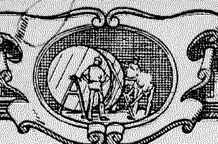
~~M. J. B. Jammer.~~



ELECTRICAL COMMUNICATION

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ELECTRICAL COMMUNICATION

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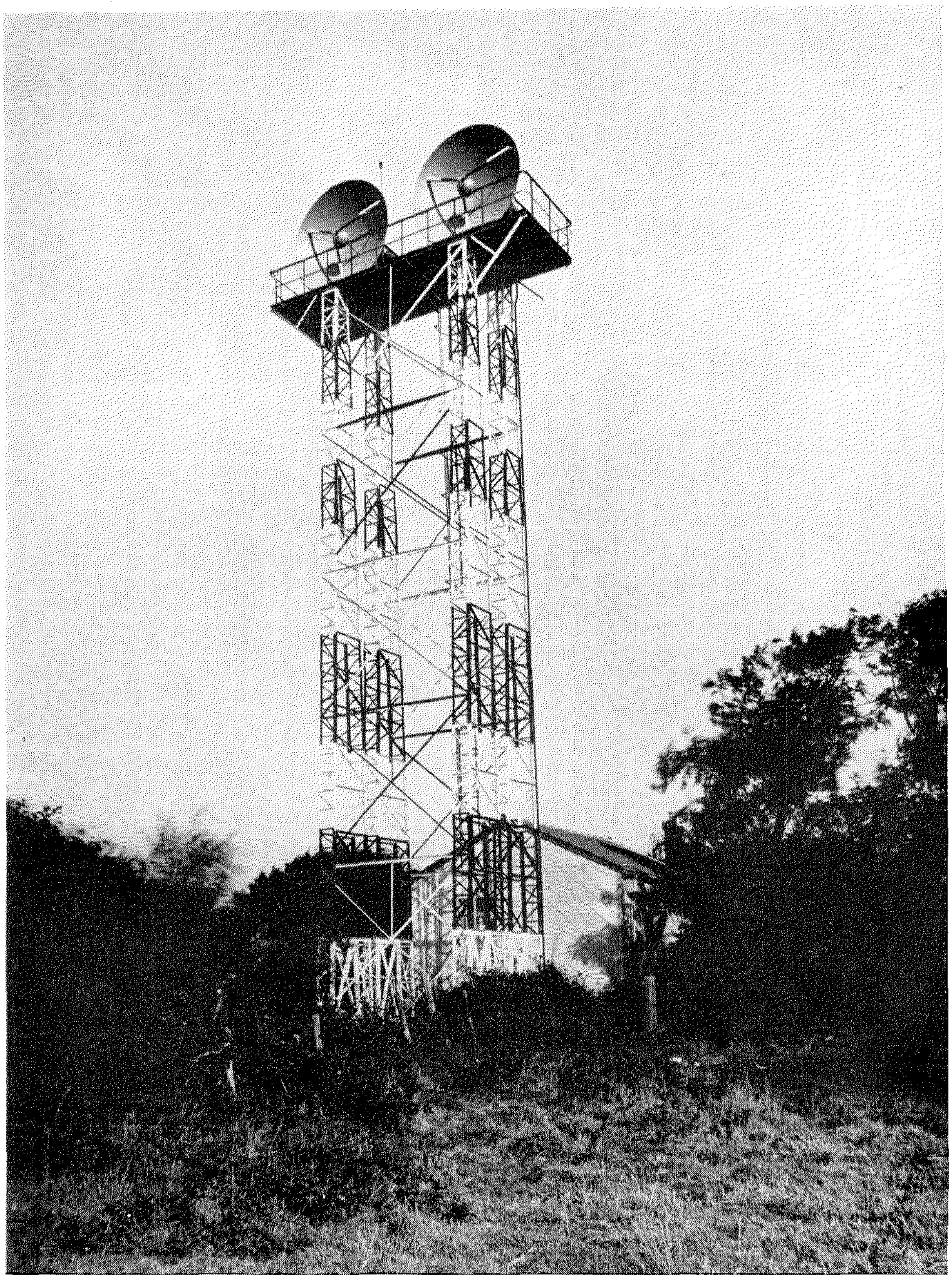


General View of St. Inglevert Station—the Anglo-French Micro-Ray Link Between Lympne and St. Inglevert. (*See page 222*)

Electrical Communication in 1933

AGAIN in 1933 the record of electrical communication was one of distinct progress. Important equipment installations and additions were made throughout the world and much was accomplished in the field of development and research.

This short review, while it makes no pretense of being complete, does show that the science and art of electrical communication moved forward in the face of unfavorable economic conditions.

Telephone Development

The indications are that in the relatively near future the world radio telephone family will be substantially complete, so that telephone subscribers in any country of the world can be connected with any other for regular commercial service.

At the end of 1932 the International Telephone Company was formed in Japan to establish and operate radio telephone services with Asia, Europe, the Americas and probably Australia. The plans call for five transmitters, and April, 1934, has been mentioned as the probable time of Japan's entry into the world radio telephone network.

Shanghai's preparations for radio telephone service with the rest of the world are advancing.

As an example of the comprehensiveness of the world radio telephone network, may be cited the inauguration in the middle of 1933 of the radio telephone service between Great Britain and British India, which completed the last link in the international chain of oral radio communications within the British Empire.

As an example of the expansion during 1933 of South America's international radio telephone services, may be mentioned the inauguration of service between Argentine and Costa Rica, Guatemala, India, Nicaragua, Palestine, Peru, Siam, Panama and Jugoslavia, as well as to the following ships: Aquitania, Berengaria, Caledonia, Columbus, Ile de France and Queen of Bermuda. Correspondingly, the Peruvian service was extended to include service to Austria, Germany, Brazil, Denmark, Esthonia, Holland, Latvia, Lithuania, England, Luxemburg, France, Poland, Sweden, Switzerland and Danzig.

A number of the leading countries of the world gained telephones during 1933, and the British Post Office, it is understood, expects to have a sizable net station gain for the year. In France the estimated gain for 1933 is almost 100,000 stations. The companies in the International Telephone group, including those of Rumania, Spain, Shanghai, Argentine, Chile, Mexico, Peru and Porto Rico, were well ahead of 1932, and despite losses due to unsettled conditions in Cuba there was a gain of about 12,000 stations throughout the year.

While these estimates involve only a few countries of the world, they do indicate that telephone service has expanded despite adverse conditions.

Micro-Ray

A micro-ray link with terminals at the Lympne Aerodrôme in Kent and at the St. Inglevert Aerodrome on the French coast has been completed. It operates on a wavelength of 17.4 centimeters and represents the shortest wavelength link in regular use. A general view of the St. Inglevert station is shown in the frontispiece, and details of the equipment are given elsewhere in this issue of *Electrical Communication.*

Ultra Short-Wave

Successful tests covering a distance of 30 miles have been conducted across the Straits of Dover over a one-way link, operating on 6 meters and giving 9 telephone channels. The transmitter equipment consisted essentially of a 9-channel carrier equipment operating in the range of 440 to 760 kc., the channels being 40 kc. apart. The carrier frequencies were so chosen as to give the well known advantages of the displaced side-band system, in particular greatly facilitating the problem of prevention of crosstalk between channels.

Experiments conducted during the year by Frederick A. Kolster, inventor of the Kolster Radio Direction Finder, for the Mackay Radio and Telegraph Company, have resulted in a distinct forward step in the radio art. They were carried on between the Mackay Radio Stations at Sayville and Southampton, Long Island, and the International Telephone and Telegraph Corporation headquarters building at 67 Broad Street, New York, in conjunction with a laboratory station at Mendham, New Jersey; the distance between Southampton and New York City being 86 miles on an air line and that between 67 Broad Street and Mendham, 75 miles. Working on wavelengths ranging from around 2 to 10 meters, with an antenna height at Southampton such that the horizon was 11 miles distant, excellent transmission was provided between Sayville and Mendham.

Marine Communication

Further progress has been made in ship and shore radio telephony and Marine Radio's equipment is now to be found on board the transatlantic liners Aquitania, Berengaria and Caledonia, as well as the Majestic and Olympic.

An event of considerable interest to the shipping world was the recurrence of the bi-annual Shipping, Engineering and Machinery Exhibition at Olympia, London. This Exhibition was attended by representatives of shipping interests from all parts of the world and the International Marine Radio's stand attracted much attention. It was particularly notable for a model of a new type of simple but efficient radio direction finder offered at a price more favorable than that to which ship owners have become accustomed. Another interesting exhibit was an entirely new type of auto alarm—an apparatus for the automatic registration of a ship's signal of distress—which has recently been approved for installation on board ships under the Safety of Life at Sea Convention by the British, Italian, Dutch and other Administrations.

Other Mobile Radio Services

Successful tests were made in the United States and Germany of blind landing of aeroplanes in thick weather. In Germany, with constant control of the transmitter, operating on 9 meters, the receiving set rendered possible simultaneous optical and acoustical signalling in the aeroplane.

A complete radio telephone installation has been made by the Newcastle Police Department. The transmitter used is a 300-watt telephone equipment and is of the automatic type, which does not require a skilled operator. In addition, the Newcastle Police Mobile Patrols have been equipped with receivers which have a special calling device which operates when the transmitter is switched on and warns the patrol that he is being called. This is the first police radio telephone service to be put into regular operation in Great Britain.

Trials are being made in several cities in Massachusetts, New York and New Jersey of two-way service between a central office and police radio cars. Ultra short-waves are being used in the tests.

One of the outstanding aircraft radio achievements of the year occurred just prior to the takeoff from Orbetello, Italy, of General Balbo and his squadron which made the mass flight to the United States and return. One of the Italian planes, while resting on the water at Orbetello, carried on a two-way telegraph conversation with the Mackay Radio and Telegraph Company station at Sayville, Long Island, a distance of 4,500 miles. This is believed to be a long distance record for communication with an aeroplane not in flight.

At no time during the flight were the planes out of contact with their land bases along the route, and huge data-gathering organizations using land and other communication systems gathered the meteorological data and other information of value to the pilots. The observations were flashed to the planes on the European side by the radio stations of the Italian Air Force at Orbetello and by various other radio stations installed by the Italian Air Force along the course of the flight and also by the radio stations of several of the Administrations of other countries in Europe. On the American side, companies of the International System—Postal Telegraph, Commercial Cables and Mackay Radio were chosen by the Italian Air Ministry to gather data, and Mackay Radio to do the communicating with the planes. The Canadian Pacific Railway Telegraphs, which connects with Postal Telegraph, collected much weather data and gave valuable cooperation.

It is interesting to note that Admiral Byrd is maintaining his radio telegraph contact with civilization from Antarctica through Mackay Radio exclusively.

Radio Link Equipment

A short-wave transmitter supplied by the Standard Electric Company, Ujpest, provides direct radio telegraph communication between Hungary and the United States and numerous other countries.

Nine radio transmitting stations were installed by the Standard Electrica, Lisbon, at the Azores Islands. Telephone and telegraph service has already been inaugurated and communication is now established between the islands, whereas before it was practically impossible to communicate from one island to the other.

Twelve stations of similar types are also being installed in the Cape Verde Islands.

Long Distance Cable Telephony and Telegraphy

Despite a low level of business activity, most of the European Administrations have carried on at a normal rate with their programs for adding to and improving their long distance networks. This has included not only effort in extending the service to new places, but also in improving the quality and speed of the service. By far the larger proportion of the toll cable added is of the "Standard Type."

Improvement in the European service has been effected by the provision of a new cable between London and the coast and the extending of this cable by submarine cables to Belgium and France. The latter cable was manufactured by the Standard Telephones and Cables, Limited, in conjunction with the Telegraph Construction and Maintenance Co., Ltd., and is interesting in that it is of the non-loaded paper insulated type. The lead covered core was made and jointed by Standard Telephones and Cables, Limited, whilst the armouring and laying was undertaken by the Telegraph Construction and Maintenance Co., Ltd. This cable is 29 nautical miles in length and contains 19 quads of 1.6 mm. conductor diameter, and is operated in accordance with the 4-wire system; it will provide 19 voice frequency and 9 superimposed carrier telephone channels.

Another interesting solution to the problem of providing additional toll circuits was the rebalancing and loading of old telegraph cables between London and Edinburgh and between Manchester and Glasgow. The circuits were loaded so as to obtain carrier telephone channels above the normal voice-frequency circuit. The telegraph circuits released were accommodated by the voice-frequency telegraph system of Standard Telephones and Cables, Limited.

Considerable progress has been made in Italy with the extension of the underground network to the South, and the Naples-Bari section was completed. During the inauguration ceremony a conversation was held between Stockholm and Bari, a distance of approximately 2,500 km. With the exception of the portion through Germany, the circuit passed through "Standard" type cables.

In Denmark considerable extensions to the network have been made, including a cable between Kolding and Copenhagen, connecting the three main islands.

In Hungary a large number of additional circuits over the Vienna-Budapest cable were equipped and put into service, whilst appreciable extension to the networks of Switzerland, Sweden, France and Czechoslovakia were made.

The continued electrification of railway systems has necessitated the provision of communication cables, notably in Sweden and Italy.

Whilst, as previously indicated, efforts have been made in improving the transmission of toll circuits, attention has also been paid to improving the toll terminal loss, that is, the combination of circuits connecting the subscriber to his toll office. Loading of the junction circuits involved, with special small loading coils to improve the attenuation and distortion of these circuits, has been the practice for some time past and is continuing. Recently it has also become the practice to use repeaters in conjunction with these circuits, either permanently connected at the terminals and intermediate points or on the cord circuit principle, as warranted by the conditions of each case. In automatic areas the cord circuit repeater points will be automatically selected and connected in accordance with the grade of the circuit being employed. The use of toll cables for telegraph, either as composite or carrier systems, is developing rapidly, and chief among the countries adopting this procedure may be mentioned Great Britain, Italy and Denmark.

As stated above, the loading of existing telegraph cables in Great Britain has necessitated the introduction of voice-frequency telegraph methods. The program which is being followed consists in concentrating the maximum number of channels over the main trunk routes, thus enabling extensive use to be made of 12- and 18-channel voice-frequency systems.

In April, a demonstration was given by the Bell System of perfect transmission of music and reproduction in auditory perspective. The Philadelphia Orchestra was located in Philadelphia and the program was reproduced in Washington, D. C. through three loud speakers, transmission between the two cities being carried out over three entirely separate cable-carrier circuits.

Toll Switching

A no delay toll system was developed and placed in operation at Basle. It contains many novel features, such as automatic selection of outlets in various directions and the automatic determination of the tariff to be applied. The operator is only required to start time and zone metering by a single key operation. If all direct paths to the destination of the call are engaged, the call does not become lost but alternate channels are made available without any extra metering charge to the subscriber.

A new cordless toll board was recently placed in service at Amsterdam, Holland. This is one of the largest installations of the kind on the continent of Europe and consists of about 350 positions equipped with 920 toll lines. These positions which are principally of the horizontal type are connected by 700 automatic toll switching trunks to the seven city dial exchanges of the S. & H. type. There are also 200 direct toll subscribers' lines, 200 booth lines and a number of trunks to a special switchboard for radio link service with the Dutch East and West Indies and for ship-to-shore calls. Recording calls are automatically distributed to free operators' positions and a "parking" feature has been introduced permitting calls to be attended in the sequence in which they arrive. Automatic equipment has been employed for various switching purposes to the greatest possible extent and in this respect also the installation contains many interesting and novel features.

The British Post Office has introduced telephone (trunk) conference service, and the Bell System has extended a similar service so that it is now available between several of the larger cities in the United States. As many as six subscribers may be connected to these circuits at one time.

Carrier

The success of the three initial 12/18 channel voice-frequency telegraph systems has resulted in the adoption of this equipment by the British Post Office for their main line telegraph systems, thus freeing important trunk cables for telephone purposes, as elsewhere indicated in this article.

A 12-Channel System will be operated over one channel of the Type "C" 3-Channel System to be installed between Cape Town and Johannesburg. This furnishes an interesting illustration of the flexibility of both types of systems.

The extensive system of Standard carrier telephone circuits installed in recent years in Turkey, Bulgaria and Yugoslavia has greatly increased both inland and international telephone traffic in these countries. While in previous years there were practically no international telephone links from these countries to western Europe, since the opening of the carrier telephone circuits they have become part of the European telephone system.

In Rumania, Standard carrier systems have played an important part in providing the country with a comprehensive national telephone service, as well as a nation-wide connection to the world telephone network.

Urban Switching Systems

In France the conversion from manual to

automatic has progressed steadily during 1933. In Paris, eight rotary automatic offices were placed in service, totalling 56,000 lines.

The experimental Bypath exchanges for the British Post Office at Advance (London) and Burton-on-Trent were put into service in February and April, respectively. One of the principles employed in the Bypath system has been found to possess such striking advantages in connection with area planning that a method has been developed of applying it in some degree to standard step-by-step exchanges. This is the principle of alternative trunking whereby small groups of direct inter-office junctions can be worked economically by providing them on a high loss basis and directing the overflow traffic via common junctions to tandem centers.

Rural Switching Systems

The year has seen considerable progress in the application of the Bypath switch to rural boards in Great Britain. It has been found possible to utilize the switch in the production of a very economical step-by-step rural office for use at a district office in networks of the 7-digit type. This board, of course, gives the usual facilities of satellite working (closed numbering scheme) multi-metering, special tone metering, etc.

Two boards with capacities for 90 and 180 lines, respectively, have been produced to cater for cases of 10 and even 20 parties per line. The 20-party lines are arranged for local battery sets and simplex dialling, and the boards are probably unique in their ability to handle a very wide range of subscribers' line limits, a condition which is brought about by the use of a special impulse correcting principle.

During the year 10-party selective line circuits have for the first time been introduced in conjunction with automatic exchanges. This party-line circuit provides all normal local and toll facilities accorded to regular subscribers and permits revertive calling between parties on the line, together with secret service. Furthermore, central battery feeding and signalling, also individual metering, are incorporated in the design, some of which features were hitherto unobtainable. These lines may be connected to unattended exchanges in rural areas, and lines of this type are already in operation in Italy and Tunis.

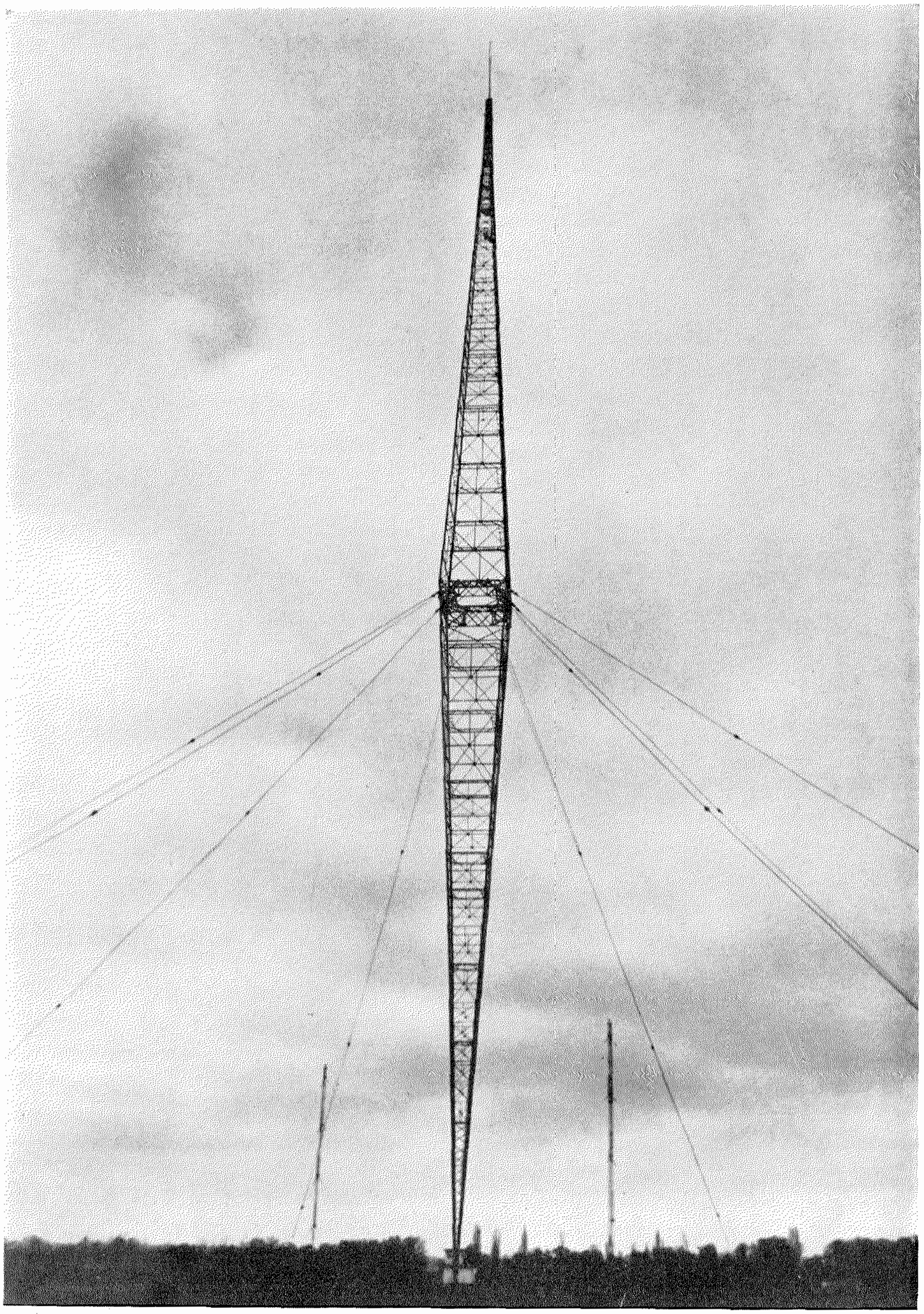
Exchanges of the redesigned 7-D system to permit "open numbering" have recently been placed in service in the Bulb District (Haarlem Rural Area) in Holland and are operating very successfully. The Haarlem Area is one of nineteen telephone zones into which the country is divided and circuits have been designed to permit not only local but also inter-area and eventually nation-wide service.

Automatic Long Distance Signalling and Dialling

A new development which is of special interest from a technical point of view is the introduction of direct communication by full automatic means between subscribers in two distant cities. This long distance dialling service was inaugurated recently between the Swiss cities, Basle and Zurich, which are situated more than 60 miles apart. Both cities have rotary automatic exchanges of the 7-A.1 type and the facility is also extended to the surrounding rural districts which are similarly equipped with 7-D. exchanges, so that actually approximately eighty large and small communities are linked together for the purpose of complete automatic service.

The existing toll line plant is used and twenty-five lines in each direction are specially equipped for the purpose. These lines, however, also remain at the disposal of the toll operators for long distance dialling calls. Subscribers may choose between the two services and experience shows that they prefer the direct method which consequently results in an economy in operating costs. The Administration, therefore, is now contemplating extending the service to all large cities in Switzerland.

Nation-wide automatic telephone facilities require the solution of many intricate technical problems, such as automatic insertion and adjustment of telephone repeaters, signalling with voice-frequency currents, special switching methods, alternate routing of calls, etc. The solution of these problems is already well advanced and their principal object is to enable the use of the expensive toll line plant to its maximum efficiency.



Antenna, 307 Meters High, of the 120 kW Broadcaster at Budapest.

Broadcasting

The year 1933 may be considered a great year for broadcasting in Hungary. In the course of the year construction was completed of three 1.25 kW and one 6.25 kW relay broadcasters for the Hungarian Postal Administration. At the close of the year the 120 kW high power broadcaster representing the very latest in design so far achieved was put into service. It is equipped with a Blaw-Knox single mast antenna higher than the Eiffel Tower and is the first of its kind in Europe.

One of the outstanding features of the past year has been the completion of the new 60 kW Broadcasting Station at Kalundborg. This station, which has been in successful operation since August, is of special interest since it represents an entirely new departure in the technique of constructing high power radio stations. This change consists in the location of all the apparatus, comprising high power radio amplifiers, in brick cubicles, instead of in a metal framework or in openwork construction as hitherto. The high power stages include apparatus operating at a tension of 20,000 volts and the change in construction therefore brings the design of this equipment into line with standard power practice for high voltage equipment. The results obtained at the Kalundborg Station since its completion have more than justified the radical change in design.

A 10 kW Broadcasting Station that is believed to be the most northerly broadcast transmitter in the world is being installed at Vadso in the extreme north of Norway. The equipment is of a similar design to a large number of highly successful 10 kW transmitters in operation both in Europe and throughout the world, and includes a special master oscillator system of very high stability so that the station can operate on a shared wavelength.

In Great Britain the most important engineering work from the constructional point of view is the building of the new long-wave transmitting station, three miles northeast of Droitwich, which will replace Daventry 5XX, and the Midland Regional Transmitter—Daventry 5GB. The former will use a power of 150 kW and the latter some 50 kW. It is expected that during the summer of 1934 Daventry 5XX will be closed, but the Daventry site will continue to be used for the Empire Station and any future extensions.

Television

For some years past experimental work has been going on in Great Britain with 30-line television transmitted by ordinary transmitters, but a somewhat different line of research is being undertaken, namely, television of the high definition type, which requires a wide side-band. The experiments are being conducted on ultra short-wave lengths by means of a special transmitter erected on the roof of Broadcasting House. The transmitter is capable of transmitting side-bands having a width of 500 kc. on either side of the carrier wave.

Train Dispatching

In France, on a 350 kilometer line equipped with auto-selective apparatus having two bifurcations, it was necessary, on account of attenuation, to insert a telephone repeater at a suitable location. The remote control of this repeater is entirely automatic. Any station calling another station sends the predetermined code followed by a letter A, B, C or D, which serves to insert or not the repeater and adjust the gain. Further, two repeaters are available in case of trouble, and one or the other repeater is automatically selected. The supervision of the repeaters is assured at a distance of 350 kilometers, the necessary arrangements being foreseen to transmit automatically the supervisory signals to the distant end of the line and enable the different operations to be performed. This installation has been realized with "Standard" telephone repeaters and the control circuit consists of "Standard" dispatching apparatus.

Remote Control

With the inauguration by the Central Electricity Board of the Electrical Grid Distribution System throughout Great Britain, the field for the remote control and indication of switchgear has been expanded. Another interesting application is supervisory equipment to give centralized control and indication of the position of the lock gates and sluices and of the water flow and level indicators on the Tummel River Hydroelectric Power Scheme in Scotland. The use of remote control system has been still further extended to provide at a central point indications of the readings of the essential meters at the generating stations for the first coal gas grid in England.

Printing Telegraphs

The person-to-person Teleprinter service (Telex) introduced by the British Post Office in August, 1932, has made good progress, and there has been a notable increase in the number of firms renting private Teleprinter channels.

The remarkable success achieved by Teleprinter systems, together with the development of efficient and economical methods of deriving by-product facilities from existing telephone lines has resulted in many other Administrations contemplating the introduction of new written communication services. In this connection Creed & Company, Limited, recently have received important orders from South Africa, Australia and Sweden.

Person-to-person service has been introduced in Holland and preliminary investigations and trials are being carried out in Switzerland and Germany.

The excellent results obtained with Teleprinter equipments in the extensive factories of the Austin Motor Company have led to the introduction of a further installation comprising nine Teleprinters and a switchboard for production control purposes.

In addition to operating important news distribution services using Creed apparatus, Reuters, Ltd. have recently introduced new stock quotation services in London and Liverpool for which one hundred Teleprinters have been supplied. For these services an attractive silencing cabinet which reduces printer noise to below that of the Noiseless typewriter has been developed.

In Denmark an important Teleprinter network has been installed for the Copenhagen police, and in Persia the Anglo-Persian Oil Company have installed Creed Teleprinters along their pipe lines for communication between their pumping stations.

The police in Spain have also introduced Teleprinters, as have the Shanghai municipal police.

Record Communications

In January, 1933 Mackay Radio opened a direct radio service between the United States and the State of Vatican City.

In May it opened a direct circuit between the United States and Shanghai, China, where connection is made with the extensive system of the Chinese Government Telegraphs.

A circuit between the United States and Copenhagen, which also provides a routing for Norway and Sweden, as well as Denmark, was opened in November.

In December a direct circuit was opened between Spain and the United States and Mackay Radio also expanded its radio telegraph facilities within the United States by inaugurating service over newly constructed stations at Chicago, New Orleans and Seattle. These service points are added to New York, San Francisco, Oakland, Los Angeles, San Diego, Tacoma and Portland, Oregon, between which Mackay Radio has been furnishing service for some years.

The alliance of services which is being made by Postal Telegraph and a number of independent telephone companies is reaching proportions which mark this plan as an outstanding contribution to communication progress. It is making available to hundreds of thousands in the smaller cities and rural communities throughout the United States for the first time a 24-hour a day telegraph service, also a cable and radio service to all parts of the world.

Technical Advances in Long Distance Cable Telephony*

By P. E. ERIKSON

THE history of technical development in the communication field tends to follow the same general lines as has happened with the older arts. Major discoveries or inventions occur at intervals and have a revolutionary influence. Between these intervals, the work of applying the newly discovered principles in what is found to be the economic field is carried on continuously. This phase of work in general is one of improvement in function, simplification of design and reduction in cost.

In the field of communication systems, the invention of the thermionic vacuum tube can be instanced as a fundamental invention of revolutionary importance, which, during the last 10 or 15 years, has been applied in the development of the telephone repeater, the oscillator, the modulator and demodulator, and from these latter, carrier current communication systems both of line and radio types. The high power amplifier, capable of amplifying currents of voice or of radio frequency and handling many kilowatts of power, is another noteworthy development originating from the same invention. The "Permalloy" series of nickel-iron alloys represent another invention of fundamental importance which is having a profound effect upon the technique of the communication art.

The brief considerations which follow are intended to convey some appreciation of the advances which have followed the first applications of such fundamental inventions in some of the more important fields, especially that of long distance telephony.

Long Distance Cable System

In the field of loaded, repeatered cable systems the tendency of improvement has been steadily towards an improvement in the quality of transmitted speech, and in the lengthening of the distances over which speech is technically and economically practicable. In the early days the systems installed provided a speech quality even for short distances which would now be considered inadequate, and such systems were incapable of extension without degrading the quality to an extent which rendered the circuit uncommercial. Much attention has accordingly been paid to the factors which control speech quality, namely, frequency band transmitted, volume, distortion and noise. In general, the quality of speech transmitted over any given type of construction is a function of the length of the circuit, while for a given length of circuit a more costly construction will provide better quality.

These considerations, as well as the necessity, in the interests of long distance international communication, of establishing standardised practices, have led to the establishing of tentative standards of speech quality which all international circuits shall meet. The standards are improved from time to time. Thus, two or three types of construction have been available for different overall lengths of circuit, a cheaper construction for the shorter circuits and a more expensive construction or constructions for the larger circuits, but all giving approximately the same overall quality of speech transmission. As technical advances have been made, so new forms of construction have become possible, and the limiting lengths of circuit for a given construction have been changed. As each advance has assumed practical form the new methods of construction have been applied together with the concept of desirable and practicable speech transmission, always to secure results in advance of those previously obtainable.

This improvement in speech quality has been rendered practical owing to the fact that new developments and increasing growth have made it possible to obtain considerable economies in line costs, and it has been consequently logical to make use of a portion of the cost reductions in improving quality of telephone circuits to meet the increasing demands of the service.

Improvements obtained by increasing the transmitted frequency band may be appreciated from the following facts:

The loading systems employed up to about

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* Paper read before the Congress International d'Electricité, Paris, July 4-12, 1932.

1921 did not permit, for a repeatered circuit, the transmission of an upper frequency limit appreciably greater than 1700 p:s. For modern loaded repeatered cable systems the circuits transmit up to 2400 p:s and there is a tendency to increase this upper limit towards 2800 p:s.

It will be appreciated that a considerable increase in intelligibility was obtained in passing from the old loading systems to the modern loading systems. Above 2400 p:s, however, the improvement in intelligibility is at a lower rate, but since other factors demand high transmission speed which involves high cut-off circuits for the longer distances, advantage is taken of transmitting up to 3000 p:s on these high cut-off, high-speed circuits. The lower frequency limit of the band transmitted has remained at about 300 p:s. Intelligibility is not materially affected by the elimination of frequencies below about 400 p:s, but 300 p:s has been maintained to preserve naturalness in conversation.

The improvement in the speech quality transmitted by long distance circuits has put these lines technically in advance of the subscriber's telephone set, and latterly much effort has been directed to the improvement of the transmission qualities of the telephone set and its associated local lines and considerable advances have been effected in this direction.

Within the frequency band transmitted there has also been a considerable reduction in frequency distortion, i.e., variation of attenuation with frequency. This has been accomplished by improvement in filter design and by improvement in devices for compensating the line distortion. In the case of low frequencies, loss is added at each repeater section so that the line loss is equal to the gain of the repeater. For the higher frequencies compensation is carried out by means of adjustment in the repeater characteristics.

In addition to improvement in frequency characteristics there has been an improvement in overall circuit attenuation.

In the early days of long distance telephony, the standards of volume or loudness considered commercially satisfactory for connection between subscriber and subscriber on long connections were much influenced by the technical difficulties of constructing suitable circuits at reasonable costs. As technical improvements have enabled a given standard of transmission to be obtained at less and less cost, so there has been a tendency for the standard of volume or loudness to be more and more improved. Whereas a few years ago overall connections, particularly in Europe, were considered satisfactory if they did not exceed a 40 decibel (4.6 nepers) volume standard, the recent tendency is towards a figure of 30 decibels (3.5 nepers).

The line plant of a complete telephone network can broadly be considered in two parts: (1) the lines used to connect subscribers in contiguous areas one to another, and (2) the tie lines which connect together the centres of different areas. When the areas are remote the tie lines are the long distance circuits.

Since long distance connections between subscribers utilise both the local lines and the long distance lines, and a large proportion of the total telephone plant investment is involved in these lines, it is of great importance that they be economically planned. Such planning includes the determination of the economical distribution of transmission loss as between the local lines and the long distance lines and this is influenced by a number of complex factors, of which a very prominent one is the cost of providing long distance circuits of any given range and transmission loss.

The rapid advance in loaded, repeatered cable circuit technique has resulted in appreciable reduction of transmission loss for a given range and given cost, and there has been a resulting tendency to improve the overall transmission loss of long-distance connections by reducing the transmission loss on the long distance circuits. This is particularly the case where these lines are of the 4-wire type, as with this type of construction repeater gain is less dependent on impedance uniformity than is the case with circuits of the 2-wire type.

The introduction of echo-suppressors has further tended towards the reduction of the transmission loss of long distance trunk or toll circuits.

At the present time the recommendations of C.C.I.F. as regards transmission loss on international trunk or toll line is that this should not exceed 0.8 neper (6.95 db.) for 4-wire circuits and 1.0 neper (8.7 db.) for 2-wire circuits. Until quite recently the recommended limiting losses for both types of construction stood at 1.3 neper (11.3 db.).

In some countries there is a tendency further to reduce these losses towards zero, so as to further equalise the grade of transmission available to subscribers for all types of connections. The use of low loss circuits makes possible the connection of a number of these in tandem, thus providing a more flexible circuit layout. Another factor is the effect which changes in long distance circuit performance and cost have upon the economic distribution of transmission loss between the local lines and the long-distance lines.

The tendency towards reducing long line losses has naturally favoured the use of 4-wire rather than 2-wire circuits but it would seem that since the number of short distance toll connections in any network is large, the economy of 2-wire circuits for this class is dominant and will prevent the universal application of 4-wire circuits.

The other form of linear distortion, i.e., phase distortion, has received considerable attention in recent years, both with regard to its effect upon quality and upon means for its compensation. Successful means have been developed for the compensation of phase distortion, so that its deterrent effect upon long speech circuits can be considered as practically eliminated. The C.C.I.F. advise that the duration of transient phenomena for any frequency in the frequency band to be transmitted must not exceed 30 milliseconds for the complete connection between terminal exchanges. For all circuits which exceed this limit it is consequently necessary to equip these circuits with phase compensators.

With the advent of successful phase compensation it was considered in some quarters that circuits with comparatively heavy loading (so-called medium-heavy) equipped with such compensators would be an economical and satisfactory solution even for the longest circuits. Actually, the range of circuits with this type of loading is appreciably limited from considerations of propagation time (the time taken for speech waves to travel from one end of a circuit to the other). Experience has shown that when the actual propagation time of a circuit is appreciable, conversation is carried on only with difficulty. There are two effects, one purely psychological. This latter is due to the fact that at least twice the delay of the circuit must elapse between the completion of a statement by one subscriber and his reception of the reply of the other subscriber. An impression is produced that either the statement has not been heard or that the other subscriber is slow in replying, and consequently difficulty is experienced in carrying out a normal sustained conversation. The second effect is that echo-suppressors, which become necessary when the delay of the circuit becomes appreciable, add a further delay to the circuit by reason of their operating time and may also lock out portions of the conversation.

The C.C.I.F. have provisionally recommended 0.25 second as the maximum transmitting time. The velocity of an extra-light loaded circuit is approximately 30,000 km. per second, so that the limiting length for such a circuit for a direct transmission time of 0.25 second under most favourable conditions is 7,500 km. This is probably sufficient to take care of any circuit which might arise in Europe, but for intercontinental circuits it is necessary to provide higher velocity circuits.

The increasing lengths of circuit has also caused attention to be drawn to non-linear distortion. Non-linear distortion in present day systems is small, it having been minimised by suitable operation of well designed repeaters and by a considerable reduction in the hysteresis of loading coils due to the use of special core material.

The non-linear distortion present during a long distance call is due chiefly to that contributed by the carbon transmitters of the subscribers' sets. However, the increasing use of telephone circuits to obtain voice-frequency telegraph systems using carrier principles, makes it important that non-linear distortion, or rather the causes of it, should be so controlled as to avoid interference between the various telegraph channels.

Improvements in the manufacture of cable and loading coil have during recent years resulted in very real improvements of impedance regularity and crosstalk. Average singing points of medium-heavy circuits have increased from 25 db. (2.9 nepers) to over 32 db. (3.7 neper) in the last few years, whilst the average crosstalk has been more than halved, a gain of 6 db. (0.7 neper).

The increased singing points enable 2-wire circuits to be set up with a lower overall loss than formerly, whilst the reduction in crosstalk has aided considerably the realisation of very long circuits.

It is interesting to reflect that in 1923 it was considered that the maximum distance over which loaded and repeatered cable systems could then be used was in the order of 1500 km. With present day extra-light loaded systems the limiting distance is in the order of 8000 km. and satisfactory one-way communication could be obtained over even longer distances; it is only the excessive transmission time of the circuit which would cause such circuits to be relatively unsatisfactory for two-way communication.

