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# ELECTRICAL COMMUNICATION

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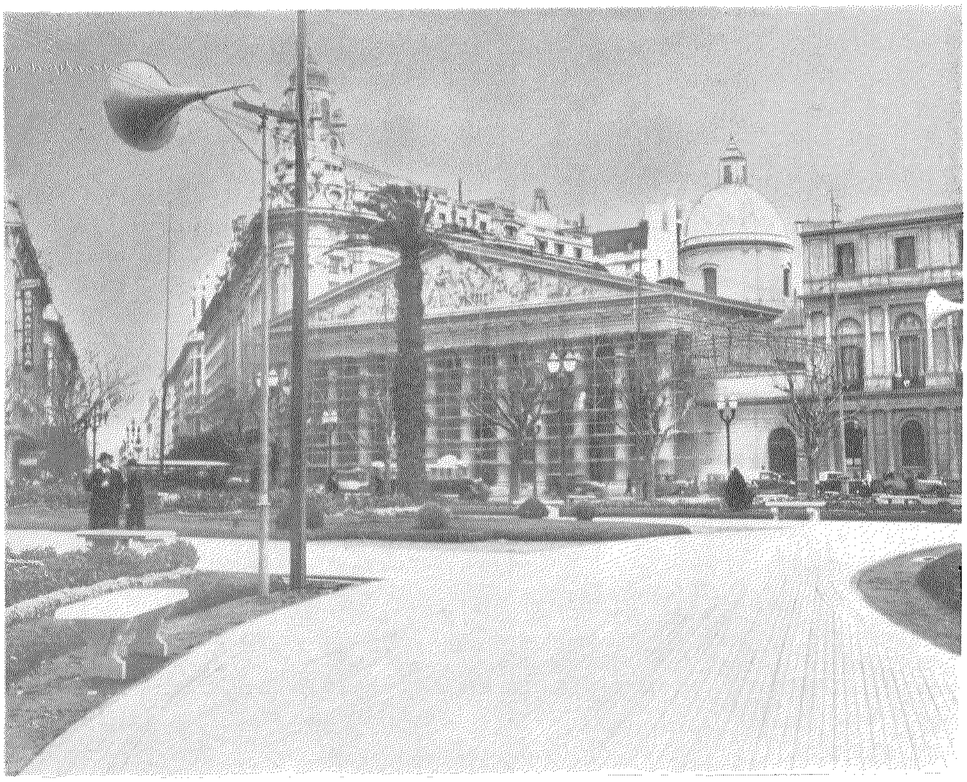

A VIEW OF PLAZA DE MAYO IN FRONT OF THE CATHEDRAL, SHOWING LOUD SPEAKERS INSTALLED BY THE UNITED RIVER PLATE TELEPHONE COMPANY, LTD., FOR THE BROADCASTING OF THE THIRTY-SECOND EUCHARISTIC CONGRESS, HELD IN BUENOS AIRES IN OCTOBER, 1934

# Electrical Communication in 1934

### *General Trend of Development*

THE year 1934 was one in which advances in the art of transmission, thought of for years, made definite strides towards the goal of practical realisation. It is interesting to note that these recent developments show in many respects a closer tie between various methods of transmission than would have been expected in the past. In general terms, one can say that both in the wire communication art and in the radio art the principal efforts have been towards the use of higher frequencies. An immediate reaction has been to give consideration to channels of communication covering a wide band of frequencies. There has been exceptional interest in the development of multi-channel telephone systems capable of using these wide bands of frequencies to full advantage, often involving newly designed feed-back amplifiers and crystal filters. This general trend of development is well illustrated in many ways, all of which bear a remarkable degree of similarity although the results may apparently be different.

Starting with the less impressive developments, may be noted the extension of carrier telephone systems over open-wire lines to the use of a supplementary channel of wide band width capable of transmitting broadcast programmes[1]. Such a system has been in operation between the towns of Bratislava and Kosice in Czechoslovakia since August, 1934, and provides, over the three normal carrier channels, one high quality channel of 7,500 cycle band width. Several installations have since been made.

Another interesting case showing the tendency to use more channels over existing facilities is illustrated by the first realisation of a telegraph installation taking advantage of the possibility of superimposing the Standard eighteen channel voice frequency telegraph system over a Standard three channel carrier system whereby, in addition to the normal telephone channel, up to as many as fifty-four additional two-way telegraph channels may be transmitted over a single open-wire circuit. A system making use, to a large extent, of these greater possibilities, has been installed between Cape Town and Johannesburg for the South African Administration, the distance between the terminals being approximately 1,000 miles.

Cable circuits, repeaters and loading coils are now designed, in most cases, to give more than one telephone circuit. One application resulting therefrom has been to superimpose on the usual telephone circuit one carrier telephone circuit operating in the band of 3,500 to 7,000 cycles. Such a system is foreseen for the new London to Glasgow cable which thereby will have a largely increased carrying capacity. It will thus be seen that the provision of a single carrier channel above the normal voice range on every circuit of a cable now presents no difficulties and, in addition, it is also readily possible to include screened pairs taking three or more high speed carrier channels for very long distance circuits. More channels, however, can be contemplated in many cases, and in this connection the recent order for a submarine cable between Australia and Tasmania may be mentioned[2], in which the total band width used will be 42,500 cycles, the terminal equipment being designed to carry, over a single wire, three both-way telephone channels in the band up to 9,000 cycles, three one-way telephone channels in the band of 11,000 to 20,000 cycles, returning over three telephone channels in the band of 21,000 to 31,000 cycles, and one one-way reversible broadcast programme channel using the range of 34,000 to 42,500 cycles.

Reverting to land cable, the experiments made at Morristown, New Jersey, in 1933 are of outstanding importance. Two pairs were looped back and forth in a 25 mile length of underground cable in such a way as to simulate 850 miles of four-wire circuit. It was found possible, by using frequencies between 4 and 40 kc. to obtain nine carrier telephone channels on this circuit[3]. Systems capable of transmitting still very much

[1] For all numbered references, see list at end of paper.

wider bands by using coaxial lines have been studied. In this latter case a band width of 1,000 kc. or more may be transmitted over long distances and divided by proper terminal equipment into some 200 one-way telephone channels. Such systems have the further advantage of being capable of transmitting the very wide band of frequencies necessary for television signals[4]. With the progressive increase in the range of frequencies used over wire, there is a corresponding increase in attenuation which involves the use of closer spacing between repeaters. The number of repeaters at each station, however, is decreasing, tending to be limited to two only at each repeater station in the case of a coaxial line, but in view of the close spacing it is necessary to consider that the stations may have to be unattended; we find here a type of development which is also becoming of importance in radio.

The development of systems using ultra-short waves and capable of transmitting wide bands of frequencies, is progressing each year. Experiments have been made to develop the new facilities provided by the single channel commercial radio link (Micro-Ray) operating across the English Channel on 1,700 Mc.[5]; also, on a nine channel telephone system on 100 Mc., in order to produce commercial multi-channel installations in the future.

One very interesting experiment along these lines is the recent extension of the land telephone lines across Cape Cod Bay by single channel unattended radio stations operating at 65 Mc.[6] An ultra-short wave radio telephone system is working as a radio link in a land line telephone circuit across the Bristol Channel. A series of transmissions between Guernsey and Shaftsbury—a distance of 110 miles— has been carried out on a wavelength of 5 metres. The preliminary results indicate that a commercial circuit is feasible although such a circuit may at present be subject to occasional "fade outs." It is proposed to extend the test circuit to the land line system at each end so that traffic trials may be carried out.

The development of aeroplane radio equipments has been directed recently towards automatic operation of the equipment on the planes. Equipments for blind landing in fog also have been placed in experimental use in airports such as Tempelhof and Zurich. An automatic direction finder for planes has been developed and was shown at the November International Aircraft Exhibition in Paris. On land, direction finders eliminating night error are superseding other types. A system using small antennae, R.F. transformers, and lead covered R.F. transmission lines, has been developed.

In the field of distribution of music and entertainment, the large radio equipments have been the object of study in order to decrease the power taken from the mains to produce a given power in the antenna. Several methods have been considered and used, such as the floating carrier system and the high power modulation system using class B voice frequency amplifiers. The basic principle of the floating carrier system consists in transmitting with a more or less constant percentage modulation and varying the amplitude of the carrier wave in accordance with changes in the strength of the audio-frequency signal. The high power modulation system involves a class B audio-frequency amplifier capable of handling, without excessive distortion, the large power output required to modulate on the last stage of the radio amplifier.

The wire method of distribution has been the object of further development[7]; distribution over the telephone network has made progress in several countries, particularly in Holland and Switzerland. The distribution over a separate network also has been developed, for instance, in England and in Belgium.

The reproduction of music in auditory perspective has been one of the recent notable achievements in the distant transmission of music. It gives for the first time a distant reproduction fully comparable with the music heard directly in an orchestral hall[8].

Frequency control methods have made further progress. A compact oscillator capable of a degree of accuracy of the order of one part in a million, has been developed. The use of crystals with a practically negligible temperature coefficient is becoming more general in view of the corresponding simplification of the equipment. Control of ultra-short waves by tourmaline crystals is now a recognised method used in commercial equipments.

Automatic switching systems have developed more and more in the direction of complete national automatic networks. Successively, automatic operation has extended from the large towns to the small rural communities. These centres have been grouped into complete networks and one can now see the start of automatisation of toll services. Switzerland is a good example of this type of development. When the Basle-Zurich plan is completed, over 100,000 lines of rotary equipment installed in 124 different exchanges will have full automatic interconnection. The most distant exchanges will be over 100 km. apart. This type of service involves many new developments, including long distance dialling, automatic insertion of repeaters, alternate routing of calls, time and zone metering, etc.

### *Progress in Communication Systems*

In Europe, the co-ordinating influence of the C.C.I. has continued to be felt.

The Comité Consultatif International des Communications Téléphoniques à Grande Distance (C.C.I.F.) held meetings of four of its technical commissions in Stockholm in June, and a plenary session of the committee itself in Budapest during September. Special attention was given to the question of transmission standards in their application to plant. Numerous problems relating to commercial practice and rates and to operating matters also were dealt with. Important work was done looking towards satisfactory transmission on international toll connections by the preliminary planning for a European general toll switching plan, specifying transmission characteristics and making provision for the rewriting of the recommendations of the various technical commissions.

The event of the year, from the European broadcasting point of view, was the application of the new wave plan for the European region drawn up at the May-June 1933 C.C.I.R. conference at Lucerne. Various factors had made the Prague plan obsolete, such as the development of the European network, the Madrid Telecommunication Convention, the enlargement of the European region, and the inclusion of the U.S.S.R. stations. It was possible to put the medium wave part of the Lucerne plan almost integrally into force on the 15th January, 1934, while in the long wave band a *modus vivendi* considerably improving the situation has since been achieved.

At the September session of the C.C.I.R. at Lisbon, a regional agreement was drawn up for the regulation of the radio telephone communications of fishing vessels in the North Sea which, it is anticipated, will greatly relieve the congestion and interference that have been increasingly experienced in the radio telephone working of this class of ship.

The C.C.I.T. held its fourth plenary session at Prague in May. Various decisions affecting the design and development of printing telegraph systems were made. In addition, new definitions were drawn up for the factors involved in the determination of printer operating margins and signal distortion.

Most of the European long distance systems have been extended to take in new areas or have had equipment added to provide further circuits where cables already exist.

In England the recent introduction of a maximum fee of one shilling for evening calls of any distance made it necessary to press forward the completion of a new cable system which will eventually extend from London to Glasgow (about 650 km.). The cable is partly armoured and partly installed in ducts and conforms to a very modern design in that 25 lb. per mile lightly loaded conductors which will take a carrier channel above the voice range are used.

A long distance cable system in Norway has been under consideration for some time as, until recently, only short lengths of cable radiating from Oslo had been installed. A new system is planned to follow three main routes: from Oslo along the south coast to Stavanger to cater for both local requirements and, eventually, submarine links to Germany and England; from Oslo across to Bergen; and, finally, from Oslo northwards as far as Trondhjem. The first section of this underground loaded cable system was in process of installation during the year 1934 between Oslo and Sandefjord (60 km.). There has been activity in the installation of railway cables in Norway and Holland.

In Italy, the extension of the main telephone network across the island of Sicily has been completed. Extensions to the northern network have also been completed between Trento and

Bolzano (62 km.) on the route towards Austria, whilst the Turin-Modane cable which links up with the French network and a second Milan-Casteggio cable are now under construction. There have also been important extensions to the long distance telephone cable networks in Holland, Denmark, Switzerland, and Czechoslovakia.

A further interesting installation in Italy, scheduled for completion in 1934, is the provision of a second telephone channel over the Italy-Sardinia cable which was laid in June, 1932[9]. Although the cable had been designed with only one telephone channel in view, tests made on the cable showed that it was possible to establish a single reversible carrier channel over the voice frequency circuit operated on a voice switching basis.

A contract has been awarded to Standard Telephones and Cables (Australasia), Ltd., for the terminal and land line equipment for a submarine cable between the mainland of Australia and the island of Tasmania. The cable, which is similar to the Key West-Havana 4, is being supplied and laid by Messrs. Siemens Bros. of Woolwich, England, and is of the coaxial type with para-gutta insulation. There are two lengths, each of 81 nautical miles, with an intermediate repeater station at King Island. Carrier telephone circuits will be employed over open wire land lines which already exist between the landing points of the cables and the cities of Melbourne (on the mainland) and Launceston and Hobart (on Tasmania). The system will provide, initially, five telephone circuits, seven telegraph circuits, and a one-way reversible broadcast channel transmitting frequencies from 35 to 7,500 cycles.

In China, an important order has been received for the establishment of telephone communication between nine provinces by open wire circuits which are designed to take carrier operation when required by traffic growth. There are many river crossings where cable will have to be used, and several repeater stations are included in the scheme.

The installation of Standard carrier systems is playing an important part in linking up the various centres of east Czechoslovakia and the Roumanian carrier systems with the Czechoslovakian toll cable network, while similar installations in Jugoslavia, Bulgaria, and Turkey have facilitated the extension to these countries of the European long distance network.

In addition to the cable network in China, mentioned previously, short wave telephone and telegraph equipments are being installed in Shanghai, Hankow, and Canton, thus forming the backbone of a radio communication system in that country. Twelve radio stations have been installed at the Cape Verde Islands for telephone and telegraph communication between these islands and also between Praia (Cape Verde Islands) and Lisbon. A high power short wave telephone and telegraph equipment has been ordered for Roberts Heights to increase the communication facilities of the Union of South Africa.

Radio Telephone service in South America was improved in 1934 through the establishment of direct connections between Buenos Aires and Bogota, and between Buenos Aires and Lima. This has resulted in improved radio telephone service between Europe and these cities.

An important advance in the United States was the placing in service of several new short wave telegraph transmitters capable of generating 50 kW. of radio power. Such transmitters, together with a 250 kW. mercury arc rectifier, were installed at the Palo Alto, California, station of the Mackay Radio and Telegraph Company for use in the recently opened radio telegraph circuit between Palo Alto and Tokyo. Incidentally, the installation of the 250 kW. mercury arc rectifier marks the introduction of high capacity mercury arc rectifiers in the United States for supplying power to large radio transmitters.

Radio telephone service between Japan and the United States was inaugurated in December, 1934.

Considerable progress has been made during the past year in the relaying of broadcast programmes to Great Britain from abroad, both by land lines and by wireless link. An outstanding example of the excellent quality which can be transmitted over present day music circuits was provided by the music relayed from Bayreuth in August.

The development in the use of radio telephone circuits was shown by the Christmas Day 1933 programme, when relays were taken over the British Post Office radio telephone services from Bermuda, Ottawa, Wellington, Sydney, Bombay, and Cape Town. The "Empire Exchange" Christmas Day 1934 programme was still more elaborate and was inaugurated by the bells of the Church of the Nativity at Bethlehem.

The British Empire short wave service has been extended inasmuch as the 20,000 letters and reports which have been received since its inauguration in December, 1932 showed that there was a demand for such a service. Experience has led to the replacement of the original aerials by more effective types, and experiments are being continued with a view to their further improvement.

The Australian Post Office Department has adopted the wide band carrier system with a cut-off frequency of 7,500 p:s developed for relaying broadcast programmes and five of these systems have been ordered.

The 10 kW. broadcasting station in Vadso (Norway), probably the most northerly broadcast transmitter in the world, was opened on May 17th.

One of the most outstanding events in mercantile marine affairs was the launching of the Cunard-White Star superliner "Queen Mary" on September 26th. This great vessel will be fitted by the International Marine Radio Company with its radio telephone and telegraph equipment.

It is interesting to note the extended use which is being made of radio equipment by the police authorities all over the world for the detection and prevention of crime.

During the course of a successful demonstration tour through Austria, Hungary, Jugoslavia, Bulgaria, and Roumania, made by the Standard aeroplane equipped with radio telephone and telegraph transmitters and receivers, broadcasts were made from the plane over the transmitters in Vienna and Budapest.

A chain of eleven ground stations in South Africa marks the equipping of the various airports with modern means of communication.

Continued progress has been made this year with the development of automatic switching in rural areas. Two thousand lines of No. 7 type Rotary District equipment were installed in eight exchanges in Basle. A noteworthy feature is the low maintenance cost.

Important orders for the No. 7 type District equipment have been received from Denmark, and new exchanges have been opened in Belgium and Holland. Most of these rural exchanges will ultimately form part of the national dialling schemes and many new facilities have therefore been included in the latest designs.

National dialling schemes are under consideration in Belgium, Holland, Switzerland, and Denmark. One of the most important problems is the method of signalling and dialling over long cables, and an important advance in this respect is the development of a voice frequency signalling system employing two frequencies of 600 p:s and 750 p:s.

In connection with the general extension of automatic working of the British Post Office telephone system, facilities for multi-registration, through dialling and other features are incorporated in the design of the type of exchange used. This exchange, known as the Unit Automatic Exchange, will in future play a very large part in the system of the British Post Office.

Progress has been made in the application of telephone switching technique for other purposes, and instances worthy of mention are the remote control of electric power, gas and water supply systems, and of switching operations when classifying goods waggons into different trains.

A new type of picture transmission equipment was developed by the Bell System and between twenty-five and thirty sets (combined transmitting and receiving equipment) have been installed in offices of the Associated Press in important cities throughout the United States. These stations are tied together over a network of open wire and cable circuits, so arranged that any station may send a picture simultaneously to all of the others or to certain groups of selected stations.

With the rapidly increasing use of teleprinters in commerce and industry, attention has been directed to the need for a keyboard which more closely resembles the typewriter. At the C.C.I.T. meeting a keyboard was demonstrated for the first time by Creed & Company which meets these requirements by providing automatic "case" insertion and signal storage, thus eliminating the need for special letter and figure shift keys.

With the completion of the installation of voice frequency telegraph systems between London and the principal cities and towns in Scotland and the North of England, a very large proportion of the public telegraph system in Great Britain has now been converted to voice frequency working.

In Germany the first steps towards realisation of a public teleprinter system were taken. The Reichspost established an automatic teleprinter exchange service between Berlin and Hamburg, including Bremen, Hanover, and Magdeburg in the network. It is intended to extend this service to the western part of Germany (Dusseldorf).

The British Railways have extended their use of teleprinters and it is of interest that one of them claims to have effected a saving of 75% of the costs hitherto incurred with the hand Morse system. The speeding up of freight trains has created a further demand for printers for the more rapid handling of way-bills and other documents.

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# The Standard Carrier Broadcast System

By K. G. HODGSON, F. RALPH, and B. B. JACOBSEN

*Standard Telephones and Cables, Limited*

SYNOPSIS:—*The Standard Carrier Broadcast System has been designed for the transmission of broadcast programmes over open-wire lines without interfering with existing facilities. A transmission band from 35 to 7,500 cycles is provided, the lower side-band of a carrier frequency of 42.5 kc. being used. Although the system is adapted for unidirectional transmission only, it may be switched for operation in either direction and the programme may be simultaneously transmitted to a number of stations on the same network. Details are given of test results obtained on an installation in Czechoslovakia, and show that the performance of the system is comparable with that of a broadcast cable circuit.*

WITH the growth of international broadcasting, a demand has arisen for telephone circuits of sufficiently high quality for the faithful transmission of music. Where a telephone cable network exists, this demand can be satisfied by the provision of specially loaded pairs in conjunction with repeaters suitable for handling the greatly increased band width. In more sparsely populated districts where telephone traffic does not justify the installation of a cable network, the provision of broadcasting facilities has generally been a matter of some difficulty since the use of physical open-wire circuits for programme transmission is subject to severe limitations. In particular, the low frequencies which must be transmitted for the satisfactory reproduction of music are frequently marred by the presence of telegraph interference while, if frequencies above 5,000 p:s are to be transmitted, the circuit becomes unsuitable for the standard types of carrier systems.

The Standard Carrier Broadcast System has been designed to fill this need and to provide a broadcast channel comparable in quality with a cable circuit without interfering with any existing facility.

## Objects of Design

At the beginning of the development, the requirements for the system were formulated as follows:

(1) The frequency band occupied by the systems should not prejudice the installation of other Standard Systems on the same or adjacent circuits. In order to meet this condition, the frequency range adopted lies immediately above that of the three-channel telephone systems. Since it is also necessary that the broadcast system be adapted to operate either in the same direction as, or in the opposite direction to, the channel operating on the adjacent frequency band, the broadcast sideband must be separated from other frequencies by means of filters at repeater stations and amplified separately.

(2) Facilities should be provided to enable a programme to be transmitted from one station to two or more stations simultaneously.

(3) The performance of the system in respect to frequency distortion, volume range, phase distortion, and non-linear distortion should be at least equal to the requirements laid down by the C.C.I.[1] for broadcast cable circuits. The band width should be greater than that specified by the C.C.I., 35-7,500 instead of 50-6,400, since the present tendency is towards a wider transmission band.

## Features of the System

In common with other Standard Carrier Systems, the single sideband suppressed carrier method of transmission is used with its attendant economies in band width and transmitted power. A carrier frequency of 42.5 kc. has been adopted, the lower sideband being transmitted. The separation of the two sidebands is evidently not a simple matter, since each extends to within 35 p:s of the carrier frequency. It is practically impossible with the normal type of filter structure to obtain adequate discrimination between two frequencies of the order of 42.5 kc. and differing by only 70 p:s. Two alternatives were therefore considered:

(1) The use of a crystal filter to eliminate the narrow band of frequencies in the unwanted sideband.

[1] *C.C.I. Red Book.* 1931, Par. A.b.3.

(2) The vestigial sideband method in which a portion of the unwanted sideband is transmitted, distortion due to the phase differences of the two sidebands being corrected by a compensating network.

If the latter method is used, care must be taken to ensure that the transmitting and receiving carrier frequencies bear a constant phase relationship to one another. In a system in which the carrier is not transmitted, the fulfilment of this condition involves certain complications even when the carrier frequencies are synchronised by the method described later. It was decided, therefore, to adopt the crystal filter method which also provides a convenient means for the accurate adjustment of the carrier frequency. The method by which advantage is taken of the properties of the crystal as a standard for adjustment of the carrier frequency is described hereinafter in the section on Maintenance. The crystal used is of the rectangular plate type and is provided with electrodes of gold deposited on its faces. Such crystals may be incorporated in filters of normal construction using coils and condensers, provided that the crystals can be ground to have suitable constants matching the remaining elements of the filter. In this case such grinding was found to be impracticable owing to the size of crystal required, and the crystal is operated between substantially pure resistances of about 50,000 ohms between the stages of a two-valve resistance coupled amplifier. The attenuation characteristic of such a filter, as shown in Fig. 1, rises very rapidly between the resonant and antiresonant frequencies. Below the resonant frequency, the attenuation in the pass range again rises slightly. The values of the resistances between which the crystal operates, and the separation between the resonant and antiresonant frequencies, are so adjusted that the desired steepness of cut-off is obtained and that the shape of the attenuation curve below resonance partially compensates for the attenuation of the modulator filter at the edge of the pass range.

The operation of the crystal filter is dealt with more fully in a previous article in *Electrical Communication*.[2] Temperature control of the crystals has not been found necessary, although crystal filters are used at both transmitting and receiving terminals. Where the two terminals are at different temperatures there will be small differences in the resonance frequencies of the two crystals, but the discrimination provided against the unwanted sideband is adequate under all conditions likely to occur in practice.

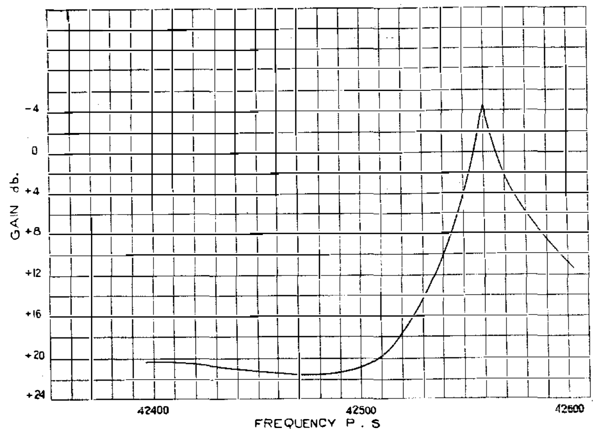


*Figure 1—Typical Characteristic of Crystal Filter.*

The next question to be considered was the maximum difference permissible in the carrier frequencies of the transmitting and receiving terminals. Any such difference will, of course, disturb the harmonic relation of the various frequencies which contribute to the timbre of a musical note. It is well known that quite considerable differences may be tolerated in a commercial speech circuit in which frequencies below 200-300 p:s are not of great importance. The requirements of music transmission are, however, very much more rigid, since deviations from normal are more readily noticeable, and, also, much lower frequencies must be transmitted. This point is of particular importance inasmuch as the distortion introduced by a given difference between carrier frequencies is inversely proportional to the frequency of the fundamental. Consequently, the distortion in a system transmitting frequencies down to 35 p:s may be six times as great as in a similar system with a cut-off at 200 p:s. Experiments carried out with a system transmitting frequencies down to 35 p:s showed that differences between carrier frequencies of less than 4 p:s could produce noticeable distortion.

The method of operation finally adopted ensures that there can be no frequency difference

[2] "The Design of Filters for Carrier Programme Circuits" by F. Ralph, *Electrical Communication*, April, 1933.

between the transmitting and receiving carrier frequencies. The carrier oscillators at the terminals and at receiving and combined repeaters are of a comparatively unstable type whose frequency of oscillation may be controlled within limits by an extraneous frequency injected into their grid circuits. This frequency need not be the actual frequency at which the carrier oscillator is desired to oscillate, but must be harmonically related to that frequency. As may be expected, the closer the relation between the required frequency and the frequency to be injected, the more readily is the control exerted. The controlling frequency or pilot frequency is generated by an oscillator of high stability located at the transmitting terminal. This oscillator controls the transmitting carrier oscillator and also provides pilot current which is transmitted to the line. At the receiving terminal and at receiving repeaters the pilot current is selected by means of a narrow band-pass filter and used to control the local carrier oscillator at each station which is receiving the programme and, incidentally, to operate a pilot indicator. The location of the pilot frequency depends on a number of factors.

(1) The harmonic relation between the pilot and carrier frequencies must be as simple (i.e., of as low an order) as possible.
(2) The pilot frequency must be sufficiently far outside the sideband range so that the band filter used to select the pilot frequency at receiving stations will sufficiently discriminate against the sideband.
(3) If the pilot frequency is too far outside the sideband range, the frequency range occupied by the system will be uneconomically wide.

In the system described a pilot frequency of 34 kc. is used, bearing a relation of 4:5 with the carrier frequency of 42.5 kc.

The switching arrangements have been designed to allow interchange of programmes between a number of stations on the same network. Where two or more stations are receiving the programme, the branching of the circuit is effected in such a way that for any connection only one modulation and one demodulation process are required, so that a minimum of distortion is introduced.

