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Lars Magnus Ericsson —

a Brief Biographical Sketch

HEMMING JOHANSSON, TELEFONAKTIEBOLAGET LMERICSSON, STOCKHOLM

U.D.C. 92 Ericsson LM

»The undersigned, who during his stay abroad has been in receipt of one of the State grants, begs to furnish herewith a brief report on the 2½ years spent at different factories in Germany and Switzerland.

In Berlin my first engagement was at Siemens & Halske's factory, where in the course of 11 months, by working in different departments I was able to acquire knowledge both of the methods of working and of the different telegraph instruments manufactured there.

I also worked in Berlin at Lud. Loewe & Co's factory, where I was able to learn something of the advantages of the American machine-tools. Moreover at Kernaull's scrap metal factory, where I also worked, I found much that had hitherto been unknown to me and which was of interest to observe, as was the case at A. Ronsack's workshops for mathematical instruments, such as theodolite level instruments etc., and there too was produced a new kind of sight control instrument of simple construction, designed by a certain Captain Mieg and employed by the Prussian Army. The instrument consists of a sight and a bead, the appearance of which may be seen on attached sketch. It is fitted on the rifle parallel with its line of aim, but in such a way that the shooter may without interference at the same time sight an object, while a person standing at the side to the right, by means of reflection from a mirror fitted behind the sight, can with the naked eye obtain a picture of the bead sighted and the object at which the rifle is aimed. Fig. A shows in natural size two vertical projections and Fig. B horizontal projection of the sight with mirror and its setting. How the sighting instrument is fitted to the rifle by means of a strap and with cordon screws united to the upper part should be easy to understand without further description. The bead, Fig. C, lies sufficiently steady by being made fast at the end of the barrel.

Moreover I have worked in Munich at the physics institution of Prof. Dr. Ph. Carl, and in Berne with the firm of Hasler & Escher, where I was employed on the assembly and adjustment of self-recording thermo-hygrometers, designed by Prof. Wild. In Neuchatel, Strasburg and Karlsruhe I have either been employed at or visited the best-known works.

Latterly I have had employment at Schäffer & Buddenberg's factory in Buckau Magdeburg, where my chief work was the assembly and adjustment of indicators, but I was able also to devote attention to the distribution of work, machine-tools and plant for special purposes, being able to discover, for instance, that the bent tube in Bourdon's gauges could be made for less than half their cost at home in labour alone. The difference in manufacture consisted essentially in that, instead of filling the tube with pitch and then bending it between two rolls, it was filled at Buckau Magdeburg with fine sand and then bent round *one* roll, for which a multi-service lathe is well adapted, as between the points the large roll in which a groove is turned along half the elliptical section of the tube is rotated and the smaller pressure roll, which likewise has a corresponding groove, is fitted on the support. It is then only a question of fixing one end of the tube in the groove of the large roll, after which it is allowed slowly to rotate a couple of turns, during which the tube is bent to the desired shape.

Öfver Lärka förmåga har jag sökt att
vara min uppgift. Trogen, uti att vinna insigt
i nutidens arbetssätt och de för olika ändamål
erfordrliga verktygen och maskinerna. De sin-
ga Kunskaper jag i denna riktning för-
värfvat, är jag nu i den anledningen jag
antagit vid Öller & Co. Fabrik, i Liljeholms
och Liljeholms församling, samt hoppas så det underhål-
las jag åtnjuta. Skall Lärka industriell ut-
veckling gagn, och hemmets välbefinnande för nem-
de undersökt. Min Smärskaste Harkram-
bet.

Stockholm den 14 Dec. 1875
L. M. Ericsson
Mekaniker

X 6190

Facsimile of Lars Magnus Ericsson's re-
port on his travels

To the best of my ability I have tried to carry out my mission faithfully, by obtaining an insight into present-day methods of working and into the tools and machines requisite for this purpose. The modest knowledge I have been able to acquire I have now occasion to make use of in the position I have taken in Öller & Co's factory and I trust that the grant I have enjoyed will prove to the anticipated advantage of the country's industry and I hereby express my humble thanks for the said grant.

Stockholm, 14th Dec. 1875

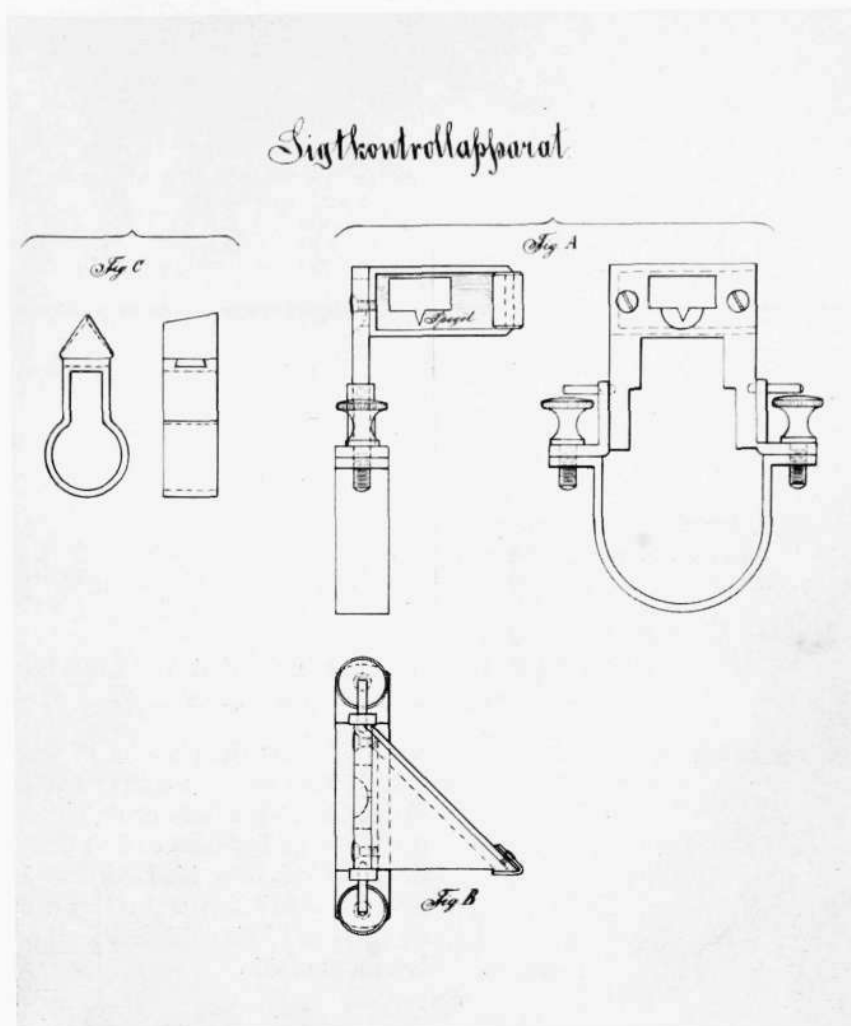
L. M. Ericsson
Mechanical engineer.»

Thus read the report Lars Magnus Ericsson gave of his studies abroad, undertaken with the support of two state grants. It is by no means lengthy and verbose. Yet rarely has hope expressed in thanks for grant enjoyed, that this might be to the anticipated benefit of the country's industry, been fulfilled to such high degree as in this case.

With those foreign studies Ericsson had completed the work of his training. On 1st April 1876 he started in independent business. The employment with Öller & Co. referred to was not of long duration, therefore.

In the phase he was now leaving behind him he had had abundant proof the serious side of life in the form of privations, grief and toil, but he had also acquired experience and knowledge of inestimable value for his future activities.

Like many other capable men who have worked up undertakings from modest beginnings to greatness and who have been privileged to make considerable contributions to developments, Lars Magnus Ericsson grew up in modest not to say poor circumstances. He was cradled in a small farm Nordtomta, owned by his father, Erik Ericsson, in the village of Wegerbol in Värmskog



Sight control instrument

Sketch of sight control instrument, attached to
Lars Magnus Ericsson's report

X 6191

Parish. There the engineer and great industrial magnate first saw the light on 5th May 1846.

In the late years of his life, when about 66 years old, Ericsson gave in a letter to one of his sons some particulars of the first 20 years of his life. It may be permitted to give some extracts from this simple though expressive document. Those who knew Ericsson's moderation of expression, his modesty and lack of pretension, will understand that behind the words quoted there lies very much more of self-denial, trouble and toil than is expressed by them.

»The first eleven years of my life were spent under the protection of a god-fearing and respected father, but with his sudden death came the first serious blow. There were left at home my mother, myself and two younger sisters; two elder brothers had already set out to earn a living. In those days there was not yet any regular school attendance and I was free to follow my bent for handicraft and general childish ponderings, intermixed with mischievousness and boyish tricks, which were common in those days as at present. Time passed in that way until my 14th year when, on condition that I was sure in repeating by heart, I was permitted to 'take lessons from the parson' one year earlier than was usual.»

According to reliable sources the lad had in 1853 reached the second class of the Wegerbol school and five years later he was in the seventh class of the Björnebol school. The education he received at school, however, was exceedingly inadequate; he had his thirst for knowledge and his good head to

X 6151
 Nordtomta, Lars Magnus Ericsson's early home in the parish of Värmskog, Värmland province



thank for the foundation on which he was later by persistent independent study to build up his by no means inconsiderable knowledge.

After attaining the maturity of confirmation, Lars Magnus had to devote himself more seriously than had hitherto been possible to the maintenance of the home. He got work as day labourer at a farm in the neighbourhood for a wage of 50 öre (about 6d in those days) per day, but he soon found that he lacked both disposition and strength for that kind of work. In his younger days his constitution was rather weak, which was certainly a result of the deprivations of his childhood. Exemption from the obligations of conscription is witness of this.

The following statement would seem to indicate that the peace of mind of this 14 year old was not free from disturbance: »Such was the course of my 14th year, spiritually rich, which directed my thoughts to the serious things of life and fortified my determination honestly and trusting in God to meet future destiny.»

He goes on: »As I was entering my 15th year there happened for me a fortunate circumstance, a mine overseer — who had been a good friend of my father — was given the mission of going to Norway with some experienced miners to investigate the value of ore deposits acquired in the region of Egersund. Though I was so young, my persistent pleas enabled me to join the troop and my first job was to carry drills from the smithy to the blasting places, and in between to help at the forge.

When we had been there about $\frac{1}{2}$ a year, it happened that the smith got a yearning for the town and stayed there longer than he should have done. While he was away I carried on with the drills and all were so satisfied with their sharpness that the result for me was that shortly after I was entrusted with the work of the smithy. This led to improvement in my pay, so that I was able to send quite appreciable amounts to those at home who were existing there in poverty, being able to earn nothing.»

Between the lines one can read that Lars Magnus had already gained a skill remarkable for his 15 years in that special domain. The 66 year old man would not directly admit it; that was quite contrary to one of the characteristic features of his being, modesty.

When after a couple of years it was found that working of the deposits could not be made to pay, Ericsson received a similar job, as leader of a labour gang to »investigate an ore-bearing seam that had been acquired in the primi-

tive forests in the neighbourhood of the township of Gösse». After having ascertained that this too was valueless, Ericsson was given work for a time on the north-western main railway line then under construction.

His thoughts and wishes, however, were turned in quite another direction. »Deep down, however, there smouldered an ever stronger desire to learn a trade, preferably in the mechanical branch and I heard of two art-metal smiths in the neighbourhood. One was Hult in Grafås and the other was Nils Andersson in Heljeboda. As by then I had put aside a little for my own needs I made up my mind to seek a place as apprentice and with this object went to Hult, with whom I was allowed to stay; but as the man was aged and moreover in poor health, so that he was seldom able to be in the smithy, both he and I decided it was useless for me to stay any length of time and through Hult's good office I went to N. Andersson in Heljeboda, getting quite a good impression at the beginning. The smithy was arranged for waterpower and there for the first time I saw a slide lathe. Soon, however, deception set in for the master smith himself was most of the time travelling and rarely in the smithy, so that one of his younger sons and I had mostly to carry on by ourselves. It soon became apparent that financial troubles were the cause of Andersson having to leave everything and he then moved to Charlottenberg Works as head of the nail-making department, which even in those days was carried on with special machines. In his contract with the Works he had stipulated that he should take me along as apprentice.»

Ericsson seems to have been satisfied with his work at the Charlottenberg Works, where as he says himself he had »a great deal to learn», but the yearning of this eighteen-year old for a field of activity offering greater prospects of development left him no peace. One after another he worked at smithies in Arvika and Karlstad. What he learned there does not transpire from his account but merely that he had to »work like a dog»: »During those years of learning I received no more than the minimum of food and rest in a dirty smithy room. Anything else I had to get as best I could and I took up the engraving of seals in my leisure time, for which there was a gratifying demand.» Here we get a glimpse of his mettle; the smithy apprentice is handling not only the sledge-hammer but also such a fine tool as the graver and, as can be divined from the modest words, with success. He saved up a little capital and this put him in a position to take a long step towards the realisation of his dreams. He journeyed to Stockholm and there, he writes: »led by a kind providence I found a place at Öller & Co's Telegraph Factory and, after one week's trial, received wages sufficient for my needs, so that I most thankfully saw life much brighter than ever before and felt then the first breath of the joy of life in my heart.» — Certainly it would not be the wage, sufficient for his needs, of 5 kronor per week that awakened that first breath of joy of life in that lad of 20, but more probably the definite feeling that he had come into a field of labour where his ability and still dormant force could make themselves fully evident.

This epoch marks the end of Ericsson's own notes.

The first seed of electro-industry in Sweden was sown in 1857 when the director of telegraphs A. H. Öller set up a workshop for the manufacture of electro-technical articles, particularly telegraph instruments and other material for telegraph stations. However, this embryo displayed no great ingrained vitality; consequently the telegraph administration found reason to intervene and arranged for the grant from state funds of 1,200 kr. for each of the years 1861—63. Öller's workshop was entirely on a handicraft basis; nevertheless it constituted a school for the training of skilled workmen in the making of electro-technical instruments. The best known of these was to be Lars Magnus Ericsson.

Ericsson served Öllers for six years and acquired the reputation of a particularly industrious and skilful instrument maker. In order still further to

perfect himself in his trade by studies abroad he applied for state travelling scholarships; twice these were awarded to him on Öller's recommendation, for the years 1873 and 1875.



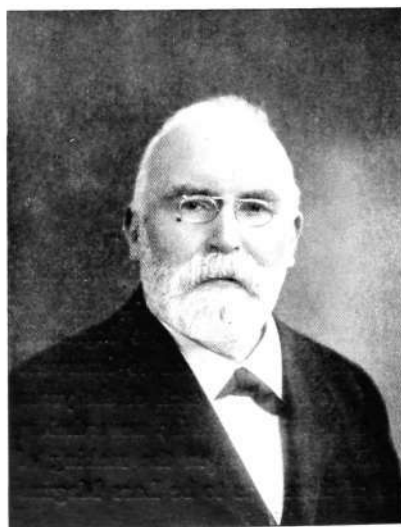
Lars Magnus Ericsson
at the age of 25

X 4425

His six years in Stockholm had been well utilised, even apart from the regular working hours at Öller's. By study in his spare time — especially in draftsmanship and languages — he had both laid a solid rational foundation for his inborn constructive bent and gained a knowledge of languages not to be despised, chiefly in German but also in English, which no doubt to some degree contributed to the granting of the travelling scholarships.

His workshop studies abroad were carried on in a manner which he himself considered ensured the greatest benefit but which perhaps was not entirely to the liking of his various employers. He took employment at one workshop after the other; after having at one place by using his eyes and straining his attention observed everything that he considered of value for his object and moreover having strengthened his travelling resources by the wages earned he would leave that place and go on to the next.

Following his return to Stockholm, Ericsson decided to realize an idea which had probably long been in his mind: his great caution would not have permitted him to set a plan in operation before it had been subjected to thorough and detailed examination. Be that as it may — on 1st April 1876 he opened, as already stated, his own electro-mechanical workshop in the building No. 15 Drottninggatan in Stockholm. The beginning of a business in more modest circumstances can hardly be imagined. »The workshop» was housed in a kitchen he rented, »The staff» consisted of Ericsson himself and a 12 year old office boy. »The machinery» was represented by an instrumentmaker's pedal lathe. »The working capital» amounted to 1 000 kr. and had been obtained on loan from one of Ericsson's acquaintances, Mrs. Maria Strömberg of Nygård, a person who seems to have been clear-sighted enough to believe in a bright future for the industrious young man. But even it outwardly the new enterprise displayed the mark of the greatest unpretentiousness, the personal contribution of Ericsson was so much the more considerable. Enormous capacity for work, tough energy, remarkable skill in the trade and extensive experience in the domain he had made his own combined with honesty and prudence in business matters were the foundation stones on which Ericsson could base his activity. The expansion up to that day in May 1903 when the man now 57 years old passed over to other hands his undertaking that had been worked up to a world industry constitutes indisputable evidence of the solidity of the foundation.



Carl Johan Andersson
Ericsson's partner, portrait taken 1920

X 4407

Shortly after starting Ericsson took in as partner Carl Johan Andersson, four years younger than himself, who had been a workmate of his at Öller's and likewise had studied abroad with the help of scholarships. Andersson put 1,000 kr. in the business, which now received the name of L.M. Ericsson & Co. Under that name work continued until 1896 when Ericsson, who in the course of time had taken over sole control with Andersson as works manager, turned over the business to Aktiebolaget L.M. Ericsson & Co. (L. M. Ericsson & Co. Ltd.). The share capital was put at 1 000 000 kronor and was owned in its entirety by Ericsson; in recognition of valuable collaboration, he presented Andersson and some of his other employees with a number of shares as a gift.

The time between 1876 and 1896 constitutes a period of intensive work and marked expansion in which Ericsson himself was ever the leader and, it is justifiable to say, the foremost worker. In the initial stages activities were devoted chiefly to the repair of telegraph and other electrical instruments, but new designs also soon appeared on Ericsson's programme of work. Among other things, on instructions from the Swedish State Railways, he designed an excellent receiver for dial telegraph instruments which at that time were



X 4424

Workshop at Oxtorget
where LM Ericsson's business was located
1877—1880

employed to a large extent on railways. Another design dating from the earlier years is a fire telegraph system for medium sized communities, a system which became wide spread not only in Sweden and which with certain modifications is applied even at the present day.

It was not long before Ericsson acquired a solid reputation for the high quality of his work and he succeeded in a short time in getting connections with administrations and institutions which had employment for instruments of the kind, such as the Telegraph Administration, the Fire Brigade, the Police Administration, state and private railways etc.; these connections have since then constantly remained.

And then one day noteworthy news reached Sweden, and this gave to Ericsson's work a direction which was to lead to unanticipated and splendid results. It was the report of Graham Bell's invention, the telephone, circulated by the newspapers and which came to Ericsson's knowledge in that way. He would seem intuitively to have perceived a great new field of work opening before him; he began to study the principle of the wonder and in a short time succeeded by experiment in producing serviceable telephones. (In the first years, before the microphone principle was devised, the telephone had to serve both as transmitter and receiver.)

From Ericsson's books we find that his first telephones for practical use were debited to the firm of Bredenberg in November 1878: »A couple of telephones with trumpet to Bredenberg Kr. 55:—.» The trumpet was intended for the giving of signals through the telephone line. Then came more deliveries in close succession. Even before then Ericsson had had telephones in for repair several times, some for the wellknown firm of Numa Pettersson. The telephone had in fact been introduced into Sweden in 1877; the first line was set up between the residence and business premises in Stockholm of H. T. Cedergren, American instruments being employed.

As long as the telephone was only used in this simple manner, *i. e.*, for private use, its spread was considerably restricted; the manufacture therefore in this period was of no great extent and was carried on entirely as a handicraft. The wages lists show the modest dimensions of the business. At the beginning of 1879 there were eight workmen, at the close of that year ten. But the following year was more lively and Ericsson, who had already found it necessary to change premises twice, now found himself obliged to move again to provide space for an ever increasing number of workmen and machines. Suitable premises were found at Biblioteksgatan 5 where the Röda Kvarn moving picture house now is. Expansion now was at a much more rapid rate; at the close of 1881 the number of workmen amounted to 30 and one year later it was 50. The business was gradually leaving the stage of craftsmanship and becoming an industry.

The increased turnover was caused essentially by the conversion of the telephone from a convenience in the nature of a luxury for private use to a means of communication in the service of the public. As far as Sweden is concerned this took place in 1880 when the American Bell Co. constructed the first telephone networks in Stockholm, Gothenburg, Malmö, Sundsvall and Söderhamn, naturally employing American material. To be in a position to compete in this domain Ericsson for his part devoted intensive and conscientious work to the improvement of his products, instruments, switchboards etc.

A clash with the Americans became unavoidable. It took place in the beginning of 1881 in conjunction with the question of the introduction of public telephones in Gefle. As the outcome of this competition was to be of decisive importance for the future expansion of the infant Swedish telephone industry and was even to open the door for its progress abroad, a brief account may here be given of the course of the struggle. It should be recalled that the widely extended American Bell Co. was at that time already strong and dominating with great technical resources according to conditions then existing, while their opponents constituted solely of the two mechanics L M Ericsson and C J Andersson.

At the beginning of 1881 the Bell Company in Stockholm offered to instal and operate a telephone network in Gefle for a price of 200 kronor per subscriber and year, on condition that at least 50 subscribers signed contracts for five years. But now competition appeared on the scene. Basing on prices and estimates from L. M. Ericsson, J. W. Sundberg of Gefle handed in a tender to execute the installation itself for 275 kronor per subscriber and thereafter to operate it for an annual subscription of 56 kronor, all on the condition of at least 50 subscribers. At the end of January there were set up for comparative tests a couple of instruments from the Bell Company and from «the Instrumentfirm Ericsson & Co.». Representatives of the press were first asked to test the installations. «Gefleposten» certified that both functioned very well, but considered Ericsson's instruments were «simpler, stronger and more attractive». Nevertheless, the Exchange Association of the city, which had charge of the question, decided to call in three advisers, two telegraph men and one technician, Lieutenant P. G. Lindahl. At a meeting on 15th February Lindahl presented a report in which it was stated: «The inspectors had found Ericsson's telephone to be better made, provided with a better ringing device and with a better designed and movable microphone than Bell's whose generator instrument for the ringing circuit has the fault that it deteriorates as years go by.»

There was then formed the Gefle Telephone Society with 57 members. On 25th February it decided to accept Mr. Sundberg's abovenamed tender — cut down to a certain extent — which means that Ericsson's instruments were to be employed.

The decision in Gefle was not only a fine local success for Ericsson and his make, gained by superiority of quality and lower price; it had a very much more extensive significance. As a matter of fact it was to act as an impulse to an unexampled rapid spread of the telephone in Sweden and neighbouring countries.

It is outside the scope of this article to seek to enquire into the details of the reasons for this phenomenon; one which chiefly contributed was without a doubt the possibility of obtaining at low prices first-class material of Swedish make, while the experience in the domain of telephony which Ericsson and his staff were gathering to an ever greater extent was constantly at the disposal of customers. At a number of places, both urban and rural, cooperative associations were formed which could offer their members exceptionally advantageous subscription terms and therefore found enthusiastic support. All were to have Ericsson's material and for this reason the workshon had time and again to increase its capacity.

It has been suggested above that the outcome of the Gefle battle also opened the door of foreign markets for Ericsson. Here it will suffice to give one of the first and most tangible evidences of this. It comes from the old Hanseatic town of Bergen in Norway. There, as in several other Norwegian cities — Christiania, Drammen and others — the international Bell Company had applied for concession to carry on telephone operation. In the capital and in Drammen the applications had been granted; in Bergen, however, things went differently. While in the beginning of 1881 the question was being eagerly discussed in the newspapers and otherwise whether the concession should be granted or whether the city should take the matter in its own hands through a society of interested citizens, there came the news of the Swedish telephones and gave a new turn to the discussion. In the Bergen newspapers of 2nd March 1881 the telegraph manager O. Norshuus, who as an expert was interested in the telephone question, published his opinion of the different proposals. In this he stated: «From what has transpired up to now it seems to be a question of introducing here a Swedish instrument that has come out recently at a comparatively moderate price concerning which the 'Gefleposten' writes: 'Lieutenant Lindahl reports' etc.» (here is given a copy of the above-named report by the advisers in Gefle on the tests that had been made). Norshuus

closes his statement with the words: »Ericsson's instruments have now been submitted to the test in Christianstad and according to reports they have been preferred to the American instruments. A couple of the former instruments will shortly be submitted to me and then opportunity will be given to the public to submit them to trial.»

Soon afterwards the Bergen Telephone Company was formed and Ericsson had acquired a firm position in Norway.

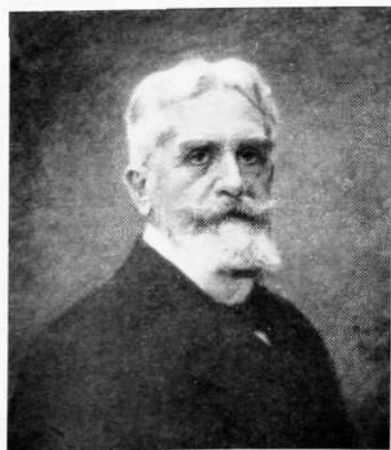
These episodes from Gefle and Bergen may possibly appear to a present day observer as of little significance. Nevertheless they constituted the breaking of the ground for the Swedish telephone industry in Sweden and its nearest neighbour countries. Ericsson had demonstrated the ability of this industry, despite relatively small resources, to engage in victorious struggle with the strong Bell concern both inside and outside the country, a circumstance which formed the basis not only of the great progress of the Ericsson undertaking but also for the subsequent intensive expansion of telephone activity in the Northern countries.

The engineer H. T. Cedergren of Stockholm was probably the first to realise clearly the importance for the life of the community the telephone might assume if its exploitation was directed along proper lines, which in his opinion was not the case in Sweden where the rates applied by the Bell Companies were almost prohibitive. When, to carry out his plans — the spread of the telephone in the widest circles (»the telephone in each home in Stockholm» to begin with) — he founded in April 1883 Stockholms Allmänna Telefonaktiebolag (the Stockholm Public Telephone Company), Ericsson's workshop had been devoted to telephony for 5 years and had gained a reputation for first-class products. What then was more natural for Cedergren than to consult Ericsson in regard to his plans in general, in the first place concerning the prospects of obtaining inside the country the material for carrying them out?

To begin with Ericsson with his cautious nature seems to have adopted a rather hesitating attitude to the audacious proposal; he was of course well aware that neither Cedergren nor any associates he had in mind possessed any experience in the domain of telephone operation either technically or financially. Nevertheless Cedergren succeeded by his enthusiasm in interesting Ericsson; the new undertaking therefore enjoyed the advantage of Ericsson's support as designer and manufacturer, which undoubtedly was of inestimable value. Indeed collaboration with Ericsson would seem to have been an essential if not an absolutely necessary condition for the realization of Cedergren's plans. Where otherwise could Cedergren have turned to satisfy his requirements of material? The Americans, whose largest plant in Sweden, the Stockholm Bell Company he aimed to beat in competition, he neither could nor would rely on. That Ericsson's business was of the greatest importance for the start and development of Stockholms Allmänna Telefonaktiebolag as indeed for Swedish telephone activity on the whole, is beyond all doubt. The collaboration between Ericsson and Cedergren continued with only one serious interruption until Ericsson retired from business, *i. e.*, for 20 years, and contributed very greatly to the building up of an outstanding world-wide industry that brought honour to Sweden and an international business enterprise of great scope.

Ericsson also provided the initial impulse for the creation of another enterprise that was later to grow into a great industry. In 1888 the brothers Max and Ernst Sievert, of whom the former had for a number of years represented in Sweden a foreign manufacture of covered copper wire, opened a factory at Sundbyberg, for the production of such wire. This plant, which under the name of »Sieverts Kabelverk» has gained a market and recognition for its products far beyond the borders of Sweden came into existence on the initiative of Ericsson.