One of the most important advances in the technique of long distance telephone communication has been in connection with the predicting of performance of long distance circuits from their physical constants and condition. Whereas a few years ago it was possible to calculate only such characteristics as attenuation and crosstalk in a long distance system, telephone engineers are now in a position to predict with fair accuracy the overall intelligibility of a transmission system from data which can be obtained by measurement or calculation from plant components, of the type which it is planned to use.

One of the noteworthy steps in this phase of the subject is the introduction of means of rating circuit performance taking into account all the factors affecting transmission rather than in terms of separate ratings for band width, volume, distortion and noise.

The technique of the prediction of interference noise has now reached a stage where it is possible by means of field measurements along the route of the proposed circuits and a knowledge of the characteristics of the power systems involved, to estimate the noise which will occur upon the circuits.

Broadcast Circuits

Special telephone circuits are now being extensively used for the interconnection of radio broadcasting stations to enable the exchange or the simultaneous broadcasting of programmes. The practice in all large countries is to divide the country into areas and to locate a broadcast transmitter in each area. The transmitters are usually situated at some distance from the towns, while the studios are usually in the towns. A network of circuits is then provided which enables any transmitter to be connected with any programme origin, and circuits are also provided to interconnect different countries. In the past the exchange of programmes in Europe was effected by radio transmission, but fading and atmospheric disturbances rendered this method far from satisfactory. Entirely reliable circuits are now obtained from the toll cable network. The technical requirements of broadcast circuits are, however, different from telephone circuits. The broadcast circuits are uni-directional so that they are free from the attendant trouble of 2-way circuits such as transmission delay, echo and singing. Nevertheless, the faithful transmission of a musical programme presents very special problems. While a frequency band of 2,500 p:s is sufficient for the transmission of speech, it is totally inadequate for the high quality transmission of music. For this purpose specially loaded circuits are included in toll cables; they have a cut-off of approximately 10,000 p:s, giving practically distortionless transmission over the range 35—7,500 p:s. Owing to the very large range of volume which can occur in a musical programme, freedom from crosstalk is particularly important. By means of special metallic screening of the broadcast circuits, induced noise and crosstalk are reduced to a negligible amount.

It is, of course, important that linear and non-linear distortion should not appreciably affect the transmission of a broadcast programme and the operation of the circuit and the characteristics of the repeaters have been designed with this aim in view.

Submarine Circuits

The necessity of providing an ever increasing number of circuits by submarine routes has resulted in considerable advances affecting not only the design of cables themselves but the transmission systems utilised.

Cables can now be manufactured, laid and satisfactorily maintained in certain circumstances, containing a large number of paper insulated conductors within a lead sheath and either non-loaded, or loaded continuously or intermittently or with coils of a type generally similar to those used regularly in land cables.

The relative costliness of submarine cables has, moreover, justified the application of carrier current transmission system practices in order to secure a greater number of communication channels over a given line circuit.

In some cases, particularly where the cable is single-core of the deep-water type, separate carrier circuits for telephony and telegraphy are obtained within the frequency range transmitted above the normal speech range: while in other cases and notably with multi-core cable of the paper insulated type, it has been found practical and economical to utilise carrier frequency telephone channels in addition to the speech frequency telephone channels.

Improvements in Cable, Loading Coils and Repeaters

Improvements in cable used for long distance systems have been mainly in the direction of improved methods of construction whereby the factors which determine the cable characteristics have been placed under control to a greater and greater extent. The cable as supplied by the factory has better characteristics than formerly in practically every respect, so that the cable installation processes have been materially simplified and standardised. With the earlier cables, the work of installation was involved and complicated, due to the necessity of preventing the loading section unbalances, etc., assuming prohibitive proportions. To-day the field work is simplified and the results greatly improved. The effect of these improved results on crosstalk, interference, etc., contributes very largely to modern circuit design and many of the later developments would have been impossible had these improvements not been effected.

The improvements in loading coils have been even more spectacular than those in cables. Not only have the electrical characteristics been improved to a tremendous extent but due to improvements in magnetic materials the size of the coils has been reduced to nearly a quarter of the former volume. The smallness of modern coils is of obvious advantage from an installation, transport and maintenance standpoint.

In order to meet the requirements of improved speech quality referred to earlier in this article, full advantage has been taken of the improvements in characteristics of cable and loading coils. New loading methods have been devised from time to time to produce the required overall characteristics for the transmission of a wide frequency band and greater speed of transmission.

The repeater has passed through several phases of redesign and in the more modern types, not only are all the improved characteristics catered for, but repeaters occupying only a fraction of their former volume have been evolved, operating from a power supply also only a fraction of that formerly required.

The improvement in space occupancy is due principally to the utilisation of "permalloy" as a substitute for iron in transformer cores and to improvements in manufacturing technique by which condensers of a given capacity can be appreciably reduced in volume without loss of reliability.

The increased economy in power supply is the outcome of researches bearing on the electron emission of hot filaments. This has made possible the use of vacuum tubes giving the same performance as the older tubes but with 0.25 ampere filament currents in place of 1.0 ampere.

Improvements in Operating Long Distance Telephone Traffic

The technical advances in long distance transmission systems reviewed above have had important reactions on the operating practices involved in long distance service.

Improvements in the quality of the service have stimulated the growth of traffic and the demand for speedy service. The reduction of waiting time has more than ever stimulated traffic growth and necessitated a new outlook on the operating problem.

In some countries there is a tendency to see the solution in terms of a no-delay national service provided by means of a trunk or toll network operated on a semi-automatic or even a full automatic basis. Even where such automatisation has not yet found favour there is a general tendency for the shorter toll traffic to be handled directly by the operator serving the originating subscriber.

The new signalling systems involving frequencies within the voice-frequency range play a vital part in these developments.

The evolving of maintenance methods and routines to ensure the efficient traffic utilisation of the costly plant constituting the long distance network has been a severe problem, especially under European conditions, where the existence of numerous separate Administrative authorities has made the coordinating influence of the C.C.I.F. of paramount importance and of beneficial effect to all phases of telephony.

The New Cordless Toll Board at Amsterdam

By Ir. H. J. UGES

Engineer of the Dutch Telegraph and Telephone Administration

Toll Exchange Premises

On May 1st, 1933, the Bell Telephone Manufacturing Company of Antwerp commenced the installation of a new toll exchange in the building called "Geldkantoor" at Amsterdam, Holland. This modern building was erected in 1925 and is situated in the center of the city immediately adjacent to the existing toll exchange. The new building accommodates, in addition to the telephone installation, the revenue offices and part of the postal services.

The third and fourth floors are occupied by the new toll equipment; on the third floor are the halls containing the automatic equipment and the repeater station, on the fourth floor the operating rooms, and on the mezzanine floor between the third and fourth stories, the room accommodating the recording and information tables.

The automatic equipment occupies two adjoining wings, with rooms having a total length of 43 meters and a width of 10 meters. In these rooms there are erected fourteen double-sided switchracks, five single switchracks and two distributing frames. As the ceiling height of this floor is low, only 3 meters, the switchracks are of a special low type construction.

The third wing, not shown in the floor plan of the automatic switchroom, is occupied by the repeater station, the room having dimensions of 25 by 10 meters.

On the fourth floor, accommodating the operating rooms, there are no windows on the street side in order to prevent street noises from penetrating. Three large rooms are required for operating purposes of which one room for rapid toll service is 16 by 10 meters, a second for regular toll service is 30 by 10 meters, and a third for concentration service is 22 by 10 meters.

The room containing the recording and information positions, on the mezzanine floor, is 15 by 12 meters.

Extent of Toll Exchange

The new toll exchange, which is considerably larger than the one existing and to be replaced, deals not only with the regular toll traffic to and from the city of Amsterdam but also with a considerable part of the international calls of the whole country of Holland and with "radio link" traffic to and from the Dutch East Indies as well as with ship-to-shore calls.

The board is constructed for an initial equipment of 920 toll lines and is connected to the seven principal local automatic exchanges by a total of 700 automatic toll switching trunks.

Besides the above equipment, there are 200 direct toll subscribers' lines, 200 booth lines, and a number of trunks to the special radio link board, located in the same building.

Of the toll lines, 600 are arranged for ringdown or delayed service, and 320 for long distance dialling or non-delayed rapid service (140 incoming and 180 outgoing lines). The toll board comprises the following positions, approximately 350 in total:

188 for regular ringdown toll line service of which 30 are arranged for day and 8 for night concentration,
60 for rapid toll service of which 2 are arranged for night service,
14 convertible positions, which for the present are arranged for regular toll service, but which may readily be converted to L.D.D. positions,
6 for transit service of which 3 are for repeatered transit connections and 3 for transit connections not requiring repeaters,
32 for recording,
12 for information,
6 for observation,
6 for chief operators,

The remaining positions are for various purposes, such as patching transit connections, special through connections for night service, attendant operators for the House P.B.X., transfer service, pneumatic receiving and distributing service, transfer of calls from the radio link board, ticket sorting, ticket filing and operators' school.

Types of Sections and Their Functions

The exchange equipment incorporates the most modern principles in construction and operating practices.

Automatic equipment has been applied to the largest extent wherever expedient and economical.

Direct Service is carried out on a full automatic basis.

Transit Service is accomplished semi-automatically and with the help of one B operator only. To facilitate the completion of this traffic some preference is given over the direct traffic in the following manner:

It is possible for the B operator to take a certain line directly, providing the line is free. The completion of transit calls is thereby greatly simplified and, since the percentage of this traffic is small in comparison with the direct traffic, no difficulties are experienced in handling the latter. These B positions have a multiple field of 600 toll lines. The lines are provided with switch-over relays which when in normal condition cause them to be connected to the relevant toll positions, but when operated switch them over to the multiple field of the B positions. The lines may all be concentrated on the day concentration positions by means of a concentration key and from there, similarly, to the night concentration positions.

The extensive employment of automatic equipment made it possible to restrict the use of cords and plugs to the transit and concentration positions. On all other positions, keys are used for all operating manipulations. The majority of positions, therefore, not requiring jack equipments, it was unnecessary to leave space behind the positions for maintenance purposes so that it was possible to use double-sided sections.

All sections, excepting those for transit service, are so constructed; they consist of four operator's positions and are of the horizontal type. The multiple field, therefore, has been entirely eliminated on regular toll sections. This permits a simple method of operation but requires positions and circuits of new construction and design.

Inward and outward calls are established by means of cordless circuits directly on these tables.

The transit connections are completed over plug-ended trunks on intermediate type B positions, provided with a multiple field. The complete control of such transit connections, including those which require repeaters, however, rests with the A operators.

The day concentration positions each have a jack-panel of 20 lines, the night positions of 50 lines. The method of operation on these positions is exactly the same as that of the regular toll positions. Concentration positions are in addition arranged for the reception of recording calls and they can be made accessible for this purpose by the simple manipulation of a key.

From the rapid toll service positions, connections may be established entirely by automatic means between local subscribers and subscribers of the telephone networks of Rotterdam, The Hague, and other cities. As a rule, this service takes place without delay. The subscribers by dialling a special 2-digit number can at once reach a rapid toll service operator and give her particulars of the desired connection. To prevent fraud and for technical reasons, owing to the construction of the local Amsterdam exchanges, subscribers are recalled by the operator.

Calls exchanged between operators of the special positions, such as wire chiefs, chief operators, information and service observation operators, also between distributing tables, transfer board, sorting tables, B positions and, in general, all internal traffic, passes over a House P.B.X. which is of the Bell Telephone Manufacturing Company's No. 7-B type. Special positions can also be reached by the toll operators via the automatic equipment already referred to, which is of the 7-A type. This can be accomplished by selection with their keysets as the arc terminals of the P.B.X. final selectors to which the special positions are connected are multipled to the corresponding arc terminals of the 7-A final selectors. The traffic incoming from internal telephone sets is dealt with on the attendant's board of the House P.B.X.

A special position is provided to complete calls from offices with lines connected through after business hours. This position also deals with traffic on lines equipped with so-called through connecting facilities (relay boxes to which as many as ten subscribers may be connected).

Finally, in a separate room, the 10-position radio link board is installed, which deals with the radio traffic to and from the Dutch East Indies and also with calls from ships to shore and vice versa. A special B position serves for the radio transit traffic.

Toll Service

The toll service at Amsterdam may be divided into three principal classes:

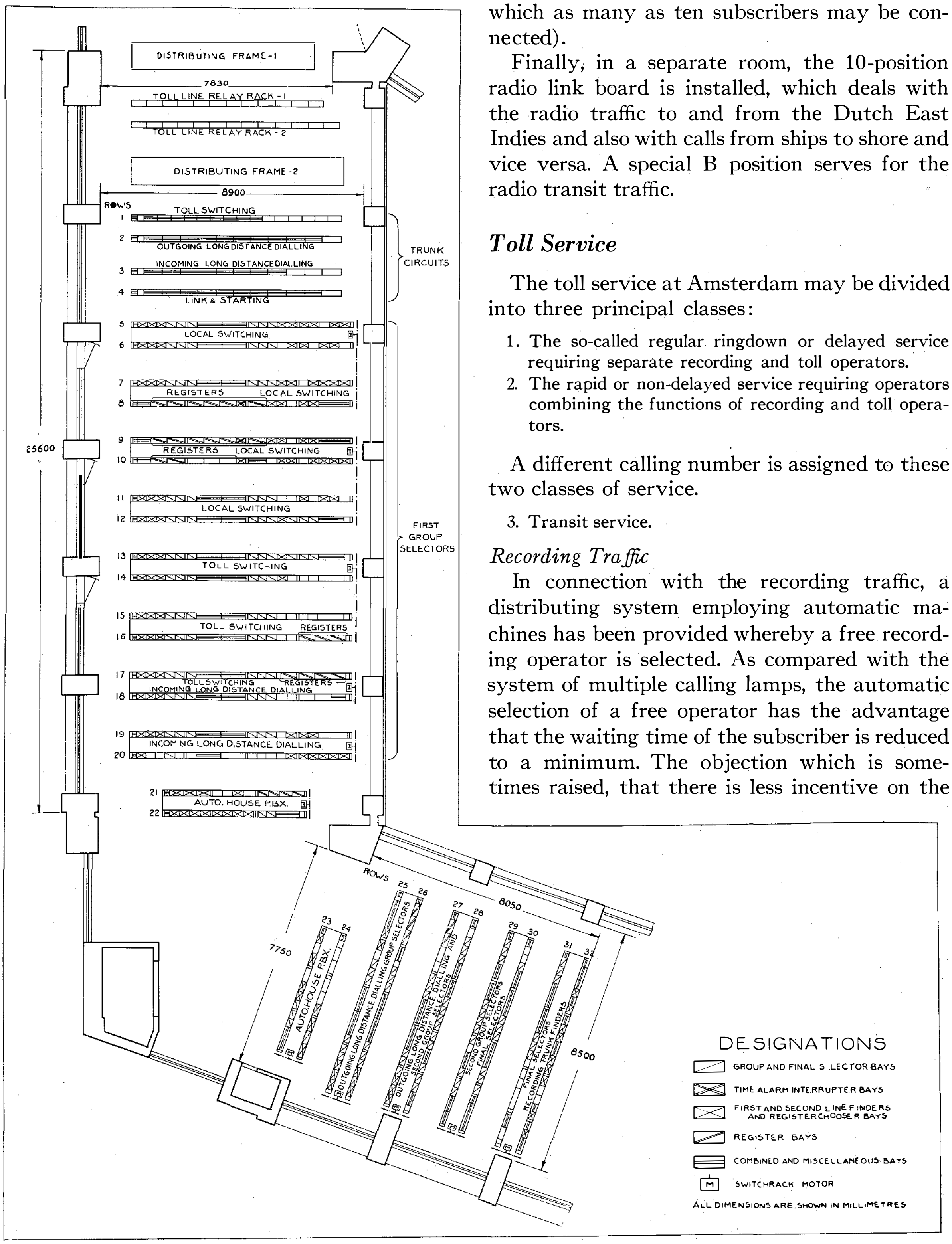
1. The so-called regular ringdown or delayed service requiring separate recording and toll operators.
2. The rapid or non-delayed service requiring operators combining the functions of recording and toll operators.

A different calling number is assigned to these two classes of service.

3. Transit service.

Recording Traffic

In connection with the recording traffic, a distributing system employing automatic machines has been provided whereby a free recording operator is selected. As compared with the system of multiple calling lamps, the automatic selection of a free operator has the advantage that the waiting time of the subscriber is reduced to a minimum. The objection which is sometimes raised, that there is less incentive on the



Floor Plan—Automatic Switchroom, Toll Exchange, Amsterdam.

part of the operators to work quickly, is surmounted by the introduction of the principle of so-called "half-blocking". An operator is barred as long as she has not restored her answering key. If, however, all operators are barred, then "blocking" is removed for the "half-blocked" operators, i.e., those operators who have not yet restored their keys but on whose positions the subscribers have already released.

If also all these operators' positions are seized by calls, then the succeeding calls are diverted to a parking arrangement which ensures that preference will be given to those calls in the sequence in which they arrive. The associated waiting lamps are mounted in plain view of the operators and indicate the exact number of waiting calls. This also is a further incentive for them to work rapidly. Furthermore, the barring of an operator is made visible on her position by the lighting of a special blocking lamp.

The recording trunks from the local city exchanges enter the toll office on finders, the arc terminals of which are connected to the recording positions, the concentration positions and the parking circuits. Testing of the recording positions is only possible when they are occupied. In the case of concentration positions they must in addition be connected by means of a key for the purpose. If none of the operators are free, the parking arrangement enters into service and the first call is directed to the first waiting call terminal, the next to the second, etc. The waiting calls are thus parked in the order of their arrival on successive terminals of the finder arc. When a position becomes free, these parked finders start to hunt one after the other with a certain short delay between them. During the period of hunting of the parked calls, new calls are prevented from hunting.

The recording operator has on her keyboard, in addition to the answering key, a key permitting her to call and speak to the chief operator and also one to reach the supervisor.

The operator places the ticket, on which particulars of the communication are recorded, on a belt carrier which conveys it to the primary sorting table which is situated at the end of the recording table line-up. From there it is transported through one of the eight available pressure tubes to the central distributing table. On the primary sorting table, one of three directions is chosen, two of which lead to the distributing table and one to the information desk. Local conditions made it impossible to place the distributing table near or adjacent to the recording positions, hence the necessity of handling the tickets twice. From the distributing table, the tickets are sent to the regular toll sections, each consisting of four positions: two adjacent and two facing, a group of four being provided with a common receiving valve.

On the toll positions there are two possibilities for sending tickets; one tube leads to the distributing table (for transit tickets) and the other to the final sorting table, i.e., the table on which the finished tickets are placed and kept in pigeon holes.

Regular Toll Positions

As already stated, the toll sections are of the flat or horizontal type. The fact that the multiple field is omitted and that rows of keys only are required to establish and complete calls, results in fundamental differences between these positions and positions with a vertical jack field, viz:

1. Toll lines after passing through the transfer board terminate on the toll position in keys. This requires that in order to permit the correct functioning of the toll lines, the associated keys must be in first-class working condition. For emergency purposes there is provided, in addition to the five toll line equipments which are definitely connected to the toll position, a sixth equipment to which each toll line may be connected as desired. The keys which are used for this purpose have two positions, one of which serves to concentrate the toll lines.
2. It must be possible to connect the toll lines through to:
    a. All local subscribers.
    b. Other toll lines (for transit service).
    c. Direct toll subscribers' lines.
    d. Booth lines.
    e. House lines.
    f. Eventually subscribers in other cities which can be reached by full automatic means.

The operator must furthermore be enabled to reach special services, such as chief operator, information desk, etc. All these connections are obtained automatically, viz: the local subscribers over levels 2 to 9 and all other connections over level 1 of the 1st group selectors.

A row of keys to establish a connection consists of a toll connecting key CK_1, a local connecting key CK_2, a two-way ringing key RK_1 and RK_2 to ring in both directions and a combined listening and monitoring key LK and MK.

The telephone operator's circuit only contains a key STK for answering on an incoming order wire and a key SCK and SLK for calling and listening to the supervisor. Although by concentrating more functions in the telephone operator's circuit, keys could have been saved, the method applied here facilitates other duties, since the operator can now work on more than one connection simultaneously (so-called "overlapping service"). For instance, she is enabled to speak or listen-in on one connection and to ring on another connection, or to select on one connection and to listen-in or ring on another connection.

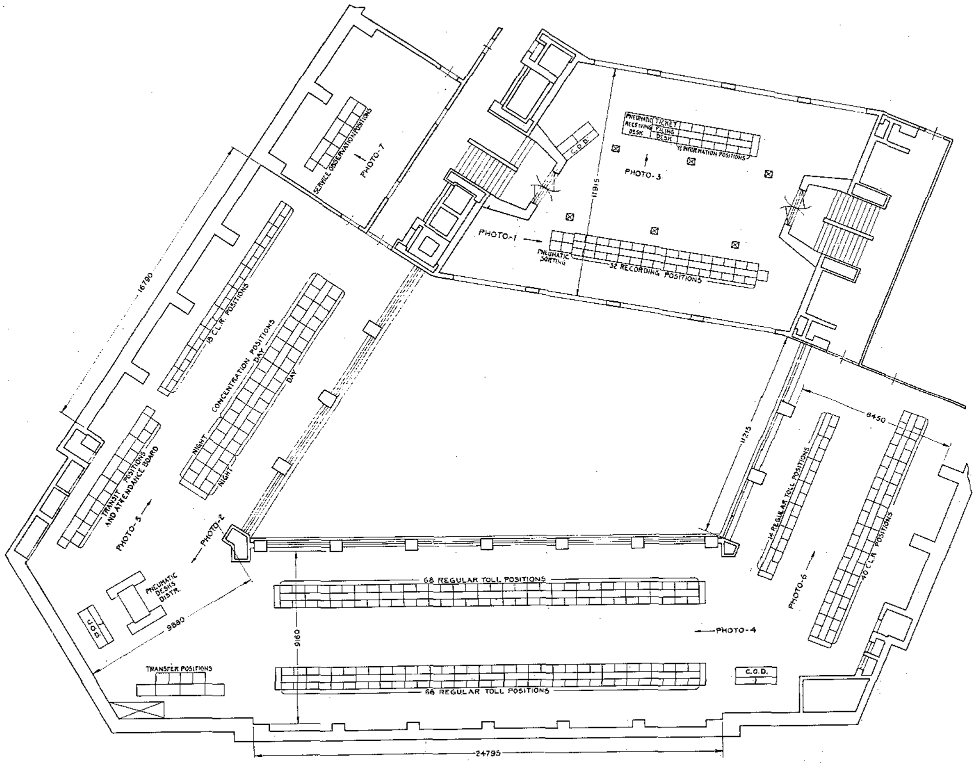
Toll Line

The toll line is provided with a line, LL, and a busy, BL, lamp mounted in the slightly inclined part of the keyboard; in addition, there is a supervisory lamp SL. The busy lamp burns when the line is engaged on the transfer board.

Both connecting keys CK_1 and CK_2 have two rest positions in the same direction, enabling the operator to push them away from her to an inclined or a completely depressed position. The depressed position is for through connection and the inclined is the isolation position. The act of moving the key lever from its normal position is equivalent to inserting a plug into the multiple field of a toll board with such a field. As long as the keys have not been restored to normal, the toll line cannot be taken by a B operator and the automatic equipment on the local side remains connected.

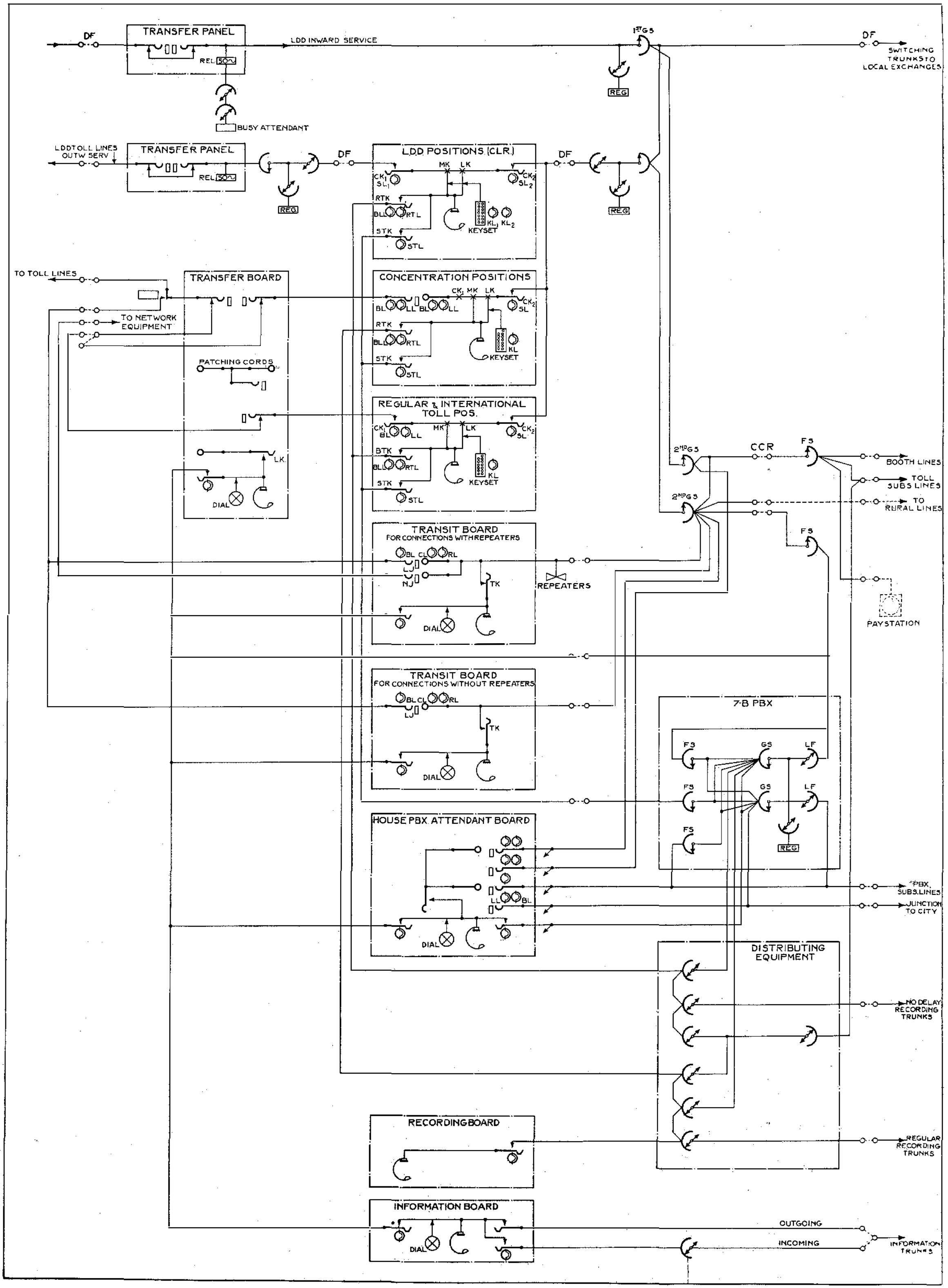
Regular Toll Connections

To build up an automatic connection, the



ALL DIMENSIONS ARE SHOWN IN MILLIMETRES

Floor Plan—Operating Room, Toll Exchange, Amsterdam.



Simplified Junction Diagram.

operator makes use of her high speed keyset. This keyset contains a connecting key KCK, impulse keys numbered 0 to 9, a register starting key RSK, and a premature release key PRK. The keyset functions in close cooperation with the register.

All local outlets from the toll positions are attached to the terminal arcs of 100-point line finders. In total, the automatic equipment comprises 17 groups of which there are 16 with 44 finders and 1 with 22 finders to cope with this traffic for 1658 outlets.

Upon the operator depressing a local connecting key, the cordless connecting circuit is seized by the finder associated with a first group selector, whereupon a register is engaged. This fact is indicated to the operator by the lighting of the supervisory lamp of the connecting circuit. The operator, by depressing the keyset connecting button connects this keyset over the "a" and "b" wires to the register.

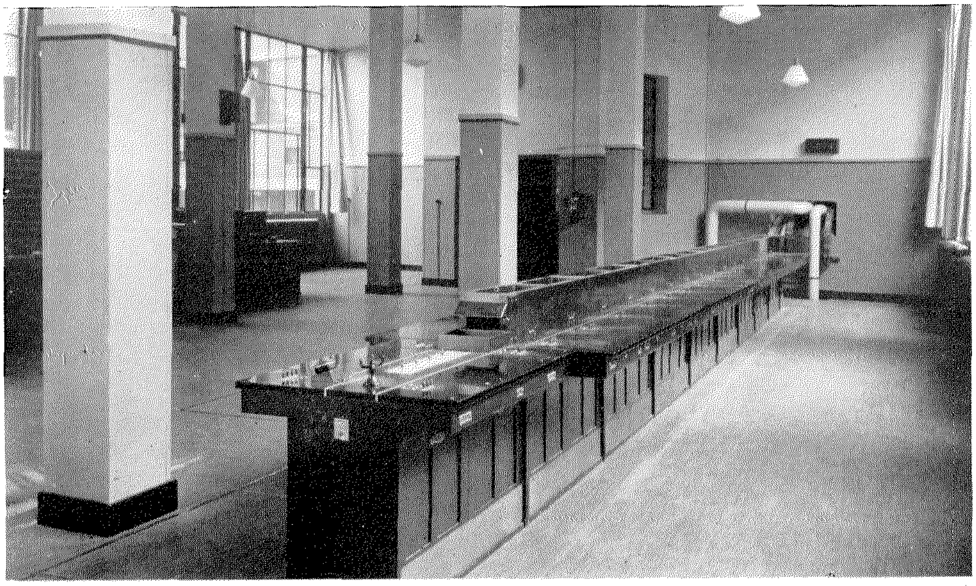
By depressing one of the numerical keys, she acts on a combination of polarized and marginal relays in the register circuit by which the numerical relays are energised. The selection does not commence until after the starting key has been depressed, thus giving the operator time to annul the keysetting if, for one reason or other, this should prove necessary.

The first digit-key depressed causes the corresponding 1st group selector level to be selected. The different local exchanges may be reached over levels 2, 3, 5, 6, 7, 8 and 9 by depressing numerical keys 9, 8, 6, 5, 4, 3 and 2 respectively. Digit 0 selects level No. 1, which is connected to a group of 2nd group selectors from which the various special service junctions are reached.

In case a call is destined to one of the local step-by-step type exchanges, the selection is accomplished by means of "forward" impulses, created by a sender switch equipped in the register circuit.

Just before sending out forward impulses the register makes a check by means of a differential device to verify the condition of the trunk, i.e., to make sure that the junction is not grounded, short circuited or open. In this connection, the following features of the 1st group selector may be mentioned.

In view of the fact that the supervisory signalling on the junction to the local exchange is done on the "c" wire on which testing also



Recording Positions.

takes place, a checking feature has been incorporated in the group selector to ascertain that the junction chosen is not one which has just been released by a previous call. This check is made via the "a" wire, the "free" criterion is indicated by a potential which is missing on a junction not released.

After the selector has passed this check, it signals to the register that impulse sending may start.

After the register has sent out all the digits received, it causes a brief delay before the group selector is advanced. This delay is occasioned by the turning of the sender switch under control of the counting relays, concurrent with a run of the sequence switch. The delay is necessary in order that tests may be made on P.B.X.'s attached to the step-by-step exchanges, which tests take a certain time. The group selector must, therefore, not be connected through for signalling until after each test is accomplished. After the period of delay, the sequence switch of the cord circuit moves to the talking position and, at this moment, the cord circuit can signal back either one or two conditions:

a. Telephone on the hook: free.
b. Telephone off the hook: busy.

In the first instance, the calling supervisory lamp burns and in the second case it flashes.

As, during the conversation, the lamp must be extinguished and may not flash, the busy condition (high ohmic c wire) in the group selector circuit is established just before the talking position is reached and this busy condition remains whilst the cord circuit passes through the talking position but disappears when the call is definitely answered (lamp extinguished).

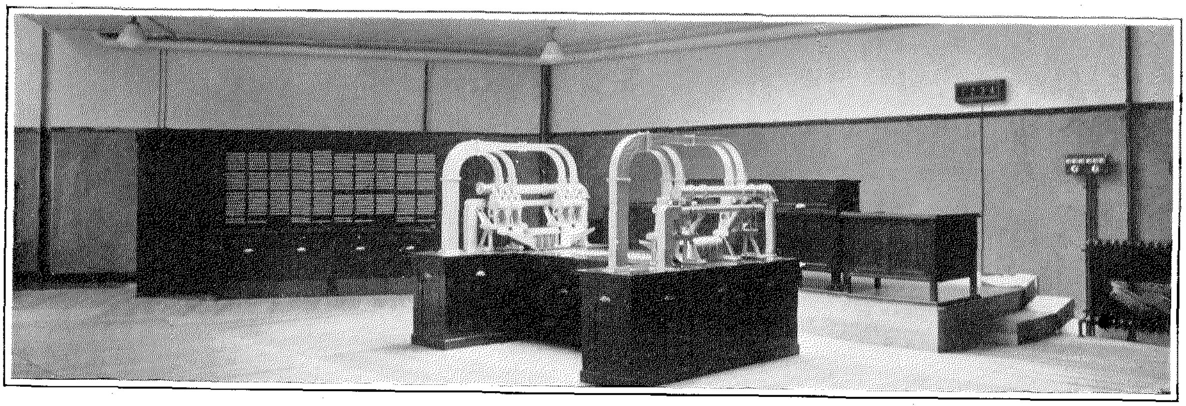
Transit Connections

The operator can, besides establishing calls to local subscribers, also complete transit connections over local outlets. For this purpose she must select the numbers 007, 005 or 003, depending on the nature of the transit connection which she desires (regular, with cord repeater, or special).

The first group selector hunts on the first level for a free second group selector and the latter in its turn tests for a free cord of a free B operator, providing free B operators are available. If such is not the case, then any free cord is tested.

There are in total six transit positions: three each with ten pairs of cords with repeaters, two with thirty ordinary single cords and, finally, one with thirty ordinary single cords which can be employed for directions with a very limited number of lines.

The arrival of a call on a transit cord shows itself by the flashing of the calling lamp. The B operator depresses the answering key of the cord, asks which line is wanted and, if this line is free, inserts the plug of the cord at once into the multiple jack, then restores the key, and the transit connection is established. At that moment, the supervisory lamp of the A operator extinguishes. If at the end of a conversation the A operator restores her connecting key to normal, then the supervisory lamp at the B operator's



Receiving and Distributing Desk, Transfer Board and Chief Operator's Desk.

position flashes, whereupon the latter operator removes the cord.

A B operator is barred:

1. As long as she has not yet answered the call.
2. As long as her connecting cord key has not yet been restored.
3. As long as she has not yet removed the cord, indicated by flashing of supervisory lamp.

This, however, only holds true as long as there are still other free B operators.

The cord circuits with repeaters are of the paired type. One of the cord-pairs is plugged into the A operator's home line and the other into the line which has been assigned to her.

If the talking and ringing keys on the A position are restored to normal, a loop is formed in the line circuit, extending over the selectors and through the connecting keys. This loop causes both lines to be connected together by means of the cord circuit repeater whilst the A operator is enabled to listen in on the connection.

In case the A operator intercepts the loop by manipulating the talking or ringing key, the repeater is disconnected and the operator is again directly connected between the lines.

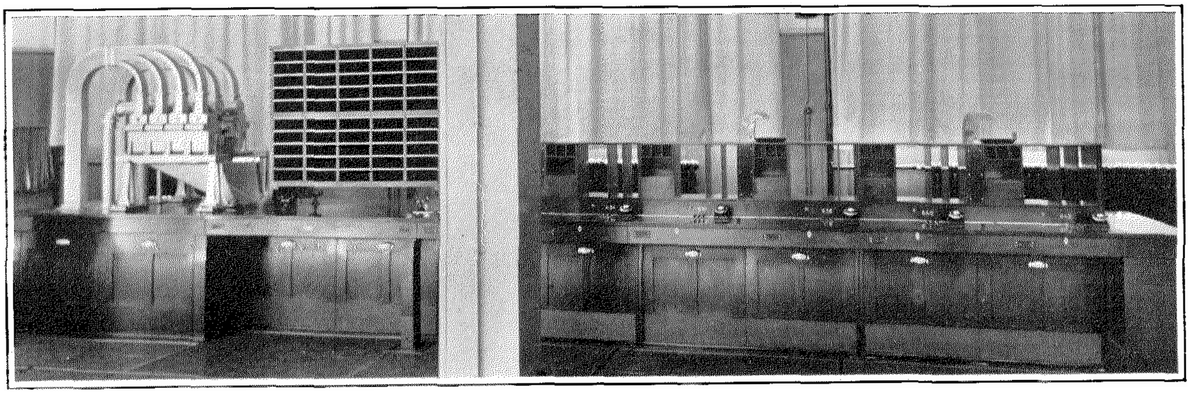
If a line asked for by an A operator is occupied, the busy lamps on the B positions burn. These busy lamps receive current from the city network through a 220 V—6 V stepdown transformer and illuminate a small transparent round pane in the designation strip. If the line is kept busy by the home operator, then the B operator can prepare the line for a transit connection by inserting a plug. By giving a disengaged signal (local connecting key in isolation position), the A operator can obtain a positive signal as soon as the line becomes free. If the line should once again be asked for on another B position, then the relevant B operator will receive a tone upon making a test by touching the line jack with the tip of her plug. In that case she may not prepare the transit connection. An A operator is enabled also to place a tone on her own lines when these are assigned to a B operator, so that it is in her power to prevent these lines being prepared for transit connections.

As a result of the fact that a toll line is definitely attached to the connecting keys, the operator's own toll line is temporarily out of use during the time she has a transit connection under preparation on her local outlet. In order to enable her to retain the toll line in service during this time, she has at her disposal a totally independent signalling system with the B tables. By this means she will automatically receive a positive indication that a line in a certain direction has become free. In order to accomplish this, she only needs to instruct the B operator to plug the signalling circuit on the latter's position into a jack associated with the desired direction. As soon as a line in that direction becomes free the toll operator's signalling lamp will flash and she is thereby informed that she may ask for the line at a B table.