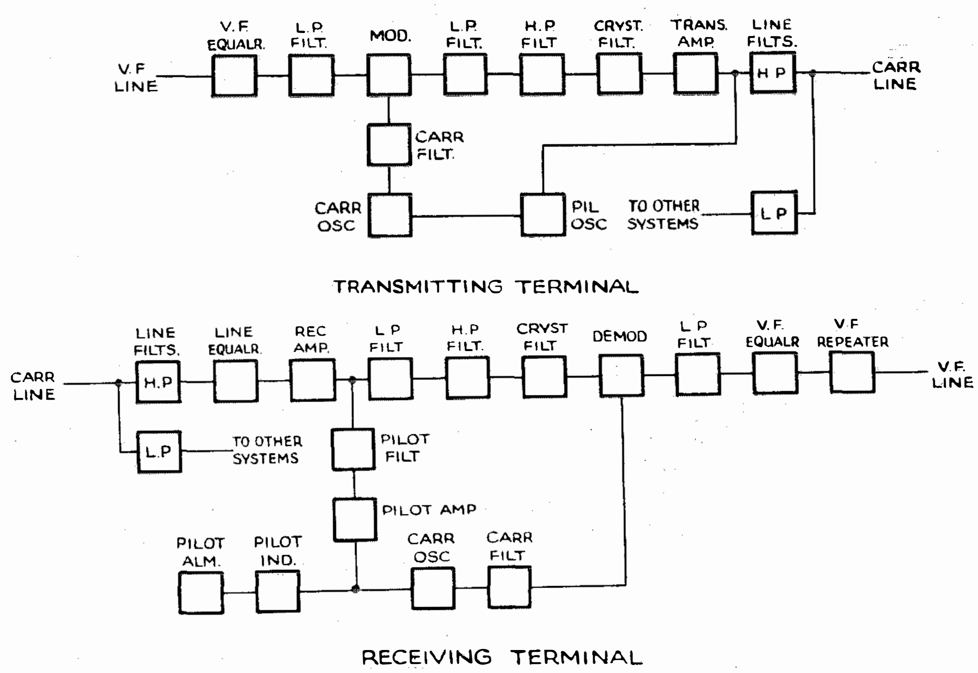


*Figure 2—Schematics of Transmitting and Receiving Terminals*

### *Description of the System*

Fig. 2 shows in block schematic form the layout of the circuits in the transmitting and receiving terminals. The modulator and demodulator are of the grid current type.[3]

The low pass, high pass, and crystal filters which follow the modulator at the transmitting station and precede the demodulator at the receiving station, form a band-pass filter having a very sharp cut-off at the upper end. The loss introduced by this filter at sideband frequencies close to the cut-off frequency is compensated by a voice frequency equaliser at both transmitting and receiving terminals. Means of adjustment are provided on the equaliser to compensate for manufacturing variations in the filters.

In order to correct for the attenuation characteristics of the lines, variable line equalisers are provided at repeater stations and at receiving terminals. These equalisers have substantially linear characteristics over the sideband range; the slope of their attenuation curve being adjustable by means of keys in steps of 0.1 db. per kc.

The pilot oscillator, which is of a very stable type[4] and operates at 34 kc., supplies synchronising current for the carrier oscillator at the transmitting terminal and also pilot current which is transmitted to the line. At the receiving terminal the pilot current is selected by means of the pilot filter which is bridged across the circuit at the output of the receiving amplifier and passes a narrow band of frequencies in the neighbourhood of 34 kc. By means of the pilot amplifier the level of the pilot current is raised to a value sufficient to synchronise the carrier oscillator, operating at exactly the same frequency as that at the transmitting terminal. A simple type of pilot indicator is bridged across the output of the pilot amplifier and gives a visual indication of any changes which may occur in line attenuation. An audible alarm device also gives warning when the line attenuation departs from normal by a predetermined amount.

The carrier filter, equipped at both transmitting and receiving terminals, ensures that no pilot current or modulation products of pilot and carrier frequencies can reach the carrier input of the modulator or demodulator.

A number of types of equipment have been standardised in order to cover a wide range of requirements: Transmitting Terminal, Receiving Terminal, Combined Terminal, Through Repeater, Receiving Repeater, and Combined Repeater. The Transmitting and Receiving Terminals are as described above, each occupying three 10-foot 6-inch bays complete with line filters.

The Combined Terminal, which also occupies three 10-foot 6-inch bays, carries all the equipment necessary for transmission and reception and may be used for either by the operation of a switch. Since a considerable proportion of the apparatus is common to both transmission and reception, the cost of this type is not a great deal more than that of the simpler type which can perform only one function. A block schematic of this equipment in Fig. 3 shows the switching arrangement adopted.

The Through Repeater is a straightforward amplifier with line filters for an intermediate station. A pilot indicator is fitted and the gain provided is more than adequate for the longest practicable section. The amplifiers may be switched by means of a key to operate in either direction. This equipment occupies two 10-foot 6-inch bays.

The Receiving Repeater is similar to the Through Repeater with the addition of a demodulating circuit similar to that of a Receiving Terminal. The demodulating equipment is bridged across the main circuit in such a way that the programme may be demodulated for the use of a broadcasting station close to the repeater without in any way interfering with the through transmission.

The Combined Repeater provides a further extension of facilities. Having all the features of a Receiving Repeater, programmes also may be originated at this type of station and transmitted to the line in both directions. The Receiving and Combined Repeaters each occupy three 10-foot 6-inch bays.

An example of the possibilities is shown in the system layout of Fig. 4. Station A can transmit a programme simultaneously to Stations B, D,

[3] "Grid Current Modulation" by Eugene Peterson and Clyde R. Keith, *Bell System Technical Journal*, January, 1928.

[4] "Constant Frequency Oscillators" by F. B. Llewellyn. *Proc. I.R.E.*, Vol. 19, December, 1931.

and E, or Station B can transmit simultaneously to A, D, and E.

### *Power Supplies*

The system is intended to operate from station batteries of 24 and 130 volts. They, with the exception of a small 4½ volt dry battery in the pilot indicator, are the only supplies required.

The current drains of the various types of equipment are approximately as follows:

| | 24 Volt. | 130 Volt. |
|---|---|---|
| Transmitting Terminal.......... | 2.0 | 0.240 |
| Receiving Terminal............. | 2.8 | 0.300 |
| Through Repeater.............. | 1.2 | 0.260 |
| Receiving Repeater............. | 3.1 | 0.380 |
| Combined Repeater............. | 3.1 | 0.380 |

The drains of the Combined Terminal will be the same as those of the Transmitting or Receiving Terminals, depending on which function it is performing. The drains given for the Combined Repeater apply when it is in the receiving condition and will be somewhat less for the transmitting condition.

### *Field Tests*

By the courtesy of the Czechoslovakian Ministry of Posts and Telegraphs, particulars are given of the circuits which have been installed in order to connect the Kosice broadcasting station with the cable network at Bratislava.

Combined terminals were installed at both ends of the circuit with a receiving repeater at Banska Bystrica. Fig. 5 shows the equipment at Bratislava.

The normal and spare circuits on which the system is operated comprise two 4 mm. bronze pairs, the route distances being:

Bratislava-Banska Bystrica......217 km.
Banska Bystrica-Kosice.........219 km.

For the greater part of the route both circuits have flat transpositions at intervals of 1 km., the transposition points of the two circuits being staggered. At intervals of 4 km., the positions of the circuits are interchanged.

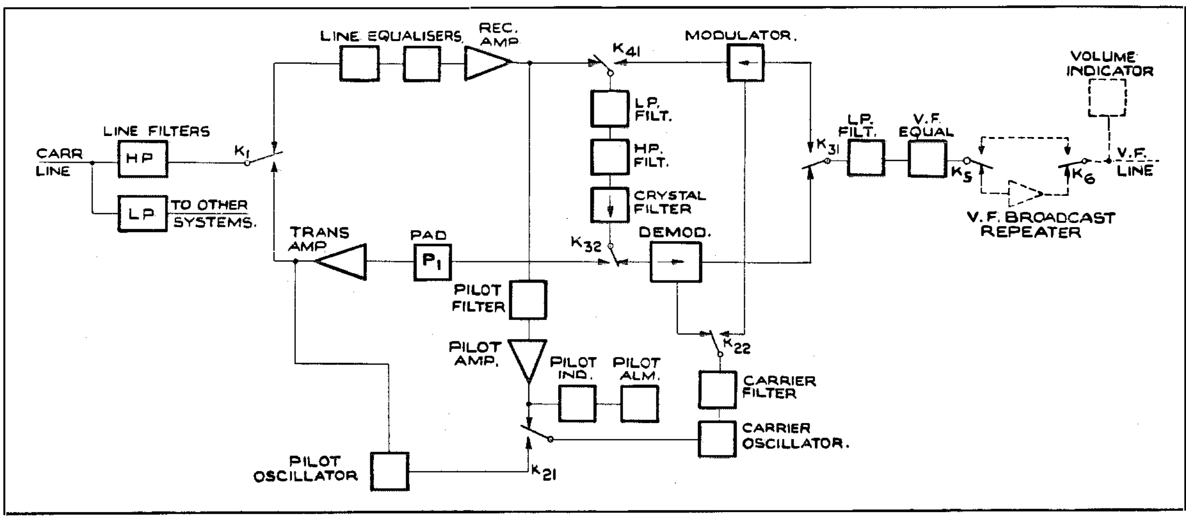


*Figure 3—Combined Terminal.*

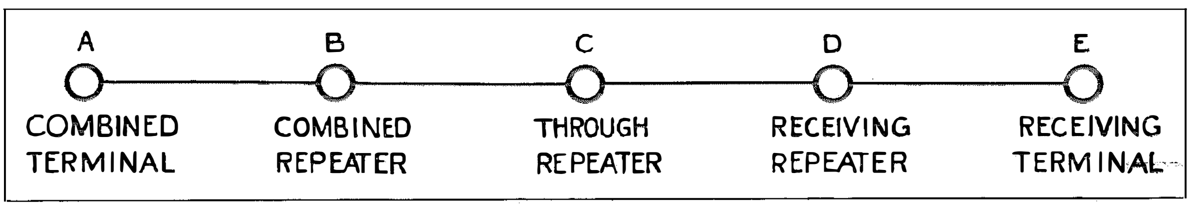


*Figure 4—System Layout.*

In addition to the broadcast system, a three-channel Type C.T.4 system, fitted with automatic gain control, was installed on the circuit.

The first measurements made on the line showed very considerable irregularities in the attenuation characteristic. These irregularities were particularly marked at the higher frequencies and the average slope of the attenuation curve was considerably higher than had been calculated. The trouble was eventually traced to a section of the line (approximately 90 km.) between Bratislava and Banska Bystrica, having an old type of construction in which the insulators are not carried on crossarms but are spaced at intervals down the pole. It is understood that this section is due for reconstruction very shortly. Fig. 6 shows the line attenuation over the range 30-43 kc.

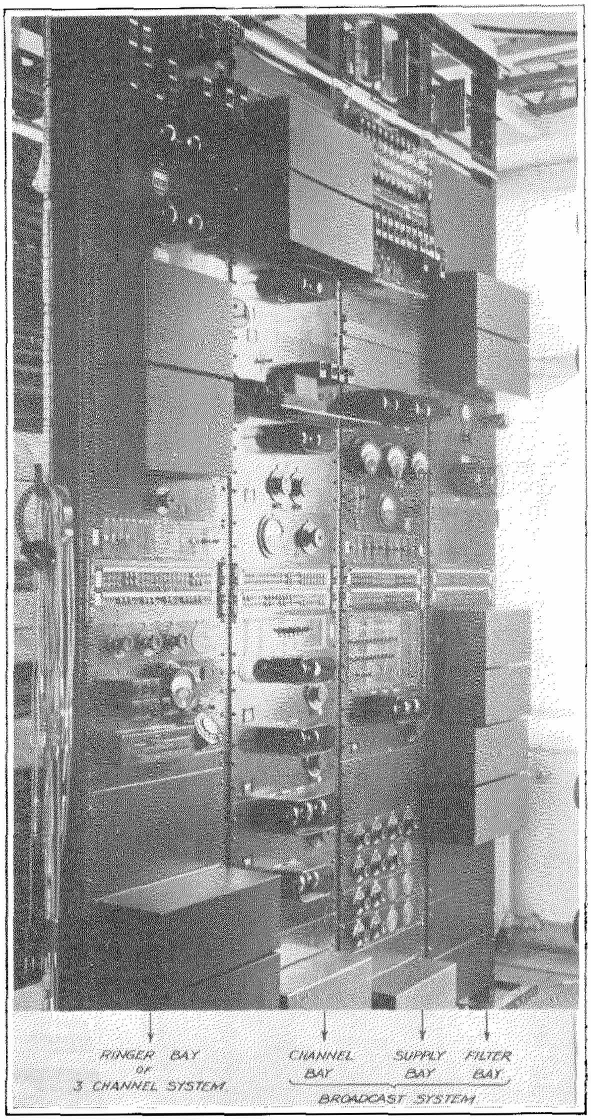


*Figure 5—Carrier Broadcast Equipment at Bratislava.*

## Test Results

The maximum voice frequency output obtainable from the carrier equipment itself is approximately −10 db. referred to 5 m.w. Where a higher output level is required, a Standard voice frequency broadcast repeater may be equipped on the line filter bay, as was done in this case.

For the tests described below, the system was lined up to zero equivalent and unless otherwise stated an input level of 5 m.w. was used.

## Quality Curve

Although the line attenuation curve was not as smooth as had been expected, very satisfactory quality curves were obtained. Fig. 7 shows the curves for the four transmission circuits obtainable with this system. It will be observed that the curves fall well within the C.C.I. limits which are indicated by the dotted lines enclosing the curve of the Bratislava-Kosice circuit.

## Non-Linear Distortion

Harmonic measurements made in the field by somewhat rough and ready methods showed quite good agreement with the results obtained in the laboratory.

In the field, measurements were made by the use of a pair of high and low pass filters, and total harmonics were found to be 35 db. below the fundamental when the system was operated with an input level of 5 milliwatts.

Measurements made in the laboratory by means of a Landeen Analyser[5] gave the following results:

2nd Harmonic—41 db. below fundamental.
3rd Harmonic—45 db. below fundamental.

## Crosstalk

Extensive crosstalk measurements were made with the other circuits on the line.

The frequency allocations of the three-channel

[5] "Analyser for Complex Electric Waves," by A. G. Landeen, *Bell System Technical Journal*, Vol. 6, No. 2, April, 1927, pp. 230-247.

Type C.T.4. System, operating on the same circuit as the broadcast system, were as follows, the upper sideband being used in each case:

| Channel | Bratislava-Kosice Carrier Frequency kc. | Kosice-Bratislava Carrier Frequency kc. |
|---|---|---|
| 1 | 12.9 | 23.7 |
| 2 | 9.4 | 19.8 |
| 3 | 6.3 | 27.7 |

Each channel was lined up to an equivalent of 6 db., and near and far end crosstalk between the broadcast system and each channel was measured at Bratislava and Kosice. Measurements also were made of crosstalk between the broadcast system and the physical circuits of the normal and spare lines.

Although the apparatus used was capable of crosstalk measurements up to 80 db., no measurable crosstalk could be detected from other circuits into the broadcast system or vice versa.

## *Noise Measurements*

During the period of installation, thunderstorms were rather prevalent and consequently noise measurements tended to be somewhat variable. Measurements made at Kosice ranged between 50 and 100 Noise Units and at Bratislava from 50 to 150. These figures correspond to a signal to noise ratio of 65-75 db.

It is of interest to note some comparative measurements made on the physical circuit which was used for broadcast relays prior to the installation of the carrier system. The measurements were made with carrier line filters in circuit with the result that the band width was 3000 p:s instead of 7500 p:s, and it may therefore be reasonably assumed that the noise would be increased by about 3 to 4 db. with the wider transmission band. Further, at the point where measurements were made, the normal programme level was approximately −15 db. as compared with zero level for the carrier system. Comparative measurements were 50 N.U. for the carrier system (zero level programme) and 80 N.U. for the physical circuit (−15 db. programme level) giving a difference of 4 db. Taking into account the difference in band width and programme level this shows an improvement for the carrier system of 4 + 3 + 15 = 22 db.

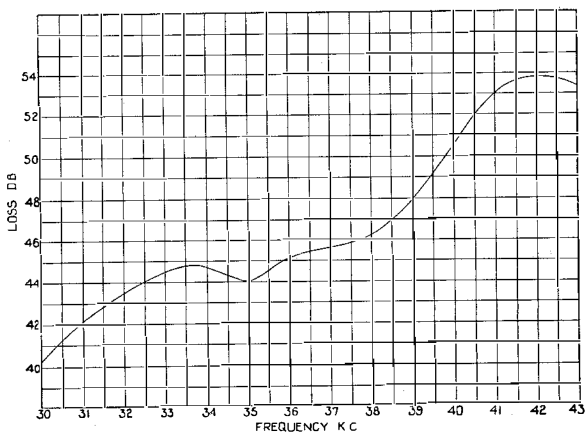

*Figure 6—Line Attenuation Bratislava-Kosice.*

## *Phase Distortion*

The phase distortion in the complete system was measured in the laboratory and extremely good results were obtained. The phase distortion to be expected due to the open-wire line over the frequency range 35−42.5 kc. is very small and, in view of the practical difficulties, it was considered unnecessary to repeat this test in the field.

The laboratory results were as follows:

| Frequency p:s | Propagation Time Milliseconds |
|---|---|
| 50 | 7.5 |
| 300 | 1.0 |
| 500 | 1.0 |
| 800 | 1.0 |
| 6000 | 0.5 |
| 7500 | 0.5 |

## *Maintenance*

The maintenance routine of the system is not greatly different from that of the three-channel Type C systems. Recommended daily tests comprise adjustment of filament currents, oscillator frequencies, and a steady tone line-up of the complete system.

The frequency of the pilot oscillator is adjusted by reference to the antiresonant frequency of the quartz crystal.

This operation is considerably simpler in practice than it appears on paper. The carrier oscillator must first be brought into synchronism with the pilot oscillator. This is performed by

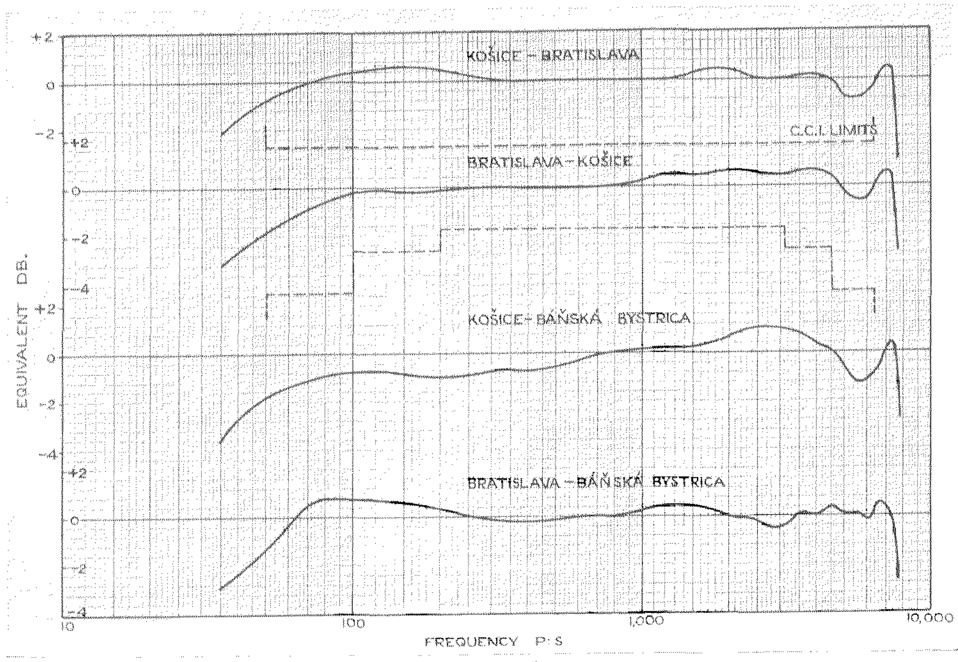


*Figure 7—Overall Quality Curves.*

means of an aural test. When the oscillator is not in synchronism an audible note is heard in a telephone receiver plugged in to the output of the carrier oscillator. This note, representing the difference frequency between the 5th harmonic of the pilot frequency and the 4th harmonic of the carrier oscillator, disappears as soon as the carrier oscillator falls into synchronism. When the variable condenser of the carrier oscillator is rotated, two points are found at which this note starts. In the range between these points the oscillator is synchronised and the condenser is set at the mid-point of the range. Under normal operating conditions, the tuning of the carrier oscillator may be varied over a range corresponding to about 500 p:s without falling out of synchronism.

A circuit is now set up to measure the level of the carrier frequency after passing through the crystal filter. Since the carrier frequency is controlled by the pilot frequency, variation of the pilot oscillator condenser will cause the carrier frequency to vary correspondingly so long as the synchronising range is not exceeded. The pilot oscillator condenser is, therefore, rotated until the level at the output of the crystal filter reaches a minimum, indicating that the frequency of the carrier oscillator is the same as the antiresonant frequency of the crystal. The pilot oscillator tuning is now changed by a predetermined amount to reach the normal operating condition, in which the carrier frequency is 45 p:s below the antiresonant frequency of the crystal.

The system line-up is carried out in a similar manner to that in use with the Type C system. The transmitting terminal sends 2 m.a. at 1,000 p:s and each station in turn makes measurements and adjusts amplifier gains as required.

A series of weekly tests is also recommended, consisting mainly of checking the carrier levels into modulator and demodulator, pilot current transmitted to line, etc. It is also recommended that a weekly system line-up be carried out at a number of different frequencies. This ensures that variations in the line characteristics are compensated by suitable adjustment of the line equalisers, thereby taking full advantage of the high quality capabilities of the system.

### *Switching*

In the majority of installations it is necessary to provide means for switching over the system or parts of the system for transmission in the opposite direction. This feature has been provided for in the case of combined terminals and all types of repeater. The switching is performed by the operation of low capacity type keys and, since the number of contacts on each key is limited, in most cases more than one key is required. Where possible, all keys which require to be operated together are connected by a link across their handles, enabling the operation to be performed in one movement. In the case of the combined repeater, when switching from transmit to receive two sets of keys may need to be operated, one set to change the local circuits and the other to change the direction of operation of the through repeater equipment. While there is no doubt that the use of a service telephone circuit on which all station attendants may speak facilitates rapid switching, a method has been evolved which does not necessitate continuous communication between station attendants during the switching process. In this method the station controlling the circuit must always be that at which the programme originates. Shortly before a change is due the attendant at the control station (say Station A) warns the attendants at all other stations either by telephone or telegraph circuit to stand-by for switching. All attendants should know from their schedules what switching is required and make any necessary preparations while watching their pilot indicators. As soon as the programme from A finishes, the attendant at A throws his switch, thus cutting off the pilot current from the line. At all other stations the pilot indicators fall to zero thus giving a signal for attendants to do the necessary switching. If the next part of the programme is to be originated at Station B, the attendant at that station will have operated the switch to "TRANSMIT", thus sending out the pilot current to line. At repeater and receiving stations the pilot current reappears from the new direction, and the attendants make any necessary amplifier adjustments to bring the pilot indicator reading back to normal. A guide to any such changes in adjustment will have been obtained during the daily line-up of the system. Each attendant, when normal conditions have been restored, should report "Ready" to the new control station B.

### *Conclusions*

The Standard Carrier Broadcast System is the result of laboratory development work spread over a number of years. The performance aimed at has been satisfactorily fulfilled in laboratory tests and confirmed by operation in the field. While the system cannot, by the very nature of the circuits on which it operates, lay claim to the stability of a cable network, its performance in all other respects is little if at all inferior. The demand which has already been experienced for this system indicates that it fills a very definite need for linking up outlying stations with the centres of population. In addition to Czechoslovakia, a system is in successful operation between Milan and Bolzano, and several systems now being installed in Australia will no doubt be in service by the time this article appears in print.

To conclude, the authors wish to express their gratitude for the co-operation and assistance rendered during the installation tests by the Czechoslovakian Ministry of Posts and Telegraphs and, in particular, by Mr. J. Michalek, Conseiller de Seccion, Mr. M. Franc, Commissaire Superieur Ministeriel, and Mr. B. Chadim, Commissaire Superieur Ministeriel.

# Submarine Telephone Cables Across the Great Belt

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## *General*

DURING 1933 and 1934 the Danish Post and Telegraph Administration laid two paper-insulated lead-covered submarine telephone and telegraph cables between Korsør and Nyborg across the Great Belt to form links in the long distance communication circuits going westwards from Copenhagen to the island of Funen and via short submarine cables across the Little Belt to Jutland (repeater station Kolding with present connections north via repeater stations Aarhus and Aalborg and south via repeater stations Flensburg, Hamburg, etc.).

The cables have all been supplied by Aktieselskabet Nordiske Kabel-og Traadfabriker, Copenhagen, which is co-operating with the International Standard Electric Corporation on loading equipment and toll cable manufacture.

The Danish Administration's plans provided for either coil-loaded submarine cables and one repeater section from Copenhagen to Nyborg, or non-loaded cables and repeater stations in Korsør and Nyborg. The latter alternative was chosen and the submarine cable order placed with the above national factory, which had also quoted for a coil-loaded star-quad cable with inserted flexible coil assemblages of Standard Electric's make and special design.

The following comments regarding these non-loaded submarine cables are thought to be of interest, although it is appreciated that larger submarine cable projects have been completed previously, both loaded and non-loaded.

## *Design and Manufacturing Procedure*

The design of the two new Great Belt cables with one broadcast pair of 1.41 mm. in a separate lead sheath and 9 + 15 = 24 quads of 1.2 mm. in the first and second layers is shown in Fig. 1. The cables are double lead sheathed and armoured with twenty-four 6.6 mm. galvanized wires. Each submarine cable is about 21 km. long and has a total weight of about 320 tons, or about 15 kg. per m. Each cable is extended by land cable sections to a total length of about 27 km. between the two repeater stations in Korsør and Nyborg.

The splitting up of the forty-eight through-quads from the adjoining land cables into two separate submarine cables with twenty-four quads in each was done in order to obtain submarine cables of a reasonable handling size and weight, as well as for safety and traffic purposes (one cable available in case the other is damaged and under repair).

According to normal Standard Electric practice the double paper insulation in these submarine cables was made very dense in order to counteract penetration of water in case of damage and also because a dense cable will maintain low unbalance figures from factory balancing during subsequent handling, such as coiling, armouring, transporting, laying, etc.

In order to obtain uniform and well balanced circuits the cables were joined up from about 2,000 m. sections, each section being again joined up from eight manufacturing lengths of about 250 m. each by means of the normal 7-test-splice method for the equalization of unbalances and irregularities by cross splicing. For the segregation in two 4-wire groups (in case of one cable taking the whole traffic), first and second layers in the cables were kept separate through all splices.

Each 250 m. length was made up to normal C.C.I.F. specifications and pressed with a provisional lead sheath. In order that the splices should be kept to the same diameter as the cable itself, the joints within quads and wires were offset, the length of each splice being about 2.5 m.

The wire joints were made with soldering connectors with additional safety helical windings of six parallel .25 mm. tinned copper wires soldered to the conductors at each side of the connector. The broadcast pair joints were protected with small lead tube sleeves soldered to the broadcast pair lead sheaths. These connections appeared liable to breakage during handling of the cables, and in the second cable they were reinforced by oilcloth tape wrappings.

All the 250 m. lengths of cable were made with provisional lead sheaths and tested before commencement of the splicing.

By suitable allocation[1] of the manufacturing lengths very low unbalances were obtained in the completed cables. Furthermore, the mutual capacities, as well as the impedance characteristics, tended towards the same values at the ends of the cables, with the result that crosstalk figures were reduced to the minimum.

The processes of testing and splicing at the intermediate joints and the joining up of 2-km. sections to the full cable length with lead sheath are shown in Figs. 2 and 3. These illustrations show ordinary testing and jointing equipment, motor driven pairs of rollers to handle drums with up to 10 tons of cable (a complete 2-km. section) and also a motor driven turn plate 7 m.

[1] For methods of allocation, see "The Reduction of Impedance Irregularities in Submarine Cable Circuits by Allocations," by Ing. Carlo Tonini, R. L. Hughes, and K. E. Latimer, *Electrical Communication*, January, 1934.