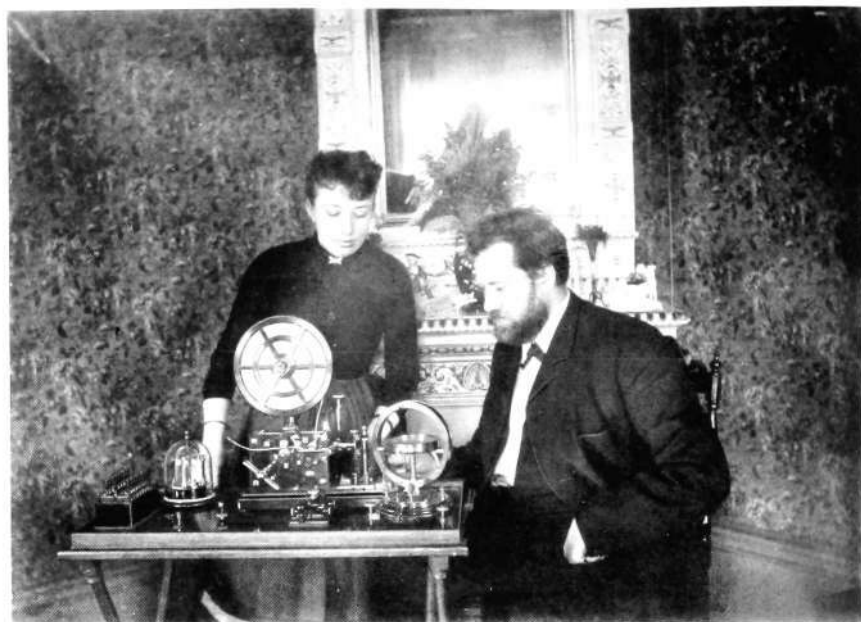
The cases of Cedergren and Sievert constitute good examples of how an able and energetic industrial leader during the early progress of Swedish industry



H T Cedergren

X 4426

X 6158
Lars Magnus Ericsson and his wife
with some instruments designed by the husband



could have an initiating and supporting influence in the building up of other big undertakings.

It has just been stated that Ericsson had great need of wound copper wire of various kinds; a considerable proportion of this consisted of silk-insulated copper wire for winding electro-magnet reels, used to a great extent in the telephone and other weak current industries. In his wife, Hilda, née Simons-son, whom he married in 1878, Ericsson had a partner not only in household matters but also in the work of his business. The winding of electro-magnet reels — typical woman's work, if such differentiation can be made in these days when even work on the big machine tools is entrusted to representatives of the »weaker sex» — was in the early years done by Mrs. Ericsson, first alone and later as the quantities grew with the aid of one or more assistants. It is narrated that when she for some reasons or other had to keep to her bed this did not prevent her continuing her work with the winding machine on her knees. There is no doubt that Ericsson in other matters also benefited by his wife's practical mind and wise counsel. One of our illustrations shows the Ericsson couple in discussion on some instruments designed by the husband, including one for the demonstration of the effects of electric current (the photograph was probably taken by Max Sievert, who was not only one of Ericsson's suppliers but also his friend socially).

What Ericsson and his work meant for Swedish technical and Swedish industrial life can naturally clearly be illustrated by complete particulars and figures. Here, however, will only be presented sufficient to characterise developments up to the year 1903 when Ericsson definitely retired.

As stated the number of hands at the close of 1882 was about 50. A little more than a year afterwards, with the working force approaching 100, Ericsson found himself obliged to find more accommodation than the premises at Biblioteksgatan provided. He bought some property on Tulegatan and had erected there a building, which could be taken into use towards the close of 1884. Some years later an adjoining property on Rådmanngatan was purchased, a building necessary for business extensions being put up there. The last extension during Ericsson's time took place at the beginning of the new century when on three plots of land in Tulegatan there was erected a factory building regarded as most up-to-date according to standards of those days. The number of hands employed in the whole range of factories at the time Ericsson left in May 1903 was around 1 000. As regards manufacture it was customary as a rough approximation to take the number of complete

telephone instruments delivered, but it should be noted that the value of other products of various kinds leaving the factory generally represented at least as large an amount. The following figures speak for themselves! In December 1883 instrument No. 5 000 was adjusted; in June 1896 No. 10 000; in January 1903 No. 400 000 (and in February 1912 No. 1 000 000). It is obvious that such quantities could not find a market inside the country; an appreciable number was exported. Even in the early eighties, as we have seen, Ericsson's manufactures had found their way abroad, in the first place to neighbouring Northern countries, and in the nineties the foreign business became ever more extensive. In some years the value of exports amounted to 60, 70 even up to 85 % of the total sales. Buyers were to be found in practically every country of the world but the chief sales areas were the Northern countries, Russia and Britain with her colonies and Dominions.

In order to satisfy the increasing demands of the most outstanding foreign customers Ericsson found himself obliged to set up branch establishments in certain countries. Thus in 1897 a factory was opened in St. Petersburg which by extensions a couple of years later attained a very large production; the following year a branch office was established in London supplemented in 1903 by a factory, and a branch office was likewise opened in New York in 1902. Moreover Ericsson had at his disposal a widespread network of agents in all parts of the world.

In 1896, as stated, Ericsson transferred the business to a company with a share capital of one million kronor. At the beginning of 1901 the capital was increased by drawing on the company's own reserves to make a total of 3 400 000 kronor, of which 400 000 kronor was employed for the purchase of an undertaking with the name Aktiebolaget Telefonfabriken, established four years earlier by Stockholms Allmänna Telefonaktiebolag.

For something over four years, up to the autumn of 1900, Ericsson guided the fate of his undertaking as managing director. But right up to May 1903 he continued to display interest in its activities. He then considered that the time had come to retire and he passed over his shareholdings to other hands.

Ericsson had now given up his great life work, but by no means with the object of enjoying the life of leisure he had well earned. Barely over 57 years he was in the full prime of life and he was well able to utilise his energy in a domain to which he had been devoting an interest for some years, farming and all that goes with it. In the estate of Ahlby, near Fittja, which he purchased in 1896 he invested large sums and put in considerable work with the object of rationalising and that gave him also opportunity to continue to satisfy his love for the work of designing. In 1916 Ahlby was taken over by his youngest son and Ericsson himself went over to the neighbouring property of Hågelby. There too he could satisfy his unquenchable thirst for work; but gradually, however, this strong man had to yield to the demands of increasing age. His greatest affliction seems to have been the progressive failing of his sight, which first deprived him of the possibility of using his dearest tools, the drawing board and drawing instruments, and later forced him to give up the society of other silent friends, books. In his later years his continual great thirst for news and knowledge could only be satisfied by having someone to read to him.

On 17th December 1926 Lars Magnus Ericsson passed away, 80½ years old. In the centuries old sanctuary of Botkyrka his remains were laid to rest on 22nd December. No speeches of tribute were allowed at the burial, no reference was made to the noteworthy lifework of the deceased, no monument shows the place in the churchyard where his remains rest. »Nameless I came into the world, nameless will I depart.»

So appeared the outer framework of Lars Magnus Ericsson's life. But what of the man, what qualities constituted the causes of his appreciable and



X 6161
Lars Magnus Ericsson's grave in Botkyrka
churchyard
immediately after the interment on 22nd Decem-
ber 1926

successful contributions to the industry of his country? The present writer was in close contact with Ericsson during the last three decades of his life — an intimate collaboration during the five years 1898—1903 — and will attempt to give a reply, by no means exhaustive, to these questions.

Ericsson was, as will have been seen, in all respect a »selfmade» man. From his 14th year he had had to shift for himself. Thanks to inborn talent and an alert and keen vision and stubborn purposeful energy he acquired a considerable amount of knowledge, not only in the sphere most nearly connected with his activity but also in other domains.

A strong feeling of respect and maybe also of inferiority was the impression that Ericsson gave at the first encounter. His outer appearance was impressive, his attitude unassuming but marked by ingrained grandeur and dignity, his utterances were always well considered, wise and logical; acquaintance had not proceeded far before one realised that the spiritual powers were no less impressive than the secular. At the beginning one's feeling of inferiority could be stifling, perhaps even hindering the development of one's own powers. But having found that beneath the apparently cold exterior there were concealed a warm heart and a sterling character, the feeling of inferiority gave place to an affection which grew in strength the more one learned to know the true personality.

Ericsson possessed great ability for directing his subordinates and gaining their respect, even though this to a certain extent might have been veiled by the moderation and consideration which constituted an outstanding feature of his character. His orders were often garbed in the soft folds of wishes, without thereby losing anything of their force. His temperament was even and the writer cannot recall a single example of Ericsson forgetting himself even under difficult and exacting situations. Wrathful words and reproaches were foreign to him. If he had reason for displeasure this found its expression in biting sarcasm and reflexions which though pointed were politely expressed, all of which possibly had a greater effect on the victim than if the correction had consisted of invective.

Among his workers Ericsson possessed an authority that recognised by all. His great knowledge of workshop practice, his generally known skill both in the design and execution of an object and his genial and unaffected manner of dealing with the staff had the result that all not only respected

Lars Magnus Ericsson
portrait by Axel Jungstedt 1905

X 6160



and looked up to him but also had a warm affection for him and tried to do their best to please him. It was a kind of patriarchal relation, a mutual trustful cooperation that prevailed, to the benefit both of the parties themselves and of the work they had to do.

One of Ericsson's outstanding qualities was caution, in business and in other matters. Many who had dealings with him considered him a pronounced pessimist. While he was at the zenith of his life work and success grew almost from day to day he might let drop an utterance something like: »Yes, it's all very well that we are full up with work. But the demand for telephones in the world would seem to be nearly filled and then where shall we get work? It might be better to start making consumption goods, matches or something like that.» Certainly such an utterance displays no prophetic vision into the development of telephony. But how many had such vision in those days? The view of things thus expressed constituted a faithfully followed guiding star in Ericsson's business; in this the term speculation was allowed no part. Which nevertheless did not prevent him when a desirable goal was to be gained from making a powerful contribution, such as when at a moment of importance for the development of the undertaking he quickly decided personally to make an appreciable capital investment in a new and promising telephone company abroad so that thereby that company's orders for material would come to his concern. For my part I cherish the opinion that Ericsson's nature was at the bottom optimistic. Extremely cautious he was, but between pessimism and caution there is a wide gulf. His energy and capacity for work, his intense love of work and his conduct in daily life were not the characteristics of a pessimist.

Energy and capacity for work — these bring us to one of the most important chapters of the reasons for Ericsson's success. When the writer entered his

service Ericsson was in his full prime, 52 years old. The amount of work he could perform was incredible. Often he brought with him in the morning at the opening of the office a sketch or a drawing of a design that he had worked out the previous evening or night or that he had put on paper during the boat trip into town from his beloved Ahlby. The whole day long he was occupied with organising and supervising the work out in the workshop, interested in the slightest details, with interruptions for discussions of business matters in the office and for participation in and supervision of the work of the drawing office. »Standard working day» was and had always been an unknown conception for Ericsson. The close of regular working hours signified most often for him merely that he returned to his beloved drawing board where undisturbed he could devote himself to his favourite occupation. Or maybe trials and experiments with new instruments and apparatus took up a great part of the hours which by others were reserved for entertainment and rest. That a 57 year old man after a long life of work, full of labour and care, might feel weary and want to retire seems hardly unnatural. Yet it seems that in the main at least it was not such reasons that led to his retirement as early as it occurred. His decision would seem to have been greatly influenced by the thought, disquieting for him with his strong feeling of responsibility, that the extent of the business made it no longer possible to follow and master every detail of the work as he had been accustomed to do, which for a man of his nature was a »sine qua non».

The quality in Ericsson which by his work became most generally known and which is usually given the greatest credit for his success and renown was his skill as designer and inventor. Unlike his famous namesake John Ericsson — likewise a son of Värmland — Lars Magnus Ericsson was not to be counted among the great inventors. Certainly there were born in his brain many ideas of value technically; but it cannot be said that any of really epoch-making importance emanated from him. In his eyes an invention was not an end in itself but only a means. His inventions may be said to represent stages in a constantly proceeding energetic work to develop and improve the branch of electrotechnics to which he had devoted himself.

An account of everything of value in the field of telephony that was created by Ericsson's genius and knowledge would take up far too much space; only a few random examples from the abundant store will be given. Ericsson was the first to give the telephone instrument and its more important components a light and attractive form without in the slightest degree neglecting efficiency. In this respect Ericsson's products were far in front of the heavy ugly types put on the market by American and other foreign factories and they were therefore the object of innumerable imitations, none of which, however, attained the quality of the original.

Ericsson's first transmitter, »the spiral microphone» of 1880, was an original and ingenious design which certainly had great importance for the development of telephone service in Sweden and neighbouring countries. Before the introduction of the carbon transmitter — in which domain Ericsson also did some fine work — now universally employed in hundreds of variations, the spiral microphone seems to have been one of the leading designs.

The first idea of combination of receiver and transmitter — the handset — did not perhaps spring from Ericsson's brain; still it was he who gave this important component its practical shaping and put it on the markets of the world, where it may now be said to have entirely established itself, since foreign manufacturers after many years of stubborn opposition have been obliged to accept the idea owing to pressure from their customers. In the domain of telephone exchanges Ericsson likewise made appreciable contributions. In 1884 he designed and made for account of Stockholms Allmänna Telefonaktiebolag the first multiple desk in Europe. In the concluding years of his business activity he participated with great interest in the design and shaping of the details in the central battery system, then quite new. It might

also be recalled that Ericsson in conjunction with Cedergren as early as 1883 had a couple of automatic connecting instruments so perfectly developed that by employing them Cedergren could offer particularly cheap subscription in his undertaking, Stockholms Allmänna Telefonaktiebolag. How the credit for the introduction of these switchboards is to be distributed between Ericsson and Cedergren it is now impossible to decide. Probably the suggestion came from Cedergren, who of course was extremely interested in getting the undertaking he had planned in operation. The development of the design, however, would have been entrusted to Ericsson. It may be mentioned that a large number of these switchboards are still employed both in Sweden and abroad, chiefly in Stockholm.

As designer, as in other respects, Ericsson was a »selfmade» man. Perhaps the expression may not be considered wholly adequate; he was a genius in that sphere, and a genius is not created by study. Persons observing Ericsson's way of working gained the impression that the design was definite and complete for his inner mind before he gave it form on the paper. So rapid and sure was the procedure. His work at the drawing board was lightened in high degree by Ericsson's thorough knowledge of his trade and all its points. He could see to the last detail how the instrument engaging his thoughts for the moment should be built up so that it could be produced in the most simple and efficient manner. He could also clearly see what demands should be made on a design intended for a certain purpose and the best manner of meeting those demands. A strong feeling of the significance of externals led him always to try to give his work an attractive appearance. And, last but not least, he put the demand for quality of execution exceedingly high, applying it to all details from the first operations in press and lathe to the giving of the final finish. In this respect he was a pioneer of great weight in telephony. His principles concerning the execution of the work raised manufacture to a higher plane than the foreign telephone factories had considered necessary to maintain; these latter were gradually compelled to try to apply the same principles, a circumstance which was to be of great benefit for this ever more universal and indispensable means of communication. The solid quality of Ericsson's work in conjunction with the elegance of design is what ensured for the »L M Ericsson» mark a general recognition as a symbol of high quality. In one of the British Dominions where the Ericsson make had acquired a large market, the Telephone Administration declared »The Ericsson instrument is the Rolls-Royce of telephones».

A characteristic example of how an accurate and elegant piece of work could act on Ericsson's feelings may be cited. During a visit to the U. S. A. in 1901, in company with H. T. Cedergren and others, he bought an automatic pistol of the famous »Colt» make. The sturdy and elegant work pleased Ericsson's trained eye and it is declared by his fellow-passengers that on the return voyage, whenever he felt at all depressed, he would take out his newly acquired treasure and gaze on it. Immediately his spirits improved and life seemed brighter.

Ericsson had little time to spare for amusement and other recreation. He was a hermit to the extent that he wasted no time on festivities, be they private or public. Lack of pretension, not to say shyness, made him avoid such occasions; there he ran the risk of attracting attention, a thing that he detested.

Many external marks of distinction came to him; probably he valued them but little, but at the same time he may have feared that refusal to accept them might attract just that attention which he found displeasing. In any case he evaded — as far as the writer knows — every occasion when he might be required to wear them. Nevertheless on one occasion he felt himself compelled to decline an outstanding honour. It was when the Stockholm University in 1909 wanted to create him Honorary Doctor of Philosophy. His response was in the following characteristic terms: »As I have been confined to bed for



X 7412

Inside views of the L M Ericsson memorial hall

located at Thulegatan 17. The hall was presented on 12th May 1943 to the City of Stockholm, which undertook to preserve and look after the room and its exhibits for posterity.

some days by illness it is only now that I am in a position to acknowledge your communication of the 30th ult. It constituted for me a surprise which carried with it deeply felt gratitude for the kind thought of the faculty for my person. Still, as my consciousness cannot overshadow my lack of qualification for the honourable distinction in question, I am compelled for my own peace of mind respectfully to decline it. Nevertheless I shall always cherish a grateful remembrance of the faculty's kind intention.»

To be in a position to present a correct and complete picture of Lars Magnus Ericsson's personality one must have been associated with him also away from work, in his home. In his Ahlby, where he and his wife had made for themselves a substantial home with the simplicity of a Tusculum, he was by no means a hermit. There as host he displayed the greatest hospitality and amiability and his pleasure in welcoming friends of various classes was great and unfeigned. On such occasions he could give free rein to gay spirits and let his sense of humour have play without the restraint which he might have thought should be maintained during working hours.

Lars Magnus Ericsson was a great man of labour. The whole of his life was a hymn of devotion to work. By his capacity of work, his genius and his energy, combined with solid aspects of character, he built up in the course of only 27 years, in harmonious collaboration unmarked by differences with his employees, an undertaking the products of which stretched out to the farthest corners of the world, bearing the name of their originator to circles wider perhaps than any other Swede's name has reached.

Developments in Teletechnics

1846—1946

Telegraphy and Telephony

Tele-signalling

Radio-Technics

Telegraphy and Telephony

N HEDEN, LATE DEPARTMENTAL HEAD IN SWEDISH TELEGRAPH ADMINISTRATION, STOCKHOLM

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621.395(091)
654.1(091)

Telegraphy

After *Volta* in 1799 had constructed his electric pile, thus demonstrating galvanic electricity, proposals were immediately put forward for remote signalling by employment of *Galvani's* frog preparation, and 10 years later *Sömmering* performed a kind of telegraphy based on the property of the electric current to split up water. None of these methods, however, was given any practical application. Other discoveries were to open the way to serviceable telegraph systems. These discoveries were made in 1820 when *Oersted* demonstrated the action of the electric current on a *magnet needle* and when *Arago* found that iron could be made magnetic by a current path wound round the iron. *Sturgeon* some years later indicated, by application of Arago's discovery, how a powerful *electro-magnet* could be constructed. Thus electric telegraphy developed along two lines both in the form of needle telegraphs and of electro-magnetic telegraphs.

The First Telegraph Systems

The first *needle telegraph* was designed by the Russian scientist *Schilling von Cannstadt* and was exhibited at the Natural Science Meeting at Bonn in 1835. The idea then became generally known, but even a couple of years before *Gauss* and *Weber* at Göttingen had a local needle telegraph installation, which was destroyed by lightning, however, in 1837. It was the English and Americans who, after numerous trials, were able to make a start with the operation of needle telegraphs. On the railways of the United States and Great Britain this very desirable accessory for traffic safety came into use around 1845. France followed shortly after and there too the needle telegraph became widespread.

The fundamental design for the *electro-magnetic telegraphs* was worked out by *Samuel F. B. Morse*. He was an American and painter of historic pictures by profession and had not previously been either physicist or engineer. Nevertheless in 1832, during a visit to Europe, he hit on the idea of employing the electro-magnet as receiver and quite unaided he worked out his first design, which he demonstrated publicly in 1837. He then entered into relations with Professor *Gale* and two engineers, the brothers *Fail*, and the design was improved by them jointly until it was in working condition. About the same time Morse published the first dot-dash alphabet which in its modified state still bears his name. The first Morse line of communication of any length was put into service in 1844 on a 64 km long circuit between Washington and Baltimore. Starting with 1845 the Morse system was introduced generally into the United States; two years later there were about 1 600 km of lines and by 1852 the length of lines had increased to nearly 40 000 km.

Morse telegraphy had thus conquered America, but as the needle telegraphy had already got a hold in the west of Europe the opposition there to the new system was extensive. Germany and Austria were therefore the first European countries to employ the American system. The first Morse circuit in Europe

was constructed in 1850, between Hamburg and Cuxhaven. After Siemens & Halske took up the manufacture of Morse equipments the system became more and more general in the 1850s.

Two other telegraph systems, both based on the electro-magnet, had come out before 1846, however. *Wheatstone* in collaboration with *Cooke* used alternating current for transmission and a polarised magnet for receiving, the latter driving a pointer step-by-step. Under the name of Wheatstone's A-B-C system, the dial telegraph was adopted in England and, after Siemens & Halske in 1857 had improved the instrument, dial telegraphs were introduced also on the railways of the Continent and in Sweden. The other system, the letter-printing system, also employs the step-by-step principle, but in combination with a type-wheel.

We have now arrived at the year of L. M. Ericsson's birth, 1846.

The First Spreading of Telegraph Networks

There is no epoch-making discovery made just that year to report, but at that date there existed many possibilities for achieving rapid and reliable telegraphic communications, so that the latter half of the 1840s and the following decade became the time when telegraphy asserted itself. The United States of America continued to hold the lead. In Europe it was the railways at the beginning which were in the fore but in a short time private and state undertakings began to construct telegraph plants for public communications. England, France, Germany and Austria were among the first of the countries of Europe. The other countries were not long behind and when Greece put in its first plant there were telegraph communications in all European States. The first international communication was opened in 1849, between Prussia and Austria. The German States formed with the latter country a telegraphic union, after which joint traffic spread out over the whole Continent. As it was feared at the beginning that aerial lines would be far too much exposed to disturbance, underground cables were employed in many places but the trials did not prove satisfactory and aerial land lines were therefore generally preferred.

Submarine cables could of course not be avoided when it was desired to obtain communication with insular countries. The trials made with un-armoured cable failed but after going over to strong iron-wire armouring good results were achieved with a cable between Dover and Calais in 1851. In the following years a number of submarine cables were laid down in European waters, including one across the Sound between Sweden and Denmark, and now the demand for connection with North America grew increasingly insistent. Cable for the purpose was procured, but during the laying in 1857 this broke over an ocean depth of about 4 000 metres. The following year, however, a cable was successfully laid across the Atlantic, but after a few weeks working this ceased to operate in September 1858, probably owing to poor insulation. It was not until 1865 that the great ship »Great Eastern» was able to lay a third and better constructed cable, while at the same time the lost end of the 1857 cable was found and the laying of that one too could be completed. Thus at the close of 1865 there were two good quality Atlantic cables. Many more were added in the course of years and by 1874 practically all countries were linked up in the world telegraph network.

The importance of telegraphy for business communications of the day can hardly be over-estimated.

Governments soon had their interest awakened in the possibility of attaining rapid communication with their subordinate bodies, but were as a rule little disposed to give the public the same benefits. Where private undertakings put up telegraph plants, however, these were immediately thrown open for commercial traffic and the governments too — not to miss the profit obtainable — soon had to follow suit. The large business houses, thanks to their expensive

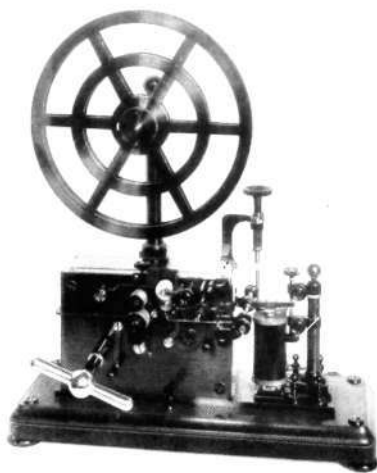


Fig. 1
Morse instrument

X 4435

but rapid courier systems had previously had an advantage over the smaller and financially weaker undertakings and could therefore better profit by rapidly changing prices. The opening of telegraphic facilities for all contributed to breaking the dominating influence of the big firms and provided possibilities of competition which in turn helped in the financial and technical advances evident in succeeding years, despite occasional setbacks.

The Introduction of Telegraphy into Sweden

Lack of interest and conflicting interests have often hampered early progress. This was the case when the telegraph was introduced into Sweden. In a written communication to King Oscar I in 1849 the American *Robinson* had offered to construct telegraphic connection between Stockholm and Gothenburg. The Chambers of Commerce in those cities did not anticipate any great utility from such a plant and would not contribute to the cost, so the Government let the matter drop. Though the public had begun to display interest in the matter, a fresh offer from Robinson the following year still failed to obtain Government support.

It was three Swedish military men that later took up the question afresh, General *Carl Akrell*, chief of the semaphore telegraphy, and Lieut-Colonel *J. F. von Heland* and Major *A. L. Fahnehjelm*. The last-named in the course of his work with the naval engineering corps had interested himself in the practical employment of galvanic electricity. In the years 1843—46 he designed in conjunction with v. Heland a telegraph instrument. During a journey abroad in 1850 Fahnehjelm made himself acquainted with the Hamburg-Cuxhaven plant and he bought a Morse instrument in Hamburg. With this as pattern two instruments were made in Sweden. Fahnehjelm and v. Heland carried out a number of experiments with these, and in the spring of 1852 they were in a position to exhibit a trial plant at the de la Croix gallery in Stockholm. Akrell by now had been entirely won over in the matter and he submitted to the King a proposal for a Swedish telegraph network to comprise Svealand and Götaland and which also envisaged communications with Denmark and Norway.

In the beginning of 1853 the Government gave its approval in principle to the plan. It was, however, restricted to the section Stockholm—Upsala—Örebro—Gothenburg, of which only the Stockholm—Upsala section was to be constructed immediately. On 16th June 1853 Sweden's first telegraph plant, Stockholm—Upsala, was ready for trials and in the autumn of the same year it was opened for public traffic. Von Heland became the head of the plant, Fahnehjelm chief of the Stockholm station and to the same position in Upsala was appointed A. H. Öller.

Akrell now submitted detailed proposals for the continuation of the line Upsala—Gothenburg and on via Helsingborg to Malmö, with branch line from Vänersborg to Norway and cable connection over the Sound to Denmark. In 1854, after funds had been voted, the work could be continued. It proceeded at such a rapid rate that Gothenburg could correspond with Stockholm by 4th July and the whole connection up to Malmö was completed by 28th August the same year.

The coming of the telegraph was celebrated in the different cities by great festivals, the newspapers were loud in praise and the ice was now broken. The Riksdag granted funds for fresh lines and construction was pressed forward to such an extent that in the next five years there were laid a main line via Norrköping and beyond along the whole of the east coast to Malmö and another via Gefle along the whole Norrland coast to Haparanda. In addition Norway was connected to Vänersborg via Uddevalla. Submarine cables had been laid across the Sound and between Västervik on the mainland and Visby on Gotland. By 1859 all county towns had received telegraph communications with the exception of Öresund, whose telegraph station was not installed until 1863.

The stations were equipped with Morse instruments. These had been made by different Swedish instrument-makers, among whom was F. J. Berg. After the above-mentioned A. H. Öller had become Director of the Stockholm telegraph station he opened in 1857 under the name of Öller & Co. an instrument-making shop. There both Morse instruments and other requisite station equipment were manufactured. The workshop was for long the main contractor for the telegraph administration and its new improved instruments also aroused attention abroad. It was also at Öller's workshop that L. M. Ericsson was to start his lifework in the domain of teletechnics.

The expansion of Sweden's telegraph network continued at a rapid pace if on a somewhat smaller scale during the 1860s. In the following decades the traffic in some years displayed stagnation or falling off, which was reflected in difficulty in getting the finances to balance and in the slowing down of the lay-out of new lines and stations or in total suspension some years. There was a disposition at the time to consider this due, in addition to the prevailing depression, to competition from the railway telegraphs and from the telephone introduced in the 1880s.

As regards railway telegraphs, it was found that the smaller places could manage with its facilities, though on the railways private correspondence could only be handled as a secondary matter. For a long time Siemen's and later L. M. Ericsson's dial instruments were those generally in use on the railways. Despite the fact that telegram traffic with these instruments was less sure than with the Morse instrument, the telegraphic facilities were of great benefit to the public and brought also to the State telegraph network a considerable amount of traffic.