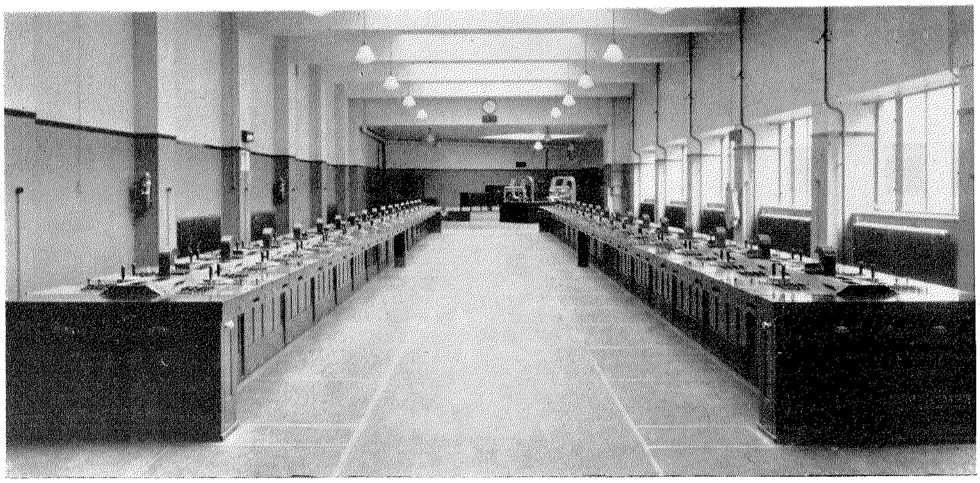
Special Services

Over the 2nd group selectors connected to the first level of 1st group selectors, in addition to B cords at the transit tables, junctions to the House P.B.X. may be reached and all subscribers connected to this automatic P.B.X.

Finally, to three levels of the 2nd group selectors, final selectors are connected over which may



Pneumatic Receiving and Ticket Filing Desk and Information Positions.



Regular Toll Positions.

be reached special service junctions to chief operators, information desk, wire chief's desk, distributing table, etc., also booths at the Bourse and subscribers' lines directly connected to the toll exchange, the so-called toll subscribers' lines.

Bourse Traffic

Traffic with the Stock and Merchandise Bourses is taken care of in the toll exchange. At these Bourses there are a few operators, who ensure that members are directed to the booths assigned to them. The operators possess service trunks to the House P.B.X. and can, via this P.B.X., communicate with all operators in the entire toll exchange and can also be called by them.

The member of the Bourse can ask for his call at a small so-called "request" wicket. He hands in a form on which his demand is recorded and which is passed to the operator by the attendant at the wicket. This operator conveys the request for a call directly over her service trunk to the toll position, where the communication is to be established and completed. When the calling member wishes to make the call, he proceeds to a second or "report" window, where he hands in the slip which he received at the first window. The operator who is located near this second wicket, rings the toll position and passes on the number of the booth if the call can be dealt with without delay. She also announces this number to the member. The relevant booth is now selected directly from the toll board. As several operators can assign booth numbers independent of each other, each has in front of her a lamp-panel on which these booths are signalled busy by the lighting of lamps. Incoming calls for Bourse members pass via the B operator located at the Bourse, who instructs an attendant to hand the ticket to the member.

Direct Lines

Direct lines, in addition to being connected to final selectors, are also attached to line finders over which regular recording positions can be chosen by dialling "000" and rapid toll positions by dialling "001", respectively.

Rapid Toll Service

A special method exists to deal with the traffic in the directions of Rotterdam, The Hague and other cities, the so-called "Rapid Toll Service", which is characterized by the following features:

1. Recording calls arrive direct on the positions.
2. The operators select directly the called subscribers at the distant cities.

For such rapid toll service it is of the greatest importance that an efficient distribution of the calls be made, since it has a direct bearing on the division of work between operators.

The rapid service positions are reached via junctions incoming from the local exchanges and terminating in finders. The positions are barred only when the answering or blocking key is thrown. Since this condition represents only about 20% of the operator's time, a special call distributing scheme has been provided by which an equal distribution of traffic is ensured.

The scheme operates in the following manner:

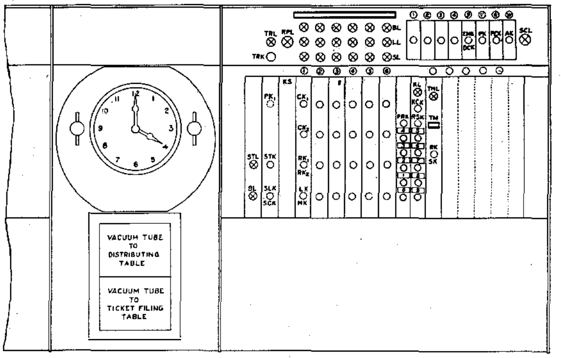
By means of a finder, to the terminal of which the positions are connected, a group of four operators' positions are made accessible for calls. When all positions so assigned have received a call, the finder steps to the next set of terminals, making another group of positions accessible for calls. Only after all the operators have had their turn, can calls again arrive at the first group.

A traffic control arrangement is combined with the above call distributing scheme, which permits at any time indication to be given on a lamp board of the density of the traffic.

No parking arrangement is provided in connection with the rapid toll service as the chance that in the advent of a call no operator would be found free is very small, because the total number of positions occupied is at least five times that which would be required to record calls only. However, an arrangement is foreseen whereby a call which has not been answered within 10 to 20 seconds causes the calling lamp to flash.

The construction of the rapid toll sections greatly resembles that of the regular toll sections. On the horizontal top are equipped per connection-circuit, two connecting keys—one for the local and one for the toll direction; also, a ringing key and a combined answering and listening key. The keyset contains two keyset connecting keys; otherwise it is of the same construction as that of a regular toll position.

On these rapid toll sections, there is further equipped a special key to call a helping operator at the distant exchange. For the reason that the local signalling systems in distant cities differ considerably among themselves, it was decided that the rapid toll operator should not be

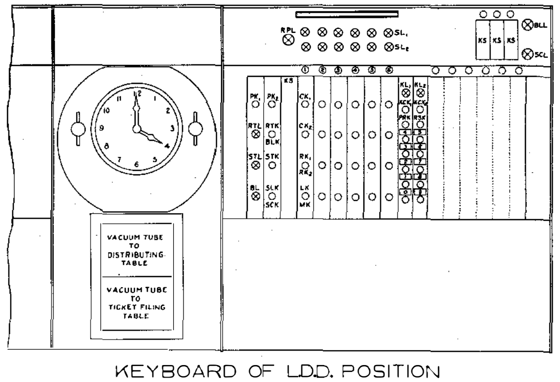


KEYBOARD OF REGULAR R.D. POSITION

ABBREVIATIONS

① CONNECTING CIRCUIT	
BL	BUSY LAMP
SL	SUPERVISORY LAMP (TRUNKSIDE)
LL	LINE LAMP
CK_1	CONNECTING KEY (TOLLSIDE)
CK_2	CONNECTING KEY (TRUNK SIDE)
RK_1	RINGING KEY (TOLL SIDE)
RK_2	RINGING KEY (TRUNK SIDE)
LK	LISTENING KEY
MK	MONITORING KEY
EMK	EMERGENCY KEY
DCK	DAY CONCENTRATION KEY
② POSITION CIRCUIT	
RPL	RINGING PILOT LAMP
PK_1	PROGRESS KEY
PK	PREPARATION KEY
PCK	POSITION CONCENTRATION KEY
AK	ALARM KEY
KS	KEY SPACE
③ KEY SENDING CIRCUIT	
KL	KEY LAMP
KCK	KEYSET CONTROL KEY
RSK	REGISTER STARTING KEY
PRK	PREMATURE RELEASE KEY
4-5, 3-6, 2-7, 1-8, 0-9,	IMPULSE KEYS
④ SUPERVISOR'S TRUNK CIRCUIT	
BL	BUSY LAMP
SLK-SCK-	SUPERVISOR'S LIST AND CALL. KEY
SCL	SUPERVISOR'S CALL. LAMP
⑤ SERVICE TRUNK CIRCUIT	
STL	SERVICE TRUNK LAMP
STK	SERVICE TRUNK KEY
⑥ TRANSIT RELEASE SIGNAL CIRCUIT	
TRL	TRANSIT RELEASE LAMP
TRK	TRANSIT RELEASE KEY
⑦ TIME METER CIRCUIT	
TML	TIME METER LAMP
TM	TIME METER
RK	RELEASE KEY
SK	STARTING KEY

Keyboard of Regular Toll Positions.



KEYBOARD OF L.D.D. POSITION

ABBREVIATIONS

① CONNECTING CIRCUIT	
SL_1	SUPERVISORY LAMP (TOLL SIDE)
SL_2	SUPERVISORY LAMP (TRUNK SIDE)
CK_1	CONNECTING KEY (TOLL SIDE)
CK_2	CONNECTING KEY (TRUNK SIDE)
RK_1	RINGING KEY (TOLL SIDE)
RK_2	RINGING KEY (TRUNK SIDE)
LK	LISTENING KEY
MK	MONITORING KEY
② POSITION CIRCUIT	
RPL	RINGING PILOT LAMP
PK_1	PROGRESS KEY (TOLL SIDE)
PK_2	PROGRESS KEY (TRUNK SIDE)
KS	KEY SPACE
③ KEY SENDING CIRCUIT	
KL_1	KEY LAMP (TOLL SIDE)
KL_2	KEY LAMP (TRUNKSIDE)
③ KCK_1	**KEYSET CONTROL KEY** (TOLL SIDE)
KCK_2	KEYSET CONTROL KEY (TRUNK SIDE)
RSK	REGISTER STARTING KEY
PRK	PREMATURE RELEASE KEY
4-5, 3-6, 2-7, 1-8, 0-9,	IMPULSE KEYS
④ SUPERVISOR'S TRUNK CIRCUIT	
BL	BUSY LAMP
SCL	SUPERVISOR'S CALLING LAMP
SLK-SCK-	SUPERVISOR'S LISTENING AND CALL. KEY
⑤ SERVICE TRUNK CIRCUIT	
STL	SERVICE TRUNK LAMP
STK	SERVICE TRUNK KEY
⑥ RECORDING TRUNK CIRCUIT	
RTL	RECORDING TRUNK LAMP
RTK	RECORDING TRUNK KEY
BLK	BLOCKING KEY
BLL	BLOCKING LAMP

Keyboard, Rapid Toll Positions.

Attendant's Board—Positions with Multiple in Foreground.

enabled to offer or breakdown the connection of a subscriber in a distant city. The helping operator upon the above key being depressed is automatically switched into the connection and takes care of the busy subscriber and either announces to the rapid toll operator that the connection is free or definitely engaged.

The group selector, which is switched in as soon as the rapid toll operator has depressed her toll connecting key, gives access on its levels to the various rapid toll service directions.

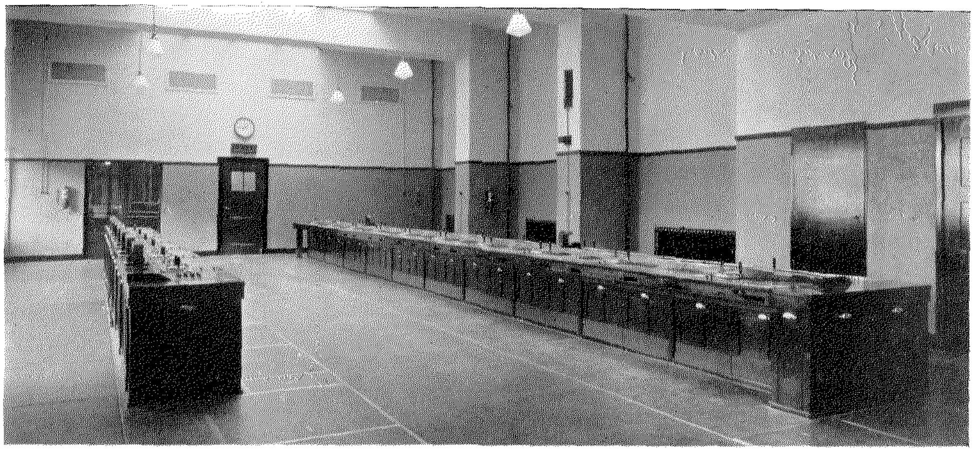
On the terminals are connected outgoing impulse translator circuits to which the toll lines are attached. At the distant end the toll lines terminate on incoming impulse translator circuits and first group selectors associated therewith. To the outgoing group selector a register is attached in which the number sent by the operator by means of her keyset is retained.

After the starting key is depressed the outgoing group selector is set to the level corresponding to the wanted city's direction. On this level a free impulse translator circuit is seized, whereupon a short 50 cycle a-c. impulse is sent out on the line. Following this impulse a register is attached to the incoming group selector and when this occurs a short impulse is sent back to the outgoing end.

Subsequently, the register advances and successively sends out the different digits in the form of series of impulses. The number is thereby transferred from the outgoing to the incoming register. After all digits have been transferred, the register at the outgoing end disconnects itself.

The incoming register will position the selectors at the local exchange and as soon as the final selector is set to the called subscriber's line a second back impulse is sent, causing the supervisory lamp of the rapid service operator to light, indicating to her that selection has been completed.

At this moment it is also determined whether the called subscriber is "free" or "busy". This condition is recorded in the incoming impulse translator via the selectors at the incoming end and is at the same time passed on to the operator in the form of a signal or tone. If the subscriber is free, this is indicated by a lamp only; if, however, he is occupied, then the lamp signal is supplemented by an interrupted tone of 400 p:s. In the latter case the operator must call in the aid of the busy attendant. To do this, she depresses a key and sends an impulse over the line. Her supervisory lamp extinguishes and again burns as soon as the busy attendant abandons



Rapid Toll Positions.

the connection. She can only do this if the subscriber is made free, by depressing the corresponding key (the operator receives indication thereof by a burning supervisory lamp); and if the subscriber does not accept the call and therefore remains busy by depressing a busy key (the operator then hears in addition a definite busy tone of 133 p:s).

Assuming that the called subscriber is free, the operator must actuate the ringing key by which a train of impulses (50 c.) is sent out on the line. This causes three events to take place:

1. The called subscriber is rung.
2. The incoming translator is changed over to a condition wherein the switchhook control is continuously signalled to the outgoing translator (train of impulses).
3. The outgoing translator is changed over locally to a condition which enables it to receive this continuous signalling and to pass it on to the supervisory lamp.

As long as the subscriber has not yet removed the receiver this train of back impulses is sent. The moment the subscriber removes the receiver it stops.

It must be possible for the operator to re-ring; therefore, she must be enabled to create a ringing condition in the opposite direction during the time back impulses are sent. This is accomplished by increasing the intervals between the impulses of the back train of impulses (approximately 108 m.s.) to let the forward train of impulses pass. By this means the ringing impulses penetrate through the back train of impulses and can thereby cause at any time an electric change-over in the incoming impulse translator.

The connection to the local side is established by the operator in the same manner as on a regular toll position. When at the end of a conversation the operator releases the connection, the outgoing impulse translator sends a long forward impulse of minimum 400 m.s. to the incoming translator which latter is thereby liberated releasing all switches.

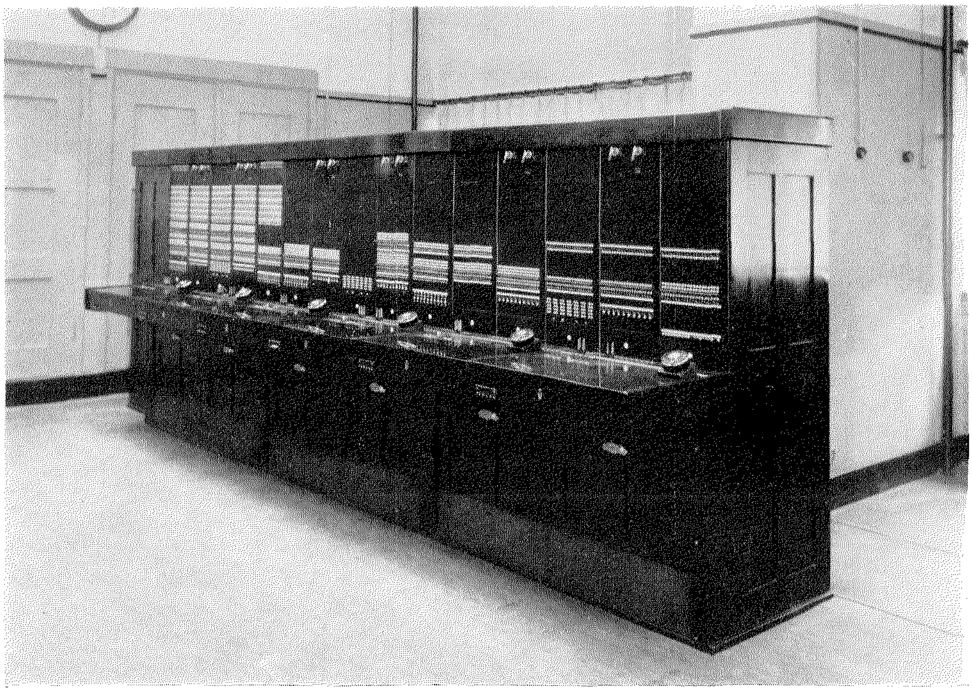
As long as the incoming group selector has not yet returned to its normal position, the incoming translator sends blocking current (continuous a-c.) to the outgoing translator to prevent the latter from being engaged again before its turn.

The quickest operation results if the operator selects first the toll and then the local subscriber. Both lamps will then light almost simultaneously.

Service Observation

In a separate room there are installed sections on which practically all manipulations and actions of the operators can be observed and controlled.

On the observation positions, talking and listening-in circuits may be supervised and controlled, also toll lines, supervision and informa-



Service Observation Positions.

tion circuits as well as service lines, city lines, etc.

Listening-in takes place over repeaters in order that as little energy as possible may be expended and the control of operators may be made without being noticed. There is a possibility of switching the control over to the chief operators.

Operators' School

In order to instruct the operators in the new methods of operation, there are installed in a separate room two regular and two rapid toll positions, also a transit position and a concentration position, all of which operate in conjunction with three instruction positions. On these instruction positions all possibilities may be imitated. Every manipulation made by an apprentice may be observed and controlled by means of lamps on the instruction table. This made it possible to instruct the large number of operators (400) in time to ensure the correct manipulation of the new toll board.

Automatic Toll Service

The toll exchange described must fit in with the general plans of automatization of The Netherlands. A brief reference thereto may here be made.

It must be possible to connect a toll line through to any subscriber in the Amsterdam district. Therefore, the whole area is made accessible over a level of the second group selectors. Furthermore, it must be possible to connect any subscriber in the district to any other subscriber in the entire country.

On the remaining levels of the outgoing

L.D.D. group selectors the main toll centers at Rotterdam, Arnhem, Zwolle, 's Hertogenbosch and Amsterdam are connected. Each main toll center gives access to the central exchanges in its home district from which in turn all subcenter and district exchanges may be reached.

In the future, therefore, subscribers of the Amsterdam district can automatically reach all subscribers in the home district and also those in all surrounding districts. Furthermore, they can eventually be connected via the rapid toll positions with all subscribers in the whole country and via the regular toll positions to any international toll lines.

Vice-versa, all subscribers in the entire country can automatically reach Amsterdam, Rotterdam and Utrecht, and surrounding districts and through the intervention of one or more operators, they can be connected to all international lines which touch Amsterdam.

Automatic Long Distance Switching

Rotary System

By J. KRUITHOF, e.i. and M. DEN HERTOG

Introduction

AUTOMATIC switching methods which have already proved their worth in city areas and are also successfully meeting the different and far more exacting conditions and requirements of rural networks are now about to be employed to modernise and perfect toll switching systems.

Modern toll practice demands the following:

1. High transmission efficiency.
2. Speed of service and ease of manipulation.
3. A convenient and reliable service for the public.
4. Flexibility.
5. Economy and practicability of construction and maintenance.

Automatic apparatus and circuits as now developed are particularly suited to meet all these requirements.

An outstanding advantage of automatic switching is that the time required to establish a connection depends to a small extent only on the magnitude of the area, i.e., number of offices covered by direct dialling service.

Advantage has already been taken of the saving in time made possible by automatic switching in the case of the long distance dialling method to establish toll calls. The operator at the incoming end of the toll line in this system is eliminated as the operator at the outgoing end is enabled to establish the call directly by means of her dial.

High standards of transmission are more easily and definitely realised by automatic apparatus than through human intervention and control. In practice it was found to be not possible to insure that in manually operated systems the cord circuit repeaters are always used when required by the routing instructions.

The reliability of service of a toll system will be considerably improved by the introduction of automatic switching. Due to the elimination to a large extent of the human element, fewer errors will occur. Further, there will be less danger of the system breaking down as a result of strikes, etc.

The practicability of construction and maintenance will be favourably affected by the automatisation of a toll system due to the resultant reduction in the number of toll exchanges, which will in turn cause a decrease in the total maintenance required for the system.

Automatic switching is more economical due to the omission of operators. The toll exchange buildings may be of simpler construction, the large operating and rest rooms being no longer required. Further, the efficiency of the line plant will increase due to the more rapid switching methods and the better utilisation of the toll circuits. The financial results of the system will also be much better through the increase of business, which will be the welcome effect of a better grade of service.

The object of this article is to describe how the various problems that arise when introducing direct dialling between subscribers in different cities have been solved in the Automatic Long Distance Switching System of the International Standard Electric Corporation.

General Considerations

A great variety of requirements is demanded from an automatic toll system; first and foremost it carries with it the obligation that there shall be available a sufficient number of circuits to allow no delay service.

In order to keep the investment to a minimum consistent with good service, the system must be so designed that the extremely expensive toll circuits, which in many instances include one or more repeaters, are utilised with a maximum efficiency.

In manually operated toll systems, the number of direct circuits between any two toll centres will normally be so determined as to be sufficient to carry the traffic on normal days only; at the same time the possibility is provided that on peak traffic days additional circuits are composed by combining smaller sections. In order to avoid disproportionate increase in the number of direct circuits when automatic switching is introduced, the overload should possibly be routed via alternative traffic paths and be passed through an additional switching centre.

The automatic interconnection of different automatic local systems, which co-exist in most European countries, offers special problems.

To each area in an automatic toll network a calling prefix or a code must be allotted which should preferably consist of a uniform number of figures, as only then the system remains comprehensive to the subscribers, a primary requirement which any public system of communication must fulfill.

The charges to subscribers for the toll service rendered must of necessity be registered on subscribers' meters on the same principle of multiple and timed metering, as already applied in automatic rural networks[1]. In an automatic toll system, however, the metering problem will be of a more complicated nature as on calls between certain areas the metering may not be uniform. As a consequence the automatic equipment which fixes the tariff will be more intricate than the metering control equipment of rural systems; for, in some cases, it will be set in accordance with both the prefix and a part of the subscriber's number.

Further requirements of some Administrations may be such that during certain hours of the day reduced tariffs are applied and that during other hours the length of conversation is restricted.

Transmission of speech should be maintained at the adopted standards and, whenever necessary, the automatic toll system must be capable of switching repeaters into a connection and fix the gain according to the class of call and the losses of the lines connected.

This automatic gain control must be such as to permit the use of the existing toll line plant which involves the possibility of interconnecting a great variety of toll lines of different lengths and types.

The signalling system should be selected having regard to both economy and quality of operation. A relatively simple and inexpensive system such as the 50 cycle a-c. signalling system may be used advantageously on the short repeaterless sections, whereas a voice frequency system may be preferred for the longer and repeatered circuits. The proper coordination of the different types of signalling equipment must be ensured.

Register

The fundamental principle of the Rotary automatic long distance switching system is, as in other rotary dial systems, the adoption of the register as the central controlling mechanism.

The register circuit which has now also been added, in some cases, in direct impulse systems and in certain other power driven systems, is not a mere addition to the Rotary System, but forms an integral part of the whole conception of that system which is actually built around the register.

A few of the outstanding features made possible by the use of the register to control the whole operation, are set down below. The exact manner in which each of these features is applied will be found described under separate headings.

a. *Full Availability*

The full complement of toll lines for any given direction is available for each call, no matter how large the group of lines. The ideal of a single undivided group of circuits is thereby fully realised and as a consequence each toll line circuit will have the maximum possible traffic handling capacity.

b. *Limited Continuous Hunting*

The well known feature of continuous hunting, which makes the Rotary Systems capable of carrying heavy overloads, is embodied also in the automatic long distance switching system, but in a form differing slightly from that of the other Rotary Systems[2]. If no free outlets are available in a certain direction, a call for that direction

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[1] "The 7-D Rotary System for Small Communities," by W. Hatton, *Electrical Communication*, July, 1932.

[2] "Rotary Automatic in Switzerland," by Gerald Deakin, *Electrical Communication*, January, 1931.

will not cause any ineffectual rotation of switches, but the circuits simply remain in the calling condition.

In addition to this, arrangements are provided whereby the calling condition is abandoned after a certain lapse of time and a new condition may be initiated automatically; for example, an operator may be called in.

c. Alternative Routing

Provision may be made to route calls in an alternative direction automatically, in case no circuits are found available in the direct route.

The possibility of including the three features mentioned above under a, b, and c, is offered by the register, owing to its ability to deliver the consecutive series of selective impulses to the different stages of selectors independent of the speed with which the digits are dialled by the subscriber.

d. Translation of Prefixes

In toll networks translation of the prefixes is of vital importance from the standpoint of economy. Without it, traffic must be routed in accordance with the numerals sent, i.e., a call must follow the route definitely assigned to it by the digits dialled, regardless of whether or not the route is an economical one.

With translation of calling prefixes, however, the routing of calls between any two toll centres may be accomplished in the most economical manner and, what is also vitally important, this routing, if changed conditions warrant it, may be altered at any time without necessitating any modification in the numbering system. (For further explanation, see description under "Numbering.")

e. Division of Toll Lines into Different Classes

When a manually operated toll line network is converted to automatic operation, cases may occur between two toll centres where there are different types of toll lines; for example, toll lines with different losses. Assuming a case where part of the toll lines have a loss exceeding the maximum permissible overall loss for a connection, then this group of lines cannot be used for direct connections between the two toll centres. In manually operated systems such lines are usually permanently connected to other toll lines with a repeater inserted at the point of juncture.

The automatic toll system follows manual practice in this respect, the register choosing the low loss trunks on direct calls between the two toll centres and the high loss trunks on tandemed connections only. On transit calls via the high loss trunks a switched repeater is introduced at the point of juncture. (For further explanation, see description under "Overflow.")

The automatic long distance switching system provides the means whereby for certain classes of calls both types of toll lines may be made available so that from a traffic point of view they may be considered as forming a single group. The register will select the most suitable type of toll lines depending upon the kind of the call, but arrangements are made whereby at any moment a call directed by the register to the group of lines with high loss, may overflow to the low loss lines in case none of those first mentioned are available.

f. Metering Indication

In a system employing translation of the prefix codes and tandem trunking, the class of tariff is not fixed by the direction selected at the originating toll centre, as a call may either terminate at or be tandemed through the next toll centre.

The register, by means of the translator, which is set in a position according to the prefix of the wanted area, is in many cases capable of indicating the proper tariff directly to the time and multiple metering equipment, provided the tariff is uniform for the whole area reached by this prefix.

In case the metering for a certain area is not uniform so that the class of tariff has to be determined from part of the subscriber's number, the register will indicate to the time and multiple metering circuit temporary connection of a control circuit of a common group. The purpose of this control circuit is to check the wanted subscriber's numerical digits and to indicate the tariff accordingly. A common group of metering control circuits for each area having non-uniform metering will be provided, and the register in such cases will be able to select the appropriate control circuits.

g. Non-Decimal Selection

Non-decimal selection may be arranged for, so that the number of outgoing directions at any switching stage may vary between 2 and 20 for a single selection. This feature is provided by the introduction of a special switching mechanism and without any wastage of multiple bank contacts if the very maximum number of directions is not required.

h. Flexibility in Emergency Cases

As a result of an emergency, for example, in the case of a cable breakdown or fire in an exchange building, it may become necessary to route certain traffic momentarily in an entirely different manner. For a system without registers this would necessitate a redistribution of the trunk groups on the group selector arcs or alternately constraining the public to dial calling codes different from the usual.

With a register system such a change in the routing or traffic can easily be accomplished by a simple jumpering alteration on the translators of the registers. As for toll service, there is only a very small quantity of registers in each exchange so that this can be done with very little delay.

There are other advantages inherent in all register systems and are so well known that they do not require to be repeated here. One of these, however, assumes special importance in connection with direct dialling between subscribers of distant cities, viz., that the selective impulses sent over the toll lines are not produced directly by the subscriber's dials with all inherent detrimental influences of distortion from short and long lines, but by an impulse machine at the register sending impulses of accurate and uniform length and ratio.

Trunking

The introduction of automatic toll service will exercise considerable influence on existing toll switching systems as a whole and more particularly on the methods of traffic routing.

In general it will be found that areas were originally planned with an excessive number of toll centres, and a careful study may reveal the possibility of eliminating certain centres as such, and converting them into tributary offices. In order to concentrate, the first step towards the introduction of automatic service should, therefore, be to determine the number and the appropriate location of the toll centres so as to obtain more economical exchange units both from a maintenance and trunking point of view.

The present day tendency of using direct trunk groups, if such are at all practicable, results in a sub-division of the circuits contained in a cable into a number of small groups necessarily of less efficiency. The underlying object of this tendency is to reduce the total switching time by avoiding too large a number of intermediate switching points.

With modern automatic switching methods, the co-existence of a great number of small circuit groups is fundamentally unsound and must be avoided on account of their inefficiency. With automatically switched connections, however, there can be no objection to the insertion of one or two more switching points as the resulting increase in switching time will be almost negligible.

The next step, therefore, will be to determine how the existing toll line plant can best be coordinated to allow the most economical and efficient arrangement which the automatic toll system affords and whether alterations may be desirable considering the conditions of the existing plant. The automatic toll system described in this article is sufficiently flexible to permit using the existing plant to its maximum efficiency. Features, such as tandem trunking, full availability of large trunk groups, alternative routing and overflow, described hereinafter under separate headings, contribute towards rendering the existing cable plant considerably more efficient than is the case with the existing manual methods of operation. In general, it may be said that the introduction of automatic switching methods into a network will result in completion rather than rebuilding of the outside cable plant.

On the other hand, combining circuit groups and centralising switching equipment may be carried too far. Too rigid an application of these principles would mean that a toll centre of tertiary importance would be connected to one parent toll centre of secondary importance only and that a secondary toll centre would depend on a single primary toll centre only. This extreme is naturally to be avoided for practical as well as economical reasons.

Combining too many small toll circuit groups soon leads to a group of such size that any further increase in circuits would not materially improve the trunk efficiency. Furthermore, the number of switching points entering on a two-wire connection may for transmission reasons not exceed certain limits.

By carrying concentration too far, the sizes of exchanges at the switching centres may actually become too large to allow economical maintenance. Moreover, centralisation of large amounts of equipment constitutes a real danger and makes the system extremely vulnerable to fires, strikes and any other uncontrollable events. Should a pivotal exchange be destroyed by fire, or should one of the cables forming the backbone of the system for some reason or other be damaged, a great part of the system may then become completely isolated.

A typical toll network has been shown in Figure 1 in order to demonstrate by an example the trunking possibilities of the automatic long distance switching system.

All exchanges shown in the figure constitute toll switching centres of areas. The numbering of the subscribers' lines of each area is "closed." This implies that when a call terminates at the centre of such an area, the further selections depend solely on the subscriber's number and no longer on an exchange prefix. The total number of exchange prefixes required corresponds, therefore, to the total number of toll centres.

Similarly, it is assumed that all toll calls, which leave such a "closed" area, pass via the pivotal switching centre which, however, does not exclude the possibility of having tie lines between two neighbouring rural exchanges situated in separate but adjacent areas.

The exchanges shown are subdivided into three types, in accordance with their importance and relative location namely: primary, secondary and tertiary exchanges. A tertiary exchange may be defined as an exchange which can only originate toll calls and receive calls terminating within its area. The automatic switching equipment provided for these exchanges will, therefore, not be arranged to deal with tandemed toll traffic.

Most of the tertiary exchanges are connected to a single primary or secondary exchange only. As long as they remain manual, there is no objection to leaving them connected to two or more secondary or primary centres, but when the area is converted to full automatic it is advisable and desirable to abandon this practice and connect the tertiary exchanges to one parent exchange only.

Each secondary toll centre constitutes the parent exchange of several tertiary toll centres and each such centre obviously also includes tertiary exchange equipment required in connection with its home rural area. The secondary centres are equipped with "switched" repeaters, which are automatically introduced whenever necessary. A secondary toll centre may be connected to one or more primary or secondary centres depending on the mutual community factor of interest and its location.

The figure shows a total of five primary toll centres interconnected by direct trunks, known as primary links. Several factors control the decision on the choice of appropriate primary toll centres. Obviously they are best located in the larger cities of the country. Their number, however, should be kept to a strict minimum in order to avoid an excessive quantity of direct traffic routes. Too limited a number of primary centres on the other hand will cause congestion of the traffic and may lead to extremely large toll exchanges, which manifestly cannot be recommended.

In Figure 1, a number of five primary toll centres has been adopted. The corresponding number of primary link groups interconnecting these five centres amounts to ten.

With a decimal numbering system, which must of necessity be introduced in the case of automatic systems which do not employ registers and, therefore, do not possess mechanisms which translate the exchange codes, the number of primary centres must be increased to, say, ten and even then four digit codes would have to be introduced for the case under discussion. The number of primary link groups required for ten exchanges is forty-five. With such a high number of groups, the trunk efficiency will obviously diminish considerably, i.e., such systems require more circuits and consequently a much more expensive outside plant. This fact is well known from experience gained with local automatic systems, but it becomes of fundamental importance with automatic toll systems where the outside plant is so much more costly.

Other factors which enter into consideration when determining number and location of primary centres may be of a geographical nature.

The toll cable network shown on Figure 1 is of a country which in its western and southern parts is densely populated. The circles designated 031, 041 and 051 indicate the primary toll centres situated in these parts, which have a mixed agricultural and industrial population.

The north eastern part of the country is mountainous and such factors as accessibility and density of population will play a decisive role when determining the number and the location of the primary exchanges as indicated by 081 and 091.

With a number of five primary toll centres,

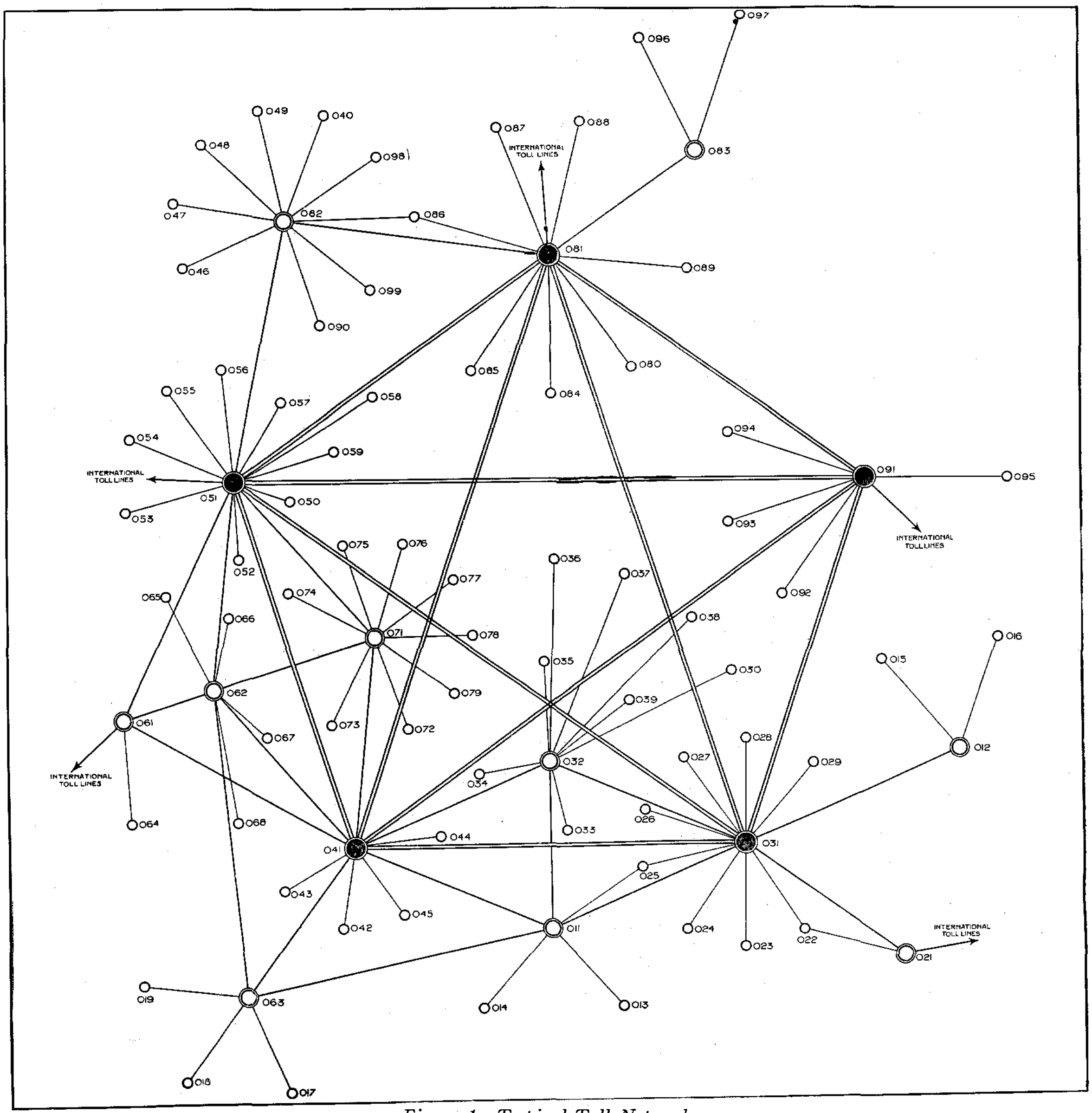

Figure 1—Typical Toll Network.

alternative routing can be accomplished in a technically simple and efficient manner as the additional number of intermediate primary switching points never needs to exceed one.

The trunk groups may be composed of circuits having different characteristics as regards transmission losses, a fact which is of great importance when full automatic switching is to be introduced into existing toll networks.

In order to ensure correct transmission standards, the trunks between two non-adjacent primary centres will be of the high velocity type. Two- or four-wire circuits may be used as local conditions demand.

The links between two primary toll centres may contain permanent repeaters. The overall loss of such links should preferably be adjusted to 9 db.

All toll circuits, including the associated automatic equipment, are common for both operators and subscribers. The traffic originated by automatic subscribers or the calls established by operators, which have direct access to the system, pass via the same groups of toll lines thus allowing a higher trunk efficiency than would be the case if two separate networks, each of which would serve a single class of calls, were installed.

By making the toll trunks common for both classes of calls, still another advantage is obtained which is of great importance in connection with gradual introduction of automatic toll service.

When an Administration introduces a new automatic city network into the system, the automatic toll switching equipment may be installed and placed in service without, for the time being, extending the automatic long distance service to the subscribers of that city. The toll traffic originated by the subscribers will continue to be handled completely by the operators on a no delay basis; the calls established by these operators passing via the newly installed automatic toll equipment. The subscribers may then be informed that from a certain date they may establish toll calls directly by means of their dials. It is likely that only a small number of subscribers, from that date, will commence immediately to make use of the new facilities accorded to them. The majority probably will continue to obtain their toll connections in the usual way, i.e., via the operator, as they may not yet be conversant with the new system or may not fully realise its advantages. The number of such subscribers will, as is proved in practice, gradually decrease and consequently the number of calls established by the operators will become less. By this displacement of traffic, the total traffic passing via the toll lines will, however, not be affected.