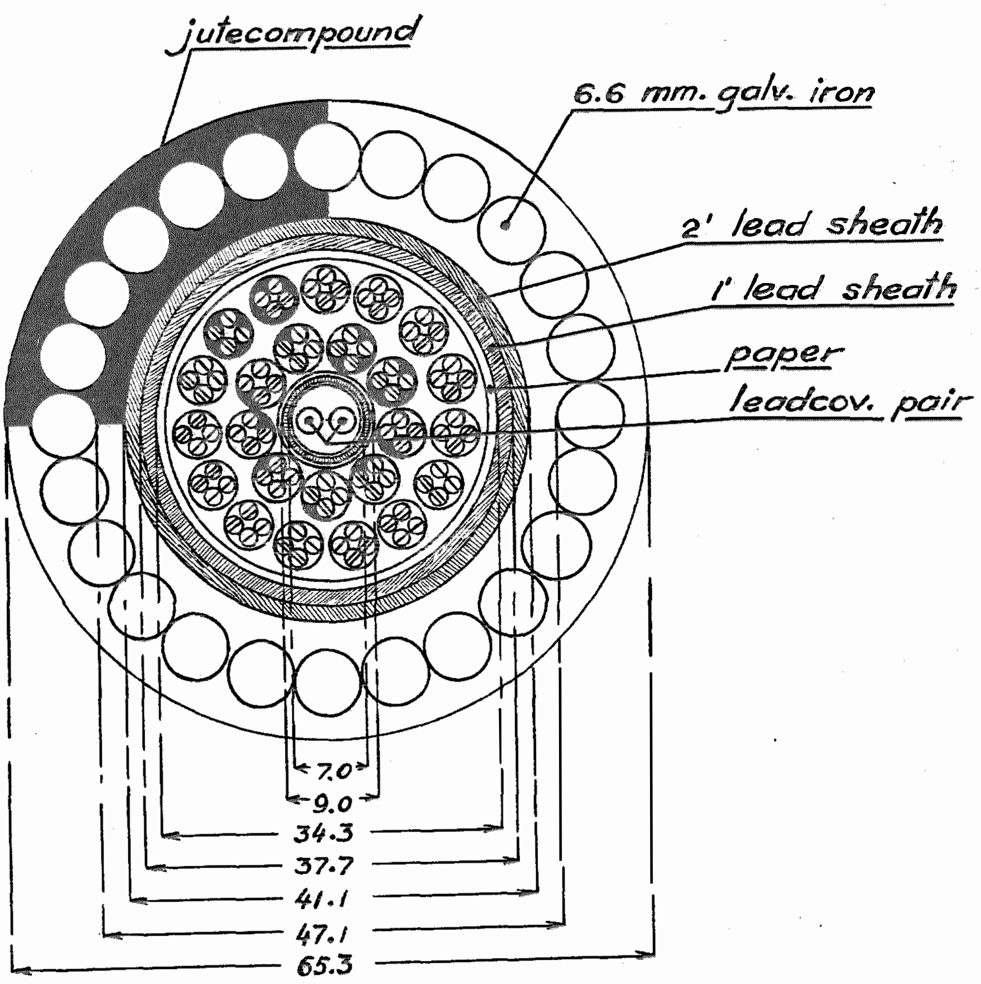



*Figure 1—Cross Section of Submarine Cables.*

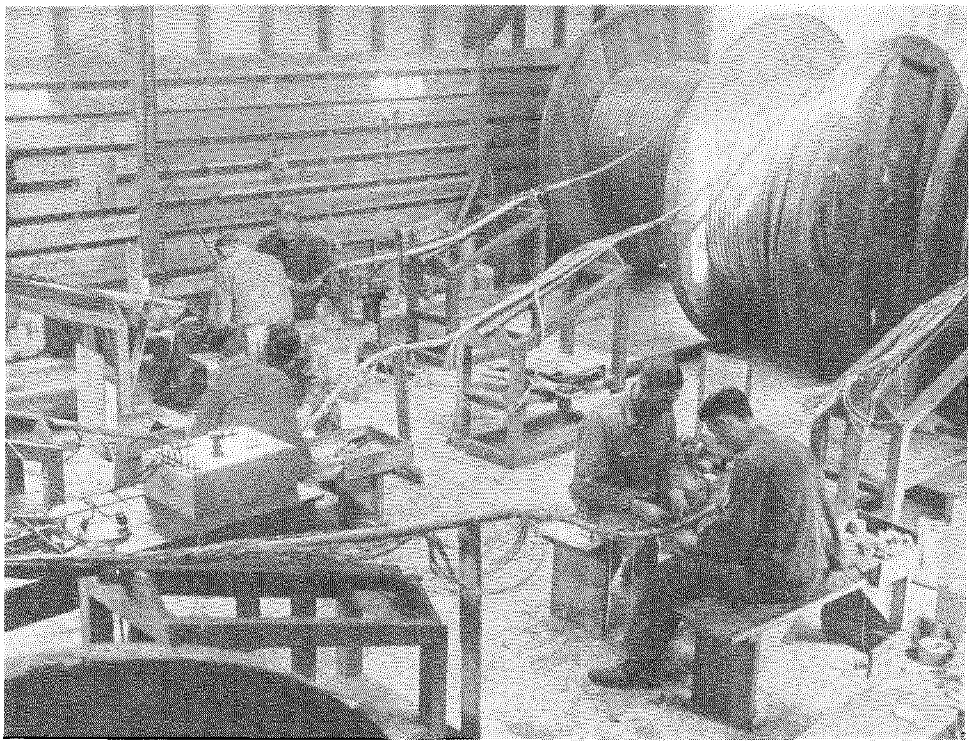


*Figure 2—Testing and Splicing of Cable from 250 m. Lengths.*

in diameter to take the full cable length (about 85 tons at that stage).

Every half section of about 1,000 m. containing three intermediate test splices was stripped, vacuum dried, and pressed with a new lead sheath. The final splices and the joints between 2-km. sections were boiled out with 170° C. paraffin wax and protected with lead sleeves soldered to the sheaths. In this way the cable could be kept dry with an insulation resistance of about 30,000 to 50,000 megohms per kilometre and a leakance constant at 800 p:s of about 15 to 20.

Due to increase in capacity, especially during armouring, a mutual capacity of .415 $\mu F$ per km. was aimed at in the provisional stages, corresponding to the figure of .45 aimed at for the finished cable.

For the 2-km. sections, the following average capacity unbalances were obtained:

| | |
|---|---|
| Ph. - S | about 13.5 $\mu\mu F$ |
| S - S | about 15 " |
| Pr. - Pr. | about 16 " |
| Ph. - Pr. | about 18 " |
| Ph. - Ph. | about 22 " |

The average resistance unbalance (a-b) obtained on 2-km. sections was about .01 ohms (less than .02% of the loop resistance, which is about 60 ohms per 2-km. cable).

Calculations for the prediction of crosstalk figures for the finished cables, according to these section unbalances, would indicate, for instance, average near end figures of about 10.5 nepers Ph. - S and about 11.6 nepers, and above for the other 1.2 mm. circuit combinations when measured with a complex tone oscillator with frequency distribution corresponding to 1,300 p : s. It would appear also that unbalances about three times higher than the above figures would still correspond to 9.5 nepers or more, or .5 neper in excess of the guaranteed 9 nepers.

The cables which were tested with 2,000 volts a-c. (R.M.S. value) in the 250 m. stage, according to normal C.C.I.F. practice, were tested during all subsequent manufacturing stages with a motor driven 1,000 volts d-c. megger and a Wheatstone bridge to ensure perfect insulation and conductor resistance.

During the progressive jointing and coiling up of 2-km. sections on the turn plate, the midpoint of the whole cable was made accessible during the jointing of the second cable, and the final splicing of this point could therefore be made to include far-end crosstalk poling tests on the whole cable for regular unbalances (Ph. - S and S - S within quads). As a result, the far-end Ph. - S crosstalk figures for this cable were better (11.3 nepers average) than near-end ones (10.6 nepers average).

### *Lead Pressing and Armouring*

When each of the two cables had been joined up to its full length on the turn plate, it was tested for crosstalk in addition to the d-c. tests and provided with its final sheath.

The cable was then led into a motor driven turning tank 7 m. in diameter and 2 m. high for the water and electrical testing of the cable before armouring (about 125 tons in lead-pressed state). On its way from the lead press to the turning tank, the cable was conveyed by motor driven sheaves as seen behind the turning tank in Fig. 4.

In order to compensate for small variations of short duration in the relative speed of the cable through the various machines and spooling devices, the cable was not always taken the shortest way between adjacent machines. Cable bends were included, especially on the stretch between the lead presses during pressing and between the turning tank and the armouring machine during the later armouring. An electrical signalling system was arranged at all the points where the cable was handled during both lead pressing and armouring, so that the whole process could be stopped from any of these places.

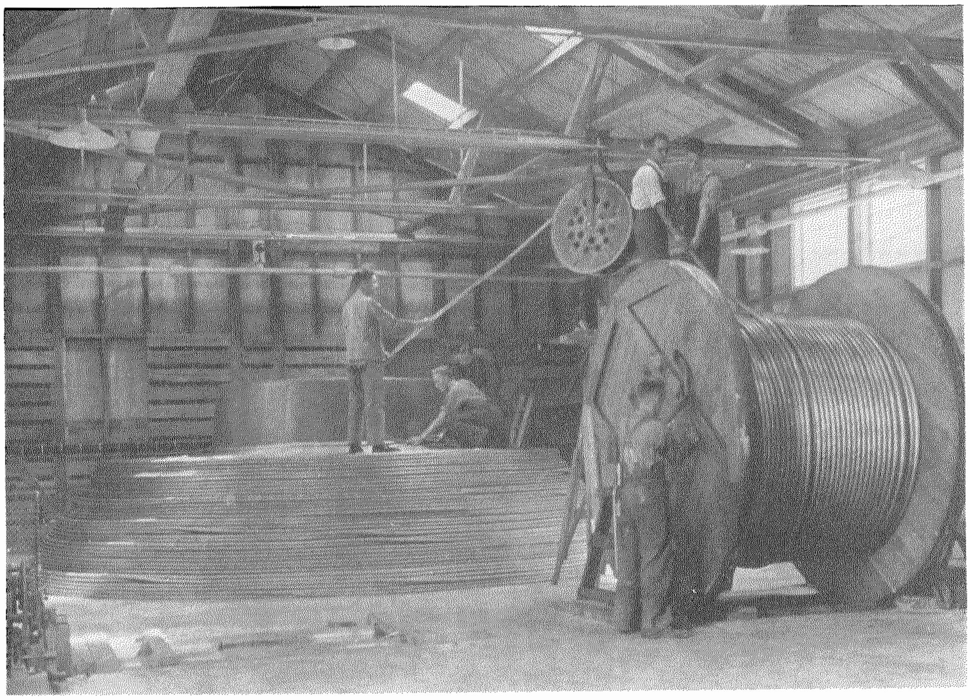


*Figure 3—Cable with Provisional Lead on Turn Plate.*

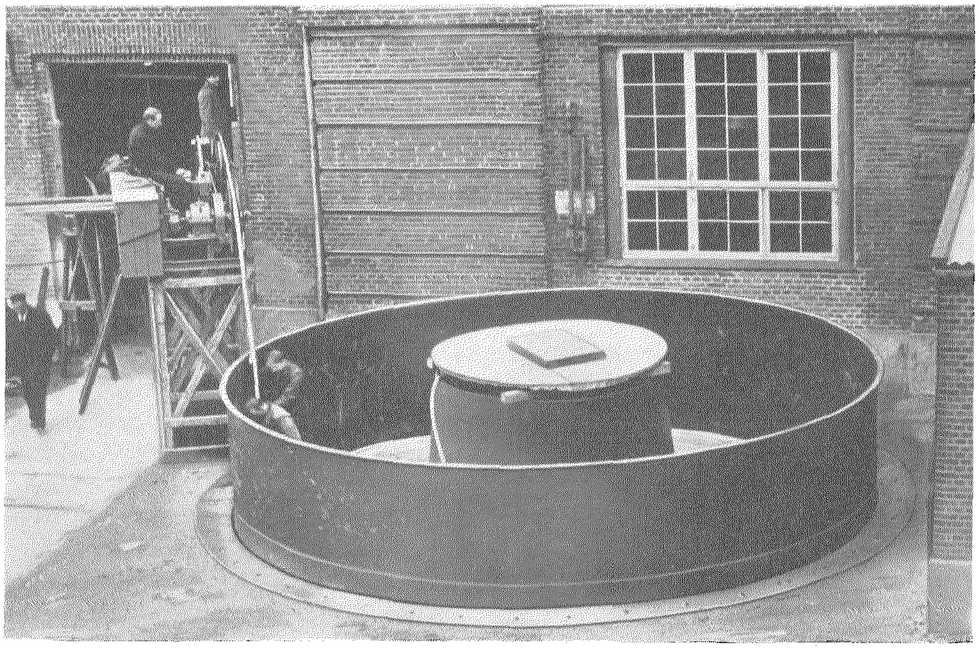


*Figure 4—Cable with Final Double Sheath Entering Turning Tank Via Motor Driven Sheaves.*

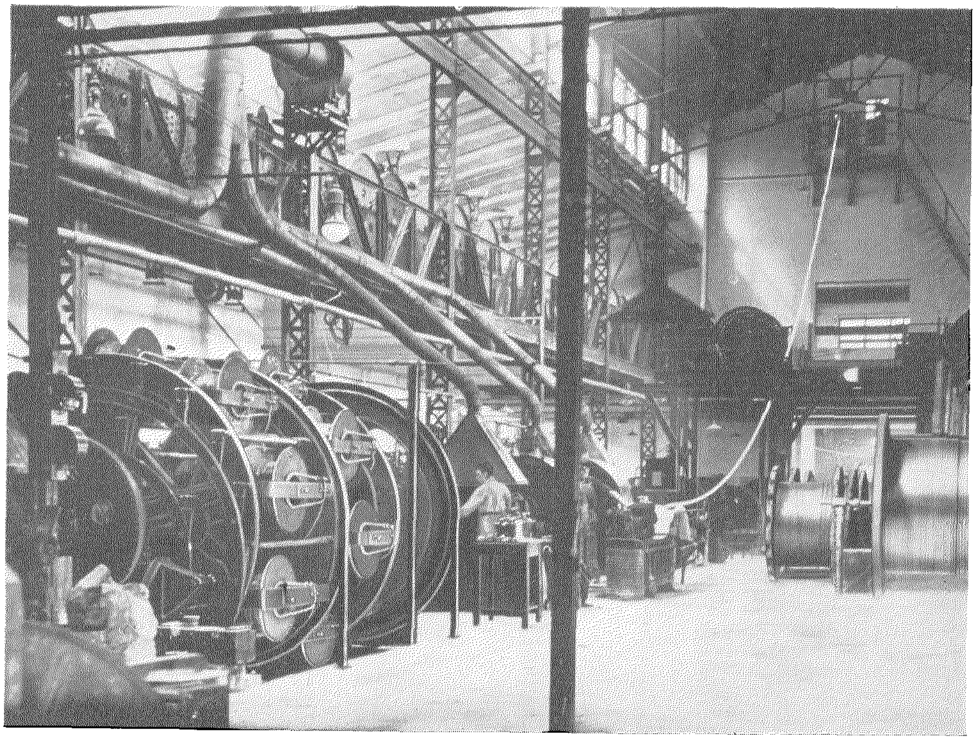


*Figure 5—Armouring.*

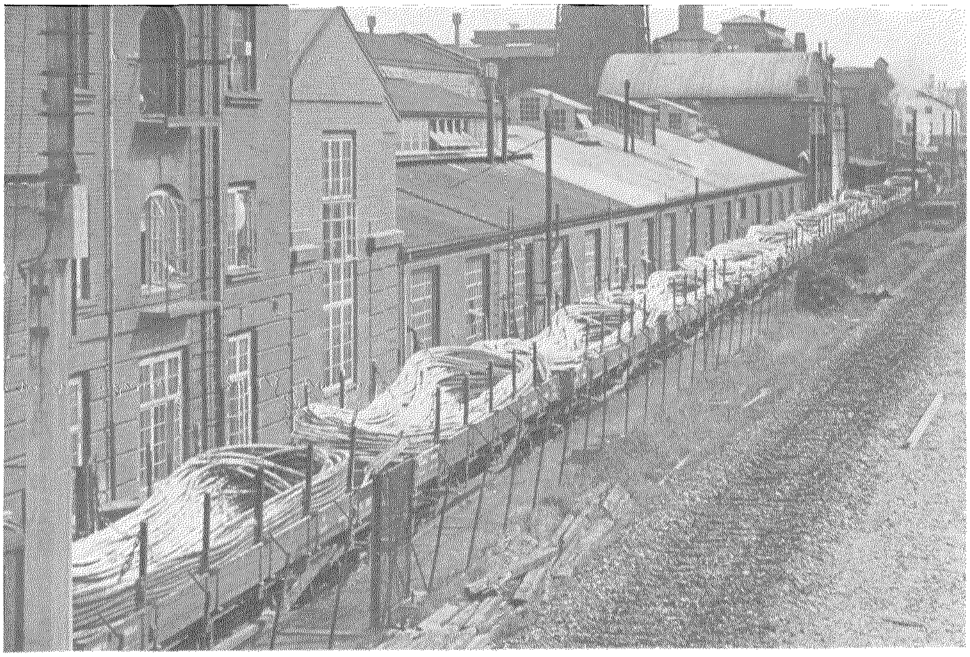


*Figure 6—Cable Leaving Factory on Eleven 30-Ton Waggons.*

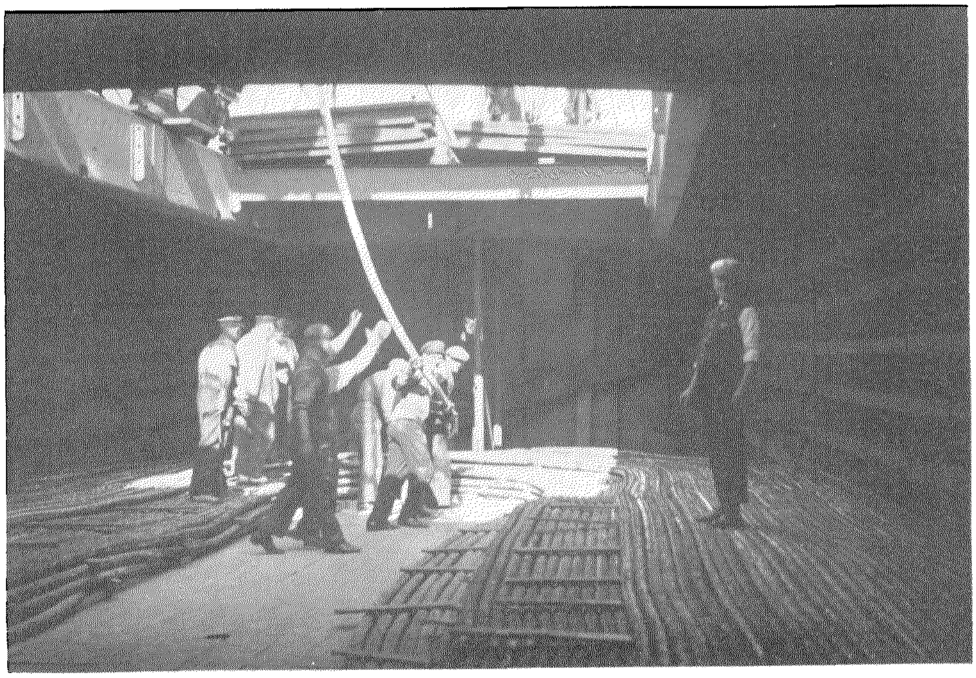


*Figure 7—Coiling Down in Lighter.*

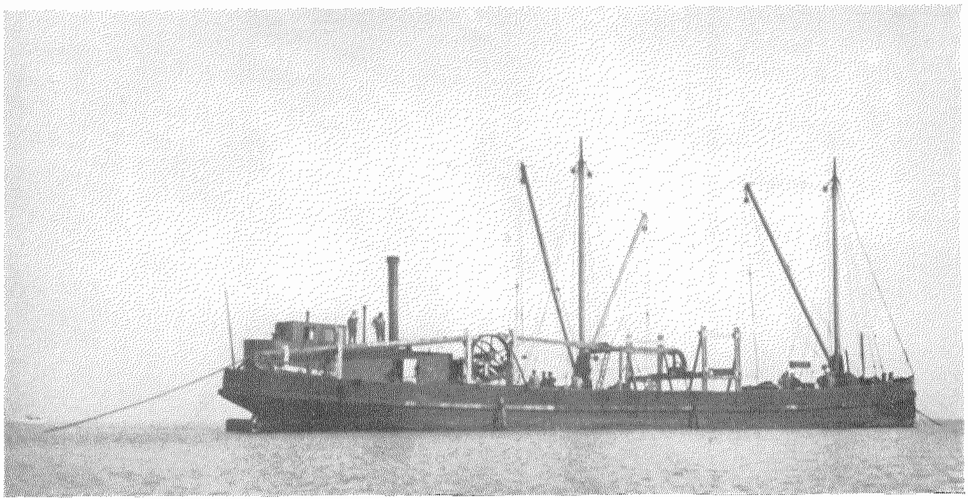


*Figure 8—Lighter Ready to Lay the Cable.*

The surface of the first lead sheath was treated with asphalt compound before entering the second lead press, a thin layer of this compound remaining between the two lead sheaths.

The provision of these two lead sheaths and the asphalt layer in between them is considered to be more safe than merely one single plain lead sheath, because a long duration continuous lead pressing (5 days in the present case) involves a certain risk of impurities from oxydation, etc. These cannot be removed during the process, and would generally be less dangerous with two sheaths than with only one sheath. Fewer refillings of each lead press is a further advantage of two sheaths, as compared with one sheath.

After lead pressing and water testing in the turning tank the cable was subjected to exhaustive electrical tests: both d-c. (insulation resistance, mutual capacity, and conductor resistance) and a-c. (crosstalk, attenuation, characteristic impedance, and singing point). It was proved that the insulation resistance, mutual capacity, and crosstalk figures remained practically unchanged from the provisional lead sheath state.

By means of the above-mentioned motor driven sheaves the cable was carried from the turning tank to the armouring machine shown in Fig. 5, and from this machine over the elevated motor driven capstan seen in the background of Fig. 5 to a fixed tank 10 m. in diameter and 2.5 m. high in the factory yard.

The armouring of each cable lasted a fortnight (8 hours per day).

After armouring, the cables were again water tested and also tested thoroughly electrically. During the armouring the mutual capacity had been increased about 7.5% with the characteristic impedance and attenuation figures changed accordingly. Otherwise, the test results were very similar to those for the lead pressed cables.

## *Laying*

As the cable factory is not situated at the waterside, each cable had to be coiled up in eleven 30-ton waggons, as shown in Fig. 6, for transport to the harbour. In the harbour each cable was coiled into a 500-ton lighter (see Fig. 7) and tugged to Nyborg, from which point the cables were laid.

For laying purposes the lighter was equipped with a paying-out machine with a 2 m. paying-out drum and a .75 m. stern sheave.

Fig. 8 shows the lighter ready to lay the cable. The cable end was kept floating by pairs of barrels during the pulling in to the Nyborg shore.

After the anchoring of the cable end, the lighter was tugged to Korsør by a 475 hp. steam-tug (average laying speed about 6 km. per hour, maximum depth about 50 m.). At Korsør the cable end was paid out along the shore and later pulled to the right position.

After the laying of each cable, the capacity and insulation resistance were checked and it was found that the average mutual capacity had dropped about 2.3% from the average armoured factory figure; the resulting increase from average lead pressed factory figure to the average figure after laying amounted to about 5%.

The first of these cables was laid the 13th September, 1933, and the second on the 17th May, 1934.

## *Electrical Test Results*

Although the two cables were not made at the same time, their electrical characteristics were very similar. Figs. 9 to 12, inclusive, in connection with the table below, give a short account of the acceptance test results.

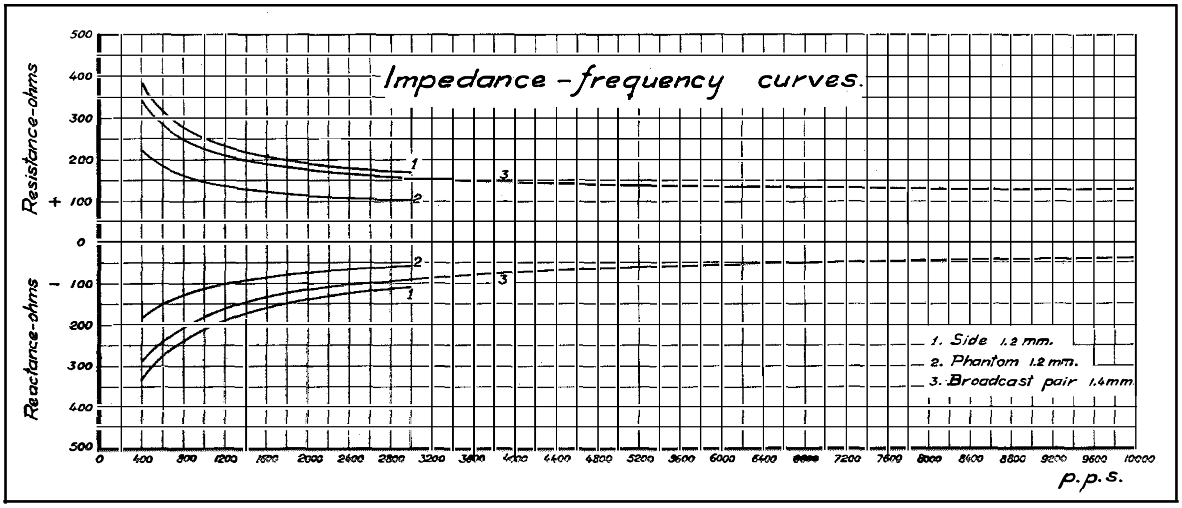



*Figure 9—Characteristic Impedance-Frequency Curves.*

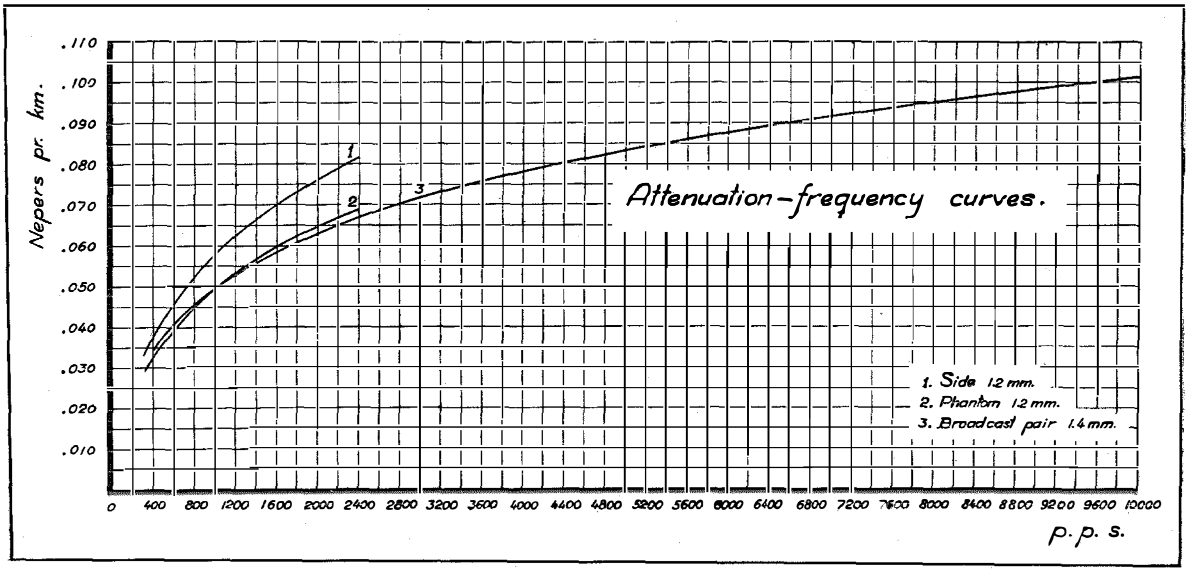



*Figure 10—Attenuation-Frequency Curves.*

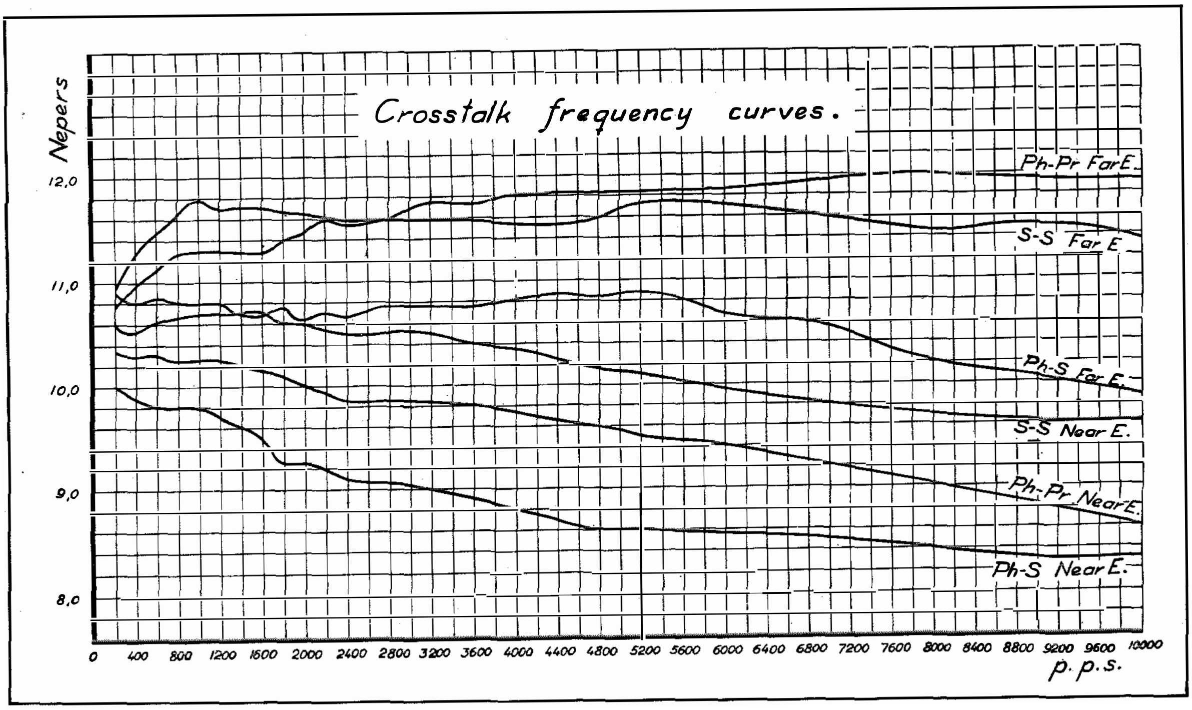



*Figure 11—Crosstalk-Frequency Curves.*

Fig. 9 shows the characteristic impedance-frequency curves, which are absolutely smooth and very similar for all circuits within each group.

