open for local traffic in both directions, providing the trunk operator herself can cut off any local call connected while the subscriber's line is blocked for trunk traffic. In such circumstances the local call could be cut off without much loss of time and the blocking could not be said to cause inconvenience to the subscribers.

At the plenary meeting of CCIF in Copenhagen in 1936 there was formulated, on the basis of a proposal presented, a new question to the following effect: »Would it be advisable to alter the instructions »Dispositions permettant de donner aux communications interurbaines la priorité sur les communications urbaines» in such a sense that international calls could be established with the *least possible delay,* while at the same time simplifying as far as possible the technical devices at the local and trunk exchanges?» Here it is a question of whether CCIF would consider it advisable to alter its recommendations applying to the handling of international calls in favour of simplifying, and thereby cheapening, the equipment of local and trunk exchanges. This is of course highly desirable, but if such simplification were to lead to appreciable economic and other disadvantages in international traffic, both for the administrations and for the users, which on present costs of the longer international and trunk lines would seem to be inevitable, it is to be hoped that the priority over internal traffic which international regulations accord to international traffic may be maintained when judging the question, taking into consideration economic utilisation of the lines, good service in handling of the calls and undisturbed exchange of international communications.

Methods for Reducing the Number of Spares in Local Telephone Networks

N. SIDENMARK, TELEFONAKTIEBOLAGET L.M. ERICSSON, STOCKHOLM

Of the total installation cost of a local telephone plant about 60 % is represented by the network, 25 % by the exchanges and 15 % by the telephoneinstruments. Consequently, in order to arrive at economical construction of a telephone plant it is necessary in the first place to determine the most economical system of construction for the network. A saving of 10 % on the network means 6 % on the whole plant while, e. g., 10 % on the exchanges means only 2.5 % on the plant. Nevertheless, the main interest in studies of the economy of telephone plants has, strangely enough, been confined to the exchanges. The networks have been more or less neglected. However, the importance has lately been more and more realized of economical construction of the network for the finance of a telephone enterprise, and detailed investigations in the matter have been put in hand. The following pages contain a description of the methods used for the reduction of the number of spares in local networks constructed on the Ericsson system.

One of the most important perhaps the decisive factor in respect of economical development of a local telephone network is the *ratio of utilisation, i. e.,* the relation of the lines utilised by subscribers to the total number of installed lines. In order to obtain a high ratio of utilisation the network has to be developed in such a way that there will be a minimum of spares at any given moment, *i. e.,* that the development of the net will be coordinated as closely as possible to the curve showing the increase in subscribers. In order to realize this coordination in practice it is necessary in the first place to determine fairly exactly the future increase in subscribers for a certain period, and secondly to choose a network system which allows of a small number of spares and permits of extension by stages. Only if these conditions are satisfied will it be possible to obtain a high ratio of utilisation and, consequently good economy, see Fig. 1.

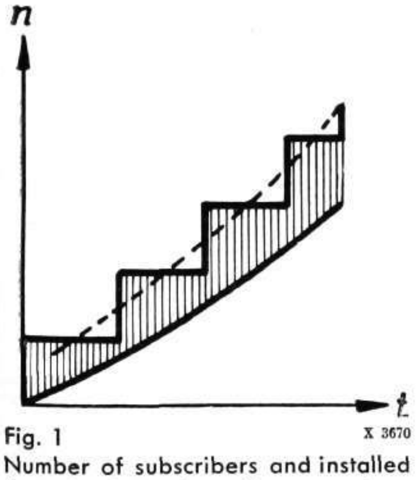


Fig. 1
Number of subscribers and installed lines in the main cable network as a function of time

For the calculation of *increase in the number of subscribers* many methods have been proposed and many rules have been established. But no matter how exact the method chosen, there must always remain a relatively wide margin of error, and the longer the period for which the project is made, the more uncertain, naturally, will be the result. Therefore it is advisable to restrict the length of this period as much as possible. Formerly, the networks could be projected for periods of 20 years or more, now periods longer than 5 years or at the most 10 years are rarely chosen. In this way the increase in the total number of subscribers can be determined with a satisfactory degree of accuracy.

However, when constructing a network it is not sufficient to fix the total increase in subscribers but a predetermination of this increase in every point or every little part of the net is also necessary. In practice, it is impossible to make this predetermination exactly, as even for so short a period as 5 years so many unexpected things can occur that the survey for the network must not be based on these estimated figures alone.

Thus, there is no other possibility except the construction of the network on *some definite system* which does away with these difficulties. The networks should be not rigid but more or less elastic, *i. e.*, the spares should not be attached to each separate point in the network but should be available for large parts of the same. Many principles have been applied for obtaining nets with this property, *e. g.*, distribution »piling up», circular cables, connection in parallel, double network, one rigid and the other flexible, or different combinations of these systems all of which are mainly directed to reduction of the number of spares in the net. The more elastic the system selected, the greater the saving in spares. Then the problem is to balance this saving against other economic and technical factors such as the reduction of the lengths of the subscribers' lines, the obtaining of a clear numbering scheme etc.

As regards construction of the network by *stages*, it is well known, however, that important savings can be achieved by running a great number of lines from the outset, the cost per line thereby being lower than if each line were run independently of the others. This fact is illustrated by Fig. 2 which shows the variation in the cost of laying underground cable in conduits (exclusive of the costs of the conduits and the conduit laying). Thus, the price per one pair and 100 m of small cables is several times higher than the equivalent price for large cables. This can also be applied to other network details. Therefore, it is not an advantage to have the network development curve quite parallel with the curve showing the increase in subscribers, and the development stages of the network should be calculated in advance on economic principles. A general rule for the determination of these stages is that the most economical system of network construction is that which results in the lowest costs when these are reduced to the time zero. The stages of construction are calculated separately for the underground conduits, the main cables, the secondary cables etc. After the stages have been decided on, attention should be given to the necessity of executing all details of the network consistently in a manner suited to this construction by stages.

The Ericsson Network-Construction System

This system is mainly based on the distribution principle. The city in which the local network is to be installed is divided into a number of interdependent

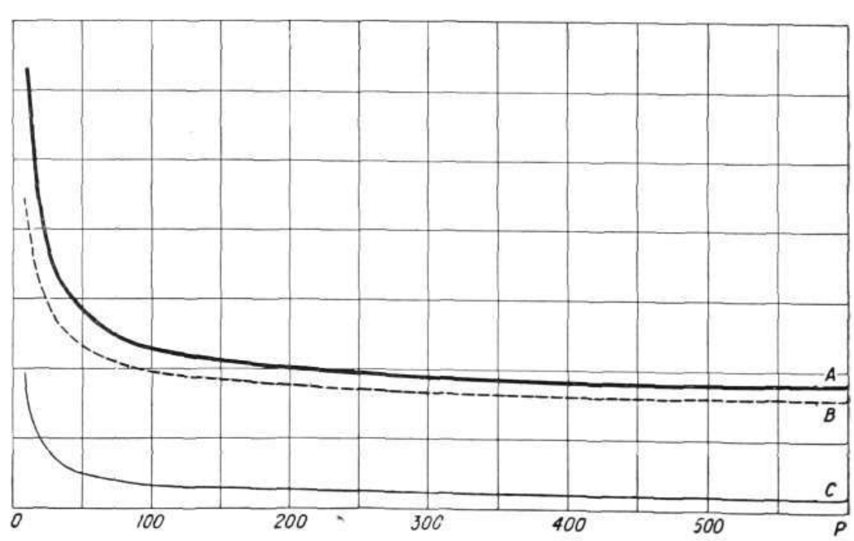


Fig. 2 X 5337

Cost per pair and 100 m of laying underground cable (exclusive of the cost of the conduits) as a function of the number of pairs

A total cost
B cost of material
C cost of labour

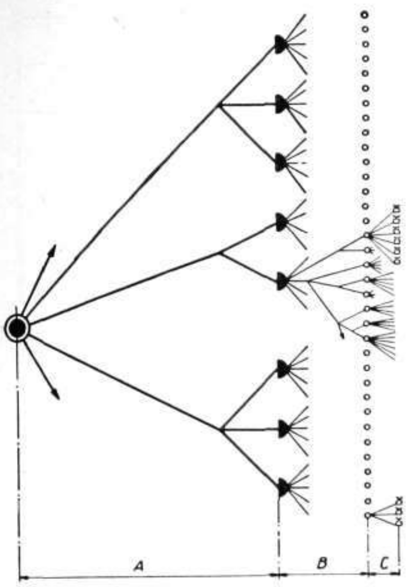


Fig. 3
Skeleton diagram of the Ericsson network-construction system, without buffer cabinets

◉ exchange
▶ cable-distribution cabinet
∘ end-distribution point
☐ subscriber's instrument

distribution areas, a distribution cabinet being placed in each area. These cabinets are the central points around which the network is constructed. Cabled lines, constituting the *main cable network* are run from the exchange to the distribution cabinets. From the distribution cabinets lines, also in cables, constituting the *secondary cable network* are run to end distribution points in each distribution area.

The main cable network generally consists of underground conduit cables or armoured cables, and sometimes — though rarely — of aerial cables. This applies also to the secondary cable network, in which, however, aerial cables are used to a somewhat greater extent. Both the main and secondary cables are terminated and sealed — each cable separately — in terminal boxes mounted in the distribution cabinet. Jumpering by means of special jumper wires is then carried out between the terminals of the main terminal boxes and those of the secondary terminal boxes. In the end distribution points, set up on walls or poles, the secondary cables are also terminated and sealed in terminal boxes of the same general construction as those in the distribution cabinets. The subscribers' lines are connected to the end distribution points by means of single pair lead-covered cables, open wire or insulated wire, these constituting the *subscribers' line network*.

Thus, on its way from the exchange, a subscriber's circuit starts from the protecting strip in the exchange building, runs in the outgoing main cables and enters the distribution cabinet, is there jumpered over from a main terminal box to a secondary one, continues in the secondary cables to the end distribution box, is there connected by means of a gland to the single pair cable or the open wires to terminate at the subscriber's set. For the rest, the Ericsson construction system is illustrated on Fig. 3. From the above it will be seen that the main cable network, the secondary cable network and the subscribers' line network are quite district from each other. This permits of *different numbers of spare lines in the three networks*, thereby achieving appreciable savings.

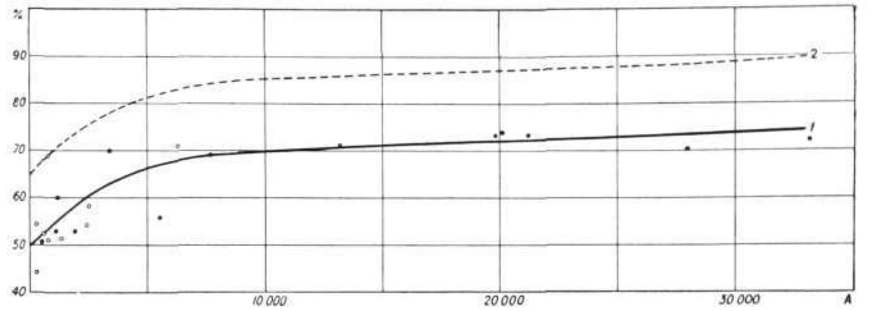
As a rule the subscribers' line network is at first developed only in proportion to the number of subscriptions received. An exception is sometimes made for large buildings where the administration may be sure of having fairly soon subscribers in every flat. Such buildings are provided at the time of their erection with a complete subscribers' line network extending to each flat. Apart from such special cases, spares are not intentionally provided in advance, and the subscribers' line network should consequently follow the curve of the subscriber increase closely and be utilised to 100 %. However, owing to removals by subscribers or the termination of subscription contracts, several of the lines which were originally utilised will become vacant, and after some years of service a subscribers' line network will always comprise a rather large number of spares. This cannot be avoided. If the subscribers' lines have been run in open wires it may sometimes pay to remove same for use elsewhere on some future occasion. This is seldom economical for lines in singlepair cable. As a rule the unemployed lines are left in place, since there always is a good possibility of obtaining a new subscriber in the premises where the previous one had a telephone.

On the other hand, the secondary and the main cable network cannot be developed in exact proportion to the number of subscriptions received. Spares must be provided in advance in order to meet demands occasioned by the future increase in subscribers. If the networks were not distinct from each other, the number of these spares would naturally be the same in both networks. Thanks to the jumpering facilities in the distribution cabinets this is

Fig. 4 X 5338

Ratio of utilisation for some plants in Sweden, Mexico and Poland (1935 and 1936) as a function of the number of subscribers

1 actual ratio of utilisation
2 probable ratio of utilisation with buffer cabinets



not necessary, and one network can be developed quite independently of the other.

The secondary cable network should be developed in such a way that the subscribers' lines, which are the most expensive, may be as short as possible. This can only be realized by placing the end distribution points rather near each other, *i. e.*, a great number of end distribution points of relatively small capacity will be necessary. Now, the smaller the capacity chosen, the more uncertain the number of spares necessary in each end distribution point. This involves a rather large margin in the construction of the secondary cable network. Furthermore, the spares required in the end distribution points should be estimated in order to allow for removals of existing subscribers and the quick connecting up of new ones. As a result the secondary cable network will always contain a relatively large number of spares. It has been found in actual practice that the total sum of these spares should be 75 % of the number of subscribers estimated for at the end of the predetermined period. This means 43 % spares in the total of the secondary cable lines or a ratio of utilisation of 57 %. It is not, however, necessary to complete the secondary cable network to its full extent immediately, this can and should be done by stages which have been calculated in advance to be the most economical. Investigations show that the secondary cable network should be developed in two stages at least. Taking an average for the different years of the period, the spares in the whole secondary cable network would amount approximately to 100 % of the actual number of subscribers, giving a ratio of utilisation of 50 %.

Similarly to what is stated above respecting the secondary cables, the main cable network should be developed in such a way that the more expensive secondary lines may be as short as possible. This can be realized only by restriction of the size of the distribution areas. In projecting these areas consideration should always be given to the subscriber density. This having been done attention should be paid, however, to the desirability of using cable units as large as possible when running the main cables. In this way the best economy both in main cables and in conduit costs will be attained. Research has shown that the most economical cable size for main routes is 600 pairs and that extensions run to each distribution cabinet should in general be 100 pairs at a time. Actual practice shows also that the main cable network will generally be extended in such a way that in the whole network there will always be spares amounting to 40 % of the actual number of subscribers, corresponding to 28.5 % spares of the total of installed main cable lines or to a ratio of utilisation of 71.5 %. As examples, the spares in the main cables for some plants may be cited, *viz.*, in Sweden, Poland and Mexico during the period 1935/1936, see Fig. 4. It will be seen from these that the ratio of utilisation is about 70 % except for the smaller networks, which have a somewhat lower ratio of utilisation. The variations in the number of spares in the main cables of a network during a long period are shown in the following table which refers to the inner district of Stockholm from 1921 to 1936.

year	subscribers	spares	total	spares in relation to		ratio of utilisation
				subscribers %	lines %	
1921	100 408	28 441	128 849	28.3	22.1	77.9
1922	97 960	35 594	133 554	36.3	26.7	73.3
1923	95 952	39 137	135 089	40.8	29.0	71.0
1924	89 487	49 263	138 750	55.1	35.5	64.5
1925	92 712	47 748	140 460	51.5	34.0	66.0
1926	97 061	45 257	142 318	46.6	31.8	68.2
1927	99 647	42 242	141 889	42.4	29.8	70.2
1928	102 864	43 156	146 020	42.0	29.6	70.4
1929	107 679	42 486	150 165	39.5	28.3	71.7
1930	111 564	42 931	154 495	38.5	27.8	72.2
1931	117 143	40 217	157 360	34.3	25.6	74.4
1932	119 914	44 001	163 915	36.7	26.8	73.2
1933	121 669	45 866	167 535	37.7	27.4	72.6
1934	121 756	48 284	170 040	39.7	28.4	71.6
1935	124 385	49 355	173 740	39.7	28.4	71.6
1936	129 577	49 763	179 340	38.4	27.7	72.3

The result of the introduction of cable distribution cabinets has been as follows:

	average number of spares in relation to		ratio of utilisation
	subscribers	lines	
secondary cable network	100 %	50.0 %	50.0 %
main cable network	40 %	28.5 %	71.5 %
saving	60 %	21.5 %	21.5 %

However, this first somewhat approximate saving in the spares has not been found sufficient and there have been evolved methods for further reduction in the spares. In networks constructed on the Ericsson system, two such methods have been employed, *viz.*, connections in parallel and introduction of a supplementary distribution stage in series with the cable distribution cabinets.

As regards the secondary cable network both methods have been used, either by connecting ten pair and distribution points in parallel two by two, or by subdividing the distribution area into smaller districts and placing sub-cabinets in them. In the latter case, the cables from the end distribution points, then termed tertiary cables, are first grouped into sub-cabinets where they are jumpered over to secondary cables, these cables being run from the sub-cabinets to the usual distribution cabinets.

In the main cable networks only connections in parallel have been used, these connections being made between adjacent cable distribution cabinets. The second method with the insertion of a supplementary cabinet has on the other hand been applied only in exceptional cases, these collecting cabinets or kiosks being rather unwieldy, if they are to accommodate all the lines from the different cable distribution cabinets. It is only recently that this method has been applied and then only in modified form, *i. e.*, merely a limited number of the lines from each common distribution cabinet have been taken into the collecting cabinet, termed *buffer cabinet.* This cabinet may then be made of a size convenient for installation and operation.

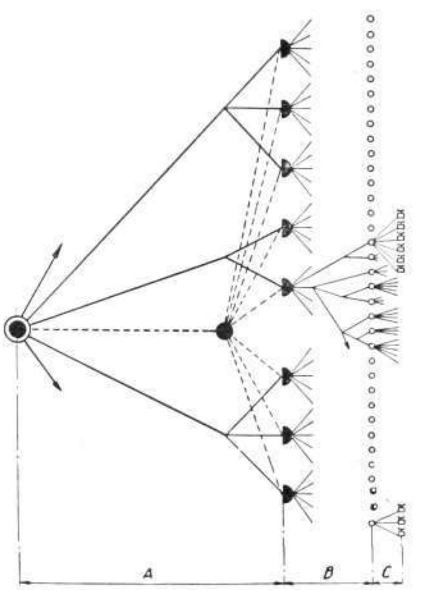


Fig. 5 X 3672

Skeleton diagram of the Ericsson network-construction system, with buffer cabinets

- exchange
- buffer cabinet
- cable-distribution cabinet
- end-distribution point
- subscriber's instrument

The Buffer-Cabinet System

The new method is based on the placing of buffer cabinets, Fig. 5 and 6, in certain points of the network where main cables from a number of distribution cabinets come together. One part of the main cables from the distribution cabinets subordinated to such a buffer cabinet is run direct to the exchange, as previously described. The rest of the main cables are connected via the buffer cabinet. The method is best illustrated by an example. For this purpose, we consider the area on Fig. 6. There are eight cable distribution cabinets in this area, and we shall now follow the development of the main cable network of same during a period of ten years, first without buffer cabinets, and later with these cabinets inserted. The increase in subscribers is shown in the following table.

	subscribers									
year	1	2	3	4	5	6	7	8	9	10
cabinet 1	128	145	163	183	205	228	245	263	285	300
2	—	—	—	16	50	108	163	205	253	285
3	6	23	40	56	78	105	127	160	206	230
4	30	62	105	135	153	178	205	206	214	220
5	81	94	107	120	130	141	154	166	184	205
6	—	—	—	—	—	10	36	59	110	155
7	59	67	72	75	81	83	87	94	122	138
8	—	—	—	—	—	—	—	15	35	65
total	304	391	487	585	697	853	1 017	1 168	1 409	1 598

A graphic figure of the increase in subscribers is represented on Fig. 7.