In this manner those subscribers who are new to the local system or who for other reasons are not fully conversant with automatic toll dialling are not handicapped as they may simply call via the local operator.

An important advantage, from a maintenance point of view, is that it becomes unnecessary to make a repeated toll line redistribution which would obviously be required if two separate toll line networks, the one handling calls originated by subscribers and the other those established by the operators, were needed.

A study of an application of the automatic long distance switching system to an existing complete cable network has revealed that the total traffic carrying capacity of the cable system would be increased by approximately 30%. Where in manual systems the efficiency of a trunk rarely exceeds 50%, the corresponding figure for the automatic long distance system will in most cases reach 70 to 75%.

Numbering

Uniform three-digit codes have been assigned to the eighty-five exchanges shown in Figure 1, as indicated. Definite rules need not be followed or regularity be observed when assigning the office prefixes.

Areas with less than one hundred toll centres require three-digit codes and with more, four-digit codes. This simple method of numbering is made possible by the translation feature incorporated in the automatic toll register, which eliminates the necessity of a direct relation between the exchange code dialled and the number of selections made and the actual selections themselves.

With systems where there is a rigid relation between digits dialled and the selections made, networks of the size as shown in Figure 1 require four-digit codes. The mixing of three- and four-digit codes cannot be recommended for reasons well recognised.

Switching Mechanism

The switching mechanism adopted in the automatic long distance switching system for selecting a direction and to hunt for a free outlet in this direction comprises a backward hunting finder of the 200 point type as developed for the 7-A.2 Rotary System[3].

This switching mechanism differs in fundamental principles from any used in the present power-driven and step-by-step systems, and has been chosen by virtue of the considerable advantages it offers.

The principle of a single selection stage is illustrated in Figure 2. It shows the manner in which an incoming toll line or local junction "A" selects a free outgoing local junction or toll line of the directions, "B," "C" or "D".

The incoming toll line circuit or the local junction contains a stepping relay Sr which receives the selecting impulses from the controlling register at the originating exchange and which acts on a direction marker switch DMS.

A "backward hunting" finder of the single-motion type is associated with each outgoing toll line or local junction. These so-called "toll line finders" are designated B1, B2 and B3 for direction "B"; C1, C2 and C3 for direction "C", etc.

It will be observed that the line terminals of the incoming line "A" are multiplied over all toll line finder arcs. The test bank contacts, however, are multiplied over the finders of one direction only and connected to terminals of arc "a" of switch DMS, which forms part of the "A" toll line circuit.

Let it now be assumed that the line "A" has been taken by a call which must select direction "C". To make this selection the controlling register sends two impulses on the line "A", operating the stepping relay Sr twice and advancing the switch DMS by two steps.

After the last impulse, a circuit is closed from battery via a test resistance R and terminal 2 of switch DMS to the test multiple of the finders associated with direction "C", and at the same time the common starting circuit for these finders is started. All free finders "C" will hunt until one of them reaches the terminal with potential and thereby stops in a position in which the line "A" will be connected through to the line "C" associated with the successful finder. At this instant all other finders "C" will immediately cease hunting for line "A".

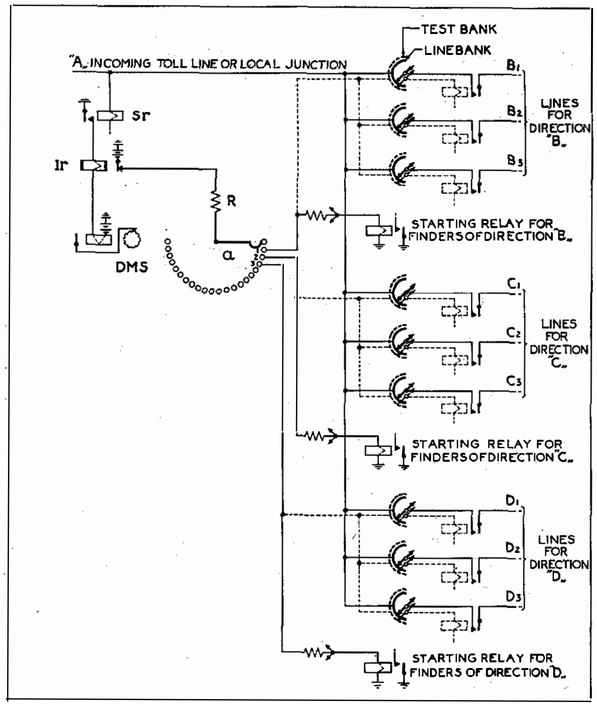

Figure 2—Switching Mechanism.

It will be evident that, if at the same time the finders "B" or "D" were hunting for other calls, none of these could stop on line "A", owing to the fact that the test terminals of circuit "A" on the "B" and "D" finder arcs do not receive potential. The possibility, therefore, that calls are directed to a wrong channel is excluded.

The following advantages are apparent from the above scheme of selection:

a. The number of toll lines per direction is unlimited as any reasonable number of finders may be multipled in a single group.
b. Every outgoing toll line is accessible for all calls.
c. The number of directions for one stage of selection depends directly on the capacity of the direction marker switch only. By choosing for example a

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[3] "7-A.2 Rotary Automatic Telephone System," by L. Schreiber and W. Hatton *Electrical Communication*, April, 1933.

twenty-two point marker switch, a maximum of twenty-one directions may be reached by a single selection.

d. Increasing the number of directions does not decrease the available number of outlets per direction as is the case with "forward hunting" single motion switches.

e. Due to the fact that generally several finders are simultaneously hunting for a calling line, the average hunting time will be short.

With a two hundred point finder type switch, the number of incoming toll lines and local junctions which it is possible to connect to a toll centre with a single stage selection amounts to two hundred. An exchange with such switches is shown in Figure 2, and is also presented in more simple form by Figure 3.

When for an exchange the number of incoming lines exceeds two hundred, there exist several methods to extend its switching capacity. These methods are discussed in the next paragraph.

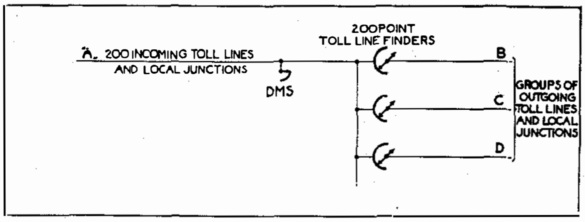

Figure 3—Single Stage Selection.

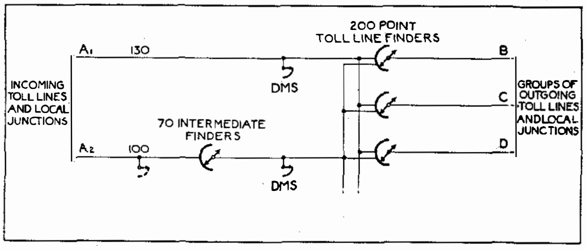

Figure 4—Single Stage Selection with Partial Intermediate Finders.

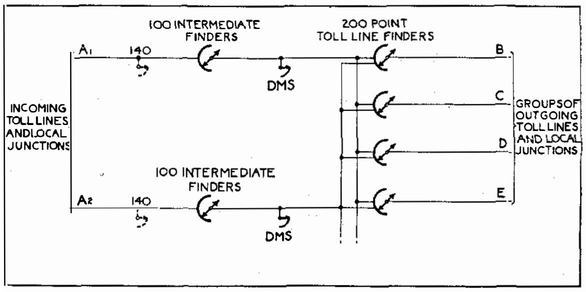

Figure 5—Single Stage Selection with Full Intermediate Finders.

Switching Methods

The switching mechanism described in the preceding paragraph allows a great variety of switching methods, due to the fact that the backward hunting finder can be used for two purposes. It may firstly be utilised as the switching mechanism of the system and secondly it may function as a machine which concentrates the traffic on a reduced number of traffic paths.

The latter feature permits the gradual extension of a toll centre beyond a capacity of two hundred incoming lines. Assuming an exchange with two hundred and thirty incoming lines, (toll lines and local junctions) a switching scheme as shown in Figure 3 can no longer be applied, unless part or all of the outgoing lines are divided in two or more traffic splits.

In order to avoid a decrease in efficiency of the toll lines which would necessarily be the result of such splitting, the method shown in Figure 4 may advantageously be used. The incoming lines and junctions are arbitrarily subdivided into two subgroups.

The group designated "A1" comprises the highly efficient lines of the larger groups which are, therefore, directly connected to the toll line finder arcs. The toll lines forming part of the smaller and therefore less efficient groups are connected to the arcs of intermediate finders so as to reduce the number of traffic paths.

The quantities introduced on Figure 4 are based on the assumption that for the traffic handled by one hundred incoming lines seventy intermediate finders are required. In this manner, the arc capacity of the toll line finders permits the accommodation of one hundred and thirty incoming lines and seventy intermediate finder circuits.

The maximum number of incoming lines, which may be connected to an exchange diagrammatically represented by Figure 4 cannot be definitely determined. Figure 5 shows a typical case when all incoming lines are multipled to the arcs of two groups of intermediate finders.

When the incoming lines constitute many small groups, their average efficiency will be low and consequently the concentration of traffic in, say, two large groups will result in a considerable

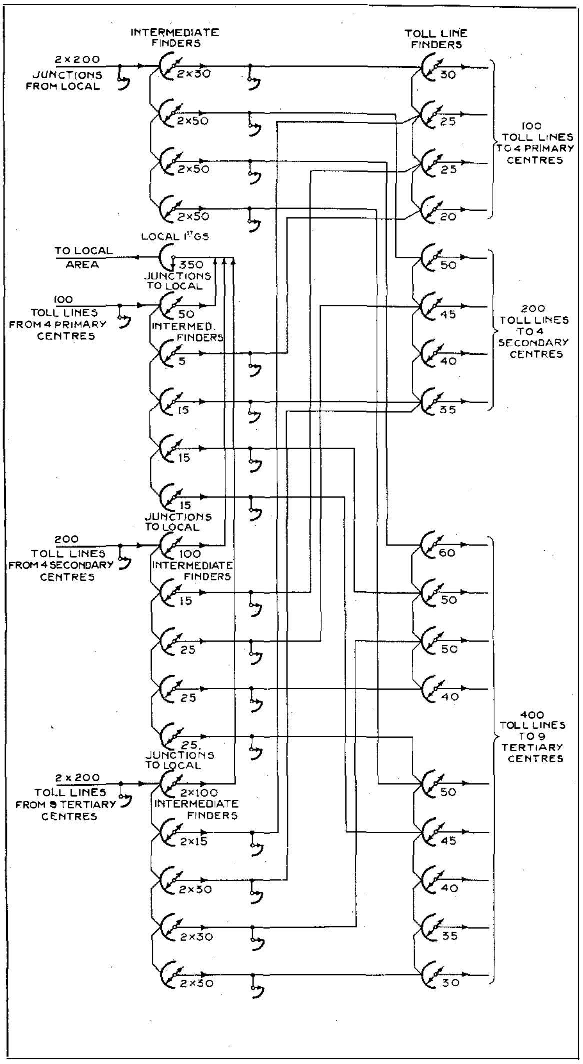

Figure 6—Full Double Stage Selection.

reduction in the number of intermediate finders, as compared with the number of incoming lines. This effect will manifest itself to a lesser degree if the incoming lines already form larger groups.

For both Figures 4 and 5 it is assumed that the number of outgoing directions does not exceed the capacity of the marker switch. The marker switches of those incoming lines, which have access to a single group of finders only, are not required and are shown dotted. In the circuits, however, provision is made for their introduction at a later date, in order to allow the system to be gradually converted to the one represented by Figure 6.

Figure 6 shows a typical example of the method in which still larger exchange capacities can be obtained by the insertion of marker switches in the incoming line circuits. The scheme also permits the increase of the number of directions, which theoretically now amounts to the square of the number of points available on the arcs of the marker switches.

The principle of the scheme is that the incoming lines, i.e., the junctions from local and the incoming toll lines, are divided into groups of two hundred. Each local junction has access to four groups of intermediate finders; each incoming toll line can reach a group of local junctions, which terminate in local 1st group selectors and therefore give access to the complete local area including its rural network. Similar to the junctions from local, the incoming toll lines have access to four groups of intermediate finders.

The reason why a number of four intermediate finder groups is adopted is that their total number equals seven hundred and ten, i.e., more than

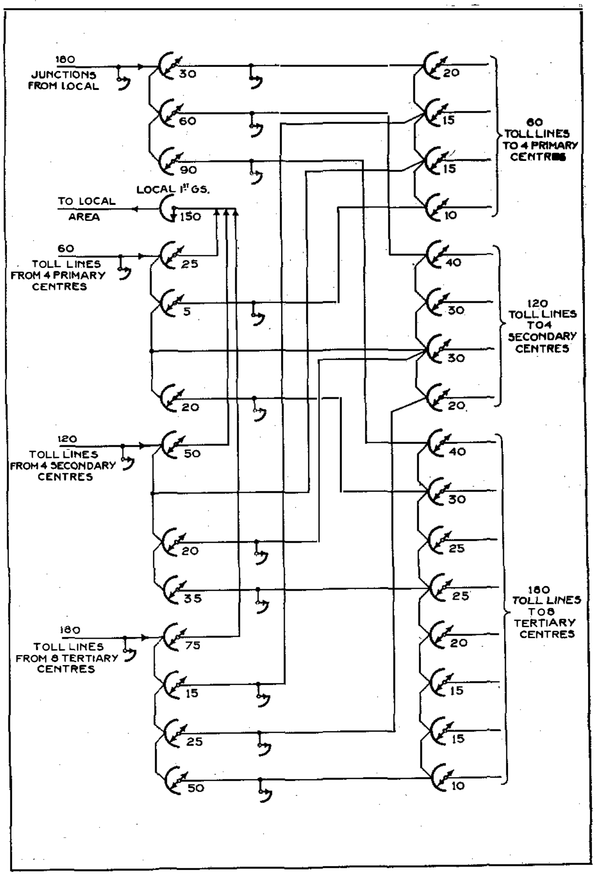

Figure 7—Partial Double Stage Selection.

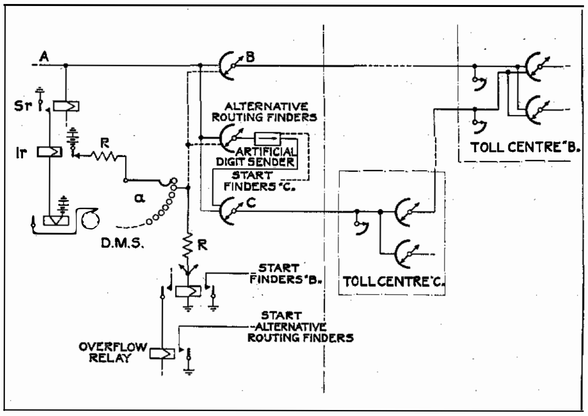

Figure 8—Alternative Routing.

three times the arc capacity of the toll line finders. Their number gradually grows with the number of toll lines.

Each group of intermediate finders is in its turn connected to the arcs of the finders associated with the outgoing toll lines. The total number of outgoing directions is divided into four groups, the same as the intermediate finders, provided that the number of directions per group does not exceed the arc capacity of the direction marker switch. Should this be the case, then the outgoing directions must be subdivided into five groups and consequently also the intermediate finders.

Figure 6 represents the exchange numbered 051 of Figure 1. The total number of toll lines amounts to one thousand four hundred with four hundred junctions from and three hundred and fifty junctions to local.

Figure 7 shows a different method of extending the scheme of Figure 5 and has considerable advantages over the one shown in Figure 6, especially if the exchange is of not too large a size.

It has the advantage that on part of the incoming toll lines only one selection is required for tandemed calls. In the example, calls from primary to secondary exchanges and calls from secondary to primary exchanges require only one selection, as the primary trunks are connected to the arcs of the finders associated with the trunks to secondaries and the reverse.

The total number of toll lines indicated on Figure 7 amounts to seven hundred and twenty and in addition there are one hundred and eighty junctions from and one hundred and fifty to local.

Attention is specially drawn to the fact that all incoming toll lines have access to every outgoing toll line in all of the schemes shown in Figures 3 to 7. This is of great advantage from the point of view of toll line efficiency.

Full availability of the junctions to local, however, is considered unnecessary, as the local links are relatively inexpensive compared with a toll line circuit.

For the same reason it will not be necessary to provide two hundred point finders for the local link circuits as the less expensive one hundred point finder will be equally satisfactory from an economy point of view.

For medium sized toll centres it may even be advantageous to use one hundred point finders throughout. Since their introduction does not affect the switching principles explained above, it is thought unnecessary to consider this in detail.

Limited Continuous Hunting

The automatic long distance switching system provides "continuous hunting" at all switching stages. Due to the fact, however, that the hunting finders are connected to the outgoing toll lines, intermediate circuits or junctions to local, the manner in which the "continuous hunting" is accomplished is of a somewhat peculiar nature. Where in the 7-A and 7-D Rotary Systems a selector will continue to rotate until a free outlet

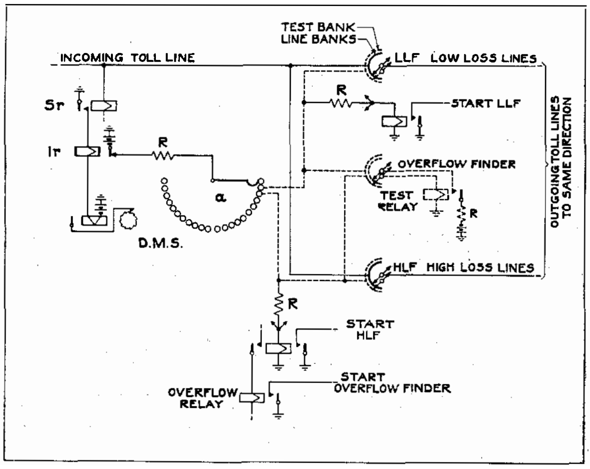

Figure 9—Overflow.

is found, no rotation of switches takes place in the automatic long distance switching system when a selective trunk circuit, incoming toll line or intermediate finder circuit finds all outlets in the wanted direction engaged. In this manner switches are prevented from turning unnecessarily.

The "hunting" circuit remains in the calling condition until it is seized by a finder of the wanted group. Calls which would otherwise be lost are, therefore, only delayed.

The continuous hunting feature not only constitutes an advantage from an operating point of view but it also permits the toll lines to carry considerable traffic overload without seriously hampering the traffic.

The time during which the calling condition of a circuit is maintained is limited.

Alternative Routing

The feature contained in the register not to send a subsequent series of impulses until a selection is completed permits traffic overloads to be routed via alternative paths.

When all direct toll lines between two toll centres A and B are engaged, a selective circuit at A when calling for a free outlet B (reference Figure 8) will, upon finding all outlets occupied, operate the overflow relay. This will start a small group of "alternative routing" finders which are placed on the same multiple as the B finders. When an alternative routing finder seizes the calling selective trunk circuit, no back signal is returned and the register therefore will not proceed with the sending of the next series of impulses. Whilst the register is waiting, the alternative routing circuit calls for a toll line in a different direction, for which purpose it is connected to the arcs of the toll line finders "C". After a toll line "C" becomes connected, the alternative routing circuit sends an artificial digit to the toll centre C, where it causes the selection of a free toll line in the direction of the toll centre B.

At the moment the toll line to B is selected, the incoming toll line circuit at "C" sends a backward impulse to the controlling register which then proceeds in the regular manner by sending the next series of impulses. It will be evident that as far as the register is concerned, the operation remains the same as if the connection to "B" had been established directly instead of indirectly via the toll centre "C".

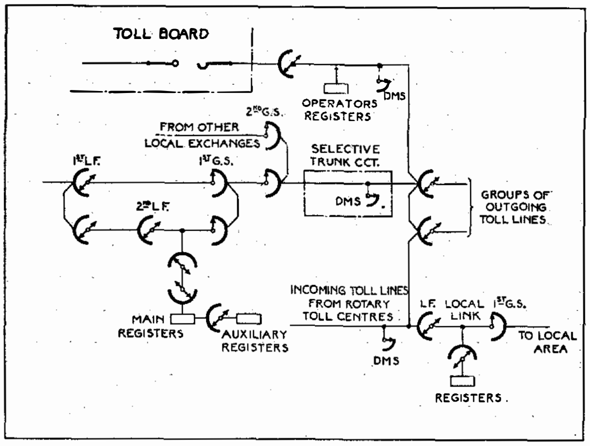

Figure 10—Adaptation of Rotary Area.

The number of alternative routing circuits is not restricted and does not reduce the number of outlets in the direction with which these are associated.

There also exists the possibility of providing several groups of alternative routing finders to assist a direct group in cases of overload. One group of alternative routing circuits may for example complete a call from A to B via the toll centre C, whereas another group may complete the call via a toll centre D. The alternative routes via a toll centre C may also have preference over those routing the calls via the toll centre D.

Overflow

In manually operated toll networks, cases may be encountered where the trunks between two toll centres are divided for transmission reasons, into two groups. The one group comprises the trunks with a transmission equivalent not exceeding 9 db., which is the maximum permissible overall loss on a connection, and the other group, trunks which exceed 9 db. The former trunks can be used for any class of connection, but the trunks which have a loss of more than 9 db. can only be utilised on tandemed connections, i.e., on connections which can be repeatered at one or both toll centres.

With the introduction of automatic toll operation, the above mentioned subdivision must, of necessity, remain. The problem of selecting two different kinds of trunks for the same direction is solved in the automatic long distance switching system in an extremely simple and straightforward manner.

At the exchange or origin of the two trunk groups, two separate finder groups will be installed. The marker switches of the local junctions or toll lines which have access to these two trunk groups will have two distinct positions corresponding to this single direction. By virtue of the register, which is able to distinguish between the various classes of calls, the marker switch can be appropriately set in accordance with the class of the call. In this manner, calls which are originated at this centre for subscribers connected to exchanges in the area of the second centre, are routed via the low loss trunk group, whereas calls which pass through the first or the second or through both centres will hunt for a free trunk in the high loss trunk group.

If, however, a tandemed call finds all outlets in the latter group occupied, the system provides the facility for such calls to overflow to the low loss trunk group in the manner explained below.

When all high loss trunks are engaged and a tandem call arrives, the overflow relay associated with the starting circuit shown in Figure 9 is energised. This relay immediately starts an auxiliary overflow finder provided for the high loss trunk finder group.

The auxiliary finder has only two rows of terminals; one row (the one composed of test terminals) is multipled to the test bank of the high loss toll line finders and the other, to the test bank of the low finders of the same direction.

The overflow finder will hunt until it reaches the position corresponding to the incoming line or junction, where it meets the potential applied by the marker switch DMS. As a result the test relay of the overflow finder operates, whereupon the latter is stopped. The fact that the finder stops in a position corresponding to the calling line, has no reaction on this line nor on the controlling register circuit since, as already stated, the line connections are not multipled to the overflow finder.

The test relay of the overflow finder, when operated, connects, via the second finder brush, a test potential to the test terminals of the calling line on the low loss toll line finders. At the same time these finders will be started, just as if the direction marker switch of the incoming line were set in the position corresponding with the low loss lines.

All free low loss toll line finders will now hunt for the calling line until one of them tests on the marked terminal, whereupon the finder stops and extends the connection in the known manner. The incoming line circuit then removes the test potential from brush "a" of the marker switch DMS, causing the test relay of the overflow finder to release and in turn to remove the test potential from the low loss finder terminals. This will also cause the release of the overflow finder, which is thereby made available for other calls which may have to overflow to the low loss trunk group.

The overflow of calls from the low loss to the high loss trunks is not permitted. With the overflow circuit described above this cannot happen, as the overflow relay only operates when shortage of high loss trunks occurs.

The moment one of the high loss trunks becomes free, the overflow relay is released and the action of the overflow finder is stopped.

Adaptation of Local Rotary Exchanges to the Toll System

As toll calls usually form a small percentage of the total number of calls originated in a local network, it is thought uneconomical to burden every local register with additional apparatus required to control the automatic toll calls. This apparatus is therefore concentrated in a small group of auxiliary registers (usually from five to ten per 10,000 line unit), which temporarily attach themselves to a main (local) register in case of an automatic toll call.

Automatic toll calls established by subscribers are distinguished from other calls by the dialling of a particular first figure (usually "0"). Upon receipt of this figure the main register to which the caller's line is connected immediately calls for an auxiliary register.

Depending upon the size of the rotary exchange and the number of main registers equipped, attaching an auxiliary register to the main register is accomplished by means of connecting relays (for small exchanges) or by connecting finders (for larger size exchanges).

In the former case, all digits following the first digit "0" are received directly by the auxiliary register.

In the latter case, a number of digits are dialled into the main register in order to allow sufficient time to permit the connecting finders to hunt and establish connection to a free auxiliary register. Thereafter, the remaining figures will be received directly by the auxiliary register, and the digits stored in the main register will be transferred to the auxiliary register consecutively. This method of operation is necessary to permit the auxiliary register to assume full control of all selections.

On automatic toll calls, therefore, the function of the main register is confined to providing access to an auxiliary register and to the setting of one or two local selectors through which the automatic toll equipment is reached.

The local registers of existing rotary exchanges which were originally designed to take care of calls within the local network only, therefore remain; but with a minor change to permit the connection of auxiliary registers.

The auxiliary register is designed with a view to providing the greatest flexibility as regards the number of digits received and selections to be made.

Calls to the automatic toll network are routed via so called "selective trunk circuits" which are multipled to the arcs of the toll line finders similar to the incoming toll lines. A selective trunk circuit contains a direction marker switch DMS which is set under the control of the auxiliary register to indicate the wanted group of outgoing toll lines.

Adaptation of rotary areas to the toll system is illustrated by Figure 10, which assumes a local network of the 7-A. rotary system. The automatic toll calls originated by the local subscribers have access to the outgoing toll lines via a level of the centralised special service 2nd group selectors, to which the selective trunk circuits are connected.

Toll operators may establish calls via individual jacks, jack finders and selective trunk circuits which have access to a group of registers. The operator's position may either be equipped with a dial or a keyset. The toll operator omits "0" as a first digit. The operator's register assumes control of the call in the same manner as the auxiliary register.

Incoming calls destined for local subscribers seize a local link circuit and a register. The latter register receives only the numerical figures of the wanted subscriber's line and controls the further local selections.

Adaptation of Step-By-Step Exchanges to the Toll System

The adaptation of step-by-step type exchanges to the automatic long distance switching system is fundamentally the problem of interworking between step-by-step and rotary systems.

It demands that a register be attached within the interdigital time of the first two figures. In the automatic long distant switching system this problem is solved by the introduction of connecting relays between the junction and the automatic toll register.

The level of the first group selector corresponding to the first figure "0" (assuming this figure to be used to indicate an automatic toll call) gives access to the automatic toll system in one of two ways determined by local conditions, as follows:

a. Selective trunk circuits which have instantaneous access to a group of registers by means of relay links (Figure 11) are provided at the step-by-step exchange. A free register is connected instantly when a selective trunk circuit is taken by the 1st group selector, the register thereupon receiving all further digits and assuming the control of the connection in the manner described for a rotary exchange.

The selective trunk circuits are connected to the arcs of toll line finders in exactly the same way as for a rotary office. These line finders are located at the toll exchange of the step-by-step type area.

By means of this arrangement, the toll centre of the step-by-step area is equivalent to that of a rotary area, and all facilities of the automatic long distance switching system are accorded to a step-by-step area.

b. Step-by-step exchanges which for some reason or another must not be provided with rotary tandem

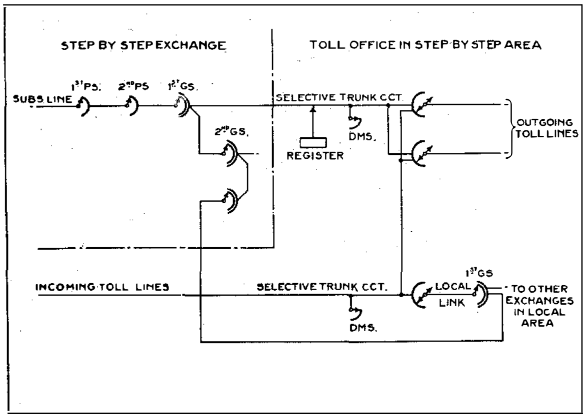

Figure 11—Adaptation of Step-by-Step Type Area (with Rotary Automatic Toll Equipment).

equipment, may be connected via toll lines directly to a toll centre provided with rotary apparatus. The incoming toll line circuits at such a rotary toll centre are similar to toll lines incoming from rotary areas except that they have access to a small group of registers by means of relay links.

One of these registers is seized instantaneously when—at the moment the toll line is picked up at the step-by-step exchange—a calling impulse is sent to the rotary exchange. All figures dialled subsequently will be stored in the register, which now assumes control of the connection and sends out the selections at the appointed time.

It will be observed that, with this scheme (illustrated in Figure 12), it will usually be necessary to introduce so-called "mixing selectors" at the toll office of the step-by-step area, so as to combine the traffic from the various local exchanges into a single group and to give each local exchange access to all toll lines. Otherwise, the outgoing toll lines would have to be split in accordance with the number of local exchanges, an arrangement which would necessarily result in reduced toll line efficiency.

Toll lines handling toll calls incoming at a step-by-step exchange may be terminated in a selective trunk circuit as shown in Figure 11, so that tandeming will be possible as for a rotary exchange. One of the directions corresponds to the local area, and the relevant finders are associated with a first selector of step-by-step type.

The register of the originating exchange repeats all figures of the wanted subscriber's number consecutively on receipt of the signal that a local link, comprising a backward hunting finder and a step-by-step first group selector, is connected to the incoming toll line.

In case the step-by-step exchange is not provided with rotary tandem equipment, the incoming toll line is directly connected to a step-by-step first group selector, as illustrated in Figure 12. In such a case, the register delivers the subscriber's number immediately after the toll line is seized at its outgoing end.

Switching of Repeaters

Telephone repeaters will be inserted, when required, by the automatic switching equipment at any of the intermediate tandem exchanges. The insertion of these repeaters is accomplished in such a manner that, as regards stability, the same degree of perfection is obtained as with permanent line repeaters. For this purpose every toll line that may be connected to a repeater is provided with its proper balancing network, which is switched with the line conductors to a repeater.

The finders associated with the outgoing toll line circuits are provided with a sufficient number of brushes to carry, in addition to the talking and signalling leads, the network leads. In this manner the repeaters are connected to one line directly and to the other line through the finder, so that the necessity that they be by-pathed across one or two selectors is overcome.

Whether a repeater is inserted at the side of the incoming line or of the outgoing toll line, is

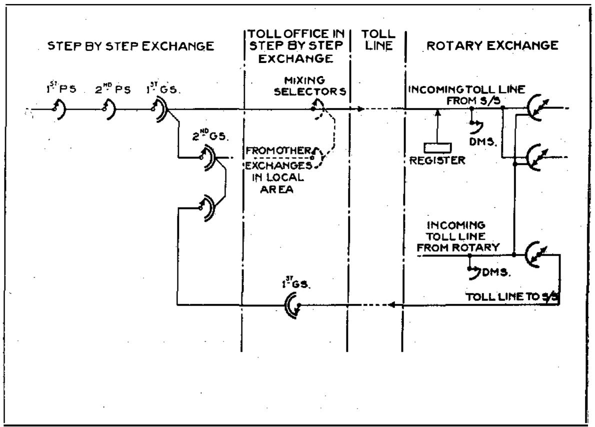

Figure 12—Adaptation of Step-by-Step Type Area (without Rotary Automatic Toll Equipment).

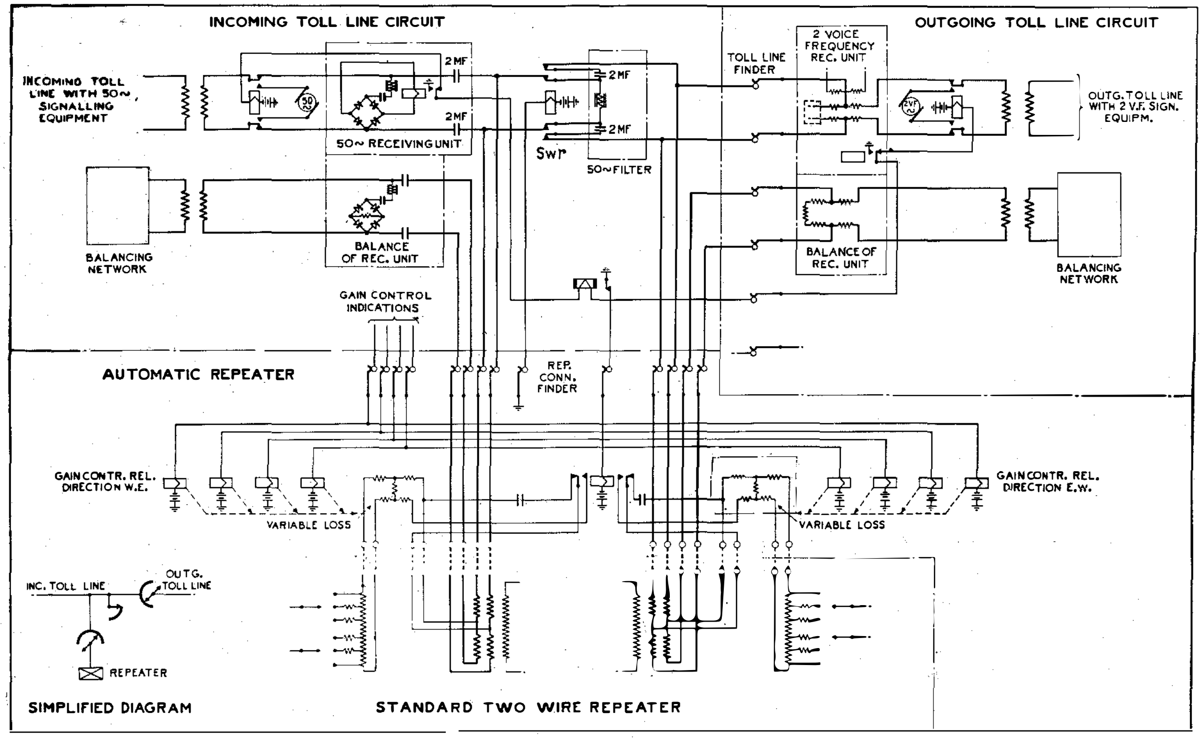

Figure 13—Insertion of Two-Wire Telephone Repeaters.

immaterial from a transmission point of view. It has been decided, on account of many practical considerations, to insert the repeater at the incoming side.

The repeater, when wanted, is called for by the incoming toll line circuit (which, besides indicating the wanted direction, also decides upon the need of a repeater) immediately after the selective series of impulses is received. The repeater connecting finders hunt simultaneously with the toll line finders of the wanted direction, and thereby save selecting time as compared with a scheme whereby the repeaters by virtue of their being associated with the outgoing toll lines can only start hunting after such line is connected to an incoming toll line circuit. This is one of the reasons why the repeaters are inserted at the side of the incoming toll lines.

The line and network circuits of the incoming toll line are connected directly via four brushes of the repeater connecting finder to the west hybrid coil of the repeater (see Figure 13).

Those of the outgoing toll line are extended via the toll line finder and four other brushes of the repeater connecting finder to the east hybrid coil.

When a repeater is connected, the relay Swr shown in Figure 13 is operated in the incoming toll line circuit and thereby opens the metallic connections to the toll line finder arc terminals, so that the talking circuit is then established through the repeater only.

Figure 13 also shows in a simplified form the manner in which the signal receiving and sending apparatus is connected in the toll lines.

The case in point depicts an incoming toll line containing 50 cycle a-c. apparatus and an outgoing toll line working with a voice frequency signalling system, so that repetition of signals by means of relays is essential. The signal repeating circuits are by-pathed across the repeater via one of the brushes of the toll line finder. During the time signals pass in either direction, the midpoints of the hybrid coils at the repeater are short-circuited, which prevents the repeater from singing owing to the disconnection from the repeater of the line at the sending side.

The signalling receiving apparatus is balanced for each line in the network circuit to ensure perfect stability under all conditions.

The 50 cycle a-c. signals received at the incoming line are so attenuated by the repeater that they do not interfere with the voice frequency equipment at the outgoing line.

In case no repeater is connected, the relay Swr is non-operated, thus providing a direct metallic circuit between the "a" and "b" wires of the incoming and outgoing toll lines.

When no repeater is connected in the case of an incoming 50 cycle line, a 50 cycle filter is provided to prevent the 50 cycle signals from reaching the signalling equipment at the outgoing line.

When two lines which both work on voice frequency signalling currents are interconnected, the signals need not be relayed around, but pass through the repeater where they regain the necessary strength to produce the operation of the signal receiving apparatus at the far end. In such a case the voice frequency sending and receiving equipment at the outgoing line is automatically disabled and the receiving equipment at the incoming end is left connected only for the purpose of responding to the release signal.

Switching of Four-Wire Lines

So far, switching of two-wire repeaters has been discussed; the system is, however, capable of switching four-wire circuits equally well.

Two four-wire lines may be switched without the insertion of an automatic repeater by simply providing metallic connections between the two lines by means of four brushes of the toll line finders.

Incoming four-wire toll lines may be switched to a two-wire outgoing circuit in the manner indicated in principle in Figure 14. In such a case an intermediate repeater will usually need to be inserted. This repeater is switched precisely the same as has been shown by Figure 13. Figure 14 shows the talking circuits only.