Even the competition which the telephone exercised, especially over short distances, turned to the advantage of the telegraph after the Board of Telegraphs introduced the facility for private branch exchanges and subscribers to despatch and receive telegrams by telephone. There was also another way in which the telephone circuits were to furnish advantages to the telegraph. By providing a telephone circuit with transformers at both terminal points and, from the middle of transformer windings turned towards the line, tapping a line it was possible without disturbing the telephoning to obtain a single-wire telegraph circuit. The first such telegraph transforming was taken into service in 1896. Even twenty years earlier efforts had been made in two other ways to avoid expensive line construction and therefore augment the traffic capacity of the existing telegraph network, *viz.* by the introduction of the rapid-writer system and by duplex telegraphing.

Later Telegraph Systems

A change-over to rapid-writing was made in 1874 on the most heavily burdened lines, where the Wheatstone system had begun to be employed. The telegraph

number of telegrams in millions

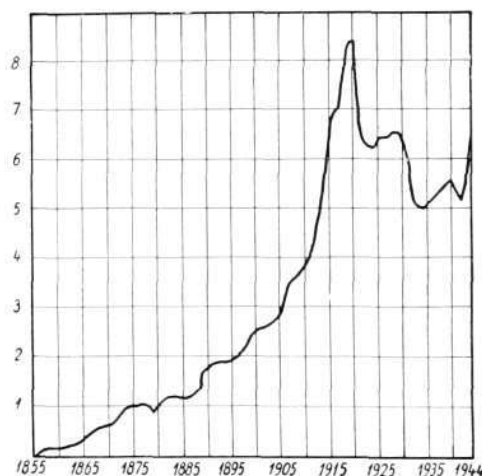


Fig. 2
Graph showing the number of paying telegrams in Sweden for the years 1855—1944

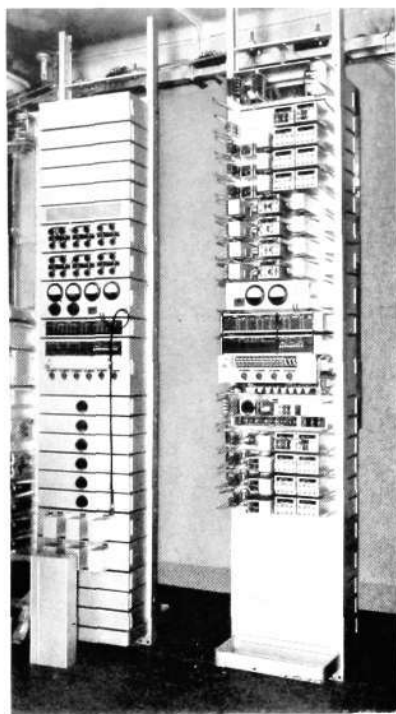


Fig. 3 X 4429
Rack for voice frequency telegraphs

signs are stamped out in paper strips by perforators. The perforated strips are fed into the transmitter which works at great speed. In the receiver, a modified Morse instrument with polarised magnet system, the signs are reproduced on telegraph strips. The system, owing to its reliability and its ability to deal with traffic blocks, has long been of great value.

The duplex-telegraphy, by means of which it is possible on a single wire to transmit in both directions, is based on a method worked out by the American *Stearn*. Duplex can be employed both with the Wheatstone system and in ordinary Morse telegraphy. The first employment of it in Sweden dates from the year 1878.

The graph of Fig. 2 shows development of telegram traffic in Sweden. A steady regular increase took place from 1889 up to the 1914—1918 world war.

Despite the fact that the above accessories enabled a great part of this increase to be coped with, it was still necessary to construct new telegraph circuits to a certain extent. The greatly increased requirements of circuits during and immediately after the 1914—1918 war necessitated during this period considerable construction. By 1924, however, the length of telegraph lines had reached its maximum. The laying of trunk cables had then begun and the telephone lines in these provided facilities for new telegraph circuits. When the aerial wires along the railway lines had to be taken down owing to electrification these were replaced by cable circuits.

For this purpose in Sweden three distinct systems were employed, *viz.*, cable telegraph, voice frequency telegraph and super-audio telegraphy.

The *cable telegraph circuits* are two-wire and without connection to earth. For telephone purposes all quads in the trunk cables are phantomised. If the middle of the phantom transformer winding towards the cable is taken out, there is obtained from each quad, in addition to three speech circuits, a single-wire line, and two of these form a super-phantoms circuit that can be utilised for telegraphing but not for telephony. Cable telegraphy is used on those sections where the demand for circuits is comparatively small.

Telephone lines are employed for *voice frequency circuits*. The frequency band that can be transmitted through the loaded cable line without too much distortion is divided up into a number of narrower bands, known as channels, each having its own carrier frequency. For this purpose one of the four-wire circuits of the cable is made available. It is possible to apply on each such circuit 24 channels in either direction and thus obtain 24 telegraphing facilities on each telephone circuit utilized. Equipment for these plants is supplied by LM Ericsson who are now also working on new and more up-to-date types of voice frequency telegraphy.

In the *super-audio telegraph system* there is employed only one carrier frequency, which lies higher than the frequencies required for good speech connection and is separated from these by filters. As with the cable telegraphy, the super-audio channel is obtained without decrease in telephone facilities. All super-audio equipments are supplied by LM Ericsson.

By the employment of telephone circuits for telegraph purposes the demand for aerial telegraph lines has fallen, so that the length of almost 44 000 km attained in 1924 has now been reduced to less than 4 000 km, while the telegraph channels in the telephone network have a total length of app. 103 000 km. The instruments and equipment for these channels are for the most part located at the cable repeater stations.

New instruments also have been introduced in the telegraph offices and now telewriters are almost exclusively used for the wired circuit telegraph traffic. Morse equipment is to be found now only at a few telegraph offices. Wheatstone instruments are still used for transit circuits of the Great Northern Telegraph Company but otherwise are now only kept as reserve.

Three machines of different makes are used for telewriting, *viz.*, Morkrum's teletype, Creed's teleprinter and Siemens' telewriter.

In recent years, with telewriter circuits rented out to a large extent to government administrations and private undertakings, the number of telewriters in service in the country now amounts to over 1 000. Plans and estimates for the introduction of subscriber telegraphy with automatic connection are being worked out.

Sweden's Telegraph Communications with other Countries

Mention has been made of the laying during the 1850s of submarine cable across the Sound. This cable was part of the Copenhagen—Helsingborg circuit, completed in the first days of 1855. The Danes had then their own telegraph office at Helsingborg, between which and the Swedish office the telegrams were carried by messengers. Direct communication was not arranged until five years later. By this time the need for more numerous and more sure communications with the Continent had arisen and a new cable to Denmark was laid in the autumn of 1863. During the Danish-German war in 1864 the telegraph lines were cut which hastened the laying in 1865 of a direct cable between Skåne in Sweden and Rügen in Germany. Keen interest at that time existed in Britain and America in a west-east transit connection through Sweden to Russia and applications for monopoly were made by several cable companies to the Swedish government, which, however, was not willing to grant any sole right. Moreover, Sweden for her own traffic with Europe had had to submit to high transit charges and it was realised that transiting through the country might provide a considerable income. Therefore when the Danish financier *C. F. Tietgen* in collaboration with foreign cable companies had begun to acquire concessions in other countries and then addressed himself to the Swedish government his proposal was favourably received though with certain reservations, and in June 1869 Sweden granted the first concession to Tietgen which he subsequently passed over to the company he established at the same time, the Great Northern Telegraph Company. By the concession Tietgen was under obligation to lay immediately a cable across the Åland Sea and later, as and when the Swedish and Russian governments required, to increase the number of circuits by this route. The Grisslehamn—Nystad cable was put into operation on 1st November 1869. After the Great Northern Company's concession had been extended to comprise communications from Sweden westwards the company laid in 1873 a cable with two wires between Marstrand and Skagen, from which junction was obtained with the Fanö—Calais and Hirtshals—Newbiggin cables. The transit lines through Sweden were laid and owned by the Swedish telegraph administration. Traffic on this route rose steadily and during the years 1877—90 two further cables were laid by the company across the Åland Sea and two cables between Gothenburg—Newcastle. The Great Northern Company's concession is still in force, though appreciably modified.

In 1898 a new telegraph cable to Germany was laid and the greatly increased continental traffic has since been provided for by submarine cables common to the telephone and telegraph.

The first telegraph circuit with Norway via Vänersborg was opened as early as 1855. New land circuits with Norway have since been arranged by lines from Gothenburg and Karlstad to Oslo, from Östersund to Trondheim and via Kiruna to Narvik. Transiting of Norwegian traffic over Swedish lines has also taken place. In 1856 Russia was connected via Torneå—Haparanda to the Swedish network. At the outbreak of war in 1939 Sweden had some 30 telegraph circuits with foreign countries. Most of these were cut by the belligerents and they have not all been restored yet. In place of them wireless telegraphy was arranged between Sweden and several countries, by which the greater part of traffic requirements could be satisfied.

Telephony

In the preceding section — on telegraphy — mention was made of Oersted's and Arago's discoveries. In 1831 *Faraday* demonstrated that, if a line circuit encloses a magnetic field and the field intensity is altered, current is produced in the line circuit. This research discovery constituted the necessary foundation for the transmission of speech with the assistance of electricity. Below will be dealt with first the basic components which together form a telephone instrument.

The Receiver

In 1837 the American *Page* performed an experiment by which he fitted a wire spiral between the poles of a horseshoe magnet. When circuit was made or broken in the wire spiral a sound was produced by the magnet. This, known as *Page effect*, was due to small alterations in shape of the magnet and was used by the German *Reis* in the receiver made by him, which consisted of an iron wire wound with copper wire. The device was fixed on a sounding box so that the sound might be better heard.

Reis, who gave his design the name of telephone, carried out his work during the years 1860—63. A couple of years later the American *Yates* took up similar experiments and further attempts in the same style were made in 1874 by *Elisha Gray*. But some years earlier, 1868, the American *House*, who was working in the domain of telegraphy, produced a sound receiver for telegraphy, which might with advantage have been used for the reception of speech if only the inventor had realized this possibility.

The man who was to come out with the final solution of the telephone problem was the American *Alexander Graham Bell*. It is true that he had many experiments by other research scholars to rely upon but, unlike his predecessors, he had by study of *Helmholz'* experiments realised that articulated speech contained a multitude of tones combined together. He gives expression to this experience in one of the instruments first produced. This consisted of a strong electro-magnet in the form of a horseshoe the arms of which were provided with a number of steel laminations, as in a musical box. These laminations were tuned to a scale of tones. Technically the instrument should have been capable of reproducing speech with correct timbre, but Bell soon found that the requisite number of laminations would have to be unreasonably large. However, he arrived at another and simpler solution by fixing the iron armature of the electro-magnet on a diaphragm, in the first design a thin gold leaf. This device proved capable of replacing all the laminations.

Now Bell had his receiver clear in principle and he announced it in 1876 in his first application for patent. Soon afterwards he replaced the gold leaf and the special armature by an iron or steel diaphragm and the electro-magnet was made with a permanent rod magnet on one pole, on which there was fitted a wire coil with soft iron core. In this way, at the beginning of 1877, the receiver had obtained the external shape which it was to retain for many years.

The Transmitter or Microphone

The distinction noticed by Bell between the pure musical tones and articulated speech with its consonant sounds and its varying timbre was of decisive significance for the design of a transmitter.

When single tones were to be transmitted this was possible to arrange, if only the intermittent circuit break or make were in time to the cycles of the tone, but in transmission of speech all the frequencies comprised in it with their mutually varying amplitudes had to be transmitted simultaneously. The valve regulating this undulating current should not in any case entirely break the line circuit.

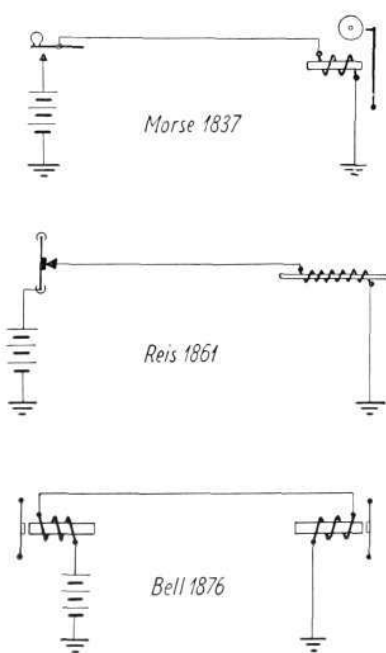
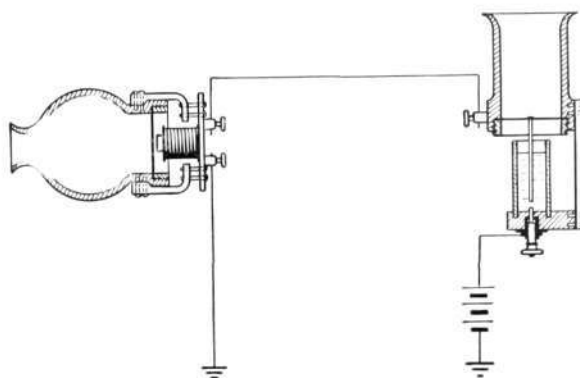


Fig. 4
Comparison of the principles for Morse's,
Reis' and Bell's designs

X 4417

Fig. 5
Grey's drawing for patent, 1876

X 6187



Reis in his instrument employed as transmitter a spring with platinum point which made contact with a platinum plate fixed on a diaphragm. When the current conveyed through the contact was broken and made alternatively by the oscillations of the diaphragm the instrument could certainly reproduce the tones clearly if not perfectly, but of the speech there came out only a word here and there. Results were somewhat better with the Yeates' instrument but only when the contact had accidentally become damp. Neither Reis' or Yeates' instruments were ever used in practice and they were forgotten for a long time.

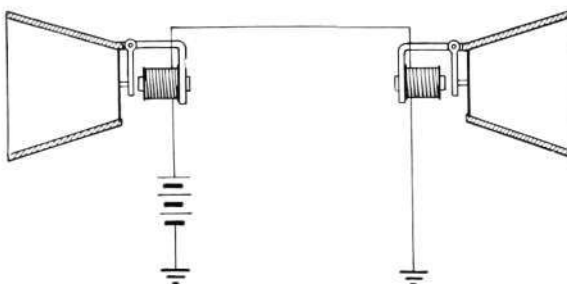
When Gray in 1874 designed his electro-harmonic telegraph employing automatic interrupters tuned for different tones he was approaching the idea Bell applied in his laminated instrument. It was only later that Gray arrived at a transmitter that worked with resistance variations. Gray then used a vessel containing a fluid with low conductor property. From the bottom of the vessel there stood up a wire with platinum point. In a steel diaphragm above the vessel there was fixed another wire with similar point, this being submerged in the fluid to an appropriate distance from the fixed platinum point. When the diaphragm was caused to oscillate, variations were produced in the circuit made through the layer of fluid between the wire points, owing to the changes in resistance.

Bell solved the question of transmission by simply employing the same kind of instrument both for receiving and transmitting. This is indicated also in the drawing for patent which he submitted on 14th February 1876. On the same day, but some hours later, Gray handed in an interim patent application (caveat) for his design already completed, to prevent Bell's patent, but this did not succeed. Gray's transmitter was that described above and his receiver differed little from Bell's.

The employment of receiver as transmitter was soon found lacking in efficiency and Bell went over to the use of different instruments for receiving and transmitting, as Gray had done earlier. Approach was again being made to Reis' design but the aim was to arrive at a contact which did not cause break but produced a resistance changeable according to the variations of sound pressure.

Fig. 6
Bell's drawing for patent, 1876

X 6186



It was *Edison* who first of all used carbon electrodes. In collaboration with *Phelps* he made a transmitter with contact between a carbon plate and a disc of platinum. Some months earlier, however, Edison's countryman *Blake* had obtained a patent for a transmitter that also had carbon-platinum contact. Compared with that of Edison-Phelps the design of *Blake* gave better facilities for accurate adjustment, a property on which the utility of these contacts was highly dependent.

Up to now in describing the different transmitters the word microphone has been avoided because it was Professor *Hughes*, mentioned in connection with telegraphy, who first made use of this name. *Hughes* demonstrated that a loose contact between two electrodes had much stronger valve effect than the fixed one used by Edison and *Blake*. The loose contact was formed of one or more carbon rods the ends of which were pivoted in hollowed pieces of carbon. It was, however, difficult to avoid intermittent interruptions in the line circuit, which spoilt the speech. A satisfactory solution of the microphone problem was brought out in 1881 when *Henry Hunnings* made public the principle of the carbon granule microphone, in which the space between the electrodes had been filled up with carbon granules of suitable kind and size.

Other Components of the Telephone Instrument

In the first telephone instruments the battery was connected in series through the magnetic coil to the line. With increase in the line resistance the current variations became weaker and Edison introduced as early as 1877 a transformer, known as the induction coil, and two current circuits in the apparatus. In the microphone circuit are comprised then the battery, the microphone and one low ohm transformer winding. In the receiver circuit are connected the receiver and the other transformer windings in series with the line.

A complete telephone instrument also requires devices for giving and receiving signals. In the first stage signalling was done by battery and ordinary electric bell but after a couple of years A.C. signalling was introduced with magneto inductor as generator and polarised bell as receiver. The requisite switching over between speech and signal was first done by hand but later by means of the hook in which the receiver is hung. The telephone thus arrived at was in its practical form an American product and its introduction as means of communication also started in the U. S. A.

The Development of Telephone Networks in Different Countries *U. S. A.*

As stated Bell and Gray put in their patent applications on the same day and the exploitation of the inventions was taken over, Bell's by a consortium formed by him, later the American Bell Telephone Company, and Gray's by the Western United Telegraph Company. Even in the 1870s the expansion of the telephone network was rapid. At the beginning of 1880 the number of instruments throughout the country was over 30 000 and only a year later it had more than doubled. The Bell Company established a countrywide organization and founded a number of subsidiary companies. One of these subsidiaries, the American Telephone & Telegraph Company (A. T. & T.) made greater progress than the parent company and the Bell Company was taken over by A. T. & T. in 1899. Ten years later the Western Union was also bought after which A. T. & T. had for a time almost a monopoly of telephone business in the States. In opposition to this with a certain support from the authorities there were formed around the beginning of the century more than a hundred so-called independent companies, which in 1907 had together a little more than 2 million subscribers against the four millions of the Bell Company. Later, however, some of the independent companies made agreements with A. T. & T. and formed what were called Associated Bell Companies. This was furthered naturally by the necessity of assembling under one hat the trunk traffic, which is still retained by A. T. & T. As chief supplier this company had had the

Western Electric Co., which was started in 1872 and during the later part of the 1870s was supplier to the Western Union, but finally allied itself entirely with its big customer A. T. & T. The direction both of commercial and technical developments has always remained with A. T. & T.

Great Britain

Bell's telephone aroused great interest in Britain immediately on its appearance. Edison's microphone design also was soon known in the country and shortly afterwards there were formed two companies, one for the exploitation of the Bell design and one an Edison company. In 1880 the companies joined up and amalgamated into the United Telephone Company.

In England, however, the state had a monopoly of telegraph business and took legal action against the company. The question was settled in 1881 by the company for a certain royalty, which was high, obtaining concession for local telephone business. In the same year the state (General Post Office) started similar business but while the private networks increased their number of subscribers rapidly the G. P. O. had but small success. When the demand for trunk traffic became apparent the state in 1884 had to begin the construction of trunk lines and continued with it. Shortly afterwards the company obtained concessions also for the building of such lines. Development after that was rapid. The United Telephone Company and other undertakings were merged in 1889 into The National Telephone Company which from then was the leading telephone undertaking.

Many people, however, considered that private interests had gained a position too much resembling a monopoly. Some years later, when the question was up in Parliament, it was decided that the state should more strongly operate its competition, previously rather weak, and that concessions should also be granted to local authorities. In 1889 G. P. O. was voted a considerable amount to enable it to open a competing exchange in London, and by hindering the company as far as possible in constructing its lines the relations between the state and the company became more and more strained. Finally when the company's concession expired in 1911 its property was taken over by the state which from then was alone in carrying on telephone business in Britain. The development of telephone business in Britain proceeded, except for the participation of the state, along lines similar to that in America. As regards the general spread of the telephone England cannot be compared with the pioneer country.

France

From the very beginning in France the telephone was declared to be a state monopoly. But, there also, private undertakings obtained at an early date concessions against high royalty. The French state, however, began its own business in the domain in 1882 and the private undertakings were taken over in 1887, after which the state alone had hand of all telephone business. In respect of the spread of the telephone France is not in the first rank.

Germany

Germany was the only one of the leading countries of Europe as regards the telephone where the business was taken in hand in its entirety by the state from the beginning. The postmaster-general *Stephan* recognized its value and introduced the telephone in all the large post offices which were without telegraph communication, so that in Germany there were by 1880 several thousand telephone instruments in service.

Bell had not taken out patents in Germany and the farsighted firm Siemens & Halske took up the manufacture of telephone equipments and made to a large extent its own improved designs. It is true that both home and American businessmen had tried to get concessions but *Stephan* carried through the state

monopoly and Reichspostamt began to accept subscribers in 1880. The development of the local networks did not proceed so rapidly and the trunk traffic did not attain any great extent until the middle of the 1880s. Since then, however, the telephone has become ever more widely distributed.

Owing to the thorough research work carried on in Germany in this domain and the great development of German industry it has been mainly German designs that have been used in Germany. These have moreover been considerably distributed in Europe generally. As regards subscriber density in Europe only a few countries can show better figures than Germany.

Denmark

The first development of telephone in Denmark displays a picture similar to that of Britain. The absence of legal provisions allowed of private enterprise right up to 1889, when the state carried through its telephone monopoly. Concessions for telephone operation, however, were granted for local areas and these are still in force. Among the large telephone undertakings are chiefly to be noted the Copenhagen Telephone Society which serves the whole of Zealand, the company for Jutland and one for Fyen. The state runs the countrywide trunk network and has also connected a number of its own subscribers to it.

In regard to density of the telephone Denmark has a leading position. The number of subscribers per square kilometre is the greatest in Europe. The number of instruments per thousand inhabitants is also very large, but in this respect Denmark has for many years been surpassed by Sweden.

Norway

In Norway the state obtained in 1881 the sole right of telephone business, but with the important exception that, in towns or hundreds, private persons might also carry on such business. The local, municipal or private undertakings, which started at an early stage, soon began to feel an ever increasing need for joint traffic with each other and the Government at one time and another granted concessions for long distance circuits. The question of trunk traffic proved to be a difficult problem. The solution arrived at was that the state in conformity with decision of the Stortinget in 1896 bought up the private trunk lines and from then on took charge of long distance traffic. At the same time the Norwegian state also began to carry on local telephone business. Gradually more and more local plants have been taken over by the state.

Interest in telephone questions has been large and widespread in Norway and has contributed to a telephone density remarkably great, when the natural and population conditions of the country are taken into account. Thus Norway takes third place among European countries after Sweden and Denmark.

Development of The Swedish Telephone Network

Finally, after this general survey, I shall turn to the development of the Swedish telephone network with some reference to technical advances as well.

The fact that in Sweden no state monopoly for telegraph and telephone business existed at the beginning or was imposed by legislation has formed the basis of the development described below.

The First Telephones

The first time a telephone was exhibited in Sweden was in August 1877, when a Norwegian engineer *Hopstock* demonstrated an installation between the Grand Hôtel and the telegraph office in Stockholm. The same year a number of Bell's hand telephones were imported and by the beginning of the next year



Fig. 7
Telephone instrument, as used by H T Cedergren in 1878

X 4433

there were two telephone lines in Stockholm, one between H. T. Cedergren's shop and his residence at Drottninggatan and one between the gasworks and the gasometer on Vasagatan. During the first part of 1878, 23 more telephone circuits had been set up in the city. Bell's telephone was then employed as transmitter and receiver.

The initiative for the laying of a real telephone network by which the telephone should be of public utility was taken in 1879 by three telegraph commissaries in Stockholm, Messrs. *Lybeck, Bratt* and *Recin*, whose application resulted in statements by both the Telegraph Administration and the office of the City Governor that there was nothing to prevent a telephone plant in Stockholm being laid. The above named gentlemen formed in 1880 the Stockholm Telephone Company. They turned, however, to the Bell Company in America for the purchase of instruments. That company, which itself wanted to run such plants, took over the Stockholm Company and the newly established Stockholm Bell Telephone Company in the autumn of 1880 opened Sweden's first telephone exchange in Stockholm on Vesterlånggatan. There were then connected 121 subscribers. Sub-exchanges were shortly afterwards opened in the south and north districts of the city and in the environs.

The Bell Company had plans for constructing telephone networks in a number of other Swedish towns, but only the networks in Gothenburg, Malmö and Sundsvall were constructed under this company's management in 1881.

On the other hand, in that year private telephone associations constructed networks at Norrköping, Gefle, Örebro, Eskilstuna, Västerås and Enköping. The Bell Company employed telephone instruments of the Bell-Blake type and the possibility for purely Swedish enterprise to execute telephone plants had by this time been created by L M Ericsson. He had been employed at A. H. Öller's workshop, referred to above, which manufactured telegraph instruments and other electrical equipment. Ericsson began his own business on 1st April 1876. When he learned about the telephone he carried out experiments with it and by 1878 he could make instruments himself and sell them on a small scale. His make proved to be equal and in many cases superior to foreign instruments. The Gefle telephone plant was the first to use Ericsson's make exclusively and was later followed in this by other telephone societies of the country. The early device with the receiver used also as transmitter had then been discarded and microphones of Blake's type had gained ground. The microphone design worked out by Ericsson, like that of the Bell Company, was of Blake model, but its extremely good facility for accurate adjustment of the carbon-platinum contact made it so efficient that for a long time afterwards it dominated the Swedish market. The Telegraph

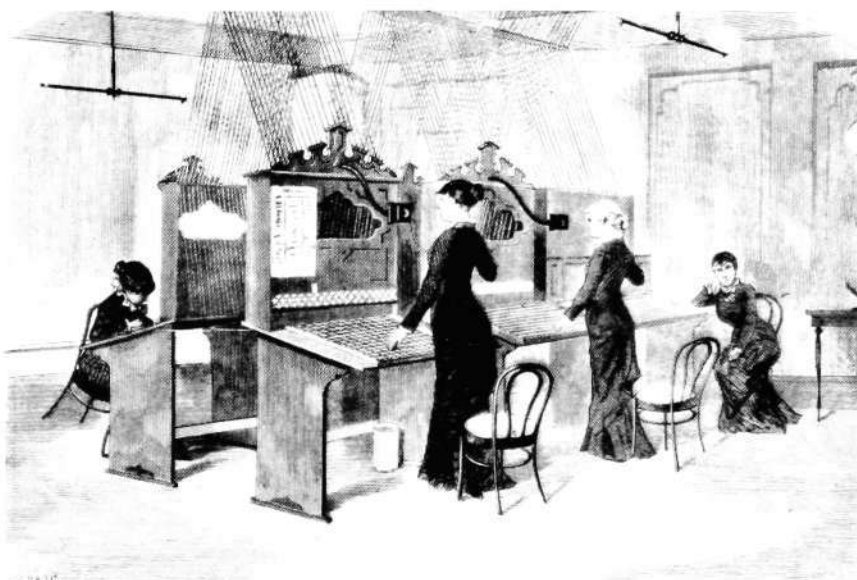
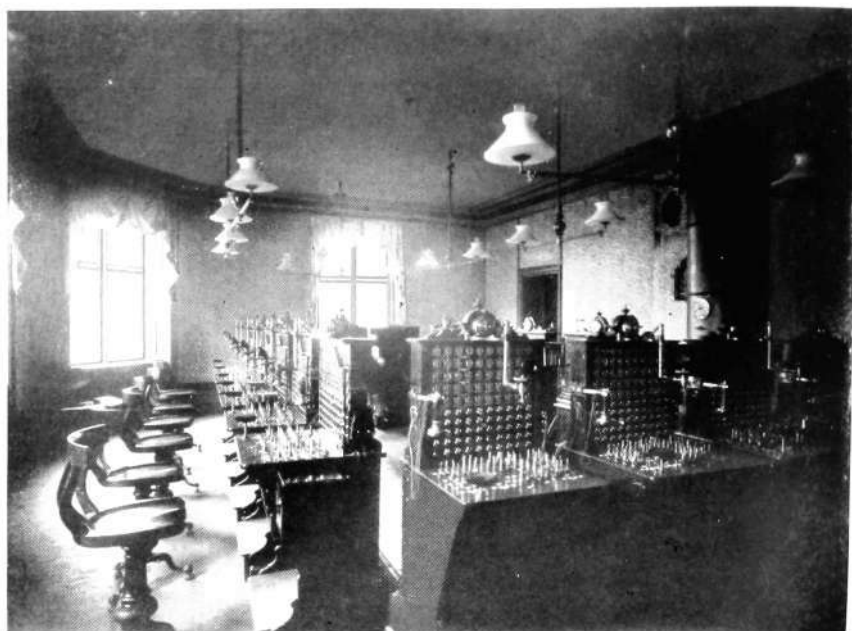


Fig. 8
The Bell Company's first exchange
after a drawing by Victor André

X 6192

Fig. 9
Allmänna's first exchange at Oxtorget in
Stockholm 1883



Administration to begin with took up a watching attitude towards the new means of communication and made no objection when concessions for the above mentioned plants were applied for.