Fig. 10 shows the attenuation-frequency curves, which are also very similar for all circuits within each type.

In addition to a large number of crosstalk tests measured with complex tone, with frequency distribution corresponding to about 1,300 p:s, the summary of which is contained in the table below, crosstalk frequency runs were made on some of the worst circuits and plotted in Fig. 11 as true crosstalk Ph. - S, S - S, Ph. - Pr., both near-end and far-end.

For balancing purposes during the singing point measurements, a 6-mesh network (Fig. 12) with fixed capacities $C_2$ and resistances $R_3$ corresponding to about 10-15 km. circuit length per mesh was used. Resistance $R_4$ was also fixed and included a suitable termination resistance, and only the entrance capacity $C_1$ and resistances $R_1$ and $R_2$ were variable and adjusted to give the best common balancing network for the circuit group in question.

A short summary of the test results, supplementary to the above curves follows:

*Acceptance Test Results*

| Conductor Resistance | Guaranteed | Measured |
|---|---|---|
| Average loop resistance in ohms per km. at 15° C. | | |
| 1.4 mm. broadcast pair.... | 23.1 | 21.67 |
| 1.2 mm. pairs............ | 31.8 | 29.31 |

| Resistance Unbalance | Guaranteed | Measured | |
|---|---|---|---|
| | | mean | max. |
| Resistance unbalance (a-b) in ohms for the whole stretch | | | |
| 1.4 mm. broadcast pair.... | 4 | 0.05 | 0.05 |
| 1.2 mm. pairs............ | 4 | 0.05 | 0.2 |

| Insulation Resistance | Guaranteed | Measured | |
|---|---|---|---|
| | | mean | min. |
| Insulation resistance in megohms per km. at 150° C. | 10,000 | 35,000 | 30,000 |

| Mutual Capacity | Aimed at | | Measured | |
|---|---|---|---|---|
| | Side | Phantom | Side | Phantom |
| Average mutual capacity in $\mu F$ per km ............ | 0.045 | 0.0695 | 0.043 | 0.068 |

| Leakance | Guaranteed | Measured |
|---|---|---|
| Leakance constant a-c. at 800 p:s............... | ≦ 25 | < 17.5 |

| Singing Point | Guaranteed from | Measured from |
|---|---|---|
| Singing point in nepers.... | 300-2,200 p:s<br>3.7 | 300-2,400 p:s<br>> 5.0 |

| Attenuation | Guaranteed | Measured |
|---|---|---|
| Attenuation in nepers per km. at 15° Centigrade. | | |
| 1.2 mm. Side... 800 p:s | 0.0577 | 0.0528 |
| 1.2 mm. Side... 2,200 p:s | 0.0890 | 0.0791 |
| 1.2 mm. Phantom 800 p:s | 0.0525 | 0.0468 |
| 1.2 mm. " 2,200 p:s | 0.0800 | 0.0689 |
| 1.4 mm. Broad-cast pair... 800 p:s | 0.0485 | 0.0467 |
| 1.4 mm. Broad-cast pair... 8,000 p:s | 0.101 | 0.0960 |

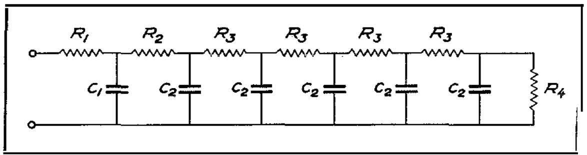



*Figure 12—Balancing Network.*

CROSSTALK
GUARANTEED VALUES

| | |
|---|---|
| Near-end and far-end values in nepers between any two 1.2 mm. circuits........................... | 9 |
| Near-end and far-end values in nepers between any 1.2 mm. circuit and 1.4 mm. broadcast pair....... | 12 |

| Measured and corrected values | | Cable I | | Cable II | |
|---|---|---|---|---|---|
| Between 1.2 mm. circuits | | mean | min. | mean | min. |
| S - S | near-end.... | 11.75 | 10.8 | 11.75 | 10.8 |
| | far-end..... | 13.2 | 12.0 | 13.4 | 12.0 |
| Ph. - S | near-end.... | 10.55 | 9.4 | 10.65 | 9.6 |
| | far-end..... | 10.2 | 9.9 | 11.3 | 10.7 |
| Pr. - Pr. | near-end.... | 12.25 | 10.1 | 12.0 | 10.6 |
| | far-end..... | 13.6 | 10.9 | 13.2 | 11.6 |
| Ph. - Pr. | near-end.... | 12.1 | 9.4 | 11.9 | 10.2 |
| | far-end..... | 13.1 | 9.8 | 13.1 | 11.4 |
| Ph. - Ph. | near-end.... | 11.8 | 10.5 | 11.6 | 10.4 |
| | far-end..... | 11.6 | 11.2 | 12.9 | 11.7 |

| | |
|---|---|
| Between 1.2 mm. circuits and 1.4 mm. broadcast pair | Average for both cables 14.6 nepers<br>Minimum for both cables 12.5 nepers |

The crosstalk guarantees refer to talking tests or equivalent methods, and the tests were made with complex tone oscillators with frequency distribution corresponding to about 1300 p:s. The circuits under test were correctly terminated and the figures corrected to true crosstalk. The stated near-end crosstalk values mean and minimum represent measurements made from both ends of each cable.

# Esterified Fibrous Insulating Materials

By A. A. NEW, M.Sc.

## PART I.

SYNOPSIS:—*The present paper deals with the importance of fibrous materials in electrical manufacture, and in particular their insulation resistance in cables, cords, and other apparatus. The chemical relationship and insulating value of the various textiles commercially available for insulation purposes is briefly sketched, and it is shown that for years the electrical engineer has utilized textiles and papers manufactured for purposes far removed from electrical engineering. It is indicated how the valuable work of the Bell System has established the scientific principles involved in the insulation resistance of fibrous materials, as well as the improvement in this characteristic obtained by the washing processes invented by them.* Cotopa *is cited as an example of fibrous materials specifically produced for electrical manufacturing purposes by modifying their chemical structure. This material is rapidly coming into prominence and is giving excellent service in the tropics. Its outstanding value is shown to be its high insulation resistance, which is superior to cellulose acetate silk, the best textile insulator previously known. It compares with cotton in mechanical strength and running properties in machines. In these characteristics and in its higher decomposition temperature* Cotopa *is much superior to acetate silk, and is immune from attacks by fungi or mildew. It is more expensive than cotton, but less expensive than certain other textiles. Part II of this paper will appear in an early issue of* ELECTRICAL COMMUNICATION.

### *Uses of Textiles and Papers in the Electrical Industry*

IN nearly every kind of electrical manufacture one finds textile materials performing some important function. The telephone, for instance, owes its comfort and convenience in no small measure to its flexible connecting cords, which consist of about ninety-five per cent. of textiles of various kinds, the remainder being copper alloy to carry the electric currents required for speech transmission. There are cotton centres to the tinsel threads to keep the tiny spirals of copper alloy from creasing and breaking, layers of silk insulation around the tinsel to prevent the currents from leaking from one conductor to another, coloured silk braids to identify the conductors, cotton filling to give the cord stiffness and good shape, and a strong braid of glazed or mercerised cotton to hold all neatly and firmly together.

An analysis, from an electrical manufacturing point of view, has been published[1] covering the uses and properties of textiles employed in the electrical industry. It is interesting to find that every kind of available textile fibre is pressed into the service of this industry in one place or another.

The functions of textiles in electrical apparatus can be classed under the following heads:

1. Mechanical protection and separation of conductors.
2. Provision of a suitable covering (e.g , artistic, flexible, flameproof, etc.) for conductors or groups of conductors.
3. Electrical insulation of conductors.
4. Serving as distinguishing "markers" in multiconductor cables (textiles are now being superseded to some extent by marked papers).
5. Providing the basic material for sheet insulating materials.
6. Miscellaneous minor uses.

In practice, of course, textiles usually combine two or perhaps more of the above functions; for example, in a very simple case such as an insulated twin bell wire, the textile lappings combine mechanical protection, separation, and insulation of the two conductors. In ribbon cable, the textile serves just the same purposes. In more complex products one notes that switchboard cable, like the telephone cord, consists, from the point of view of materials, merely of copper wires embedded in various textiles. Then there is all

[1] For all numbered references, see list at end of paper.

the apparatus in which coils of one type or another are the main feature: transformers, chokes, dynamos, motors, relays, electric bells, telephones, loudspeakers, wireless tuning coils, etc., all of which depend on some form of textile or paper to separate, protect, and insulate the turns of their metallic conductors. In the larger cables, such as power and telephone cables, cost and other considerations require an insulator other than textiles, and paper is a more suitable material for both. In condensers, where a sheet dielectric is obviously called for, paper has been a prominent insulating medium since the earliest days.

Although paper is the main insulating material for power and telephone cable and condensers, textiles creep in even here in minor capacities: the power cable engineer binds up joints with cotton tape; the telephone cable engineer uses cotton whippings to hold quads together; brightly dyed cottons provide identification schemes in many types of cables; and lappings of cotton tape hold the cable together before lead sheathing. For armouring cables, both use large quantities of jute either as yarn or in sheet form as hessian canvas impregnated in pitchy or bituminous compounds. While it may seem rather strange, from an engineering point of view, to talk somewhat indiscriminately of textiles and papers, it should be borne in mind that chemically the difference between cotton yarn and paper is insignificant compared with the difference between cotton yarn and silk yarn. The outward form of the material governs all the details of mechanical application, type of insulating machine used, etc., but it is the chemical nature of these materials that controls their most important property in electrical manufacture—namely, their insulation resistance and other electrical properties.

### *Insulation Resistance of Textiles*

A century ago Faraday wound coils of wire which he insulated with twine and calico. Cotton tapes also were used by him and by other investigators, mainly for insulating windings such as magnet coils. The progress from this state of affairs has not been remarkable until quite recently, mainly due to the fact that the electrical industry has merely accepted the materials produced by the textile and paper industries for entirely different purposes and has adapted its methods of manufacture to the peculiarities of these raw materials, overcoming their defects where possible by mechanical ingenuity or the use of excessive amounts of insulating material.

A raw material may be "good" or even "very good" from the point of view of one industry, and yet be very poor for the purposes of another. Viscose silk for example, a lustrous synthetic fibre now used in enormous quantities for hosiery and similar purposes, in certain applications can gain a high measure of approbation but, nevertheless, it is not as good as a plain grey cotton, at one-third the price, for electrical insulation. The fact that this vital difference in the methods of grading raw materials exists is still inadequately appreciated by most textile suppliers and many electrical engineers, and it is a cause of much misunderstanding. To put it briefly, by a "good" textile the textile manufacturer generally means one of pleasing appearance and good wearing properties when made into clothing; but, when the engineer wants a "good" textile for electrical manufacture, these two features are comparatively irrelevant to him and his main requirements are high insulation resistance, complete freedom from traces of chemicals which will corrode copper wires, and sufficient tensile strength to run satisfactorily on the machines. In nearly every case in electrical work, these three requirements are more important than the appearance of the textile. A similar difference in standards of "goodness" exists between the paper manufacturer and the electrical engineer.

The next step after Faraday's twine and calico was the application of yarn in the insulation of wires, and from quite early days the standard insulating materials for wire insulation have been silk and cotton yarns. It was gradually realised that silk was a better insulator than cotton, that insulations which when dry would give good service, were liable to break down when wet, and that most textiles have a high insulating power when dry but that they absorb moisture easily and can be quite poor insulators under conditions of high humidity. While these general ideas were fairly widely known, the valuable work of the Bell System made it possible to estimate the likely value of a textile as an insulator by other than purely empirical methods. Mainly through the work of Murphy and Walker,[2,3,4] knowledge of the principles of the mechanism of electrical conduction in textiles has come into being, and also the main principles of the accurate measurement of the insulation resistance of fibrous materials themselves as opposed to insulation resistances of cables or cords in which the mechanical construction affects the results considerably. The work of these investigators has shown that the insulation resistance of textile fibres as a whole is not simply a function of the amount of water present, but that it depends also on the manner in which the water is held. Wool and silk, for instance, are more hygroscopic than cotton, but electrically they are superior to it under equal humidity conditions. Murphy and Walker[2] have shown that the logarithm of the insulation resistance of a sample of textile plotted against the logarithm of the moisture content gives a straight line, the slope of which is independent of the form of the sample and of the impurities it contains but which is characteristic of the particular material tested. In this connection, Fig. 1 shows that materials with a cellulose type of structure give graphs with a similar slope, while the results for natural silk, having a different internal structure, give a line of steeper slope. The work of these two investigators has shown quite conclusively that the insulation resistance of a textile is completely determined by the following factors:

1. The chemical structure of the fibre.
2. The moisture content of the fibre.
3. The electrolyte content of the fibre.

For any given fibre the moisture content is a function of the relative humidity of the atmosphere surrounding it, and this is shown graphically in Fig. 2. It is clear that to improve the insulation resistance, it is necessary to change the structure of the fibre, reduce its moisture or electrolyte content, or decrease the relative humidity of the surrounding atmosphere. The variation of insulation resistance of textiles, with changes in relative humidity, is shown graphically in Fig. 3.

Considerable work also has been done by the British Cotton Industries Research Association to determine how the moisture is held by the cotton. This led to the conclusion that the water is held in two distinct ways: (a) the water molecules are loosely linked with the cellulose unit, producing changes in its physical and mechanical properties; (b) the water molecules fill the spaces available between and in fibres under capillary forces such as those of a liquid. Except at highest humidities, the (a) form largely predominates. This has an important bearing on the problem of protecting textiles against moisture absorption when impregnation with compounds such as oils and waxes is employed. It is obvious that unless these compounds are themselves nonabsorbent and are able to seal the fibres completely, they can only affect penetration of the water in class (b), and absorption of water in class (a) will only be retarded. Two methods based on these principles have been in use for many years: the textile insulated apparatus can be dried and sealed in a closed sheath or other container, or the interstices between the fibres can be filled with some oil or wax having high insulation resistance. The first of these is satisfactory in a way but it is cumbrous and expensive even if the container serves some other purpose such as mechanical protection; there is, moreover, the difficulty of making joints between

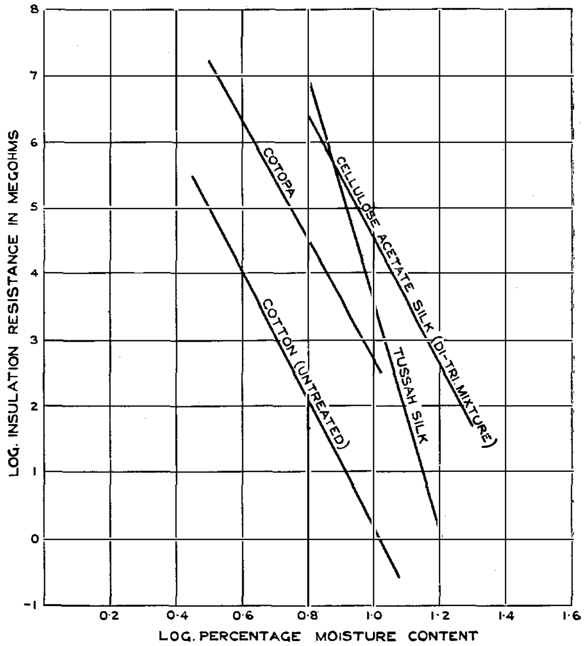



*Figure 1—Insulation Resistance of Textiles as a Function of Their Moisture Content.*

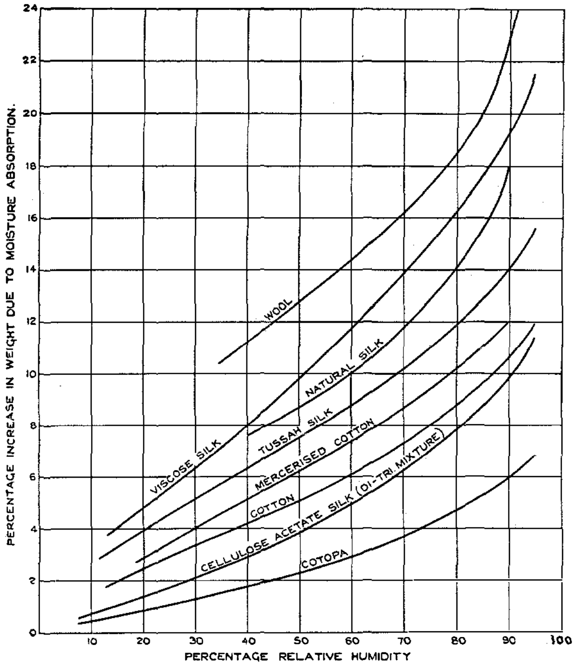



*Figure 2—Relation of Moisture Content of Textiles to Relative Humidity.*

consecutive lengths of cable made up in this way, and the difficulty of redrying after a leak due to any accidental puncture of the sheath or container. In the second method, it is found that the treatment merely retards the rate of absorption of water unless precautions are taken to prevent access of moisture to the apparatus. This is clearly shown in Figs. 4 and 5. There are, however, few impregnating compounds which are flexible, stable, and themselves completely nonabsorbent. Many which are otherwise suitable will themselves absorb some water, and the fibrous material having a greater affinity for moisture takes up water from the compound. This is experienced in oil immersed transformers where it is frequently found that the textile coverings on the wires have absorbed moisture from the oil, and for this reason it is necessary to prevent, as far as possible, the access of moisture to the oil. Similarly, in the case of power cables and condensers, it is found to be necessary to protect the impregnated paper by sheathing or by enclosing in a container, respectively. It is important to note that the sheath and the container are thus essential for electrical reasons as well as for the mechanical protection they afford.

Frequently the impregnating compounds themselves do not have the highest electrical properties and, while improving the insulation resistance of textiles at high humidities, lower it under ordinary conditions. In addition, the effect of impregnation on the handling and colouring of the material is not always beneficial. Williams and Murphy[3] achieved considerable success by attacking the last factor mentioned above—the electrolyte content—and showed that considerable improvements can be obtained both with cotton and natural silk by a special washing process.[5] Walker and Quell[6] showed that the essential was not just the removal of impurities but the removal of soluble sodium and potassium salts, which are highly dissociated in solution. The special washing treatment does not change the inherent absorption power of the textile itself but decreases the conductivity resulting from the absorbed moisture. Recently, marked improvements have been made in textile insulations in an entirely novel manner, that is, by affecting the first factor in the above enumeration, i.e., the chemical structure of the fibre.

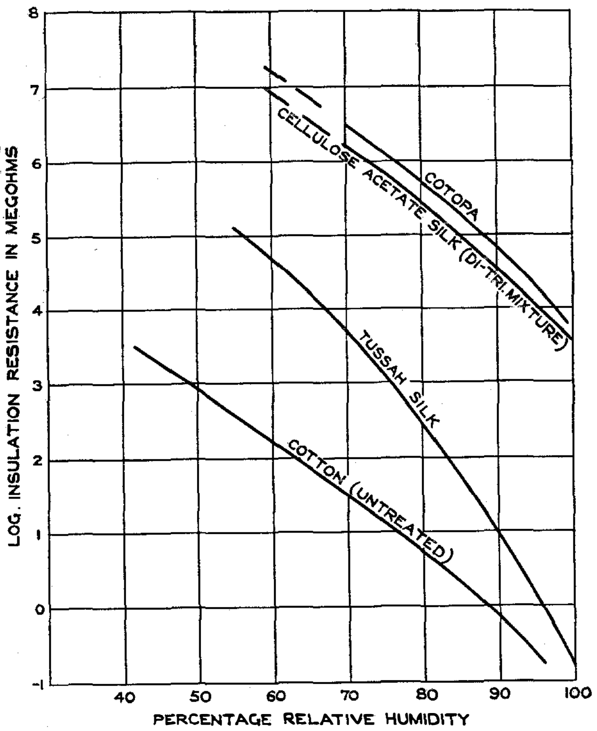



*Figure 3—Relation of Insulation Resistance of Textiles to Relative Humidity.*

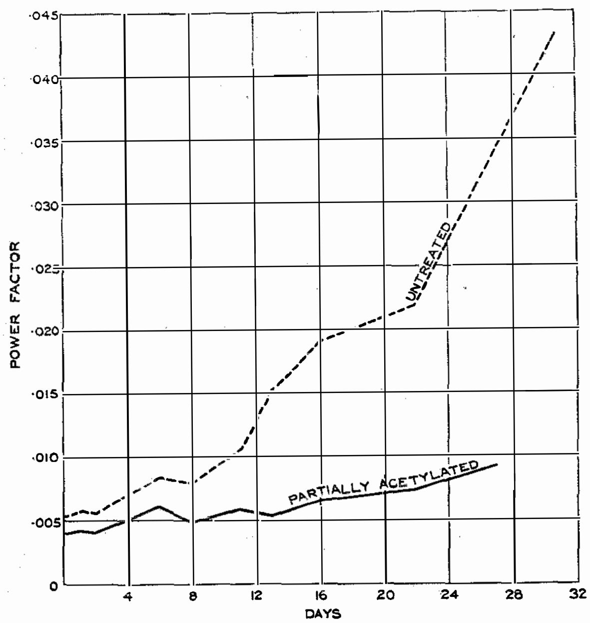



*Figure 4—Power Factors of Oil Impregnated Paper With and Without Partial Acetylation Treatment Exposed to Air of Normal Humidity.*

## *Textile Fibres Considered Chemically*

Before attempting to describe these improvements it is desirable to review briefly the characteristics of textile fibres from a physical and chemical point of view. The outstanding features of these materials are their fibrous nature, pliability, and remarkably high tensile strength, as shown by the following table[7]:

| Material | Tensile Strength in kg./mm.$^2$ |
|---|---|
| Steel | 50-160 |
| Flax | 60-110 |
| Hemp | 80-92 |
| Silk | 35-44 |
| Iron | 34-50 |
| Cotton and *Cotopa* | 28-44 |
| Copper | 20-50 |
| Aluminum | 10-40 |
| Ebonite | 2.5-5.5 |

Only good steel, tantalum, and some other of the heavy metals are superior in tensile strength to the fibres of the textiles listed above.

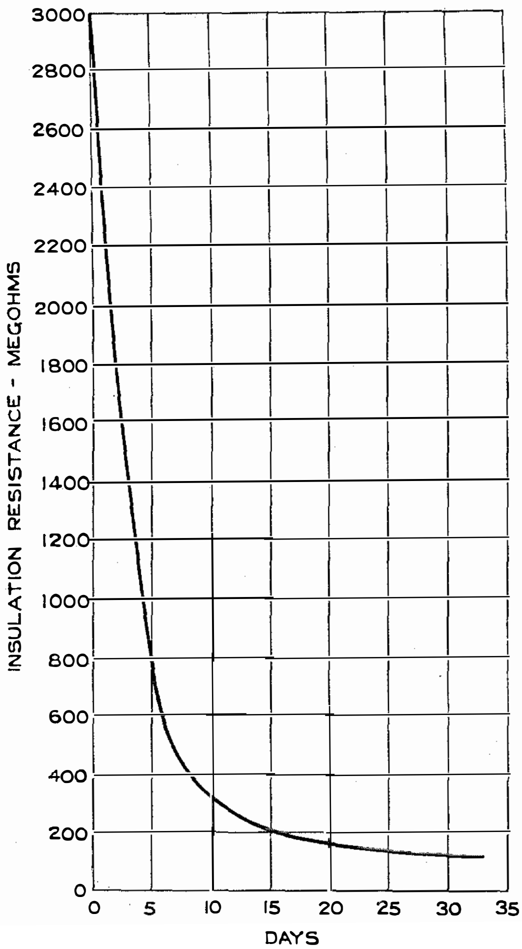
The textile fibres suitable for electrical insulation purposes fall into three main groups:

(1) Animal fibres such as wool and natural silks.
(2) Vegetable fibres such as cotton, linen, hemp, etc.
(3) Synthetic fibres such as viscose and acetate silks.

Considered chemically, the animal fibres belong to the group of proteins, being of similar composition to gelatine, casein, etc. All vegetable fibres consist of cellulose with varying amounts of impurities, and all the usual synthetic fibres are either merely cellulose in an altered form or a chemical derivative of cellulose. At present there are four distinct types of synthetic or modified fibres derived from cellulose:

*Group 1.* Fibrous structure of cotton retained.

(a) Final product modified cellulose, e.g., mercerised cotton.
(b) Final product a chemical derivative of cellulose, e.g., esterified cottons or papers.




READINGS, AFTER 1 MINUTE'S ELECTRIFICATION.

*Figure 5—Variation of Insulation Resistance of Impregnated Paper Condenser (Without Container) Exposed to Air of Normal Humidity.*

*Group 2.* The cellulose or cellulose ester is dissolved in a suitable liquid, squirted through tiny spinnerets into a precipitating bath, and wound off as a continuous filament.

(a) Final product modified cellulose, e.g., viscose and cuprammonium silks.
(b) Final product a chemical derivative of cellulose, e.g., cellulose acetate silks.