The dotted connections on Figure 14 refer to the case where the four-wire incoming toll line

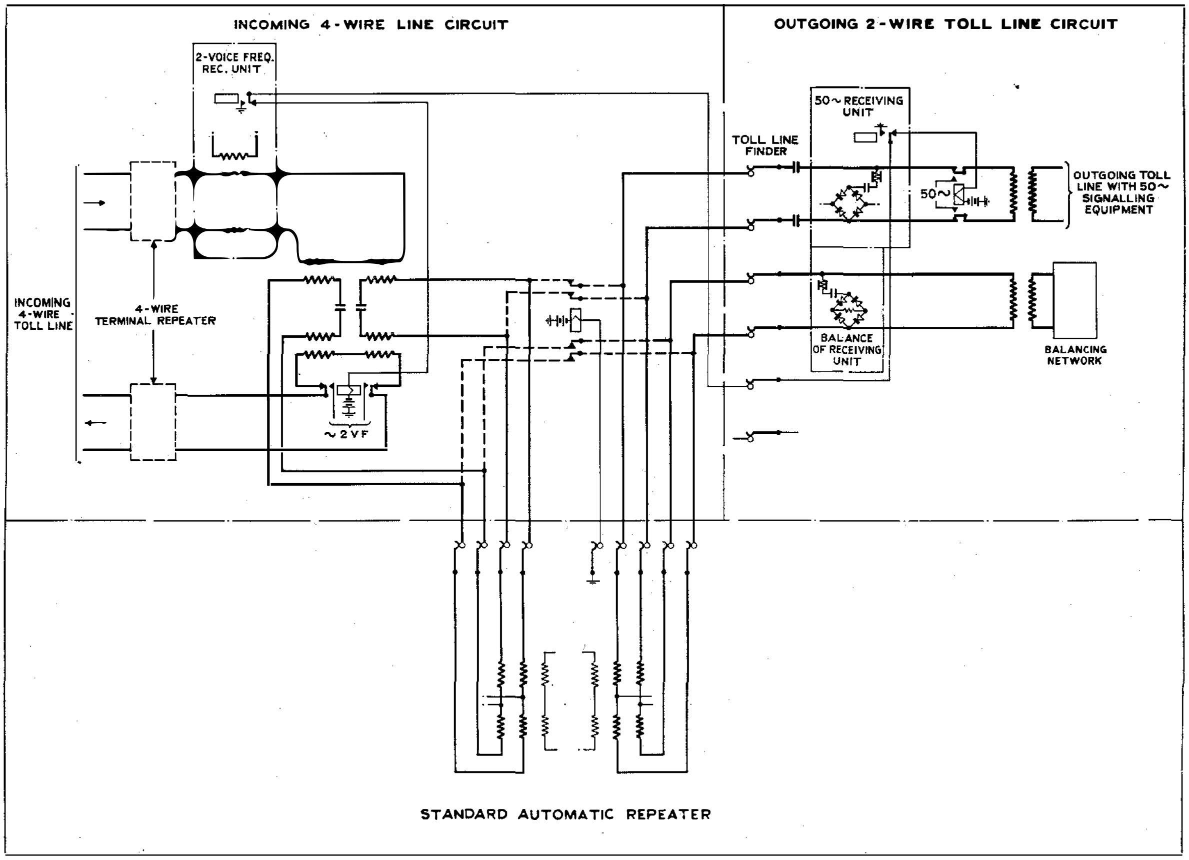

Figure 14—Connection between a Four- and Two-Wire Circuit.

has to be switched without the introduction of an intermediate repeater, a condition which may obtain for calls terminating at the home toll centre.

The connection of an incoming two-wire circuit to a four-wire outgoing circuit occurs in a manner similar to that indicated in Figure 14.

Repeater Gain

The insertion of switched telephone repeaters introduced the entirely new problem of fixing the repeater gain by means of automatic apparatus. This demanded that certain definite arrangements be incorporated in the design of the automatic circuits which, when followed mechanically by the gain control apparatus, ensured correct overall transmission loss, perfect intelligibility, freedom from noise and a stable connection.

In the automatic long distance switching system, the gain of the repeater will be equal for both directions and is automatically fixed in accordance with the following two distinct rules:

A. On calls tandemed through primary or secondary toll centres, the gain of the repeater will equal the loss of the incoming toll line, except in case of the connections mentioned under B.

B. The last repeater of a connection will have a gain equalling the sum of the losses of the two toll lines to which it is connected, decreased by 9 db.

After an incoming toll line is seized by a repeater, the toll line circuit will signal its loss to the gain control apparatus associated with the repeater. The means required in the toll line circuit to send this signal and the automatic apparatus needed in the switched repeater to receive this signal via a limited number of brushes of the connecting finder, also the apparatus controlling the gain of the repeater, are of an extremely simple nature.

The gain of all repeaters engaged on a connection with the exception of the last is, therefore, fixed in accordance with rule A. To fix the gain of the last repeater, the incoming toll line circuit must be notified of the fact that the tandem call by which it is seized, terminates at the following toll exchange. This fact is indicated to the incoming toll line circuit by the position of the direction marker switch in the following manner:

When the call is directed to a tertiary exchange, the incoming toll line circuit is informed *ipso facto* by the position of the marker.

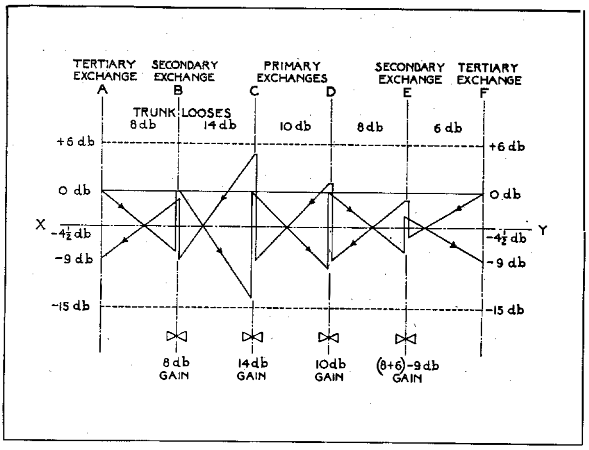

Figure 15—Transmission Diagram.

When the call is directed to a primary or secondary exchange and terminates there, the register notifies the incoming toll line circuit by sending a special selection. This selection differs from the one the controlling register would send for selecting the same direction on calls tandemed through the following exchange.

For certain positions of the direction marker switch, therefore, the gain control equipment forming part of a switched repeater circuit will also receive a signal indicating the loss of the outgoing toll line. When such second signal is received, the gain control apparatus will automatically change the gain of the repeater from a value equalling the loss of the incoming trunk to a value equalling the sum of the losses of both toll lines decreased by 9 db.

From the above it will be evident that the repeaters inserted in a connection all have a gain which offsets the loss of their incoming toll lines with the exception of the last repeater, which brings the overall transmission loss down to 9 db. This figure of 9 db. for the overall loss is arrived at from several considerations, as discussed hereinafter.

When fixing the gain of several two-wire repeaters placed in series in accordance with a certain rule, for example with the one mentioned above under A, the transmission limits of the repeaters (+6 db. and −15 db.) are observed in the forward direction of the call, provided that none of the toll lines has a loss exceeding 15 db.

When tracing the transmission diagram for the same connection but in the backward direction of the call, it will be evident that the transmission diagram can only be kept within the repeater limits when the overall transmission loss lies within the limits of 9 and 15 db.

Figure 15 demonstrates this. In this figure the transmission diagrams for both directions are shown superimposed. It appears that the one curve represents the reflexion of the second curve in respect to line X-Y, i.e., any point on one of the curves which lies above X-Y has its corresponding point on the second curve below this line and the reverse. It will be recognised from this fact that by choosing the position of X-Y such that it lies exactly equidistant between the limits of a repeater, i.e., at 4.5 db. below the "0" line, the possibility is excluded that a correct diagram for the forward direction of the call leads to an incorrect diagram for the opposite direction of the connection.

The location of line X-Y is determined by one factor only, i.e., the overall transmission loss and it follows that the minimum value of the overall transmission loss should be equal to 9 db. in order to ensure that the limits of the repeaters are observed.

Automatic Long Distance Switching

Impulse Transmission

By S. VAN MIERLO and T. S. SKILLMAN, M.A.

General

THE requirements of signalling systems on long telephone lines are dictated primarily by the operating methods employed. Until recently ringdown methods have been generally used, with the result that ringer panels designed to transmit and receive only a ringing signal have become standardised. The methods employed are 500 p:s signalling for long repeatered lines, and 16 to 25 p:s signalling for shorter lines.

Now that the programmes for automatisation of local networks are well advanced, it has become clear that important savings in line plant and operating costs are to be obtained by the completion of long distance calls by automatic or semi-automatic methods. Administrations in many countries now give one operator complete control of a connection with facilities for dialling into distant automatic areas, while in several cases full subscriber-to-subscriber working is being developed.

These changes in operating method lead to considerable complications in the signalling requirements. The simple ringer panel is replaced by a receiver which will reproduce dialling impulses and which is associated with a comparatively large relay group to give control and supervision.

On shorter lines, previously worked on a 16 p:s basis, 50 p:s signalling has been widely adopted. On longer lines the limitations of voice frequency signalling with regard to false operation on voice currents have led to the adoption of multi-frequency systems in which each signal consists of two frequencies transmitted simultaneously. Such signals occur comparatively rarely in speech currents and serve to simplify the construction of the receiver and its relay group.

The primary problem on low frequency systems is the transmission of the impulses. The associated signals can readily be obtained by means of series of short impulses or by short and long impulses. In voice frequency systems, on the other hand, the transmission of impulses without distortion presents no difficulty, requiring only a straight detector with some means, such as a limiting tube or a saturated relay, to avoid distortion due to level changes. The problem in this case is primarily that of avoiding the generation of false impulses by voice and noise currents and the transmission of the control and supervisory signals without mutual interference between signals and without demanding excessively long sending and receiving times.

In connection with the general subject of this paper, the reader is also referred to an interesting and important article in *Technische Mitteilungen,* No. 6, December, 1933, "Städtewahl und Schnelldienst in Basel," (La sélection intervilles et le service rapide à Bâle) by E. Frey.

LOW FREQUENCY SYSTEMS

Choice of Frequency

The a-c. from ringing machines has too low a frequency to permit dialling at an average speed of 10 steps per second. The impulses would be greatly distorted, their length at the receiving relay depending to a large extent upon the moment at which the sending a-c. is closed and opened.

With a frequency of 50 cycles, this distortion may still be as high as 10 ms. (milliseconds) at the closure and 6 ms. at the opening, but as currents of such a frequency can be obtained from most light or power mains, it was, of course, desirable to adopt it when possible. The main trouble is that the consecutive impulses are not distorted the same way. As the dial speed is usually not exactly 10 and the a-c. frequency not exactly 50, the distortion varies from one impulse to the next one. The result is that the received impulses have not the same duration and are not equally spaced.

For the distortion due to this source to be reduced, it would be necessary to use higher frequencies. It is, however, important to keep in mind that the permissible amplitude of the line current depends on the frequency. The following table is an extract from that given in the C.C.I. proceedings of 1931 and shows the relative weighting of the disturbing effect due to different frequencies.

Frequency	Weighting in db.
16⅔	−84.4
50	−54
60	−48
100	−33
150	−22.2
200	−18
300	−15.5

While it is therefore possible to use rather strong 50 cycle currents, the intensity at 100 or 200 cycles for instance should be kept much lower. It should, however, be mentioned that the noise is not only due to the fundamental frequency, but to the transients occurring at the beginning and the end of the signals.

The choice of 50 cycles makes it possible to use at the receiving end a relay needing no delicate adjustment. As the current for a frequency of 100 or 200 cycles would have to be much smaller, the adjustment would be more difficult and the maintenance would be increased.

Source of 50 Cycle Current

In most cases a-c. mains are available. It is, of course, desirable to have some reserve source and sometimes a motor generator operated from the battery may have to be considered. In most cases voltage variations of ±10% and frequency variations of ±1% have to be reckoned with. We will see further the effect of these variations and that it would be desirable to reduce them. The interconnection of large power stations and the narrow frequency regulation which is now introduced in many cases will improve conditions.

Small harmonics have little importance as regards dialling, but will increase the noise. From the above table it is seen that the influence of the third harmonic, 150, can be important.

Transmission over the Long Distance Line

The 50 cycle current is, of course, attenuated by the repeating coils and the line. The loss in the repeating coils varies with the strength of the current. In the case of loaded cables it is satisfactory to use the normal voice frequency inductance of the coils to calculate the attenuation for 50 cycles.

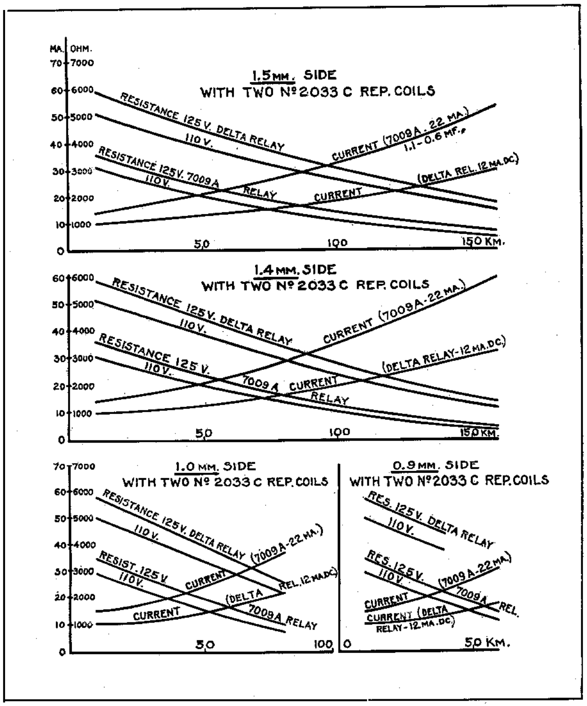

Figure 1—Current at the Sending End of the Line and Approximate Value of Resistance to be Placed in Series with the Repeating Coil.

When 50 cycle long distance dialling was first applied, rather high line currents and voltages were accepted. This was to a certain extent permissible as the number of circuits was small. But with the gradual increase in traffic it became advisable to reduce the currents as much as possible and it now seems desirable to keep the value of 50 volts maximum at the sending end of the line, determined by the C.C.I. for simultaneous telephony and telegraphy. The maximum current should be about 25 mA.

At the sending end a resistance is introduced in series with the mains in order to adjust the line current in such a way that the current in the receiving apparatus has a specified value. It is necessary to always keep several hundred ohms in series, in order to avoid heavy transients at the closure and opening of the current.

Figure 1 indicates the approximate current and resistance at the sending end for various types of cables in function of their lengths and for the two types of receiving apparatus described below.

Receiving Apparatus

Two classes of relays are used for the reception of the impulses:

A-C. Relays

In this case, several solutions are possible in order to obtain a steady pull on the armature, for instance,

a. Two mechanically coupled relays with 90° phase angle difference between the currents.
b. A single relay with two magnetic circuits and common armature, the two magnetic fluxes having about 90° phase angle difference.
c. A single relay with shaded pole.

Solution (b) has been adopted and will be considered further below.

D-C. Relays

Instead of using a-c. directly it is possible to rectify it first and operate a d-c. relay.

Relay with Double Magnetic Circuit

This is in fact a double relay with a common armature and contact arrangement. In order to reduce the variations of the pull on the armature, it is necessary to have a difference between the phase angles of the currents flowing through the two windings. This can be obtained by condensers and one of the most usual arrangements is to have two identical windings and different condensers in series with each windings.

At first sight one would believe that the phase angle between the currents should be 90° to obtain the best results. In fact, the operation is quite complicated as there is some leakage and interaction between the two magnetic circuits. When determining experimentally the values of the condensers which give the smallest armature vibrations and permit the largest variations of current and frequency without objectionable distortion of impulses, it appears that the difference in phase angle should not be 90°.

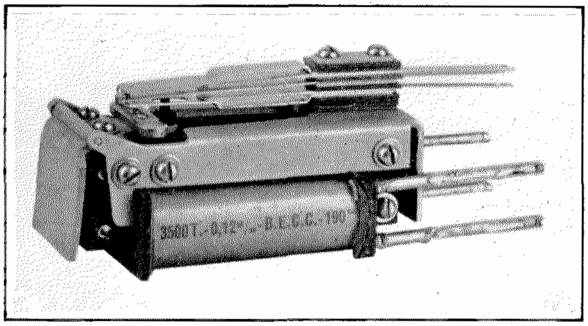

Figure 2—Fifty Cycle Relay.

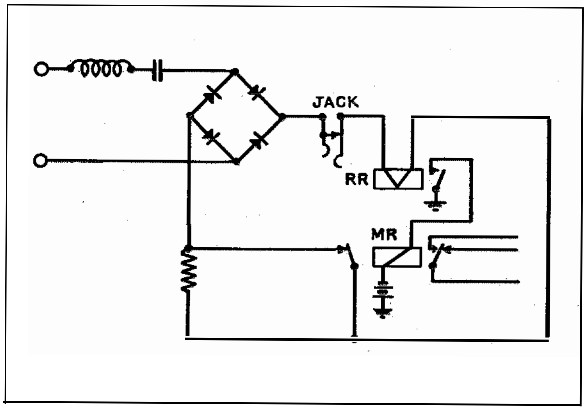

Figure 3—Typical Connections for Line Equipment.

A number of factors have to be observed to obtain the most satisfactory operation. It is important to avoid all short circuits in the windings and to have an exact number of turns. In order to reduce impulse distortion it is necessary to use relatively large air gaps and back pressures, making the relay less sensitive than in the case where no timing requirements have to be met. The position of the armature should be such that the air gaps are always equal for both magnetic circuits. The condensers should have rather narrow capacity limits.

When the above points are observed, the influence upon the relay of voltage and frequency variations and of the type of cable or line used, is reduced to its minimum value. The difference between the current in the operated and non-operated positions will also be rather small, for instance, of the order of 10%. The line current should preferably be adjusted with the relay in the non-operated position.

In one case a screw adjustment has been provided. A more recent type is simpler and more easy to construct and the use of flexible springs is in some respects to be preferred. This later type is shown by Figure 2.

Relays with a double magnetic circuit have been used quite extensively and have in general given satisfactory service if well manufactured. The general disadvantage is that they need quite a large amount of energy to give contact pressures above 10 grs. and small impulse distortion.

Their efficiency is low, partly because large air gaps are needed.

The transmission loss caused by these relays is of the order of 0.1 decibel at 1000 cycles.

When the increased use of 50 cycle dialling made it necessary to reduce the line currents, a more efficient receiving arrangement had to be developed. One of these is described below.

D-C. Relay with Rectifier

In principle this solution is very simple, but in practice there are a number of difficulties to overcome to obtain good results.

After careful examination of different arrangements, the circuit shown by Figure 3 has been adopted. A rectifier with bridge connection has been preferred over the arrangement where two rectifiers are connected in series with the two windings of a d-c. relay. In this latter case only half the winding space of the relay is used effectively. A higher current or a larger relay is therefore needed.

The use of a bridge in series with a retardation coil and condenser makes it possible to increase the 50 cycle efficiency of the receiving equipment to its maximum value and to decrease at the same time the transmission loss for speech currents to a very small amount, as shown by the table below for an office impedance of 600 ohms.

Frequency	Loss in Decibels
300	0.4
1000	0.06
2000	0.02

A jack is preferably connected in series with the RR relay so that the d-c. current received by this relay can be checked at any time. This measurement is more important than that of the a-c. current supplied to the rectifier and checks the retardation coil, condenser and rectifier.

The d-c. received by the relay depends on the voltage and frequency of the supply. The curves in Figure 4 show the variations in the current received by the d-c. relay when the mains potential and frequency change. These are average values for side and phantom circuits of 130 km. 1.5 mm. The difference between the currents in both types of circuits is very small.

In most cases the 50 cycle mains do not vary more than 1% in frequency and the current variation due to this cause can then be neglected in view of the much larger variations with voltage. Frequency variations cause changes in the received current for the following reasons:

1. The attenuation of the cable for frequencies of about 50 cycles is nearly proportional to the square root of the frequency.
2. The losses in the repeating coils vary somewhat.
3. The impedance of the receiving equipment changes.

It would be possible to compensate to some extent the variable attenuation of the cable by choosing appropriate values for the retardation coil and condenser. This would, however, make the receiving equipment less efficient. Further, a decrease in potential will usually occur together with a decrease in frequency and this latter compensates to a certain extent the effect of the former.

The best value of retardation coil and condenser depends to some extent on the type and length of the cable. As the tuning is, however, not sharp, it has been found sufficient to adopt a single value for all cases. If it appears necessary in some cases to use a more refined equipment, the simplest solution is to use a retardation coil with three tappings, so that the inductance can be adjusted to nearly the best value in each particular case.

One of the difficulties of a dialling equipment using a rectifier is to reduce the releasing time of

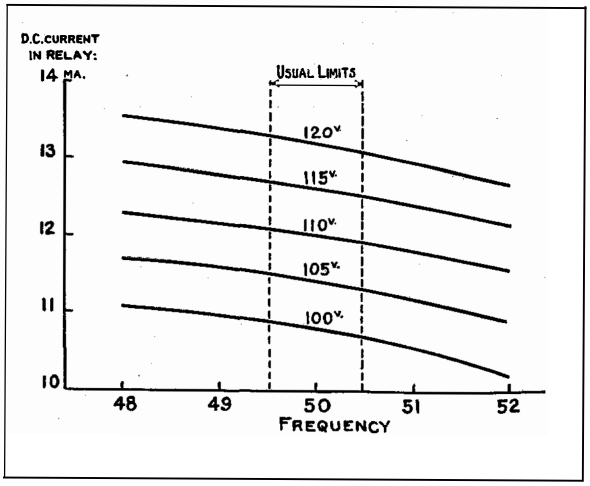

Figure 4—Variations of d-c. Current in Relay Due to Variations in Mains Voltage and Frequency.

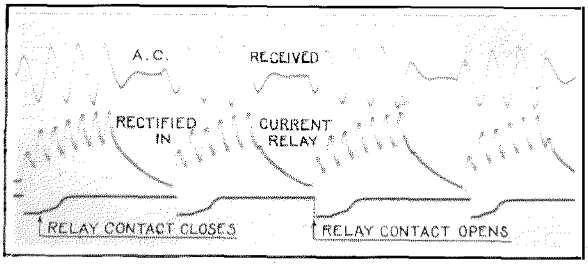

Figure 5—Relay Operation without Series Resistance.

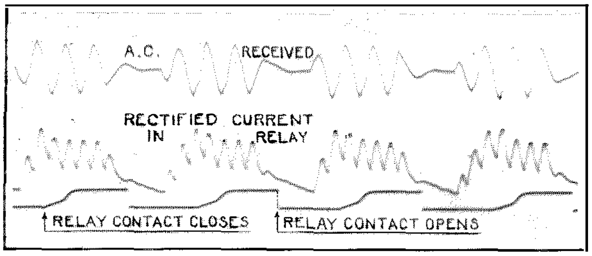

Figure 6—Relay Operation with Series Resistance.

the d-c. relay to a satisfactory value and in such a manner that the time is not too much influenced by a change in adjustment or current. This relay is shunted by the rectifier and if no special precautions are taken, the releasing time is too long and too variable. The oscillogram, Figure 5, shows how the current varies in the relay when 50 cycle impulses are sent over the line and when the d-c. relay is connected directly to the rectifier. It will be seen that the time needed by the current to reach the releasing value is rather large.

Several arrangements to improve these conditions have been examined and it was finally decided to adopt the circuit shown by Figure 3, in which the operation of the relay introduces a resistance to quicken release. The oscillogram, Figure 6, shows the current in the adopted circuit. The releasing time is reduced a good deal and is less variable.

The d-c. relay connected to the rectifier is of the flat type ("Delta" type in Figure 1) having adjusting screws and provided with a follow spring. As the front contact only is used, it is not difficult to obtain a satisfactory operation and easy adjustment. Life tests, including heating-up of the relay, have shown that after millions of operations the contact is still good and the timing little affected. Field tests under normal service conditions have confirmed this. In order to reduce variations in the impulses, contact chatter has been eliminated by using a flexible spring on the armature. Heavy contacts are provided to reduce the wear.

Adjustment of Line Current

The normal current which the RR relay should receive in the circuit is 12 mA. before the introduction of the resistance. In this case, the a-c. voltage should be 11 volts maximum at the line terminals of the circuit shown in Figure 3.

The sending current has to be adjusted to obtain this value, the relay being kept in the non-operated position. If the potential and frequency of the 50 cycle mains differ from normal, the receiving current is adjusted to a value obtained from curves similar to those shown in Figure 4. In the absence of such curves it is sufficient to make a correction proportional to voltage and inversely proportional to frequency.

When checking currents during maintenance it is not necessary to readjust the current when the value does not differ by more than 5% from the values given above.

50 Cycle Dialling Through Repeater Stations

In view of the low cost it is attractive in the case of short repeatered lines to retain the 50 cycle dialling system. The additional repetition is, however, likely to increase the distortion of the impulses and the percentage of faults. The problem is particularly difficult when the line current has to be kept below 25 mA.

The easiest solution is to connect the 50 cycle equipment in bridge with the line before the repeating coil. The contact of the relay then controls a second relay sending fresh 50 cycle current to the outgoing line. The main objection to this arrangement is that the exchange equipment is no longer protected by the repeating coil against high voltage charges of the line.

A second solution is to place the 50 cycle relay across the line circuit after the repeating coil. In order to reduce the shunting effect of the repeater, it is then necessary to use two balanced 2 mf. condensers between the relay and the hybrid coil. It is further necessary to balance the 50 cycle equipment and condensers on the network side. All this may need additional cabling and wiring. When the 50 cycle equipment must be associated with the line, as for instance in case of automatic insertion of repeaters, this solution is indicated.

The solution adopted in other cases consists in placing a low impedance 50 cycle equipment in parallel with the input potentiometer of the repeater. Two 2 mf. condensers are inserted to reduce the shunting effect of the potentiometer. This solution avoids the above mentioned objections and makes it possible to replace the existing 20 cycle ringing panel by a dialling panel without any other change. The only inconvenience is that the line current needs to be some 10% higher than when the equipment is connected immediately after the repeating coil.

The 50 cycle signals are sent both ways through the repeater stations and in some cases the discharge of the cable at the end of a signal sent in one direction affects the receiving relay of the other direction. To avoid any false operation due to this effect, an additional relay has been provided.

It should be mentioned that the incoming 50 cycle current is also amplified by the repeater and this current added to the fresh 50 cycle current causes amplitude variations in the outgoing current. The frequency of these variations corresponds, of course, to the difference between the frequencies of the two 50 cycle sources. The current variation may be of the order of 15% and is an additional cause of distortion of impulses which does not exist in non-repeatered lines.

Timing

The complete 50 cycle dialling system contains many variable factors influencing the timing of the impulses. Each installation has to be studied as a whole and the available limits distributed in such a way as to make the installation the cheapest possible as regards first cost and maintenance for a given probable percent of faults.

The following causes of distortion of the impulses have to be considered:

1. Variation in speed of the dial or impulse sender.
2. Variation in ratio of closure to opening of dial or impulse sender.
3. The use of 50 cycle current
4. Variations in potential and frequency of the 50 cycle course.
5. Line distortion.
6. The initial adjustment and variations of adjustment of all stepping relays.

It will be interesting to examine the distortions introduced by these various factors in a typical case. The nominal speed of the dials was 10 steps per second with a maximum of 12. The ratio of closure to opening was normally 1.6/1 with variations of 1.3/1 to 1.9/1. The receiving equipment needed a closure of minimum 10 ms. and an opening of minimum 24 ms. The mains potential could vary about 10% and the frequency about 1%. With these figures and some measurements, the following tables could be prepared:

MINIMUM CLOSURE AND OPENING OF THE DIAL

	Minimum Closure	Minimum Opening
Normal dial: 10 steps; ratio 1.6/1	61.5	38.5
12 steps dial; ratio 1.6/1........	51.3	32.0
12 steps dial; ratio 1.3/1........	47.1	
12 steps dial; ratio 1.9/1........		28.8

MARGINS OF OPERATION

	Milli-seconds	Per Cent.
Total margin available: (61.5-10+38.5-24)...........	66	100%
Part of margin absorbed by speed variation of dial (100-51.3-32).	16.7	25%
Part of margin absorbed by ratio variation (51.3−47.1+32−28.8).......................	7.4	11%
Part of margin absorbed by the use of 50 cycles..............	16.0	24%
Part of margin absorbed by the variations of the mains.......	13.0	20%
Total absorbed by dial and mains	53.1	80%
Margin left for stepping relays..	12.9	20%

The results of this computation can be visualised in Figure 7.

It should be noted that there were at least three relays following the dialling impulses: one at the sending end to connect the 50 cycle current to the line and two at the receiving end. It happened that the margin remaining for these relays was sufficient to guarantee a faultless operation without special maintenance. If an additional repetition of impulses is wanted at a repeater station there is, however, no margin left. As we have seen above, the modulation of the 50 cycle current by the repeater is a cause of

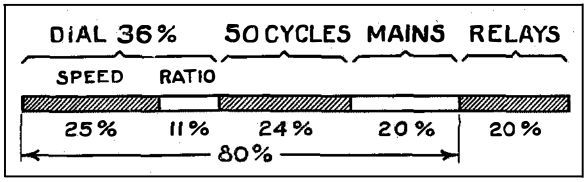

Figure 7

distortion which has to be added to that due to the additional relays.

The probability that all causes of distortion have their maximum effect simultaneously is not very small. One has indeed to bear in mind that any dial is more or less irregular in operation and that the 50 cycle effect and that of the mains variations are continuous. As the effect of the line upon the distortion has been neglected, it seems reasonable to proceed as shown in Figure 7, i.e., to take the sum of the partial distortion in order to estimate the margins left for the other parts of the system.

Experience has shown that the total number of faults with rotary equipment at each end can be kept near 0.5% without special maintenance. With an additional repetition, the number of faults would, of course, increase.

It is possible to have more uniform signals (not spacings) by the use of pulse correctors, but this practice cannot always be recommended. At repeater stations, for instance, it is desirable to reduce the number of relays as much as possible and to avoid the need of readjustments, as no skilled relay adjusters may be available.

The above example shows that much can be gained by taking more care of the dial and the mains. It seems illogical to provide operators with a dial which is designed for use by subscribers. The apparatus controlled by the operator to send the impulses need not be extremely cheap and as it is submitted to continuous operation and should give very uniform impulses, it would be better to make use of a special impulse sender. This solution would give more margin to the other parts of the system, particularly the relays.

In case of subscriber dialling, the conditions are better as the impulses in the long distance line are then obtained from an impulse sender at the central office. These impulses are less distorted than when an operator is sending with a dial.

VOICE FREQUENCY SYSTEMS

The experience gained on 50 p:s dialling has shown very clearly the value of automatic switching methods on longer circuits. As a result, many routes involving signalling over a number of repeaters are now being converted to these methods. The widespread use of 50 p:s methods on the shorter lines has led to a demand for a voice frequency signalling system in which the same signalling methods are employed, so that the same, or similar, signalling and switching circuits can be used. The ideal voice frequency signalling method for such cases is one that can be introduced into an area already using 50 p:s dialling by the simple substitution of a voice frequency detector in place of the 50 p:s relay. This would enable the relay equipment and the maintenance methods to be identical for all long distance lines.

The use of voice frequency current, however, introduces a problem not met with in 50 p:s circuits. The danger of interference with neighbouring circuits necessitates the use of small line currents, comparable with the currents occurring during conversation, and as a result the necessarily sensitive receiver may be operated by voice currents, automatic tones, d-c. surges in the line or even by noise. Many ways of overcoming this are available, but the more practical methods demand in all cases the use of a time delay so that short false operations of the receiver are ineffective in producing a signal, and for this reason complete interchangeability with 50 p:s equipments is rendered difficult. Nevertheless, recent developments have resulted in a new voice frequency signalling system in which close similarity to 50 p:s equipments in circuits and signalling methods is obtained. This system may be termed the two frequency system.

The Two Frequency System

This system is a modification of the four frequency system[1] in that all signals are sent by means of the same two frequencies instead of by different two frequency combinations for different signals. The receiver is designed so that

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[1] T. S. Skillman, M.A., "The Four Frequency Signalling System," *Electrical Communication*, July, 1930.

both frequencies must be present for a minimum time in order to produce a signal. The spacing between the frequencies, and their position in the frequency band, are so chosen that this condition is not fulfilled by voice currents, so that no false operations occur.

One of the first commercial installations working on this principle was made by the Societa Telefonica Tirrena, the Concessionaires of the Italian Fourth Zone. In this case, in order to use the 50 p:s relay groups already available, a number of four frequency units were modified so that the same combination of two frequencies was sent for all signals. The different signals are identified by the duration of the impulses and the number of impulses in exactly the same way as on the 50 p:s circuits.

An improved receiving unit using the two frequency principle has been produced by the Suddeutsche Apparate Fabrik of Nuremberg in conjunction with the Bavarian Telephone Administration. This is working in Bavaria, and has also received a trial in service on a line between Basle and Zurich. In a somewhat modified form, this type of receiver is now being installed on the lines between Brussels-Antwerp-Verviers.

Operation of Receiver

The circuit of this modified receiver is shown in Figure 8, and a photograph in Figure 9.

The principle used is that of double detection, the first detection being used to produce a frequency equal to the difference between the two received frequencies, and the second detection being used to produce continuous current in the output relay. A filter is connected before each detector, the first filter serving to check that the two frequencies lie within the proper range, and the second filter serving to check that the difference of the two frequencies is also in the proper range.

In this receiver an additional voice protection feature has been introduced by providing a limiting amplifier so arranged that the output is largely independent of the input. With such an arrangement, since the total output is fixed, the output at the signalling frequencies will be reduced when other frequencies are present. If in

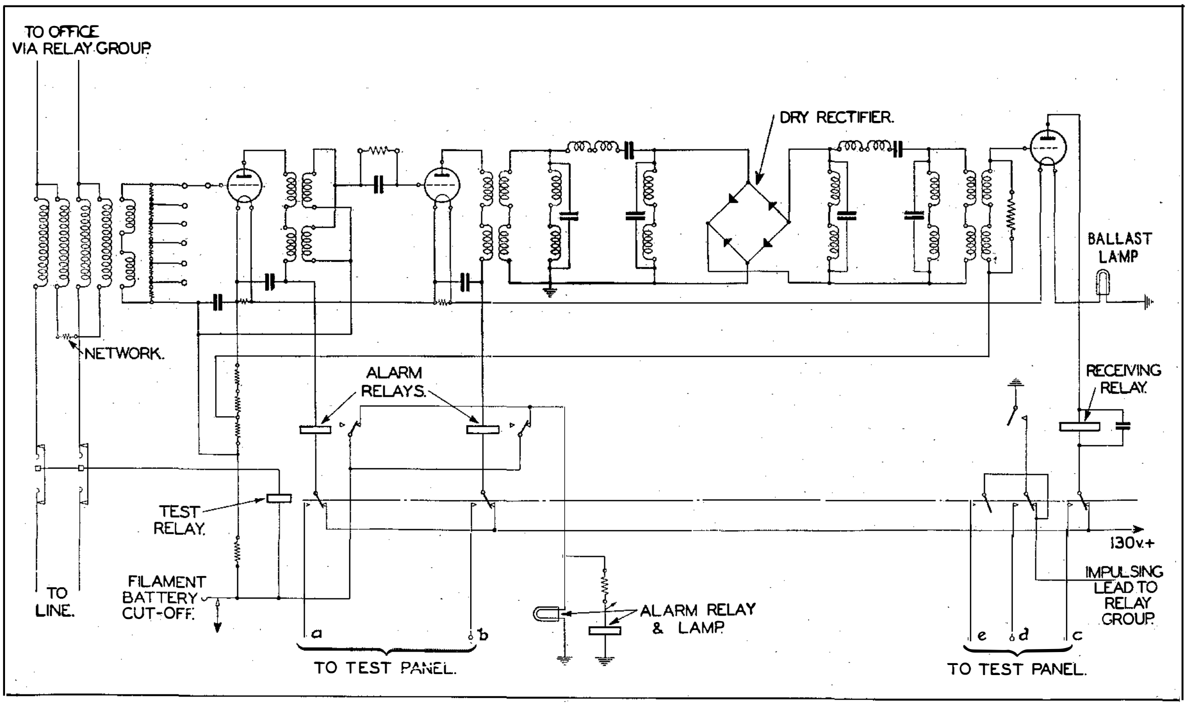

Figure 8—Schematic of Two Frequency Detector for V.F. Dialling.

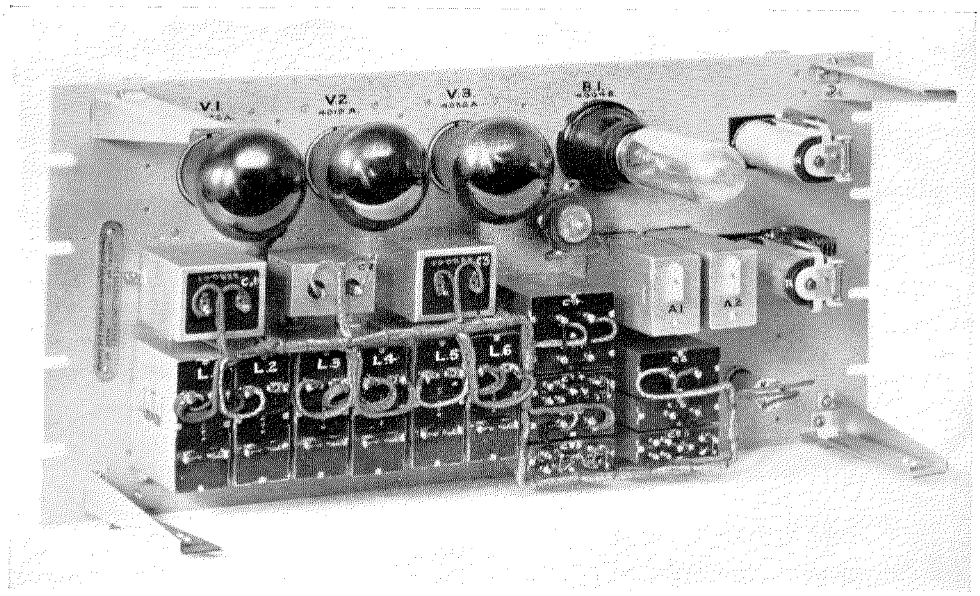

Figure 9—Two Frequency Detector for V.F. Dialling.

voice currents the energy of the unwanted frequencies is large compared with the energy at the effective frequencies, then even if the 600+750 p:s combination occurs, it will be passed to the filter at too low a level to operate the receiver. Thus an extra guard is produced against false operation.

A further protection against voice currents of considerable value is the combined hybrid coil and input transformer, which prevents voice currents originating on the office side from reaching the signalling equipment. In this way high level voice currents are prevented from reaching the receiver, except in low loss circuits where, of course, the sensitivity of the receiver can be proportionately reduced.

An input potentiometer is provided which enables the sensitivity to be adjusted by strapping on the terminal block.

The received signal is amplified by the first and second tubes of the receiver in the usual way, the second tube acting as a limiting amplifier by reason of the large grid swing impressed upon it. The grid condenser and leak cause the biassing voltage to increase as the magnitude of the signal increases, and thus to reduce the gain of the tube in the well-known manner. The output of this limiting tube is impressed upon the first filter, which passes 600 p:s and 750 p:s plus a frequency band on either side of these two frequencies to permit the dialling side-bands to pass. A typical characteristic of this filter is shown in Figure 10. The output from the voice frequency filter is rectified by a dry rectifier of the bridge type, and passes to a low frequency filter having a characteristic of which that shown in Figure 10 is a typical example. The impedances of the filters are chosen to give a non-matched termination to the voice frequency filter, resulting in a square characteristic of the kind shown in Figure 10.