For the development of the network the following two assumptions may be made:

1. between the exchange and the point where the buffer cabinet is to be placed the extensions are made in stages of 600 pairs, this cable size having proved the most economical on main routes, both in respect of reasonable cable cost and of the cost of the underground conduits;

2. between the buffer cabinet and the distribution cabinet the extensions are made in stages of 100 pairs at a time, this figure also having proved the most economical for distribution cabinets of a maximum of 300 pairs to be used here.

Basing on these assumptions, the development without buffer cabinets and with the same will proceed according to Fig. 8, which shows how the network increases each year for the two alternatives.

The advantages derived from the system with buffer cabinets are obvious. In the older system the spares are not available for distribution over the whole district concerned but are confined to each distribution cabinet. As a result, as soon as the subscriber increase in one of the distribution cabinets exceeds one hundred, even if the excess be only a few subscribers, then one hundred new pairs in the main cables will have to be reserved all the way from the distribution cabinet to the exchange. In this manner, it will be necessary to run new 600 pair main cables from the exchange to the buffer point in the following stages: the first cable the first year; the second cable the third year; the third cable the sixth year and finally the fourth cable the ninth year. Between the buffer point and the different distribution cabinets new 100 pair cables are run each time the subscriber increase exceeds one hundred in each separate distribution area.

In the system with buffer cabinets, a number of the main cables from the exchange, *viz.*, 300 pairs, is connected via these buffer cabinets and these are thus available for distribution to any one of the distribution cabinets in the district.

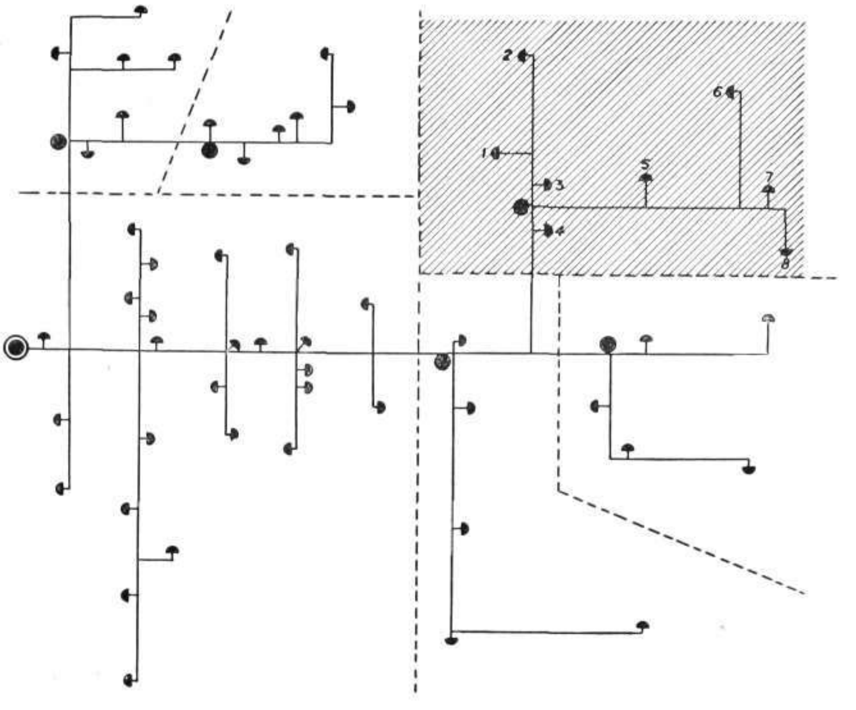


Fig. 6 X 5339

Plan of main cable network with buffer cabinets in the exterior sections

- exchange
- buffer cabinet
- cable-distribution cabinet
- end-distribution point
- subscriber's instrument

Consequently when the subscriber increase in one of the distribution cabinets exceeds one hundred, it will not be necessary to reserve 100 new pairs all the way to the exchange, it being sufficient to reserve this group only between the distribution cabinet and the buffer cabinet. Not until the hundred pairs concerned are almost fully taken up by subscribers, is a new group of hundred pairs connected up in the cables between the buffer point and the exchange. In this manner, new 600-pair cables will be run on this route in the following stages: the first cable the first year; the second cable the fifth year; the third cable the ninth year. A fourth 600-pair cable will not be necessary at all in the ten year period, since at the end of this period there will still be a considerable number of spares in the three previous cables. The requirement of 100-pair cables between the buffer point and the different distribution cabinets will be exactly the same as in the previous case, however.

The sequence of development on the system with buffer cabinets will be as follows. In the first 600-pair cable from the exchange *e. g.* 300 pairs are connected in suitable manner to the buffer cabinet, this number being sufficient for the whole period concerned. Also each first 100-pair cable from each distribution cabinet is connected to the buffer cabinet. Thereafter, as soon as one of the distribution cabinets has to be extended by 100 pairs, a new cable is run from the distribution cabinet to the buffer point and connected through over a direct cable to the exchange. Those subscribers who were previously connected via the buffer cabinet are jumpered over to the direct cable. Thus the 100-pair cable connected to the buffer cabinet becomes free to take up once more increases in subscribers until the next hundred is reached. Then the movement is repeated. Consequently no rearrangement of the joints, either on the 300-pair cable between the buffer cabinet and the exchange or on the 100-pair cables between the buffer cabinet and the distribution cabinets, is needed. Not until a distribution cabinet has been loaded to its maximum capacity, *viz.*, 300 pairs, has the corresponding 100-pair cable via the buffer cabinet to be rearranged for through connection direct to the exchange.

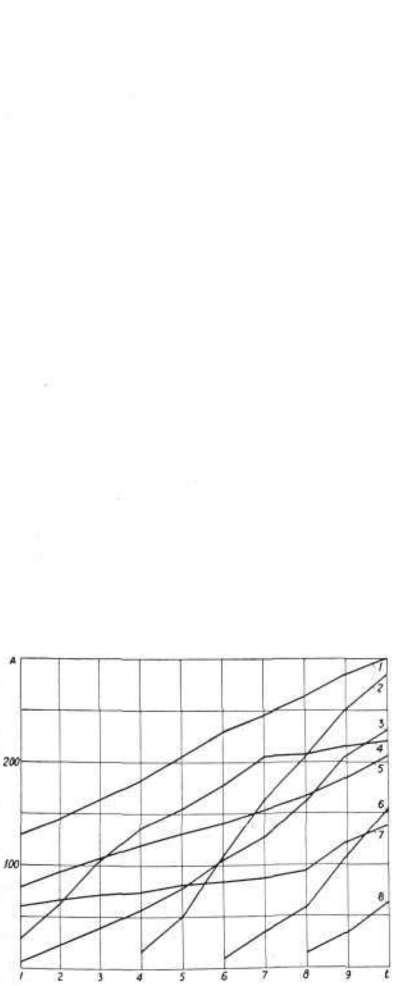


Fig. 7 X 3673

Subscribers connected to cable-distribution cabinets 1 to 8 during a ten-year period

Thus, the result of the new construction method will be a saving in cable circuits on the distance between the exchange and the buffer point, while the requirements of cable between this point and the different distribution cabinets will be exactly the same as in the construction method without buffer cabinets.

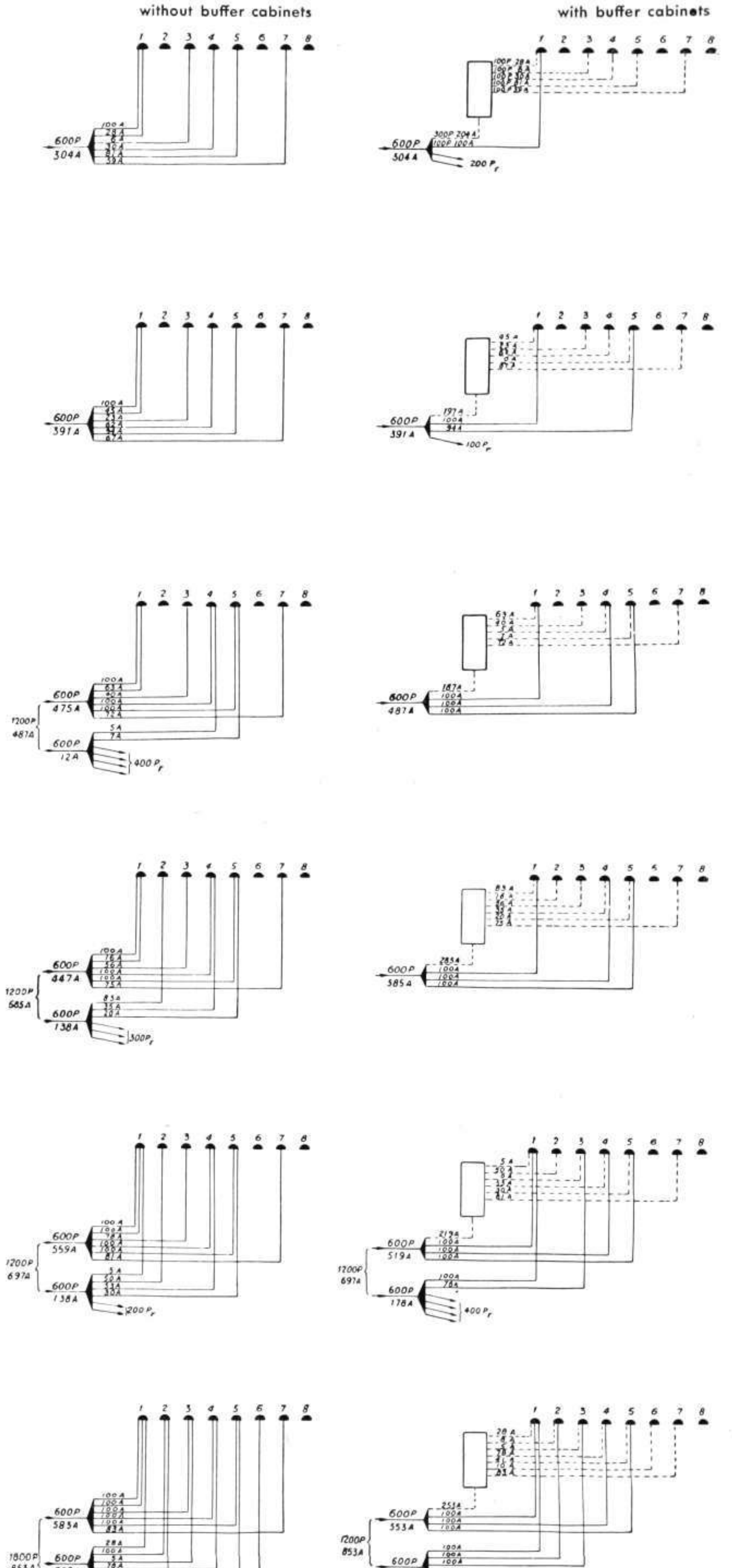


Fig. 8 X 5340

Development of the main cable lines connected to cable-distribution cabinets 1 to 8 during a ten-year period

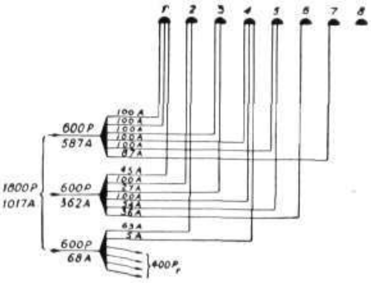
A subscribers

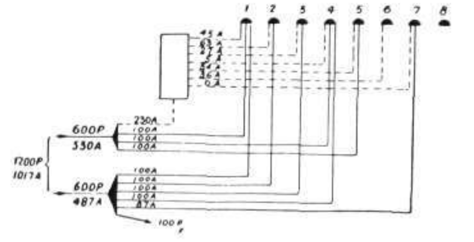
P installed lines

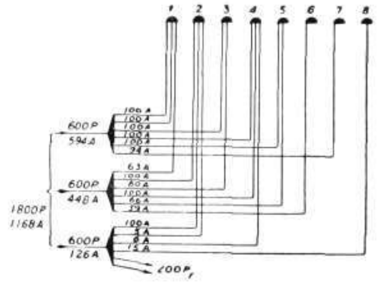
Pr spare lines

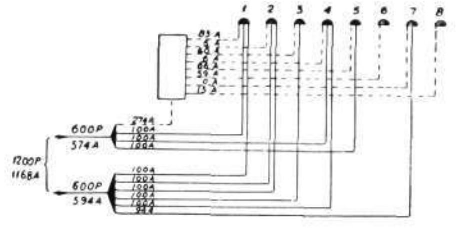
without buffer cabinets

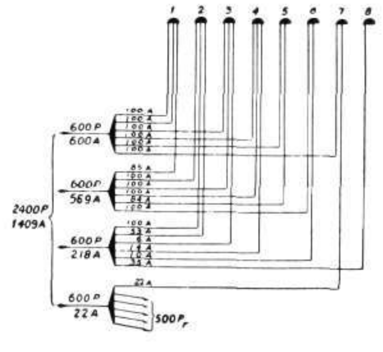
with buffer cabinets

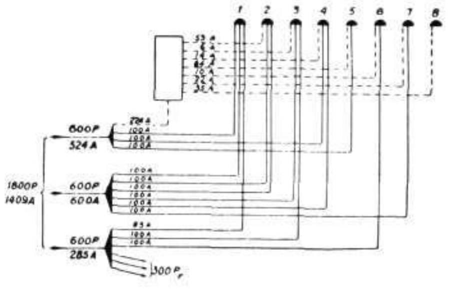


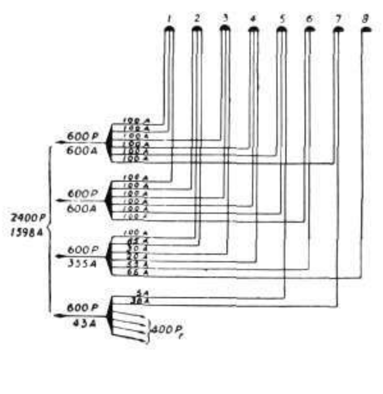


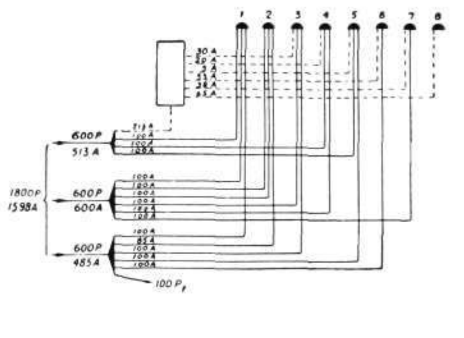












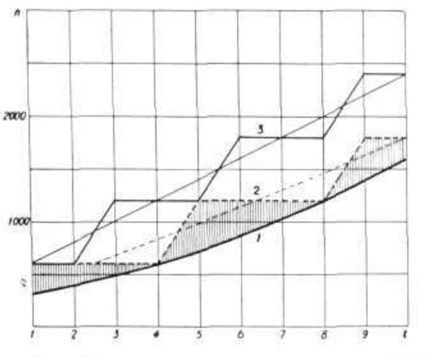


Fig. 9 X 3674

Number of subscribers and installed lines in the main cable network between the exchange and the buffer point

1 subscribers
2 installed lines, with buffer cabinets
3 installed lines, without buffer cabinets

Fig. 9 shows a diagram of the development of the main cables in the example chosen, without buffer cabinets and with them; it can be seen from this diagram how considerable a saving in main cables may be attained by the use of buffer cabinets. A purely theoretical calculation shows that the reduction of spares in the main cables between the exchange and the buffer point can amount to from 20 to 30 %. In the practice, for new networks which on the first surveying were destined for the introduction of buffer cabinets, this figure may amount to 20 %, and in older networks which have been completed without provision for buffer cabinets the insertion of these later can give a saving of up to 15 %. *Thus in a network developed on the Ericsson system the ratio of utilisation for the main cables from the exchange, which previously was about 70 % can by the use of buffer cabinets be increased to 85 %.* For comparison, a corresponding curve has been traced on the diagram, Fig. 4.

This increase of the ratio of utilisation results naturally in considerable savings which apply not only to the cable costs themselves but also the costs of the corresponding conduits and exchange equipment. Besides these savings other advantages are obtained thanks to the arrangement with two routes to each distribution cabinet, *viz.*, the one direct from the exchange and the other via the buffer cabinet. When cable faults occur it permits of obtaining a test loop of good quality and of jumpering over particularly important subscribers from one route to the other. On the other hand, there will be the extra cost for the buffer cabinets and the necessary manholes as well as the costs due to the introduction of a new connection point in all the lines run via the buffer cabinet and the costs arising in the jumpering over of each group of 100 pairs from a cable via the buffer cabinet to a direct cable. If these extra expenses are weighed against the savings mentioned it will be found that the farther from the exchange the buffer point is situated the greater the resulting gain will be. Consequently the method is most suitable in the outer sections of a network. On the contrary, in the central parts of the network, the insertion of buffer cabinets is, as a rule, not an advantage. Investigation has shown that the distance between the exchange and the buffer point for buffer cabinets of the above-mentioned magnitude should be at least 600 m. However, the method may also be easily used in small networks, *viz.*, if smaller buffer cabinets are used, the minimum distance then also being reduced.

Since the method with buffer cabinets has been in practice for only a short period, it is too early as yet to set up any general rules governing the dimensions suitable for the buffer cabinets, how many distribution cabinets should be connected to a buffer cabinet and how large a cable should be connected up to same. Therefore, before a buffer cabinet is installed an economic calculation should be made for each special case. Nevertheless, it may be suggested that buffer cabinets should not be installed for fewer than four distribution cabinets. Further, it has been found that the following numbers of lines from the exchange should be connected up in the buffer cabinet: 200 pairs for a buffer cabinet controlling four 300-pair distribution cabinetes, 300 pairs for six and 400 pairs for eight 300-pairs distribution cabinets. Finally, it may be mentioned that the method concerned has begun to be introduced in the Ericsson local networks in Mexico with good results already.