In appearance, the products in the first group still closely resemble the parent fibre, while in the second group they have very long fibres and the high lustre generally described as "silky." It is interesting to note that with those types of synthetic or modified fibre which in the final stage consist of regenerated cellulose, the moisture content is always greater and the insulation resistance lower than cotton untreated other than by washing free from electrolytic material. In every case the treatment has made the cellulose a poorer insulator, the main reason being that a molecular rearrangement has taken place.

Considering now the chemical derivatives of cellulose, only three have ever attained considerable commercial importance:

(a) cellulose—nitric acid derivative—chardonnet silk.
(b) cellulose—acetic acid derivative—acetate silk.
(c) cellulose—acetic acid derivative—acetylated cotton.

The first, which was a poor insulator and very inflammable, has now been completely superseded by the second. Cellulose acetate silk is the only type of "artificial silk" or rayon found to be satisfactory as an electrical insulator. It is superior electrically to any of the other textiles in common use, but its mechanical properties are not so satisfactory. It is springy, giving it a tendency to unravel when used as a lapping on wires. Its comparatively low tensile strength makes it necessary to run wire covering machinery, etc., at a lower speed than with cotton, and its smooth surface necessitates more careful attention on the part of the operators. Decrease in machine speed and increase in the number of operators adds greatly to the cost of the manufactured product. It has the further disadvantage that its low melting point makes its use undesirable where many soldered joints are necessary, as for instance in wiring a telephone exchange.

None of the materials which have been discussed thus far can be considered as being entirely satisfactory as an electrical insulating material. Cotton is cheap and has good mechanical properties, but it is relatively poor electrically, especially under humid conditions, when it is also liable to attacks by fungi. Natural silk, while good mechanically and reasonably good electrically at ordinary humidities, fails at high humidities and, moreover, it is expensive and for this reason can be used only for special purposes. Cellulose acetate silk, on the other hand, is poor mechanically although it is usually considered to be the best material electrically and for this reason is frequently used where high insulation resistance is the chief requirement. Wool is also sometimes used, but not to any very great extent because of its protein nature, its highly hygroscopic character, and its liability to attack by insects and fungi; nevertheless, it has useful applications where a textile insulator with flameproof properties is required.

The textile approaching the ideal, obviously would be one possessing the electrical properties of cellulose acetate silk (or better if obtainable), and the mechanical properties of cotton combined with low cost.

### *Cotopa and Its Properties*

Quite recently a new textile material, fulfilling the above conditions, has been marketed under the trade name of *Cotopa.* It is a chemical derivative of cotton, containing about 21% noncellulose material and closely resembling a good cotton in appearance and in mechanical properties.

Cellulose, which is the constituent material of cotton and also forms the bulk of all the other vegetable fibres, is a compound of carbon, hydrogen, and oxygen, united in the percentage proportions:

| | |
|---|---|
| C | 44.2% |
| H | 6.3% |
| O | 49.5%, |

corresponding with the empirical formula $C_6H_{10}O_5$ by which it is also defined as a carbohydrate. By a careful treatment with sulphuric acid and water, cellulose can be broken down and made to combine with water to yield glucose:

$$C_6H_{10}O_5 + H_2O = C_6H_{12}O_6 \text{ (Glucose)},$$

from which it was not unreasonable that chemists at first supposed that cellulose was the anhydride of glucose. It was obvious that there must be some reason for the difference in physical properties between glucose and cellulose which was not accounted for in the above very similar formulae. For a long time this was believed to be due to the cellulose molecule consisting of an aggregate of glucose anhydride molecules represented by the empirical molecular formula $(C_6H_{10}O_5)_n$. In the last few years it has been shown that this assumption is not quite correct, and the majority of the details of the space arrangements of the atoms in the molecule have been worked out chemically[8, 9] and by X-ray analysis.[10] However, for the time being, the simpler formula will be employed and the implications of the recent X-ray work reverted to only in Part II of this paper, since the formation of esters can be clearly understood, provided it is borne in mind that they are only units of colloid fibres. After a very large number of experiments it has been found impossible to introduce more than three acyl groups into cellulose, thus indicating that only three of the oxygen atoms are present in hydroxyl groups and that the other two are present in the unit in a nonreactive form. Hence we may represent the formula by:

$$(C_6H_7O_2)\begin{matrix} -OH \\ -OH \\ -OH, \end{matrix}$$

but it must not be assumed that this necessarily implies equal combining affinities on the part of the three hydroxyl groups.

It is important to stress at this point the difference in behaviour between such a unit acting in the form of separate detached molecules or acting in an aggregate with other similar units as a part of one of a number of long molecular chains. In the first instance three types of esters are theoretically possible and in most cases could be separated in the pure state, the mono-, di-, and tri-esters, each group having its own definite characteristics. In the second instance, however, this is not to be expected, especially with a particle the size of a cellulose molecule. Only the tri-ester could be separated pure. There is no experimental evidence that such a material as pure mono- or pure di-ester ever exists.

It was discovered by Schutzenbugen in 1865 that acetic anhydride under certain conditions will esterify the cellulose unit; Franchimont, in 1879, discovered the advantage of adding a catalyst to hasten the reaction. The final product on complete esterification is the triacetate:

$$(C_6H_7O_2)\begin{matrix} -O.CO.CH_3 \\ -O.CO.CH_3 \\ -O.CO.CH_3, \end{matrix}$$

which is soluble in chloroform but insoluble in acetone and which contains 62.5% acetic acid by analysis. The cellulose acetate silk of commerce is obtained by stopping the process before it reaches this stage; and, while the product is still soluble in acetone, mixing the reaction liquid with water to precipitate white flakes of the cellulose mixed acetates containing about 55-58% acetic acid by analysis; washing, drying, and dissolving them in acetone, and forcing the resulting solution through spinnerets into a precipitating bath from which the silk is wound off as continuous filaments. Alternatively, the cellulose can be fully acetylated and partially hydrolysed before dissolving in acetone and forming into fibrils. Acetylated cotton is made by a modification of this process by employing a less violent treatment (a lower temperature and a weaker bath), whereby the rate of acetylation is moderated and the process so controlled that it may be stopped at any desired stage.

*Cotopa* is a low acetylated cotton in which the process has been adjusted to produce a fibre having approximately the acetyl group content corresponding to a monoacetate. Its relation to cellulose and the di- and tri- acetates is:

| | |
|---|---|
| $(C_6H_7O_2)\begin{matrix} -OH \\ -OH \\ -OH \end{matrix}$ | $(C_6H_7O_2)\begin{matrix} -OH \\ -OH \\ -O.CO.CH_3 \end{matrix}$ |
| *Cellulose* (Cotton, mercerised cotton, viscose silk, paper) | *Cellulose Monoacetate* *Cotopa* |
| $(C_6H_7O_2)\begin{matrix} -OH \\ -O.CO.CH_3 \\ -O.CO.CH_3 \end{matrix}$ | $(C_6H_7O_2)\begin{matrix} -O.CO.CH_3 \\ -O.CO.CH_3 \\ -O.CO.CH_3 \end{matrix}$ |
| *Cellulose Diacetate* | *Cellulose Triacetate* |

Cellulose acetate silk is a mixture of these two.

It might be supposed from the position of *Cotopa* in this series of formulae that it would be expected to have a higher moisture content and a lower insulation resistance than cellulose acetate silk. The fact that the reverse is actually the case is due to differences in the molecular structure of the fibre. This is also illustrated by a comparison of cotton and viscose silk, both of which are cellulose and have the same molecular formula, but the alteration in the arrangement of the molecules produced by the chemical processes used to convert the cotton into viscose silk greatly increases the moisture content and lowers the insulation resistance.

The main properties of *Cotopa*[11,12] are the following: In appearance it closely resembles the cotton from which it is made; it has a slightly harder feel, is equally strong and elastic; and has similar running properties on machines. The characteristic structure of the cotton fibre is preserved entirely; even the light reflections in polarised light are the same. It can no longer be dyed with substantive dyes (direct cotton colours) but it has a pronounced affinity for the disperse colours. Unlike cellulose acetate silk, it is not swollen and dissolved by chlorinated solvents such as carbon tetrachloride, nor is it affected by acetone (also a solvent for acetate silk). It has much less tendency to absorb moisture and, in general, has electrical insulation resistance characteristics very greatly superior even to the best grade of cotton commercially available.

## *History of Esterified Cottons and Cotopa*

The history of acetylated cotton goes back to 1905 when Cross and Bevan produced a low acetylated cotton by treating bleached cotton with boiling acetic anhydride, while in 1907 Cross and Briggs[13] were awarded a prize of £10 by the Society of Dyers and Colourists, under the prize scheme then existing, for a somewhat similar process at lower temperatures. The products, however, were of no commercial value owing to loss of tensile strength and irregular acetylation due to lack of control over the reaction.

The later work has been dealt with recently by Chippendale (of Cotopa, Ltd.) in a paper[12], read before the Society of Dyers and Colourists at Manchester, in which it was shown how Rheiner and other chemists of the Sandoz Chemical Works were at last able to produce successfully a low acetylated cotton without any loss in tensile strength by substantially moderating the conditions as compared with those necessary for the production of the triacetate. The activity of the process is reduced so that acetylation, even to the monoacetate stage only, occupies a considerable period of time, of the order of 20 hours. That the fibres are evenly acetylated throughout can be shown by preparing cross sections after dyeing with cellulose acetate dyes. An even dyeing will be found to have taken place, indicating that the fibres are chemically and physically homogeneous. Details of the above processes are given in the patent literature.[14,15]

In addition to the acetylated cottons, other esterified cottons have been prepared from time to time. Benzoates[16,17] of cellulose can be prepared by treating cotton with caustic soda and benzoyl chloride thus:

$$\text{(i)}\quad (C_6H_7O_2)\begin{matrix}-OH\\-OH\\-OH+NaOH\end{matrix} = (C_6H_7O_2)\begin{matrix}-OH\\-OH+H_2O\\-ONa\end{matrix}$$

cellulose caustic soda soda cellulose water

$$\text{(ii)}\quad (C_6H_7O_2)\begin{matrix}-OH\\-OH\\-ONa+C_6H_5COCl\end{matrix} = (C_6H_7O_2)\begin{matrix}OH\\OH\\OOC.C_6H_5\end{matrix} +NaCl$$

benzoylchloride cellulose benzoate salt

Another esterified cotton, prepared in a similar manner, is cellulose toluene-parasulphonyl ester,[18]

$$(C_6H_7O_2)\begin{matrix}-OH\\-OH\\-O.SO_2-C_6H_4-CH_3.\end{matrix}$$

The reason for this rather unusual compound coming into prominence was mainly the commercial availability of the raw material—toluene sulphonic chloride—as an intermediate in various chemical manufactures.

By either of these two treatments, the cotton is so modified as to be suitable for use as effect threads, i.e., threads of this material when woven with untreated cotton and dyed in the ordinary manner will be completely unaffected by the dye and hence will give a white patterned effect.[19]

An important point with relation to the above processes is that the final product in each case consists of an inner core of unaltered cellulose surrounded by a tube of the cellulose benzoate or toluene sulphonic ester. This can be shown clearly by preparing cross-sections of the fibres, after dyeing with 1 : 4 diaminoanthraquinone or other dyestuff having the property of dyeing cellulose esters but not cellulose itself, and examining under the microscope, when the esterified portion appears as a coloured ring around a centre of undyed cellulose. In addition, the thickness of the outer layer of ester varies considerably from place to place. For this reason fibres made thus are not of much use electrically even though cellulose benzoate or toluene sulphonic ester have much higher resistivity than cellulose. What happens, of course, is that in a heterogeneous insulation of this type, electricity passes through the paths of lower resistance provided by the unchanged cellulose, and the insulation resistance is only a small fraction of what it would be if the material were evenly esterified. Both "resist cotton" and "immunised cotton" (the types referred to above) are obsolescent now and are almost entirely superseded by the low acetylated cottons, *Cotopa* (nonlustrous) and *Crestol* (lustrous).

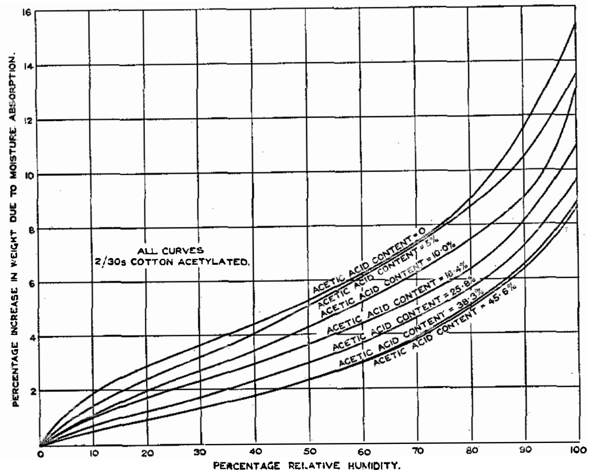



*Figure 6—Relation of Moisture Content of Acetylated Cottons to Relative Humidity and (Combined) Acetic Acid Content.*

## *Change in Properties Produced by Acetylation*

If a series of acetylated cottons of increasing acetyl content up to about 30% be examined, it will be observed that the appearance changes only very slightly, the feel becomes slightly harder and the tensile strength remains unchanged. The diameter of the fibres naturally increases and hence, also, the diameter of the yarn, thus giving it greater coverage than the original cotton. However, it should be noted that, since an increase in weight occurs along with the increase in diameter, the comparison of covering power of the two materials on an equal weight basis brings them more nearly equal. The problem is also complicated by the different counts in use, etc., and will be dealt with more fully later. If the moisture content at a given humidity, say 70% relative humidity, is measured, a steady decrease from about 7½% with ordinary cotton, to about 4% with a cotton acetylated, to 29.4% (acetic acid by analysis) is obtained, as shown in Fig. 6.

If a series of these acetylated cottons be treated in a dye-bath such as is used for dyeing cotton with "direct" or substantive colours, the amount of colour absorbed from the bath decreases steadily with the degree of acetylation. The substantivity of individual direct cotton colours, of course, varies widely and is greatly affected by the presence of electrolytes,[20] but using Chlorazol Sky Blue FF under normal dyeing conditions no colour at all is taken up by an acetylated cotton of 29.4% acetic acid content. Just as the affinity for substantive colours falls off, so the affinity for disperse colours such as are used for dyeing cellulose acetate silk increases with the degree of acetylation.

Lastly, the property of most interest to the electrical engineer, the insulation resistance, steadily increases with the degree of acetylation.

The insulating power of acetylated cottons is thus seen to be largely controlled by the degree of acetylation and the actual value chosen in practice is a matter of economics. If the same product can be used for textile purposes as resist threads, etc., and also for electrical insulation purposes, they will both be cheaper than if different processes are used and two different materials marketed. In practice at present, *Cotopa* as used for electrical insulation work consists of an acetylated cotton of 29.4% acetic acid content and has an insulation resistance superior even to commercial acetate silk.

*Cotopa* can be impregnated with any of the compounds normally used for impregnating cotton or silks, though it must be borne in mind that the insulation resistance of the impregnating compound may be lower than that of *Cotopa*, particularly if the compound has deteriorated due to prolonged heating. When the impregnated material is left in an atmosphere of normal humidity, reabsorption takes place in accordance with the moisture content curves shown in Fig. 2, and with the effect on the insulation resistance shown in Figs. 1 and 3.

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# 400 Line P.A.B.X.—7055 Type

By M. A. BISKE, A.I.Lg.

*Bell Telephone Manufacturing Company, Antwerp*

THE 7055 P.A.B.X. belongs to the series of modern private branch exchanges, full automatic in operation and adapted to operate with manual or dial central offices. It embodies all of the recent requirements such as "call back," "transfer," etc., and ordinarily functions with a small key type cabinet for the use of the attendant. For larger capacities in trunks to city, two attendant sets may be equipped.

When required, provision is made for conference and preference circuits, code calling, tie lines to other P.B.X.'s, fire alarm, etc.

The maximum capacity of the 7055 P.A.B.X. is 400 lines, and it may be recommended for use for an initial capacity of at least 100 lines.

The normal operating voltage is 48 volts, but the circuits are designed to work satisfactorily between the limits of 44 and 56 volts. The permissible loop resistance of subscriber's line and substation equipment may vary from 0 to 1,000 ohms, with an insulation resistance of minimum 10,000 ohms wire-to-wire. The maximum permissible resistance of trunk loop is governed by the limitation of the dial speed. If the speed of the dial is limited to 12 steps per second, the maximum permissible trunk resistance is 1,000 ohms; if the speed of the dial is limited to 13 steps per second, the maximum permissible trunk resistance is 800 ohms. In both cases the allowable minimum insulation resistance of the trunk wires is 10,000 ohms.

The subscriber set used with this P.A.B.X. is the standard dial set except for a non-locking push button grounding key required for the aforementioned call back, transfer, etc., service. The standard central office bakelite dial set is designed and built to permit this transfer button to be installed at any time should it be desirable to convert main line sets for P.A.B.X. use. When a P.A.B.X. station is restricted to local service only, the transfer button may be omitted or disconnected.

Before describing the standard equipment for the above P.A.B.X., the methods of operation are briefly explained.

## *Local Call*

A station originates a local call in the usual manner by removing the receiver from the switchhook and dialling the wanted party's number after hearing the dialling tone.

The release of the connection is under the control of the calling party and, when the latter restores his receiver, the engaged circuit becomes available for another call.

Should the called party be found busy, the usual intermittent busy tone is heard by the originating party.

## *Outgoing City Call*

Unrestricted stations originate outgoing city calls by dialling the single digit "0." If the central office is automatic, the P.A.B.X. station hears the dialling tone of the city exchange and then dials the complete subscriber's number. If the city exchange is manual, the P.A.B.X. station awaits the answer of the city operator and then communicates the wanted subscriber's number.

At the end of the conversation, the P.A.B.X. and central office connections are released when the calling party hangs up.

Should all the trunks be busy at the moment an outgoing city call is originated, the calling subscriber hears the busy tone after dialling "0."

## *Incoming City Call*

*Called Line Free.* Calling lamp CL on the attendant's cabinet lights. The attendant replies by throwing the answering key AK and removing the common handset. Lamp CL extinguishes.

The attendant ascertains that the dialling key DLK is thrown and dials the requested party's number. Lamp CL flickers.

When the selection is completed lamp CL

lights fully. If the called P.A.B.X. line is found free, ringing current is automatically connected to the line.

When the called party answers, lamp CL extinguishes. The attendant informs him of the city call and, if it is accepted, restores key AK, whereupon the wanted party is connected to the trunk and the attendant is cut out of the conversation.

The central office connection is released when the distant subscriber hangs up and the P.A.B.X. connection is released when the P.A.B.X. subscriber hangs up.

*No Reply or Non-Acceptance.* If the called party does not accept the city call or in case he does not reply, the attendant depresses momentarily the release button RB associated with each individual trunk. The attendant is thereby again connected to the trunk party and if necessary can start a new call to obtain another local party.

*Called Line Local Busy.* If the called line is found busy on a local conversation, the attendant hears busy tone and in addition lamp CL flashes with a periodicity of about one flash per second.

The attendant may either depress the button RB to inform the city that the called party is engaged, or may listen in on the established connection by depressing the key LIK. If the city call is accepted, the local connection is released by the attendant's restoring key AK.

*Called Line Trunk Busy.* If the called party is found busy on a city call the attendant hears a special "trunk busy" tone and in addition lamp CL flashes.

The attendant offers the new call. If it is accepted, the attendant restores key AK. When the called party restores his instrument, ringing current is connected and, on replying, the called subscriber is automatically connected to the new city call.

*Through-Connection Before Reply.* If the called P.A.B.X. party is free but does not reply at once, the attendant may restore key AK without waiting for the reply. As soon as the P.A.B.X. party answers the connection is established.

*Holding the Connection.* In case the attendant cannot complete the call immediately, she places the trunk in the "hold" position by throwing key HK.

### *Calling In of the Attendant*

The P.A.B.X. party can call in the attendant both on outgoing or on incoming city calls. For this purpose the P.A.B.X. party depresses momentarily the button associated with his set, identified as transfer button, and when hearing the dialling tone dials "9." Lamp CL of the trunk lights and the attendant answers by throwing key AK. The attendant becomes connected to the P.A.B.X. party, the trunk being disconnected but held engaged.

If the city connection is to be transferred to another party, the attendant depresses momentarily button RB and proceeds in exactly the same manner as for an incoming call.

If, on obtaining the required information, the P.A.B.X. party requests the attendant to re-establish the trunk connection, the attendant merely restores key AK and the attendant is cut out from the conversation.

### *Call-Back*

A P.A.B.X. party connected to a trunk may place the trunk temporarily under "holding" condition and may call any local party. For this purpose he momentarily depresses the transfer button on his set and, on hearing the dialling tone, dials the number of the wanted P.A.B.X. party. The trunk is disconnected from the calling station but is held busy.

The connection to the local party is established in the normal manner. To return to the trunk, the P.A.B.X. party releases the local connection by momentarily depressing the switchhook; when dialling tone is heard, the P.A.B.X. party again depresses the transfer button.

### *Transfer*

The P.A.B.X. station engaged in a trunk connection and desiring to transfer the call, first sets up a "call-back" to the wanted party as described above.

When the called party answers, the originating station informs him that the party on the trunk wishes to talk to him. If the called party accepts the trunk call, the calling party again depresses the transfer button and then replaces his hand set, thereby automatically transferring the trunk call to the called station (provided the latter has unrestricted service).

## *Night Service*

The attendant before going off duty throws the common night switching key NSK.

When an incoming city call arrives at night, ringing current is applied to the first free line of the group of lines assigned as night attendants. When the attendant replies, he becomes automatically connected to the calling trunk.

Transfer facilities are given to night attendants who can extend the call to the wanted party in the usual manner.

Local and outgoing trunk calls are made at night in exactly the same way as during the day.

## *Restricted Service*

Any station may be debarred from making or receiving city connections. Such stations are restricted to local service only.

In case a restricted station endeavours to set up a city connection by dialling digit "0," the trunk finders are set in motion but none of them can become connected to the line. A restricted service finder, to which all the restricted subscribers are multipled, becomes connected to the restricted line and connects a busy tone indicating that a city trunk cannot be obtained.

During a city connection a call-back to a restricted station may be established but the connection cannot be transferred to it. If the P.A.B.X. party engaged on a city connection endeavours to make the above transfer, the connection is broken but the trunk party is directed to the attendant by the lighting of CL lamp of the trunk. The attendant replies by throwing key AK and may extend the call to an unrestricted line in the regular way.

If, at night, when there is no regular attendant, a subscriber tries to transfer a city connection to a restricted line, the trunk is released.

## *Tie Line Service*

Tie lines to provide service between two or more P.B.X.'s may be supplied upon request. The exact method of operation depends upon the requirements and upon the nature of the P.B.X.'s involved.

To obtain a connection with a distant P.A.B.X. party, the P.A.B.X. subscriber (after obtaining the local dialling tone) dials the single digit assigned to the particular tie line route wanted. An idle tie line to the distant P.A.B.X. becomes connected and the local link circuit is released.

When hearing the dialling tone of the distant P.A.B.X., the calling party dials the number of the wanted distant P.A.B.X. party. When the latter replies, the connection is established. At the end of the conversation the tie line is usually released only when both the calling and called parties hang up.

Should all the tie lines be busy, the calling subscriber hears the busy tone after dialling the special digit assigned to the tie line calls.

*Trunks Calls Over Tie Lines.* In most cases each of the P.A.B.X.'s in a P.A.B.X. network is equipped with trunks to the city exchange so that tie lines are used exclusively for connections between subscribers of different P.A.B.X.'s. However, it may happen that a small P.A.B.X. connected to a central P.A.B.X. is deprived of direct city service and that the subscribers of this small P.A.B.X. require city connections over tie lines. In this case an outgoing city call from the distant P.A.B.X. is created by a station dialling "0" instead of the single digit call assigned to tie line service. A free tie line to the central P.A.B.X. becomes connected to the originating party. The wires towards the central P.A.B.X. are reversed, thereby creating a call at the central P.A.B.X. for a free trunk circuit. When dialling tone from the central office is heard, the originating party dials the wanted subscriber's number, the impulses being retransmitted from the tie line circuit over the trunk circuit to the central office exchange. At the end of the conversation when the calling P.A.B.X. subscriber hangs up, he releases the tie line circuit, the central office trunk, and the connection in the distant central office.

An incoming city call for a distant P.A.B.X. is relayed by the attendant of the central P.A.B.X. The attendant depresses the common tie line button assigned to the group of tie lines to the wanted P.A.B.X., thus connecting the trunk to a free tie line to this P.A.B.X. The attendant now dials the wanted number in the usual way. She is disconnected from the trunk when the called party answers, and the release of the tie line and of the trunk takes place when the called party hangs up.

*Call-Back and Transfer Facilities on Tie Lines.* The tie lines associated with P.A.B.X.'s for which the city connections are given over these tie lines, are usually provided with call-back and transfer facilities. In exceptional cases, the same facilities may also be given on tie lines used exclusively for calls between stations connected to P.A.B.X.'s.

## *Conference Call Service*

A limited number of predetermined stations can be arranged to receive and to originate conference calls.

To originate a conference call, a subscriber entitled to it sends a special digit after hearing the dialling tone from the local link. When the conference circuit becomes attached, the local link circuit is released and the second dialling tone from the conference circuit becomes connected.

The calling subscriber dials the first of the wanted numbers and, when the called party answers, instructs him to remain at his telephone until all the parties who are to take part in the conference have been called.

To call the second party, the calling subscriber momentarily depresses the transfer button, thus restoring the conference circuit to the calling condition. The number of the following station is then dialled, and when the second party replies he becomes connected to the common conversation circuit. When the last party has been called, the conference may take place.

Any party may retire from the conference by hanging up, thereby releasing his line. The originating party, after having retired from the conference, may resume by setting up a conference line call and, instead of dialling a subscriber's number, dialling digit "0" after hearing the dialling tone.

## *Preference Call Service*

Provision can be made for certain stations breaking in on an established connection in order to convey urgent information or to give important instructions.

In order to obtain a connection to the preference circuit, the authorized P.A.B.X. subscriber dials the single digit assigned for this purpose. When the preference circuit becomes connected, the local link circuit is released and a second dialling tone is connected to the calling subscriber.

The subscriber dials the number of the wanted party and the preference switch is advanced to the listening-in position. The calling station may now talk to the called station, in case the latter is found busy. If required, the originating party may break down the established local connection by dialling digit "1."

If the wanted line is found free when the selection is complete, the calling party advances the switch from the listening-in position by dialling digit "1." Ringing is automatically connected to the called party and, when the latter answers, the connection is established.

## *Code Calling*

Code calling provides means whereby a subscriber is informed of a call by means of bells or lamps conveniently located throughout the building.

To call a party by means of a code, the originating subscriber dials the single digit assigned for code calling. A free code line circuit becomes connected and the engaged link circuit is released.

When hearing the dialling tone from the code calling circuit, the originating party dials the regular number of the desired station. When the selection is complete, bells convey an audible signal, repeated at even periods, corresponding to the code assigned to the individual.

A visual, instead of an audible signal, may be displayed by means of a combination of a few lamps forming a code. In this case an alarm bell is rung simultaneously to attract the attention of the called party.

The called party answers by dialling a special code reply number from the nearest telephone set. The connection with the calling party is thus established over the local link circuit and the code line circuit, the code signal being stopped.

The connection is placed under the control of the called party and the circuits are released when the latter hangs up.

If required, a few simultaneous code conversations may be arranged for. In this case a code register is provided. It is freed when the called party replies and may then be taken by a new code call. Only one code signal, therefore, may be displayed at a time.

### *Fire Call*

Fire calling consists of means whereby a predetermined station (fire chief) may be connected to a certain number of other stations by merely removing the handset and depressing a special key associated with his set. A ringing signal is given to all the firemen. The latter reply by removing the handset and then become connected to the fire chief who transmits the orders over a common talking circuit.

If a called line is found local busy, the established connection is broken down. If a called line is found trunk busy, a warning tone is conveyed to the station which should release the trunk in order to obtain connection with the fire chief.