It was only in 1881, when these undertakings had attained such an extent that their activities might have an adverse effect on the telegraph business, that the Telegraph Administration asked for and obtained authority to, as it was put, »facilitate, by the laying down of telephone lines, telegraphic communication in those places that may be in need of it.» Consideration for the telegraph was undoubtedly the main interest of the Board of Telegraphs but recognition of the telephone as independent means of communication was to be found in measures by the board the same year to provide telephone communication between the ministries of state and the central administrative offices. The switchboard was set up in the central telegraph office at Stockholm and the plant when coupled up comprised 32 instruments which could also be linked with the private network. In accordance with the above authority, there were constructed in the years following a number of connections from telegraph offices to iron works, saw mills and large estates, which connections often were of considerable length, some of them as much as 50 km. When, later on, a number of such lines were connected to one telegraph section, the subscribers could begin to have calls with each other and this was the origin of the Telegraph Administration's local network outside the capital.

Some of these subscriber lines were also linked with the private network of the locality via the telegraph office. In many cases there was opened in rural districts also joint traffic between the Telegraph Administration and the telephone societies. The high subscription rate of the Bell Company undoubtedly contributed to the success of the telephone societies which were formed and operated without any idea of financial gain, and the subscription policy of that company also led to the establishment in Stockholm of another undertaking which in the course of time was to take precedence over the Bell Company.

Stockholm's Allmänna Telefonaktiebolag

The engineer H. T. Cedergren, who was responsible for the installation of one of the first telephone circuits in the country and later was a subscriber of the Bell Company, pointed out to the company's management that lowering of the charges would lead to increased expansion of the business. When he

was not listened to, he entered into relations with L. M. Ericsson and came to an agreement with him for the supply of telephone equipment. He was then, after careful estimates, ready — despite doubts expressed in many quarters — to establish *Stockholm's Allmänna Telefonaktiebolag*, which was formed on 13th April 1883. In the same year in October »Allmänna's» first telephone exchange was opened at Oxtorget in Stockholm. Cedergren's measure of reducing the rates from the 160—280 kr. applied by the Bell Company to 100 kr. for all subscribers pointed the way by which Sweden was to become one of the foremost telephone countries of the world.

Provincial Networks

The Telegraph Administration in 1882 constructed telephone networks in Härnösand and Uddevalla, the first state networks outside Stockholm. In the beginning of 1883 the administration purchased the Bell Company's network in Malmö and in the following years extended this plant in Scania to Lund, Eslöv, Trelleborg and Landskrona. In addition a number of smaller networks or call offices were established in the regions of Bohuslän, Bergslagen and Norrland. The national telephone's network in Scania was later developed to comprise the whole province.

Alongside these developments there had taken place throughout the country great expansion of the activities of the telephone societies. Thus the number of societies, amounting to six in 1881, had by 1884 reached about fifty, an increase which was to continue.

Instruments and Switchboards

The material employed by the Bell Company in this period was entirely of foreign make. The Allmänna Company on the other hand had used nothing but instruments and switchboards of L. M. Ericsson's manufacture and the same was the case with the Telegraph Administration and the telephone societies.

In the Ericsson instrument there was used the improved Blakemicrophone referred to above and a receiver of modified Bell type. The telephone switchboards to begin with were made with metal guides fitted on a board, but Ericsson very soon introduced jacks and connecting cords with plugs, thus facilitating the work of the operators and reducing the space required. These switchboards were made for 50 subscribers. As the number of subscribers grew, switchboards had to be set up side by side and junction lines arranged between them. To avoid having excessively large exchanges and to keep down the length of the subscriber lines both the Stockholm companies in their early years established branch exchanges in the various sections of the city. The difficulty in dealing with operation, however, grew with the increase of subscribers and the large numbers of switchboards required. In each exchange the operators had to call out the wanted subscriber's names and numbers to each other and conditions finally became unbearable. However, the engineer *Schribner* in Chicago had as early as 1879 designed a multiple switchboard in which every subscriber line was accessible to all the operators. When Cedergren and Ericsson learned of the system, the latter designed the first Swedish multiple switchboard and this was installed in Allmänna's exchanges. The company, whose business was constantly expanding, could then plan the construction of large exchanges with good operating facilities and in July 1887 there was officially opened at Malmkillnadsgatan in Stockholm an exchange for 7 000 subscribers.

As regards instruments, another design should not be ignored in this connection. Even when Cedergren in 1883 was making his first appeal for subscriptions to those subscribers who were content with a common or party line he could offer automatic switching instruments invented by him and Ericsson. These were available for 2 or 5 lines respectively and subscription for party line meant even lower charge than the 100 kr. applied in competition with the Bell Company.

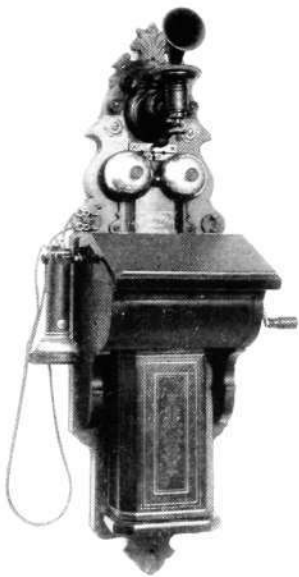


Fig. 10
Telephone instrument with redesigned
Blake microphone, manufactured by
L. M. Ericsson

X 4439

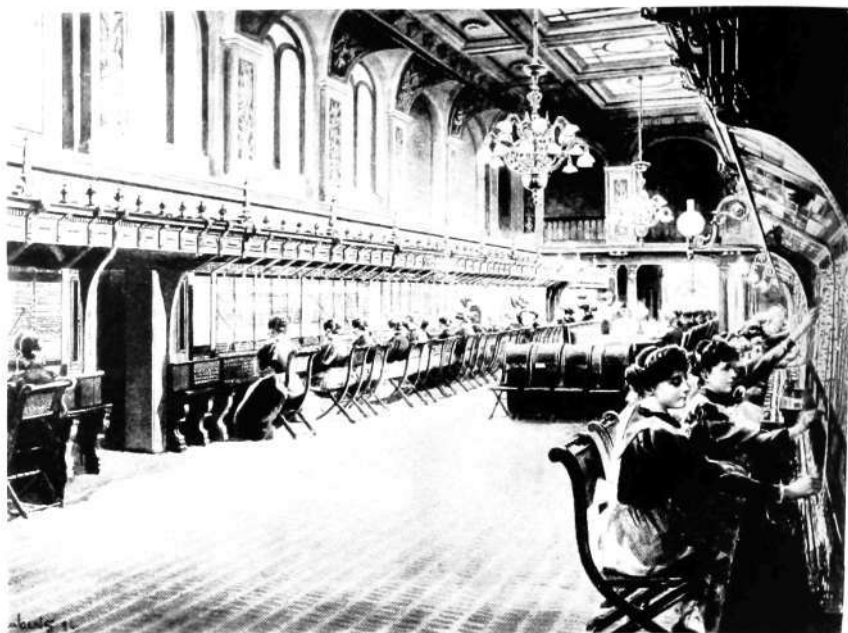


Fig. 11 X 6199
Allmänna's telephone exchange at Malm-skillnadsgatan in 1887

Competition Between the Telephone Undertakings

The competition that took place from 1883 between Allmänna and Bell resulted in victory for Allmänna. The growth in the number of subscribers to the Bell exchanges fell off, despite a certain reduction of charges, and ceased in 1887 after which it was replaced for many years by decrease. This circumstance gave rise to negotiations between the Telegraph Administration and the Bell Company for the sale of the company's telephone plants in Stockholm and Gothenburg. In 1888 the Telegraph Administration purchased the Gothenburg network but as regards the plants in Stockholm the matter dropped. Instead, Cedergren that year bought up the majority of shares in the Bell Company, which three years later was merged into the Allmänna Company.

In Cedergren, Allmänna had a chief with both initiative and force of action and the Board of Telegraphs found ever greater reason to consider the question whether the state or private enterprise should in the future provide the country with telephones and arrange communications between different centres and regions. From the beginning — as stated above — the Telegraph Administration had held a watching brief. Nevertheless attempts were made more and more to limit and regulate private activities, to a certain degree by laying down telephone lines and networks, but to a greater extent by decrees and administrative measures.

In 1883 a royal decree was issued which included prohibition for companies or private persons without royal permission setting up telephone circuits on crown lands or on the ground of public roads or railways. Tightening and clarifying of this decree called for by the Board were not supported by the Riksdag nor was there accepted a proposition submitted by the Government in 1888 for telephone tax, though even then fears had been expressed in the Riksdag that the Allmänna Company might attain far too great an influence.

By this time the company, which then as regards telephones dominated Stockholm and its environs, had arranged communications with several provincial towns such as Södertälje, Nyköping, Enköping, Uppsala, Norrtälje and Västerås. Cedergren in February 1888 had even applied for permission to construct telephone lines from Stockholm to Örebro, Gothenburg, Malmö and Sundsvall, making use of the ground bordering roads.

That was for the state the deciding impulse which was to make the Board of Telegraphs change-over to a more positive form of competition. Cedergren's application was rejected but the Board of Telegraphs declared itself

prepared to lay down not only the long distance line in question but any subsequently required, and the Government granted the requisite funds for the construction of the Stockholm—Gothenburg circuit. The work on this was begun in the autumn of 1888 and was completed the following year. Before the close of 1888 the Board of Telegraphs also submitted to the Government a plan for a national telephone network, comprising altogether over 2 700 km trunk lines. That was not all. In July 1889 the Board of Telegraphs invited those persons who wished to avail themselves of the facility of long distance calls to become subscribers at the exchanges of the administration and that same year a new trunk telephone exchange was ready for service in Stockholm. The Stockholm—Malmö circuit was opened in 1890.

In the beginning of that year a new director-general came to the Telegraph Administration, an engineer and organizer of unusual quality, *Erik Storckenfeldt*.

At this time the National Telephone had about 5 000 instruments, Allmänna and Bell together about 7 000 and other private networks something over 8 000 instruments. Storckenfeldt's first measures were devoted to technical improvement and rationalisation of the telephone service. More up-to-date instruments and switchboards were put in, still of L M Ericsson's make, uniform methods for the establishment of calls were worked out. In the early 1890s there was also constructed a large number of new trunk lines and from the Allmänna Company were purchased its lines to Västerås and Nyköping as well as the line constructed the previous year to Norrköping.

After some negotiations there was reached in 1891 the agreement with Allmänna Company, of great importance for further developments, that the sphere of activity of Allmänna should be restricted to a circle with 70 km radius and with the Great Square of Stockholm as centre. This meant that Allmänna had its area restricted but also that it could concentrate its operation, which the company did successfully. The Telegraph Administration, which retained its own network in Stockholm, had as regards the rest of the country liberated itself from its energetic competitor and now began to buy in more and more of the private provincial and local network. In certain places these efforts encountered strong opposition and the administration therefore in 1893 began to construct its own plants in direct competition with the local networks.

During this period the question of joint traffic between state and private networks, which naturally was of great interest to the public, became more pressing. In Stockholm joint traffic with the Bell Company had been arranged even when the Telegraph Administration's first switchboard was put into service in 1881 and with Allmänna also in 1884. When the Telegraph Administration became sole owner of the trunk lines the question of joint traffic took on a new aspect. Naturally the administration was not disposed to give subscribers in private networks as cheap access to the trunk lines as the National subscribers, nor would the Allmänna Company without a struggle let the relatively few National subscribers in Stockholm have the benefit of free access to the company's considerably greater number of subscribers, especially as annual subscriptions were lower for National than for Allmänna. The question was also dependent on whether the subscriber lines were double-wire or not. An agreement in which it was fixed that joint traffic charges, different for local and trunk calls, should be debited to the subscribers, was reached in July 1890 and joint traffic then proceeded up to 1st July 1903.

It would take up far too much space to deal in detail with the competition between the Telegraph Administration and the private telephone undertakings, which especially as regards the National-Allmänna struggle in Stockholm presents interesting points and was followed by the press and the public with a great interest easily to be understood. The weapons employed by the two parties were lowered rates and other more temporary benefits but also technical improvements, all designed to attract new subscribers.

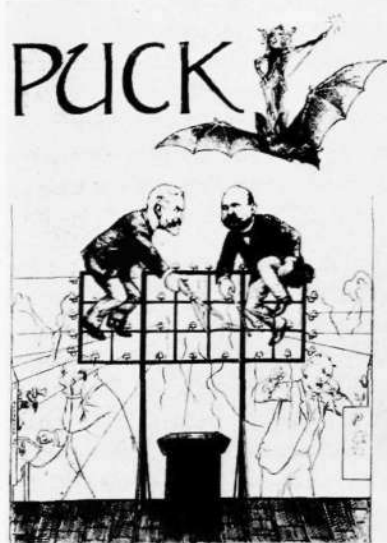


Fig. 12
Director general Sahlin and Director
Cedergren cut off joint traffic

Cartoon from Puck 1903

Nationalisation of The Telephone

For the public in the 70 km area the competition obviously constituted an advantage, but it was extremely vexing for the operators of the networks and the natural consequence was the idea of an amalgamation by state purchase of the Allmänna Company's plant. At the close of 1901 the first purchase agreement preliminarily approved by the Board of Telegraphs and the Company was ready. After foreign experts called in had approved the agreement, the Government presented a bill containing it to the Riksdag of 1902, which, however rejected it.

Storckenfeldt had more success in his measures to transfer the networks out in the country to state ownership. Both the telephone associations and private companies had constructed local networks in the provinces, the number of instruments in which exceeded the National telephone in 1890. The telephone associations were a kind of cooperative undertakings with very inexpensive administration. The premises were the simplest possible and the operators, who often had the switchboard work as a sideline, were poorly paid. The annual charges therefore were not burdensome, but the maintenance, as regards the exchanges carried out by some selfinstructed person resident on the spot and as regards lines by the subscribers themselves, was most often unsatisfactory. To augment the value of the telephone the associations had begun to form telephone federations and to build circuits between the local networks.

Both the subscriber lines and the junction circuits between places were single-wire. The quality of speech, on which only modest demands were imposed, on the longer lines was far too poor and as the annual charges did not allow of renewals or improvements, the situation began to be troublesome for those who required surer and quicker call facilities. The Telegraph Administration which had begun to construct good trunk lines had very good quality to offer but could despite decreasing the annual charge, usually to 50 kronor, exercise no direct price competition. Nevertheless Storckenfeldt opened negotiations. Even before then, isolated purchases had been made but the landslide began in 1891. Among the networks then acquired may be mentioned the Haglind provincial network in Östergötland, the city networks of Norrköping and Sundsvall as well as several networks affiliated to the Örebro telephone federation. These purchases comprised in all 2 000 instruments. The following year there was acquired the network in Gävle town and the rural district around, and buying continued. The Allmänna telephone society's network in Gothenburg, where the Telegraph Administration had owned the former network of the Bell Company since 1888, was taken over in 1896. By 1894 the national network had more instruments connected than all the private companies together. Leaving aside the 70 km area of Stockholm, the Telegraph Administration in 1889 owned but 28 % of the instruments in the country. At Storckenfeldt's death in 1902 the figure was 97 %. The increase shows the energy and success displayed by this notable man in carrying out the task he had imposed on himself.

The curves of Fig. 13 show the numbers of instruments during years gone by in Sweden. From these it will be seen that the Telegraph Administration during the years 1902—1918 had approximately $\frac{2}{3}$ of the instruments in the whole country including the Stockholm network. The remaining third belonged for the most part to Allmänna — from 1907 known as Stockholm Telephones Limited (S.T.). The private networks in the provinces were then insignificant in extent. The increase in number of instruments in these networks to be noted in the figures from 1904 is due to inclusion in them also of the state railways and private railways service instruments, which in 1944 constituted about $\frac{9}{10}$ of the private network instruments. Both the National and the Allmänna (S.T.) had in the whole time from 1912 increased their instruments, but the proportion 2:1 continued practically unchanged, which means that the Stockholm Telephones Ltd. had in the 70 km area the greater progress. A proposal in 1904 to divide this area up in such a way that the

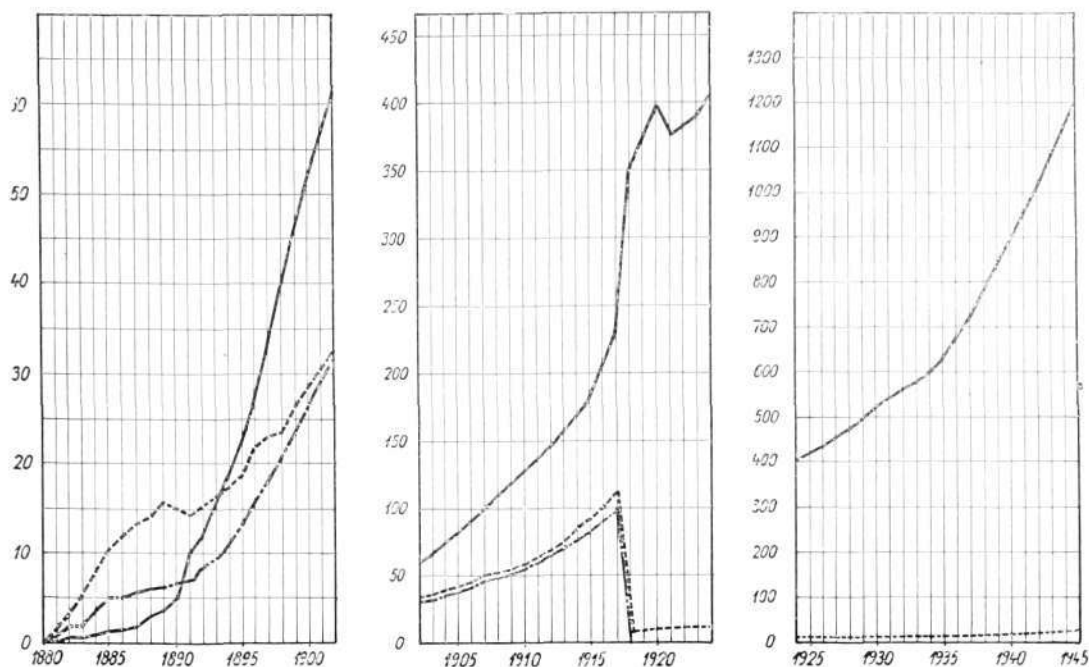


Fig. 13
Diagrams showing the number of telephone instruments in Sweden for the years 1880—1945

— in the Telegraph Administration networks
 - - - in all private networks
 - · - · in the Stockholm Company's network

Telegraph Administration would take over Allmänna's network south of Norrström and pay a certain compensation to the company while the latter would take over the National Telephone's local network north of this boundary a year later to buy the whole network of the company for about 16.5 millions did not gain the acceptance of the Riksdag. The same fate met a proposal 1891. It was only in the Riksdag of 1918 that the question was settled. The purchase price then was about 46.7 millions and in July of that year Stockholm Telephones Ltd. handed over to the Telegraph Administration the whole of its telephone plant in Stockholm and a radius of 70 km.

Technical Developments

It has been stated that both the Allmänna Company and the National telephone continued to make technical improvements. In regard to the telephone instruments the Ericsson instruments with their special microphone design were for many years among the foremost. Later when the carbon granule microphone became known a change-over to this was also made in Sweden. The new instruments were made by L M Ericsson and from 1891, when they started their own factory, by the Telegraph Administration also.

An important advance is represented by the combining of transmitter and receiver to one unit, the handset. To make his work more comfortable one of the men at the Allmänna Company had hit on the idea of tying a microphone to a receiver. His foreman took up the idea and L M Ericsson developed it. The first model and a number of transition forms have been preserved so it is possible to follow the development up to the types now employed in Sweden. In other countries too the handset is now generally used.

As regards station equipments it is only possible to mention a few designs here. Allmänna introduced in its larger exchanges desks with multiples for a large number of subscribers. The largest multiple of its time was arranged in the demonstration switchboard at the Stockholm 1897 exhibition, with 20 000 numbers. Later Allmänna installed in its new exchanges in Stockholm multiples of up to 36 000 numbers, but the maximum capacity of the desks was reckoned for no fewer than 60 000. Desks with similar multiple fields were supplied also to Moscow and Warsaw. Space had to be saved in the switchboard panels and 100 jacks therefore took up only 36 cm² of space.

Engineer J. A. Arén of the Telegraph Administration designed at the opening of the century a distribution system for the national telephone exchanges in

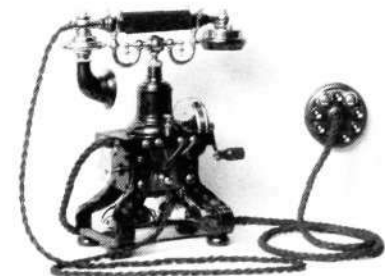
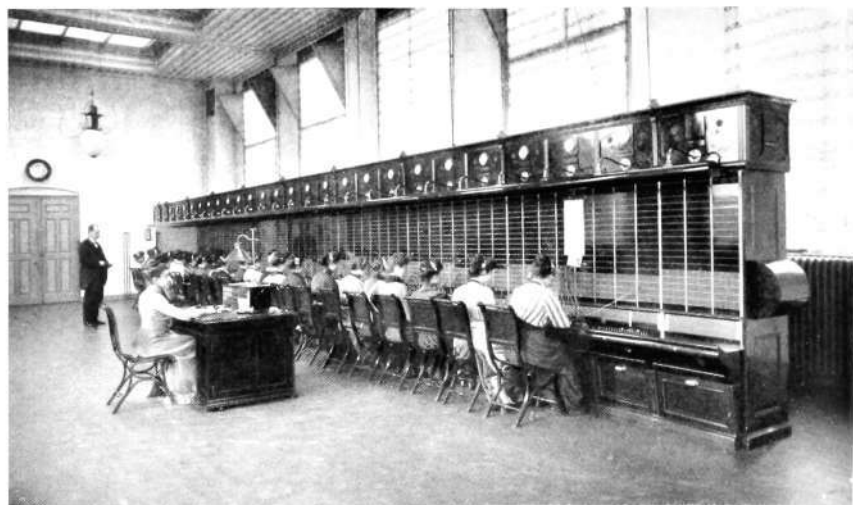


Fig. 14
L M Ericsson table instrument with handset, 1895

Fig. 15

L M Ericsson's first C.B. exchange,
supplied to the Hague in 1903

X 6198



Stockholm and Gothenburg, which had the call indicators housed in special desks where »dumb» operators connected the calling subscribers by connecting cords to multiple boards where another operator completed the connection. In this way the staff were better utilized and the times of answering were shorter and particularly more even.

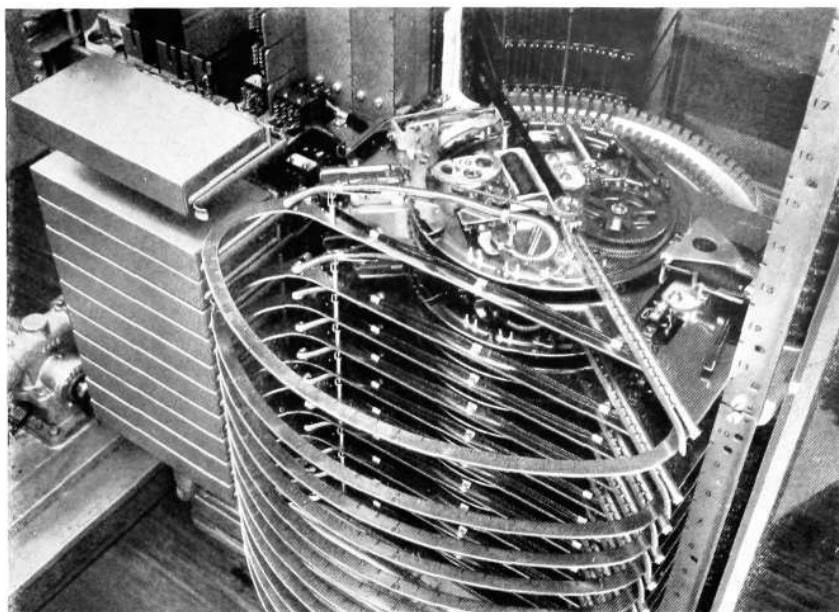
Signal lamps instead of drop indicators were introduced by Allmänna as early as 1897. Lamp signals later became general, especially when change-over was made to the central battery system, which after impulses from abroad was developed by both L M Ericsson and the Telegraph Administration.

L M Ericsson's first C.B. exchange was put in service at the Hague in 1903 and the first Swedish Telegraph Administration exchange of this type was supplied by Ericsson in 1909. For smaller exchanges and for private branch exchanges new improved switchboard types were produced in the following years, many of which are still in service. A problem which it was found difficult to surmount in the large cities was constituted by the traffic that had to be established between the different sub-exchanges. Many methods were tried and automatic selection of disengaged trunk line and disengaged operator was introduced in Stockholm shortly after 1918, when the national telephone took over the subscribers of the private networks and introduced full joint traffic, before the networks and exchanges of the different undertakings could be merged. Even later, trouble and cost was caused by the junction traffic which required at least two operators to complete the connection, and this only disappeared with the automatization of the whole Stockholm network.

Automatisation

The idea of entirely replacing manual operation by automatic and thereby escaping the expense of operators had arisen at an early stage. In principle the problem is simple, consisting in the replacement of the manual telephone switchboard by connecting devices, known as selectors, set by remote operation, which as is known is executed by means of a dial. The first known idea for an automatic telephone switchboard was the subject of patent application in America in 1879. The first automatic telephone switchboard, which had a capacity of 100 numbers, was installed at La Porte, Indiana, in 1892. These selectors were of a type called Strowger selectors, after the inventor. The Strowger system made great progress in America and the first exchange for 10 000 subscribers was put into operation at Chicago in 1903. Gradually automatic exchanges began to become more general in Europe as well, Germany getting its first trial exchange in 1908.

Fig. 16 X 6195
Selector in the Hultman-Ericsson automatic telephone system with 500-line selectors



In Sweden, as mentioned earlier, Cedergrén and Ericsson had as early as 1882 designed small automatic switchboards, the selectors of which were operated over a circuit by an operator at the manual exchange. In the later part of the 1890s G. A. Betulander designed small fully automatic switchboards and some exchanges were equipped with them. These Swedish contributions, however, were merely in the nature of trials. After 1910 the Telegraph Administration set itself seriously to study the problem. A trial plant with rotary selectors was purchased in America and set up at Landskrona in 1915. War then stopped business with foreign countries but L. M. Ericsson, who had begun his experiments in 1913, had a trial exchange completed in 1918. The Hultman-Ericsson machine-driven system with 500-line selectors was ready for delivery a couple of years later and as it proved to be more satisfactory than the foreign systems the Board of Telegraphs decided that it should be introduced in Stockholm and Gothenburg. The first exchanges of this type were at Rotterdam, Hamar and Kristiansund these being completed in 1923, and Norra Vasa in Stockholm which was opened for traffic in January 1924. L. M. Ericsson has made most of the Telegraph Administration's large exchanges as also a great number of foreign ones on this system.