Reliability and Maintenance at the Stockholm Automatic Exchanges 1931—1935

A. LIGNELL, DIRECTOR OF TELEPHONES, STOCKHOLM

In Ericsson Review No 2, 1934, particulars of reliability and operating costs at the Stockholm automatic exchanges for the period 1931—1933 were given. Below are given similarly detailed particulars for the year 1935, with the yearly results for the period 1931—1934 included in the tables for the sake of comparison. As the exchanges by 1935 had been in operation for 12, 7 1/2, 7, 4 1/2, 3 3/4, and 2 3/4 years respectively, it is possible from the results obtained to form a trustworthy judgment of the operating reliability and the maintenance costs of the Ericsson automatic system.

Reliability

Table I shows the reliability in 1935. In all 756 286 calls made by subscribers themselves were checked during the year and of these there were
98.275 % without fault,
1.541 % fault of caller,
0.037 % fault of manual exchange operator,
0.147 % lost because of technical fault at the automatic or manual exchanges, on lines or instruments or for reason not localised.
Faults in technical devices and for reasons not localised — for all exchanges an average of 0.147 % — were, for the individual exchanges:

	calls checked	fault %	exchanged opened	
Norra Vasa	95 178	0.076	January	1924
Kungsholmen	102 504	0.206	July	1928
Centralen	159 663	0.279	January	1929
Söder	151 982	0.047	July	1931
Södra Vasa	90 183	0.043	March	1932
Östermalm	156 776	0.173	April	1933

As regards »Centralen» the percentage, though even here exceedingly slight, is the greatest chiefly due to the fact that this exchange has the largest traffic with exchanges still operated manually.

Table II shows the reliability for all the exchanges for the years 1931—1935. In 1931 faultless calls amounted to 96.355 % of the number of connections checked; this percentage rose to 98.275 in 1935. The number of completed connections with answer rose in the same period from 79.179 to 80.229 %, the number of unanswered calls diminished from 8.518 to 8.075 % and the number of engaged subscribers rose from 8.658 to 9.971 %. Fault of subscriber which comprises the greater part of the fault percentage fell from 3.323 % in 1931 to 1.541 % in 1935, a natural consequence of the greater familiarity of the users with automatic traffic as time went on. Operator fault constituted about the same low percentage at the beginning as at the close of the period. On the other hand, fault in technical devices at automatic and manual exchanges, on lines and instruments and for reasons unlocated sank from 0.281 % in 1931 to 0.147 % in 1935. It should here be noted that this fault percentage diminished as manually operated exchanges were reduced in number and during the last three years, with the number

Table I Reliability Check at Stockholm Automatic Exchanges 1935

exchange	opened	calls checked	faultless connections: calls established	faultless connections: number altered, vacant or cut off	faultless connections: no reply	faultless connections: busy	faultless connections: total	fault of subscriber	fault of operator	fault in technical devices or for cause not localised: localised: to home exchange	localised: to another exchange	localised: to line or instrument	localised: total	not localised	total
Norra Vasa	Jan. 1924	95 178	76 397	541	7 380	9 049	93 376	1 684	55	20	16	5	41	31	72
%			80.268	0.568	7.754	9.507	98.097	1.769	0.058	0.021	0.017	0.005	0.043	0.033	0.076
Kungsholmen	June 1928	102 504	79 901	531	9 249	10 675	100 356	1 905	32	107	17	4	128	83	211
%			77.949	0.518	9.023	10.414	97.904	1.858	0.031	0.104	0.017	0.004	0.125	0.081	0.206
Centralen	Jan. 1929	159 663	127 645	1 031	12 559	16 362	157 597	1 585	35	89	21	—	110	336	446
%			79.947	0.645	7.866	10.248	98.706	0.993	0.022	0.056	0.013	—	0.069	0.210	0.279
Söder	July 1931	151 982	122 871	824	10 827	14 719	149 241	2 602	68	35	7	1	43	28	71
%			80.846	0.542	7.124	9.684	98.196	1.712	0.045	0.023	0.004	0.001	0.028	0.019	0.047
Södra Vasa	Mar. 1932	90 183	70 576	604	8 060	9 183	88 423	1 669	52	14	6	4	24	15	39
%			78.259	0.670	8.937	10.183	98.049	1.851	0.057	0.016	0.007	0.004	0.027	0.016	0.043
Östermalm	Apr. 1933	156 776	124 893	946	12 998	15 421	154 258	2 204	43	60	34	30	124	147	271
%			79.663	0.604	8.291	9.836	98.394	1.406	0.027	0.038	0.022	0.019	0.079	0.094	0.173
total		756 286	602 283	4 477	61 073	74 409	743 242	11 649	285	325	101	44	470	640	1 110
%			79.637	0.592	8.075	9.971	98.275	1.541	0.037	0.043	0.013	0.006	0.062	0.085	0.147

Table II Reliability Check at Stockholm Automatic Exchanges 1931—1935

year	connections checked	faultless connections: calls established	faultless connections: number altered, vacant or cut off	faultless connections: no reply	faultless connections: busy	faultless connections: total	fault of subscriber	fault of operator	fault in technical devices or for cause not localised: localised: to home exchange	localised: to another exchange	localised: to line or instrument	localised: total	not localised	total
1931 4 automatic exchanges 63 556 subscribers	241 466	190 078	1 113	20 568	20 906	232 665	8 024	99	247	55	14	316	362	678
%		78.718	0.461	8.518	8.658	96.355	3.323	0.041	0.102	0.023	0.006	0.131	0.150	0.281
1932 5 automatic exchanges 84 908 subscribers	434 403	345 113	2 720	35 231	38 207	421 271	12 019	152	334	90	16	440	521	961
%		79.446	0.626	8.111	8.795	96.977	2.767	0.035	0.077	0.021	0.003	0.101	0.120	0.221
1933 6 automatic exchanges 100 956 subscribers	644 830	520 214	4 102	48 375	58 957	631 648	12 037	231	322	73	21	416	498	914
%		80.675	0.636	7.502	9.143	97.956	1.866	0.036	0.050	0.012	0.003	0.065	0.077	0.142
1934 6 automatic exchanges 101 726 subscribers	690 277	551 271	4 183	54 677	67 088	677 219	11 714	320	310	84	44	438	586	1 024
%		79.862	0.606	7.921	9.719	98.108	1.697	0.047	0.045	0.012	0.006	0.063	0.085	0.148
1935 6 automatic exchanges 104 523 subscribers	756 286	602 283	4 477	61 073	75 409	743 242	11 649	285	325	101	44	470	640	1 110
%		79.637	0.592	8.075	9.971	98.275	1.541	0.037	0.043	0.013	0.006	0.062	0.085	0.147
1931—1935 total	2 767 262	2 208 959	16 595	219 924	260 567	2 706 045	55 443	1 087	1 538	403	139	2 080	2 607	4 687
%		79.825	0.600	7.947	9.416	97.788	2.004	0.039	0.055	0.015	0.005	0.075	0.094	0.169

of automatic exchanges unchanged, has remained practically unaltered. Of the 2 767 262 calls checked in the period 1931—1935 there were 4 687 faulty or 0.169 %, while 44.4 % of the faults were located and remedied in the course of the check.

The reliability as may be seen is extraordinarily good and has improved with the progress of automatisation. The age of the exchanges has not had any adverse effect whatever on the extremely good functioning of the automatic system.

Fault Frequency

Table III shows the fault frequency for the exchanges for each year of the five year period, totally, per 10 000 calls, per subscriber's line and per day.

Table IV gives the number of faults in the automatic system per 10 000 calls and per day for each exchange, both for the whole period and for the last year of the period for the sake of comparison. The number of faults per 10 000 calls has diminished and has in the last year of the period displayed a minimum which is evidence of the reliable functioning of the system and the effective maintenance. The fault figures are remarkably low and should be looked at in conjunction with the extraordinary reliability during the time. As witness of the efficiency of the maintenance it can be stated that during 1934 there were 93.6 % and during 1935 there were 93 % of the faults observed on the first investigation which were remedied. Thus there were

Table III **Fault Frequency at Stockholm Automatic Exchanges 1931—1935**

exchange	year	average subscribers lines during year	outgoing calls during year	faults during year: in automatic equipment				faults during year: in exchange devices outside automatic equipment		
				total	per 10 000 outgoing calls	per sub-scribers line	per day	total	per sub-scribers line	per day
Centralen	1931	14 944	51 872 910	1 579	0.30	0.11	4.3	1 568	0.10	4.3
	1932	16 495	68 719 323	1 979	0.29	0.12	5.4	865	0.05	2.4
	1933	16 083	74 284 443	2 906	0.39	0.18	8.0	687	0.04	1.9
	1934	16 178	80 935 756	2 034	0.25	0.13	5.6	523	0.03	1.4
	1935	15 986	87 043 355	1 557	0.18	0.10	4.3	501	0.03	1.4
Kungsholmen	1931	12 834	23 325 540	947	0.41	0.07	2.6	729	0.06	2.0
	1932	14 576	26 830 717	1 156	0.43	0.08	3.2	498	0.03	1.4
	1933	15 437	28 363 718	1 052	0.37	0.07	2.9	733	0.05	2.0
	1934	16 205	30 571 203	810	0.27	0.05	2.2	576	0.04	1.6
	1935	17 113	34 006 607	991	0.29	0.06	2.7	367	0.02	1.0
Söder	1931	—	—	—	—	—	—	—	—	—
	1932	25 911	47 450 109	1 960	0.41	0.08	5.4	872	0.03	2.4
	1933	25 594	46 786 226	1 484	0.32	0.06	4.1	764	0.03	2.1
	1934	25 416	48 624 102	1 269	0.26	0.05	3.5	427	0.02	1.2
	1935	25 930	51 190 806	989	0.19	0.04	2.7	356	0.01	1.0
Södra Vasa	1931	—	—	—	—	—	—	—	—	—
1/4—31/12	1932	19 719	26 014 350	701	0.27	0.04	2.6	564	0.03	2.1
	1933	20 072	35 001 584	1 262	0.36	0.06	3.5	488	0.02	1.3
	1934	20 370	37 882 211	958	0.25	0.05	2.6	357	0.02	1.0
	1935	20 631	40 236 161	797	0.20	0.04	2.2	292	0.01	0.8
Östermalm	1931	—	—	—	—	—	—	—	—	—
	1932	—	—	—	—	—	—	—	—	—
1/4—31/12	1933	16 629	29 181 490	1 102	0.38	0.07	4.0	600	0.04	2.2
	1934	16 972	41 129 454	890	0.22	0.05	2.4	292	0.02	0.8
	1935	18 201	44 789 725	734	0.16	0.04	2.0	283	0.02	0.8

Table IV Fault Frequency at Stockholm Automatic Exchanges 1931—1935

exchange	year	calls		faults per 10 000 calls in automatic equipment		faults per day			
						in automatic equipment		in exchange devices outside the automatic equipment	
		whole period	1935	whole period	1935	whole period	1935	whole period	1935
Centralen	1931—1935	362 855 787	87 043 355	0.277	0.18	5.5	4.3	2.3	1.4
Kungsholm	1931—1935	143 097 785	34 006 607	0.346	0.29	2.7	2.7	1.6	1.0
Söder	1932—1935	194 051 243	51 190 806	0.294	0.19	3.9	2.7	1.7	1.0
Södra Vasa	$^1/_4$1932—1935	139 134 306	40 236 161	0.267	0.20	2.7	2.2	1.2	0.8
Östermalm	$^1/_4$1933—1935	115 100 669	44 789 725	0.237	0.16	2.7	2.0	1.2	0.8

Table V Maintenance Costs at Stockholm Automatic Exchanges 1931—1935

exchange	year	average subscribers lines during year	cost of labour, including night work, holidays and off duty				cost of material		total maintenance cost	average per connected subscribers line and year						maintenance cost per 100 calls
			staff[1]										cost of material			
			male	female	working hours		within automatic system	outside automatic system		number of staff	working hours	cost of labour	within automatic system	outside automatic system	total maintenance cost	
						Kr.	Kr.	Kr.	Kr.			Kr.	Kr.	Kr.	Kr.	Kr.
Centralen																
	1931	14 944	13	5	42 122	63 589: —	5 435: —	8 789: —	77 813: —	0.00120	2.82	4: 25	0: 36	0: 59	5: 20	0: 150
	1932	16 495	13	5	41 602	63 630: —	3 285: —	5 096: —	72 011: —	0.00109	2.52	3: 86	0: 20	0: 31	4: 37	0: 105
	1933	16 083	13	5	41 750	62 322: —	1 004: —	2 010: —	65 336: —	0.00112	2.60	3: 88	0: 06	0: 13	4: 07	0: 088
	1934	16 178	13	4	41 251	61 632: —	4 440: —	2 019: —	68 091: —	0.00111	2.55	3: 81	0: 27	0: 12	4: 20	0: 084
	1935	15 986	14	5	42 933	64 842: —	538: —	6 308: —	71 688: —	0.00119	2.68	4: 06	0: 03	0: 39	4: 48	0: 082
Kungsholmen																
	1931	12 834	9	4	29 828	45 042: —	2 342: —	1 300: —	48 684: —	0.00101	2.32	3: 51	0: 18	0: 10	3: 79	0: 209
	1932	14 576	9	4	30 293	46 961: —	1 663: —	1 756: —	50 380: —	0.00089	2.08	3: 22	0: 11	0: 12	3: 45	0: 188
	1933	15 437	11	4	34 297	50 055: —	808: —	678: —	51 541: —	0.00097	2.22	3: 25	0: 05	0: 04	3: 34	0: 182
	1934	16 205	12	4	36 356	52 356: —	1 649: —	495: —	54 500: —	0.00099	2.24	3: 23	0: 10	0: 03	3: 36	0: 184
	1935	17 113	12	4	36 881	53 880: —	297: —	2 058: —	56 235: —	0.00093	2.15	3: 15	0: 017	0: 12	3: 28	0: 165
Söder																
	1932	25 911	14	5	46 249	66 689: —	1 765: —	5 934: —	74 388: —	0.00073	1.81	2: 57	0: 07	0: 23	2: 87	0: 157
	1933	25 594	14	5	46 931	65 255: —	861: —	1 238: —	67 354: —	0.00074	1.84	2: 54	0: 03	0: 05	2: 62	0: 144
	1934	25 416	14	5	46 105	66 229: —	2 984: —	1 008: —	70 221: —	0.00075	1.81	2: 60	0: 12	0: 04	2: 76	0: 144
	1935	25 930	12	5	41 380	60 017: —	364: —	2 437: —	62 818: —	0.00066	1.59	2: 32	0: 013	0: 09	2: 42	0: 123
Södra Vasa																
$^1/_4$-$^{31}/_{12}$	1932	19 719	12	2	26 458	39 572: —	1 133: —	1 080: —	41 785: —	0.00071	1.34	2: —	0: 06	0: 05	2: 12	0: 161
	1933	20 072	12	4	38 323	53 106: —	233: —	927: —	54 266: —	0.00079	1.91	2: 65	0: 01	0: 04	2: 70	0: 155
	1934	20 370	12	4	39 656	53 591: —	1 927: —	909: —	56 427: —	0.00079	1.94	2: 63	0: 09	0: 04	2: 76	0: 149
	1935	20 631	12	4	39 436	54 420: —	385: —	1 143: —	55 948: —	0.00078	1.91	2: 63	0: 018	0: 06	2: 71	0: 139
Östermalm																
$^1/_4$—$^{31}/_{12}$	1933	16 629	13	4	27 359	42 919: —	436- —	550: —	43 905: —	0.00102	1.65	2: 58	0: 03	0: 03	2: 64	0: 150
	1934	16 972	13	4	39 797	60 593: —	2 087: —	222: —	62 902: —	0.00100	2.34	3: 57	0: 12	0: 01	3: 70	0: 153
	1935	18 201	12	5	38 964	58 365: —	289: —	1 341: —	59 995: —	0.00093	2.14	3: 21	0: 015	0: 07	3: 29	0: 134

[1] *The male staff attend to the fault section and the distribution frames (which occupy 3 men at each of the above-named exchanges) and all work in the selector halls and other exchange equipment, as also the power house.*
The female staff is employed on cleaning the automatic devices taken out, and for cleaning of the premises (also for washing the floors).

only 6.4 and 7 % of these faults respectively which disappeared without the location of the fault being determined and its cause removed.

»Norra Vasa» exchange is not included in the tables of fault frequency and maintenance, since calls from manual exchanges there were for a large portion of the period dealt with over manual B-positions, so that the results are not comparable. The reliability of this exchange, however, as shown by table I, is of the same quality as the other exchanges.

Maintenance

Table V shows the maintenance costs at the exchanges for each year of the period 1931—1935, totally, per subscriber and per 100 calls. The maintenance and operating staff at all the five exchanges during 1935, with an average of 97 861 subscribers, numbered 85 persons or per 1 000 subscribers 0.87 persons, 0.63 male and 0.24 women. During the same year the staff numbered, per one million calls,

Centralen	0.218 of whom	0.161 male and	0.057 female
Kungsholmen	0.471	0.353	0.118
Söder	0.332	0.234	0.098
Södra Vasa	0.398	0.299	0.099
Östermalm	0.380	0.268	0.112

During 1935 the following particulars applied on the average to all the exchanges, per subscriber and year

working hours	2.04
working costs	Kr. 2.98
maintenance costs (material and labour)	Kr. 3.13

The cost of maintenance (material and labour) per 100 calls was Kr. 0.119. If the average cost for reliability supervision at all exchanges, Kr. 0.020 per 100 calls, be added there is obtained a total maintenance and operation cost (cost for energy not included) of Kr. 0.139 per 100 calls.

Evidence of the accurate workmanship in the Ericsson automatic system and of the stable functioning of the 500 line selector system is the small need for trained fitters to ensure first class operation. The busy »Centralen» exchange with an average of 15 986 subscribers and about 2.2 calls per subscriber per hour in peak periods had thus in 1935 — the seventh year of operation — 0.161 male fitters for each million calls; the number of fitters per 1 000 subscribers was 0.880. For all the exchanges together these figures were 0.241 and 0.63 respectively. It should be observed that these fitters, in addition to all work in the selector halls, attended to the fault section of the exchange, work on the distribution frames, the power supply and night duty.