### *Typical Junction Diagrams*

To illustrate the above description, a few

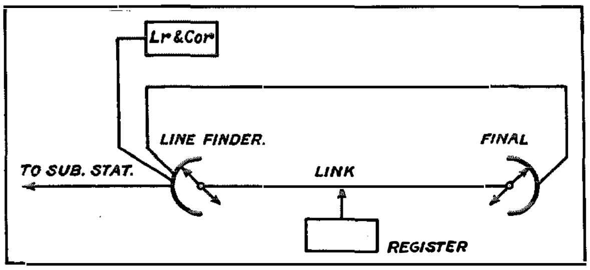


*Figure 1—Local Service, 100 Line Capacity.*

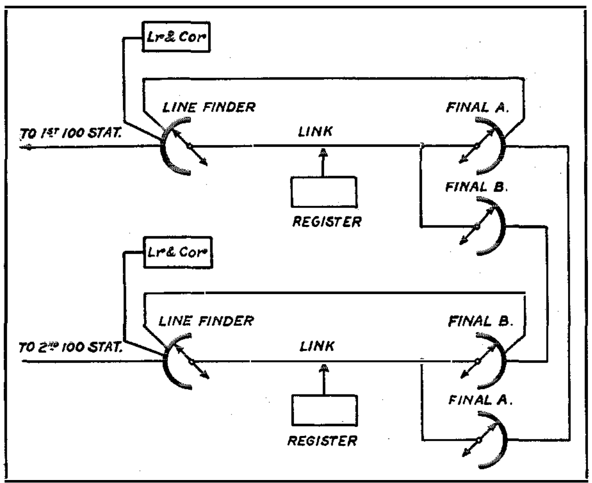


*Figure 2—Local Service, 101 To 200 Line Capacity.*

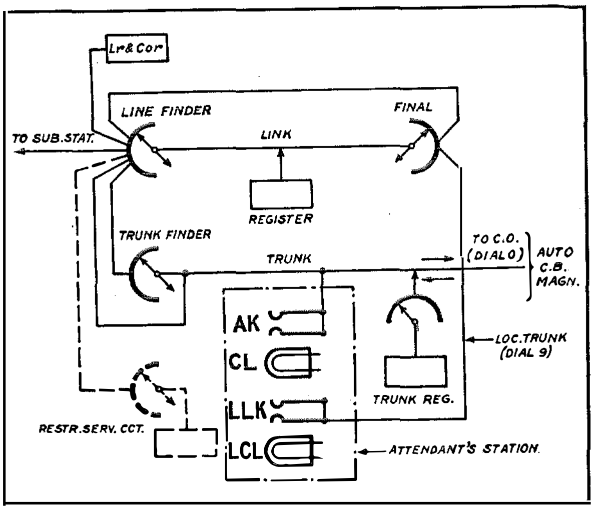


*Figure 3—Local and Trunk Service, 100 Line Capacity.*

typical cases have been chosen:

Fig. 1 shows a 100 line capacity P.A.B.X. for local service only.

Fig. 2 shows a 200 line capacity P.A.B.X. for local service only.

Fig. 3 shows a 100 line capacity P.A.B.X. arranged for local and trunk service. The trunk register is used for incoming traffic only and is disconnected as soon as the wanted party is selected by the attendant. The restricted service circuit shown in dotted lines is used in case some of the subscribers are restricted to local service only.

Fig. 4 shows a 200 line capacity P.A.B.X. arranged for local and trunk service. Each of the link and trunk circuits is provided with additional selectors.

Fig. 5 shows a 100 line capacity P.A.B.X. arranged for local and trunk service and in addition with tie lines to a distant P.B.X.

### *Numbering*

For a 400 line capacity P.A.B.X., the subscribers' numbering is usually as follows:

100 - 199, 200 - 299, 300 - 399, 400 - 499.

0 is reserved for automatic outgoing city calls; 9 for calls to the attendant.

The remaining available single digits (5, 6, 7, 8) may be used for tie line calls, conference and preference calls, and code calling.

### *Equipment*

The 7055 P.A.B.X. makes use of 100 point gear driven finders also used as selectors, as well as step-by-step marker switches.

The attendant's cabinet consists of a moulded handset and cradle mounted on a small desk turret, as shown in detail in Fig. 6, and is described below.

In case of special requirements, a floor type attendant's board with jack per station, cords, and plugs may be used.

The equipment is mounted on relay and finder bays lined up together in a simple single row switchrack, the length of which depends upon the number of lines and the kind of service required. However, according to the dimensions of the room in which the P.A.B.X. is to be located, the equipment may be mounted on two or more short rows instead of on one long switchrack. The height of the switchrack is 2,450 mm. (96.5 inches). It requires a minimum clear ceiling height of 2,750 mm. (108.3 inches).

The whole P.A.B.X. is driven by one 1/16 H.P. direct current motor fed from the main storage battery. This motor is started each time a call is originated but means are provided to

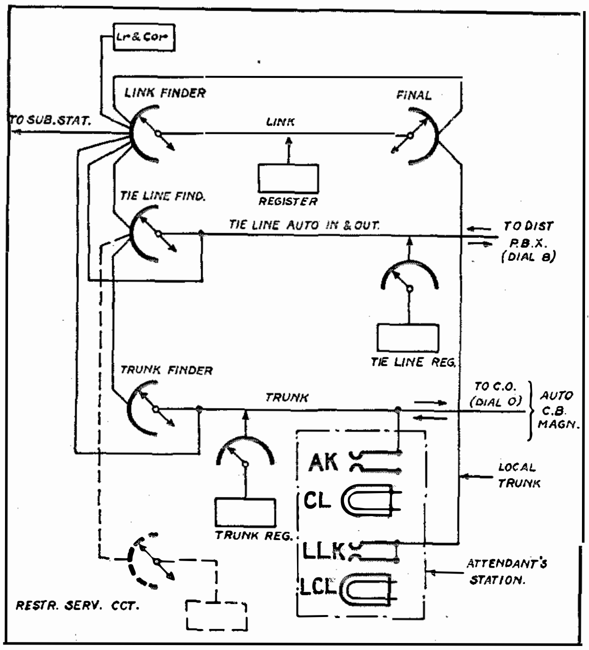


*Figure 5—Local, Trunk and Tie Line Service, 100 Line Capacity.*

allow continuous running which may be preferable during busy hours. On request a Duplex motor is supplied.

The equipment of the 7055 P.A.B.X. is subdivided in units such as local units, trunk units, special service units, etc.

*Local Unit.* A local unit consists of a relay bay and of a finder bay, completely equipped, wired, tested, and shipped as a unit. The finder bay has a capacity of twenty-four line finders, selectors or trunk finders.

The relay bay framework has been designed with a view to avoiding any drilling for mounting the apparatus. The same bay, therefore, suits all cases. The full equipment, when individual line and cut-off relays are used, is: 100 line circuits, 9 link circuits, 3 register circuits, common circuits as well as a terminal strip mounting and a marker switch frame. If combined line and cut-off relays are used, the capacity of the relay bay is increased by three link circuits and one register circuit.

Mounting plates and marker switch frames are provided with dustproof covers, giving the bay a uniform appearance.

The total width of a local unit is 800 mm.

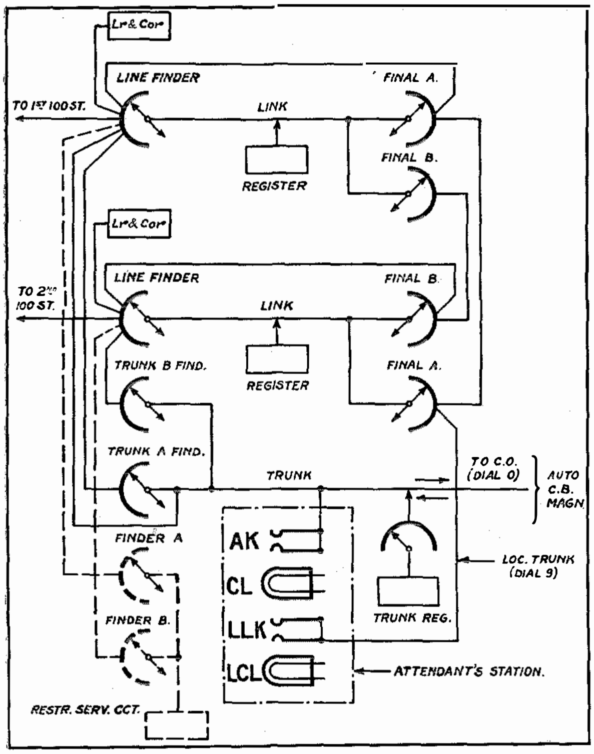


*Figure 4—Local and Trunk Service, 101 To 200 Line Capacity.*

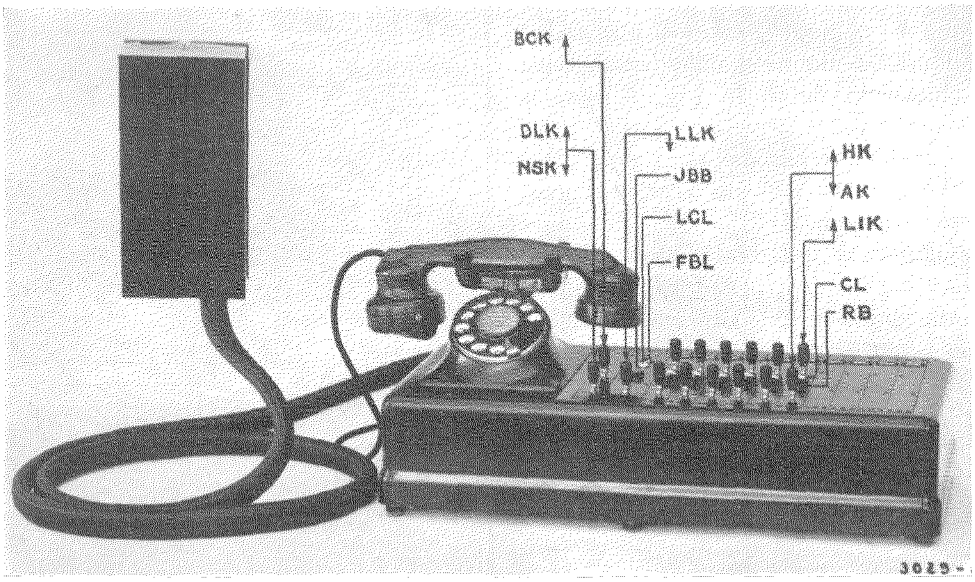


*Figure 6—Attendant's Cabinet.*

(31.5 inches) including free space between the two bays for cabling purposes.

When the number of lines exceeds 100, additional selectors are required for each local unit. They are mounted on separate finder bays located as near as possible to the associated local units.

It is worth remarking that the use of the latest type of finder has made it possible to reduce the number of terminal strips to a minimum. The finder arc is provided with double terminals which permit the direct soldering of a circuit connection as well as the cable patterns.

*Trunk Unit.* The number of bays making up a trunk unit depends on the number of trunks required and the number of subscribers entitled to exchange service.

The relay bay has a capacity of 10 trunk circuits, 2 trunk register circuits, terminal strip mounting, and marker switch frame. The finder bay is arranged for mounting 20 trunk finders and 2 trunk register finders.

When the number of unrestricted subscribers exceeds 100, additional finders are required for each trunk circuit. Therefore, for 200 unrestricted subscribers and 20 trunks to the city exchange, a total number of 2 finder bays and 2 relay bays is required for the trunk unit.

*Special Units.* Subsidiary circuits such as alarm circuits, motor starting circuit and apparatus, which cannot be located under the dustproof covers of the mounting plates, are mounted alongside the switch rack upright near the motor. On the opposite end of the switch rack are mounted the fuse panels.

Special service units, such as used for tie line circuits, conference, preference code calling, and fire alarm circuits, are similar to the local units. If, however, the number of special service circuits does not exceed 1 or 2, it is of interest to consider the possibility of combining the special service unit with the trunk unit in order to save floor space and reduce cost.

*Illustrations.* The illustrations, Figs. 7, 8, and 9, show a typical 2-row switch rack 7055 P.A.B.X. for an initial capacity of 130 and a final capacity of 200 lines equipped with 8 trunks to the city exchange (capacity 20) and provided with code calling facilities.

Fig. 7 shows at the left an upright fuse panel followed by the first local unit equipped with 9 links, 3 registers, 100 line circuits, common

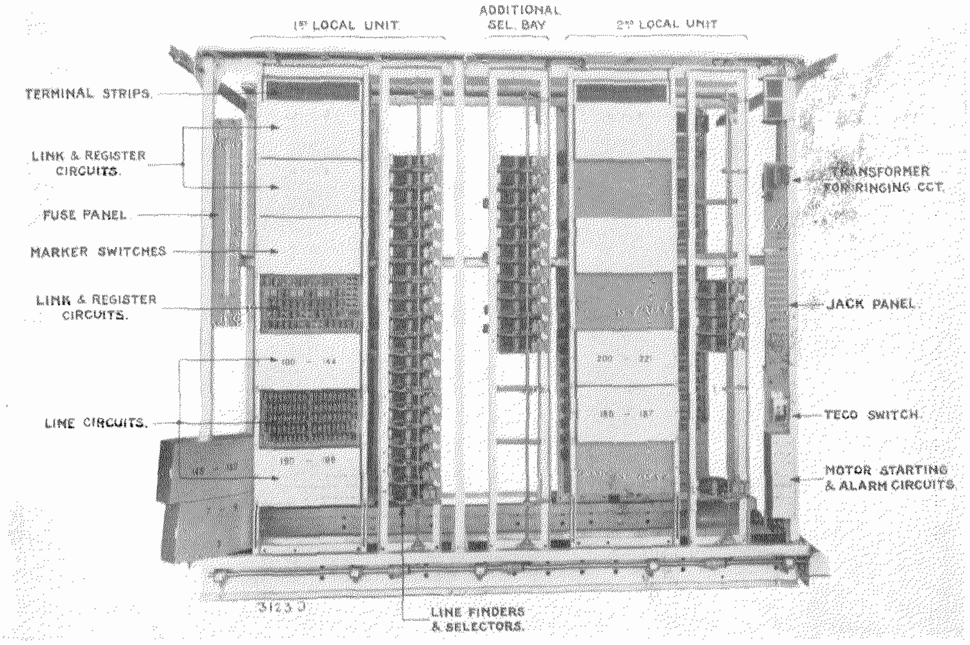


*Figure 7—Local Circuits.*

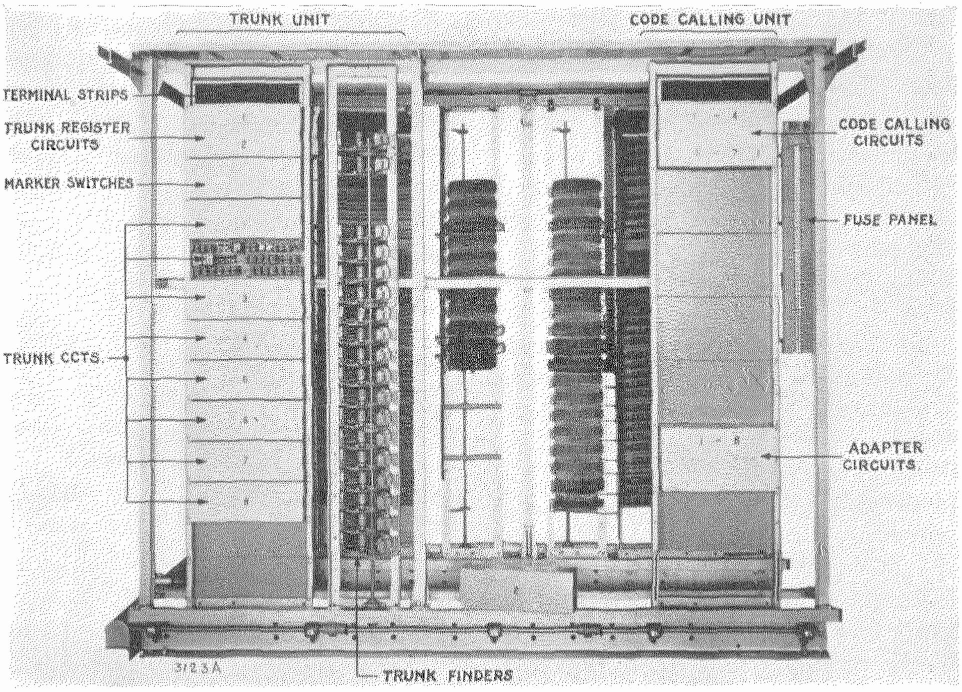


*Figure 8—Trunk and Special Circuits.*

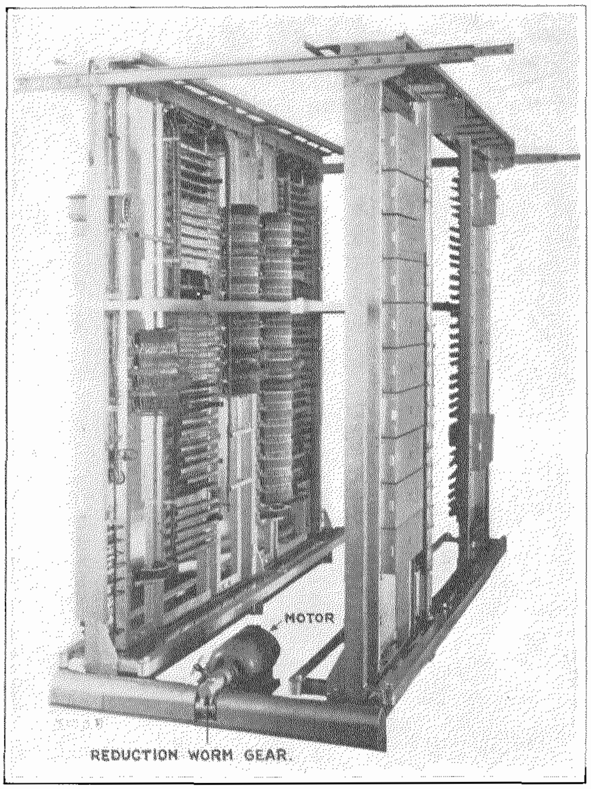


*Figure 9—Cabling Side and Motor Drive for One 1/16 H.P. Duplex Motor.*

circuits, and marker switches. The terminal strips are mounted at the top of the relay bay.

The first local unit is followed by an additional selector bay and by the second local unit equipped with only 2 links and 1 register circuit, in addition to the line circuits and marker switches.

At the right is mounted a miscellaneous upright unit comprising an output transformer and retardation coils belonging to the ringing and tone circuits, a jack panel, a Teco switch for the protection of the switch motor, and a mounting plate equipped with the motor starting and alarm circuits.

Fig. 8 shows at the left the trunk unit equipped with 8 trunk circuits (capacity 10), 2 register circuits, marker switches, and terminal strips at the top. At the right a special service unit is shown equipped with code calling circuits and with adapter circuits to suit the special requirements of a local battery exchange. The free space between the two units is reserved for extension to 20 trunk circuits.

Fig. 9 shows the cabling side of the local units and the connection of the motor.

## *Attendant's Set*

Fig. 6 gives a clear idea of the general appearance of the attendant's set which may be located on a desk, table, or other convenient place. For a set with ten trunks the dimensions are: length 447 mm. (17.6 inches); width 218 mm. (8.15 inches). The set shown in the illustration is equipped with six trunks and four apparatus blanks.

The apparatus, i.e., keys, lamps, and push-buttons, required per trunk are mounted on individual units each provided with a special terminal plug fitting into a corresponding jack assembly fixed to the frame of the set. Each key unit is wired separately, with a view to easy removal for inspection and readjustment, without disturbing the normal service at the set.

The key unit system affords the possibility of extending partially equipped attendant's sets in a practical and quick manner. The installer has merely to remove the apparatus blanks and to put in place thereof a corresponding number of key units since cabling for the sets is always furnished for the full capacity. By means of a flexible extension cord, the set is connected to a terminal box.

The use of keys and buttons equipped on the attendant's set has been explained above.

## *Power Plant*

The power plant required for operating the board consists of one or two storage batteries with suitable charging equipment. Where alternating current supply is available, a metal rectifier floating a single battery is recommended.

The size of the battery should be of sufficient capacity to operate the switchboard in case of a main supply failure during a certain number of reserve hours with the usual allowances for contingencies.

Where d-c. power is available, a double battery scheme is provided, alternately charged directly from the mains through a suitable rheostat or bank of lamps, or by means of a converter.

# Cathode-Ray Electro-Cardiograph

By C. H. W. BROOKES-SMITH

*Standard Telephones and Cables, Limited*

### *Introduction*

THE discovery that the activity of the heart muscle developed cyclic potential differences was made in the middle of last century, but little use was made of it until Einthoven devised his string galvanometer and established the essential technique of electro-cardiography at the beginning of this century. By 1914 his instrument, which made use of a conducting quartz fibre as the moving element with high optical magnification, had been put into practical form, and numerous workers turned their attention to its possibilities. Since then a very large amount of work, which bears witness to the electro-cardiograph's value as a means of investigating obscure cardiac disorders, has been published in all leading countries. The advent of the thermionic valve used in conjunction with a more robust form of galvanometer or with a cathode ray oscillograph tube has provided an alternative means of recording the extremely small voltages involved, and various forms of equipment have been devised. They, however, have had a common disadvantage that arises from the eye being unable to apprehend the shape and details of complex low frequency waves, with fundamental frequencies of the order of one cycle per second, when spread out by any device such as a rotating mirror. In consequence it has been impossible to observe the wave form directly, so that the use of a moving film or plate to produce the time scale has invariably been necessary. Although the desirability of permanent records demands photographic recording, it has the objection of the inevitable delay that occurs before the examination of the developed record and a diagnosis can be made.

The introduction of a cathode-ray oscillograph tube with a fluorescent screen material having considerable after-glow has completely changed the situation, it being possible with such a tube to move the spot slowly across the screen by means of a time base circuit, and to see the wave form of the heart-beat traced out and remaining visible for a sufficient length of time to enable characteristics and details to be clearly recognised. Such a device is of great value, as it not only enables a leisurely and considered examination to be immediately made, but also ensures that the conditions are favourable, as regards absence of interference and complete relaxation of the patient, before permanent photographic records are taken.

The almost continual development of new electro-medical apparatus is undoubtedly making severe demands on the medical profession, particularly non-specialists, as it necessitates a good working knowledge and keeping abreast of advances in many branches of science in addition to medicine. Consequently the introduction of any new form of instrument, such as the electro-cardiograph herein described, in addition to providing new facilities, should represent an advance in convenience and simplification, so as to relieve the operator as much as possible of distracting adjustments and to enable him to concentrate on the clinical aspect of the case. The desirability of mains operation and avoidance of batteries is self-evident in all equipment destined for hospital use, batteries being necessary only in completely portable sets.

The layout of the electro-cardiograph has provided certain difficulties, in that it necessitates looking at the oscillograph screen through a viewing piece to exclude light during the visual examination; and, while still observing the screen, to operate the camera controls to take records. Every effort, therefore, has been made to enable the screen to be viewed in a comfortable manner without strain, and to group the essential keys and controls near at hand where they can be adjusted with a minimum of movement and without looking at them once their respective functions have been memorised.

### *Nature of Electro-Cardiogram*

Before describing the electro-cardiograph it may be well to consider the nature of the wave-forms to be recorded, and to outline briefly the technique and requirements necessary to obtain comparable records in a standard manner. A typical normal electro-cardiogram is illustrated in Fig. 1 which shows that the wave consists of several distinct peaks P.Q.R.S.T., one of which in each complete cycle consists of a short period deflection of large amplitude and of other deflections of lower amplitude and of longer period. In normal cases, the general appearance remains the same but the time interval between the peaks, their amplitude, shape and polarity vary considerably for each individual; and, in abnormal cases, the appearance due to variation in phase relationship during successive cycles and inversions of peaks produce even more diverse types, the recognition of which forms the essential part of clinical cardiography. The technique due to Einthoven is almost invariably followed: connections are made by strapping to the patient's left arm, right arm, and left leg suitable electrodes consisting of pads soaked in a saline solution, the potentials from which are applied successively in pairs designated as Leads I, II, and III to the amplifier and recorder.

The maximum potentials normally obtained, apart from the steady skin potential which is eliminated and on which the fluctuating potentials are super-imposed, are of the order of one or two millivolts, and are invariably asymmetric about the zero line. This asymmetry brings out the chief difference between true D.C. amplifying systems and those that are strictly A.C. amplifiers using resistance-capacity coupling adapted for use down to very low frequencies; for, in the former, the wave shape is faithfully recorded however low the frequency whereas, in the latter, distortion may result if the response characteristic falls off too abruptly at the low frequencies. The interstage couplings on an electro-cardiograph amplifier, therefore, must have a sufficiently long time constant to produce sustained deflections of the recording element with D.C. impulses of about 0.2 to 0.4 seconds duration; failure to meet this requirement produces cardiograms in which slow asymmetric peaks are followed by inverse peaks which are not present in the potential wave from the heart. A true D.C. amplifier, of which most types have the inevitable drawback of sensitivity to drift and tendency to low frequency feed-back particularly when operated from rectified mains supplies, is unnecessary for clinical cardiography; and a suitably designed resistance-capacity amplifier can be used with advantage as the steady D.C. skin potential is stopped by the first condenser and the drift quickly settles down. For convenience of comparison Einthoven's standard of one centimeter amplitude on the record to represent 1 millivolt input is essential, though for visual observation on the fluorescent screen double size, i.e., 2 cms. per millivolt, has been found more convenient. The overall gain frequency characteristic must be flat and variations between 0.1 and 100 cycles per second should not exceed about 15% (1.4 decibels) if faithful records are to be obtained. It is also advantageous to have a high input impedance to the amplifier as polarisation effects at the electrodes are thereby obviated.

### *Description*

The cardiograph which is primarily intended for hospital and consulting room use consists of a single unit in the form of a metal case mounted on a 12 x 23 inch base fitted with casters, and standing 3 feet, 6 inches high (Fig. 2). The finish is a dark green stove enamel with chromium plated fittings. To facilitate manufacture all the components are mounted on a chassis which forms a complete unit over which the outer case fits. The viewing piece is provided with a rubber face piece which is removable for cleaning, and plug and socket connections are made through apertures in the rear of the case for the

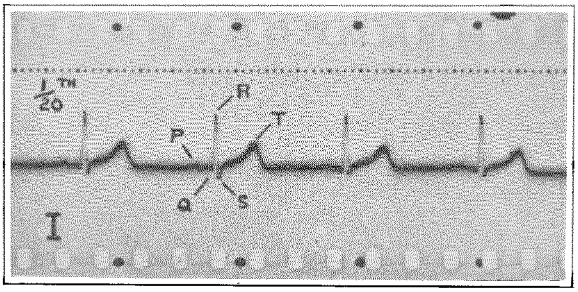


*Figure 1—Normal Electro-Cardiogram.*

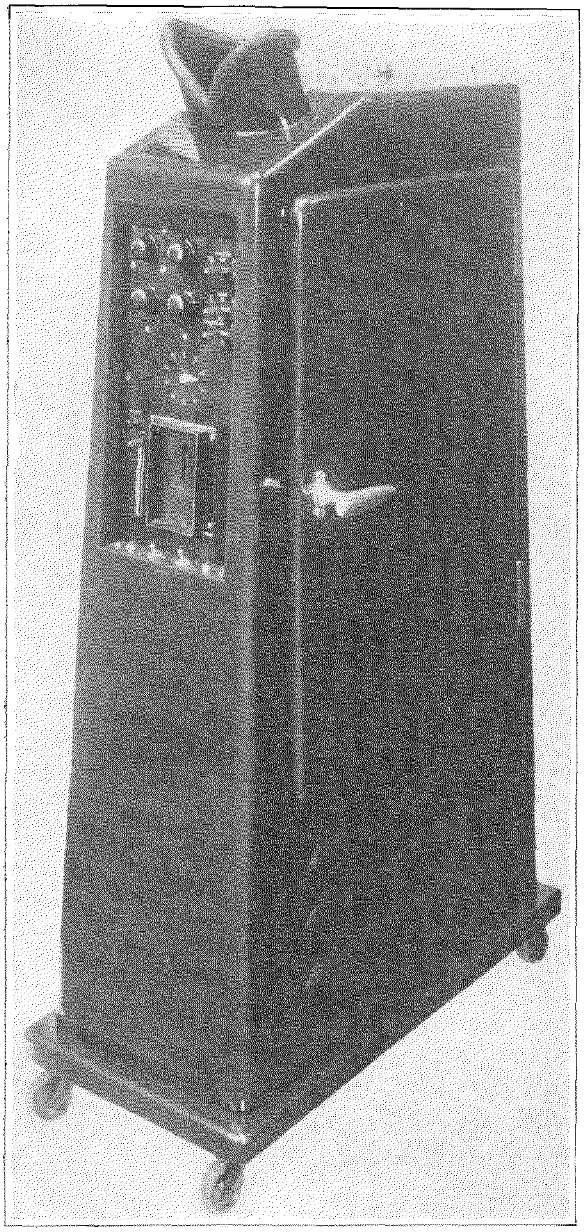

*Figure 2—Electro-Cardiograph.*

leads and mains connections. A large door at the side gives access to the amplifier, camera and sub-control panel.