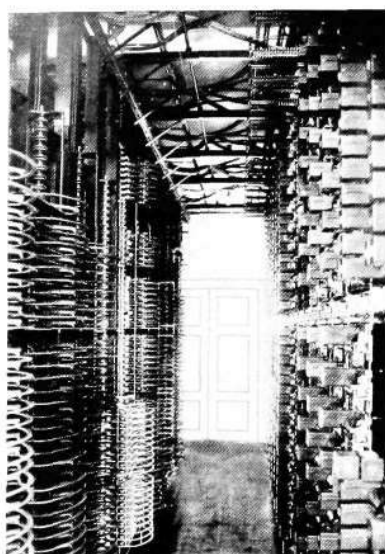
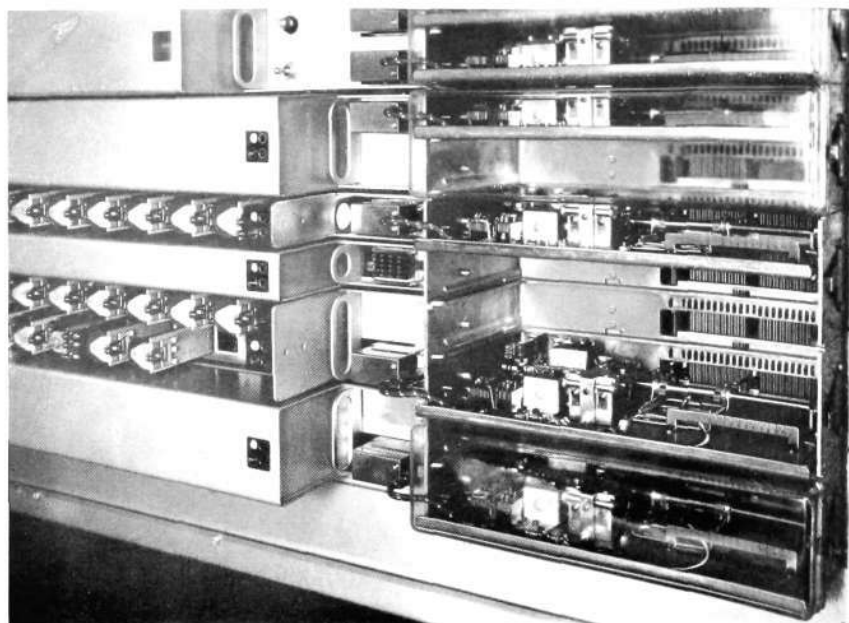


Fig. 17 X 4431
L. M. Ericsson automatic exchange at Hamar, Norway, delivered 1923

Around 1915 the Telegraph Administration began to interest itself in another type of selector, known as crossbar selector, which consists of relays with armatures intersecting. Plants with these selectors were designed by Betulander, H. Olson and they were made in the administration's workshops. The first exchange of this type was opened at Sundsvall in 1926. In addition, the Malmö exchange and some other main exchanges are fitted with crossbar selectors, though these have found their greatest utility for small exchanges. L. M. Ericsson also has taken up the making of crossbar selectors of improved construction, worked out in conjunction with the Telegraph Administration, and the administration will be adopting these. The concern has moreover developed a modification of the 500-line selector, smaller and adapted for small exchanges, which has been given the name of XY-selector and is direct driven like the Strowger selector. The first of these were ready for delivery in 1938. The XY-selector is chiefly employed in inter-communication telephone plants.

From 1920 automatization began in Sweden, the start being made with the large main exchanges as the financial gain with these is comparatively large. In the last decade, however, side by side with the large exchanges, automatization has also been extended to medium-sized exchanges and to a number of

Fig. 18
Section of rack with L M Ericsson's XY-selector



small ones. While in 1934 only 12 exchanges were provided with automatic switchboards, by 1945 over 1 000 exchanges, including some 30 main exchanges, were automatised. The number of instruments connected to automatic exchanges is approximately 650 000, representing about 56 % of the instruments in the country. More than $\frac{1}{2}$ a million of these instruments are connected to L M Ericsson switchboards.

Lines

Open-wire Lines

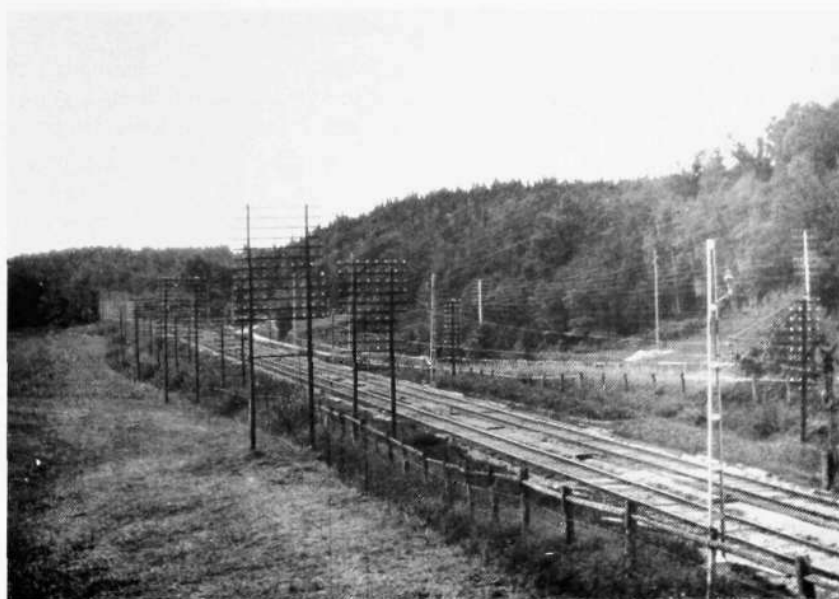
The first telegraph circuits of any length were constructed as open-wire aerial lines on poles or wall brackets. The insulators were made of gutta-percha, a material which when exposed to the air and particularly to sunlight dried and became brittle. Trials were made with various materials and porcelain has finally been adopted. The insulators are now made with domes, usually two, to increase the insulation resistance.

It may be surprising to learn that the poles put up in Sweden during the 1850s had not a longer life than 5 years, sometimes only 2 or 3 years. Evidently this was due to the fact that they had been felled in the early summer. After impregnation of the poles had been introduced, a durability of some 30 years was finally obtained by the employment of creosote-oil. Lately good results have also been obtained with arsenic preparations, but no figures for durability are available yet.

The telegraph lines in Sweden were constructed up to about 1890 solely of iron wire 4–5 mm diameter. The first telephone lines were made in the same way as the telegraph lines, though mostly with thinner wire. In the larger networks use was made of 1 mm bronze wire. For the longer telephone circuits it was soon found that copper wire must be used. Thus as early as 1885 the Allmänna Company built a copper line between Stockholm and Enköping.

It was also found that the sound transmission quality was very appreciably deteriorated by noises from the earth connection and by crosstalk from adjoining single-lines, so that the long lines at least had to be made double-wire. The two iron lines laid by the Telegraph Administration in 1883 between Malmö and Lund were the first double-lines in the country. The following year these were improved by transposition which counteracted crosstalk. Twisting of the wires, a method much better in this respect, was

Fig. 19
Pole lines along the Stockholm—Söder-
tälje railway 1924
X 6200
carrying about 280 wires



introduced in 1889 when setting up the copper lines between Stockholm and Gothenburg.

At this time all local networks in the country were single-wire. Today it is difficult to conceive how it was possible in the large towns to manage with the low quality these simple networks could offer. At the same time it must be remembered that there were not then any disturbing strong current lines and that the pretensions of the public are much greater today than they used to be. Nevertheless, towards 1890 the leading telephone undertakings realised clearly that doubling of the single networks would be necessary. The last local network made by the Telegraph Administration with single lines was constructed in 1889. After 1892 the Telegraph Administration accepted no new single-wire subscribers at its exchanges though those already existing were kept on for a time. The Allmänna Company too had in 1889 taken up the question of doubling the lines, but this work was dependent on permission from Stockholm city to use street ground for subterranean lines. The work of doubling, however, was begun in 1891 and was practically completed in 1893.

The private networks out in the provinces retained their single-wire and were doubled only as and when they were taken over by the Telegraph Administration.

After the area of activity of the Allmänna Company had been restricted in 1891 to the 70 km radius, all further extension of the long line network devolved on the Telegraph Administration. The administration continued to build both copper and iron lines at a rapid rate and at the beginning of the century all places of any importance in Sweden had call facilities with each other, with the exception that upper Norrland could not exchange calls at all with southern Sweden and only with difficulty could reach exchanges south of Sundsvall. In the last years of the previous century lines of 4.5 mm copper wire had been constructed from Stockholm to Gothenburg and to Malmö. Such circuits were laid between 1901—02 from Stockholm also to Sundsvall and Östersund as well as to Luleå. After about 6 000 km of 3 mm copper line had also been laid throughout the country, including Norrland, it was considered that satisfactory trunk traffic had been made possible for the whole kingdom. The development of the national network continued in similar manner in the next 20 years.

Local Cables

In the forming of the local networks after 1890 the new cable practice had led to great changes. With a number of telegraph lines in the middle of last century gutta-percha cables had been used also as underground cables. The gutta-percha was not suitable and a change to rubber as insulation material was made. When it became a question of the large number of lines in the telephone networks these cables chiefly on account of the great expense were not suitable. Even earlier both the Allmänna Company and the Telegraph Administration had considered the possibility of using telephone cables. Lead-sheathed cables, which began to be manufactured just before 1890, proved the best. To begin with the conductors in these were insulated with cotton yarn, but a change was soon made to paper as insulation material.

The changes in local cables since then have chiefly consisted in measures by which, without any deterioration of the electric properties of the cable, larger numbers of conductors could be got into the same cable section. The first lead cables were supplied to Sweden in 1889 from Germany and England. These countries were the chief suppliers up to 1910 when Sievert's cable works began to make lead-sheathed telephone cables. In 1890 the Telegraph Administration succeeded in getting permission from Stockholm city to lay underground cables along certain stretches, but conditions set up later by the city were considered unacceptable, so the laying of cable blocks was stopped and the network for some time to come had to be extended by aerial cables. The same hesitation regarding the terms of the city was felt by the Allmänna Company, whose first cable net therefore was aerial. Later both from Stockholm and from other towns acceptable terms could be obtained and in all towns and larger communities subterranean cable networks were extended.

The method of laying in ducts generally used in Sweden was worked out by *Axel Hultman*, then a telephone inspector, following a journey of inquiry to America in 1890. Hultman, however, did not apply the American methods, but made a design of his own, cement blocks with conduits for different numbers of cables. The number of cable conduits in such blocks have since varied between 2 and 48. Allmänna used blocks with up to 87 conduits.

Before dealing with the employment of telephone cables for long distance lines, mention should be made of some methods to ensure good sound transmission while at the same time keeping down the number of lines and the dimensions of the conduits.

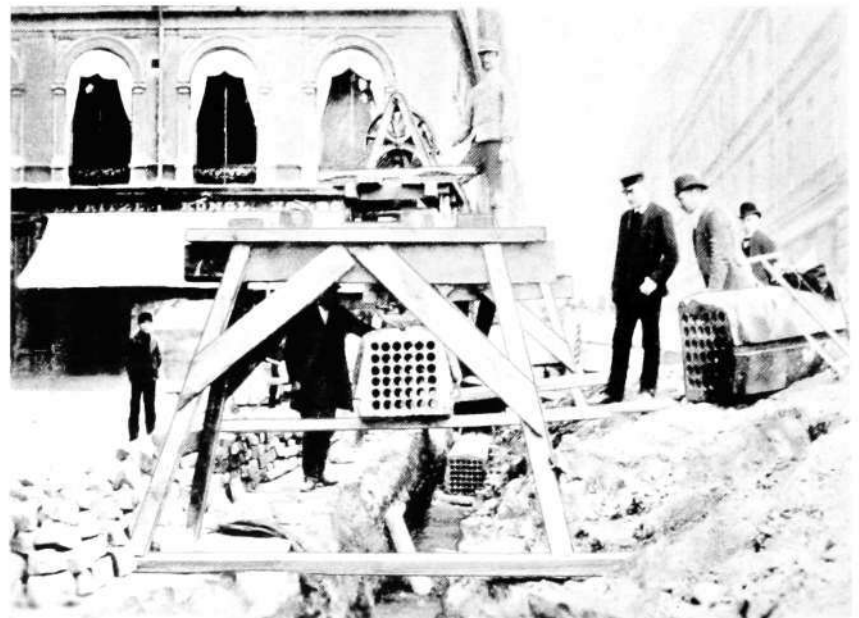


Fig. 20
Laying of cable blocks in Stockholm
about 1890

X 6196

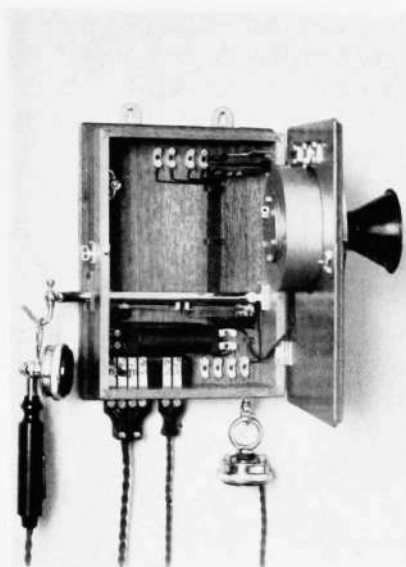


Fig. 21
Egnér-Holmström's strong current microphone

X 4434

Strong Current Microphone

First mention should be made of Egnér-Holmström's strong current microphone. The design aimed at increasing the amplitude of the outgoing speech current by making the current in the microphone circuit, and thus also the current variations, stronger than the ordinary microphone could produce. In test pieces there was attained an outgoing speech current some 30 times greater than normal, but for practical reasons a tenfold increase was not exceeded. L. M. Eriesson took up the manufacture and a hundred or so instruments were set up at the beginning of the century. Two circumstances were to limit the employment of the instrument. As is known the attenuation of speech increases in geometrical progression with the length of line. If it were possible with an ordinary microphone to talk satisfactorily over a section of, say, 3 000 km then, with the ten times more powerful strong current microphone, one would not be able to converse for a greater distance than about 5 000 km. Moreover the strong current caused great crosstalk to other lines. Therefore when the designers tried out a specially arranged circuit of 2 270 km between Stockholm and Paris the sound transmission in Germany, where the lines were not transposed, was so strong that the system could not be permitted there. Since the introduction of amplification of the speech currents at intermediate points on the line by telephone repeaters, the strong current microphone has lost its utility.

Phantoming

To enable two line pairs to convey three simultaneous conversations what is known as phantoming is employed. The phantom circuit is formed in the same way as is done in the telegraph transforming referred to earlier, by two circuits being joined up to make a double circuit. The two metallic physical circuits must in this case either be twisted or transposed so that both the pairs and the two wires in the same pair change place with each other according to a definite plan. Phantom circuits began to be used in Sweden towards the end of the century. In 1944 the Telegraph Administration had in its national and rural networks some 264 000 km bare-wire double lines. From these have been obtained about 86 500 km phantom circuits, representing an increase of circuits of app. 33 %.

Loading

The third method is loading. After *Heaviside* had at the end of the 18th century mathematically dealt with the electrical process with the conveyance of alternating current over lines, methods for counteracting the weakening of the sound of the voice in long lines were worked out by many investigators, among whom may be noted *Pupin*, *Breisig* and *Pleijel*. *Pupin*'s name is associated with the method, loading, which in the present century has come into use in all telephone countries. The method consists of counteracting the attenuating effect which the capacity between the two wires in the lines has on speech, by inserting into the line self-induction coils. The first loading in Sweden was done in 1911 on a copper line between Örebro and Sundsvall according to instructions of *Pleijel*. Iron lines could also be used and the loading of bare-lines proceeded so rapidly that in ten years some 21 000 km national and rural lines were furnished with loading coils, thus providing considerable savings in line material. Nevertheless the inductive load introduced at points on the lines involved difficulties when telephone repeaters began to be used. Simultaneously leakances occurring on the lines had an adverse effect on the loaded speech circuits. At the beginning of the 1920s, with the introduction of telephone repeaters, bare loaded lines had reached the above maximum figure of 21 000 km and from then on so many lines were unloaded — or taken down — that the figure by 1931 had sunk to about 2 000. In 1941 the last loading coil was disconnected from the bare-line network.

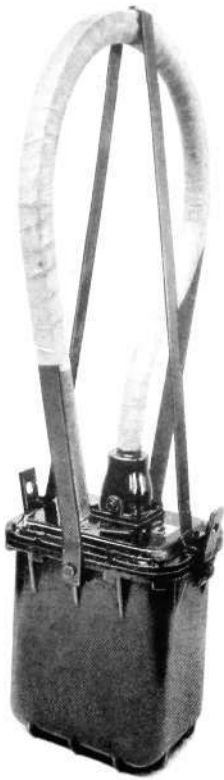


Fig. 22
Loading-coil pot
of L M Ericsson make

X 4427

The loading of cable lines, however, had then obtained much greater importance. As early as 1910 both the Telegraph Administration and the Stockholm Telephones Ltd. had begun to load cables between Stockholm and its suburbs. The Telegraph Administration, besides rural cables, also loaded lead-in cables to long lines to the more important trunk exchanges. Apart from trunk cables it may safely be reckoned that loading will be used more and more, in any case for rural cables of any great length.

Long Distance Telephony

The amplifier valve opened not only for radio technique but also for long distance telephony a new era. The American *de Forest* and the Austrian *Lieben* produced the first amplifier valves and the American *Langmuir* perfected the design. Edison was the first to indicate suitable coupling for a telephone repeater. The coupling now generally used was indicated by *W. C. Richards*, also an American. During the 1914—18 world war, amplifiers came into great use.

The telephone repeaters allowed of the employment of cables even for long distances. In Sweden consideration was begun in 1918 of a Swedish trunk cable network and in 1920 the Board of Telegraphs ordered from Western Electric Co. in U. S. A. a cable plant Stockholm—Gothenburg, at the time the most up-to-date in Europe. Western Electric supplied cables, loading coil pots and repeater equipment and exercised technical supervision of the plant through their own engineers. The work, in other respects carried out by Swedes, was begun in the spring of 1921 and completed in the autumn of 1923. When the following year the Telegraph Administration proceeded with a cable Stockholm—Norrköping the repeater station equipment had been re-designed to Swedish patterns and only the repeaters themselves were imported. The cable was delivered in this case for the most part by Sievert's cable works, which had obtained a licence from the Western Electric, but the loading coil pots were still bought from that firm.

Now the Swedish trunk cable plants mainly use purely Swedish material. The cables are made by Sieverts while L M Ericsson supplies pots and repeaters.

The conductors in the cables are twisted on the Dieselhorst-Martin system. Two wires are twisted into a pair with different pitches, the pairs then being twisted into a quad. In this way there is achieved, after the capacitance unbalance on splicing has been smoothed out, high values for crosstalk attenua-



Fig. 23
Trunk cable drum

X 6201

tion between the speech circuits in the cable. The cables contain both 2-wire circuits when the speech is conveyed on the same line in both directions, and 4-wire circuits when 2 speech circuits are required for the conversation, one in each direction. In the last 14 years there had also been inserted in the cables special line pairs for wireless broadcast distribution. The loading has in the course of years been altered with the object of obtaining lines with higher cut-off frequency. On such lines it is possible to superimpose carrier frequencies in the 3 000—6 000 c/s band.

Carrier Frequency Systems

Carrier frequency telephony was first used on bare-wire lines, which have no equivalent to the cut-off frequency of the loaded lines. In the years 1921—22 a German two-channel carrier frequency system was installed on a Stockholm—Malmö line. Svenska Radiobolaget, which at the same time delivered a plant abroad, supplied one in 1923 for Örebro—Sundsvall and the following year for Stockholm—Umeå. This system operated with high cycles. It proved difficult, however, to link the high frequencies to the bare-wire lines used. The increase in attenuation which hoarfrost deposit on the wires caused also contributed to a change-over to single-channel systems with the highest carrier frequency around 10 000 c/s. Such systems allow of the utilisation both of physical and phantom circuits as well as of several lines laid in one and the same pole line. The device has been of great value, among other things in avoiding the construction of new bare-wire lines pending the cablification. When later the section is cablified the carrier frequency equipments are moved to other places where similar conditions prevail. In 1921 the Telegraph Administration began to purchase single-channel equipments from L M Ericsson, who had carried out considerable work of development in the domain. This Swedish firm has since 1936 been sole contractor for such plants and the number of single-channel circuits now amounts to about 115. Carrier frequency equipments for cable lines, both single and multi-channel, are also supplied by L M Ericsson.

On the 4-wire lines there is generally superimposed still another circuit and later multi-channel systems have been introduced on unloaded cable circuits. When the Gothenburg—Malmö section was cablified in 1939, there were laid at the same time both a loaded cable and two unloaded cable pairs intended for carrier frequency. These latter two serve one for each speech direction and one line pair is now utilised for 12 channels, a number which is to be increased to 18. The two 10-pair cables Gothenburg—Helsingborg will then enable the connection of no fewer than 342 carrier frequency circuits. Between Helsingborg and Malmö the number of cable pairs is 14, which allows of 252 such circuits.

A beginning has also been made with the de-loading of circuits in cables previously laid. This occurred in the 1923 Stockholm—Gothenburg cable, where 10 quads for multichannel operation have been arranged, thereby gaining 160 4-wire circuits by giving up 30 2-wire circuits. On account of the higher attenuation in the unloaded cables there have been inserted between the former repeater stations new smaller stations with remote controlled intermediate repeaters.

Trunk Cable Network

The trunk cable network at the close of 1944 comprised a total length of cable of 5 728 km, stretching from Ystad in the south to Boden in the north. Owing to the greatly increased trunk traffic of recent years the trunk cables are heavily burdened, so that many new cable projects are now awaiting execution. The extent of the cablifying of trunk and rural circuits in Sweden will be seen from the figures below, relating to the close of 1944. At that time there were in service approximately 865 000 km of trunk circuits, of which app. 520 000 km physical circuits, app. 230 000 km phantom circuits

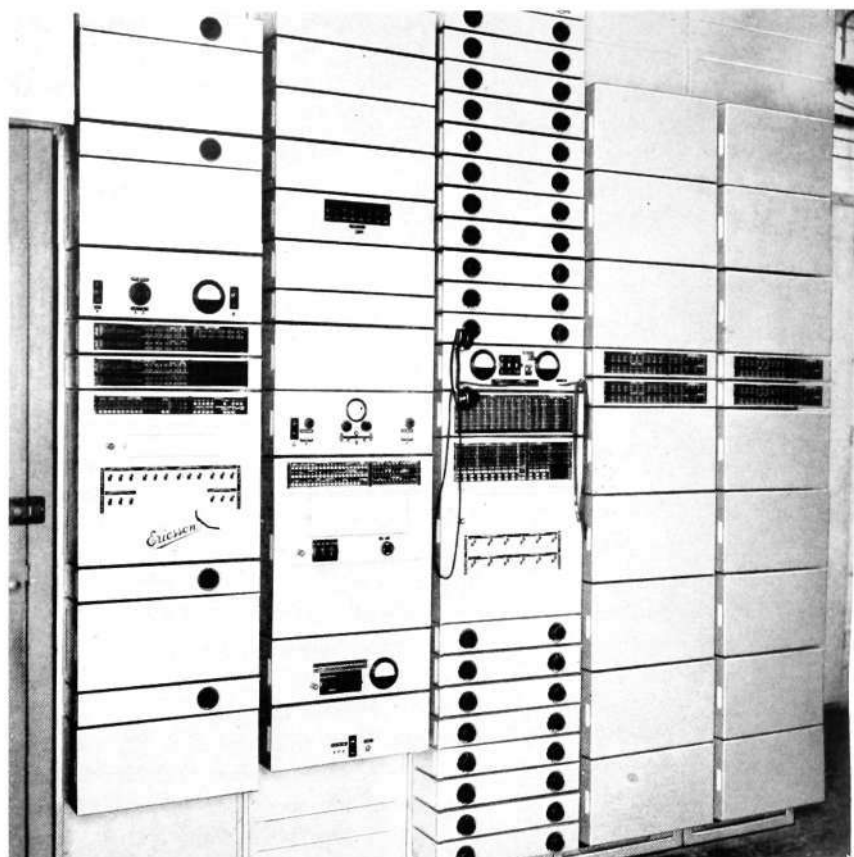


Fig. 24
Carrier frequency equipment
L M Ericsson's single-channel system

X 4428

Fig. 25
Carrier frequency equipment
L M Ericsson's multi-channel system

X 6193



and app. 115 000 km carrier frequency circuits. Of the trunk circuits some 700 000 km or 81 % were laid in cables. At the same time the Telegraph Administration had about 445 000 km rural circuits. Of these some 194 000 km or 44 % were drawn in cables.

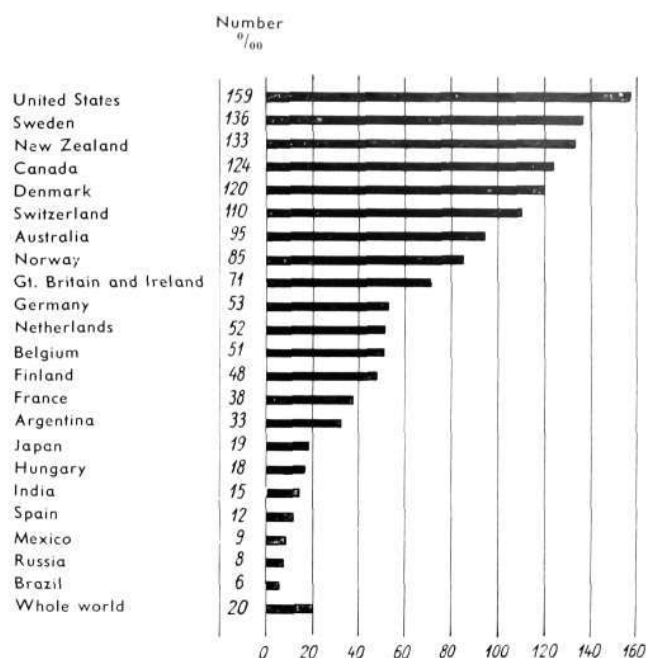
Sweden's Telephone Communications with other Countries

In respect of Sweden's telephone communications with foreign countries it may be mentioned that in the years 1891—92 there was constructed a line Örebro—Karlstad—Oslo. In 1893 there was arranged, by utilisation of the wires in a telegraph cable, the first telephone circuit between Malmö and Copenhagen.

Finland obtained via Torneå connection with Sweden in 1919 and the first telephone cable to Germany was laid in 1921. In the 1920s and 1930s the number of foreign circuits was greatly increased. Sweden then obtained direct lines to the most important telephone centres in Europe. By way of these it was possible to talk with all European and many extra-European countries. New ocean cables have been laid to Denmark, Finland and Germany and the underground cable network has been linked with Norway. If all cable reserves are included and the carrier frequency circuits provided for are also counted, then Sweden in 1939 had the provision for more than 300 telephone circuits with countries abroad.

The introduction of the telephone and its development in some countries have been dealt with at the beginning. It would take far too much space here to give a picture of subsequent progress of the telephone in foreign countries and moreover particulars are not available which would enable a survey to be made of the position in the last few years. Nevertheless a comparison of telephone intensity in some countries is shown by Fig. 26. Though the

Fig. 26
Graph showing number telephones per
1000 inhabitants in 1940



expansion of the telephone has been rapid in all countries. Sweden has well maintained her place. We too have followed the jump in development displayed by the years following the first world war.

The necessity for rapid communication has always stood out the strongest during times of unrest. In war intensive research and trials have been carried out without the slightest consideration of cost and when peace again prevailed the results have gradually been made public. Thus the beginning of the 1920s marked a new period of development in radio-technique and long distance telephony. Now that the last world war is over we may expect a fresh sharp advance in developments, but how they will turn out it is still too early to forecast. That prophecy may have its dangers may be seen from the extract from a Boston newspaper of 1867, with which we close this account.

»A certain Josua Coppersmith of New York has been taken into custody. He has attempted to fleece credulous people by exhibiting to them a device which, according to his claims, is capable of transmitting the human voice by means of connecting wires so that the speech can be heard at the other end of the line. The instrument he calls »telephone», which presumably is a plagiarism of telegraph. Well-informed folk know that it is impossible to transmit human speech through wire lines, and even were it at any time possible, such a device would not have the slightest practical value.»