These operating results, however, do not only demonstrate the good functioning of the automatic system but are also evidence of an efficient and economic management of operation as well as of the staff's ability and interest in their work.

Table VI
Energy consumption for machine drive and battery charging at Stockholm automatic exchanges 1935

exchange	kWh per subscriber			cost per subscriber Kr.
	machine drive 220 V	battery charging 48 V	total	
Centralen	1.44	—[1]	—[1]	—[1]
Kungsholmen	1.20	2.68	3.88	0.230
Söder	0.73	2.14	2.87	0.165
Södra Vasa	0.66	2.26	2.92	0.166
Östermalm	1.02	3.06	4.08	0.235

[1] »Centralen» has a battery in common with the trunk and suburban traffic exchanges installed in the same building.

Measuring Accuracy in Adjustment and Checking of Electricity Meters

A. GARTNÄS, TELEFONAKTIEBOLAGET L.M. ERICSSON, STOCKHOLM

In the Ericsson Review No 1, 1936, a description was given of the most usual methods of adjustment for electricity meters. The present article deals with the different kinds of errors attached to the measurements by the various adjustment methods. In addition the limits are defined within which measuring accuracy lies, with special reference to the lowest error which in general can be guaranteed.

By *measuring accuracy* is meant the accuracy by which a magnitude — *e. g.* load — can be measured. The measuring accuracy is consequently subject both to *objective* and *subjective* error. To the former belong indication error in the instruments employed, error in measuring method, etc., and to the latter reading error, reaction error etc.

By *error* is meant the difference between the figure given by the measuring instrument and the true value. Incorrect indication is recorded as a rule in per cent. It is not, however, sufficient to give the per cent of error, it must be stated besides whether the error refers to the nominal value or to the true value corresponding to the reading. By *nominal value* is designated the figure given on the measuring instrument's cover plate. In similar way one can speak of nominal current, nominal voltage, nominal frequency and so on; for ammeters the nominal value is thus represented by nominal current, for voltmeters by nominal voltage, for wattmeters by nominal current and nominal voltage etc.

With am-, volt- and wattmeters, or with indicator instruments in general, the error is usually given in percentage of nominal value or, which amounts to the same thing, in percentage of full deflection. With kilowatt-hour, ampère-hour, kilovar-hour the indication error is normally recorded in percentage of the true value. Indication error may be positive as well as negative. If the figure given by the instrument is above the true value then the error is positive, and it is negative if the figure indicated is lower than the true value. When noting errors therefore it must also be recorded whether the error is positive or negative.

To explain the difference between the two ways of noting error, there are reproduced in Fig. 1 curves of the maximum error — the error in both cases is ± 0.3 % — the error in one cases relating to mark value and in the other case to true value. From the diagram it can be seen that a certain per cent of error displays an entirely different significance according as it relates to nominal value or to true value.

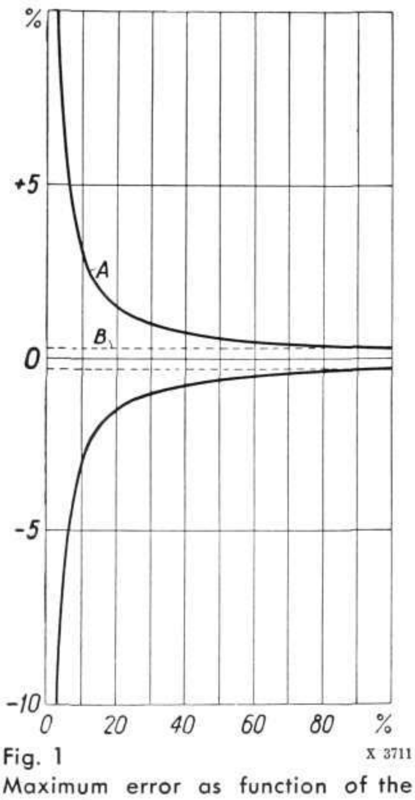


Fig. 1
Maximum error as function of the true value

A maximum error ± 0,3 % of nominal value
B maximum error ± 0.3 % of true value

The demands on low error with electricity meters have in recent years appreciably increased. This applies particularly to electricity meters destined for metering large amounts of energy. It often occurs that the suppliers of electricity in their eagerness to furnish their clients with good meters, are so exacting regarding low error in their conditions of delivery that a responsible maker is compelled to forego the order, unless he can succeed in convincing the buyer of the unreasonableness of his demands.

The error can be divided into two main groups. The first comprises *systematic errors* by which is meant those errors which arise from the construction of the electricity meter and which vary with the current, tension, frequency, etc. The most common systematic errors are current error, tension error, frequency error, phase-shift error, temperature error and untrue suspension error. To the second group of errors belong *adjustment* errors, by which are meant those metering errors due to errors in the measuring instruments employed in adjustment (instrument errors), error in the method of adjustment employed (measuring method error), together with errors arising from faulty reading of the instruments used or from the reaction ability of the person carrying out the adjustment (reading and reaction error).

Adjustment with Stop-Watch and Wattmeter

The instrument errors to be reckoned with in this method of adjustment are wattmeter error and error in stop-watch. According to VDE norms the maximum indication error in a wattmeter class E, the highest, may attain ± 0.3 % of the full deflection (nominal load).

If the error of the wattmeter is determined by means of compensator and the correction curve plotted, the wattmeter's error is known to an accuracy of ± 0.1 % of nominal value (full deflection), provided always that the wattmeter correction curve is determined at the place of use, so that the meter is not exposed to disturbance in transport and that the same series resistance is used, while the same temperature prevails in the room as when the correction curve was determined. Otherwise the error may change very appreciably — for a class E instrument by 0.03 % per 1° C change of temperature and by up to 0.1 % if the series resistance is changed.

Reading error is in the most favourable cases ± 0.1 % of scale division. To attain this great precision in reading, the load must be kept constant, *e. g.* by use of a tension regulator, which maintains the voltage variation within ± 0.05 %.

To check the time a stop-watch is used. The finger of a stop-watch does not move continuously but in jerks. In stop-watches where the whole dial is divided into 30 s and the balance wheel gives 10 oscillations/s the error may for this reason amount to ± 0.1 s. With other stop-watches with dial divided into 60 s and balance wheel making 5 oscillations/s, the corresponding error may attain ± 0.2 s.

The starting of the second finger may be done in various ways. With stop-watches not combined with ordinary time indication, the balance wheel is stopped when the second pointer is not moving but is released on metering. With those stop-watches, however, which are combined with ordinary time giving, the second finger is set in motion by connection of a geared drive to the watch mechanism as it is running. At the instant of starting and stopping, errors arise which can be estimated together to a maximum of ± 0.1 % for watch with balance wheel giving 10 oscillations/s and to 0.2 % for watches with balance wheel giving 5 oscillations/s. A well-regulated stop-watch's running time deviates from the true figure by 5—15 s/day, *i. e.* by about 0.01 %.

Another error arising in stop-watches is due to the second finger not being pivoted in the exact centre of the dial. Fig. 2 shows in a diagram a second finger dial. If the finger were pivoted at the true centre o it would after rotating 180° reach the figure 15 s, but as the finger is now pivoted at another point o_1 the finger after rotating 180° shows the figure $15 + \Delta'_t$

seconds. If the excentricity oo_1 is 0.2 mm and the diameter of the dial is 40 mm so that the revolution corresponds to 30 s then the maximum indication error Δ'_t is about 0.1 s. If the period of observation is selected so that the second finger can stop in the vicinity of the starting point this error can be reduced sufficiently to be neglected.

The maximum indication error of the stop-watch can thus, if a first-class watch is used, be brought down to about $\pm$ 0.2 s, which time consists of the sum of the starting and stopping error together with the error due to the jerky forward movement of the finger.

Another source of error in determining the time lies in observation and reaction errors by the person carrying out the adjustment. The operator has to note and calculate the number of revolutions made by the rotor disc and start the stop-watch the instant the rotor disc index passes a certain point, and stop the watch when the rotor disc has made a certain number of revolutions. This source of error is the most difficult to estimate. The observation and reaction errors in question vary with different persons and may moreover vary in the same person depending on the mental and physical condition in which he may be at the moment of noting the time. With tests made it has been found that, if the time of observation is not too long, the total of observation and reaction errors varies as a rule between 0.1 and 0.2 s if in readiness and between 0.2 and 0.3 s if not prepared for what is to occur. The sum of maximum observation and reaction errors can thus in the best cases be taken as being as low as 0.1 s at the beginning of the time taking and 0.1 s at its close, *i. e.*, a total of 0.2 s.

With a view to reducing observation and reaction errors when checking time, revolution counters have lately been used. These by means of a photo-cell with amplifier start the stop watch, count a certain number of revolutions of the rotor disc and thereupon stop the stop-watch. Good results have been obtained but the apparatus at its present stage is hardly suited for factory production adjustment. On the other hand the apparatus is exceedingly useful for accurate laboratory tests and for adjustment of standard meters.

Nothwithstanding the taking of all the precautionary measures mentioned above and leaving out of account temperature errors and running time errors, the maximum error of the wattmeter may reach $\pm$ 0.1 % of full deflection, the wattmeter's maximum reading error $\pm$ 0.1 scale divisions, the stop-watch error $\pm$ 0.2 s and the maximum obsevervation and reaction errors $\pm$ 0.2 s.

If the deflection read on the wattmeter be α scale divisions and the sum of the wattmeter's indication error and reading error be $\pm F_w$ scale divisions, the maximum error when determining the load will be $\Delta_t = \pm \frac{F_w}{\alpha}$ 100 %. If the time read on the stop-watch be t seconds and the sum of the stop-watch's indication error and observation and reaction errors be F_t seconds, then maximum error in fixing the time is $\Delta_t = \pm \frac{F_t}{t}$ 100 %. The total maximum error when determining the error of the electricity meter may thus attain $\Delta = \pm \left(\frac{F_w}{\alpha} + \frac{F_t}{t}\right)$ 100 %.

If the values given above be introduced in this equation the maximum error for the different values of wattmeter deflection α may be calculated. From Fig. 3, which shows the error as function of the wattmeter deflection α for different times, it can be seen that the maximum adjustment error may be brought down if the time of observation be extended; it is, however, a truth with a modification, for the observation and reaction errors often augment if the time of observation is prolonged over 120 s. Moreover it is difficult

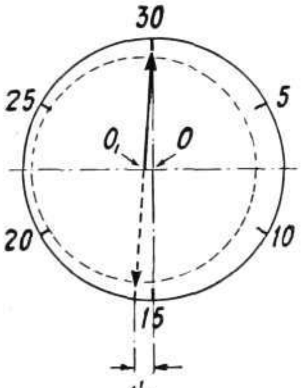


Fig. 2 X 3710
Watch face with excentrically pivoted finger

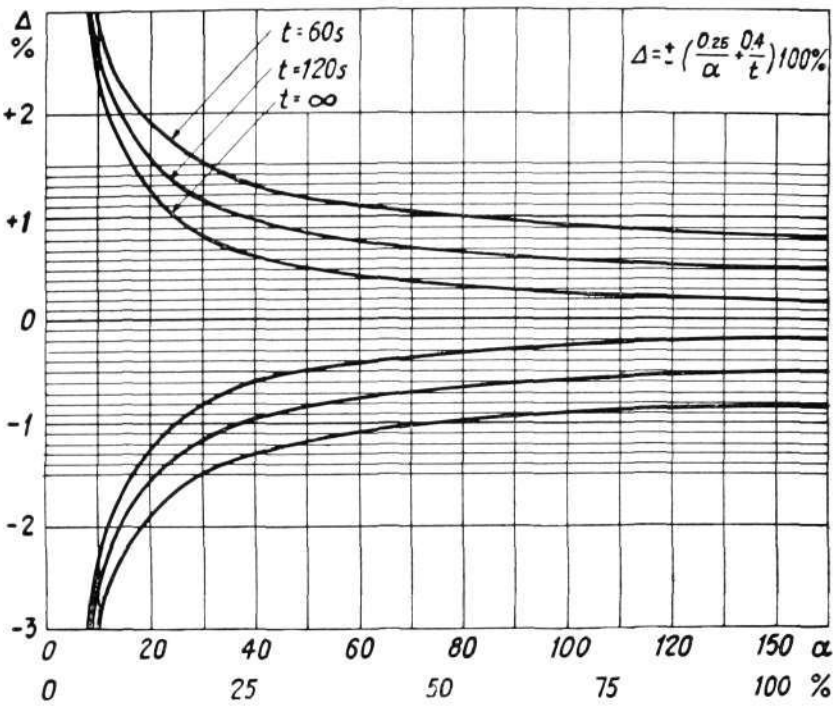


Fig. 3 X 5351
Maximum indication error as function of wattmeter deflection

to maintain the load constant for a lengthy period, which results in increase of the wattmeter's maximum reading error. We can thus take it that *the maximum adjustment error may amount to ± 0.5 % of the true value.*

The above applies when current and voltage are in phase with each other, *i. e.*, when $\cos\varphi = 1$, and when the wattmeter is read in the neighbourhood of full deflection. With $\cos\varphi = 0.5$ on the other hand, when the wattmeter's deflection keeps to around the middle of the scale, the maximum error increases at once to about ± 0.7 % of the true value and to about ± 1.2 % with $\cos\varphi = 0.2$. If a wattmeter is employed which can be overloaded so that it gives full deflection even with different phase shifts, the maximum error can still be set so low as to ± 0.5 % of the true value provided that the indication error $\Delta\,\delta_w$, arising from the angle error of the wattmeter is zero. This, however, is usually the case only when $\cos\varphi = 1$. If the angle error be δ minutes and the phase shift φ degrees then the indication error is $\Delta\,\delta_w = \frac{\delta\cdot\pi}{108}\,\mathrm{tg}\,\varphi\,\%$. With an angle error $\delta = 10'$ then $\Delta\,\delta_w = \pm\,0.5\,\%$ with $\cos\varphi = 0.5$ and $\Delta\,\delta_w = \pm\,1.4\,\%$ for $\cos\varphi = 0.2$. Basing on the angle error it can be understood that measuring with large phase shift may be accompanied by large error.

Even if an electricity meter is thus adjusted before delivery in accordance with what is stated above and the buyer later checks the meter, observing the same accuracy as the factory, it can happen that the values in the factory adjustment record and the buyer's check record differ by 1 %. If moreover the meter be checked with, *e. g.* $\cos\varphi = 0.5$ and $\cos\varphi = 0.2$ it can quite easily happen that the factory and the buyer's measures may differ by about 2 and 5 % respectively, if on the one wattmeter the angle error $\delta = 0'$ and on the other wattmeter the angle error $\delta = 30'$. To the adjustment errors dealt with above must also be added the system errors of the meter, which differ for different makes.

Adjustment with Standard Meter or with Standard Meter and Stroboscope

The maximum adjustment errors for electricity meters adjusted with standard meter or standard meter and stroboscope can naturally not be lower than when wattmeter and stop-watch are used, for the standard meter must be adjusted by wattmeter and stop-watch. To the standard meter's error must then be added the adjustment error due to the fact that the meter to be adjusted can never be set to the same speed as the standard meter. With the synchronous adjustment method employed by Ericsson this additional error does not exceed $\pm$ 0.3 %. The maximum adjustment error for electricity meters adjusted by the Ericsson synchronous method can thus reach $\pm$ 0.8 %. If a standard meter is employed, whose real indication error is $\pm$ 0 %, the maximum adjustment error for the meter to be adjusted with this standard meter will fall within the limits $\pm$ 0.3 %. If, however, the standard meter's real indication error be + 0.5 % the adjustment error will lie between the limits + 0.2 % and + 0.8 %, etc.; there is thus a difference of 0.6 % between the limits.

It should be noted that the maximum indication error can only with great difficulty be kept within the limits $\pm$ 0.5 % when the adjustment is done with wattmeter and stop-watch and that the error often falls outside these limits because of observation and reaction error combined with variation of load; it is however easy, when the standard meter has been adjusted, to keep the maximum indication error within the limits $\pm$ 0.8 % with synchronous adjustment. Moreover a much more even adjustment result is obtained, since the limits of error are not separated by more than 0.6 %, as long as the same standard meter is employed. In addition, one is to a high degree independent of variations in temperature and load, since the standard meter and the meter to be adjusted have the same coefficient of temperature, which is not usually the case with a wattmeter and an electricity meter. From this it is clear that adjustment with standard meter and stroboscope may result in a rise in the maximum error but the limits of error will be nearer each other and a more even adjustment result is obtained.

From the above, which applies generally for single- and three-phase meters and to a great extent also for DC meters, it is evident that it is useless to impose too high demands on the adjustment of electricity meters, since in general it is not possible, even with the best measuring devices, to determine deviations from the true value with greater accuracy than $\pm$ 0.5 %. To this it will certainly be objected by many that such great deviations seldom occur. This may be taken to be true in general, because it does not usually happen that all sources of error are add *i. e.*, have the same sign, but the errors often partially cancel out each other. On the assumptions given above, however, the result is that *the maximum adjustment error can amount to + 0.5 % of the true value.*

High-Frequency Attenuation of Open-Wire Circuits

T. BOHLIN, TELEFONAKTIEBOLAGET L. M. ERICSSON, STOCKHOLM

For the planning of long-distance telephone transmission networks it is necessary to calculate beforehand with suffient accuracy the attenuation of open-wire lines. This problem has already been studied in great detail. However, the results obtained are spread over many sources and it may thus be interesting to make a short survey of the subject.

The investigation which is probably of the greatest value is that made by *E. I. Green* partly on experimental lines built for this purpose and partly on lines operated by the American Telephone & Telegraph Co. The results of this investigation were published in 1930. At the same time *T. Wilson* made a study of the leakance of different types of insulators used on American long-distance lines. Later measurements have been made also in Europe, and here the effects of white-frost were also studied, which was not the case with the American investigations. Finally, certain laboratory tests by *M. Boella* at the university of Milan in 1931 may be noticed; the results of these tests correspond comparatively well with the values obtained by *Green* and *Wilson*, as will be seen below, but give some additional information of interest.

The American lines are to a great extent of the same design throughout the country, while in Europe and other parts of the world lines of several types are found, *i. e.*, lines with iron or wood crossarms and pins, with porcelain or glass insulators and with wire spacing varying from 20 to 40 cm and more. To produce a series of curves showing the attenuation as a function of the frequency for all these types of lines would not be desirable as there would always be cases where the curves would not be satisfactory; the clarity would also be reduced. It is possible, however, to produce curves in such a form that they are applicable to lines of any particular construction.