The 150 p:s output from the low frequency filter is impressed upon the grid of the detector tube on the right-hand side of the panel. The resultant increase in plate current is used to operate the standard automatic relay shown in the top right-hand corner of the panel in Figure 9. This relay, therefore, operates whenever 600 p:s and 750 p:s are impressed simultaneously upon the input of the receiver. During conver-

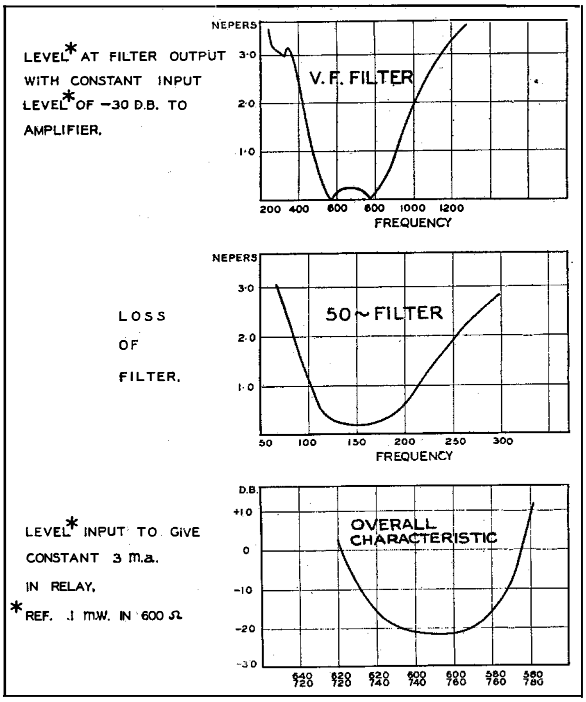

Figure 10—Filter Characteristics.

sation the relay operates intermittently but never for a sufficient length of time to affect the relay groups which are associated with its contacts.

When dialling impulses are received the relay repeats these with negligible distortion. The absence of distortion is secured partly by providing ample ampere turns to the relay, and partly by the action of the limiting tube which prevents excessive variation in current supplied to the relay. Figure 11 shows the current in the relay with different input levels and it will be seen that there is no special difficulty in obtaining good impulsing over the working range of levels.

Line Conditions

As previously mentioned, the receiver is adjusted individually to suit the attenuation of the line, thus ensuring optimum working conditions. This is a very simple operation which can be carried out by reference to a record of line attenuations, without any experimental work. It seems that this procedure should be adopted as a point of principle for all signalling equipment.

The sending level used has to be as low as possible from the point of view of interference, but as high as possible from the point of view of using an insensitive receiver to reduce the time delay necessary to obtain freedom from voice operation. A compromise between these considerations has to be made, and it is proposed at present to use a sending level of 2.5 m.w. per frequency at a point of zero planning level.

The transmission loss produced by the signalling equipment is of the order of 0.5 db. and is practically independent of frequency. It can thus be compensated by an increase in the repeater gain and no difficulty arises in balancing the equipment, when required, for cord circuit repeater purposes.

Equipment Arrangements

The general equipment arrangement of the signalling unit will be gathered from Figure 9. It will be observed that the alarm relays, filament ballast lamps and test relay are all included on the panel so as to avoid the provision of any external apparatus. The talking circuit is brought through the panel so that no circuit corresponding to the cut-off relay on the 500 p:s ringer panel exists. Associated with each signalling unit is a relay group, the nature of which depends upon the local automatic exchange, the operating method employed and the toll board. This relay group controls the transmission of signals, suppresses d-c. surges which are likely to affect the equipment, and receives the signals from the impulsing relay and changes them to a form suitable for the automatic equipment.

Associated with the panels are patching jacks

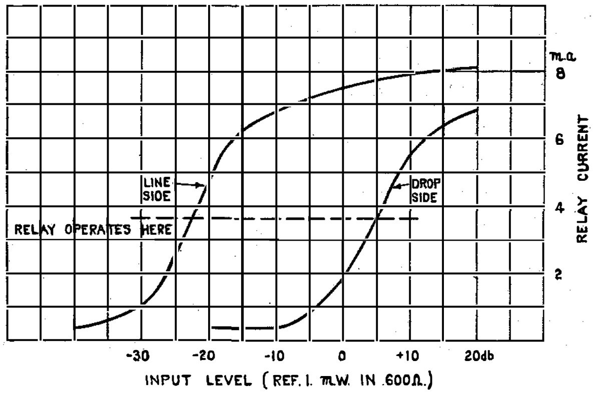

Figure 11—Relay Current v. Input.

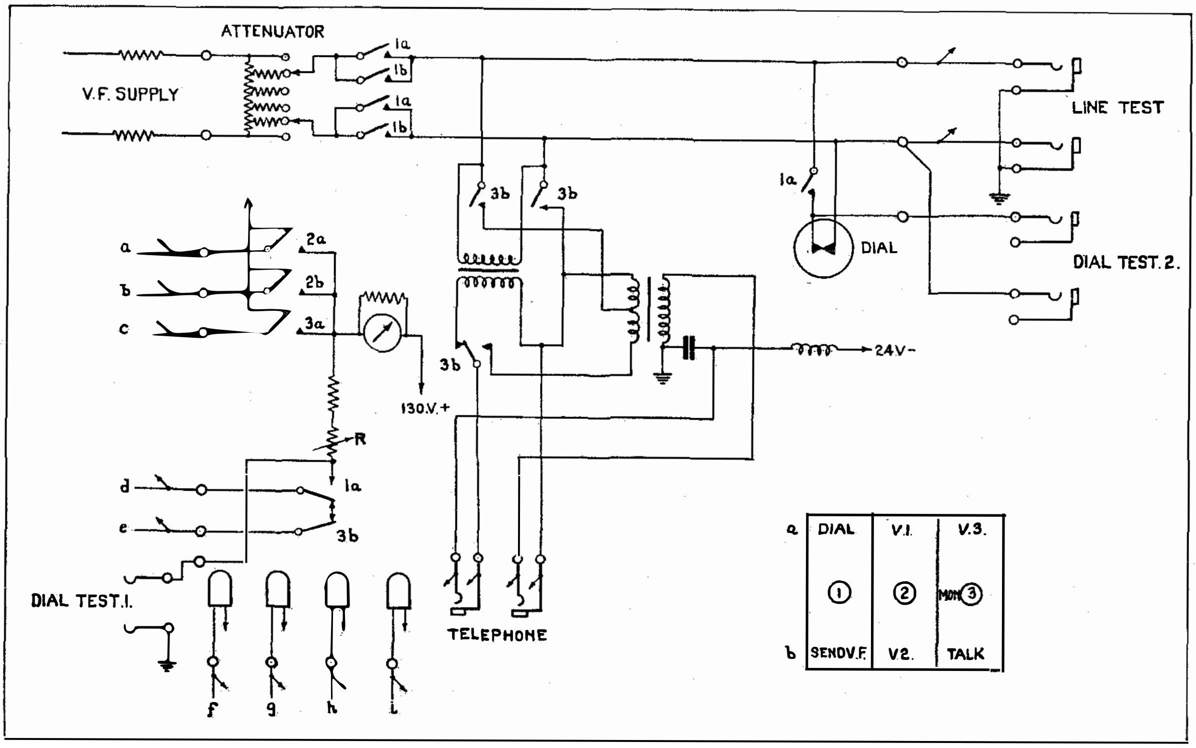

Figure 12—Test Panel for V.F. Dialling Equipment.

of the kind used on repeaters, and patching can be carried out in the usual manner. These patching jacks are indicated in Figure 8. Patching on the office side is not normally provided, owing to the fact that the relay group on incoming circuits is provided with access to a number of automatic outlets over a finder switch, while the relay group on outgoing circuits can easily be made busy.

Testing and Maintenance Methods

Figure 12 shows the circuit of the test panel which is provided with the signalling equipment in order to enable maintenance tests to be carried out. This panel provides the following facilities:

1. Observation of current in the signalling panel output relay for different values of input level.
2. Observation of impulse ratio delivered by the signalling panel when undistorted voice frequency impulses are transmitted to it by means of the dial on the test panel.
3. Observation of plate current in the amplifier valves.
4. Transmission of voice frequency current at known levels over a line to enable equipment at the distant end to be lined up.
5. Speaking and monitoring on a working circuit.
6. Observation of the progress of a call by means of supervisory lamps which are associated with the line relay group.

The test panel is associated with any signalling panel by way of a common test multiple, which is looped into all panels. This multiple is shown in Figure 8 marked "To test panel".

The connection of the line panel to the test multiple is effected by the operation of a test relay in the signalling panel. This test relay is associated with the sleeve of the patching jacks, but is not energised when normal patching is carried out. It is, however, energised when connection is made to the test panel, owing to the earth on the sleeve of the line test jacks shown in Figure 12. The energisation of the test relay does not affect the operation of the signalling panel so that the line test jacks can be connected in parallel with a working circuit for monitoring and supervisory purposes. This is done either by the provision of monitoring jacks in parallel with the line jacks of Figure 8 or by the provision of paralleled line test jacks so that both line and equipment jacks can be connected in parallel to the test panel.

In order to carry out maintenance tests the line test jacks (which are multiplied over the jack fields) are connected to the appropriate signalling panel jacks. The relay group associated with the signalling panel is made busy, thus busying the automatic equipment or the toll board jack. Special maintenance arrangements must generally be made to ensure that the distant end is also taken out of service. Alternatively, a special busy jack can be provided to transmit a continuous voice frequency signal to the far end.

The operation of key 1b (Figure 12) to "Send VF" causes voice frequency currents to be transmitted to the line test jacks by way of the attenuator. Since the voltage of the generator supplying the voice frequency current is kept substantialy constant, a known voice frequency level depending upon the setting of the attenuator is obtained. This current passes to the signalling panel under test with the patching described above, or if the line test jacks are patched directly to a line, this current can be transmitted to a distant station.

Key 1a connects voice frequency current as described above, but at the same time short-circuits the line by way of the dial contacts. No voice frequency current is transmitted, therefore, except when the dial contacts are open. By operating the dial, trains of impulses of the same form as those transmitted over the line (voice frequency current on the line during the break period) can thus be transmitted to the panel under test. At the same time key 1a breaks the connection over terminals d and e to the relay group and connects the contact of the signalling panel output relay through to the meter in the test panel. When the output relay is operated a full scale deflection is obtained on the meter, an accurate adjustment being made by means of the variable rheostat R. When impulses are received, the meter needle takes up a position dependent upon the make-break ratio of these impulses. The damping of the meter is so designed that when zeros are dialled it is sufficiently fast for the needle to take up its final position, while, at the same time, the individual impulses are not followed, so that a reasonably steady deflection is obtained. The ratio between the reading during impulsing and the full deflection gives the ratio between the make time and total time of the impulses, and this enables an accurate check to be carried out on the performance of the signalling panel.

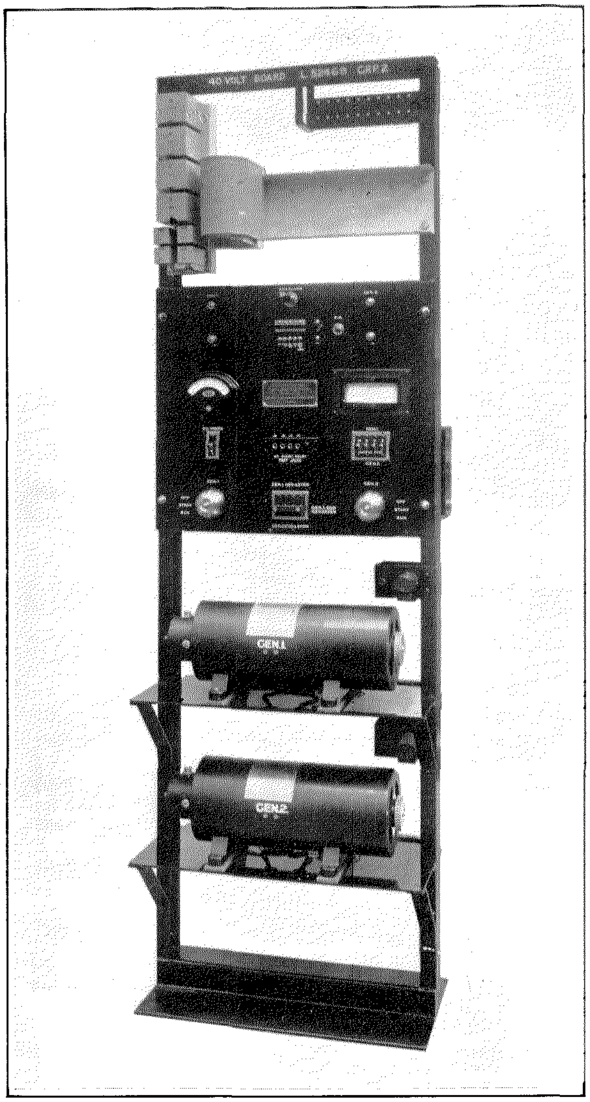

Figure 13—Generator Bay.

The impulse ratio of the dial itself can be checked by patching together the two "dial test" jacks shown in Figure 12. It will be seen from the circuit that this connects the meter and resistance to earth directly through the dial contacts.

Keys 2a, 2b and 3a are used to enable the plate currents of the valves to be read on the meter. The circuit for this will be readily observed from Figures 8 and 12. The plate current of V3 is, of course, the current received by the output relay and this key is used in sensitivity measurements in conjunction with key 1b and the attenuator.

By plugging a head set into the telephone jacks, monitoring and talking can be carried out in the usual manner. The four lamps shown in Figure 12 are connected by the test relay to earthed contacts of the most important relays in the associated relay group. This is a valuable facility for fault location since it is possible to monitor on a line and observe the voice frequency signals passing while at the same time having in view the consequent operations of the associated relay group. The exact function of each lamp depends upon the circuit of the relay group which, in turn, depends upon the operating method and the local equipment. In general, one lamp indicates the seizure and release of the circuit, the second lamp indicates the reply and hang-up of the wanted party, the third lamp is used for busy indications and the fourth lamp only on both-way circuits, to indicate the direction in which the call is set up.

Voice Frequency Supply

The voice frequency supply in small stations is obtained from vacuum tube oscillators and in larger stations from small motor generators. Most long distance circuits terminate in fairly important centres where the convergence of a number of groups makes the probable ultimate number of dialling circuits large and, for this reason, existing installations have been made with voice frequency generators. Figure 13 shows a typical generator bay. These machines consist of a shunt field motor working from the exchange battery (generally 24 or 48 volts), together with a V.F. generator of the induction type in which a toothed rotor without windings causes changes in the flux through the teeth of a wound stator. Windings on the stator teeth supply the voice frequency current, and larger windings concentric with the machine are energised from the motor battery to provide the polarising flux.

These machines are provided with the well known centre contact type of governor used on 500 p:s generators, and are also provided with compensated motors. A constancy of at least ±0.5% in the frequency of the output is thus obtained.

HERNAND BEHN

1880—1933

On October 7, 1933 there passed away in St. Jean de Luz, France, at the age of 53, Hernand Behn, President of our parent company, the International Telephone and Telegraph Corporation.

To all who had the privilege of knowing him Hernand Behn will ever be remembered as a man of outstanding personality and rare business judgment, a conversationalist of exceptional ability, a charming companion with a kindly disposition and consideration for others that endeared him in a unique and enduring way to his many friends.

Born in the Island of Saint Thomas, he was destined to extend his activities to much wider fields than was possible in that beautiful little corner of the West Indies. From earliest childhood the ties binding him to his brother Sosthenes Behn were of the closest and most affectionate nature and this happy relationship was to continue in after life in a business association lasting for more than thirty years and broken only by death. This association developed into the partnership of Behn Brothers and later the incorporation and launching of the International Telephone and Telegraph Corporation. These activities in the communications field in many parts of the world gave him a broad and cosmopolitan outlook and an exceptional grasp of international affairs.

When the history of the company is written, to Hernand Behn will go the honor of being, together with his brother Colonel Sosthenes Behn, its co-founder whose untiring energy, foresight, loyalty, and courage made the organization and successful development and expansion of the Company possible.

A lover of his own home, Mr. Behn was blessed with a most happy family life and the devotion of a wife and four children, all of whom survive him. For them and for his brother and sister, Colonel Behn and Madame Steen, his death is an irreparable loss.

Apart from his business activities Mr. Behn had many interests. Principal among these we may mention his Church, for he was a man of deep religious conviction and served his Church with an untiring devotion. Various honors were bestowed upon him, including that of Officer of the Legion of Honor, Grand Cross of Isabela la Catolica of Spain, the Grand Cross of Saint Gregory the Great, and others.

His memory will be cherished throughout the International System with an abiding affection, for in him we have lost truly a good friend.

The Reduction of Impedance Irregularities in Submarine Cable Circuits by Allocation

By ING. CARLO TONINI, R. L. HUGHES, B.Sc., and K. E. LATIMER, B.Sc.

IN the paper by Admiral G. Pession, published in the October, 1933 issue of *Electrical Communication*, the technical requirements of the Italy-Sardinia Cable are fully explained, and it is established that a high singing point is necessary, as in the case of the Tenerife-Gran Canaria cable, over the working frequency range.

It is proposed to discuss here, from the theoretical and practical standpoint, the technique of obtaining high singing points by allocation, particularly as applied to continuously loaded submarine cables designed for voice frequency operation. It is believed that the same technique is partially applicable also to the reduction of near end crosstalk in continuously loaded multi-circuit cables since both crosstalk and impedance irregularities arise from the combined effect of a large number of individual causes, each associated with a transmission path having a different time lag.

THEORETICAL CONSIDERATION

Singing Point of an Unallocated Cable.

In an article by G. Crisson entitled "Irregularities in Loaded Telephone Circuits",[1] general formulae fairly satisfactory for purposes of toll cable design have been evolved, whereby the relationship connecting the magnitude of the impedance deviations in a transmission line with the singing point observed from its terminals may be approximately determined. The Crisson formulae can be readily adapted to continuously loaded cables, and they were in fact useful in estimating what were the tolerances to be permitted in manufacturing the Italy-Sardinia cable in order that the singing point requirement of 40 db. should be met.

The singing point of a coil loaded cable is given as:

$$S = 10 \log_{10}\left(\frac{(1-W^2)\ (1-A^4)}{W^2 H_s^2 \ \log_e\ (1/F)}\right) \qquad \ldots\ldots\ldots\ldots (1)$$

where S is the singing point in decibels.

W is the ratio between the frequency considered and the cut-off frequency.

A is the current ratio per loading section.

F is the probability of obtaining a singing point lower than S, and

H_s is the "representative" combined fractional deviation of inductance per loading coil and capacity per loading section and is thus the square root of the sum of the squares of the representative deviations of inductance and capacity. The latter representative deviations are themselves the square roots of the means of the squares of the individual deviations measured on the loading coils and loading sections of cable respectively. This is more fully discussed by Crisson.

A continuously loaded cable can be considered to be the limiting case of a coil loaded cable when the loading spacing is reduced to zero. In this case, of course, W will be zero and A will be unity and the expression becomes indeterminate. It is therefore necessary to examine the behaviour of equation (1) as the spacing becomes very small.

$$\text{Now } W^2 = \frac{\omega^2\ LC\ S^2}{4}$$

Where L is the inductance per unit length
C is the capacity per unit length
S is the loading spacing

$$\text{Also } 1 - A^4 = 1 - e^{-4\beta S}$$
$$\simeq 4\beta S$$

Where β is the attenuation per unit length in nèpers.

Let S now be reduced to an elemental length λ_o.

Introducing now the relation, applicable to a continuously loaded cable:

$$\propto\ = \omega\sqrt{LC}$$

where $\propto$ is the phase constant per unit length, the following result is obtained:

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[1] *Electrical Communication*, Vol. 4, October, 1925, p. 98.

$$S = 10 \log_{10}\left(\frac{16\beta}{\lambda_o \, \alpha^2 H_o^2 \, \log_e (1/F)}\right) \ldots\ldots\ldots\ldots (2)$$

H_o is the combined representative capacity and inductance deviation on a length of core λ_o.

It has been assumed in Crisson's work that the distribution of capacity and inductance deviations along the line is at random. It is known that in these circumstances the fractional representative deviation measured on any given length (the measurements being made under such conditions that propagation effects do not arise) will vary inversely as the square root of the length.

Thus, if it be desired to express formula (2) in terms of the deviation measured on long lengths of core, the following relation is used:

$$H_o^2 \lambda_o = H_c^2 \lambda_c \ldots\ldots\ldots\ldots (3)$$

Where H_c is the representative deviation on a length λ_c of core. By way of example, the core on the Italy-Sardinia cable was manufactured in lengths[2] of one nautical mile. It is convenient to choose this length as λ_c. The other parameters have the following numerical values:

$$H_c = .03$$

$$\left.\begin{array}{l}\beta = .031 \text{ nêpers/n.m.} \\ \alpha = .575 \text{ radians/n.m.}\end{array}\right\} \text{at 2500 p:s}$$

By way of example F will be assumed to have a value .01 in which case the singing point indicated by the formula is 25.6 db. This means that there would be one chance in a hundred of obtaining a singing point lower than 25.6 db. at a frequency of 2500 p:s if the lengths of core were distributed at random.

It is, however, not possible from Crisson's formulae to estimate the probability of obtaining a given minimum singing point over a finite frequency range; this difficulty arises because his formulae are not concerned with the fact that the singing point at any given frequency f is closely related to that at a frequency f + Δf, i.e., that the singing point frequency curve is necessarily continuous. Crisson's formulae would apply equally well if the singing point curve were everywhere discontinuous. It is, therefore, justifiable to use Crisson's formulae as a basis and make an empirical estimate of the minimum singing point over a finite frequency range. Figure 1, curve (a), shows the result as a function of probability.

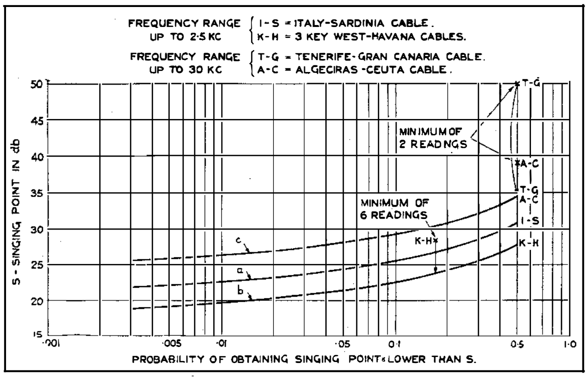

Figure 1—Comparison of Singing Points obtained on allocated cables with the expected singing point, assuming no allocation. Crisson's formulae used for computations.

The value of H_c actually obtained on the coil lengths was about .03 so that on the basis of the above calculations it was required to obtain an improvement of rather more than 15 db. in order to be reasonably certain that a singing point of at least 40 db. would be obtained.

It is interesting to compare the singing points obtained on the Key West-Havana (1921) loaded cables and on the Tenerife-Gran Canaria and Algeciras-Ceuta cables with the results of calculation by the above formulae.

Curve (b) shows the singing point which would have been obtained on the Key West-Havana cables without allocation, while curve (c) gives similar information for the Tenerife-Gran Canaria and Algeciras-Ceuta cables. A comparison between the actual results obtained and those to be predicted from Figure 1 will indicate differences dependent on the following factors:

1. The various methods of allocation employed.
2. Changes of impedance during armouring and laying.
3. Errors in estimating the essential electrical constants of the cables, particularly the representative deviations.
4. Errors connected with the basic assumptions made in deriving the Crisson formulae and with the empirical estimates of the minimum singing point in a finite frequency band.

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[2] Referred to in deep sea submarine cable practice as coil lengths.

Of these, the first has probably much the greatest influence, so that the improvement in singing point, which is summarised in Table I gives some indication of the efficacy of allocation.

TABLE I.

Cable	Improvement	Measurements Made Upon Coils for Purposes of Allocation
Key West-Havana	5 db.	Inductance and capacity
Tenerife-Gran Canaria	15.5 db.	Iterative impedance
Algeciras-Ceuta	4.5 db.	Capacity only

The following conclusions were thus reached:

(a) In the absence of special precautions there was a risk of obtaining a singing point lower than 25 db. on the Italy-Sardinia cable.

(b) The precautions taken in the case of the Key West-Havana cables were not sufficient to ensure a 40 db. singing point.

(c) If the methods used on the Tenerife-Gran Canaria cable could be applied with equal success to the Italy-Sardinia cable there was a good chance of reaching a 40 db. singing point.

Effects of Irregularities Within Coil Lengths

Two objects are achieved in basing the allocation of a submarine cable upon the results of iterative impedance measurements rather than inductance and capacity data.

In the first place, the iterative impedance may be measured on the core (together with its copper return), using a frequency in the neighbourhood of which the maximum singing point is desired. By this means the essential impedance information is obtained by a direct reading method approximating as closely as possible to working conditions. Secondly, it is possible to obtain an estimate of the distribution of inductance or capacity within a length of core, so that the impedance of every half mile of core is virtually known, although measurements are made on lengths of one nautical mile. The knowledge so obtained is necessary if the allocation is to be effective at the higher frequencies, while the avoidance of an excessive number of joints, which are sources of dielectric weakness, is a most important consideration.

The relation between the iterative impedance measurements on a coil of core and the distribution of impedance within the coil will now be examined.

Consider a uniform transmission line of infinite length having an impedance Z and propagation constant P per unit length and fed by a generator of impedance Z[3]. Let the sending end voltage and current be V and I, respectively. Now suppose that a small impedance z be connected in series with the line at a distance λ from the sending end. (See Figure 2.)

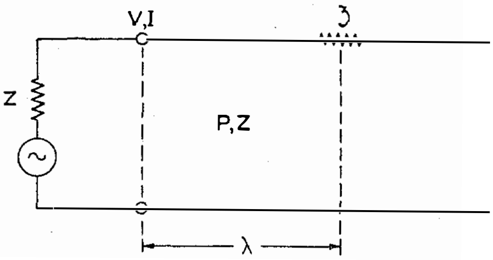

FIG. 2.

The reflection coefficients at the point λ for voltage and current are, respectively,

$$\text{R voltage} = \frac{(Z+z)-Z}{(Z+z)+Z} \backsimeq \frac{z}{2Z} \quad \ldots\ldots (4)$$

$$\text{R current} = \frac{Z-(Z+z)}{Z+(Z+z)} \backsimeq -\frac{z}{2Z} \quad \ldots\ldots (5)$$

The reflected voltage and current as observed at the beginning of the line will be

$$\frac{zVe^{-2P\lambda}}{2Z} \text{ and } -\frac{zIe^{-2P\lambda}}{2Z}$$

as they have passed twice through a line of length λ. Since the reflected wave will be absorbed by the generator, the new voltage and current at the sending end in each case will be

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[3] It is not essential that the generator impedance should be Z but the discussion is thereby simplified.

the sum of the original and reflected waves. The sending end impedance Z_a will then be

$$Z_a = \frac{V\left(1+\frac{z}{2Z}e^{-2P\lambda}\right)}{I\left(1-\frac{z}{2Z}e^{-2P\lambda}\right)}$$

As neither of the two quantities in the brackets differs greatly from unity,

$$Z_a \simeq Z\left(1+\frac{z}{Z}e^{-2P\lambda}\right)$$

$$\simeq Z+ze^{-2P\lambda} \ldots\ldots\ldots\ldots (6)$$

In a similar manner it may be shown that if there are other series impedances they may also be referred back to the beginning of the line by a similar process and, provided that the propagation constant of the line is not modified appreciably by the presence of the irregularities, the total impedance change produced at the sending end will be the sum of the changes produced by each acting separately.

For the present it will be assumed that shunt irregularities, such as those due to capacity deviations, are replaced by series irregularities giving the same reflection coefficient.

Let z be regarded as representing the excess reactance of some elemental portion of cable whose inductance per unit length is $L(1+h)$, where h is small. The characteristic impedance of this elemental portion will be designated Z_λ. It will further be assumed that the resistance and leakance are small so that the following relations apply:

$$\alpha = \omega\sqrt{LC} \text{ (as before)}$$

$$Z=\sqrt{\frac{L}{C}}$$

and by the binomial theorem.

$$Z_\lambda=\sqrt{\frac{L(1+h)}{C}} = Z\left(1+\frac{h}{2}\right).$$

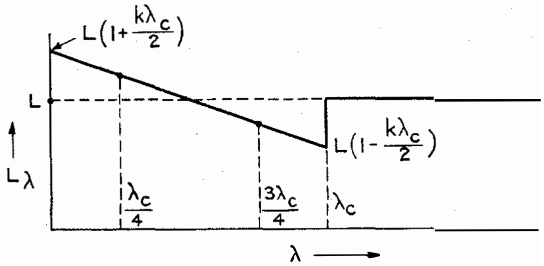

FIG. 3a.

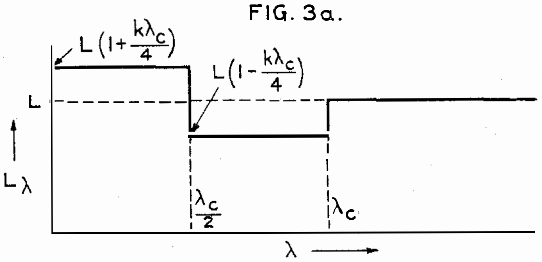

FIG. 3b.

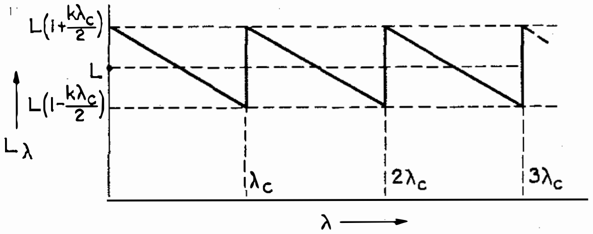

FIG. 3c.

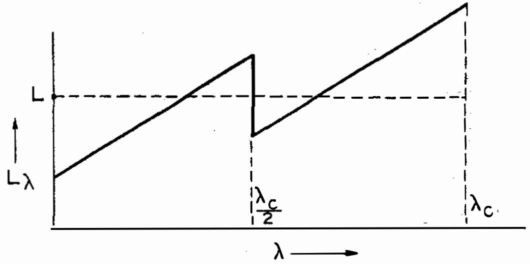

FIG. 3d.

The value of z is then obtained from the following formulae:

$$z=j\,\omega\,h\,L \ldots\ldots\ldots\ldots (7)$$
$$=j\,\alpha\,h\,Z \ldots\ldots\ldots\ldots (7a)$$
$$=2\,j\,\alpha\,(Z_\lambda-Z) \ldots\ldots\ldots\ldots (7b)$$

Applying the above to equation (6) it is seen that the sending end impedance of a line composed of elemental portions whose characteristic impedance is some function of the distance λ from the sending end becomes

$$Z_a = Z + j \propto Z \int_0^{\infty} h e^{-2P\lambda}\, d\lambda \ldots\ldots (8)$$

Referring now to Figure 3a, the case of a coil having tapering constants will be considered[4]. The capacity is assumed to be uniformly distributed but the inductance per unit length at any point distant λ along the coil is taken as that given by the formula

$$L\lambda = L\left[1 + k\left(\frac{\lambda_c}{2} - \lambda\right)\right]$$

Where $L\lambda$ is the inductance per unit length at the point λ,

k is a constant

and λ_c is the length of the coil.

Putting $h = k\left(\frac{\lambda_c}{2} - \lambda\right)$ from $\lambda = O$ to $\lambda = \lambda_c$ and $h = O$ from λ_c to infinity, the effect upon the sending end impedance due to placing a tapering coil at the beginning of an infinite line may be calculated, using formula (8), thus:

$$Z_a - Z = j \propto Z \int_0^{\lambda_c} k\left(\frac{\lambda_c}{2} - \lambda\right) e^{-2P\lambda} d\lambda$$

$$= \frac{j \propto Z\, k\lambda_c}{4P}\left(1 - e^{-2P\lambda_c}\right) - \frac{j \propto Z k}{4P^2}\left\{1 - e^{-2P\lambda_c}(2P\lambda_c + 1)\right\}$$

If $P\lambda_c$ is not very large it is permissible to put $P = j\propto$; it is also permissible to expand $e^{-2P\lambda_c}$ in powers of $P\lambda_c$, so as to obtain a power series for $Z_a - Z$ of which only the first term will be considered. The following expression is thus obtained:

$$Z_a - Z = -\frac{kZ \propto^2 \lambda_c^3}{6} \ldots\ldots\ldots\ldots (9)$$

It is convenient to express $Z_a - Z$ also in terms of the mean values of $Z\lambda$ for the halves of the coil. These will be the values of Z_λ for $\lambda = \frac{\lambda_c}{4}$ and $\lambda = \frac{3\lambda_c}{4}$ and will be referred to as Z_1 and Z_2. Now $Z_1 - Z_2 = \frac{kZ\lambda_c}{4}$ so that (9) becomes

$$Z_a - Z = -\tfrac{2}{3}(Z_1 - Z_2) \propto^2 \lambda_c^2 \ldots\ldots (9a)$$

The same calculations may be repeated assuming that Z_1 and Z_2 remain fixed, but that the inductance per unit length of each half of the coil is uniform. (See Figure 3b.) The result obtained is

$$Z_a - Z = -\tfrac{1}{2}(Z_1 - Z_2) \propto^2 \lambda_c^2 \ldots\ldots (9b)$$

If the product $\propto^2\lambda_c^2$ is small compared with unity it can be seen, from the above equations, that $Z_a - Z$ will be small compared with $Z_1 - Z_2$, that is to say, the high impedance of one half coil compensates for the low impedance of the other half coil, and the resulting irregularity is small. In practice, however, when using one mile coil lengths, $\propto\lambda_c$ is not sufficiently small, its value being .575 radians at 2500 cycles[5] in the present cable and the resultant irregularity is from one-fifth to one-sixth of that which would occur at the junction of two infinite lines of impedances Z_1 and Z_2, respectively.

Further, it can be seen from the occurrence of λ_c^2 in 9a and 9b that the reflection produced by a given impedance difference between two full coils will be only about four times as great as the same impedance difference between two half coils.

From what has been said in connection with equation (2) it can be seen that in the absence of special precautions $Z_1 - Z_2$ (for half coils) is likely to be $\sqrt{2}$ times as great as the corresponding difference between the mean impedances for full coil lengths so that, even if the effects of the latter differences were completely removed by allocation, the irregularity in the impedance frequency curve would only be reduced to about

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[4] This has been partly dealt with by A. Rosen in the Journal I. E. E., Vol. 65, November, 1927, p. 989.

[5] The formulae (9), (9a) and (9b) were evolved on the assumption that $2P\lambda_c$ was small. Although at first sight when $\propto \lambda_c = .575$ radians, $2P\lambda_c$ might seem too large for the approximations to be reasonably good, actually the error involved is small.

one-third of that to be expected if no allocation were employed.

It has already been shown that an increase of singing point of 15 decibels above that to be expected without allocation was necessary, requiring a reduction of the irregularity to one-fifth of the unallocated value. It was therefore necessary to consider the impedance of half coils in the present case.

It will now be shown how the impedances Z_1 and Z_2 may be determined by iterative impedance measurements. The iterative impedance of a structure is defined as the impedance presented by an infinite series of structures connected in tandem, all facing the same way. If the structure is dissymmetrical, there will be two iterative impedances depending upon the direction in which the structures are connected up. A method of measuring iterative impedances is described elsewhere[6]. Let an infinite number of the coils shown in Figure 3a be connected in tandem as in 3(c). The first coil will, according to equation (8), give rise to an impedance irregularity

$$Z_a - Z = -\tfrac{2}{3}(Z_1 - Z_2) \propto^2 \lambda_c^2$$

The successive coils of the series will give rise to irregularities referred to the sending end of

$$-\tfrac{2}{3}(Z_1 - Z_2) \propto^2 \lambda_c^2 e^{-2P\lambda_c}$$

$$-\tfrac{2}{3}(Z_1 - Z_2) \propto^2 \lambda_c^2 e^{-4P\lambda_c}$$

$$-\tfrac{2}{3}(Z_1 - Z_2) \propto^2 \lambda_c^2 e^{-6P\lambda_c} \text{ etc.}$$

This is evidently a geometric progression and the required iterative impedance Z_1' is thus

$$Z_1' = Z - \sum_{n=o}^{n=\infty} \tfrac{2}{3}(Z_1 - Z_2) \propto^2 \lambda_c^2 e^{-2nP\lambda_c}$$

$$= Z - \frac{\tfrac{2}{3}(Z_1 - Z_2) \propto^2 \lambda_c^2}{1 - e^{-2P\lambda_c}}$$

Taking the first term of the expansion of $e^{-2P\lambda_c}$ (P may again be assumed to be equal to $j \propto$)

$$Z_1' = Z + \tfrac{1}{3}(Z_1 - Z_2)\ j \propto \lambda_c$$

By symmetry

$$Z_2' = Z + \tfrac{1}{3}(Z_2 - Z_1)\ j \propto \lambda_c$$

$$Z_1' - Z_2' = \tfrac{2}{3}(Z_1 - Z_2)\ j \propto \lambda_c \quad \ldots\ldots(10)$$

$$\frac{Z_1' + Z_2'}{2} = Z = \frac{Z_1 + Z_2}{2} \quad \ldots\ldots\ldots(11)$$

(10) may also be expressed in the form

$$Z_1' - Z_2' = j\frac{k \propto Z \lambda_c^2}{6} \quad \ldots\ldots\ldots(10a)$$

The iterative impedances thus differ from one another in reactance rather than resistance, and when $Z_1' - Z_2'$ is a positive reactance Z_1 is greater than Z_2 and vice versa.

For the purpose of checking the above work a coil of core was cut in half and the following iterative impedance measurements were made, A and B being the ends of the coil and M the centre point:

Measurements Made On	Iterative Impedance at 2500 p:s	
	Resistance (ohms)	Reactance (ohms)
Whole coil, A to B (Z_1')	115.2	−4.8
Whole coil, B to A (Z_2')	115.1	−3.4
First half, A to M	113.9 $\backsimeq Z_1$	−4.4
First half, M to A	113.9	−3.9
Second half, M to B	116.5 $\backsimeq Z_2$	−4.4
Second half, B to M	116.5	−3.7

$$Z'_1 - Z'_2 = -j\ 1.4 \text{ ohms.}$$

$$\tfrac{2}{3}(Z_1 - Z_2)\ j \propto \lambda_c = -j\ \frac{2x2.6x.575}{3} = -j\ 1.0 \text{ ohm.}$$

The above agreement does not appear to be satisfactory. The discrepancy evidently arises from the assumption of linear distribution of

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[6] *Electrical Communication*, Vol. 9, April, 1931, p. 226.

inductance; the differences of iterative impedance measured on the half coils are larger than would be expected on this assumption, and indicate that the actual distribution is similar to that shown in Figure 3d. This is not so improbable as it might seem at first sight, as each coil was made up from two half-mile lengths of loaded conductor, the dielectric being subsequently applied as a continuous coating over the whole length. Naturally, part of this irregularity may have been due to some non-uniformity of the dielectric, as capacity and inductance deviations are indistinguishable in their effects. It will be remembered that the coils of the Tenerife-Gran Canaria cable[7] showed tapering constants, although this cable was not loaded.