Tele-signalling

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U.D.C 654.147(091)654.9(091)

Electrical tele-signalling may be said to date from *Oersted's* discovery in 1820 of the effect of an electric current on a magnet needle. *Oersted* himself, *Ampère*, *Schilling* and others immediately tried to utilize the discovery for the transmission of communications. The actual year when *Schilling* had his needle dial telegraph completed is not definitely known. *Wheatstone* and *Cooke* improved the instrument and applied for patent for their design in May 1837. In the same year *Steinheil* had completed his writing needle telegraph. *Wheatstone* continued to work on the problem and in 1840 he designed the first dial telegraph.

In the 1840s *W. von Siemens* and *Breguet* also designed dial telegraphs. The first of these was subjected in 1856 to a complete re-designing when *Siemens* invented the magneto generator.

As early as 1832 *Morse* had begun his attempts to design a telegraph instrument and in 1837 he was ready to make known his first instrument. It did not, however, find any practical employment before 1845.

The first fire telegraph was set up in Berlin by *Siemens* in 1851.

Experiments in operating clocks electrically had been begun in 1839 by *Steinheil*, when he tried to use pole-reversing impulses for the purpose. Nevertheless, the first to succeed in finding a practical solution of the problem was *E. Stöhrer*.

Who actually invented the galvanic bell is not known with certainty, but the automatic interrupter in the bell was invented by *Werner v. Siemens*. The



Fig. 1
Dial telegraph instruments

X 6182

left, stationary; right, portable for railways

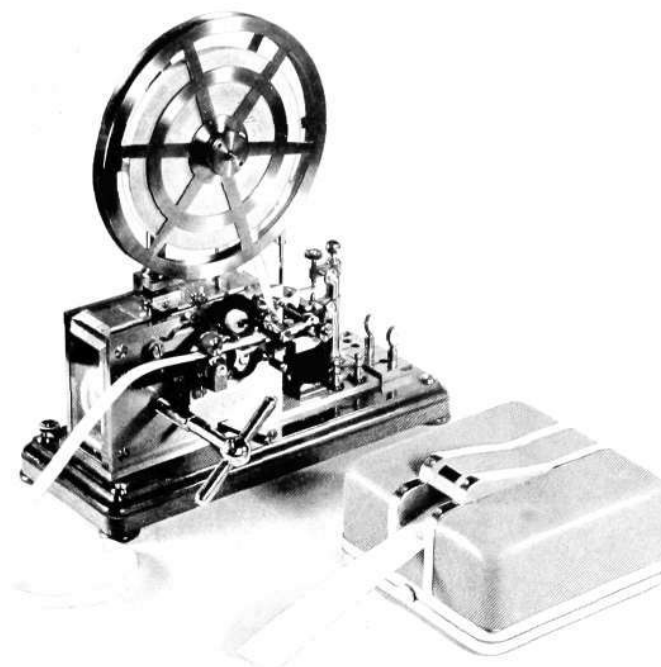


Fig. 2
L M Ericsson's Morse telegraph instrument
left, 1885 model; right, latest construction

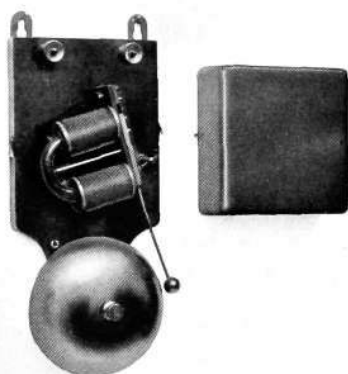


Fig. 3
Bell
1878 model

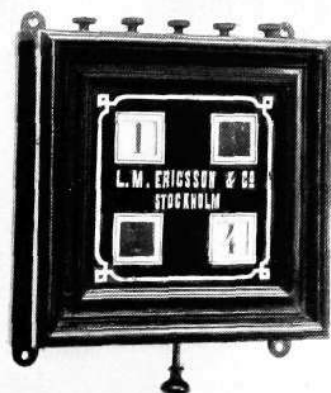


Fig. 4
Number board
for four lines, 1878 model

first to use galvanic bells for practical purposes was *J. Miraud*, at Rouen in 1853.

When L M Ericsson started his undertaking in 1876, he was first engaged on the repair of electro-magnetic instruments.

The first client of the new undertaking was the Stockholm Fire Service, for whose account a dial telegraph was repaired.

Telegraph Instruments

Ericsson's first big delivery consisted of two dial telegraphs, in those days used by the railways for signalling between stations. These instruments, supplied to the State Railways, were of a design that had previously been manufactured both by Öller and Siemens.

As early as 1878, however, Ericsson on instructions from Director of Telegraphs *Stork* of the State Railways designed an entirely new receiving device for the dial telegraph and he also modified the transmitter device. The manufacture of dial telegraphs continued right to the middle of the 1880s, when the railways began more and more to change over to telegraph instruments on the Morse system. Ericsson's own design of Morse writer instruments would appear to have been complete in 1885. This design has since been manufactured almost without alteration right up to the 1940s.

In 1901 there was designed a modified instrument for employment in fire telegraph systems. As the railways in the last few decades have replaced telegraphy by telephony, the manufacture of telegraph instruments has been mainly concerned with instruments for fire telegraph systems.

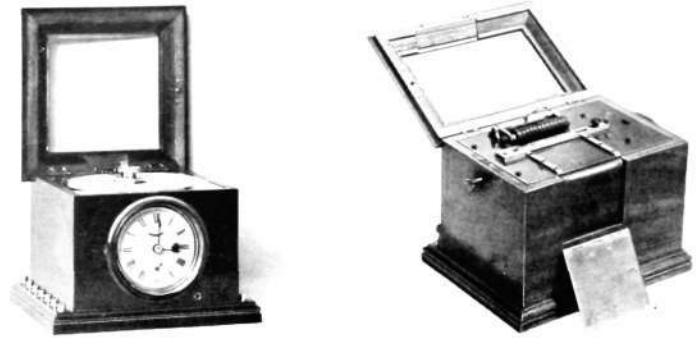
It was not until 1943 that a new telegraph instrument, entirely differing from the earlier model, was designed. The length of life of the old instrument provides sufficient evidence of how well thought out and correct Ericsson's designs were. The telegraph sounder key that he designed is still being manufactured in conformity with the original model.

Fig. 5

Night watchman control clocks

left, 1883 model in which the recording is done on a circular paper disc; earlier model, where the recording is on a paper strip

X 6183



Besides ordinary telegraph instruments, Ericsson in March 1877 made a type telegraph instrument for the State Railways. From notes in the memorial this consisted of a type telegraph like previous ones, but with changes and necessary additions to produce figures and punctuation marks.

In addition it may be stated that the company during 1917 and 1918, at the request of the Board of Telegraphs and for its account, manufactured teleprinter instruments on the Creed System.

Signalling Systems

Bells and number boards for signalling systems were first supplied by Ericsson in 1878. Such instruments, however, are not to be found in any catalogue before about 1920, when Ericsson, Vienna, was engaged on the manufacture of annunciator boards and similar material. Work of development was also begun in the Vienna factory of the illuminated signal material, which was later more and more to replace the older system of bells and drop indicators. The continuation of the development and the manufacture of the illuminated signal material was transferred towards the close of the 1930s to the Stockholm factory, which is now manufacturing illuminated signal material for a variety of purposes.

Night Watchman Control

In December 1879 the first night watchman control instrument, which according to sketches consisted of a night watchman control clock for 8 posts, was supplied to the State Railways. That first instrument, which stamped the times on a paper strip driven by clockwork, was replaced in 1883 by an instrument in which the recordings were done on circular paper discs. In both cases, the plants consisted of stationary central instruments and stationary contact cabinets for the marking. The 1883 model of the night watchman control instrument continued to be made and sold right up to the 1930s, when the design was replaced by a more up-to-date instrument.

In recent years there has also been designed a portable night watchman clock. In that the marking is done on a paper strip driven by clockwork, the procedure being that keys placed at the various control spots are inserted in the clock and turned.



Fig. 6

Interior view of the Vasterås fire station with dial telegraph plant

The station was opened for operation in 1897 and the plant was still functioning in 1937

X 4413

Fire Telegraph

Ericsson's collaboration with the fire brigades soon led him to begin the manufacture of fire telegraph systems. As early as 1878 there were delivered to the Sundsvall Fire Service various instruments, including fire alarm boxes.

Fig. 7
Bell tolling machine for fire alarm
exhibited at Paris 1881

X 6178

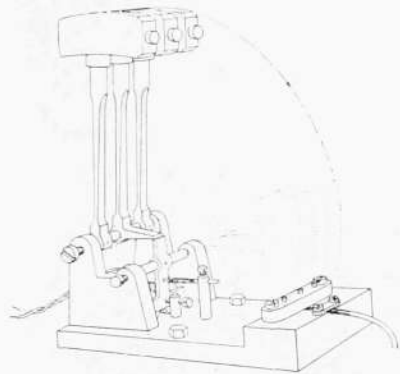


Fig. 8
Hammer mechanism for the firing of
cannon shots

X 4409

Supplied to Visby in 1885

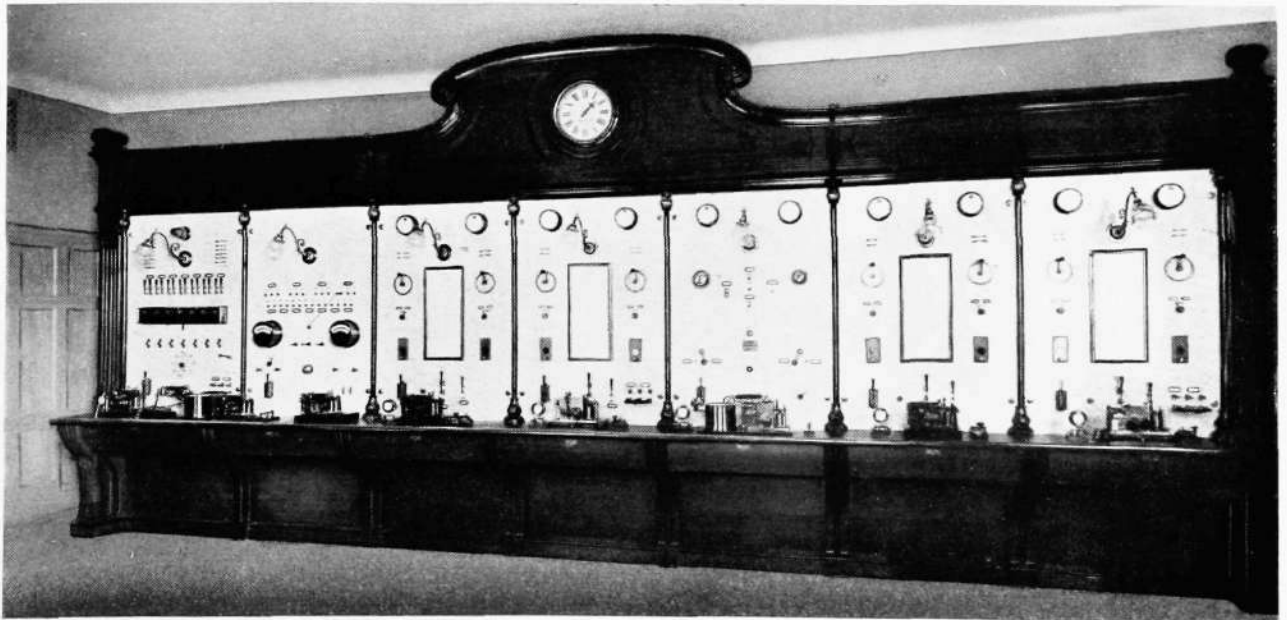
Fig. 9
Interior of Johannes fire station, Stock-
holm, 1909

X 7408

Two years afterwards he worked out models for a new automatic bell tolling apparatus for fire alarm and other instruments required for fire telegraph stations. Such a fire telegraph equipment was exhibited in Paris in 1881.

The bell tolling apparatus was designed for placing below the church bell, so that the hammers of the apparatus struck a blow on the bell each time the signal button was pressed. The necessary power was stored by winding up a heavy weight.

The same tolling apparatus as was exhibited in Paris was supplied to Visby in 1885. Visby, however, had previously also had fire announcing by means of cannon shots and the Visby people wished to retain this form of alarm. Ericsson therefore supplemented the apparatus by a unique design, namely an automatic hammer mechanism for firing the alarm cannon.



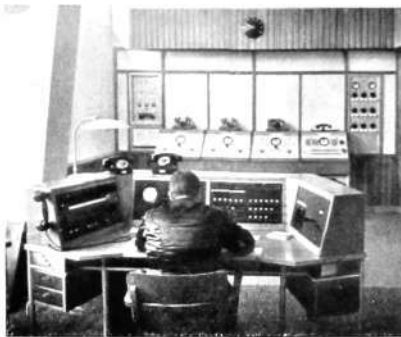


Fig. 10 X 4410
The telegraph room at Brännkyrka fire station

In the foreground, control board. In the background: the central fire telegraph apparatus with charging panel mounted flush in the wall at the right and the automatic fire alarm central instrument at the left

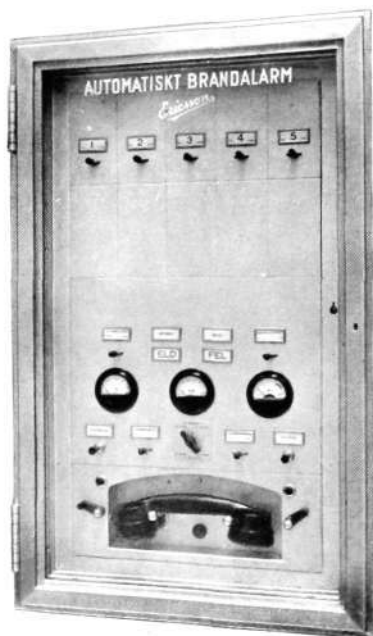


Fig. 11 X 4418
Central apparatus for automatic fire alarm plant

Fig. 12 X 7410
Thermo-contacts

left and in middle, fire signal contacts of 1890 for barns; right, thermo-contact of latest design



At the request of the then Director of the Stockholm telegraph station, Nyström, who was also inspector of fire services in the provinces, Ericsson worked out a fire telegraph system for the provincial towns. The first delivery of this system, known as the dial system, was made in 1885 to Karlskrona, and similar plants were shortly afterwards installed in most towns and large communities of Sweden.

The fire alarm boxes were so fitted that after the button had been pressed a fixed number of circuits was made, so that both the district and the number of the box could be read off at the fire station dial central apparatus.

The magneto generator system, intended for small towns and communities, was designed in 1917. The system now employed in large towns was designed in 1907 and in 1920 was subjected to thorough revision. Since then it has repeatedly been the subject of small modifications. In recent years fire telegraph plants have frequently been combined with police telephones, so that the lay-outs have undergone certain changes. At the same time the equipment has been given a more up-to-date appearance.

Automatic Fire Alarm

A firm concerned with fire telegraphy would naturally try to discover some method of automatic alarm in case of fire. L M Ericsson in 1890 designed contacts for this purpose, but for some reason this branch of activity was not further developed. It was not until 1926 that serious interest in automatic fire alarm began to be displayed. The system which then began to be manufactured was provided with two-wire circuit loops, in which soldering metal contacts sensitive to heat, known as thermo-contacts, were coupled in series. The loops were connected to a central apparatus comprising devices for electric supervision of the plant, receiving and indicating of alarm and fault signals etc. Alarm signal was registered when break occurred in the two wires of the loop. A single-wire break, shortcircuiting between the loop wires, leakage to earth or combination of these faults was signalled as fault.

By means of this arrangement with double-wire current supervised loops there was attained an unusually high degree of security for the conveying of the alarm, while the risk of false alarm owing to line fault was reduced to a minimum. The efficacy of these plants was still further increased by the fire services agreeing to the connection of the central apparatus to the public fire telegraph network, so that alarm and signal could be transmitted direct to the fire brigade without any intermediary.

After a number of these plants had been in service and had also shown their worth for fires, the fire assurance companies showed their appreciation of

Fig. 13
Water-level indicator

X 6184

left, self-recording water-level indicator; right, impulse mechanism for water-level indicators of older construction

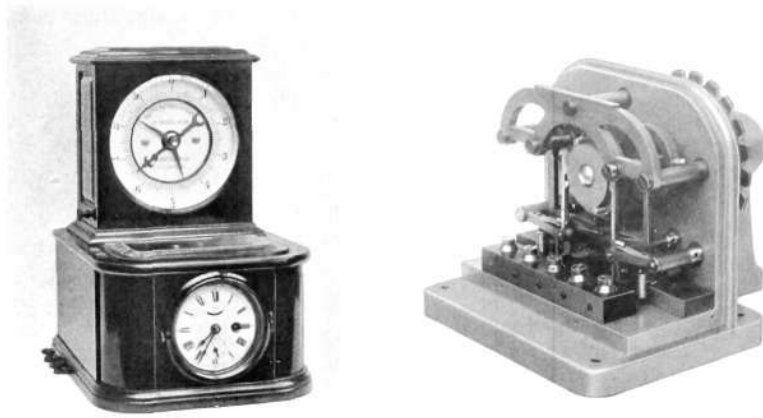


Fig. 14
Impulse mechanism for water-level indicator of latest construction

X 4421

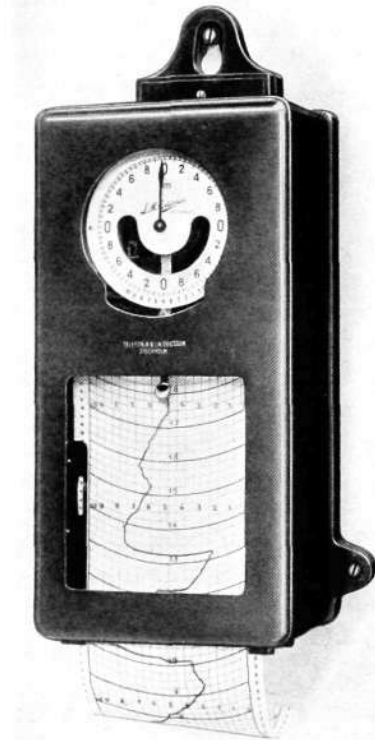


Fig. 15
Recording water-level indicator of modern construction

X 4419

them by granting rebates on fire insurance premiums for those risks where the L M Ericsson fire alarm was installed.

The basic principle of two-wire loops and automatic transmission of alarm and fault signals to the fire brigade is still applied, but the mechanical construction of the central apparatus was altered in 1936, so that while it had formerly been made for each individual case it could now be mass produced. The thermo-contacts are the same type as in 1926, but are about to be replaced by a new type with bi-metal springs soldered together having more rapid reaction than the former design.

Water-level Indicators

The first water-level instrument to be driven by galvanic cell was designed by Ericsson at the beginning of the 1880s and was succeeded in 1887 by a magneto generator driven water-level indicator which in principle was the same as that now used. In 1892 the apparatus was complemented by a recording device. L M Ericsson's water-level indicators have been installed in the course of the years at many places throughout the world.

Clock and Time Recording Plants

Among the recording apparatus referred to above were comprised mechanical clockworks manufactured in Ericsson's own factory.

Clockworks for ordinary clocks were not, however, manufactured before the 1920s. It is true that the tower clockwork mounted by the firm of Linderot in Ericsson's factory on Thulegatan was provided with a contact device which delivered 4 impulses a minute to a number of secondary clocks, made in the workshops, set up in the factory. But no business in clocks of this design was done.

In 1907 there was designed what is known as the Farad clock, driven from the strong current mains. This clock was sold to quite a large extent.

When the Stockholms Telephones Limited in 1918 sold its telephone plant to the Telegraph Administration and was reconstructed to form Industri AB H T Cedergren, this company began to look around for fresh manufactures

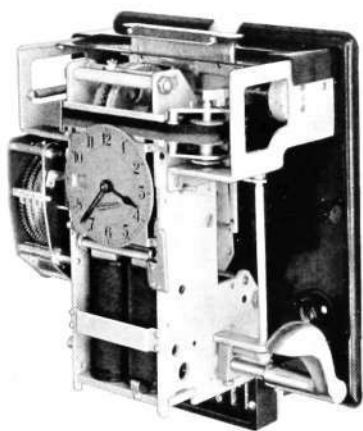


Fig. 16
Time recording apparatus
with cover removed

x 4422

for its workshops. In the autumn of 1918 work was begun on the design of a time recording apparatus and at the same time a start was made with secondary clock mechanism. The work of designing was about completed in 1921 when the Cedergren company was taken over by LM Ericsson.

The first installation of recording apparatus was made in 1921 at Norra-hammars Bruk. In conjunction with the progressive moving of the manufacture of time recording apparatus from the Cedergren factory to the LM Ericsson establishment, certain re-designing of the recording apparatus was done to make the manufacture less that of a small workshop than it had originally been and also to make the apparatus more reliable. The first apparatus of this altered model were sent out from LM Ericsson's during 1924.

The apparatus in question for recording arrivals and departures have since undergone certain modifications, but in principle it is the same design that is still manufactured.

With more or less the same components as used for the recording apparatus there were constructed from the beginning both a calculating recorder and a recorder for monthly records. The calculating recorder, like the recorder for weekly records, had automatic card setting, while the card slot on the monthly recorder was set by hand.

In 1936 there was completed a new design for the calculating recorder, made up of entirely new components. To begin with it was made as a monthly recorder but has since been complemented with recording mechanism for weekly records. The recorder types now made are fixed for mass production, but work on new designs is constantly going on to keep up the company's position in this domain.

The first secondary clock was delivered one year after the first recording apparatus left the factory, that is 1922, and mechanisms of this design were manufactured up to 1929. Since 1929 no change in the principle of the mechanism has been undertaken. Certain changes in design have been made to adapt the mechanisms to mass production. Hitherto during the time that LM Ericsson has been engaged with material for clock plants the master clocks have been purchased abroad, mostly from German makers.

In 1940 work on designing a master clock of Ericsson's own was started, on the basis of a design that had been made earlier in the French Ericsson factory. The result has been that the company has recently begun to supply master clocks from the first quantity of its own design.

Centralographs

In 1930 the company came into contact with a Hungarian engineer who had designed an apparatus for control of the running of machines, mainly with an eye to the textile industry. The inventor called his apparatus the centralograph and negotiations led to the purchase by LM Ericsson of the patent.

The first plants made in the company's factory were supplied in 1932 but even before that the inventor had himself sold a couple in Sweden.

The work of improving and developing the apparatus was immediately put in hand and by 1936 there had been produced the model of an apparatus that not only recorded machine time but also by means of a figure code in the

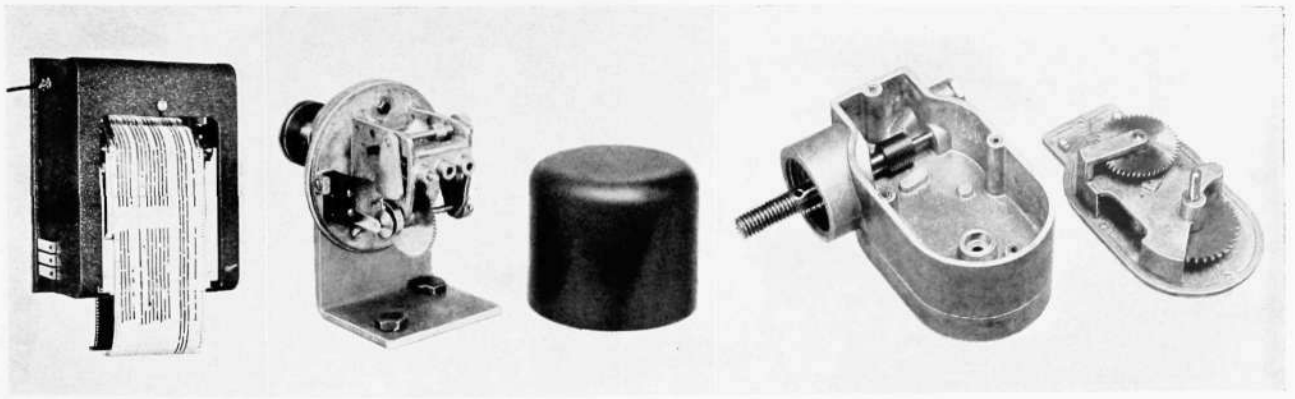


Fig. 17 X 7409
Centralograph, at left with impulse transmitter;
in middle, of older construction; at right, of later design

diagram indicated the causes of stoppages. A first trial lot was manufactured and these were submitted to prolonged tests. In 1943 the first of these apparatus were put on the market.

Miscellaneous Tele-signalling Plants

Besides the apparatus described above, which are made and supplied in large mass-produced quantities, the undertaking has from the beginning made single apparatus for tele-signalling plants of various kinds.

Thus LM Ericsson himself designed and manufactured signal plants for mines, the first of which was delivered in 1883, wind direction indicators combined with wind meters, both indicating and recording, water quantity and current direction indicators and burglary alarm plants.

Later there were made mine igniters and fire control plants for the Navy, Parliament voting plants, stock exchange prices plants, timing plants for racing tracks, talking machines, location plants for hospitals etc.

In conjunction with the outbreak of the last world war the company made a big contribution by rapidly producing a reliable air raid alert system. This system was installed to a very great extent not only in Sweden but also in certain other countries.

Moreover in recent years what are known as central alarm plants for burglary alarm have been designed and such plants to begin with have been set up in Stockholm and Gothenburg.

Left, Fig. 18 X 4416
Dial instrument for mines
Delivered 1883 to C O Grafström, the Kärr mines



Right, Fig. 19 X 4415
Recording wind direction indicator and wind meter
1888 model

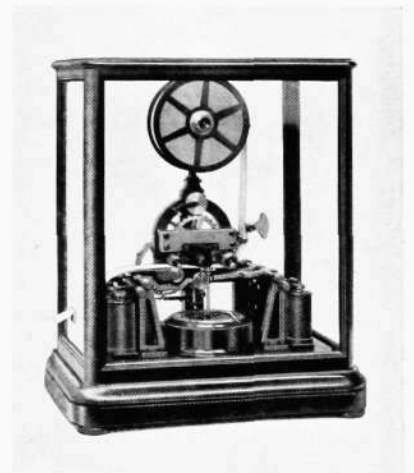




Fig. 20 X 7413
Price recording plant at Helsingfors stock exchange
left, prices board; right, stock exchange chief's equipment



Fig. 21 X 4436
Results board for voting plant in the Riksdagshus (parliament building), Stockholm



Fig. 22 X 4414
Dial locator

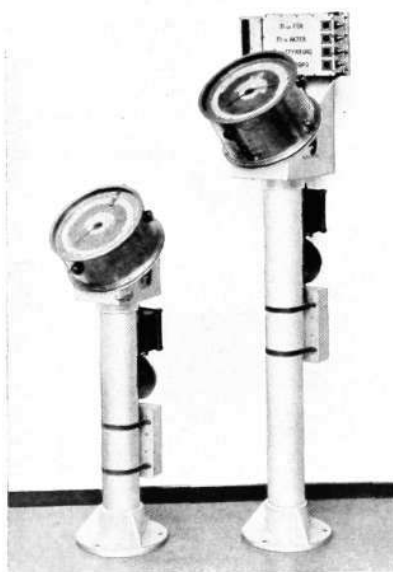


Fig. 23 X 4433
Fire control telegraph for warship

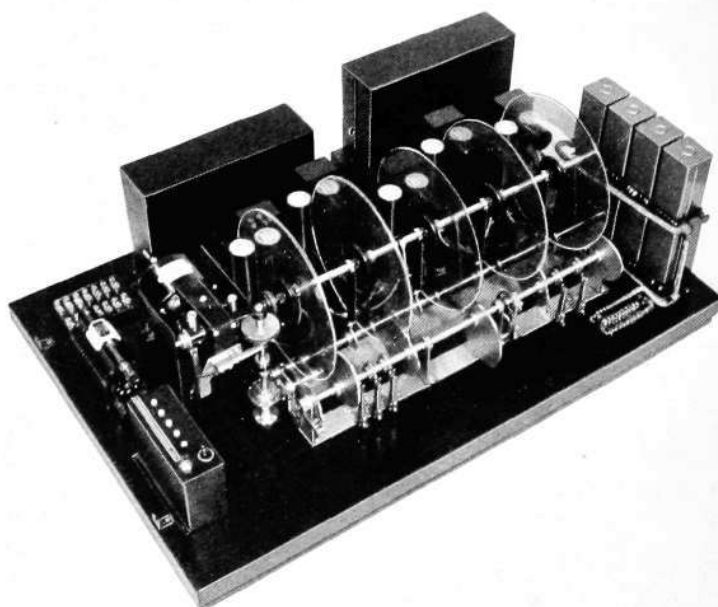


Fig. 24 (at right) X 6179
Time announcing machine

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Radio-Technics

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U.D.C. 621.396(091)

An account of the development of radio-technics up to the present day, restricted to the space available in an article for a periodical, cannot be more than a collection of episodes. Numbers of researchers and engineers will of course be mentioned, but not the majority of them. Even the unknown radio engineer is behind this development and recognition of his important work therefore has its place here.