With a minor approximation the line attenuation may be written as the sum of two terms

$$\beta = \beta_R + \beta_G = \frac{R_\sim}{2} \cdot \frac{1}{Z} + \frac{G}{2} \cdot Z$$

where $R_\sim$ is the ohmic resistance per unit of length, used with its value for the frequency in question and thus including the eddy-current losses in the wires; G is the leakage conductance per unit of length and includes all other losses; Z is the nominal characteristic impedance of the line, normally 525 to 675 ohm or as an average about 600 ohm.

The two terms in the formula for the line attenuation are directly and inversely proportional to the characteristic impedance of the line but they depend also, one only on $R_\sim$, *i. e.*, the wire diameter etc., and the other only on G, *i. e.*, all factors determining the leakage conductance.

It is possible to assume that the characteristic impedance remains constant and equal to 600 ohm and then set up curves for β_R with different wire

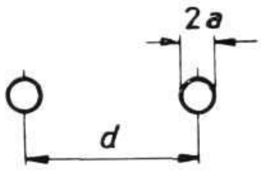


Fig. 1 X 3707
Location of conductors for transposed circuit

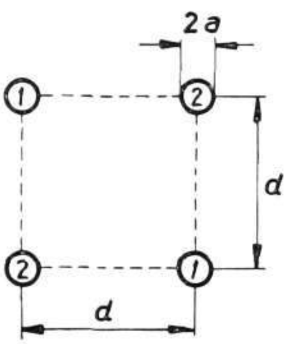


Fig. 2 X 3708
Location of conductors for twisted circuit

diameters and for β_G with different leakances. The attenuation of any line may then be obtained from these curves by calculating the characteristic impedance Z, adjust the curve values β_R and β_G in accordance herewith and add the two terms. The curves, Fig. 3 and 4, are obtained in this manner.

With satisfactory accuracy the characteristic impedance of transposed lines with the conductors in one plane, Fig. 1, may be written

$$Z \cong 120 \ {}^{e}\log \frac{d}{a} \ \text{ohm}$$

where a = wire diameter in cm,
d = wire distance in cm.

For twisted lines with the wires at each end of a diagonal in a square, Fig. 2, the characteristic impedance is

$$Z \cong 120 \left[0.132 + {}^{e}\log \frac{d}{a} \right] \text{ohm}$$

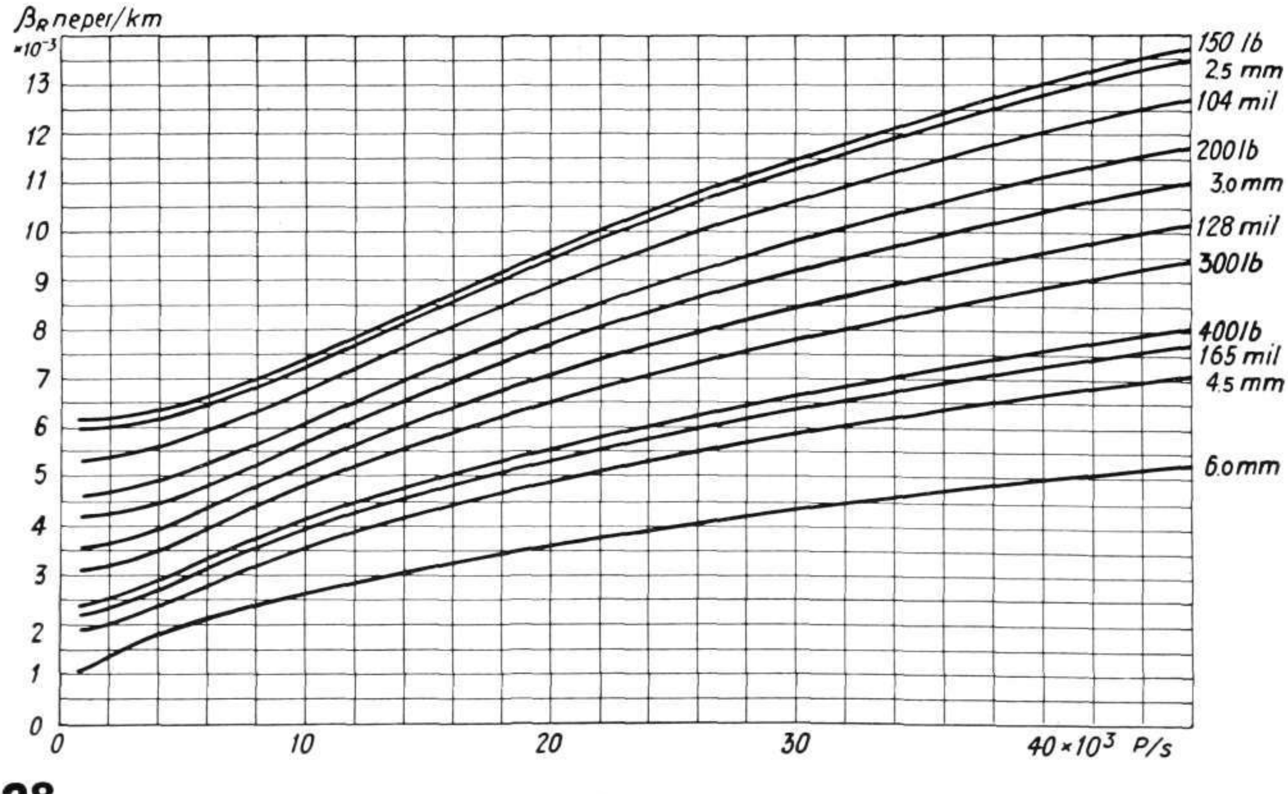
where a = wire diameter in cm,
d = side of square in cm.

These expressions do not take into account the internal field of the conductors or the additional capacity of the insulators. Within the range of interest in our case these errors approximately compensate each other. The curves for β_R are based on values of $R_{\sim}$ drawn from tables calculated by *P. O. Pedersen*. The curves are valid for lines of pure copper ($\varrho = 0.0175$ ohm/m/mm² at 15° C) and with a characteristic impedance of 600 ohm. For other values of ϱ and Z and for other temperatures β_R is corrected in accordance with

$$\beta_{(R t_0 \varrho_0 Z)} = \beta_R \cdot \left[1 + \xi \frac{\rho_0 \left[1 + \alpha (t - 15)\right] - 0.0175}{0.0175} \right] \cdot \frac{600}{Z} \ \text{neper/km}$$

where ξ = a coefficient obtained in Fig. 5,
α = temperature coefficient for DC (for copper 0.004),
ρ_0 = specific resistance for DC in $\frac{\text{ohm}}{\text{m} \cdot \text{mm}^2}$,
t = wire temperature.

Fig. 3 X 7109
Attenuation caused by conductor resistance
for telephone circuits of pure copper, characteristic impedance 600 ohm at 15° C



The correction holds good with insignificant errors for reasonable values of t and ρ_0 but gives errors of 5—10 % if the factor $\frac{\rho_0[1 + \alpha(t - 15)] - 0.0175}{0.0175}$ comes close to unit value.

The temperature t of the wire is generally that of the surrounding air and may be read from the meteorological records. During days with strong sunshine the temperature of the wire may rise slightly above that of the air but according to *Green* the difference is not greater than 5° C.

The curves for β_G are the results of measurements on short experimental lines. The leakance is concentrated at the insulators and consequently β_G is directly proportional to the number of insulators. The curves are valid for 20 pairs of insulators per kilometer, which is a normal value for European lines. They also hold good for a characteristic impedance of 600 ohm. If the number of insulators is not 20 and the characteristic impedance deviates from 600 ohm β_G may be corrected according to

$$\beta_{G\,(n,z)} = \beta_G \cdot \frac{n}{20} \cdot \frac{600}{Z} \text{ neper/km}$$

where n = insulators in pairs/km.

With white-frost the leakance is localized to the ice coat on the conductors and consequently the curves are correct irrespective of the number of poles. The figures for white-frost conditions are very variable, of course, but the curve indicated can serve as a calculation basis.

The different curves, Fig. 4, are valid for different insulator types and different weather conditions; when calculating the attenuation of a line, one has to select a curve which corresponds as far as possible with the actual conditions.

Fig. 4 X 7110

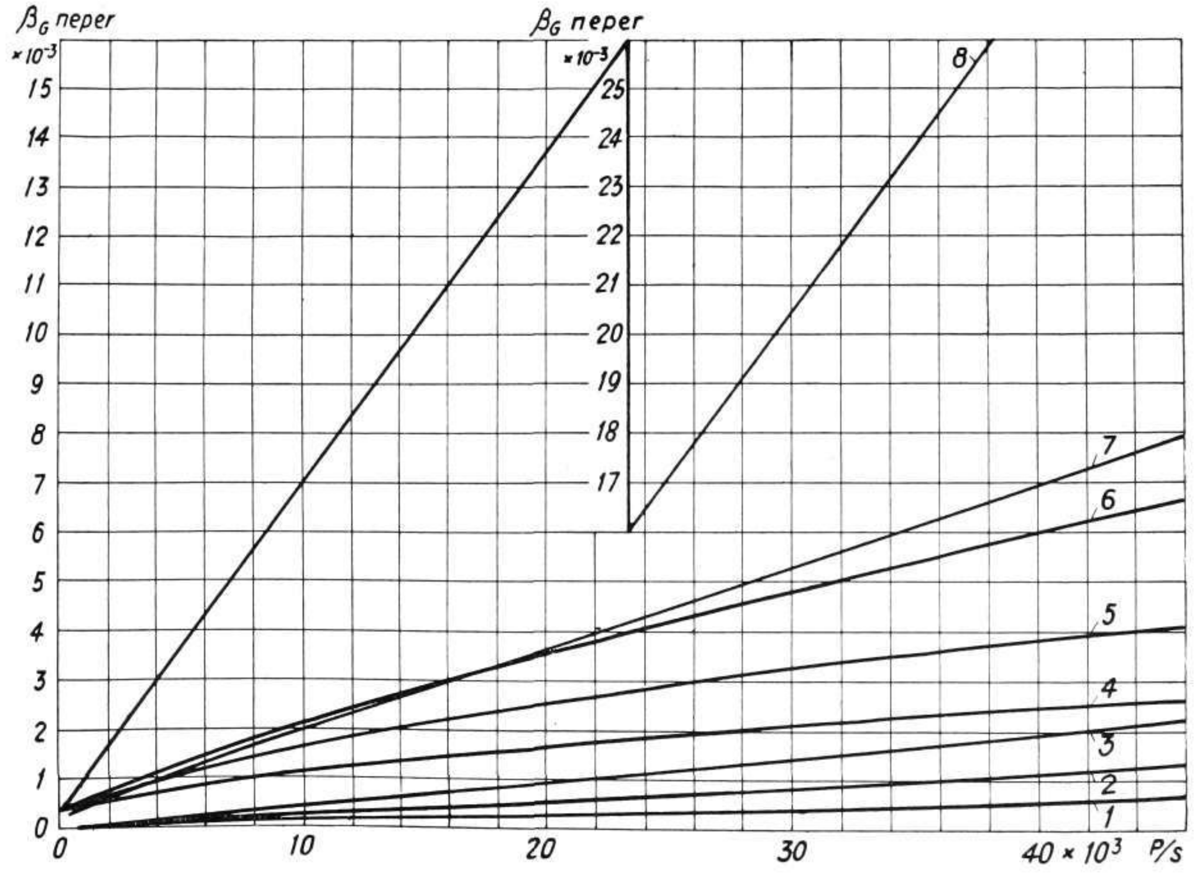
Attenuation caused by leakance

for telephone circuits, characteristic impedance 600 ohm, 20 pairs of insulators per km

1, 2, 3 dry weather

4, 5, 6, 7 wet weather

8 white-frost



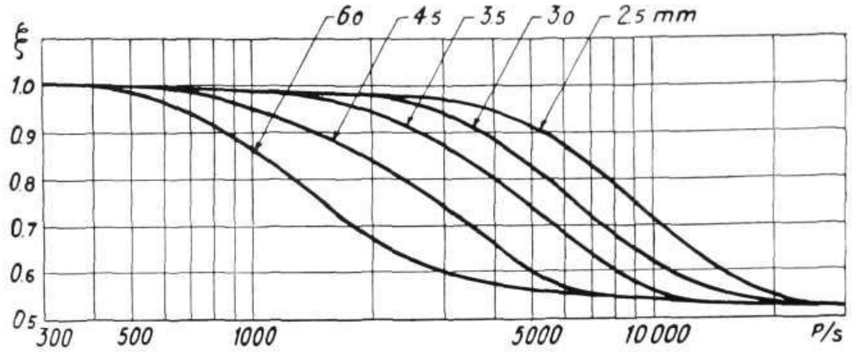


Fig. 5 X 5350
Correction factor for β_R

Curve 1 represents the leakage attenuation at dry weather for *CS*-insulators, curve 2 for *CW*-insulators and curve 3 for *DP*-insulators. The curves 4, 5 and 6 show the leakage attenuation under wet weather conditions for *CS*-, *CW*- and *DP*-insulators. All the curves are the results of the measurements by *Green*.

The insulator names are American standard; *CS*-insulators are of borosilicate glass and mounted directly on iron pins. The pins are formed in pairs by an iron screwed to the wooden crossarm; the *CW*-insulators are also of borosilicate but mounted on wooden pins covered with a metal foil. The metal foils belonging to a pair of pins are interconnected and mounted on crossarms of wood; the *DP*-insulators are of alkali glass and mounted on unclad wooden pins on wooden crossarms.

Curve 7 represents the leakage attenuation under wet weather conditions and curve 8 the leakage attenuation with white-frost. Both these curve are measured by *Kaden & Brückensteinkuhl*, but no information regarding insulator and crossarm types is given.

As far as is known no very satisfactory measurements have been made on European lines. For a single frequency, 28 000 c/s, a measurement has been carried out on a 4.5 mm line with a heavy white-frost; the results give values for β_G of 16×10^{-3} to 23×10^{-3} neper/km, which corresponds fairly well with curve 8, Fig. 4, which for the same frequency gives $\beta_G = 19 \times 10^{-3}$ neper/km.

There are, however, the interesting laboratory measurements carried out by *Boella*, who has measured a number of normal and experimental insulators under varying conditions. *Boella* has tried a metal cap on the insulators as proposed by *Wilson* and has also made trials with a protecting ring around the base of the insulator, Fig. 6.

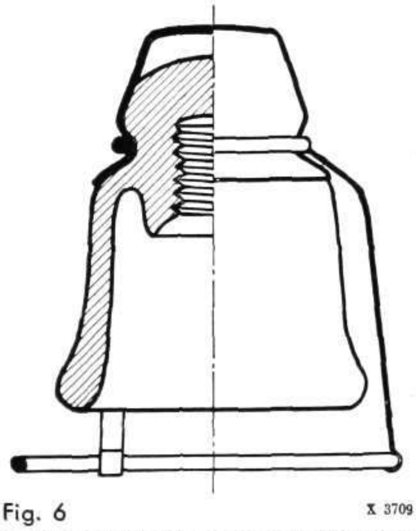


Fig. 6 X 3709
Insulator with cap and protection ring

When calculating the effective attenuation to be covered by a carrier system the figures for wet weather conditions are generally used; when the exact knowledge of the characteristics of the lines and insulators is missing a value of the leakage attenuation must be chosen in accordance with curve 6, Fig. 4. The ranges shown with full-faced types in the table below are then obtained.

The leakage attenuation obtained when *Boella's* figures for the leakance are used as a basis of calculation are shown in Fig. 7. For comparison's sake some of the curves in Fig. 4 are reproduced.

The reduction in leakance is considerable. It may be of interest to investigate which ranges could be obtained with single and three-channel carrier telephone systems now in use if *Boella's* low leakance values could be attained.

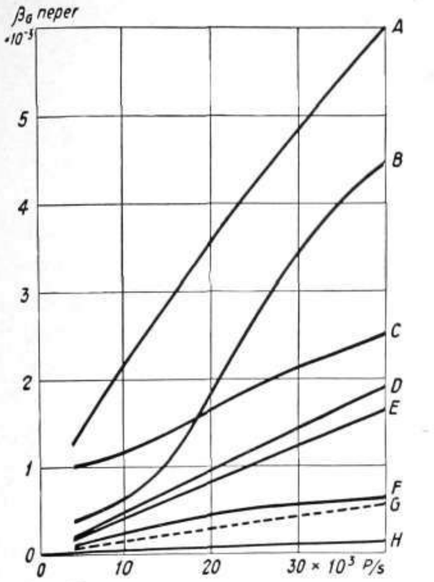


Fig. 7 X 3712

Leakage attenuation caused by leakance

for experimental insulator

- A DP-insulator, wet, wooden crossarm *(Green)*
- B porcelain insulator, wet, iron crossarm *(Boella)*
- C CS-insulator, wet, wooden crossarm *(Green)*
- D DP-insulator, dry, wooden crossarm *(Green)*
- E porcelain insulator with cap, wet, iron crossarm *(Boella)*
- F porcelain insulator with cap and protecting, ring, wet, iron crossarm *(Boella)*
- G CS-insulator, dry, wooden crossarm *(Green)*
- H porcelain insulator, dry, iron crossarm *Boella)*

lines with a wire distance of 30.5 cm	wire dimensions		range in km for			
			DP-insulators	CS-insulators	porcelain insulator to *Boella*	
	mm	lb/mile			with cap	with cap and ring
three-channel system, range 5 neper, highest frequency 30 000 c/s	2.84	200	**350**	440	480	515
	3.48	300	**400**	520	570	620
	4.50	500	**470**	625	700	770
single-channel system, range 3.75 neper, highest frequency 10 000 c/s	2.84	200	**470**	540	610	630
	3.48	300	**550**	645	745	770
	4.50	500	**660**	800	940	980

As will be seen from the table the range will increase considerably and furthermore the insulator with the cap shows a much smaller variation in leakage from wet to dry weather conditions than other insulators. Thanks to this fact the regulation of the communication channel is simplified and stabilized. Of course, one will ask why these insulators have not come to be used. Firstly it must be remembered that the figures of *Boella* are based on laboratory tests and consequently probably too favourable; secondly very few new long-distance lines are built nowadays and thirdly the manufacture of an insulator with a cap and ring would be rather expensive and has up to now met with considerable technical difficulties. However, the ceramic industry has made such progress during the last few years with metal-plated goods that possibly also insulators could be manufactured with satisfactory economical result, which would make it possible to reach in practice the results *Boella* has found in the laboratory.

References

Green, E. I.: »The Transmission Characteristics of Open-Wire Telephone Lines», Trans. Amer. Inst. Electr. Engr., Oct. 1930.

Green, E. I.: »Methods of Measuring the Insulation of Telephone Lines at High Frequencies», Trans. Amer. Inst. Electr. Engr., Oct. 1927.