It is interesting to note that although iterative impedance measurements may only give rough indications of the impedances of the half coils, they do indicate with considerable precision the effect of inserting a coil containing irregularities in an otherwise uniform cable, which is, after all, more important.

Figure 4 shows the effect of reversing the direction in which "tapered" coils are inserted in a long cable. When the tapering is consistently in one direction the impedance curve is smooth, whereas when some coils are reversed an irregularity appears at the higher frequencies. This experiment was conducted with coils specially chosen for a high degree of uniformity.

Prediction of Impedance Characteristic from Known Coil Deviations

The probability of obtaining a given singing point, when only the representative deviation is known, may be determined, as has been shown, by a modified form of Crisson's formulae. If, however, the individual deviations are completely specified, the singing point is capable of exact calculation. For this purpose formula (8) may be used.

The corresponding formulae for the components of Z_a are

$$R_a = Z + \propto Z \int_0^\infty h e^{-2\beta\lambda} \sin 2\propto\lambda \, d\lambda \qquad (12)$$

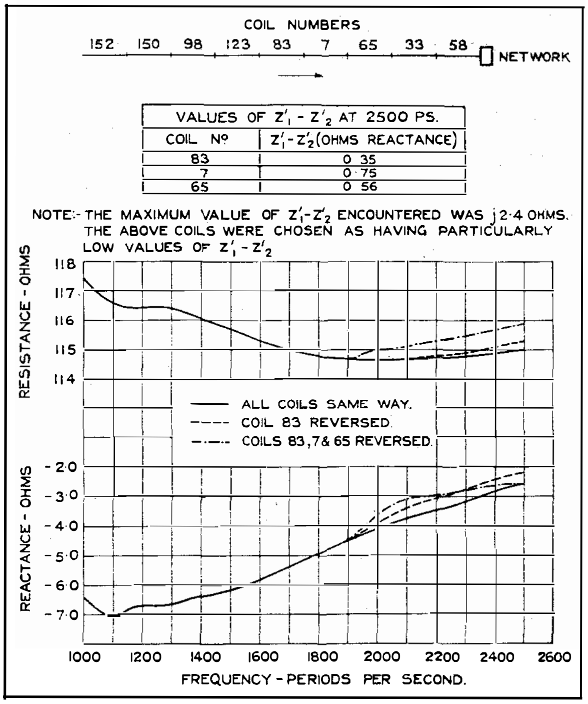

Figure 4—Impedance changes caused by reversing the direction in which certain coils are inserted in the cable.

$$X_a = \propto Z \int_0^\infty h\, e^{-2\beta\lambda} \cos 2\propto\lambda \, d\lambda \quad ..(13)$$

In order to illustrate the significance of equations (8), (12) and (13), various distributions of deviations will now be assumed. Let h be determined by the expression

$$h = h_o \sin 2\theta\lambda$$

$$= -jh_o\left(\frac{e^{2j\theta\lambda} - e^{-2j\theta\lambda}}{2}\right)$$

Then:

$$Z_a = Z + \frac{h_o \propto Z}{2} \int_0^\infty e^{2(j\theta - P)\lambda} d\lambda$$

$$-\frac{h_o \propto Z}{2} \int_0^\infty e^{-2(j\theta + P)\lambda} \, d\lambda \, ... (14)$$

$$= Z + \frac{jh_o \propto Z\theta}{2(P^2 + \theta^2)}$$

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[7] *Electrical Communication*, Vol. 9, April, 1931, p. 226.

In the above expression, when $\theta = \alpha$, $P^2+\theta^2 \simeq 2j\alpha\beta$ so that (14) becomes

$$Z_a = Z + \frac{h_o \alpha Z}{4\beta} \quad \ldots\ldots\ldots(14a)$$

The second term may be very large. It is thus clear that if the deviations happen to be distributed in a sinusoidal wave, a large irregularity is to be expected at the frequency at which $\theta = \alpha$ although the effect will be small at other frequencies. One of the objects to be aimed at in allocation is to eliminate, as far as possible, cases in which large deviations occur at regular intervals, unless those intervals are so spaced that the condition $\theta = \alpha$ is not satisfied over the useful frequency range.

It is interesting to note at this point the similarity between equations (12 and 13) and those which are commonly employed in harmonic analysis. The curve formed by plotting deviations against their location in the cable is to be regarded as the "transient" to be analysed, and the irregularities in the impedance curve obtained give the "frequency spectrum" of the "transient." To make this mental picture more complete, the impedance irregularity should be plotted to a scale of $\frac{\alpha}{\pi}$. The allocation problem, as seen from this point of view, is to avoid pronounced "harmonics" in the deviation curve; in the Italy-Sardinia cable the value of $\frac{\alpha}{\pi}$ at 2500 p:s is .183 so that the most important frequency in the above analogy is .183 cycles per nautical mile, corresponding to a period of $\frac{1}{.183} = 5.45$ nautical miles.

Another piece of information may be extracted from equations (8), (12) and (13) by assuming that the value of h is determined by the equation.

$$h = h_o(e^{-2\phi\lambda} - 1)$$

Then (12) and (13) become

$$R_a = Z + \alpha Z h_o \int_0^\infty (e^{-2\phi\lambda} - 1)e^{-2\beta\lambda} \sin 2\alpha\lambda d\lambda$$

$$= Z - \frac{\phi^2 h_0 Z}{2(\alpha^2+\phi^2)} \text{ when } \beta \text{ is small} \quad \ldots(15)$$

$$X_a = \alpha Z h_o \int_0^\infty (e^{-2\phi\lambda} - 1)e^{-2\beta\lambda} \cos 2\alpha\lambda\, d\lambda$$

$$= \frac{\alpha\phi h_0 Z}{2(\alpha^2+\phi^2)} \text{ when } \beta \text{ is small} \quad \ldots.(16)$$

If ϕ is small compared with α the irregularity introduced by a tapering impedance of the type assumed is also small.

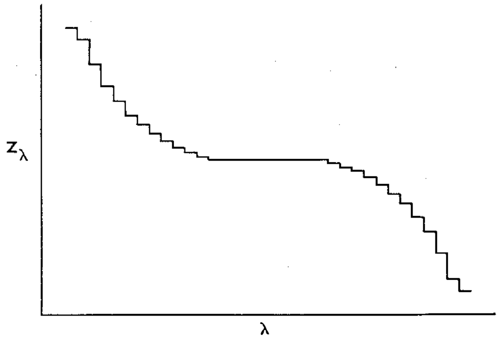

FIG. 5a.

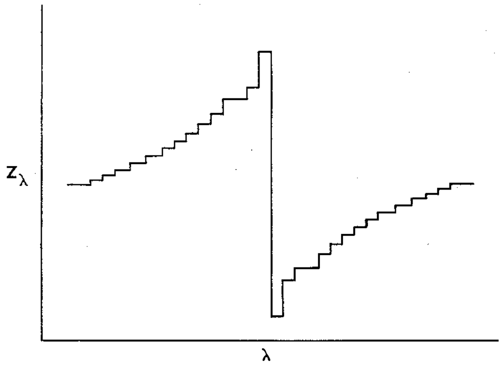

FIG. 5b.

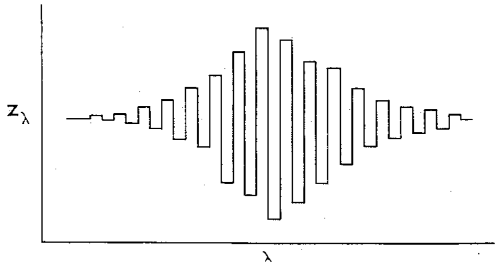

FIG. 5c.

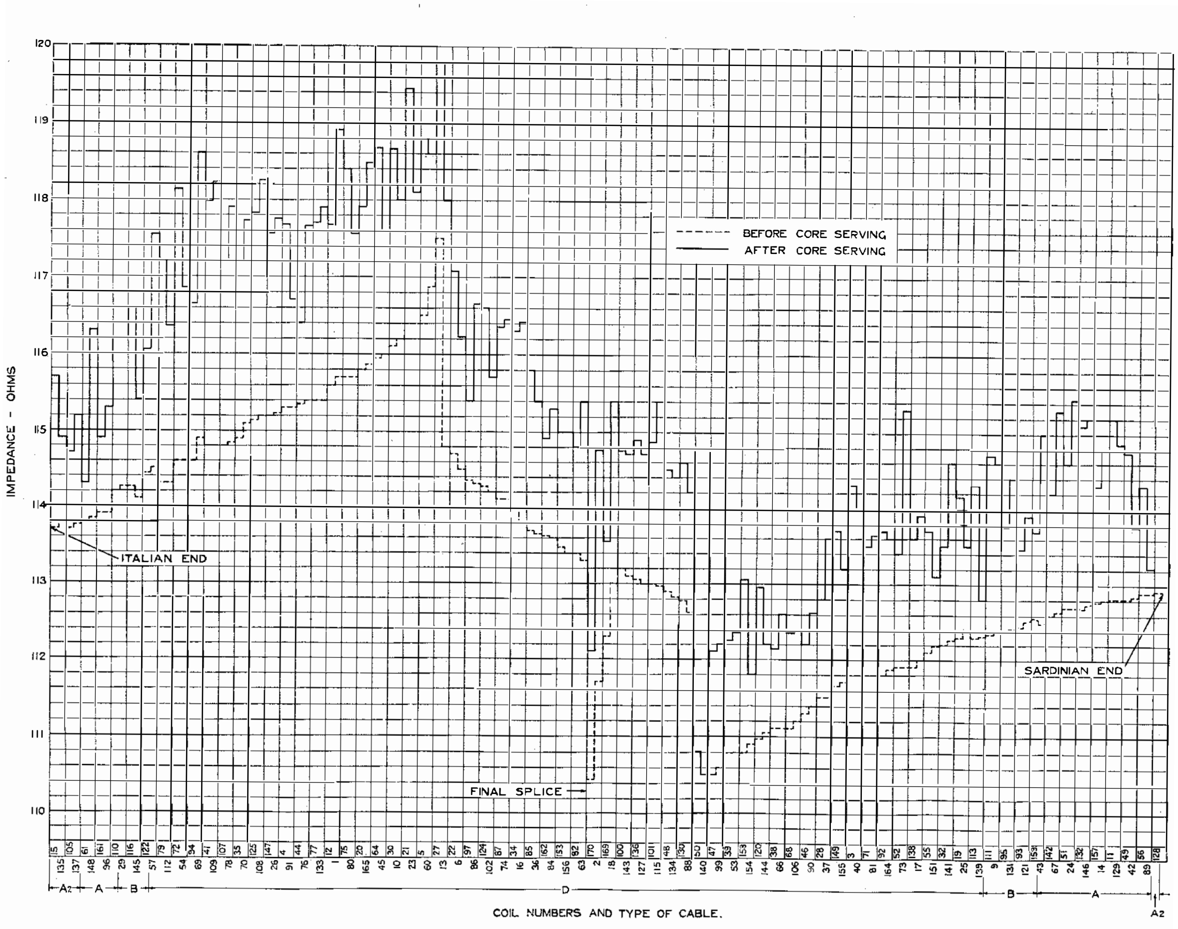

Figure 6—Diagram showing Impedances of Individual Coils before and after core serving.

Method of Allocating Coil Lengths

The deviations of the impedances of individual coils from their average value in general follow the normal law of errors. The bulk of the coils have impedances approximating to the average value, while the greatest deviations only occur infrequently. If the coils are arranged in the order of their impedances, large and irregular gaps occur between successive impedances at the beginning and end of the list. For this reason any allocation scheme in which the coils having the greatest deviations from the average are placed at the ends of the cable, as in Figure 5a, is doomed to failure.

The two most obvious methods of allocating the coils are as shown in Figure 5b and 5c. Spare cable of average impedance is provided in each case. While at first sight (5c) seems more desirable, as it avoids the centre irregularity, there is a serious objection from the point of view of possible repairs; the length of spare cable inserted generally exceeds that of the faulty cable cut out by an amount sufficient to disturb the sequence of high and low impedance coils, which would have a very undesirable effect. As the centre irregularity is of little practical importance, the method shown in Figure 5b is somewhat preferred. The method shown in Figure 5c was used on the Key West-Havana cables, the impedance irregularity observed at a frequency of 3400 p:s being due to the condition represented by equation (14a).

On the Italy-Sardinia cable, the irregularities within coil lengths were dealt with by removing from the shore ends to the centre, coils having large iterative impedance differences, and by slightly altering the order of the remaining shore end coils, so that the iterative impedance differences follow a smooth curve.

Calculation of Deviations from Impedance Irregularities

The analogy of harmonic analysis mentioned above suggests that the reverse process (the reconstruction of the transient from the frequency spectrum) is applicable to the present case, so that the deviations may be deduced from the impedance curve.

The determination of the impedances of the two halves of a coil from the iterative impedances of the whole coil is a special case of this reverse process. The application of the same idea to very long circuits is, to some extent, possible. If the nominal impedance and propagation constant are known and the attenuation is small, and, given that the deviations are due to capacity and inductance only, then the distribution of these deviations for a limited distance may be approximately determined from either the resistance or reactance component of the impedance curve. The fact that the impedance is not known at all frequencies from o to ∞ necessarily limits the accuracy of the computations, as it is possible to obtain an infinite number of distributions, each of which gives an impedance curve coinciding with the experimental data over a finite frequency range. For this reason there will not in general be complete agreement between the distribution determined from the resistance curve and that from the reactance curve, although it should be possible to recognise features common to both which are essentially associated with the experimental data. It is possible that a development of this idea may make it possible to construct, under field conditions, a multi-section network having an irregular impedance characteristic and matching that of the cable, but there are a number of practical difficulties which make it undesirable to place too much reliance upon such a procedure. The partial ability to examine the characteristics of individual portions of the cable by observations from the ends is, however, of considerable interest.

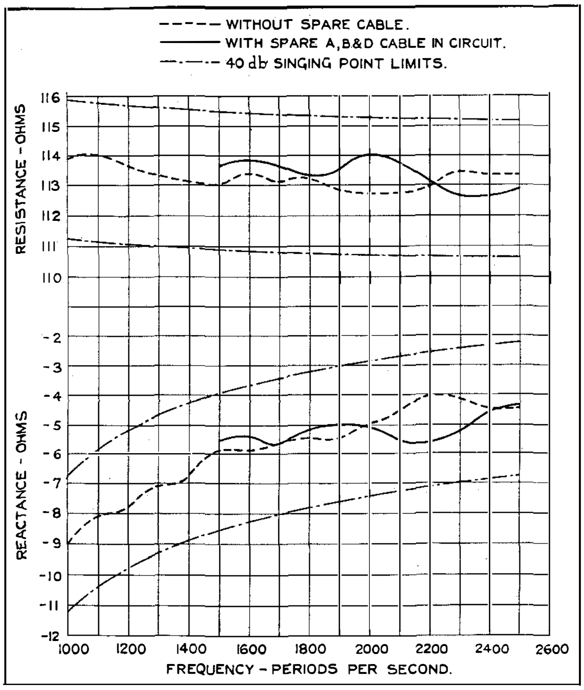

Figure 8—Impedance frequency curve measured from the Sardinian end after allocation and before core serving. Effects of inserting spare cable are shown.

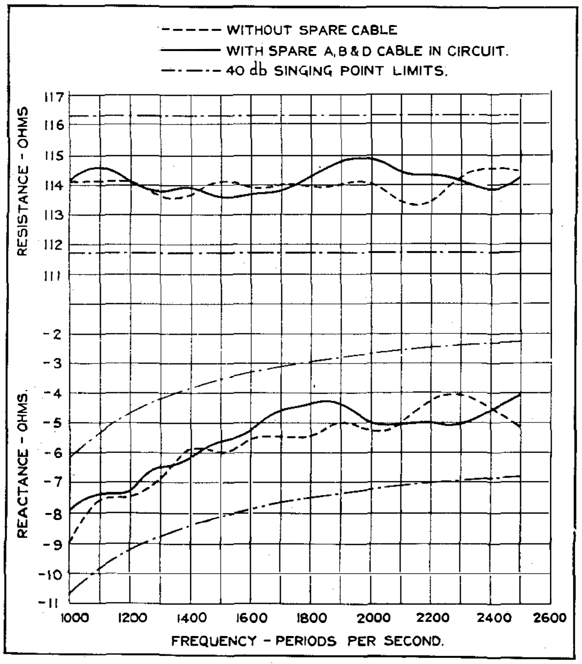

Figure 7—Impedance frequency curve measured from the Italian end after allocation and before core serving. Effects of inserting spare cable are shown.

MANUFACTURE OF THE CORE

A description will now be given of such features of the manufacture of the core for the Italy-Sardinia cable as are relevant to the present discussion.

The core was manufactured by the Societa Italiana Pirelli in the Bicocca factory near Milan. The conductor, which consisted of a round wire surrounded by five copper strips[8], was made in lengths of one-half nautical mile as alreadymentioned, over which the iron wire was applied. A number of machines giving a total of 18 lapping heads were used in the application of the loading, owing to the slowness of this work. The copper tapes and the loading wire were applied with left hand lays[9]. After annealing the loaded conductor, the interstices were completely filled with Chatterton's compound to exclude all traces of air which might otherwise cause trouble during laying. Three layers of gutta percha were then applied over the loaded conductor in coil lengths of one nautical mile so that each coil contained one conductor joint which was, of course, made before covering with gutta percha.

Subsequently a tanned cotton tape, copper teredo tape, fifty-two copper wires and a paraffined cotton tape were applied in two converted core serving machines. The directions of lay were respectively left hand, right hand, left hand and right hand, the lay of the teredo tape being about 30 mm. and that of the return wires 20 cm. The core, after this process, was coiled on wooden drums and placed in tanks of water at a temperature of 75°F. for the usual dielectric and conductor resistance tests. At this stage iterative impedance measurements were made and the coils were allocated. The iterative impedance measurements of successive coils, as allocated at this stage, are shown in Figure 6, while the impedance characteristics with and without spare cable in circuit are given in Figures 7 and 8. It will be seen that the results were highly satisfactory as the singing point, even with spare cable inserted, was over 45 db., so that the theoretical expectations were amply fulfilled.

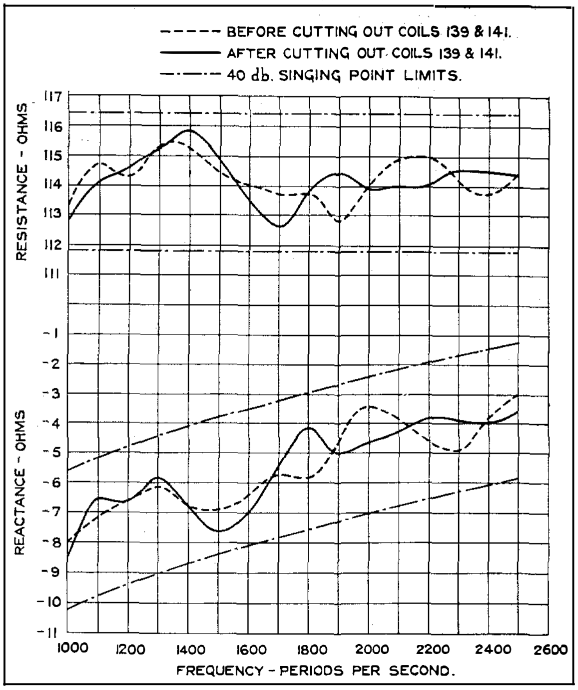

Figure 9—Impedance frequency curves of Sardinian end before and after cutting out coils 139 and 141.

IMPEDANCE CHANGES DURING CORE SERVING, ARMOURING AND LAYING

The coils of core were then passed through the core serving machines which applied the correct thickness of tanned jute to serve as a bedding for the various types of armouring. The served core was coiled down into small tanks of about two metres diameter, several coils being placed one above the other, and all the ends left clear of the tanks for testing and jointing[10].

It was found at this stage that the impedances of individual coils were increased during the core serving process by about 2 ohms, the increase being by no means regular. Two coils were then armoured, by way of experiment, with the result that the impedance returned part way towards the original value. These impedance changes came as an unpleasant surprise, as the inductance of the core before the application of the return conductor was very stable both mechanically and magnetically. Further, no appreciable change

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[8] For dimensions, see previously mentioned paper by Admiral Pession.

[9] A wire wound in the thread of an ordinary screw would have a right hand lay.

[10] The twin core was twinned and core served in one operation in an armouring machine and coiled down in large tanks normally used for armoured cable.

of this kind had been observed on the Tenerife-Gran Canaria cable.

At this stage, there were four possible courses of action:

(1) Stop manufacture until the exact cause of the trouble had been located, and then make a decision as to procedure.
(2) Continue manufacture without taking any special action, hoping that the impedance changes due to core serving and armouring were complementary.
(3) Re-allocate on the basis of impedance after core serving.
(4) Cut out the coils likely to cause the greatest irregularities and transfer them to the centre portion of the cable, but otherwise continue as in (2).

The programme of manufacture was such that a long delay for investigations could not be considered. To re-allocate would have been almost equally objectionable, particularly as the core serving suitable for one type of armouring would be unsuitable for another; also as several coils had been put in each tank, most of them were inaccessible. Further, if the impedance returned to its original value, re-allocation would be harmful. On the whole, alternative (4) seemed wisest, for even if the impedance did return to its original value no great harm would be done, while if it did not, the cutting out of a few coils would be beneficial.

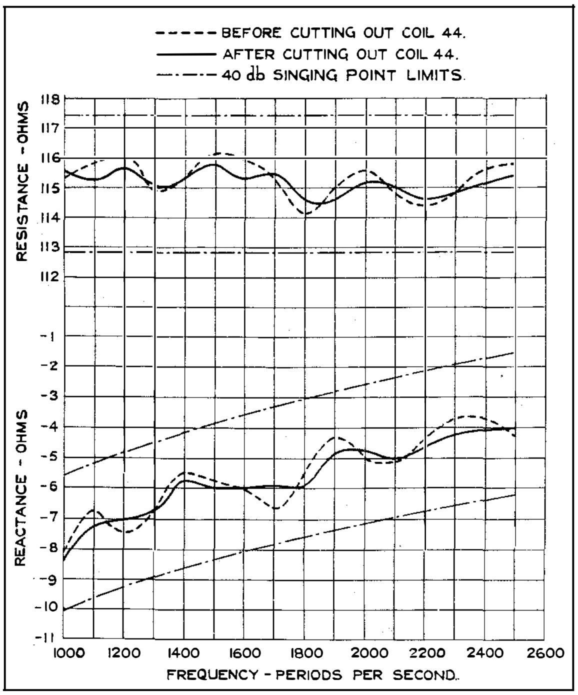

Figure 10—Impedance frequency curves of Italian end before and after cutting out coil 44.

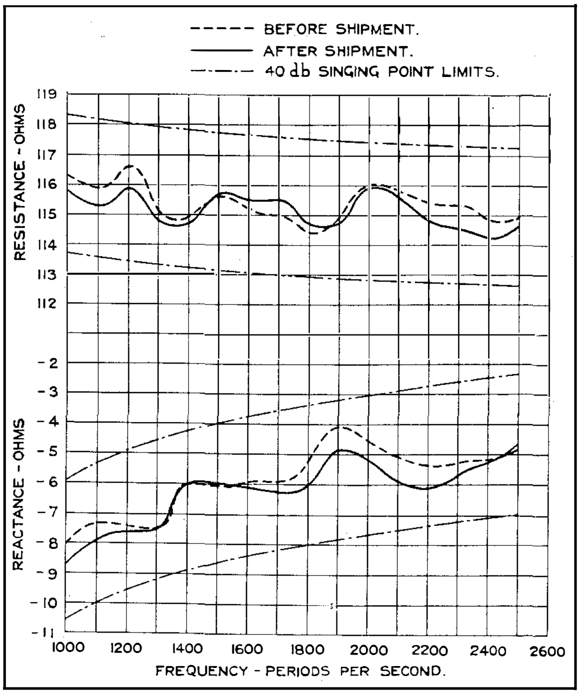

Figure 11—Impedance frequency curves of Italian end before and after shipment.

As all the core for this cable, about 150 lengths, had to be tested for allocation before armouring, and as the core must be kept under water until required for armouring, the storage accommodation for served core was severely strained, particularly as the core was of unusually large size.

In the normal manufacture of gutta percha cables armouring proceeds simultaneously with core manufacture and only a small amount of served core is in the core tanks at any one time.

In view of the demand for core tank accommodation the whole of the served core for the types A, B and D cable for the eastern half of the route had to be jointed up and transferred to a large armoured cable tank before the core serving of the western half could be completed, so that a very large amount of turning over of core from tank to tank would have been necessary if many irregular coils were to be cut out. The possibilities on the western half of the cable were, however, greater, and were used to the best advantage. These efforts were mainly directed towards improvement of the singing point at the higher frequencies, for not only was the singing point of greatest importance at these frequencies but irregularities at low frequencies are, as has been seen, due to the combined deviations of large groups of coils whose return to the original impedance could be expected with somewhat more confidence than that of individual coils.

The result of these operations is indicated in Figure 9. This improvement was obtained by removing two separate coils from the early part of the type D cable. The advisability of removing other coils was considered, but the improvement obtained by trials before the joints were made did not justify the turning over operations necessary. The armouring of the cable was then commenced, one of the machines being stopped later on for the removal of a coil from the eastern half of the cable, with the result shown in Figure 10. The coils which were thus removed were inserted in the centre portion of the cable.

Some considerable anxiety was felt when it was discovered that the twin core cable did not drop in impedance on armouring as did all the other types[11], but it so happened, fortunately, that the deviations of the individual coils near the junction between the twin core and the single core types on the eastern half of the cable were such that no serious irregularity was introduced.

After the completion of the armouring process, the impedance of the cable, both in the factory tanks and on board the Cable Ship "Citta di Milano", was measured, with the results shown in Figures 11 and 12, from which it will be seen that the operation of shipment caused little impedance change and that the singing point was very satisfactory.

The actual process of laying caused much greater changes as may be seen from Figures 13 and 14. These changes seemed to be of a temporary character as measurements made during the installation of the terminal equipment showed that the cable was already returning to the condition before laying although the time of recovery was evidently going to be rather long.

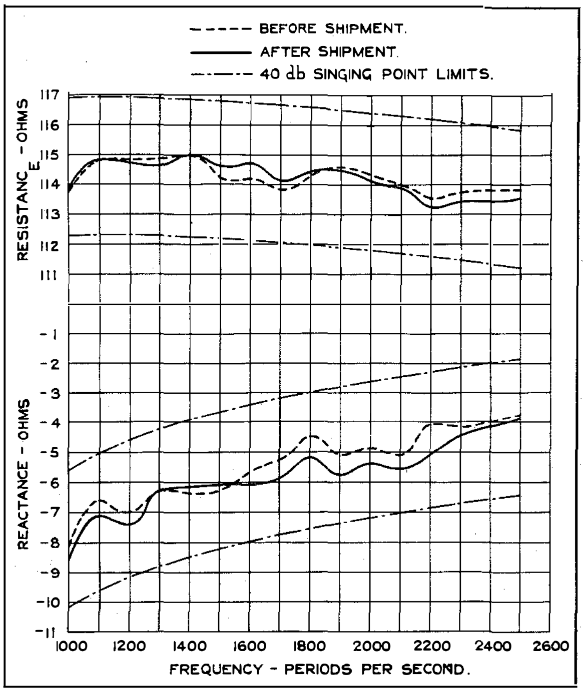

Figure 12—Impedance frequency curves of Sardinian end before and after shipment.

Fortunately the worst of these temporary irregularities occurred at a rather low frequency so that it was possible to obtain a low overall equivalent up to 2500 p:s with good stability, particularly as the gain possible in Sardinia was greater than was originally anticipated.

Figure 15 gives the impedance characteristic recently obtained from the Italian end and confirms, for this end, the improvement already noted on Figure 14 for the Sardinian end. The temporary changes associated with laying have largely disappeared. Recent tests of the Sardinian end are in close agreement with those made seven weeks after laying.

INVESTIGATIONS INTO THE NATURE OF THE IMPEDANCE CHANGES

At the time the impedance changes were first observed, it was thought that if the cause of the phenomenon could be ascertained, and the behaviour of individual coil lengths during the various stages of manufacture predicted, the knowledge might be very useful, as the core could have been re-allocated so as to give the best possible final result. Although much effort was devoted to the solution of this problem, it was found to be much more complicated than was

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[11] The armouring of types A, B and D produced an impedance change of about 1 ohm.

originally anticipated, and a satisfactory conclusion was only reached after the manufacture was completed. Now that the nature of the phenomenon is more clearly understood, it seems doubtful whether the policy adopted during the manufacture could have been improved upon.

It may be interesting to record some aspects of this investigation. As soon as the difficulty was noticed in the factory, experiments indicated that the change was due to an increase of inductance and was to a large extent connected with the twisting of the core, which occurred when it was taken off a drum and coiled down in a small core tank after the application of the jute serving. The process of coiling down puts one complete twist in the core for each turn round the tank. Attempts were made to correlate the inductance changes with the various electrical constants, such as conductor resistance, added inductance, and capacity, or with the particular machines and appliances used in the manufacture of the core such as the lapping heads, core serving machines, core tanks, etc. No connection could, however, be traced between the behaviour of individual coils and their previous history, except for a certain tendency for groups of coils passing successively through the core serving process to show similar variations. This might be explained by the fact that the core tanks were not all of the same size and were at different distances from the serving machines.

The next line of attack was to trace the changes of impedance, through the successive stages of manufacture, with the following results.

As an experiment a length of one-half nautical mile of core was tested before serving and was found to have an impedance of 113.9 ohms. Serving then commenced and when half the length was served the impedance measured 115.1 ohms, while when the serving of the whole length was completed the impedance was 115.5 ohms. It would thus seem that the first half of the length changed three times as much as the

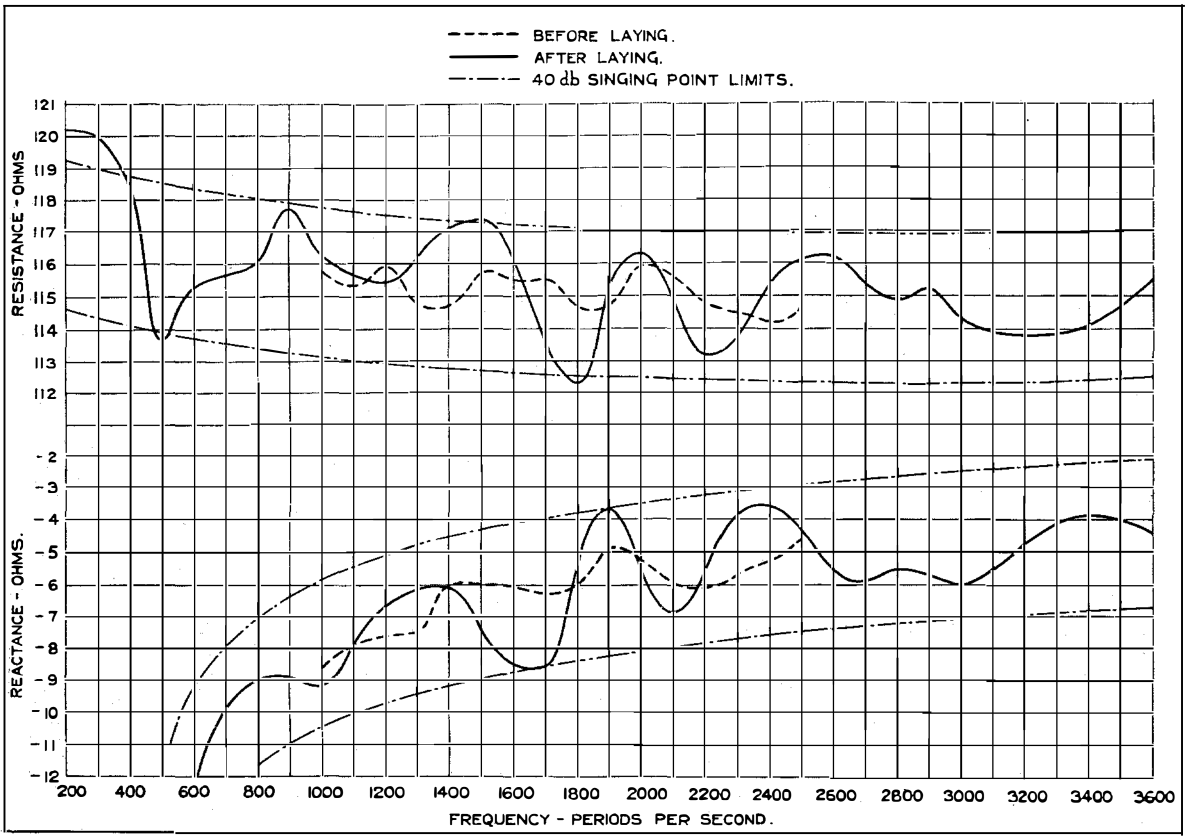


Figure 13—Impedance frequency curves of Italian end before and after laying.

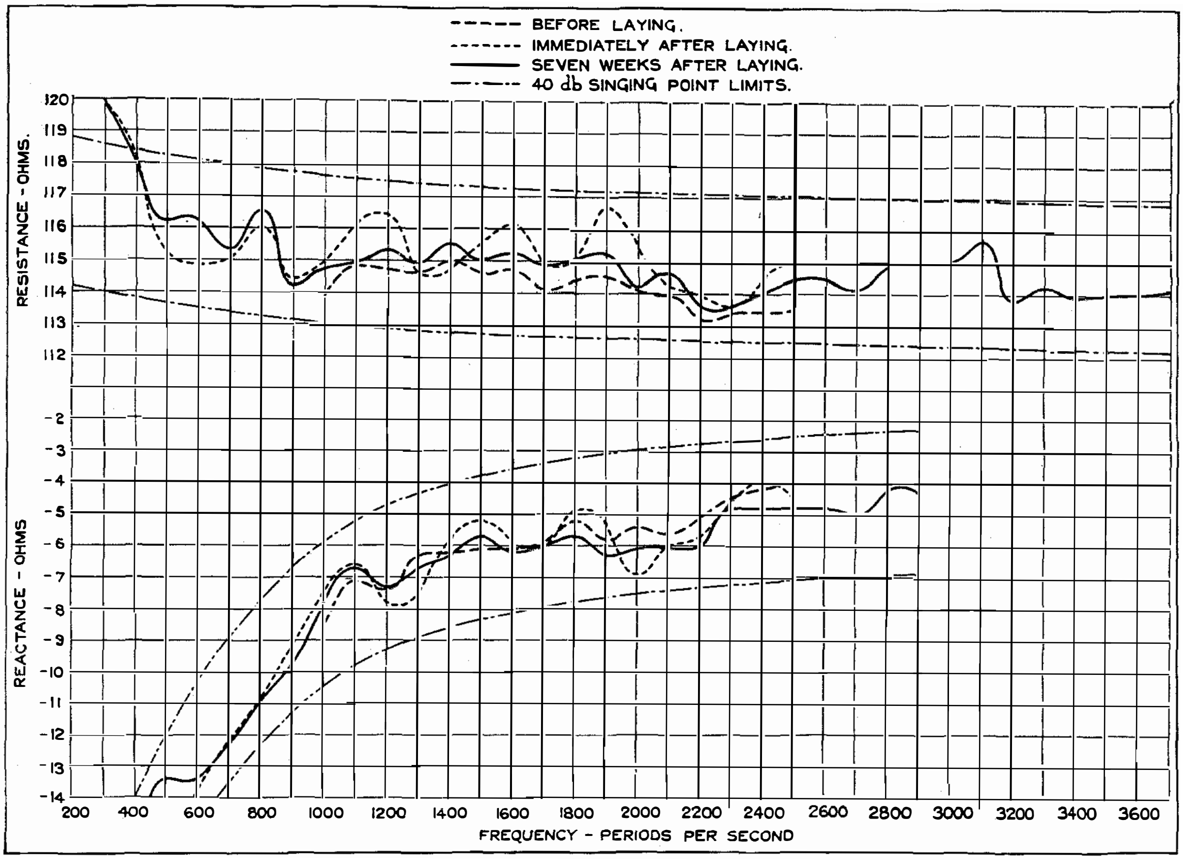


Figure 14—Impedance frequency curves of Sardinian end before and after laying.

second half of the length. The length of one-half nautical mile was significant in that the loaded conductor, as already mentioned, was made in one-half nautical mile lengths and only one such length was involved in the experiment.

A series of impedance measurements was made on a length of served core during its transfer from small core tanks (2 metres diameter) to a large armoured cable tank (6 metres diameter) in preparation for armouring. The result of this transfer was to drop the impedance on the average by about 1 ohm, thus supporting the theory that the increased impedance after core serving was connected with the torsion, which was naturally less in the tank of larger diameter.

It was noted that the result of transferring the core from one small tank to another was to increase the impedance.

Arrangements were made to feed a number of coils separately into the armouring machine, measuring the impedance before and after armouring. After the armouring of one coil was completed a joint was made behind the machine, and the next coil fed through without a break in the armour wires.

The impedances of individual coils before and after armouring were calculated in accordance with the general principles laid down in the beginning of this article, with the results shown in Figure 16.

With the exception of the tests on the type A_2 cable the armouring experiments were for convenience carried out on coils fed direct from the small core tanks into the armouring machine. The A_2 core was twinned and served in one operation in an armouring machine, and placed in the armoured cable tanks, from which it was fed into the armouring machine. The drop in impedance noted on types A, B and D was, therefore, analogous to the drop of one ohm observed on passing the core from the small core tanks to the armoured cable tanks, inasmuch as the core was twisted to a greater extent before armouring than after. This was not the case

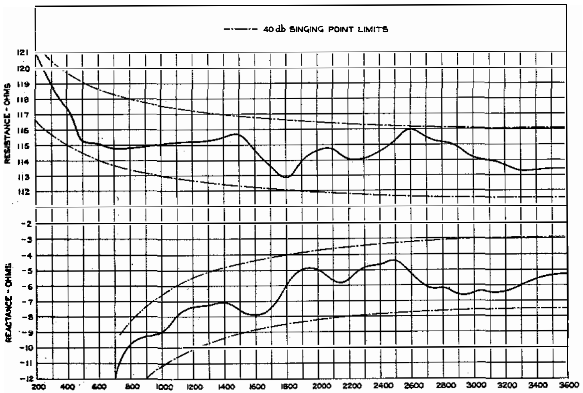


Figure 15—Impedance frequency curve of Italian end (Autumn, 1933)

with the type A_2 cable, so that the drop of impedance on armouring is not comparable with that of other types.