A century ago, as now, the technology of the future was entrenched in the men of science. The principle of energy had been presented four years previously but was still far from being recognised by the physicists of the day. Faraday's ingenious experimental investigations into the nature of electricity were available as raw material for the mathematical physicists of those days. The fundamental knowledge for radio technology was given by *Lord Kelvin* in his discovery of the electrical oscillation circuit. Kelvin's formula is still the one most employed in the technology of radio.

Maxwell's mathematical work on Faraday's investigations resulted in 1873 in his electro-magnetic light theory. This may well be described as the finest mathematical description of natural phenomena of the 19th century. Verification of this theory was provided by *Hertz* in 1887 in his famous experiment, which employed Lord Kelvin's oscillation circuit to produce waves of metre dimensions. Hertz demonstrated that electro-magnetic waves were a reality and of the same nature as light. It was natural to think of using these waves for remote communications and several researchers worked on these lines, such as *Branly*, known for his coherer, and the Russian *Popoff* who in 1895 succeeded in telegraphing over a distance of 4 kilometres.

It was *Marconi*, who began his experiments in 1896, that first succeeded in conveying radio telegraphy over a long distance. A reason essentially contributing to his success was his idea of using a vertical aerial that was made higher and higher and also of using an earth connection. The wave-lengths he worked on lay around 300 m. After a series of trials, in which the distance was progressively increased, he succeeded on 11th December 1901 in conveying signs by wireless between the giant station of Poldhu in Cornwall and St. John in Newfoundland. His system for the transmitter includes the aerial which itself constitutes a Kelvin's oscillation circuit, the oscillations being produced through a spark-gap in the aerial itself. The receiver device consisted likewise of an aerial and a coherer connected to it.

The stage from the transmission of simple signs to commercial traffic is however long and it took until 1905 before regular commercial traffic was exchanged across the Atlantic. Marconi had in the meantime found it an advantage to increase the wave-length for his experiments to 4 000 m. Definite traffic across the Atlantic was later exchanged over the station of Poldhu and Cape Cod, U. S. A. The speed amounted to app. 30 words a minute.

In Germany, under the patronage of Kaiser Wilhelm II, Professor *Braun* was working on a system much resembling Marconi's. As early as 1898 he introduced a special oscillation circuit, the spark circuit, to which the aerial was connected. The limit for Marconi's transmitting power was determined by the capacity of the aerial, the number of spark-overs in the aerial per second and the aerial voltage. The aerial thus had two functions, the production of the

high frequency oscillations and radiating. These functions, however, in technical and economic respects are contrary to each other. The introduction of the Braun circuit, known as the intermediate circuit, meant that the two functions could be separated. The spark circuit had to generate the oscillations and the aerial had to radiate the energy.

There was also another system that was born in Germany, that of *Slaby-Arco* in 1897, behind which stood the German General Electric Co. This system was surprisingly similar to that of Marconi. After patent conflicts between the two German systems these were merged into one: »Telefunken». As might be expected the Telefunken system was first made available to the German navy.

At this time the big Atlantic passenger liners began to install radio stations as well, mostly of Marconi's make. Thanks to its fixed stations on the European and American coasts, the Marconi Company was at an early stage fairly predominant in respect of ships' radio traffic. In 1903 Germany sent out invitations to a radio conference in Berlin, at which the traffic between ships and land was to be discussed. The radio stations should be under obligation to exchange telegrams, irrespective of the system they represented. Officially it was humanitarian standpoints, especially the thought of disasters at sea, that animated the conference. In the background, however, lay an attempt to break the powerful position of the Marconi Company. Britain and Italy could not in the more important points accept the proposals put forward.

Theoretically the Telefunken system with the Braun intermediate circuit should be capable of delivering many times the power of Marconi's. It was found, however, that the aerial circuit, in addition to radiating energy, delivered an appreciable part of it back to the spark circuit, thus deteriorating the radiation and in addition obtaining two wave-lengths at one time in the aerial. This circumstance meant that the Marconi and the Telefunken systems were after all fairly equal. The weakness in the Telefunken system was overcome in 1906 by Professor *Wien* by his system of quenched sparks. Without going too closely into his idea, it should be stated that the problem consisted in quenching a spark gap and de-ionising it in an interval of some micro-seconds. His solution of the problem, known as the spark section, is both theoretically and practically one of the finest solutions produced in radio-telegraphy. The effect is ideal, the spark circuit delivers its energy to the aerial in perhaps 1/100 000 second, after which the spark circuit by means of the Wien spark section is disconnected, and the aerial radiates its energy in the form of slightly damped distinct waves. The number of sparks per second could in this way be in-

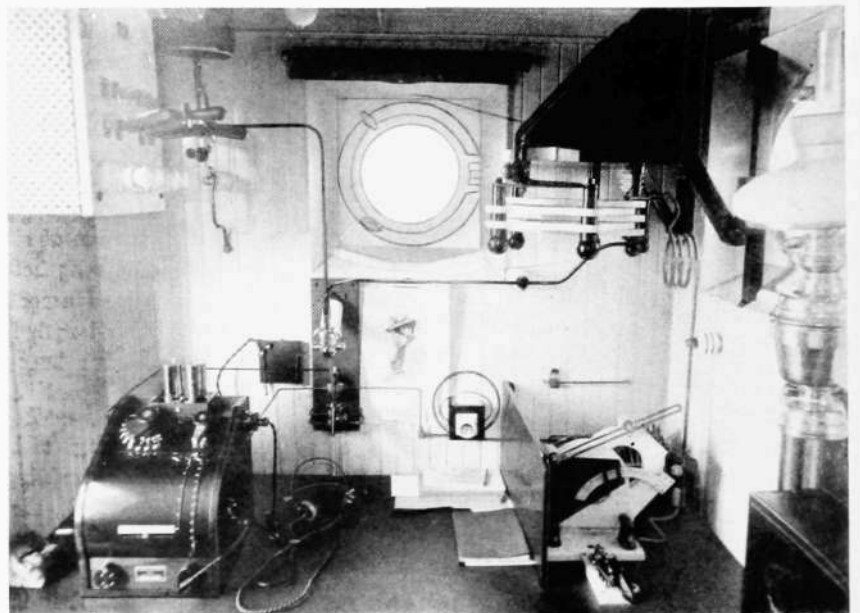


Fig. 1
Typical German ship's station, system
Telefunken, Rendahl, of 1920

X 6166

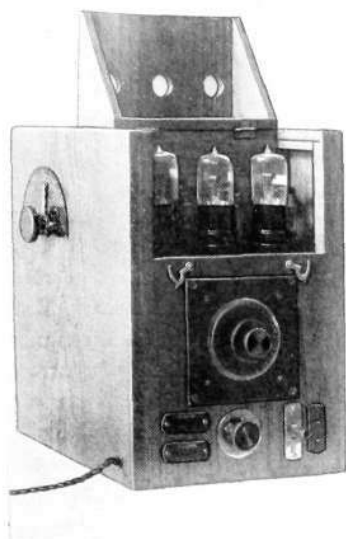


Fig. 2
Ship's receiver with detector and 2-stage
low frequency amplifier
Svenska Radioaktiebolaget's make 1921

X 4397

creased from 30 to 1 000. The result was that in the receiver earpieces there was obtained a clear high tone, easily distinguishable from atmospheric disturbances. The system was worked out for Telefunken by its chief engineer, the Swede *Rendahl*, and was put on the market in 1908.

This system may be regarded as decidedly superior to Marconi's though the latter had likewise solved the problem by his rotary spark section. The Marconi system with rotary spark section has persisted for a long time in merchant ships. It is still possible to find ships equipped with this system. The Telefunken system with quenched sparks has still its importance as emergency transmitter in ships. Its reliability is practically 100 %, its efficiency from a technical standpoint is exemplary: from input 500 cycle power to high frequency energy in the aerial, 85 %. As example of large stations on the Telefunken principle we had in Sweden the Karlsborg radio in 1916, 80 kW, which was of great importance for Sweden's traffic with the Continent during the first world war and some years afterwards. The ranges attained with ship's stations in the time before the first world war were in the neighbourhood of 300 to 400 nautical miles. Some of the Swedish Transatlantic Co's ships had, however, communication with each other in the Indian Ocean at almost 2 000 nautical miles distance.

The total number of coastal and ship's stations was

year	1913	1920	1929	1939
number	3 280	9 050	17 000	40 000

Illustrative of radio conditions of the time was the result of the international radio conference at Berlin in 1906, in which thirty states including the Scandinavian countries participated. The Conference led to the first International Radio Convention in a real sense and it fixed in the main rules for exchange of telegrams between coastal stations and ships. The Conference also decided on the establishment of an international bureau which should collect and publish information regarding radio telegraph stations. This bureau formed from the beginning a new branch of the already existing International Office in Berne.

The next international congress was held in London in 1912. Not least the Titanic disaster had prepared the ground for this conference at which the partially out-of-date convention of 1906 should be freshened up and extended to constitute greater uniformity. The Conference recommended the establishment of a network of coastal stations for the benefit of shipping and the regulation was introduced that ships provided with radio should also have an emergency radio station independent of the ship's source of power. In addition there were introduced international abbreviations (the Q code) and a certain system of attendance at the stations, especially for passenger ships etc.

In the time before the first world war, parallel with the developments of radio-technics described, there went on research work of considerable extent regarding radio transmission in general. The wave distribution theory established by Maxwell was further developed by many research scholars: *Zenneck*, *Sommerfeld* and others. The ionised air layer postulated by *Heaviside* at an early stage as laying at an altitude hundreds of kilometres above the earth, which even in Marconi's early experiments had had a certain influence on transmission, began to be investigated by physicists and this research has up to the present attained an enormous extent. Other domains of radiotechnics, such as the forming of the »corner-stones» of radio, resistances, coils and condensers, had undergone intensive development. Both shaping and insulation were of great importance. It was during this epoch that the Litz wires came out and also that knowledge of dielectric losses was deepened. The wave meter saw the light at the beginning of the century. The mathematical conditions for the treatment of damped oscillations were created in outstanding fashion by the Norwegian *Bjerknes*. About the same time, radio began to be used for other purposes, chiefly for direction finding, partly by the rotary frame indicated by Braun and partly by *Bellini* and *Tosi's* system with fixed frame.

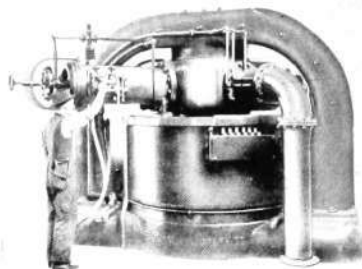


Fig. 3
500 kW Poulsen generator

X 4403

In respect of the equipment of the receiver side it is chiefly the detector that is of interest. As early as 1874 the above-named Professor Braun discovered the detector action in crystals. It was not until about 1906, however, that the crystal detector began to be generally used; Marconi's magnetic detector of 1902, *Schloemilch's* electrolytic detector 1903, *Fleming's* diode 1904 and *de Forest's* audion 1906 show the development in this connection.

The system that was to signify most for traffic between the Continents during the first world war and on to 1924, however, was produced in Denmark in 1906, where *Valdemar Poulsen* on the basis of *Duddel's* harmonic arc of 1899 created the first system with undamped oscillations in the aerial. *Lecher* 1888, *E Thomson* 1892 and *Duddel* 1899 had found that a Kelvin oscillation circuit coupled in series with a D.C. fed arc could in certain circumstances generate undamped oscillations. Prior to Poulsen these were of far too low a frequency for radio use. By enclosing the arc in hydrogen gas Poulsen succeeded in increasing the cycles to something like a million per second. He was also the first to telephone by wireless. Moreover his method of telephony found employment in the American Navy during the first world war.

The theoretical treatment of the oscillation problem with arcs and generally with circuits of falling characteristic has been developed chiefly through *Barkhausen* and *P O Pedersen*. The system is represented by *Lorenz A G* of Berlin, *C F Elwell* of London and the *Federal Telegraph Co.* of New York. It allowed of a tuning sharpness hitherto undreamed of and the transmitter has an efficiency of 50—60 %. The transmitters were made for powers of 30 W up to 3 000 kW for wave-lengths from 600 to 23 000 metres. In 1923 there were some 80 large stations on this system distributed over the whole world. The largest were Malabar 3 000 kW, Shanghai and Bordeaux 1 000 kW, Anapolis, USA, and Cavite on the Philippines and Pearl Harbour, Hawaii, for 500 kW. A high official of the General Post Office in London assured me in 1924 that better stations than Poulsen's did not exist. »They may be of any size and they are so simple that a nigger can operate them.«

At the same time as Poulsen, a rotating single-phase generator for 75 000 cycles per second and 0.5 kW was designed by *Fessenden* with the assistance of the Swede *E F V Alexanderson* in 1906. This type of machine was further

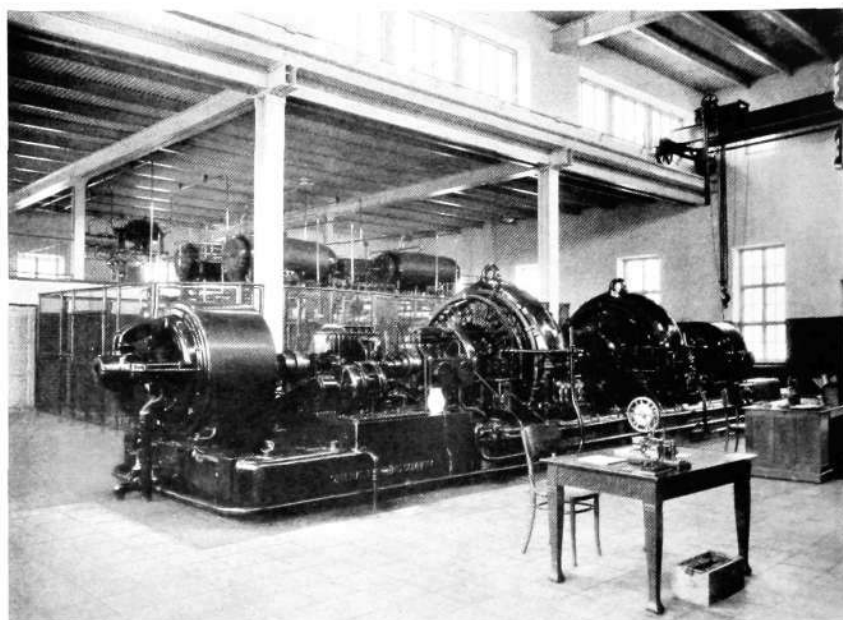


Fig. 4
Alexanderson's 200 kW high frequency generator
Varberg radio station 1924

X 6163

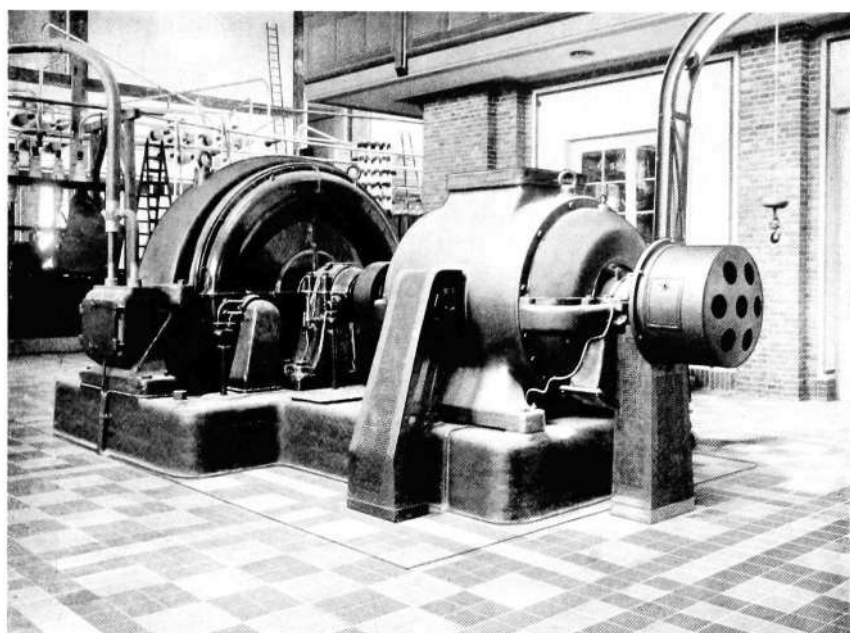


Fig. 5 X 6168
Telefunken 400 kW high frequency generator at Nauen radio station

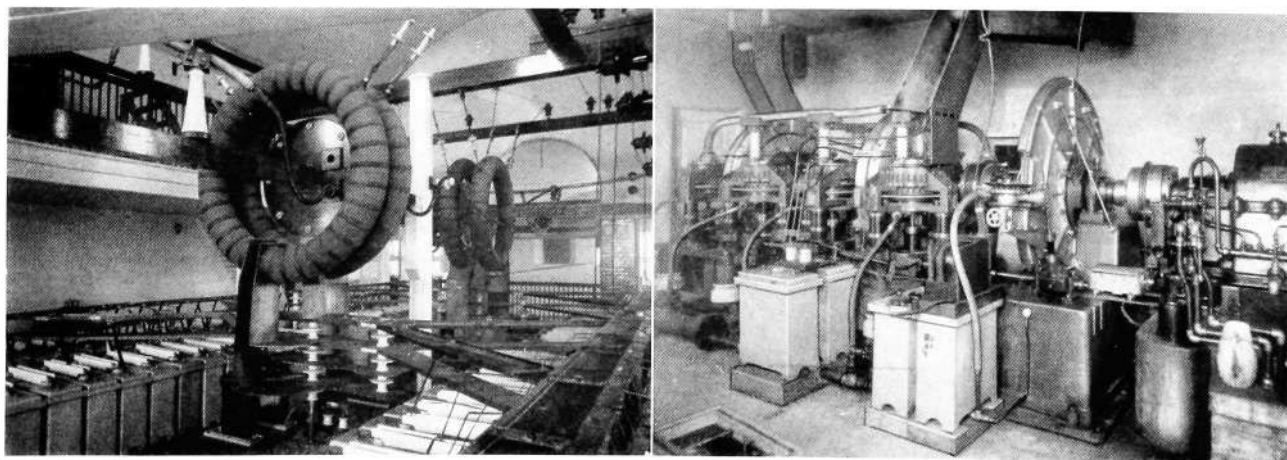
developed by Alexanderson in the General Electric, Shenectady, and was employed by Radio Corporation of America in their trans-ocean traffic. The machine has been standardized for 200 kW and for cycles of about 15 000 to 22 000. To this system also belongs a special aerial, known as the Multiple Tuned Antenna, the radiating efficiency of which is appreciably superior to other long-wave aeral. The principle is a form of delivering energy to an oscillation circuit that had long been known. It is surprising that nobody had used the principle long before Alexanderson and it is evidence that the fresh glance of the discoverer is something quite different from mere theory.

Sweden's first radio connection with USA was established in 1924, the Alexanderson system being used.

Telefunken employed high frequency generators of moderate cycles, the cycles being raised in transformers. By deforming the transformer field by D.C. there were obtained overtones in the secondary circuit, these being later cultivated and further multiplied in fresh transformers. The typical Telefunken station on this system is Nauen 1919 with 400 kW machine output. There was also constructed in France a system with high frequency generators for equivalent traffic.

Fig. 6 X 7406
Inside view of radio station at Stavanger in 1917

Left, Marconi's long distance transmitter with three rotary spark gaps; right, inside view of the transmitter station



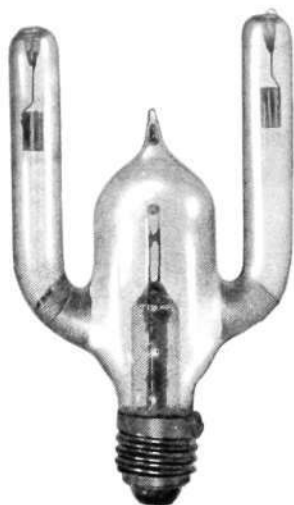


Fig. 7
Rectifier valve with Wehnelt cathode, 1920

X 4405

The Atom Traffic Makes Its Appearance

The discovery of electron emission from glowing bodies, a discovery of inestimable scope for civilisation, was made in 1883 by *Edison*. Manifolding of this »Edison power» was introduced by *Wehnelt*, who in 1904 demonstrated that oxides of barium, caesium and strontium produced considerably augmented emission. The phenomenon was utilized in *Fleming's* detector 1904 and in the electrode vacuum valve, the triode, designed simultaneously by *de Forest* and *von Lieben* in 1906. *Richardson's* renowned equation for emission as function of the temperature and *Langmuir's* $3/2$ exponent law for electron flow in vacuum constitute milestones in the development of radio valves before the recent world war. In the triode, radio practice had acquired an Aladdin's magic lamp. To begin with it was used as detector. In 1912—13 *de Forest*, *Armstrong* and *Langmuir* in America, *Franklin* in England, *Meissner* in Germany and *Strauss* in Austria, all independently of each other, discovered the return coupling, which at a stroke opened up the most fantastic prospects for the future for the technics of radio and high frequency. By means of the triode with return coupling there was obtained a convenient and inexpensive source of A.C., the cycles of which could be regulated to the region of 10 millions. It is difficult to decide in which domain this invention has had the greatest significance, for mathematics or for communication with or without wires. The triode also furnished the convenient facility of amplifying weak A.C. tensions with a precision hitherto unimagined.

On the Western Front in 1914—1918, where the armies dug into their trenches were seeking by means of listening apparatus to obtain knowledge of their adversaries' actions, the American *Armstrong* created the type of receiver which was given the name of super-heterodyne. Small valve transmitters began also to be made for military purposes during that war. As evidence of the conditions in Sweden, it may be mentioned that there was at the Technical University in 1918 an amplifier valve of *Siemens* make. It was kept in a velvet case, was stated to have cost 100 kronor and was used for laboratory work only by a few privileged persons.

The time up to 1924 was characterized by the building up of the theory of vacuum valves as amplifiers and generators, with the methods and terminology gradually becoming international. The receiver valves were usually triodes and double grid valves. Towards the close of that period the low temperature valves made their triumphal progress through the world. The transmitter valves were for small outputs up to $2\frac{1}{2}$ kW. In special cases, with quartz glass it was possible to attain up to 5 kW. The high vacuum technique was of great significance in this connection. Pioneers in this domain were *Gade*, *Langmuir* and others.

As regards inventions, this period was characterized generally by an incredible number of receiver and transmitter couplings, among which may be noted *Hartley's* and *Colpitt's* 3-point couplings. The receivers consisted usually of detector and two-stage low frequency amplifier stages. The amplifier valves of those days had a disposition with high frequency amplification to get into oscillation. This difficult problem was solved by the American *Hazeltine* in 1923 with his neutralisation method, applied in the neutrodyne, which was regarded as the foremost type of receiver up to 1927—28 when an improved valve type, the screen grid valve, made neutralising superfluous. The development of the transmitter valve for large outputs, standardized to 10 and 20 kW, was worked out by the Western Electric Co. in 1922. Success was achieved in making a vacuum-tight join of copper and glass, so that the hot anode could form the outer wall of the valve and thus be cooled directly from outside.

Developments as regards long distance communication had since 1900 proceeded in the direction of longer wave lengths with increased distance. As years went by experience grew and resulted in the generally employed *Austin's* formula for radio transmission. Thus for traffic between the Continents waves of between 5 000 and 23 000 m were self evident. Developments in the domain

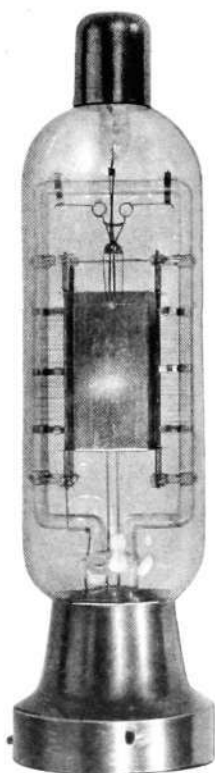


Fig. 8
0.5 kW transmitter valve, Telefunken, 1920

X 4404

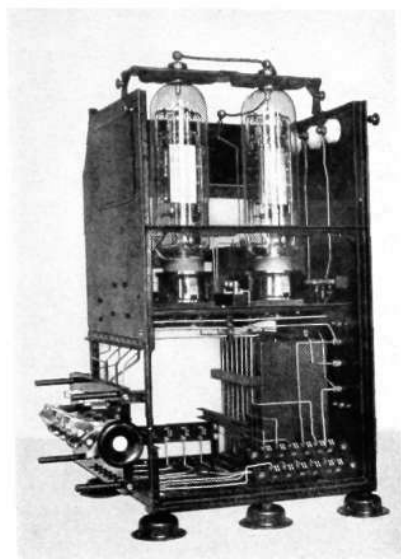


Fig. 9 X 4401
1 kW valve transmitter, type Telefunken,
at Karlsborg Radio, Sweden, 1920

of the high frequency generator also contributed to views concerning the necessity of the long waves for long distance traffic becoming axiomatic. Marconi's main patent, however, applied to spark stations, which for the requisite outputs became cumbersome. It may be said that the Marconi system was technically outdistanced during the first world war by the Poulsen system.

Marconi, as the world's foremost «explorer of the ether» wondered whether wave lengths below 200 m might not be useable for long distances. At an early stage with ship's telegraphy 1901—1909 ships had been allotted a wave length area around 120 m for small output powers. It had then been found on several occasions at night that extraordinary ranges of 1000 up to 2000 nautical miles could be attained. Marconi therefore decided to make thorough investigation in this wave length area and in conjunction with Franklin he began in 1916 trials with wave-lengths from 2 to 15 metres. In these there was demonstrated in 1919 the quasi-optical character of the ultra-short waves and the sudden drop of the field intensity beyond the horizon. In 1921 there was arranged, as a trial, telephone traffic on 100 m wave-length between Britain and Holland, which trials turned out well. Quite unexpectedly, however, it was found that good reception was obtained in Oslo during the night and sometimes in the day.

The trials were continued in 1922—1923 from the historic station of Poldhu with parabolic reflector aerial, 97 m wave-length and 12 kW input power. Marconi's yacht Elettra was used as receiver station on a voyage from Southampton to St. Vincent in the West Indies. With these it was possible to demonstrate good commercial traffic conditions practically the whole twenty-four hours of the day and that with only 1 kW input power at Poldhu. The trials showed that waves below 100 m could give results over considerable distances.