Wilson, T.: »A Study of Telephone Line Insulators», Trans. Amer. Inst. Electr. Engr., Oct. 1930.

Kaden, H., & Brückensteinkuhl, K.: »Die Ableitungsverluste von Freileitungen bei Raureif», Elektrotechn. Z. No 47, 1934.

Boella, M.: »Prove su isolatori per linee ad onde guidate», Alta Frequenza No 2, 1932.

Pedersen, P. O.: »Wirbelstromverluste in und effektiver Widerstand von geraden, runden Metallzylindern», Jb. drahtl. Telegr. Teleph. Vol. 4, No 5, 1910.

Gebe Electric Light Fittings

E. JENSEN, SIEVERTS KABELVERK, SUNDBYBERG

The first fittings of Gebe type were put on the market by Sieverts Kabelverk in 1932 and there are still some of them giving good service in a large number of installations, being as a rule fitted in places where conditions are unfavourable. It is natural, however, that the experience gained during these years has led to improvements both in the Gebe fittings and the Gebe cable. The latter was described in its new form in Ericsson Review No 3, 1936, and below will be found particulars of the thoroughgoing revision recently undertaken in the Gebe fittings.

The Gebe system is a combination system with which it is possible to build up from a comparatively small number of parts a large number of fittings. The system comprises a series of bakelite distribution boxes and a series of cast-iron distribution boxes, a switch, a lamp-holder, a pair of bakelite suspension covers — upper and lower — and a pair of cast-iron suspension covers. These parts may be combined together as desired to form various fittings, see Fig. 1: fixed fitting, suspension or wall arm, all with or without switch. The fittings made up in this way can then be provided with globes, glass shades, metal shades or combinations of these. With a view to still further increasing the versatility of the fittings there has been developed a system of consoles also.

In the revision just completed of the Gebe fittings the original system and the original main dimensions have been retained, so that the old and the new are still suited to each other. The aim of the revision has been to attain better standardisation of the parts comprising the system, lower cost of manufacture along with further increase of reliability when the material is to be used in the worst of localities.

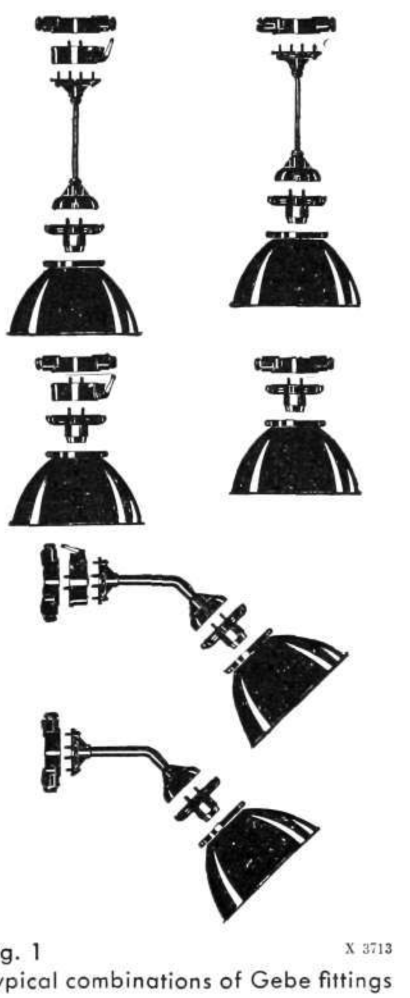


Fig. 1 X 3713
Typical combinations of Gebe fittings

Distribution Boxes

In the new system the parts of the fitting are fixed together by four screws. When bakelite is constantly exposed to great humidity it absorbs a certain amount of moisture after a period. If at the same time it is subjected to mechanical strain it displays a certain tendency to change shape. When a lamp-holder or a shield is screwed tight on a box, the packing between these parts will exercise a pressure in the opposite sense to the pressure exercised by the screws used. When only two diametrically opposed screws are used, the bakelite may in particularly bad cases be forced out of shape to such an extent that the joint is no longer tight. By making use of four screws and giving a suitable shape to certain of the parts the risk of alteration in shape and defective tightness is eliminated. On boiling distribution boxes, with cover fixed, in water at 100° C for 50 to 100 h — probably one of the severest tests to which bakelite can be submitted — it was found that the change of shape in the bakelite was not so great that the boxes did not remain tight with an inside pressure of over 1 at.

As the Gebe cables are now always supplied with earth wires, the connection of the sheaths can now be done by joining up the earth wires on a terminal in the box, which allows of appreciable simplification of the bakelite boxes. These are moulded now in two types only, one with four and one with five cable bushings, Fig. 2. All the apertures are closed on moulding. The boxes are, however, delivered with packing and cap screws for the bushings corresponding to the descriptions. For bushings with packings the hole is made

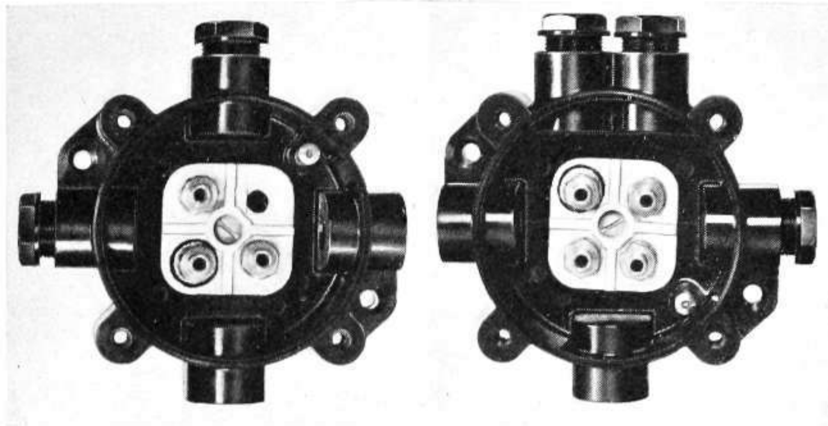


Fig. 2 X 5352
Gebe distribution boxes
left with four, right with five inlets

in the bottom. The other bushings have closed bottom and in addition have the opening covered outside by a thin bakelite blank, see Fig. 3. By means of this system it is possible without further additions to obtain all the connecting combinations imaginable. Fig. 4 shows the combinations kept in stock. The bushings not used can be utilised later if required: the bakelite blank is removed, the hole in the bottom is opened and packing and capping screw set in. In such case it is therefore possible to connect a new cable quite normally to a box already installed, without disturbing the box or existing connections. In the case of cast-iron boxes this system cannot be applied, on account of expense among other reasons. They are made in a sufficient number of types to cover the various specifications.

Two further small details should be mentioned. Boxes with double inlets have parallel bushings for the double inlet, which gives a smart cable lead. The two holes for fixing the box are diametrically opposite and have the same positions on all boxes, giving the special advantage that it allows of a simple console system to be made. The lead opening is cylindrical where the packing comes, see Fig. 3, and it is only outside this that the screwed part comes. All risk of the packing being caught in the screw thread is thus eliminated. In conjunction with this the inner end of the cap screw is not threaded, and it can thus press up the packing. The thread is normal armoured tube thread of 22.5 mm outside diameter.

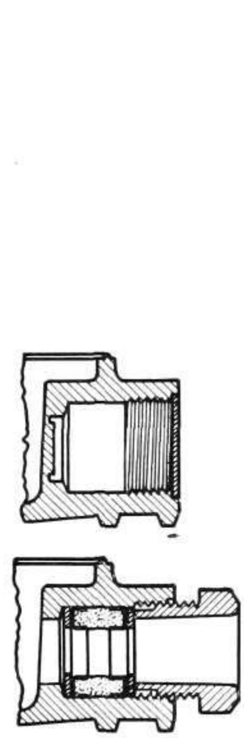


Fig. 3 X 3714
Section of inlet bushing
above, unutilised inlet, below, bushing with packing and cap screw

Lamp-Holder

The former lamp-holder was a safety holder insofar as it had a guard ring of bakelite which pressed against the end of the lamp and covered its metal socket. The screw cap carried current. This design has numerous advantages and one in particular which unquestionably is of value in practical use: like older lamp-holders of good makes, it gives a thoroughly dependable contact. For various reasons, however, this design was considered to have outlived its purpose. An entirely new one has been made, which in its main features resembles other safety holders. It has, for instance, a bottom contact against which the bottom of the lamp socket rests and a double lateral contact against which the exterior of the lamp's metal thread makes contact, see Fig. 5. The threaded cap of the lamp-holder not carrying current is firmly fixed in the protector. This last is fixed by two screws to the bakelite bottom of the holder. Four threaded holes have been pressed out of the bakelite base, to which fitting can be screwed parts of different kinds.

A point of great importance affecting the tightness of the fitting and thereby its reliability is the bushing which must exist between the outer contact parts of the lamp-holder and the contact pins in the box. Close investigation of models based on various designs has demonstrated that decidedly the most dependable, while at the same time simplest and least expensive, is that employed in earlier holders with through-going brass bolts moulded in the bakelite when making the lamp-holder base.

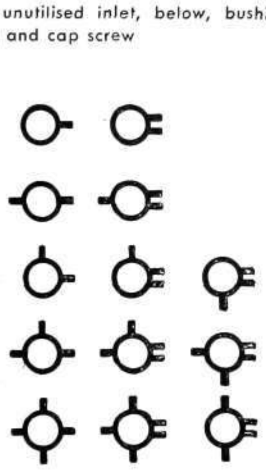


Fig. 4 X 3715
Inlet combinations in stock

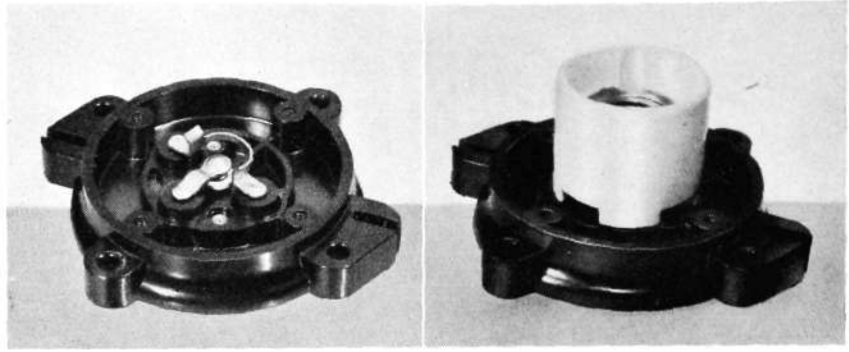


Fig. 5 X 5353
Gebe lamp-holder
left, socket with bottom and lateral contacts right, socket with guard ring

Suspension Cover

The suspension cover, Fig. 6, has been given an attractive appearance. Each contact pin or hole has been firmly set in a steatite socket and the two sockets of a cover are fixed to a sheet-iron bridge.

In Ericsson Review No 3, 1936, reference was made to the investigations on which were based the discarding of the support wires in the suspension cable. As the holding of the cable by means of packing has proved very reliable and it is besides simple and inexpensive, it has been retained. It might perhaps be mentioned that even ordinary rubber tube cable, Type RDV, which never did have support wires, has been used in conjunction with Gebe suspension cable, Type RDCU, and has always been held by packing alone.

All ears on lamp-holders, covers and suspension covers are of the same height, with the result that only two lengths of screws are required for screwing together the fittings, namely a short one for fitting without switch and a long one for fitting with switch. In order that the pins employed for connecting up the fitting parts shall have good spring, they have before the groove is sawn been bored with holes of diminishing diameter towards the bottom. The four tongues on the completed pin thus grow in thickness towards the base.

Consoles

When Gebe fittings have been fixed on a wall, a wall-arm of a console of some other type has generally been used. On revising the Gebe fitting it has been possible to work out a simple console system for fixing the fitting to walls or in corners without the use of wall-arms.

The new system comprises two consoles of different lengths for fixing fittings with vertical axis and one console for fixing the fitting at an angle of 45°, Fig. 7. The two first are long enough for the fitting's centre to come 160

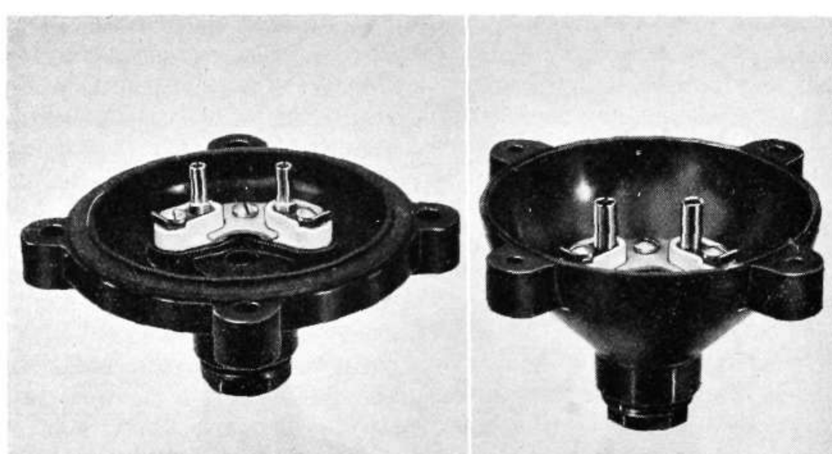


Fig. 6 X 5354
Gebe suspension cover
left, upper cover with contact pins; right, lower cover with contact holes

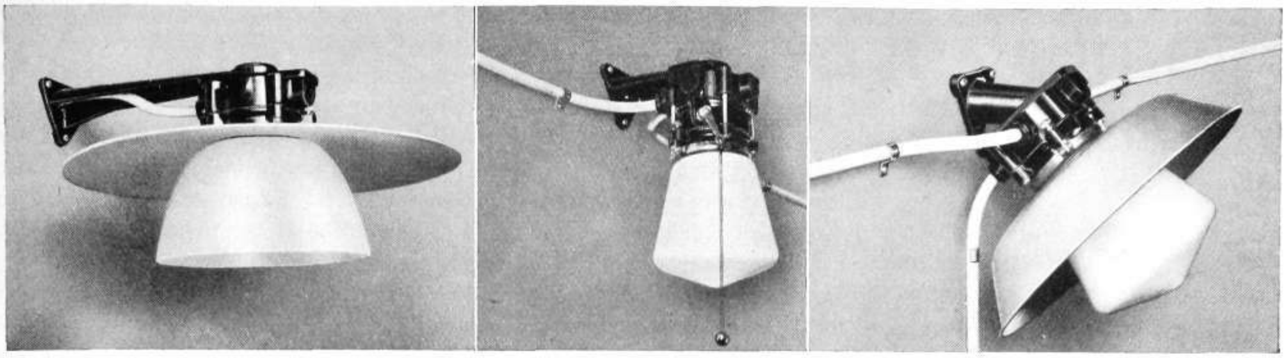


Fig. 7 X 7111

Gebe consoles

left, long console, centre, short console, both for vertical fittings; right, short console for fitting at angle of 45°

and 300 mm respectively from the wall. If the console is to be fitted at a corner a corner-piece is first fixed, Fig. 8 — one for an outer corner and another for an inner corner — and the console is then attached to that. The feet of the consoles are the same shape so that they require no adaptation for the corner-pieces. The consoles have a plate to which the box of the fitting is attached in the ordinary way by two screws. This plate is made loose and with two screws can be set in two positions, for the occasions where it is required that the box shall have in one case one position in relation to the cable and in another case a position at 90° to same.

The shape of the console has been determined with a view to allowing the cable being led to the box in a natural and neat manner. The new consoles allow of connection of one or two cables from below, from above, from the side or from behind through a wall.

It has already been stated in regard to boxes that certain investigations have shown that the principles applied in the design of Gebe fittings were correct. Sieverts Kabelverk have aimed at coming as close as is at present possible to perfection. Alongside the work of design has proceeded very comprehensive research to discover as far as possible all weaknesses in former designs. Each new detail of design has been executed in model and tried. As the new parts were completed they were likewise tested and adjusted until the desired result was achieved. Finally the completed material has undergone duration tests in certain installations giving extremely difficult service conditions, which it had formerly been impossible to get installation material of any kind to withstand. As bakelite for years has been the scapegoat of experts great and small in installation material, Sieverts Kabelverk when redesigning have been especially concerned to eliminate the weaknesses which might have attached to the earlier material. No small part of the investigation referred to was therefore devoted to the shape of the bakelite and to the moulding of the bakelite itself. The results obtained on laboratory tests and in installations actually made should demonstrate beyond all dispute that the new Gebe fitting as regards reliability and suitability to its purpose is right in the forefront of what can be produced at the present day.