It will be seen that the impedance changes which occurred over the whole process of manufacture, were of a fortuitous nature, but that there was a noticeable tendency for a large increase of impedance on core serving to be associated with a large decrease on armouring. Also, if such a conclusion can be drawn from so few lengths, the greatest net changes, after both core serving and armouring, were associated with large increases of impedance on core serving, and small net changes with small increases. It was, therefore, probably a wise plan to remove to the centre those coils which were causing the greatest irregularities after core serving.

Although it would have been very interesting to have obtained similar data on more coils, to have done so would have involved making splices in the armour wires, whereas the above coils, which were all located near the beginning of various sections of cable, were tested without additional splices being necessitated.

The preliminary experiments, by which it was ascertained that the phenomenon was associated with torsion, were extended by a long series of tests on samples. The following facts were established:

(1) The core, without the teredo tape and return wires, was insensitive to torsion and tension.

(2) The inductance was reduced when high hydrostatic pressures were applied to the core; recovery occurred when the pressure was removed.

(3) The effect of torsion on the core; with return wires in place, was to increase the inductance, when the twisting was in the direction which tightened up the return conductor. It was, of course, impossible to coil down the core in such a way as to loosen the return conductors, as this would have resulted in bird caging.

(4) The effects observed were altogether too large to be accounted for by dimensional changes producing variations in the natural inductance. It was found that a piece of non-loaded core to which a similar return conductor system was applied only exhibited very small inductance changes on twisting. For this reason, any small changes in the configuration of the outer return conductors were only to be considered from the point of view of possible reactions on the added inductance due to the iron loading.

It was finally established that the changes of inductance resulted from the strain-sensitivity of the loading material. The mechanism, by which the changes of inductance occur only when the return wires are present, has been the subject of prolonged investigation, as a result of which a theory has been formed in agreement with all the known facts. It would perhaps be premature to discuss this part of the subject before a stable core has been manufactured on a commercial basis. The greatest confidence is felt, however, that it will be possible to avoid this difficulty in future work by comparatively simple expedients.

The more important changes of impedance which occurred during laying were probably produced by hydrostatic pressure.

At the Italian end the water is shallow for twenty nautical miles, then gets deep fairly gradually at the point indicated by the irregularity shown in Figure 13, the increase of depth being 450 fathoms in four nautical miles. After this point the depth remains constant.

The sea bottom profile has the form of a portion of a sine wave. Taking the period of the change of depth as eight nautical miles the conclusion is reached that the worst irregularity would occur round about a frequency of 1700 p:s (see equation 14), which is precisely the case.

At the Sardinian end (see Figure 14) the profile is very irregular, although the actual range of values is much smaller. There is a deep spot about twenty-six nautical miles from the Sardinian end which might be expected to produce an irregularity in the region of 3200 p:s but this is not clearly defined on account of the high

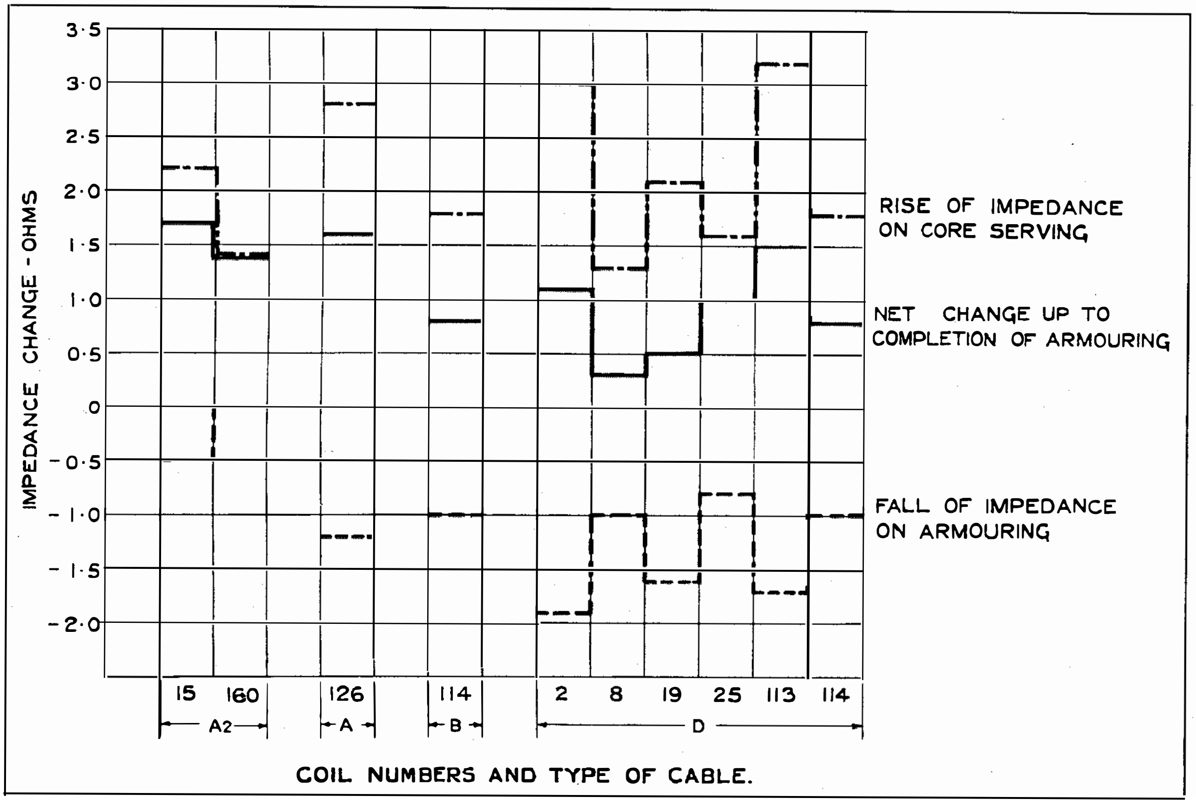


Figure 16—Diagram showing changes of impedance during manufacture.

attenuation. Otherwise, the irregularities are evenly distributed over the frequency range, as might be expected.

CONCLUSION

The general principles to be observed in allocating a continuously loaded cable are explained, and the theory of the method of determining the impedance of half coils by measurements of iterative impedance is given.

The manufacture of the Italy-Sardinia cable is described, and details are given of the precautions taken during manufacture, with a view to obtaining a high singing point. Impedance frequency curves illustrate the impedance changes which took place during manufacture, shipment and laying. The impedance changes during manufacture and laying are discussed.

The Anglo-French Micro-Ray Link Between Lympne and St. Inglevert

By A. G. CLAVIER and L. C. GALLANT

Les Laboratoires L. M. T.

1. General

IN the July, 1933 issue of this journal there appeared an article on the production and utilization of micro-rays, reference being made to the successful demonstration of two-way telephony given between Dover and Calais on a wave-length of 18 centimetres, in March, 1931. Results obtained on this occasion and during the experimental period which preceded and followed the actual demonstration, whetted the appetite of the technical world for deeper knowledge of the scientific and practical possibilities of wave-lengths of this order. Nevertheless, efforts have been directed almost exclusively to the region between 40 and 80 centimetres—a region which, though it does not enjoy the full advantages of the still shorter wave-lengths, presents less serious difficulties as regards production of the waves. The Dover-Calais link still remains the only instance of a duplex radio telephone circuit which has been publicly shown capable of operating on a commercial basis at wave-lengths of the order of 18 centimetres.

The British and French Air Ministries recently decided to establish such a micro-ray communication system between the aerodromes of Lympne and St. Inglevert, and the present article is intended to give a description of the equipment installed for this purpose. It represents the shortest wave-length radio telephony link in regular commercial exploitation today and may be considered as heralding an era in which the practical advantages of privacy, efficiency and reliability of these wave-lengths will be exploited to the full.

The link will be used to send teleprinter messages across the channel in order to signal the passage of aeroplanes over the Straits of Dover. Whilst the present equipment provides for only one-way teleprinter communication, provision has been made to extend it to two-way teleprinter communication as well as, eventually, to duplex telephony.

The distance between the two terminal stations is 56 kilometres and the sites have been so chosen that the line between the terminal stations is clear of obstacles, the electro-optical equipment being installed on suitable steel towers.

The wave-length used is 17.4 cm. and the tubes employed are of the same type as those described in the preceding article on the production and utilization of micro-rays (see *Electrical Communication*, July, 1933).

The equipment of each terminal station may be described as follows:

(a) Electro-optical systems (transmitter and receiver units),
(b) Micro-ray tubes and circuits,
(c) Transmitter and receiver control bays,
(d) Power supply,
(e) Teleprinter desk and switchboard.

2. Description of the Equipment

2.1. Electro-optical Systems (Transmitter and Receiver Units).

The antenna and reflector assemblies for transmitter and receiver are similar in construction. The main reflector is paraboloidal—3.2 metres in diameter and is spun out of an aluminum sheet about 5 mm. in thickness. At the periphery of this reflector an aluminum ring is riveted, which serves to keep the reflector rigid and undistorted. A spherical reflector 3 wave-lengths in diameter faces the large reflector to which it is attached by three radial wooden members.

The antenna, which is of the half wave-length type, is placed at the focus of the paraboloidal reflector, which coincides with the centre of the spherical reflector.

The focus of the paraboloidal reflector is situated in the aperture plane of said reflector, this being the condition for optimum working for a given outside diameter. The radiation

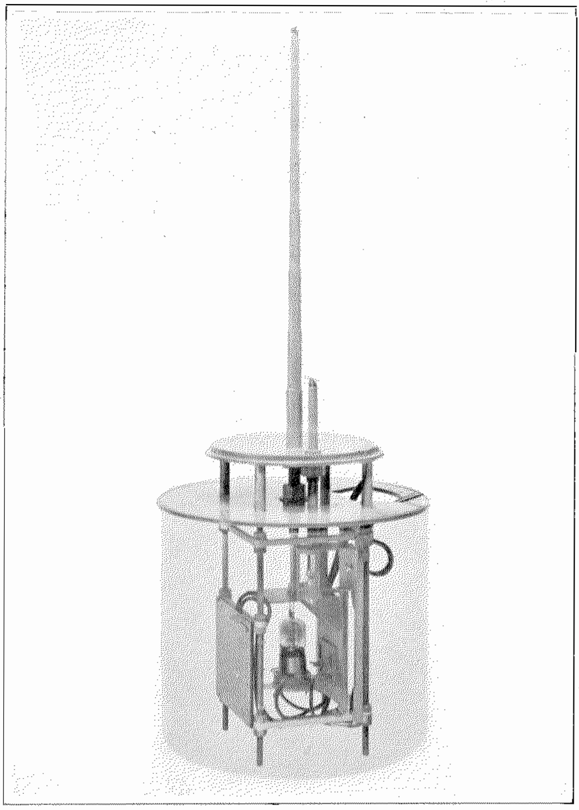


Figure 1—Tube Housing.

emitted from the antenna on the transmitting side is concentrated into a very sharp beam by means of the main paraboloidal reflector. The spherical reflector is used to reflect the direct forward radiation of the antenna back to the paraboloidal reflector, thus increasing the gain of the total electro-optical system. The gain of the paraboloidal reflector alone is of the order of 28 db. and it becomes 33 db. when the spherical reflector is added to the system. Of course, the same gain is obtained on the receiving side where the electro-optical system concentrates the incoming wave towards the receiving antenna. The reflector assemblies have welded fittings at the rear to facilitate fixing to convenient supports.

The antenna is fed by a specially designed concentric transmission line, the external surface of the outer tube being tapered and of great rigidity in order that the antenna should not appreciably move on windy days. The inner member is insulated by means of micalex spacers located at voltage nodes in order to keep the loss as low as possible. The only difference between the transmitter and receiver assemblies is that the former includes an auxiliary antenna and short transmission line which is used to feed a radiation indicator as explained below.

2.2. Micro-ray Tube Housing and Circuits.

At the rear of the large reflector is located the housing for the micro-radion tube (Figure 1). It is mounted in an ordinary socket, but the lead-in wires to the oscillating electrode of the tube are adjustable in relation to the transmission line. This adjustment is provided in order to tune the oscillatory circuit of the micro-radion tube on site, using data obtained from the laboratory tests and furnished with each particular tube. The oscillatory circuit is connected to the tubular transmission line through small H.F. condensers so that no d-c. voltage is applied to the transmission line and antenna.

The tubular transmission line comprises a movable part, the length of which is equal to three-fourths of the wave-length used. This serves to match the impedance of the antenna to the internal impedance of the tube, thus giving optimum working conditions. The sliding of the ¾ wave-length tube is obtained by means of a screw and small hand-wheel providing an adequately fine adjustment.

All surfaces conducting high frequency currents are gilded by a galvanic process in order to prevent corrosion. As for the other metallic parts, they are painted with a special weather-resisting paint as a protection against the unfavourable weather conditions which prevail near the sea coast.

On the transmission side, the auxiliary transmission line is connected to a thermo-couple and an associated galvanometer situated in the control room and acting as a radiation indicator. A support with terminals has been arranged inside the tube housing to hold the galvanometer when, for instance, tuning up the circuit or for checking purposes. When the tube is oscillating, the adjustment of the auxiliary line for maximum deflection of the galvanometer shows on what wave-length the tube is oscillating and also whether it gives its correct output.

In order to adjust the transmitting tube to the desired wave-length, the thermo-couple line is adjusted to a given setting known from previous calibration and the main transmission line is then adjusted for maximum deflection of the radiation indicator.

The reflector assemblies and the tube housing are installed on a platform supported by a steel tower in order to avoid all obstacles on the path of the beam between the two terminal stations. Such a system is shown in the Frontispiece. The tube housing is water-tight and is covered by a semi-circular shelter of aluminium sheet intended for the protection of the operator and apparatus if it is required to change the tube during bad weather conditions.

The mounting of the reflector assemblies on the platform is such as to reduce vibration or deformation due to the wind. The steel tower and platform have been erected so as to give the right direction for the beam but it is possible to compensate for any small error within ±5° by means of a device provided on the reflector itself. In the case of St. Inglevert, the steel tower is 20 metres high with a platform of 2 by 8 metres.

2.3. *Control Bays.*

Apart from the adjustment of the oscillatory circuit and transmission line, which does not have to be changed except in the event of a tube burning out, all control adjustments are located in the station building which is placed at the foot of the steel tower (see Frontispiece).

The control equipment for the micro-ray installation consists of a number of panels mounted on two vertical bays about 2 metres high and 50 cm. wide. The bays are mounted close together

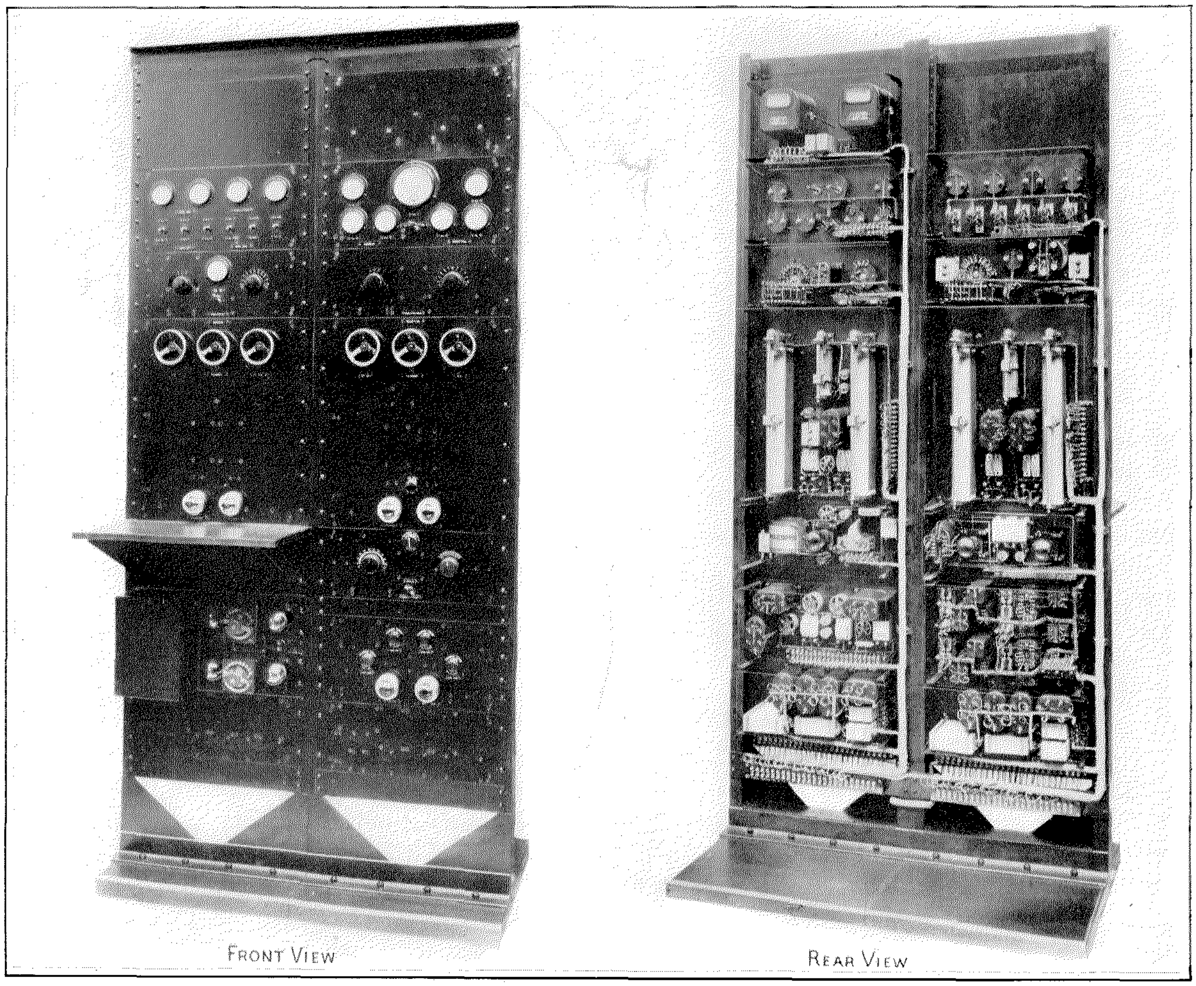


Figure 2—Control Equipment Bays.

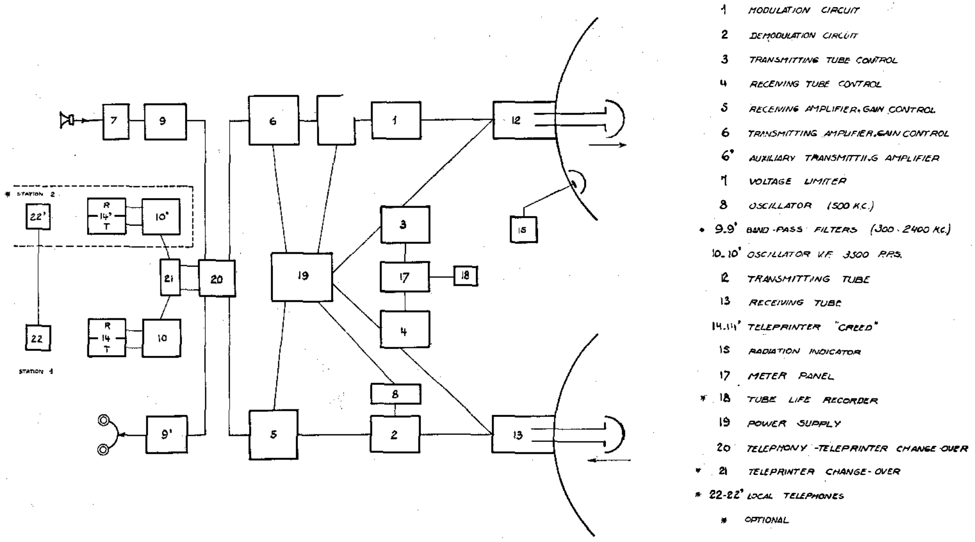


Figure 3—Block Schematic.

and side by side, as shown in Figure 2. The purpose of the various panels is shown on the block schematic, Figure 3.

Once the circuit has been established and the voltages applied to the micro-radion tube adjusted, there should be no necessity for close supervision of the control bays except an occasional readjustment of the supply voltages and gain control. The radiation indicator serves to show that the transmitter is operating satisfactorily.

The St. Inglevert installation includes both teleprinter and telephonic facilities. In this case use is made of batteries to supply the necessary voltages, and the power equipment (No. 19 on the schematic) of the complete terminal consists of the following:

(a) A 340-volt battery to supply the voltage to the oscillating electrodes of the micro-radion tubes, with tapping at 130 volts for the plate circuits of the auxiliary amplifiers and oscillators.
(b) A 60-volt battery used to bias the reflecting electrodes of the micro-radion tubes.
(c) A 12-volt battery divisible into two 6-volt units for the filament circuits of the tubes.

On both transmitting and receiving sides, the 340-volt and 60-volt supplies are applied to suitable potentiometer devices (3 and 4) with adjustments and meters (17) controlling the voltages applied to the different electrodes of the micro-radion tubes as well as the currents supplied.

The speech originating in an ordinary type of microphone is passed through a band-pass filter (No. 9) and a voltage limiter (No. 7). Though these devices might be omitted for a straightforward telephone channel, they have been included in case the system is connected to the telephone land line or in case it becomes desirable to superpose the telephonic channel and teleprinter channel in the micro-ray cross-channel link.

The modulation which may be speech or 3,500 cycle signals coming from the teleprinter unit, as explained below, is then increased in amplitude by means of amplifiers No. 6 and 6′. No. 6 is an ordinary transformer-coupled 2-tube amplifier of the repeater type with attenuators for gain control, and 6′ is a push-pull output stage, the tubes employed being one 4101 D, one 4102 D and two 4019 A. Signals coming from the amplifiers are then applied to a voltage divider (1) which supplies the modulation to the electrodes of the micro-radion tube in a proper ratio, as explained in the preceding article on micro-ray tubes already referred to.

A meter of the rectifier type serves to show that the correct voltages are applied to the tube. It is located on panel No. 1.

Signals incoming from the distant micro-ray terminal are picked up by a receiving reflector, focussed on the receiving antenna and demodulated by means of the micro-ray tube. In order to stabilise this demodulation process an auxiliary oscillator (8) applies a 500 kc. voltage to both electrodes of the receiving tube in a definite ratio which is determined from the constant frequency curve of the tube in the same way as the corresponding ratio for the modulation on the transmitting side. This is very helpful in rendering the adjustment less critical.

The demodulated signal is then fed into a receiver amplifier and gain control panel No. 5 and thereafter, either passes through a panel band-pass filter No. 9′ and is sent into an ordinary telephone receiver, or is transmitted to the teleprinter equipment for a second demodulation.

The detailed schematic of the complete micro-ray system will be found in Figure 4.

The various panels may be seen in Figure 2.

On the left bay, starting from the top, we find:

1. Meter panel to control all voltages applied to the anode circuits of the amplifiers and oscillators as well as the bias voltages for the grids, also the anode and filament currents.
2. Modulation panel comprising switches for the potentiometer resistances, and a voltmeter showing the modulating voltages applied to the oscillating and reflecting electrodes of the transmitting micro-radion tube.
3. Tube control panel (transmitter) on which potentiometer hand-wheels can be seen which serve to adjust the d-c. voltages for the tube electrodes. On this panel are also located the two rotating switches in the main battery supply.
4. Auxiliary amplifier panel used on the transmitting side.
5. Low frequency amplifiers, two stages being used for transmission and two for reception. This panel comprises a gain control arrangement on each amplifier.
6. Band-pass filter panel (240 to 2600 cycles) for the transmitting side.
7. Terminal strip.

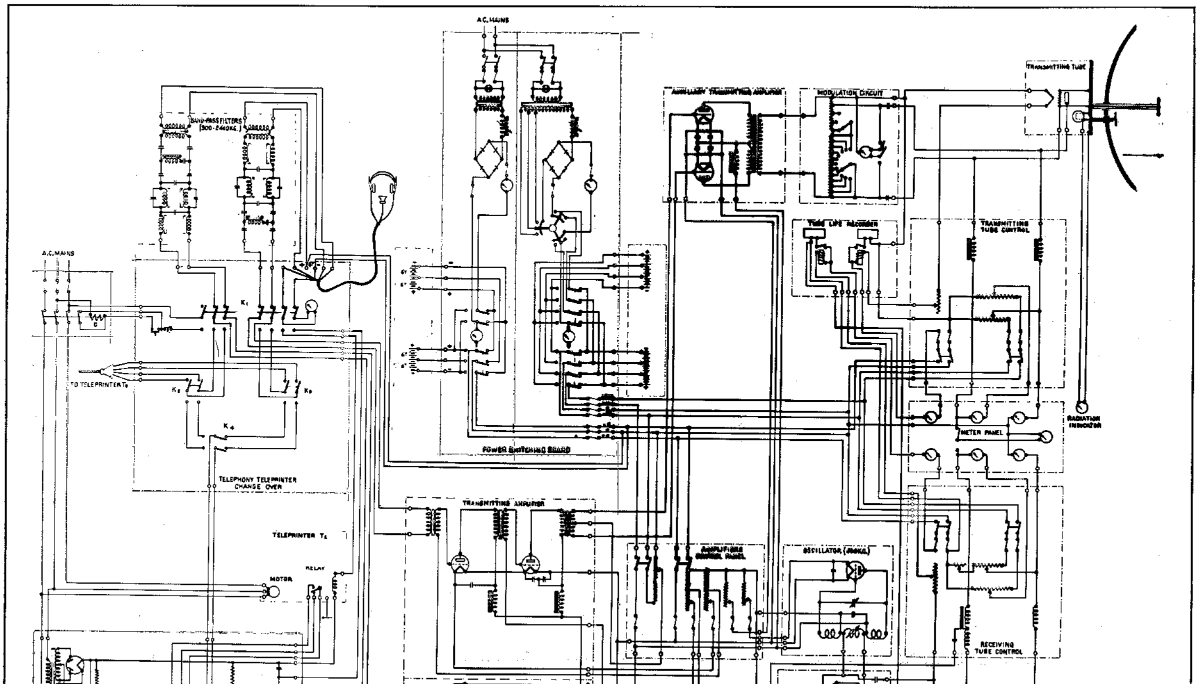


Figure 4—Detailed Schematic of Complete Micro-Ray System.

On the right bay, starting from the top, we find:

1. Tube life recorder panel for the micro-radion tubes. These recorders are fed by the filament batteries across a relay operated by the filament current of the corresponding micro-radion tube.
2. Tube meter panel with suitable meters to measure the voltages and currents relating to the micro-radion tubes.
3. 500 kc. voltage divider to adjust 500 kc. modulation on receiving tube electrodes and to obtain better stability for receiving adjustments.
4. Receiving tube control panel with potentiometer hand-wheels and vernier adjustment for the receiving electrode bias voltage; also, the main switches on battery feeders.
5. 500 kc. oscillator with frequency and coupling adjustments.
6. Amplifier control panel with rheostats to adjust the bias voltages and filament currents of the amplifier tubes. This panel includes a general switch for the d-c. supply to the amplifiers.
7. Band-pass filter panel (240—2600 cycles) for the receiving side.
8. Terminal strip.

2.4. Power Supply Equipment.

As mentioned above, the power supply equipment is constituted, on the St. Inglevert side by: (1) A 340-volt battery with a tapping at 130 volts; (2) A 60-volt battery; and (3) A 12-volt battery with a mid-point tapping.

A set of spare batteries has been provided in order to give full-time service, one of the batteries being in use while the other is being charged. The capacity of the 12-volt battery is 150 ampere-hours and the capacity of the other batteries is 8 ampere-hours. All batteries are charged by means of two dry rectifiers of the copper-oxide type with full wave rectification. Suitable reactors are inserted in the circuit to adjust the charging current. As the 8 ampere-hour elements do not carry the same load in operation, they have to be charged accordingly. The high-tension rectifier has consequently been arranged so as to charge these batteries in parts, this being done by means of a single switch which connects the desired batteries and also the corresponding tappings on the rectifier transformers.

The power board is divided into two panels, one for the 12-volt battery and the other for the 400-volt battery (340+60). These panels are 2 metres high and 60 cm. wide. The two rectifiers are mounted behind the board and are easily accessible from the side. On the board may be seen (Figure 5) the different switches for charge and discharge operation as well as the usual ammeters and voltmeters.

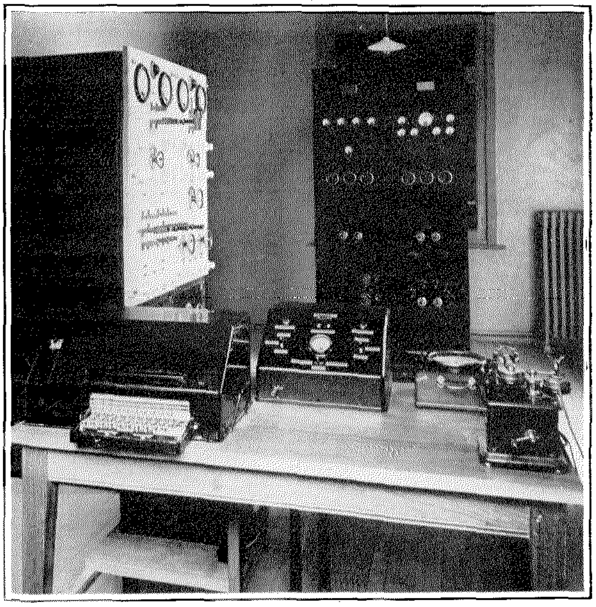


Figure 5—Traffic Room in St. Inglevert Building.

At Lympne it has been thought advisable to use a motor alternator with suitable speed regulation to correct the variation of the mains supply. The alternator feeds the rectifiers from which the high-tension power supply to the tubes is obtained.

The filaments, as at St. Inglevert, are fed from a 12-volt battery with the provision of a charging plant and spare battery.

2.5. Telephony Equipment.

Standard microphones and receivers are used, and duplex operation is obtained with the possibility of connecting the micro-ray link to the land line if ultimately required.

2.6. Teleprinter Equipment.

The teleprinters are of the 3A Creed type used in conjunction with a single-current voice-frequency equipment. The transmitting contacts of the teleprinter control the flow of voice-frequency current to the input side of the modulation equipment. Signals being transmitted also operate the receiver side of the voice-frequency unit and give a home record of the message. A 3500-cycle frequency has been chosen in case of future simultaneous working of the telephonic channel.

Voice-frequency signals received from the micro-ray receiving equipment are amplified by means of the voice-frequency equipment and after demodulation these signals are sent to the teleprinter magnet, the detected current output being 20 milliamperes for correct operation. The voice-frequency unit is fed from the a-c. mains. It does not require any adjustment if valves are changed. The only adjustment necessary when putting an equipment into service is the connection of the supply mains to the correct tapping on the power transformer. The signal distortion is very small and the circuit includes a device to maintain the detected current approximately constant for a wide variation of signal strength.

2.7. *Teleprinter Desk and Switchboard.*

The St. Inglevert terminal has been equipped either for telephonic or teleprinter operation; moreover, the French Administration has decided to install two teleprinters, one located in the micro-ray building and the other in the Administration building situated about half a mile away. Each teleprinter must be able to transmit while the other is being used for reception. The teleprinter desk (Figure 5) at the micro-ray station comprises:

1 Teleprinter
1 Voice-frequency unit (3,500 cycles)
1 Switchboard and 1 galvanometer connected to the radiation indicator.

On the switchboard can be seen the keys which are used to change over from one kind of operation to the other, and also to connect one or the other teleprinter. On the same equipment a milliammeter shows the microphone current or the detected current coming from the voice-frequency unit and flowing into the teleprinter magnet. The schematic of the teleprinter desk can be seen in Figure 6.

For telephonic working, key K.1 performs the following functions:

(a) It switches the 6-volt battery on to the microphone and connects this microphone to the input transformer of the transmitting low-frequency amplifier.
(b) At the same time it inserts the above mentioned milliammeter into the microphone circuit.

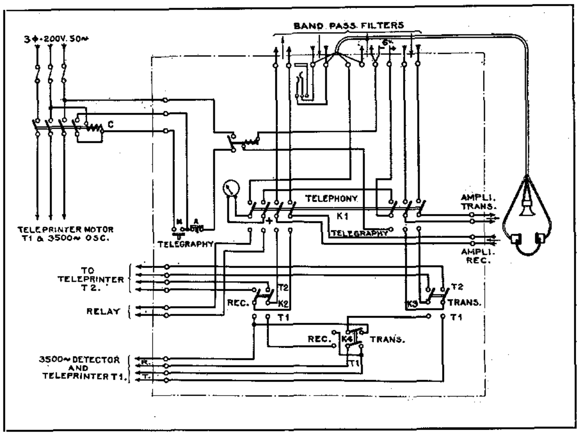


Figure 6—Schematic of Teleprinter Desk.

(c) It connects the output transformer of the receiving amplifier to the telephone receiver through the band-pass filter.
(d) It opens the holding circuit of contactor C and thus switches the a-c. mains off the teleprinter motor and voice-frequency unit.

In the teleprinter position, key K.1:

(a) Connects the transmitting and receiving amplifier respectively to switches K.2 and K.3 which are used to put one or the other teleprinter into service.
(b) Switches the milliammeter into the voice-frequency unit output circuit to control the detected current.
(c) Switches on auxiliary contact of contactor C holding circuit.

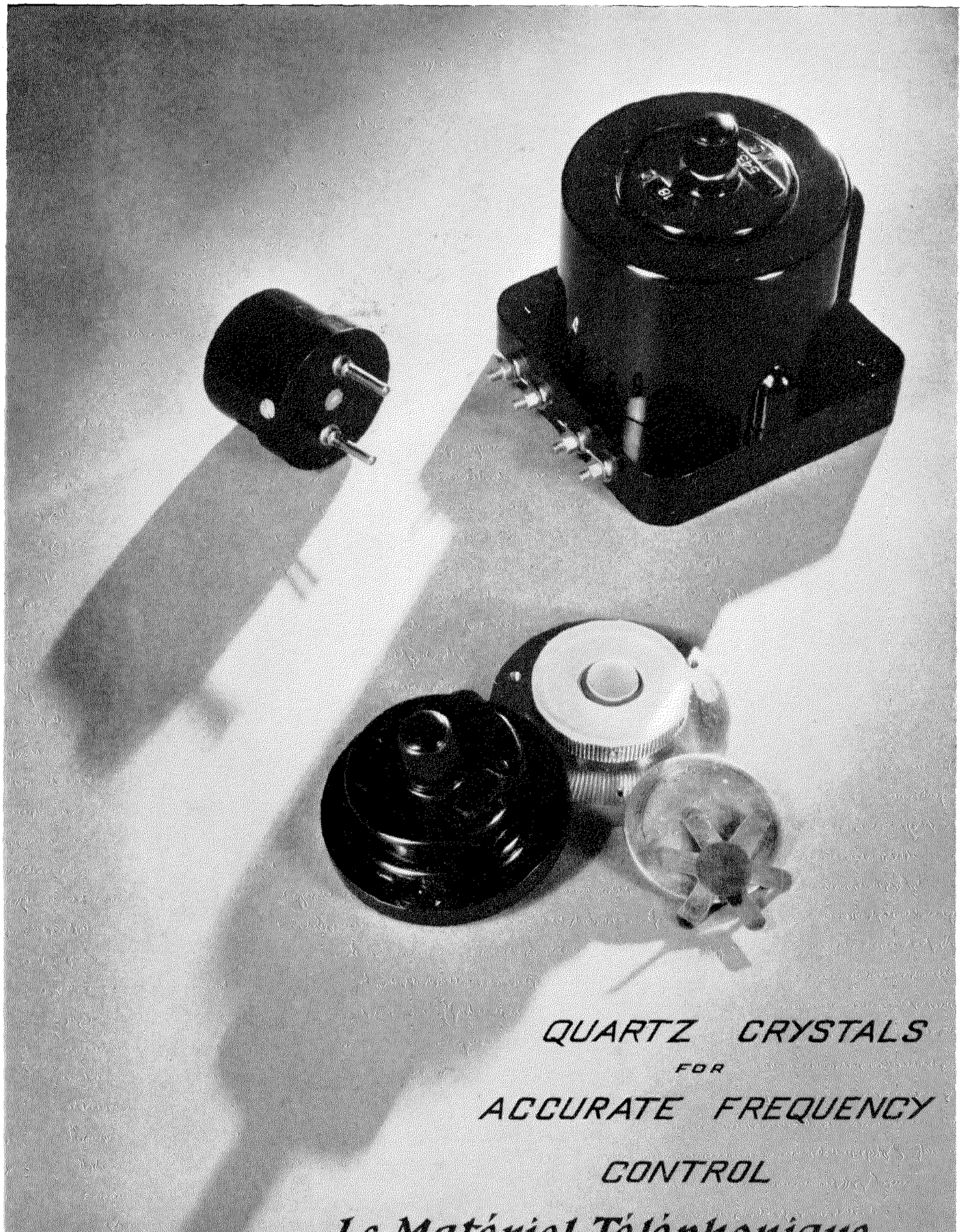
Key K.4 is used to switch the local teleprinter on either to reception or transmission.

The equipment is completed by a set of push-buttons controlling contactor C in order to switch on or off the mains from the teleprinter equipment.

It is thus possible either to obtain duplex operation, one teleprinter transmitting and giving a home record and the other receiving, or to use either teleprinter for simplex operation, with a home record during transmission. In the latter case, K.4 is used to change over from reception to transmission.

On the Lympne side only simplex teleprinter operation has been installed for the moment, but the equipment could easily be extended later to provide the same facilities as on the French side.

The Anglo-French Micro-Ray link between Lympne and St. Inglevert is scheduled for inauguration the latter part of January, 1934.



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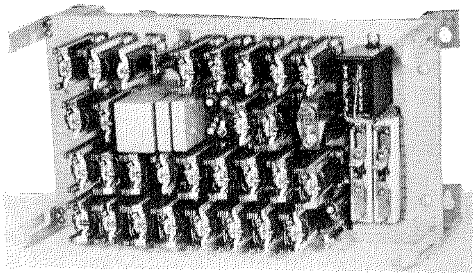

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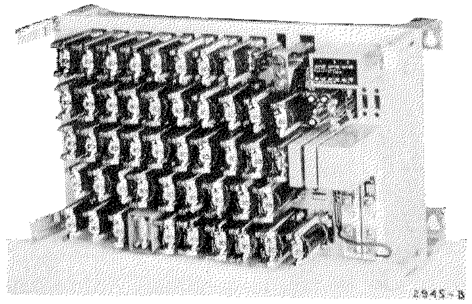

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Bell Telephone Manufacturing Company	*Antwerp, Belgium*
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Compañía Standard Electric Argentina	*Buenos Aires, Argentina*
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