The upper part of the chassis is occupied by the resistance-capacity coupled three stage amplifier, and the cathode ray tube, which is sprayed with aluminium cellulose to exclude light and is held in an inclined position facing the viewing piece aperture. The camera, which photographs the fluorescent screen through a mirror, and its driving motor form a unit which is located near the front control panel and partly underneath the cathode ray tube. Below the level of the shelf supporting the camera is the sub-control panel which can be seen in Fig. 3. It contains the oscillograph tube filament ammeter, rheostat and focus adjustment, necessary jacks with a plug connected to the meter to measure the valve anode currents, a control to vary the time base traverse speed, and adjustable transformer tappings to suite various mains voltages. The base of the chassis contains all the necessary transformers, rectifiers and smoothing circuits. The main control panel is located on the front at a convenient level, and incorporates controls for sensitivity (amplification), spot centering, A.C. mains interference compensators and three keys. The upper key provides CALIBRATE-OFF-ON positions for the amplifiers, the lower key provides TRAVERSE-OFF-ON positions for the cathode ray tube spot, and the centre key gives I, II, III positions for the Leads corresponding to connections to the right arm-left arm, right arm-left leg and left arm-left leg, respectively.

The calibration of the amplifier is effected by applying a 1 millivolt A.C. peak input from a step down transformer connected to the 50 cycle A.C filament heating supply, the sensitivity control being adjusted until the resulting line extends between two calibration marks 4 cms. apart on the screen. The TRAVERSE position of the second key, after biassing the spot initially to the left hand side of the screen, allows a condenser in parallel with the oscillograph's Px deflecting plates to charge up slowly through a high resistance and hence moves the spot across the screen at an approximately constant speed of about 2 cms. per second, the process being repeated at each throw of the key. Time marks appearing at 1/20 second intervals are made on the record, the marks occurring at 1/5 second intervals being darker. To assist the recognition of each Lead record, each time mark consists of a series of 1, 2 or 3 dots corresponding to Leads I, II and III. These are illustrated in Fig. 4, which shows records from the three leads of a normal electro-cardiogram. The time marker consists of a slotted disc driven by the camera motor at a standard speed, and intermittently illuminates three holes situated in the same plane and close to the oscillograph tube screen. A lever operated from the lead key uncovers the second and third holes in succession so that the number of dots corresponding to the lead key position are automatically recorded on the film.

The camera uses a 35 mm. cinema film on 100 foot reels or paper on 70 foot reels which can be loaded into the magazine in daylight, each reel being provided with several opaque outer turns to prevent fogging. A trigger, which is pressed when records are to be taken, operates the drive mechanism and automatically stops it after feeding 4½ inches of film through the exposure gate at a constant rate of 2 cms. per second. Longer lengths can however be taken by continuous pressure on the trigger. The exposed film feeds into interchangeable receiver boxes which fit on to the front of the control panel and easily accommodate a total length of approximately three feet of film. Depressing the knife lever on the control panel moves the exposed piece of film safely within the film receiver, cuts the film and closes the sliding light-tight shutter in the film receiver, which can then be removed for developing. A small rotating pointer on the front panel indicates on a scale the length of unexposed film remaining in the magazine. Since the film movement is at right angles to the time base traverse, the camera trigger is fitted with contacts that interchange the connections to the Px and Py deflecting plates of the oscillograph tube and also, since the lens has a 4:1 reduction ratio, doubles the amplitude on the oscillograph screen. As a sensitivity of 2 cms. per millivolt is used for the visual scale, standard size electro-cardiograms of 1 cm. per millivolt are therefore obtained on the film.

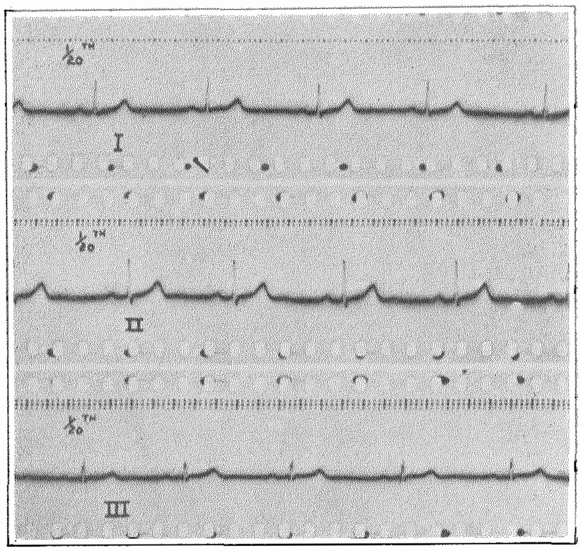


*Figure 4—Normal Electro-Cardiogram Showing All Three Leads.*

*Figure 3—Electro-Cardiograph with Side Door Opened.*

At the base of the main control panel is situated a small horizontal panel on which are mounted the main and motor switches with their pilot lamps.

### *Performance*

The gain frequency characteristic, which is shown in Fig. 5, is substantially flat between 0.5 and 200 cycles per second, the maximum gain available being a little over 100 decibels. The residual 50 cycle hum is very small and the interference compensators, which inject a small 50 cycle potential adjustable in phase and amplitude into the amplifier input in opposition to the interference picked up by the patient, effectively remove 50 cycle ripple from the record. The initial settling period after first switching on the mains supply is approximately 5 minutes and, if at any time the amplifier is allowed to choke by open circuiting the input, 20 to 30 seconds usually elapse before the spot regains its normal position. The OFF position of the amplifier key, however, short circuits the input so that, provided the precaution is taken to return the key to OFF before moving the Lead Key, all three Leads can be quickly connected in succession without any loss of time. Complete record, including the necessary interference compensation of each Lead, may therefore be taken in less than half a minute. The after-glow on the fluorescent screen of the 4018 AD. oscillograph tube lasts between 5 and 10 seconds and there is no difficulty in recognising all the peaks and details of the wave. Observation of the oscillograph spot during recording ensures that a good record is made, a record being repeated if interference is observed. It is also convenient that, without moving the head from the viewing piece, the position of the Lead Key can be checked by noting the number of holes uncovered by the time marker. As will be seen from Figs. 1 and 4, the records are sharp and clear and no blurring occurs from the after-glow.

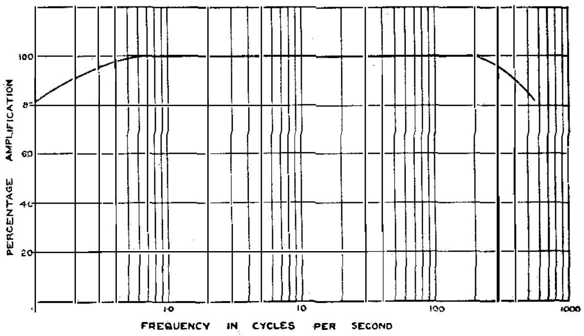


*Figure 5—Overall Response Characteristic.*

It is too early as yet to give examples of the advantages of rendering the wave form of the heart beat continuously visible, and of this type of cathode-ray electro-cardiograph as a whole. Nevertheless its immunity from damage by involuntary movement of the patient or maladjustment of the controls, its simplicity of operation, small physical size and complete mains operation cannot but be attractive features, particularly to non-specialists. Its value also, apart from normal clinical use, as a means of making continuous observations during the administration of drugs and aneasthetics has yet to be explored.

# Ultra-Short Wave Diathermy

By D. B. MIRK and B. J. AXTEN

*Standard Telephones and Cables, Limited*

WITH the constantly increasing application of science to new and varied fields, it is perhaps not surprising that radio frequency oscillations should be found to be of value in medicine. That energy of such a form beneficially affects the body tissues has been known for many years, and treatment by this means has been widely practised. Recent developments in the radio art have greatly enhanced the value of this branch of medicine and a new technique has been established.

It is of interest to review briefly the history of the association of high frequency current with medicine. According to records, d'Arsonval showed as early as 1890 that when alternating current was passed through an animal body muscular contraction was absent at frequencies in excess of 10,000 p:s. In 1891 this worker demonstrated that heat could be produced in the body by the passage of high frequency current, and after further studies the therapeutic properties of this form of energy were demonstrated in 1898. Soon after 1900 the practise was established, although the benefits obtained were attributed to various causes, but not to the generation of heat.

Further investigations were made and about 1907 it was realised that the thermal generation was responsible for the curative properties of the current and that the heat was actually developed in the tissues. The term "diathermy" was consequently adopted for the treatment as being indicative of the "through-heating" of the tissues.

Since this time the treatment has become extensively employed in many countries and until comparatively recently was performed almost exclusively on wavelengths of 300-600 metres. The development of short and ultra-short wave generators enabled medical workers to try the effects of the higher frequencies and the results obtained have led to their rapidly increasing use for diathermy.

The fundamental principle of diathermy is the generation of heat in a tissue due to the dielectric losses caused by the passage of high frequency oscillations. In practice, a pair of metal electrodes is placed on either side of the affected part of the body and connected to a source of high-frequency energy. The resultant heat generation and its distribution depend on the individual properties of the tissues, their location relative to each other, and the wavelength employed. In determining how these various factors affect the heat distribution, it is necessary to consider the electrical representation of tissue.

Any animal tissue is a dielectric and if it is placed between two electrodes fed by a high frequency generator, heat is developed due to the losses which occur. Each type of tissue comprises an enormous number of resistive and capacitative components arranged in an irregular and complicated network. In a preliminary examination of the matter it is permissible to consider these components as concentrated, rather than distributed, and thus the simplest possible electrical representation of a tissue is a resistance and capacity in parallel.

On the wavelengths of 300-600 metres used in the original diathermy, the capacitative components of the tissues have such high reactances that they play practically no part in the current distribution, and hence the tissues behave substantially as a resistance network. Consequently, if electrical energy at these wavelengths is applied to a group of tissues arranged in series, those of the highest resistance develop the most heat. If the tissues lie in parallel, those of lowest resistance become the hottest.

As the wavelength is reduced the current through the capacitative components becomes appreciable, so that tissues in series must be regarded as in Fig. 1. If, for example, the middle resistance is lower in value than either of the outer resistances, then on 300-600 metres the outer resistances will develop the most heat. As the wavelength is reduced the capacities exert a shunting effect on the resistances and, assuming that the capacity values are approximately the same in each case, the shunting effects will be greater on the outer resistances than on the inner one. Consequently, a wavelength is reached at which there is approximately the same heat generation in each tissue. If the wavelength is still further reduced, the shunting effects of the

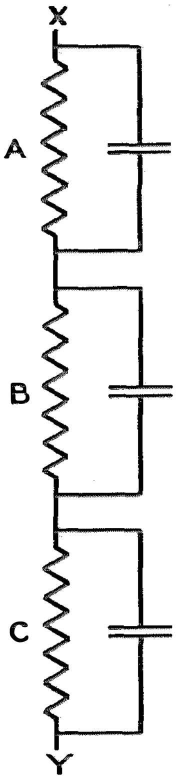


*Figure 1—Simple Electrical Representation of Tissues in Series.*

capacities will cause more heat to be generated in the inner tissue than in the outer tissues. Thus, by change of wavelength the heat gradient may be straightened or even reversed in shape and it is this property which is responsible for "deep penetration" effects, to which further reference will be made later.

The equivalent electrical circuit of the tissues is, of course, of a very complex nature. Fig. 2, however, is a more accurate conception than Fig. 1. In Fig. 2, R represents the resistance path (it will be termed the leakage resistance) which is responsible for the conduction of current on long wavelengths, or even on direct current. C represents the capacitative component, r the dielectric losses other than leakage resistance and $r'$ the resistance of conductive paths in the capacitative branch. In such a network, C might represent the cell membranes, r the dielectric losses in them, and $r'$ the fluid contents of the cells.

Considering now, the traversal of the tissue by high-frequency current, it will be realised that the shorter the wavelength the more current will flow through the capacitative branch for a constant applied voltage. Thus, the shorter the wavelength, the greater will be the thermal generation, due to the increasing current through r and $r'$, and the lower the impedance of the tissue.

In Fig. 3 is shown a group of six of the networks of Fig. 2, arranged in a series parallel combination. It is assumed that each network represents a different kind of tissue, so that not only may R, C, r, and $r'$ have different values in each case, but also different mutual relationships of values.

On long wavelengths the current is restricted almost entirely to the purely resistive branches. As the wavelength is continuously reduced, more and more current flows through the C, r, and $r'$ paths, tending to increase the thermal generation in each tissue. At the same time the impedance of each network is varied, causing alteration of the voltage across each pair A, B, and C. Simultaneously, the division of current between the various parallel paths is also changed. The overall effect of these changes is to shift the region of optimum heat generation from one tissue to another, according to the wavelength used. Hence, each tissue may be said to have its optimum wavelength, and selective heating is possible.

The properties of deep penetration and selective heating as mentioned above are of great value in diathermy. It frequently happens that with long wavelengths an inner tissue or organ cannot be adequately heated without raising the temperature of the high-resistance subcutaneous fatty tissue to an intolerable degree. A number of eminent electro-medical workers have found that with wavelengths of 10-30 metres all tissues become heated approximately equally, and that deep-seated organs can be heated to the desired degree without overheating the surrounding tissues. Hence, the short waves are sometimes said to give deep penetration. Below 10 metres these workers have observed selective effects, i.e., that different tissues require different wavelengths for the maximum possible effect to be obtained.

These "deep penetration" and "selective" effects are greatly accentuated by the use of

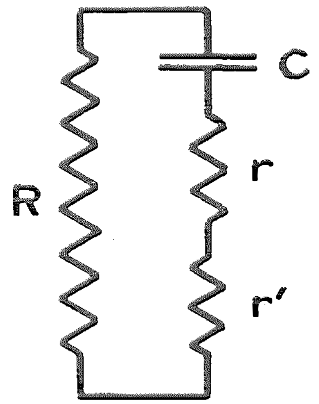


*Figure 2—Electrical Representation of Properties of Tissues.*

insulated electrodes. These cannot be used on long wavelengths, except for large couches, owing to their high reactances at such wavelengths. On wavelengths of 30 metres and below, however, they may be separated from the body by distances up to about one inch. The difference in heat distribution using insulated and non-insulated electrodes is strikingly demonstrated by placing each hand on one electrode of a diathermy equipment. Even on the ultra-short waves, an intense concentration of heat at the wrists is experienced with contact electrodes, just as is obtained with long wave diathermy due to the high resistance of these parts of the circuit. With insulated electrodes on ultra-short wavelengths the intense heat at the wrists is absent and a general glow pervades the arms. The explanation of this phenomenon seems to lie in the fact that when the electrodes are removed from actual contact with the skin the series reactance thus interposed causes a greater reduction of the conduction current component than of the displacement current component.

Consideration of diathermy in this article has so far been on the basis that the beneficial effects are derived from thermal effects. Several eminent workers have, however, recently stated that with ultra-short waves they obtain effects which they cannot attribute entirely, or even at all, to heat generation. At present there is a lack of conclusive evidence as to whether this theory is correct or otherwise. If the theory is correct, however, it seems reasonable to suppose that the important factor is that of field intensity. Since the latter is not necessarily associated with thermal generation, a new technique of treatment may become established for the purpose of obtaining maximum field intensity, rather than maximum heat intensity, in the affected organ or tissue.

It must be appreciated that in the foregoing examination of the principles of diathermy the electrical representations of the tissues have been reduced to a simple form. Actually, the resistive and capacitative components are distributed while the tissues themselves are in irregular formation. Furthermore, the distribution of the thermal generation is disturbed by respiration and blood streams. It is the problem of the physicist to investigate the physical properties of the tissues and the physical aspect of the application of high frequency current to a tissue group. It is the function of the physiologist to utilise the resultant data in determining the best way of applying diathermy to the body according to the particular affection to be treated.

In commencing the production of the Standard Radio ultra-short wave diathermy equipments, it was decided that the first type to be made should be adequate for general treatment and procurable at a price which would make it available to all members of the medical profession. For the same reason it was necessary that it should be exceedingly simple in use and require negligible maintenance. Accordingly, a special spark-gap arrangement was utilised rather than a thermionic valve, and this choice has been found very satisfactory in meeting the requirements laid down.

In the circuit employed, the main supply voltage is stepped up by a transformer and applied across a spark-gap assembly comprising a number of gaps in series. This multiplicity of gaps gives very rapid quenching which is further improved by the draught from an electric fan and by "blow-out" coils. The spark frequency obtained is of the order of 75,000 per second.

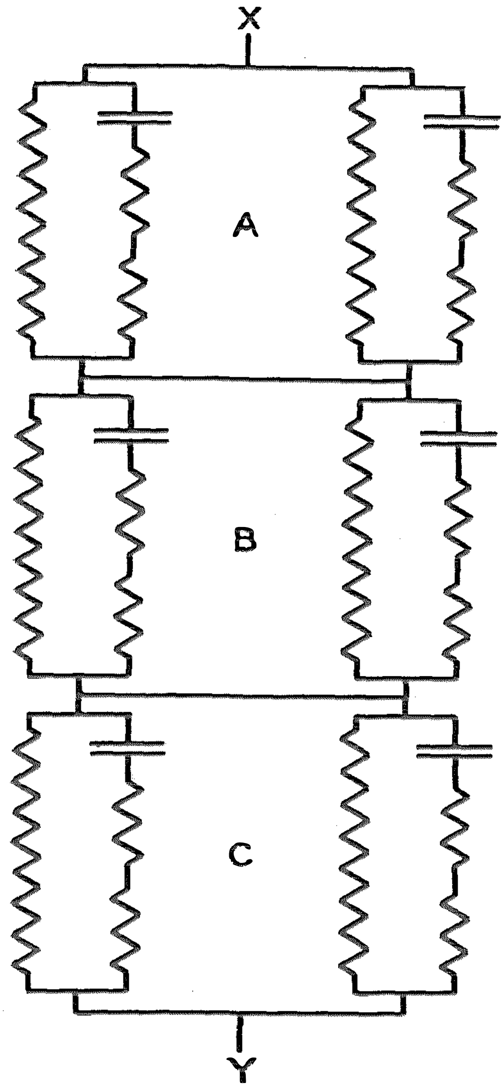


*Figure 3—Network Corresponding to Six Tissues in Series—Parallel Combination.*

The radio-frequency circuit is formed by a variable capacity, the inductance of the leads between the capacity and the patient electrodes, and the capacity between the patient electrodes. The load imposed by the patient is virtually a resistance in series with the circuit, and the current flowing in the patient circuit is indicated on a radio frequency ammeter. The patient circuit is isolated from 50 cycle current by stopping condensers; and, to prevent any possibility of a 50 cycle potential occurring across the patient electrodes in the event of a breakdown of the stopping condensers, radio-frequency chokes are connected between the patient and earth.

The simplicity of operation is apparent from Fig. 4, which shows the exterior of the equipment. The controls merely comprise an On/Off switch and a control dial for a variable condenser which is actually used for regulating the power supplied to the patient.

On the front of the cabinet is a handwheel by means of which all the spark-gaps may be opened or closed simultaneously. Normally this adjustment need not be touched but a slight rotation of the wheel in either direction enables the optimum output to be obtained under any condition of operation.

The patient electrodes plug into the two sockets on the left-hand side of the cabinet. The electrodes are flexible and may be bent to fit the part of the body under treatment. Since they form part of the tuned circuit their size automatically determines the wavelength generated and thus greatly simplifies the use of the equipment. Five pairs of electrodes are normally provided, each marked with its operating wavelength. If it is desired to use one of the larger electrodes on a wavelength shorter than that for which it is marked, a lower wavelength may be obtained by spacing the electrodes from the patient by means of pads of lint or felt. Special electrodes are made up for individual requirements and treatments, and by the use of divided cables two pairs of electrodes may be employed so that two affected areas may be treated simultaneously.

Full protection against burns and shock to both patient and operator are given by the insulated electrodes and safety devices already mentioned, and by a gate switch on the door which interrupts both main supply leads when the door is opened. Red signal lamps on the top panel glow whilst the equipment is in operation.

The radio frequency output of the equipment is 150 watts, which is adequate for general treatment. In practice the equipments have been found extremely robust, reliable, and easily maintained. Cleaning or adjustment of the spark-gaps is necessary only at intervals of about nine months, even when the apparatus is used for many hours daily.

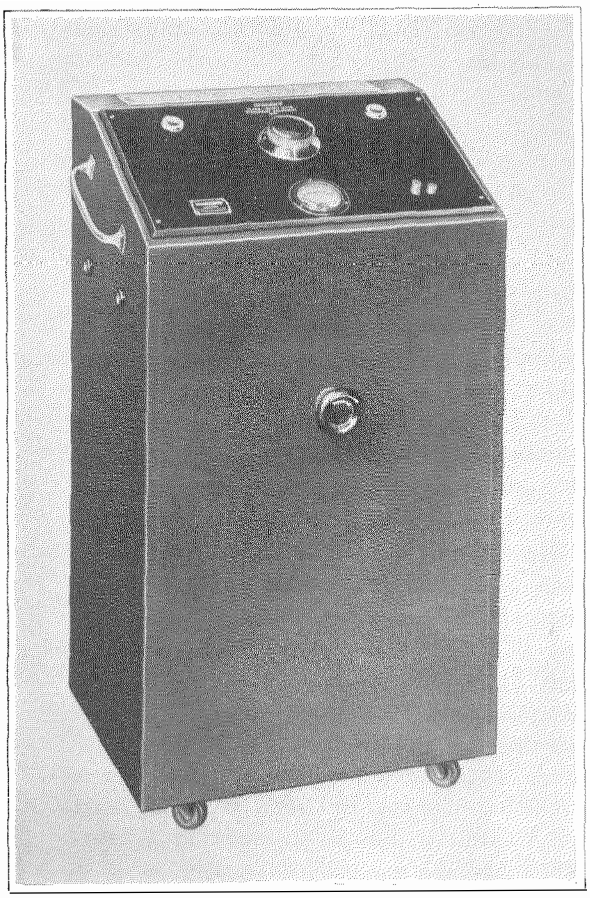

*Figure 4—Exterior View of "Standard Radio" Ultra-Short Wave Spark Diathermy Equipment.*

In use the electrodes are held lightly on the patient by means of rubber straps. Since they are insulated there is no chance of a high-frequency burn occurring, and they may be applied over bandages, wooden splints, or the clothing. The latter fact is greatly appreciated by many patients. With the original long wave diathermy it was not possible to employ insulated electrodes of normal size owing to the high reactance of the series condensers virtually introduced. It was therefore generally necessary to rub a conductive cream into the skin and then bind the electrode tightly against it, a process requiring time and care. Furthermore, an electrode slipping out of position frequently produced a high frequency burn. The ability to use insulated electrodes by virtue of employing ultra-short waves has remedied these disadvantages of the treatment. The removal of the need for contact electrodes is especially valuable in cases where the affected part is sensitive and painful, the electrode being then supported on a stand about ¼ inch away from the skin.

There has been, in the past, considerable controversy regarding the respective merits of valve apparatus and spark apparatus for diathermy, some workers having stated that with the spark system they could not get the results they obtained with the valve systems. This has probably been due to the fact that at the time the investigations were made with spark apparatus the latter was not highly developed for the generation of ultra-short waves and the output available was very low. The suggestion has been put forward that spark apparatus is not so beneficial as valve apparatus on account of the intermittent nature of the energy emitted by the former. Such a theory does not seem reasonable, firstly, because the time intervals between the groups of oscillations are very small and secondly, because the suggestion came from workers

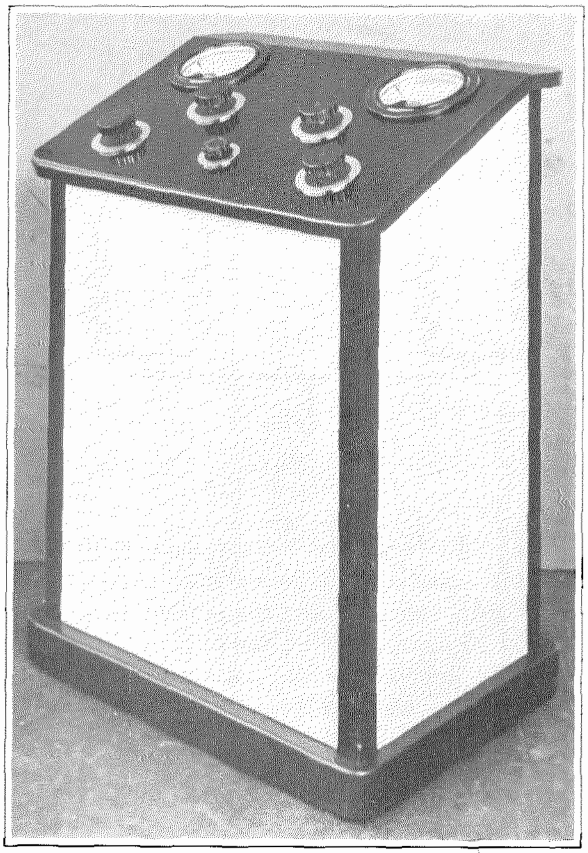

*Figure 5—Exterior View of "Standard Radio" Ultra-Short Wave Valve Diathermy Equipment.*

using valve apparatus in which was employed a single valve with an a-c. anode supply. Hence, alternate half-cycles were completely suppressed, while during the remainder the output was modulated 100%.

With the apparatus herein described the high spark-frequency of 75,000 per second is obtained and it is difficult to conceive why the resultant energy output should be less efficacious than valve generators using raw a-c. on the anode of a single valve. There seems therefore to be a definite field for each class—the spark system for all general treatments for which 150 watts output is adequate, and the valve system for research and special treatments necessitating higher power outputs for the generation of which the spark system is inherently unsuitable.

For this reason a Standard Radio valve equipment also has been produced and is illustrated in Fig. 5. The radio-frequency output is 300 watts on 6 metres and on 30 metres, either of which wavelengths is obtainable at will. The general operation of the apparatus and its uses are substantially as already described in connection with the spark equipment.

In conclusion it will perhaps be of interest to mention a few of the conditions for which ultra-short wave diathermy has been, and is being, employed with gratifying results. In cases such as acute suppuration where long wave diathermy may be useless or even detrimental, ultra-short waves have been found highly beneficial. Other conditions responding excellently to ultra-short wave treatment, according to the records of various medical workers, are abscess of the lung, carbuncles, lumbago, neuritis, arthritis of various forms, and bronchial asthma.

This new branch of medicine is being increasingly employed and there is still much to be discovered regarding its possibilities and applications. For its furtherance, full cooperation is necessary between the engineer and the physiologist to ensure the development of apparatus capable of fulfilling the requirements of the medical profession. Research in these directions is being steadily pursued and it may safely be predicted that valuable developments will be forthcoming in the immediate future.

# A Super-Audio Telegraph System

By B. B. JACOBSEN, B.Sc., A. W. MONTGOMERY, B.Sc., A.M.I.E.E.