Progress in installation practice which has occurred since Sieverts Kabelverk put its new system on the market can without exaggeration be characterised

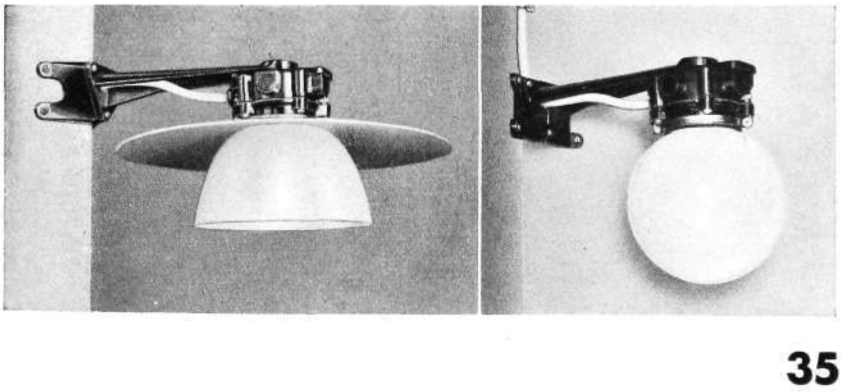
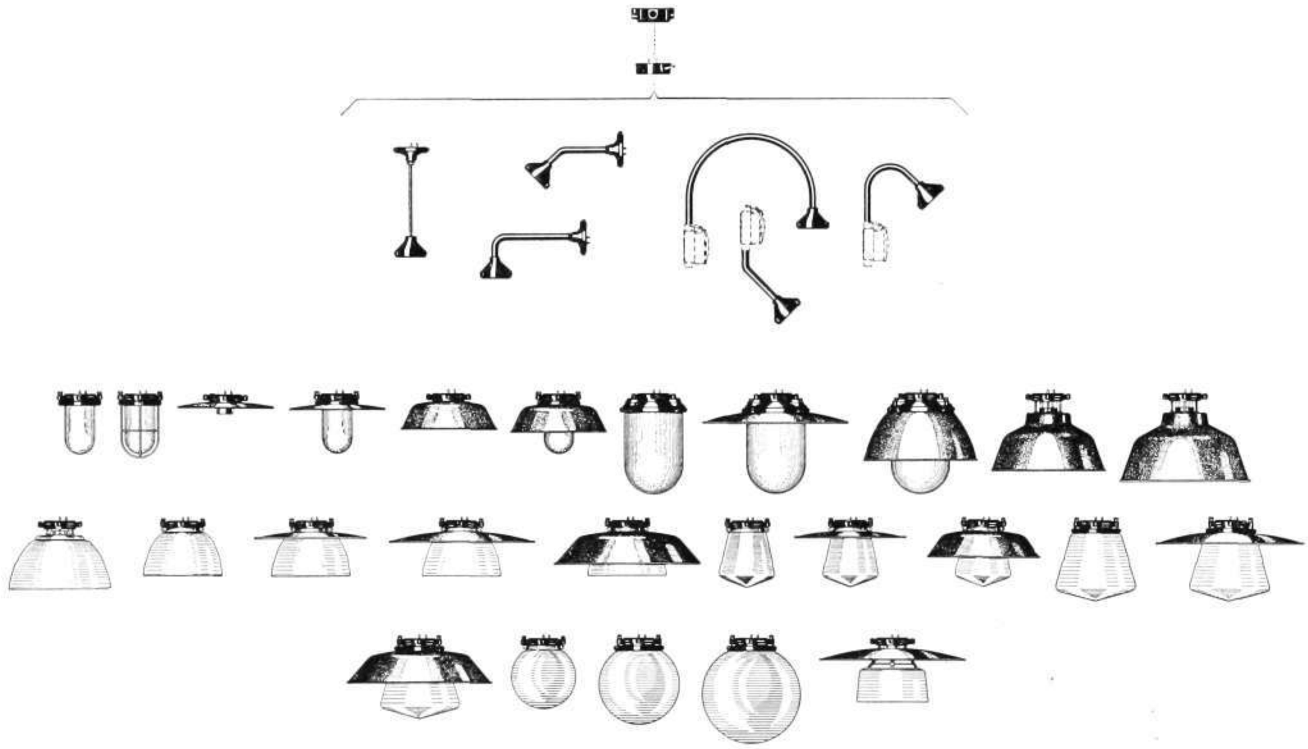


Fig. 8 X 5355

Gebe consoles

left, attached to outer corner, right to inner corner as a revolution of its kind. From the outset it was considered that improvement in safety against fire, in reliability and durability were obtainable for the inflammable and damp premises of farms when installations were of the new material. The superiority of the system over older material soon attracted the attention of industrialists, however. It was found that it offered high reliability and that it was simple and comparatively inexpensive to fit. Gradually it was realised that in the long run it did not pay to employ older material but that it was cheaper and better to employ the Gebe system throughout in all premises, no matter whether they were damp or inflammable or more normal in character. As the system has been developed side by side with the increased demand for good lighting it has consequently with the years become an extraordinarily widespread installation system which is used in all kinds of premises both for industrial and farm buildings. In addition it has found considerable employment in other spheres, such as in hospitals, restaurants, dwelling houses, etc.

Fig. 9 X 7112
Combination possibilities of Gebe fittings



Watertight Telephone Instrument

S. WERNER, TELEFONAKTIEBOLAGET L. M. ERICSSON, STOCKHOLM

Telefonaktiebolaget L.M. Ericsson has designed a new telephone instrument, intended for mounting in exposed positions, such as damp localities, workshops, shipyards and railway yards; it is made both as LB-instrument and for connection to manual and automatic exchanges. In addition, with special equipment it is adapted for use as mine telephone and as police telephone.

The instrument, Type DAT 1001, Fig. 1, is of watertight construction and enclosed in a black-enamelled cast-iron box with door for opening by a simple handle when the instrument is to be used. Where required the handle is provided with lock. Dimensions of the instrument are: height 350, width 215, depth 180 mm, and it weighs about 20 kg.

The instrument box is provided with three strong fixing ears. The cables are led to the instrument from below through cable bushings. To connect the cables the lower panel inside the instrument is opened, exposing the terminal block, see Fig. 2. Connection can thus be made without taking the instrument apart.

The handset is held by a pair of thick chrome-plated metal pins, the lower one fixed and the upper moveable. The latter, pressed upwards by a strong spring, holds the handset rigidly in the proper position. It also acts on the switchhook when the handset is lifted. The handset is furnished with rubber cable which is connected through a bushing with packing to a terminal block inside the instrument. This block is accessible when the upper panel of the instrument is opened, see Fig. 2.

The generator crank is strongly made and easy to operate. It is coupled direct to the generator which is screwed on to the middle cast-iron panel. The generator may be taken out complete for inspection on unscrewing the panel. The crankshaft connection through the panel is made by packing.

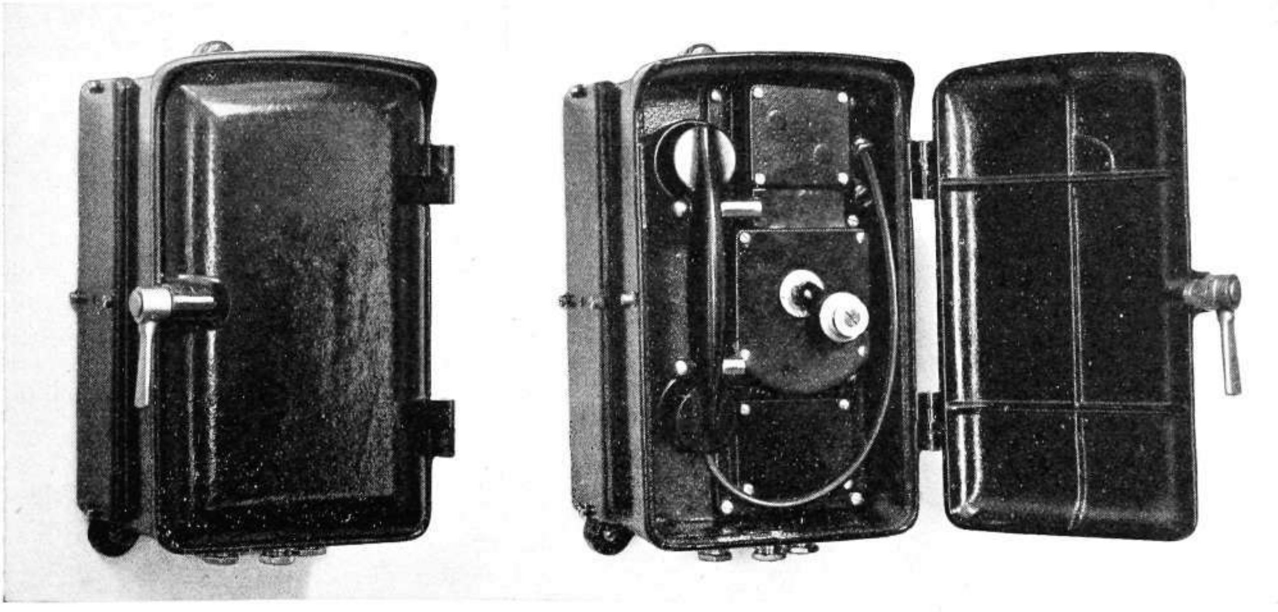


Fig. 1 X 7108
Watertight telephone instrument, Type DAT 1001

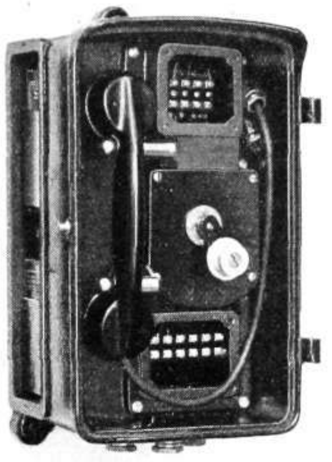


Fig. 2 X 3704
Watertight telephone instrument
with panels removed; above handset terminal, below cable terminal, at side battery compartment

Fig. 3 X 3705
Instrument set
from top downwards induction coil and switch hook, generator, terminal block

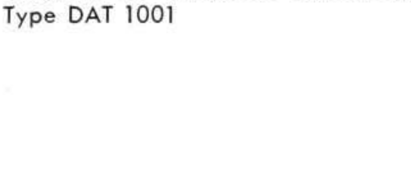


Fig. 4 X 3706
Diagram of telephone instrument, Type DAT 1001

The batteries are located in a compartment at the lefthand side of the instrument. There is room for two dry cells each of 1.5 V and measuring 125×55×55 mm, connected by two watertight bushings with the inside of the instrument. For inserting or replacing batteries the cast-iron panel, see Fig. 2, is unscrewed. This panel is provided with holes for ventilating the battery space.

The instrument is not fitted with bell for incoming call, since it is advisable that the most suitable signal device be selected according to local conditions, and consequently under certain circumstances it may be necessary to locate the signalling device elsewhere than on the instrument. On the lower part of the instrument there is a bushing for introducing the cable from the bell, the wires being connected to the same terminal block as the wires from the instrument. A suitable bell, designed for outdoor mounting, is described elsewhere in this number.

The transmission qualities of the instrument are considerably better than earlier instruments of similar kind, mainly on account of the good properties of the bakelite handset in combination with a suitable induction coil. Likewise the strength of the outgoing signal is especially high because of the adaption of a small but particularly effective generator.

Construction

The instrument, which consists of an inset, case with door and battery compartment and batteries, is constructed specially with a view to adaption for various purposes. The inset has therefore been made as a unit which can be fitted with different parts for different types of apparatus, thus making it possible to satisfy unusually high requirements for a special instrument of this kind.

The inset, Fig. 3, comprises all parts for a complete instrument, combined on a cast-iron frame which is furnished, mounted, connected and tested for inserting in the case. Between the inset and the case there is a packing preventing the penetration of moisture. The inset frame for a normal LB-instrument carries handset, ringer, induction coil, switch-hook and two terminals of bakelite, the lower for connecting to line and signal bell and the upper for connecting the handset, and extra receiver if required. All panels on the inset, which can be opened from outside, are tightened with packing. The handset is normal bakelite type. It is provided with four-wire cord made as a rubber cable with circular section. The generator is of a new type giving great output but of smaller size and weight than generators hitherto used; it was described in Ericsson Review No 2, 1935. The induction coil is also of normal type; it has closed iron core of sheet alloy and is anti-sidetone connected. The diagram for a normal LB-instrument is shown by Fig. 4.

The watertight telephone instrument can be supplied in several different designs. For instance, the normal LB-instrument may be provided with extra receiver which is connected at the inlet below the bushing for the handset cord, see Fig. 1. The instrument can also be supplied with dial in place of generator, and, finally, it may be used as a combined LB and automatic instrument if the normal LB-instrument is supplemented by a dial and two press-buttons mounted on the upper panel.

Watertight Bell for AC

S. WERNER, TELEFONAKTIEBOLAGET L. M. ERICSSON, STOCKHOLM

There has now been added to the series of bells for various purposes developed lately by Ericsson a new polarized AC bell of watertight construction. The bell, which is mainly intended as signal device for telephone instruments, is particularly suited for mounting outdoors and in damp or otherwise exposed places.

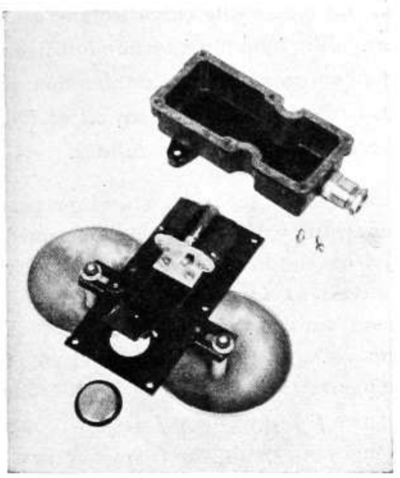


Fig. 1 X 3632
Bell mechanism

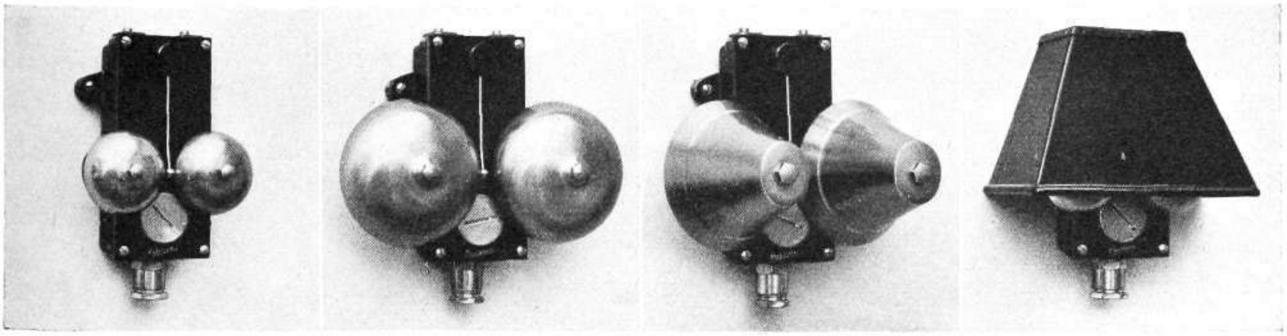
Fig. 2 X 7099
Watertight bell
left to right, Types KLA 62, KLA 63, KLA 64 and KLA 62 with protective roof

The bell is made watertight and despite its strong construction is small and neat. The mechanism, Fig. 1, is enclosed in a cast-iron case, with cable bushing below for leading in the wires.

The bell mechanism, of normal type, is mounted on a front plate which with packing between is screwed in the cast-iron case. The trembler of the mechanism has watertight bushing. The projecting part of the trembler which carries the clapper is protected by a cowl. Connection of the wires is to a bakelite terminal accessible from outside through the round panel on the front plate. The bell is simple to mount; fixing is by two screws only.

The bell is designed for 16—25 c/s AC, but is made also for connection to 50 c/s AC. It is normally made with winding for 300, 1 000 or 2 000 ohm resistance.

The bell is delivered in three patterns with gongs of different sizes, Fig. 2. The smallest, Type KLA 62, has two gongs of different tones each 64 mm diameter; the two larger, Type KLA 63 and KLA 64, have 108 mm circular and sheep gongs respectively; the last-named gives a distinctive signal easy to distinguish when several bells are mounted in proximity to each other. Bells, Type KLA 62 and KLA 63, may for outdoor mounting be provided with roofs as protection against snow and rain.



Frequency Transformations, Applied on the Heaviside Expansion Theorem

T. LAURENT, TELEFONAKTIEBOLAGET L. M. ERICSSON, STOCKHOLM

The frequency transformations, shortly described in the Ericsson Review No 4 1935, and more closely dealt with in the Ericsson Technics No 5, 1934, No 2, 1935 and No 1, 1936 as well as in the Elektrische Nachrichten-Technik No 11, 1936 have been studied further. This time the question has been to find out their importance for transient phenomena by the application of the Heaviside expansion theorem. The result has been an extension of this theorem giving a considerable simplification of practical calculations.

It has been shown in the papers mentioned how the design and properties of complicated, passive linear impedance networks may be determined by means of frequency transformations of simple and easily calculable networks. The properties are then expressed as frequency functions; for instance the complex relationship between an applied sinusoïdal EMF E of angular frequency ω and the resultant voltage drop V in any part of the network may be expressed as a frequency function. If we call this property of a simple impedance network $f[j\omega]$, where $j = \sqrt{-1}$, and make a frequency transformation of the network with the frequency function $w(j\omega)$ the said property will be $f[jw(j\omega)]$.

It may now be seen how this change in the property is reflected in the building-up of the voltage drop V due to an instantaneous voltage change E at the time $t = 0$. Then $j\omega$ is replaced by the operator p and $jw(j\omega)$ by $P(p)$. The symbolic solutions of the original and frequency transformed networks are then

$$f[p] \text{ and } f[P(p)]$$

which may be written in the form

$$\frac{Y[p]}{Z[p]} \text{ and } \frac{Y[P(p)]}{Z[P(p)]}$$

in such a way that the equation $Z(p) = 0$ contains the largest possible number of roots. Supposing that no root is zero and two roots not identical the time functions for $t \geqq 0$ may be determined by means of the *Heavisides* expansion theorem as follows

$$f[p]_t = \frac{Y[0]}{Z[0]} + \sum_{p_1 p_2 p_3 \cdots} \frac{Y[p]\, e^{pt}}{p \frac{dZ[p]}{dp}}$$

where $p_1 p_2 p_3 \cdots$ are the roots of $Z[p] = 0$

$$f[P(p)]_t = \frac{Y[p(0)]}{Z[P(0)]} + \sum_{p'_1 p'_2 p'_3 \cdots} \frac{Y[P(p)]\, e^{pt}}{p \frac{dZ[P(p)]}{dp}}$$

where $p'_1 p'_2 p'_3 \cdots$ are the roots of $Z[P(p)] = 0$.

If the inverse function to $P(p)$ is called $T(p)$ the latter expression may be transformed to

$$f[P(p)]_t = \frac{Y[P(o)]}{Z[P(o)]} + \sum_{p_1 p_2 p_3 \dots} \left[\frac{Y[p]\,e^{pt}}{p\,\frac{dZ[p]}{dp}}\right]\left[\frac{p}{T(p)} \cdot \frac{dT(p)}{dp}\, e^{[T(p)-p]t}\right]$$

where $p_1 p_2 p_3 \dots$ are the roots of $Z[p] = o$.

The constant term is determined in the ordinary way be means of frequency transformation. The terms after the sign of summation consist of two factors, the first of which determines the building-up properties in the original network, while the second factor which, being a function of p and t, depends only on the frequency function in question, determines the change in the building-up properties when the frequency transformation is applied. The latter factor, which can be called the *transformation factor* $U(p)$, is a function of p and t and consequently it may be determined once and for all for each frequency function.