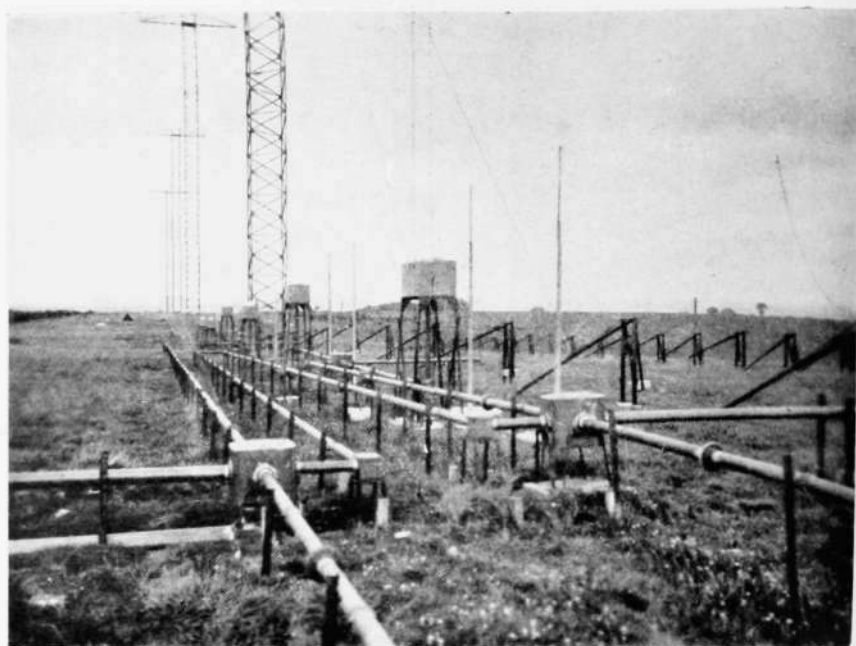
Radio amateurs, who in Britain and America had been allotted wave-lengths below 200 m as these at that time were considered unsuitable for more important communications, succeeded in 1923 in bringing about two-way radio connection at night on 100 m wave-length between Britain and USA. More sporadic long distance communications could also be recorded by them. Marconi's continued trials at Poldhu resulted in 1924 in good telephone communication with Sidney, Australia, and a number of other places in the world also obtained satisfactory and continuous reception from Poldhu.

The General Post Office at this time had been planning a long-wave traffic system with Canada, Australia, India and South Africa. Marconi took then what was perhaps the boldest step of his life both financially and as radio technologist. He succeeded in inducing the General Post Office to interrupt the plans for the long-wave network and instead to lay down a brand new system for short-wave. The contract with the General Post Office comprised exceedingly heavy traffic demands. Thus, during 7 days uninterrupted test in both directions there should be maintained a traffic not falling below 100 words a minute, for 18 hours per day with Canada, 11 hours with Africa, 12 hours with India and 7 hours a day with Australia. Should this programme fail the General Post Office should not bear any other loss than that due to the time required for the establishment of the much more expensive long-wave network. The stated traffic capacity was appreciably greater than had previously been known in wireless and ocean cable traffic and the project was described generally as «a speculative jump into the unknown». It was mainly Marconi's own experience with directed beams on short wave and assuredly his extraordinary intuition that gave him courage to sign the contract.

The work of construction that followed meant in actual fact a multitude of problems in respect of transmitters, receivers and aerials, all of which had to be solved by trial and error. On 25th October 1926 the Canada communication for 16 m wave-length was opened and the other Imperial connections came into being the following year. At the delivery trials with the Australian connection the phenomenal speed of 350 words a minute was attained. The

Fig. 10
Typical Marconi-Franklin short-wave
aerial plant
Dorchester 1929

X 6165



success with this short-wave network was so complete that the competing cable companies lost a great deal of their traffic.

It was found, however, that the cables were of essential importance to the Empire and that it would be much more advantageous if radio and cable were complementary to each other instead of carrying on murderous competition. A gilt-edged company therefore was formed in 1928, The Imperial and International Communications Ltd., which took over the Eastern Telegraph Co., The Imperial Cables, the new Empire short-wave network and Marconi's long-wave network. The path shown by Marconi was quickly followed by the other big civilized powers, so that these at present have a number of short-wave radio connections for both telegraphy and telephony.

Technical progress since then has chiefly concerned direction aerials, among which in particular the Tannenbaum aerial introduced by Telefunken has found great favour. In this connection mention should also be made of the romban aerial invented by the American *Brown*.

The old long-wave stations with a traffic capacity of perhaps $1/5$ and a power requirement 10 times these short-wave stations soon became out of date. Some of the old giants are still running today, however. A couple of days each year, when sunspots tear aside the connections for the short-waves, the ionosphere, they become once again »kings for a day» in the ether ocean.

It should also be recalled that before the short-wave asserted itself a great deal of work had been devoted to attempts to telephone on long-wave, one result being that Western Electric designed the single side-band system. The first commercial telephone traffic between the old and new world was exchanged by this system and was put into operation in April 1926. This system is still generally applied in short-wave telephony between the Continents.

Ultra Short-wave Technics

At an early stage of valve technics it was found that the triode's method of working and coupling as high frequency generator only permitted the generation of frequencies up to about 300 megacycles per second, i. e. 1 m wave length. For higher frequencies the conditions as stated were altered for the manner of working of the valve. New methods were required to attain still higher frequencies.

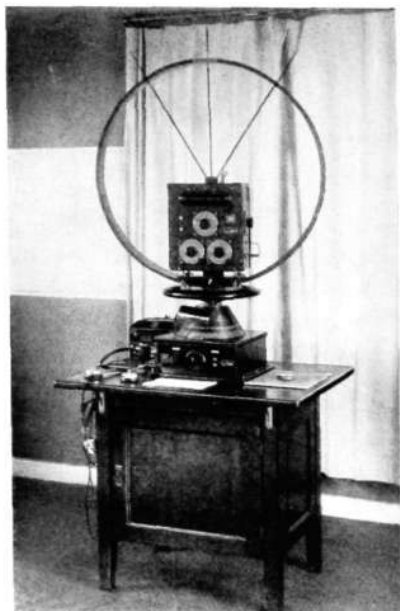


Fig. 11 X 4399
Direction finding receiver with Braun's frame

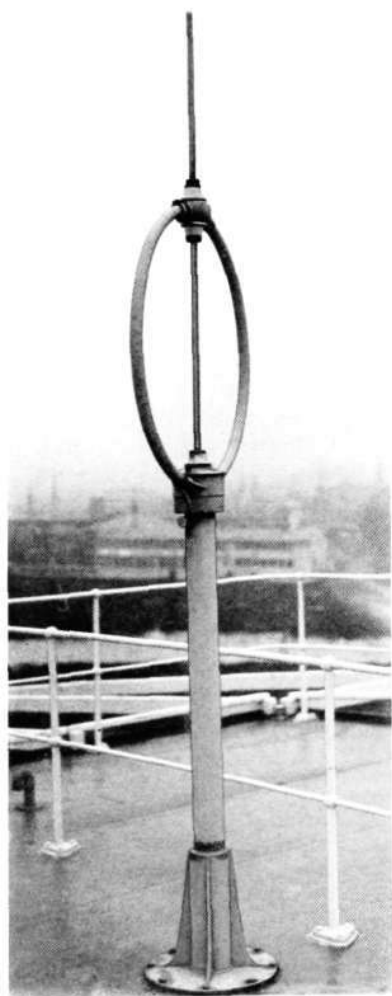


Fig. 12 X 4398
Rotary frame for direction finding receiver on board ship

Barkhausen-Kurz 1920 and *Gill-Morrel* used the triode in a new coupling, where the electrons were allowed to oscillate between the electrodes. For waves below 50 cm the efficiency drops very rapidly to below 5%. By this system success has been achieved in getting out some few W.

Hull in 1918 invented another method, where the electron oscillations were controlled by magnet fields, known as *magnetron*. Since 1933 this has been rapidly developed and before the war it gave better power and efficiency than the above method. A further development of *Hull's* system forms the foundation of the generators employed in echo-radio technics.

At the beginning of the late world war there was produced still another solution of the ultra short-wave generator problem, the *clystron*, with what are called velocity controlled electrons, which seems to promise some 100 or more W power output with centimetre waves.

Echo-radio technics is now producing generators for centimetre waves which, momentarily for 1 microsecond, can develop 300 kW with 10 cm wave-length and 60 kW with 3 cm wave-length. Just before the war the limit of output was about 100 W, in other words a thousandfold output increase.

The naval and air war forced on the belligerents incredible efforts in the sphere of echo-radio technics. It has been claimed, though obviously with some exaggeration, that the echo-radio technics won the war and that the atomic bomb terminated it.

Just a few applications of this new technics will be referred to, such as the echo-radio telescope in which a picture of surroundings is obtained right through darkness, cloud and fog. An innovation of inestimable value for merchant shipping is the echo-radio localizer, which gives in a picture the direction and distance from objects round the whole scope of visibility within 80 nautical miles, with magnifying possibilities up to 2 naut. miles. The price including installation of such an instrument is estimated at present at 40 000 kronor.

Another masterpiece in echo-radio technics searches the whole heavens automatically and detects aircraft within 70 km distance. When the plane comes within 30 km distance, the instrument can be made to follow the target automatically and in conjunction with this automatically control the anti-aircraft defences. At each instant it gives particulars of the distance from the target with not more than 25 m error and 0.06° error in azimuth and elevation. The impulse power is 300 kW and its duration 0.8 microseconds. It was designed at the Massachusetts Institute of Technology Laboratory in April 1941, the final military tests were complete in February 1942 and the first firing tests took place at Anzio in February 1944. About a couple of thousand such instruments have been delivered, the price is approximately half a million kronor.

A terrifying weapon has been obtained in the echo-radio grenade, which explodes when it has come within effective distance of the target. The echo-instrument in this case must stand 20 000 times greater acceleration than for calling freely, the centrifugal forces on the projectile's rotation and — 60° C temperature. The problem was taken up in 1940 at the Carnegie Institution and the John Hopkins University. During the war 100 000 persons were engaged on the production of 20 million such projectiles and the cost was app. 1 milliard dollars.

The Importance of Radio for Navigation

As stated before, it was possible at an early stage (*Braun*, *Bellini*, *Tosi*) to take bearings on radio stations. For the benefit of navigation there were established in the early 1920s radio bearing stations along the coasts. A ship with radio could by means of this obtain its angle of direction from the bearing stations and thus determine its position. Since then the system has

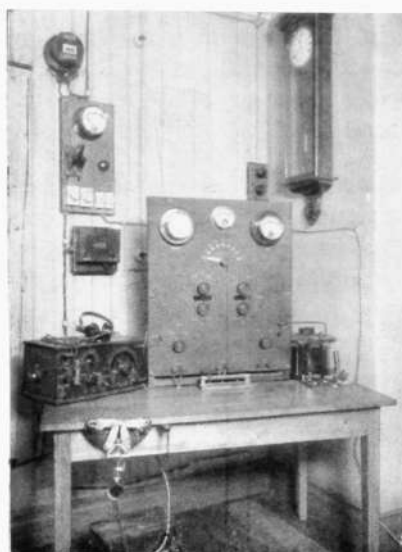


Fig. 13 X 4402
The Gothenburg coastal radio station 1919
Telephony transmitter

been supplemented in high degree by providing the ships with direction finding instruments on board. At present practically all ocean-going vessels are equipped with such instruments. The lighthouse services of many countries have extended their installations to include radio beacons in the service of navigation. The Baltic countries and Norway at a conference in Stockholm in 1932 agreed on a common radio beacon system of this kind.

For aviation the radio technics constituted a decided factor of safety. It is not more than 12—15 years since aircraft were keeping to the line of highways of or railways to be sure of not losing their course and preferably did not start if the cloud blanket was so low that such lines could not be used for guidance. Aviation therefore at an early stage made use of radio direction finding both in the aircraft and on the ground. For night flying, however, the older methods of taking bearings are unreliable, owing to the polarization distorting of the radio waves that takes place in the night. The solution of this problem was indicated by the Englishman *Adcock* in 1919. It was not until 1926 that his direction finding instrument was used and up to the war this method of obtaining bearings was predominant for aviation safety. The larger airfields in Sweden have for long been equipped with this type of bearing indicator.

In the 1930s the European countries came to agreement for a common triangle network of radio beacons for the benefit of aviation. The problem of blind landing has been solved in principle since the 1930s, the solution being since developed, chiefly by C Lorenz A G, Berlin. The system works on ultra-short waves and is such that from the far end of the runway there is transmitted a beam of such a kind that the crew of the plane landing hear different signals according to the side of the direction of landing they happen to be. Moreover the beam is so shaped that the pilot of the plane follows the beam in an instrument as a wide arc to the runway. The system further tested and revised in USA constitutes the standard for all large airports. By 1937 there were 35 such airport installations and 200 aircraft equipped with the instruments for blind landing.

Unlike the Europeans, the Americans have directed radio beacons between the airports, »radio lines» along which the air traffic runs. The intercontinental aviation realized during the war has made necessary a coordination of the European and American air radio systems, fixed at the world conferences in

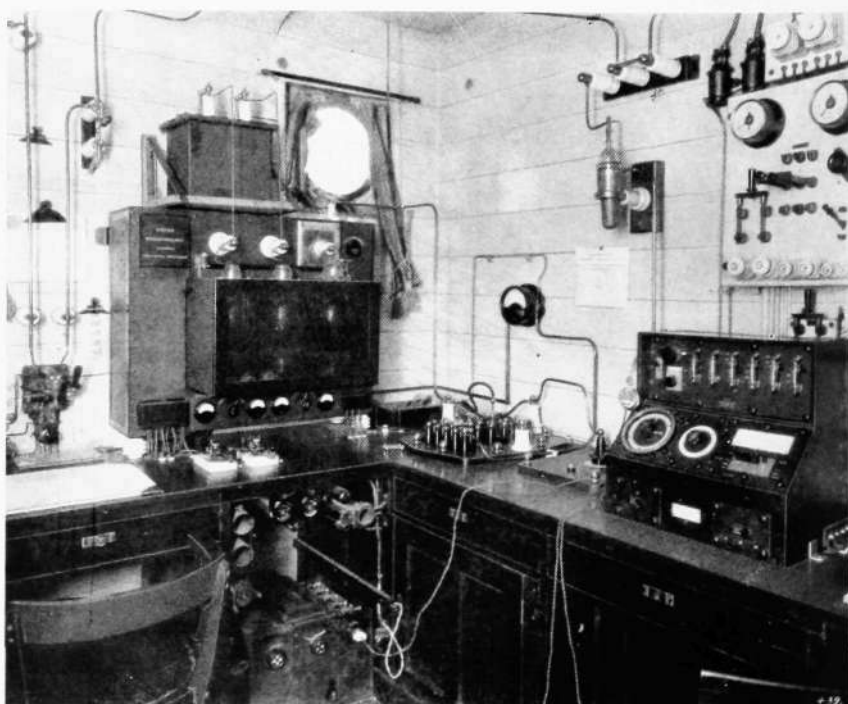


Fig. 14 X 6167
Radio station of s/s Drottningholm
left 1 kW valve transmitter made by Svenska
Radio Aktiebolaget, right direction finding re-
ceiver, system Bellini—Tosi, of Marconi's make.

Chicago 1944 and Montreal 1945. Through this, new aids to navigation have been added, that have sprung up during the war, such as the echo-radio collision averter and the Loran system for long distance navigation. Synchronized impulses are emitted from transmitter stations on the ground, these being received in the aircraft. The impulses are given varying time characters according to where they are read, which Loran charts established in advance permit. From the character of the impulses read the pilot can read the plane's position direct on the Loran chart. The system permits a trained navigator even to take signals reflected against the ionosphere, which enables the system to be used up to 1 500 nautical miles. Further serviceable systems have come out during the war and may be expected to have importance for the navigation of both aircraft and ships. One of these was used for the invasion of France. By it ships could determine their position to within 7 m at the entrance to the Scheldt guided by signals from radio stations in England.

Broadcasting

After the first trials with broadcasting had been made in the United States towards the end of 1920, this new means of communication made extremely rapid progress in that country and quickly spread over the world. In France regular broadcast emissions were begun in the middle of 1921 from a military station in the Eiffel Tower. At the beginning of 1922 the Marconi Company in England obtained permission from the authorities to broadcast music programmes by radio once a week and at the close of that year the British Broadcasting Company was formed.

As regards Sweden, the government on June 29 1923 approved the broad lines of broadcasting, according to which it was the State that would establish transmitting stations. The question of programmes, however, was to be handed over to private enterprise. The first practical trials with radio broadcasting in Sweden began at the training establishment of the Telegraph Administration in Stockholm, where from September 1922 to the close of that year a half hour's programme was transmitted each evening. At the beginning of 1923 Svenska Radioaktiebolaget started trial broadcasts three times a week from its factory on Kungsholmen in Stockholm. From the coastal radio station of Nya Varvet at Gothenburg there were broadcast regular weather reports during the summer of 1923. From the Boden coastal radio station also broadcasts were undertaken about that time.

The technical basis for Swedish broadcasting was the trial station at Stockholm of the Telegraph Administration, the first transmitter specially built for broadcasting, with an output of 0.5 kW, in the autumn of 1923. The

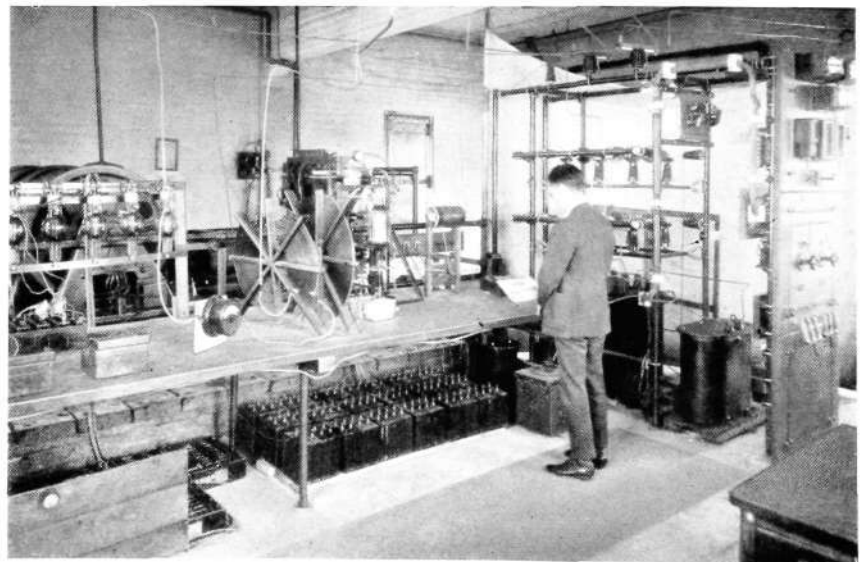


Fig. 15 X 6169
Inside view of broadcasting station WGY
(USA) 1922

Fig. 16 X 6164
Radio receiver of Svenska Radio Aktiebolaget's make 1921

The receiver is equipped with 3 valves, one as detector and two as low frequency amplifiers.



station which was made by Svenska Radio Aktiebolaget was housed in the training establishment of the Telegraph Administration at Malmkillnads-gatan, where a lecture hall was converted into a studio. With this installation trial broadcasts were carried out, as also a number of tests and experiments of a radio technical and acoustic nature, providing useful experience which was to be of great value in the technical lay-out of later plants.

During the whole of 1924 there were regular broadcast emissions from the laboratory of Engineer *K G Eliasson*, on his own initiative.

New licence regulations came into force on 1st January 1925. The charge was then 12 kronor per year. From the beginning of 1926 the licence fee has been 10 kronor per year. On 27th September 1924 the Board of Telegraphs was authorised to erect 5 broadcasting stations, at Stockholm, Gothenburg, Malmö, Sundsvall and Boden. At the opening of 1926, when AB Radiotjänst (the Swedish Broadcasting Corporation) started operations, the Board of Telegraphs could place the new stations in Gothenburg and Malmö together with the experimental station at Stockholm at the corporation's disposal for the broadcasting of the opening programme. During 1925 there were set up on private initiative broadcasting stations in 15 towns. A further 7 private stations were added during 1926. The demand of rural districts for a station with greater power was met in 1927 by the 30 kW station at Motala. In 1928 the power of the Gothenburg station was increased to 10 kW, as was the case with the stations of Sundsvall 1929 and Hörby in Scania. Finally the Brunkeberg transmitter in Stockholm was replaced by a broadcasting station of 55 kW at Spånga outside the city. Stations synchronously operated were established in 1932 at Karlstad, Norrköping and Trollhättan. The result was so satisfactory that another group of synchronous stations was formed in 1935 at Umeå, Hudiksvall and Örnsköldsvik.

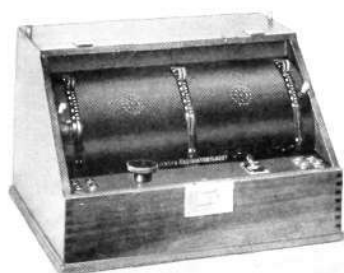
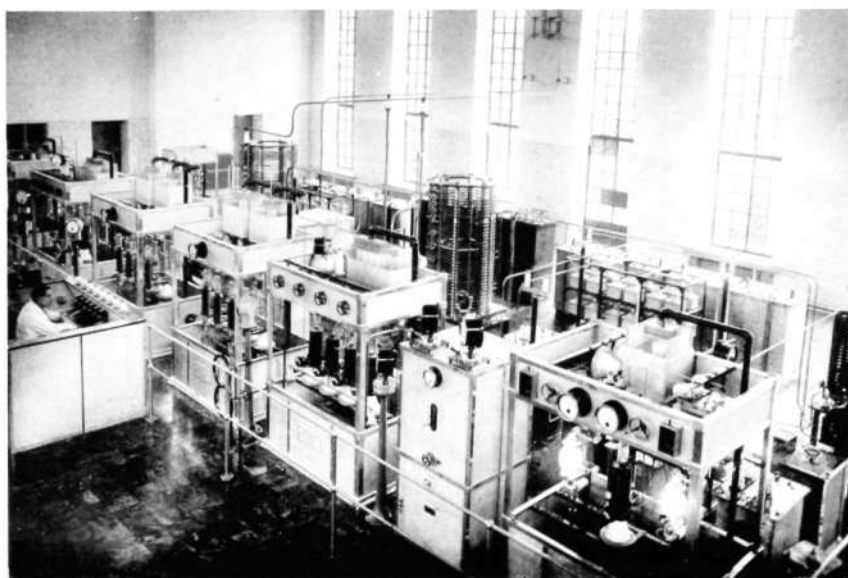


Fig. 17 X 4400
Radio receiver of 1925 model
Radiola M 25 IV

The keen international competition for wave-lengths had in the course of years resulted in a race between the countries, during which the transmitting powers of stations were progressively augmented. If Sweden was to have any chance of retaining the wave-length that Swedish delegates had secured at the international radio congresses there was nothing else to be done than to occupy these wave-lengths with transmitters of the greatest permitted power. In consequence the Motala station was extended for 150 kW in 1935 and the Hörby station to 100 kW in 1937. In 1938 the old station at Boden

Fig. 18
Inside view of Motala broadcasting
station 1927
30 kW transmitter

X 6162



was replaced by a new broadcasting station at Luleå for 30 kW. The latest big plant in the broadcasting network was added in 1939 with the 100 kW station outside Falun.

Technical developments in broadcasting stations are in many respects connected with progress in the methods of modulating. Special reference should be made to *Heising's* anode modulating of 1920 and the frequency modulating realized in practice by *Armstrong* in the 1930s. The frequency modulating, the great advantages of which as regards disturbances were first only felt in the ultra short-wave range, has been applied at a large number of broadcasting stations in the United States as a complement to other broadcasting.

The crowding of the ether in the broadcasting bands, which compelled the states of Europe to arrange a receiver station at Brussels for control of broadcasting stations' wave-lengths, meant a particularly sharp frequency constancy in the transmitters concerned. Foremost aid for this is to be found in oscillating crystal. The oscillation properties of crystals, discovered in the 19th century by the brothers *Curie*, were theoretically expounded by *Cady* in 1921. In the domain of broadcasting receivers the construction of the modern mixing valve in 1932 meant that the super-heterodyne receiver surpassed in quality the earlier neutrodyne and became practically predominant among the types of receivers.

Television

Photo-electric power was discovered accidentally by *Hertz* during his experiments to check the theory of electro-magnetic light. The discovery was worked on by *Hallwachs*, *Lanard*, *Elster*, *Geitel* and others but no satisfactory explanation was obtained until *Einstein* 1905 with the aid of *Planck's* quantitative theory established his renowned equation for photo-electrical emission, for which he was awarded the 1921 Nobel price. The technical result, the photo-cell, has now attained a high degree of perfection and in *Zworykin's* iconoscope of 1933 has provided us with the most ingenious means of transforming light impressions into electric current. The necessary reverse procedure of converting the electric current to light had been done earlier by several methods, *e. g.*, in the Kerr cell. It is now chiefly done by cathode beam valves, which were highly perfected during the war. Television has gone through a number of stages of development but it was not until the above mentioned instruments that it could be realized in useful form.

Owing to the enormous number of light impressions, several millions a second, that must be transmitted by radio for television, the wave-length in television, must lie in the ultra-short wave, under 10 metres wave-length. As the ranges of these waves are limited by the horizon the sphere of employment of television is directed to densely built up centres. The largest television system at present is that of the National Broadcasting Company at New York, which from its station at the Empire State building transmits programmes over New York and, via ultra short-wave connections, to Schenectady and Philadelphia, where the relaying is done over amplifiers. The Americans are extremely optimistic about the future of television and it is reckoned that in the regions named, with a population of 30 millions, hundreds of thousands of television receivers can be disposed of, which with light and 10×8 inch size of picture would cost about 200 dollars at pre-war prices. During the war the Radio Corporation of America has developed a television cathode beam valve of small diameter and such intensive picture point that the picture can be amplified direct and give good light intensity on a cinema screen.

The electron optic developed in conjunction with television, which at present plays an important part in the computation of new valves, has also led to the construction of electron microscopes with a dissolving property some 100 000 times greater than in light microscopes. Siemens of Berlin have been the pioneers in this respect.

It has only been possible to give a summary account of developments in the field of radio technics that entirely falls within the very short period, in this connection of half a century. Nevertheless we are but little acquainted with what has been done in this domain and its various branches during the last six years. We do know that it has exercised a great influence on war operations and one may venture to hope that it may be applied also in peace conditions to the benefit of humanity. We know also that the big industrial countries have gained a considerable advance over our country of Sweden. We can only try to make up this lead by energetic work and purposeful research and once more take up our position in the front rank.

JOHANSSON, H: *Lars Magnus Ericsson — a Brief Biographical Sketch*. Ericsson Review 23 (1946) No. 2 pp 105—120.

The article opens with a copy of LM Ericsson's report on his journey of study abroad. His early years are described. LM Ericsson becomes a pupil of A H Öller, and opens his own machine shop on 1st April 1876. Graham Bell's invention, the telephone, leads LM Ericsson to arrive by experiment at improved types of telephones. LM Ericsson beats the Bell Company in competition for the construction of a telephone network at Gefle. Stockholms Allmänna Telefonaktiebolag takes up the competition with the Stockholm Bell Company. Brief description of LM Ericsson's character.

U.D.C. 621.394(091)621.395(091)654.1(091)

HEDEN, N: *Telegraphy and Telephony*. Ericsson Rev. 23 (1946) No. 2 pp. 122—149.

Oersted's, Argo's, Sturgeon's and Faraday's discoveries in electrotechnics were to show the way for telegraph and telephone technics. The first telegraph systems. The first spreading of the telegraph network and the introduction of telegraphy into Sweden. Transition to newer telegraph systems. Sweden's telegraph connections with foreign countries. The telephone and its development in different countries. Lines.

U.D.C. 654.147(091)654.9(091)

ERICSSON, T. *Tele-signalling*. Ericsson Rev. 23 (1946) No. 2 pp. 150—160.

Electrical tele-signalling technics may be said to have arisen in and with Oersted's discovery of the action of electric currents on a magnet needle. The work of the undertaking started in 1876 by LM Ericsson consisted to begin with in repairing electro-mechanical instruments.

In the article there are described the tele-signalling systems designed and manufactured by LM Ericsson up to the present day, such as telegraph instruments, signalling systems, night watchmen control, automatic fire alarm, clock and time record plants, centralographs etc.

U.D.C. 621.396(091)

ÖVERGAARD, T: *Radio-technics*. Ericsson Rev. 23 (1946) No. 2 pp. 161—174.

Faraday's investigations into the nature of electricity were available as raw material for the physicists of the day, but the fundamental knowledge for radio-technics was provided by Lord Kelvin in 1853 by his discovery of the electrical oscillation circuit. Marconi began in 1896 to convey radio telegraphy over a long distance by using vertical aerials and earth connection. Account of the developments of radio-technics. Ultra-short wave technics. Radio direction-finding. The first trials with broadcasting. Television is gaining ground.