For the simple frequency functions the expansion theorem may be written as follows

$$f[P(p)]_t = \frac{Y[x]}{Z[x]} + \sum_{p_1 p_2 p_3 \dots} \left[\frac{Y[p]\,e^{pt}}{p\,\frac{dZ[p]}{dp}}\right] \cdot U(p)$$

frequency function	x	$U(p)$
b	o	1
d	∞	$-e^{-p\left[1-\left(\frac{\omega_m}{p}\right)^2\right]t}$
m	∞	$\pm\frac{1}{\sqrt{1-\left(2\frac{\omega_m}{p}\right)^2}}\,e^{-\frac{p}{2}\left[1\mp\sqrt{1-\left(2\frac{\omega_m}{p}\right)^2}\right]t}$
n	o	$\pm\frac{1}{\sqrt{1-\left(2\frac{p}{\omega_m}\right)^2}}\,e^{-\frac{p}{2}\left\{1-\left(\frac{\omega_m}{p}\right)^2\left[1\mp\sqrt{1-\left(2\frac{p}{\omega_m}\right)^2}\right]\right\}t}$
bm	ω_1	$\frac{1}{1-\left(\frac{\omega_1}{p}\right)^2}\,e^{-p\left[1-\sqrt{1-\left(\frac{\omega_1}{p}\right)^2}\right]t}$
dm	∞	$\frac{1}{\left(\frac{\omega_1}{p}\right)^2-1}\,e^{-p\left[1-\frac{\frac{\omega_1}{p}}{\sqrt{\left(\frac{p}{\omega_1}\right)^2-1}}\right]t}$
bn	o	$\frac{1}{1-\left(\frac{p}{\omega_1}\right)^2}\,e^{-p\left[1-\frac{1}{\sqrt{1-\left(\frac{p}{\omega_1}\right)^2}}\right]t}$
dn	ω_1	$\frac{1}{\left(\frac{p}{\omega_1}\right)^2-1}\,e^{-p\left[1-\frac{\omega_1}{p}\sqrt{\left(\frac{\omega_1}{p}\right)^2-1}\right]t}$

As may be seen double signs appear in $U(p)$ at m and n transformations, which means that for each term in the summation for the original network there are two factors $U(p)$, one for each sign. Consequently the number of terms in the summation is doubled.

At repeated frequency transformations, for instance with the operator functions $P_1(p)$, $P_2(p)$ and $P_3(p)$ the resultant operator function is obviously $P(p) = P_1\{P_2[P_3(p)]\}$ and the resulting inverse function $T(p) = T_3\{T_2[T_1(p)]\}$. If the transformation factors for $P(p)$, $P_1(p)$, $P_2(p)$ and $P_3(p)$ are $U(p)$, $U_1(p)$, $U_2(p)$ and $U_3(p)$ resp. the following relation is obtained

$$U(p) = U_1(p) \cdot U_2[T_1(p)] \cdot U_3\{T_2[T_1(p)]\}$$

With reflexionless cascade connection of impedance networks the following symbolic solution may be of interest

$$f_P = \frac{Y_1[P_1(p)]}{Z_1[P_1(p)]} \cdot \frac{Y_2[P_2(p)]}{Z_2[P_2(p)]} \cdot \frac{Y_3[P_3(p)]}{Z_3[P_3(p)]}$$

With the same designations as above the time function will be

$$\mathrm{f}_t = \frac{Y_1[P_1(0)]\; Y_2[P_2(0)]\; Y_3[P_3(0)]}{Z_1[P_1(0)]\; Z_2[P_2(0)]\; Z_3[P_3(0)]}$$

$$+ \sum_{p'_1 p'_2 p'_3 ---} \frac{Y_2\{P_2[T_1(p)]\}\; Y_3\{P_3[T_1(p)]\}}{Z_2\{P_2[T_1(p)]\}\; Z_3\{P_3[T_1(p)]\}} \cdot \left[\frac{Y_1[p]\, e^{pt}}{p \frac{dZ_1[p]}{dp}}\right] U_1(p) \quad \begin{array}{l} p'_1 p'_2 p'_3 -- \\ \text{for } Z_1(p) = 0 \end{array}$$

$$+ \sum_{p''_1 p''_2 p''_3 ---} \frac{Y_1\{P_1[T_2(p)]\}\; Y_3\{P_3[T_2(p)]\}}{Z_1\{P_1[T_2(p)]\}\; Z_3\{P_3[T_2(p)]\}} \cdot \left[\frac{Y_2[p]\, e^{pt}}{p \frac{dZ_2[p]}{dp}}\right] U_2(p) \quad \begin{array}{l} p''_1 p''_2 p''_3 -- \\ \text{for } Z_2(p) = 0 \end{array}$$

$$+ \sum_{p'''_1 p'''_2 p'''_3 ---} \frac{Y_1\{P_1[T_3(p)]\}\; Y_2\{P_2[T_3(p)]\}}{Z_1\{P_1[T_3(p)]\}\; Z_2\{P_2[T_3(p)]\}} \cdot \left[\frac{Y_3[p]\, e^{pt}}{p \frac{dZ_3[p]}{dp}}\right] U_3(p) \quad \begin{array}{l} p'''_1 p'''_2 p'''_3 -- \\ \text{for } Z_3(p) = 0 \end{array}$$

In addition to the transformation factors obviously correction factors are also obtained by means of inverse frequency transformation of the symbolic solutions.

The practical advantages of this extension of the expansion theorem is that only the roots of the equation $Z(p) = 0$ have to be determined and used, *i. e.*, the roots of the comparatively simple original network. Therefore $Z(p) = 0$ will not be of a high power and will be easy to solve. The roots will not be complicated, which means that they may easily be inserted in the operator expressions and the risk of obtaining two equal roots is reduced. The calculations may also be simplified by means of the determination once and for all of the transformation factors employed.

Finally it may be mentioned that there is no need to change the name »frequency transformation», even if the transformation be used on operators. The operator differs from the angular frequency only by the constant factor j. Thus an operator transformation must mean a frequency transformation.

In a future issue of the Ericsson Technics the new extension of the expansion theorem will be dealt with in detail together with examples.

Theory of Rectifier Modulators

S. KRUSE, TELEFONAKTIEBOLAGET L. M. ERICSSON, STOCKHOLM

In the description of the new single-channel carrier telephone system for open-wire circuits, published in the Ericsson Review No 2, 1936, a brief account of the rectifier modulators employed in this system was given. The rectifiers were assumed to be ideal, i. e., to have a constant conductance for one current direction and to block completely for the opposite direction. A short survey of the theory for modulators composed by rectifiers with any current-voltage characteristic will be given below.

The modulator, Fig. 1, is assumed to consist of four identical rectifiers with the current-voltage characteristic $i = f(v)$. At the terminals $1'2'$ is connected a sinusoidal EMF $e' = E' \sin \omega' t$. The current and the voltage at these terminals are i' and v' and at the output terminals $1''2''$ they are i'' and v''. The carrier voltage is v_c and its angular frequency ω_c. If v' and v'' are small the following equations for i' and i'' are obtained

$$\left.\begin{aligned} i' &= hv' - mv'' \\ i'' &= -mv' + hv'' \end{aligned}\right\}$$

where

$$h = \frac{f'(v_c) + f'(-v_c)}{2}$$

$$m = \frac{f'(v_c) - f'(-v_c)}{2}$$

$$f'(v_c) = \frac{d\, f(v_c)}{d v_c}$$

It is found advantageous to choose for the carrier voltage v_c a time function that contains only odd harmonics. If v_c is such a function h and m may be written as follows according to the *Fourier* series

$$\left.\begin{aligned} h &= a_0 - 2a_2 \cos 2\omega_c t + 2a_4 \cos 4\omega_c t - \dots \\ m &= 2a_1 \sin \omega_c t - 2a_3 \sin 3\omega_c t + 2a_5 \sin 5\omega_c t \dots \end{aligned}\right\}$$

If investigating which modulation products occur at the terminals $1'2'$ and $1''2''$ it will be found that i' and v' contain only components with the angular frequencies ω', $2\omega_c \pm \omega'$, $4\omega_c \pm \omega'$ etc., while i'' and v'' contain only the angular frequencies $\omega_c \pm \omega'$, $3\omega_c \pm \omega'$, $5\omega_c \pm \omega'$ etc.

By inserting the expressions obtained for h and m in the first two equations, vector equations for the different sub-frequencies of i' and i'' are obtained. In order to find more suitable expressions the general angular frequency may be written as $\omega' \pm p\omega_c$. The corresponding current and voltage vectors are written as $\overline{I}'_{\pm p}$, $\overline{V}'_{\pm p}$, when p is an even number, *i. e.*, for the angular frequencies ω' $\omega' \pm 2\omega_c$, $\omega' \pm 4\omega_c$ etc. and $\overline{I}''_{\pm p}$ $\overline{V}''_{\pm p}$, where p is an odd number, *i. e.* for the angular frequencies $\omega' \pm \omega_c$, $\omega' \pm 3\omega_c$ etc One will find a group of vector equations, the matrix of which may be written as follows:

frequency		$\overline{V}_0'$	$\overline{V}_1''$	$\overline{V}''_{-1}$	$\overline{V}_2'$	$\overline{V}'_{-2}$ etc.
ω'	$\overline{I}_0'$	a_0	$-ja_1$	ja_1	$-a_2$	$-a_2 \dots$
$\omega' + \omega_c$	$-\overline{I}_1''$	$-ja_1$	$-a_0$	a_2	ja_1	$ja_3 \dots$
$\omega' - \omega_c$	$-\overline{I}''_{-1}$	ja_1	a_2	$-a_0$	$-ja_3$	$-ja_1 \dots$
$\omega' + 2\omega_c$	$\overline{I}_2'$	$-a_2$	ja_1	$-ja_3$	a_0	$a_4 \dots$
$\omega' - 2\omega_c$	$\overline{I}'_{-2}$	$-a_2$	ja_3	$-ja_1$	a_4	$a_0 \dots$
etc.	etc.			etc.		

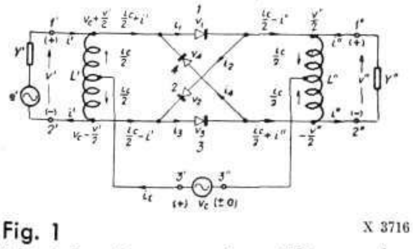


Fig. 1 X 3716
Principle diagram of rectifier modulator

Here $j = \sqrt{-1}$ and the coefficients a_p are half the coefficients of h and m in the *Fourier* series (the whole coefficient for $p = 0$). If all the composants of i'' are introduced in the equations with negative signs the matrix will become symmetrical.

Now the problem arises to find suitable termination impedances for the different frequencies in order to obtain a high efficiency and good operation of the modulator. In this connection it is of interest to look at the vector equations in a special way. As the frequencies are not to be found in the equation the different vectors may be regarded as corresponding to currents and voltages of one and the same frequency. The vector equations then represent a linear multi-pole network with the current $(-1)^p \bar{I}_p$ and the voltage $\bar{V}_p$ at the p:th pair of terminals (indices may be left out as even values of p correspond to $'$ and odd values to $''$). Consequently the modulator problem is brought back to the investigation of a linear multi-pole network, which one can treat mathematically by means of ordinary transmission theory.

The theory indicated above together with examples will be dealt with in detail in a future issue of the Ericsson Technics.

The Ericsson Group

Associated Enterprises

EUROPE

Československo Prchal, Ericsson & spol.	*Praha I*, Malé náměstí 1
Danmark L. M. Ericsson A/S	*København K*, Studiestræde 24
Deutschland Ericsson Verkaufsgesellschaft m. b. H.	*Berlin W 62*, Kurfürstenstrasse 118
Eesti Tartu Telefonivabrik A/S	*Tartu*, Puiestee 9—11
España Cía Española Ericsson, S. A.	*Getafe (Madrid)*
France Société des Téléphones Ericsson	*Paris XX*, rue Villiers-de-l'Isle Adam 111
Great Britain Ericsson Telephones Ltd	*London WC 2*, Kingsway 67/73
The British Automatic Totalisator Ltd	*London WC 2*, Kingsway 56
Electric Totalisators Ltd	*London WC 2*, Kingsway 56
Production Control (Ericsson) Ltd	*London WC 2*, Kingsway 56
Italia Società Elettro Telefonica Meridionale	*Milano*, corso del Littorio 3
»SIELTE«, Società Impianti Elettrici e Telefonici Sistema Ericsson	*Roma*, via Appia Nuova 572; C. P. 24
»FATME«, Fabbrica Apparecchi Telefonici e Materiale Elettrico Brevetti Ericsson	*Roma*, via Appia Nuova 572; C. P. 25
Società Esercizi Telefonici	*Napoli*, Palazzo Telefoni, piazza Nolana; C. P. 274
Società Urbana Immobiliare	*Napoli*, Palazzo Telefoni, piazza Nolana; C. P. 274
Jugoslavija Jugoslovenski Ericsson A. D.	*Beograd*, Knez Mihajlova 9; P. F. 726
Magyarország Ericsson Magyar Villamossági R. T.	*Budapest 4*, Fehérvári-út 70; F. P. F. 282
Nederland Ericsson Telefoon-Maatschappij N. V.	*Rijen (N. Br.)*
Norge A/S Elektrisk Bureau	*Oslo*, Middelthunsgate 17; P. B. MJ 2214
Österreich Ericsson Österreichische Elektrizitäts A. G.	*Wien XII*, Pottendorferstrasse 25/27
Polska Ericsson Polska A. S. Elektryczna	*Warszawa*, aleja Ujazdowska 47
Polska Akcyjna Spółka Telefoniczna	*Warszawa I*, Zielna 37/39
România Ericsson S. A. Română	*București II*, strada Luterană 23
Suomi O/Y L. M. Ericsson A/B	*Helsinki*, Neitsytpolku 1
Sverige Telefonaktiebolaget L. M. Ericsson	*Stockholm*, Döbelnsgatan 18
Svenska Radioaktiebolaget	*Stockholm*, Alströmergatan 12
Sieverts Kabelverk	*Sundbyberg*
Aktiebolaget Alpha	*Sundbyberg*
Svenska Elektromekaniska Industri A. B.	*Hälsingborg*, Rönnovsgatan 18
Elektriska Aktiebolaget Skandia	*Stockholm*, Tunnelgatan 14
L. M. Ericssons Försäljnings A. B.	*Stockholm*, Kungsgatan 31
L. M. Ericssons Signal A. B.	*Stockholm*, Sveavägen 90
Fastighetsaktiebolaget L. M. Ericsson	*Stockholm*, Kungsgatan 33

ASIA

British India Ericsson Telephones Ltd	*Calcutta*, Grosvenor House, Old Court House Street 21
Nederlandsch Indië Ericsson Telefoon-Maatschappij N. V.	*Bandoeng*, Tamblongweg 11
Türkiye İzmir ve Civarı Telefon Türk A. Ş.	*İzmir*, Dr Hulusu caddesi; P. K. 314

AMERICA

Argentina Cía Sudamericana de Teléfonos L. M. Ericsson S. A.	*Buenos Aires*, Moreno 986
Corp. Sudamericana de Teléfonos y Telégrafos S. A.	*Buenos Aires*, Bernardo de Irigoyen 330
Cía Argentina de Teléfonos S. A.	*Buenos Aires*, Bernardo de Irigoyen 330
Cía Entrerriana de Teléfonos S. A.	*Buenos Aires*, Bernardo de Irigoyen 330
Soc. Telefónica de Santa Fé S. A.	*Buenos Aires*, Bernardo de Irigoyen 330
la Tresarroyense S. A. Telefónica	*Buenos Aires*, Bernardo de Irigoyen 330
Brasil Sociedade Ericsson do Brasil, Ltda	*Rio de Janeiro*, rua General Camara 58
México Empresa de Teléfonos Ericsson S. A.	*México, D. F.*, 2:a Victoria 53/61; apartado 1396
Cía Comercial Ericsson S. A.	*México, D. F.*, 2:a Victoria 59; apartado 9958
Cía de Teléfonos y Bienes Raices	*México, D. F.*, 2:a calle Victoria 53/61; apartado 1396
Uruguay Cía Sudamericana de Teléfonos L. M. Ericsson S. A.	*Montevideo*, rio Branco 1381

AUSTRALIA & OCEANIA

Australia Ericsson Telephone Mfg Co.	*Sydney*, Reliance House, Clarence Street 139; G. P. O. B. 2554 E

Agencies

EUROPE

Belgique "SOTCO", The Swedish Occidental Trading Co.	*Bruxelles*, rue van Orley 14
Bulgarie M. Chichkoff	*Sofia*, Rakowsky 94
España Sobrinos de R. Prado, S. L.	*Madrid*, Príncipe 12
Grèce D. Missaelidis	*Athènes*, odos Amerikis 11
Irish Free State E. C. Handcock	*Dublin C5*, Handcock House, Fleet Street 17
Latvija W. Endel	*Riga*, Doma laukums 7; P. K. 86
Portugal Sociedade Herrmann Ltda	*Lisboa*, calçada do Lavra 6
Rodi Fratelli Calomeni	*Rodi (Egeo)*, C. P. 139

ASIA

Afghanistan Ahmad Shah	*Kabul*
China The Ekman Foreign Agencies Ltd	*Shanghai*, Hamilton House, Kiangse Road 115; P. B. 1503
The Swedish Trading Co. Ltd	*Hongkong*, China Building, des Voeux Road 12
Manchukuo A. Mauer	*Dairen (South Manchuria)*; P. O. B. 138
Palestine Jos. Muller	*Haifa*, P. O. B. 243
Iran Iranska Kompaniet A. B.	*Teheran*, avenue Cheikh
Philippines Elmac Inc., Electrical & Machinery Co.	*Manila*, Rizal Avenue 627; P. O. B. 625
Saudi Arabia Mohamed Fazil Abdulla Arab	*Jeddah*, P. O. B. 39
Siam The Borneo Co., Ltd	*Bangkok*
Syrie S. A. Égyptienne des Roulements à Billes S K F	*Beyrouth*, Place Bab Edriss; B. P. 931
Türkiye Selaheddin Adil Paşa	*İstanbul-Şişli*, Abidei Hurrivet caddesi 138; P. K. 1098 Galata

AFRICA

Égypte Swedish Industries	*le Caire*, rue El Maghraby 25 B. P. 1722
Moçambique J. Martins Marques Ltda	*Lourenço Marques*, rua de Electricidade 9; C. P. 166
Southern Rhodesia Rogers-Jenkins & Co. (Pty), Ltd	*Bulawayo*, Fort Street 124; P. O. B. 355
Union of South Africa Rogers-Jenkins & Co. (Pty), Ltd	*Johannesburg*, Marshall and Nugget Streets; P. O. B. 654

AMERICA

Bolivia Cía S K F de Bolivia	*la Paz*, avenida Montes 642; cas. 678
Chile Flaten, Royem, Anker y Cía, Ltda	*Santiago*, Morandé 230; cas. 2168
Colombia Emil F. Bogstrom y Cía	*Medellín*, calle 49, 51-21; apartado 43
Ecuador Ivan Bohman	*Guayaquil*, 9 de Octubre 211; cas. 1317
Peru Neisser y Cía	*Lima*, Mercaderes 432-436; cas. 597
Venezuela Harry Gibson	*Caracas*, Edificio Washington 11; apartado 891

AUSTRALIA & OCEANIA

New Zealand B. L. Donne	*Wellington*, Australasia Bank Chambers, Customhouse Quay

ESSELTE AB. STOCKHOLM 1937