*Standard Telephones and Cables, Limited*

## *Introduction*

A Super-Audio Telegraph System is a carrier telegraph system superimposed on a speech circuit, using a carrier frequency or frequencies above the speech range.[1] Several telegraph administrations have made experiments with this type of system.

Super-audio telegraph systems are intended mainly for use on extra light loaded 4-wire telephone circuits. This type of loading is used to obtain a high and uniform velocity of propagation for the voice currents and gives as a by-product an extended frequency range. The higher frequencies of the range provided are not utilised for the telephone circuit, the frequency range being limited in the terminating sets, and may be appropriated for a carrier telegraph channel, provided, of course, that the power handling capacity of the line and repeaters is adequate.

A telegraph channel obtained in this manner, generally speaking, will involve special equipment only at the terminals; the telephone repeaters used for the voice circuit will serve also for amplifying the telegraph signals. For this reason the system will be very economical on long circuits.

The composite system which requires by-pass equipment at telephone repeater points is more suitable for moderate distances. The super-phantom system is suitable for quite long distances, but its application is limited by the number of conductors available. The super-audio system requires only two pairs and may be applied to a circuit which already carries super-phantom telegraphs.

Important advantages of the super-audio system over the other superimposed telegraph systems are the smallness of the current which the Super-Audio System sends into the loaded line, the absence of need for line balancing, and the fact that no very sensitive relays are required.

[1] Super-Audio Telegraph Systems working on open-wire lines have in the past not usually been so called.

## *Requirements for a Super-Audio Telegraph System*

Present day telegraph practice tends towards the exclusive use of apparatus operated at a speed of 50 bauds and any new telegraph system should be arranged for this speed. There is, however, still a certain demand for channels capable of a higher speed and if a new system can be made to permit working at higher speeds without undue sacrifice in other directions, this is an advantage.

A wide band of frequencies is available for super-audio systems. The voice circuit requires frequencies up to 2750 p:s (the highest frequency for which transmission requirements have been proposed) and the cut-off frequency of an extra light loaded circuit is approximately 5600 p:s. From this range must be subtracted the frequency band required for separation of the voice and telegraph channels, and a range of high frequencies, which are subject to too much phase distortion owing to their nearness to the cable cut-off frequency. This leaves a frequency band from approximately 3300 p:s to 4300 p:s or about 1000 p:s.

This band may accommodate several telegraph channels provided that the repeaters and loading coils will carry the extra current required for the telegraph channels. In practice, it is found that if even two channels are used simultaneously, there is in the general case an audible beat note equal to the difference between the two carrier frequencies. Systems are in service in special circumstances in which two or even three super-audio channels are employed, but in general it is probable that one channel only will be used.

If only one channel is to be used it is easily possible to arrange it for high speed operation. Extra light loaded 4-wire lines equipped with Standard repeaters may readily be equalised up to 4000 p:s or even higher. Phase distortion is tolerably small for carrier frequencies up to 4200 p:s (2000 km. line, 50 baud working). Filters giving the necessary discrimination and introducing only a small loss in the telephone circuit for frequencies up to 2750 p:s will permit the use of a telegraph carrier frequency as low as 3350 p:s (for 50 baud working). It will be seen that there are no serious restrictions on the carrier frequency. A low carrier frequency offers the advantage that the equalisation of the line is easier. A carrier frequency of 3540 p:s has been standardised. This frequency falls in the continuation of the series of odd harmonic frequencies of 60 p:s already standardised by the C.C.I.T. for other purposes.

When this carrier frequency is used and the band of frequencies allotted to the telegraph circuit is not restricted by sending or receiving filters, it has been found possible to use a simple type of detector for the reception of the signals. The one employed requires a wider band of frequencies for a given telegraph speed and performance than does the detector used for the multi-channel voice frequency telegraph system, but allows larger and more rapid changes in receiving level before a given telegraphic distortion is exceeded.

The addition of a super-audio system to an existing line does not, in general, necessitate any changes in the 4-wire circuit. The repeaters should be lined up for a transmitting level not exceeding + 6 db. With this adjustment the momentary peak levels of speech coming from a nearby subscriber's station may occasionally cause a slight overloading of the repeater. When the repeater overloads, the level of second order modulation products is increased; some of these products having frequencies above approximately 3200 p:s will reach the super-audio detector, and may have sufficient amplitude to disturb the telegraph circuit. A simple voltage limiter, however, may be introduced to remove abnormally high speech levels before they enter the repeatered circuit. This limiter will rarely come into action, but even when it works frequently it has no noticeable effect on the quality of the speech circuit.

If the telephone circuit is equipped with an echo suppressor, it is necessary to add a by-pass circuit for the super-audio channel. This by-pass prevents the super-audio carrier frequency from actuating the echo suppressor and ensures that the super-audio channel is "through" in both directions, independently of the echo suppressor.

When in a repeater station a monitoring set is placed across a 4-wire circuit, the two pairs of the circuit are coupled together and speech going in one pair is to some extent sent back by the other pair and causes an unobjectionable echo. When a super-audio telegraph circuit is connected to a 4-wire circuit, this same effect will occur, but since the two pairs are used simultaneously and independently, currents reaching one pair from the other represent interference which must be avoided. This coupling together of the "go" and "return" pair at super-audio frequencies is easily avoided by connecting a

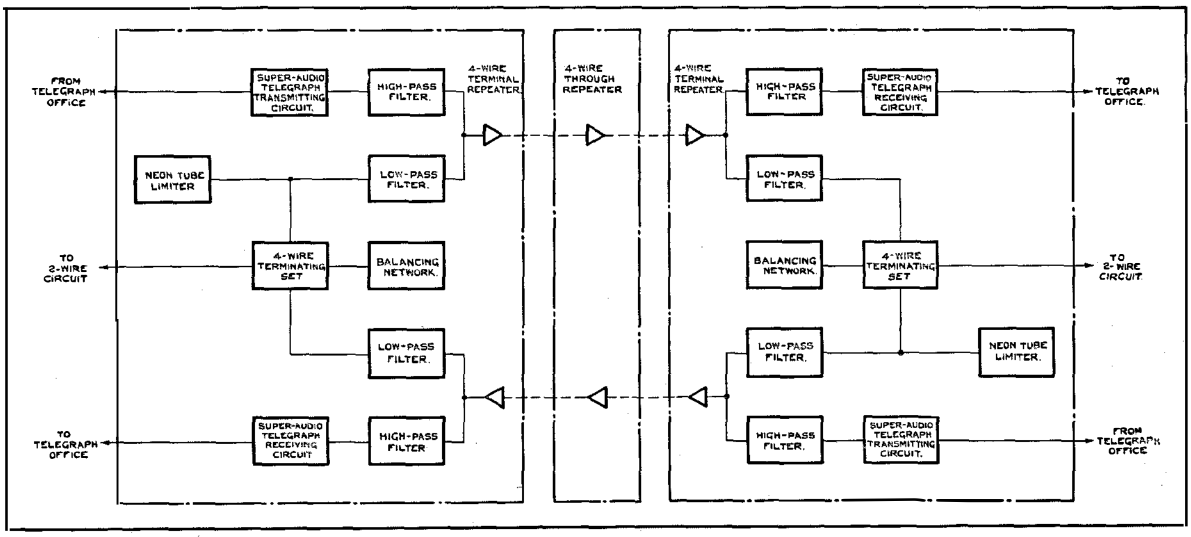


*Figure 1—Block Schematic of a Super-Audio Telegraph System.*

simple filter to the monitoring set. The inclusion of the filter also reduces the shunt loss which the monitoring set causes on the super-audio channel.

The carrier current level for the telegraph is adjusted to be approximately 1.6 mW. measured at the output of the terminal repeater.

### *Circuits*

The block schematic (Fig. 1) shows how the super-audio channel is related to the 4-wire circuit. The super-audio filters are connected between the 4-wire terminating set and the terminal repeaters. The neon tube limiter shunts the input to the transmitting super-audio low-pass filter. This limiter includes a transformer, the primary of which is bridged across the speech circuit, the secondary being closed through a neon tube. The tube is inactive for speech voltages less than that represented, at a point of zero level, by a sinusoidal E.M.F. sending 5 mW. into the speech circuit. For higher values of speech voltages the neon lamp strikes and causes a shunt loss which prevents the voltage from increasing further. It has been found that this simple limiter does not introduce noticeable distortion in the speech circuit, while adequately protecting the telegraph channel.

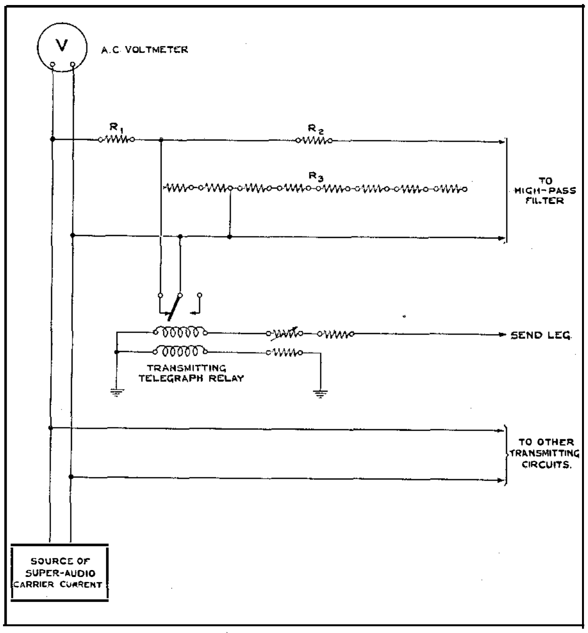


*Figure 2—Schematic of Transmitting Circuit—Super-Audio Telegraph System.*

Fig. 2 shows the transmitting circuit for double current full duplex working. The source of super-audio carrier current is normally a valve oscillator capable of supplying as many as fifteen super-audio channels with the present design, each channel requiring, of course, a separate 4-wire circuit.

With the relay in the rest condition no current is sent into the high-pass filter, while in the active condition the current sent into the filter depends on the value of the resistance $R_3$.

### *Filters*

Schematics of the filters are shown in Fig. 3. Identical filters are used in transmitting and receiving circuits.

The low pass filter attenuation at 2750 p:s does not exceed 1.5 db. and the delay at that frequency is very small.

The filters do not seriously modify the impedance looking into the 4-wire terminating set from the 2-wire side.

### *Receiving Circuit*

The receiving circuit is shown in Fig. 4. The detector panel uses three valves; the first valve is an amplifier limiter valve, the second a detector valve with a special grid circuit, while the third valve acts as a d-c. amplifier.

The incoming signal causes the anode current of the third valve to be reduced to zero. In the rest condition the anode current of this valve, flowing through one winding of the receiving relay, is 25 mA.

The grid circuit of the second valve has a gain controlling property. On reception of a high level signal the gain is reduced and this has the effect of making the rate of change of current in the third valve a function of the percentage rate of change of input, rather than of the actual input level. The received carrier signals have a finite rate of change of amplitude (the signal envelope is somewhat rounded due to the restriction in the band of frequencies transmitted); if they were received by a receiving circuit not possessing this feature, the shape of the resulting direct current signals would depend on the strength of the incoming signals, rather than on their shape, and any change of input level would cause a change

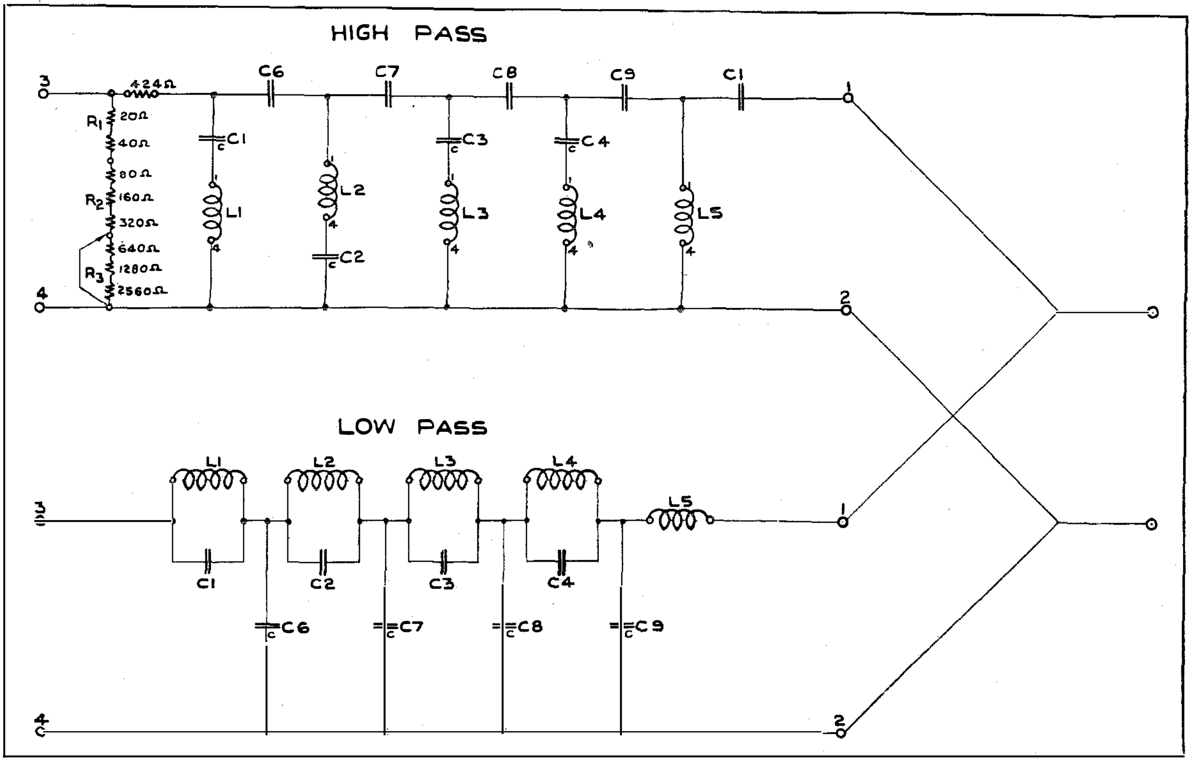


*Figure 3—Line Filters for Super-Audio Carrier Telegraph System.*

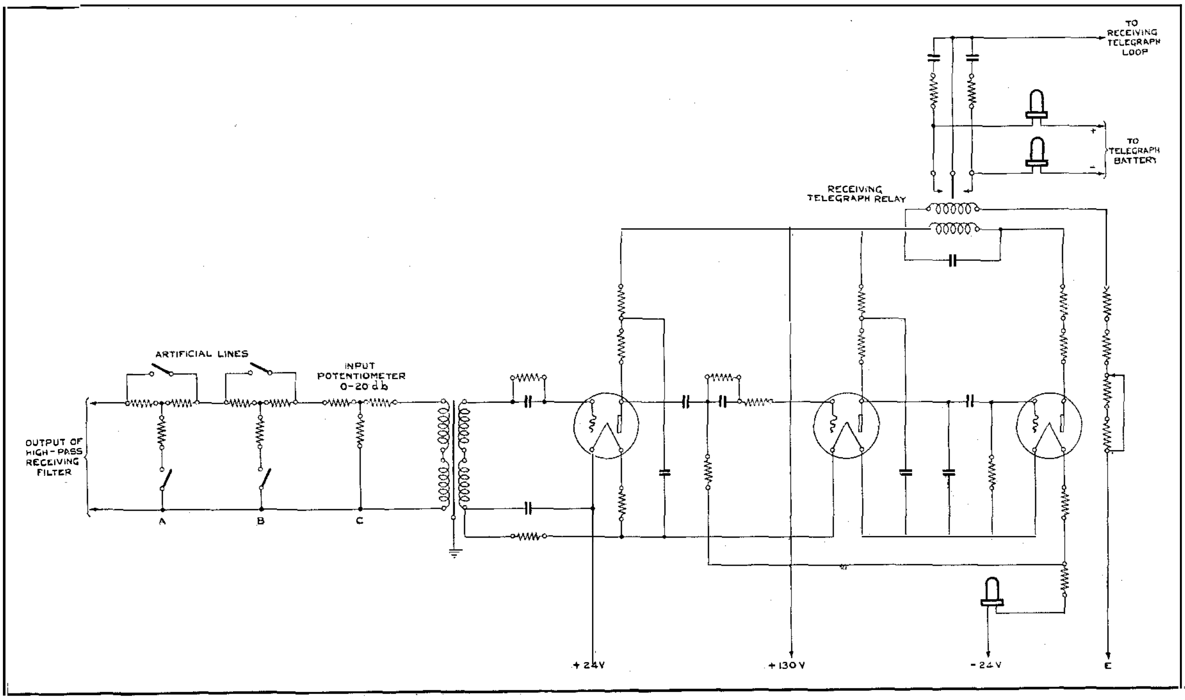


*Figure 4—Schematic of Receiving Circuit—Super-Audio Telegraph System.*

of signal bias. For a full discussion of the detector problem see *Electrical Communication*, April 1932.[2]

The detector used for the multi-channel voice frequency telegraph system satisfies the above requirements very exactly indeed over a range of input levels, but is not as well suited for detection of signals having a steep arrival curve, as is the present detector, which satisfies the same requirements less exactly, but over a wider range of input levels, and gives a higher current for operation of the receiving relay.

The input circuit of the detector has a variable input potentiometer for adjustment of the receiving sensitivity and two resistance networks which may be switched in or out of circuit by means of a key. The adjustment of the potentiometer is very simple and not critical.

### Telegraph Circuits

The super-audio telegraph channel terminates in Send and Receive telegraph legs, which have adjustable resistances and means for measuring the current.

Keys are incorporated in the equipment, to permit easy change from double to single current working, and from full to half duplex operation. The actual arrangement of these circuits is exactly the same as that described in the article on the multi-channel voice frequency telegraph system already referred to.

### Equipment

Fig. 5 is a front view of a super-audio telegraph bay. The equipment is of the double sided type, adopted so far for repeaters and voice frequency telegraph systems.[3]

The upper part of the bay shown is devoted to apparatus common to several channels, while the lower part mounts the complete equipment for one channel. The back of the bay can accommodate two further channels (each channel requiring a separate 4-wire circuit). If still further channels are required, subsequent bays each provide four channels until a total of fifteen channels has been reached. If more than sixteen channels are to be terminated in one office, another bay similar to that shown starts a second series of fifteen channels.

Super-audio telegraph equipment can also be supplied in a simpler form intended for small

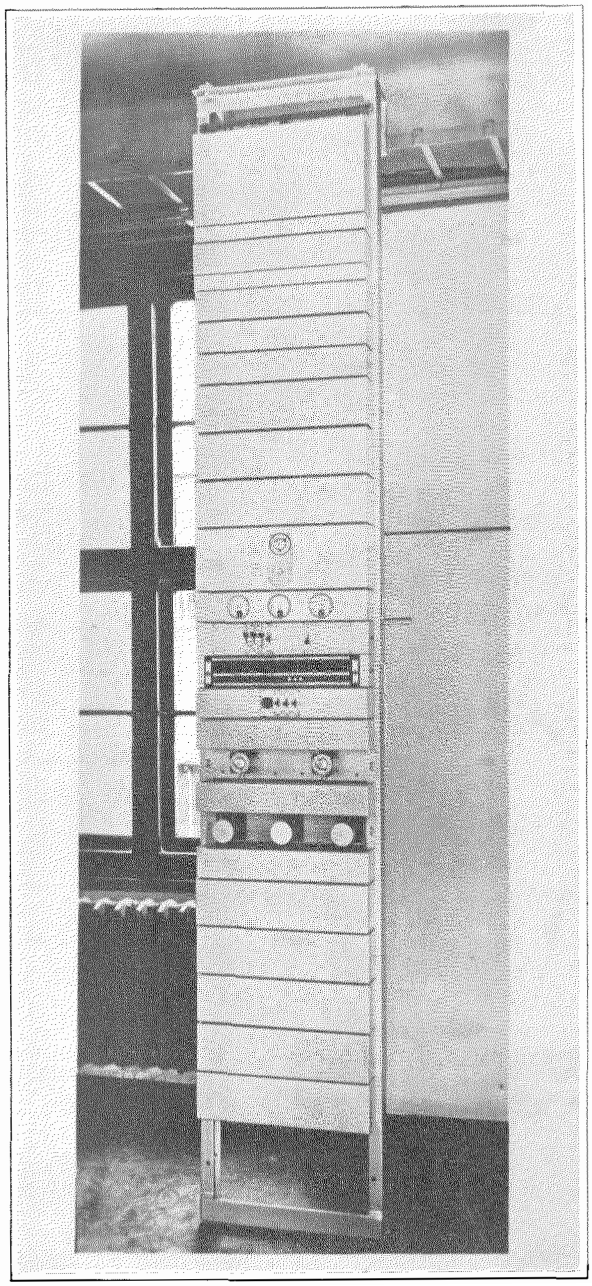

*Figure 5—Super-Audio Telegraph Bay—Front View.*

[2] "A New Voice Frequency Telegraph System," J. A. H. Lloyd, W. N. Roseway, V. J. Terry, and A. W. Montgomery, *Electrical Communication*, April, 1932.

[3] "A New Voice Frequency Telegraph System," J. A. H. Lloyd, W. N. Roseway, V. J. Terry, and A. W. Montgomery, *Electrical Communication*, April, 1932.
"The New Standard Repeater Equipment," by J. S. Lyall, *Electrical Communication*, October, 1932.

stations where only one channel is required. This simplified equipment consists of four filters, one neon limiter, and a super-audio telegraph set. The filters may be mounted on a wall or rack, while the super-audio set can be mounted on or under the teleprinter table if the channel is used for teleprinter working.

The super-audio set, which is mains-operated, need not necessarily be mounted in the same office as the filters, but may be placed on a renter's premises, the necessary connection with the super-audio set being made by special extension lines from the filters. If such a channel is used in connection with a teleprinter, it will often be found possible to use the set without telegraph relays.

The system described here was demonstrated in Prague during the C.C.I.T. Reunion. For the purpose of this demonstration the Czechoslovakian Administration had kindly provided a 1,000 km. loop of extra light loaded 4-wire circuit. The system gave very satisfactory operation over this circuit.

The telegraph channel did not cause any audible disturbance of the telephone circuit, nor was it possible for the telephone circuit to disturb the telegraph channel, regardless of the loudness of the speech level.

# Coaxial Communication Transmission Lines[1]

By S. A. SCHELKUNOFF

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*A nonmathematical discussion of the mechanism whereby energy may be transmitted over long distances at high frequencies by the use of "coaxial conductors" is presented in this paper. A coaxial system consists of a cylindrical conducting tube within which a smaller conductor is coaxially placed. Such conductors, which reduce interference and cross-talk, are applicable for the transmission of telephone, telegraph, and television signals over a very wide range of frequencies.*

THE technical possibilities of the use of "coaxial conductor" systems for bands of frequencies as wide as 1,000,000 cycles or more are discussed in a recent paper by L. Espenschied and M. E. Strieby ("Coaxial Conductor Wide Band Transmission Systems," *Electrical Engineering*, volume 53, Oct. 1934, pp. 1371–80).[2] A comprehensive mathematical discussion of coaxial transmission lines is given by the author in another paper ("The Electromagnetic Theory of Coaxial Transmission Lines and Cylindrical Shields," *Bell System Technical Journal*, volume 13, Oct. 1934, pp. 532–79). The present paper attempts to give a nonmathematical discussion of the physical mechanism by which physical energy is conveyed along a coaxial pair, dissipated in it, or transferred between it and other neighboring systems. It is believed it will be of interest to engineers who may not wish to follow through the mathematical treatment.

## *Mechanism of Transmission of Energy*

A coaxial transmission system is comprised of a central wire surrounded by a coaxial shield which is employed as the return conductor. The laws of transmission of energy along such a system do not differ in any essential respect from those governing a parallel pair. If one member of the parallel pair were to be replaced by a cylindrical shell coaxial with the other wire and at the same distance from it, the capacity per unit length would become about twice as great and the inductance about one-half as great, so that at high frequencies, where the influence of the resistance on the surge impedance of the line is negligible, the surge impedance of the coaxial line is about one-half the surge impedance of the parallel pair.

Within a coaxial pair (Fig. 1) the lines of magnetomotive intensity $H$ are coaxial circles and the lines of electromotive intensity $E_p$ are substantially radial. The word "substantially" is used because although most of the energy travels *along* the pair, a slight amount of it moves radially into the imperfect conductors, where it is dissipated in heat.

By electromagnetic theory this radial movement of energy implies the presence of the longitudinal component $E_l$ of the electromotive intensity parallel to the conductors. This $E_l$, negligible for most purposes, is an important factor in calculating the a-c. resistance of coaxial pairs and in matters of interference and cross-talk. Being tangential to the cylindrical boundaries between different mediums comprising the coaxial pair, it is continuous across them while the radial component $E_p$ is practically annihilated on entering the conductors. In the conductors themselves $E_l$ and $H$ constitute the principal field, and energy moves there almost exclusively outward (or inward, as the case may be) and not lengthwise as in the dielectric between the conductors. Because of heavy absorption of energy by the conducting substance, the field is rapidly attenuated in this outward direction.

A quantitative idea of the rate of decay can be gained by considering the simplest case of a plane wave, in which $E$ and $H$ are uniform all over the wave front (Fig. 2). The formulas for the propagation of such a wave in a homogeneous medium are very similar to those of wave propagation in

[1] Republished by permission from *Electrical Engineering*, December, 1934.

[2] *Bell System Technical Journal*, October, 1934 and *Electrical Communication*, October, 1934.

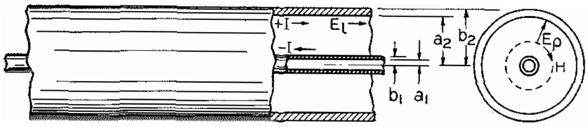



*Figure 1—In a Coaxial Transmission Line the Lines of Magnetomotive Intensity are Circles and Those of Electromotive Intensity Not Very Different from Radii.*

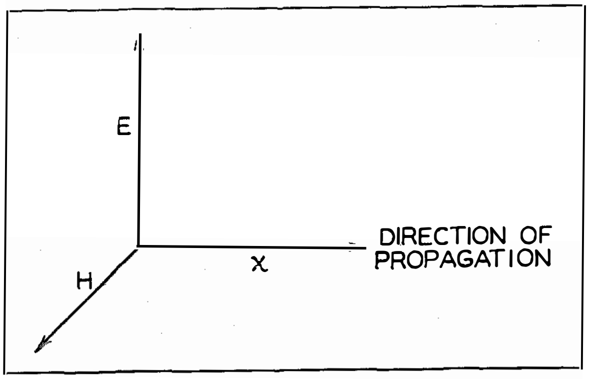



*Figure 2—Relative Orientation of the Field Components in a Plane, Plane-Polarized Electromagnetic Wave.*

transmission lines, the permeability $\mu$ playing the rôle of series inductance, while the conductivity $g$ and the dielectric constant $\varepsilon$ take the part of the shunt conductance and capacity, respectively (see Fig. 3). In metallic substances the conductivity is large and the dielectric constant can be neglected, so that the propagation constant is expressed simply as $\sqrt{j\omega\mu g} = \sqrt{\pi\mu f g}\ (1+j)$ nepers per centimeter. (Here the conductivity $g$ is expressed in mhos per centimeter and the permeability $\mu$ in henries per centimeter. Also, $\omega = 2\pi f$ where $f$ is the frequency.) In copper, for instance, $\mu = 1.256 \times 10^{-8}$ henries per centimeter and $g = 5.80 \times 10^5$ mhos per centimeter, so that at 1,000,000 cycles the attenuation constant is 151 nepers or 1,315 decibels per centimeter. The phase change is 151 radians per centimeter, so that the wavelength in copper is 0.415 millimeters. Both the attenuation and the phase change are thus exceedingly rapid.

In the outer conductor of the coaxial pair the wave is not plane, but it could be regarded as such without introducing a serious error, because the "attenuation" (in the more general sense) of the wave, due to the outward divergence, is slight and the attenuation due to the energy absorption is very great. This fact will be useful when the shielding afforded by the outer conductor is discussed later in this paper.

A hollow conductor has an optimum thickness from the point of view of its resistance; this optimum thickness equals one-quarter of the wavelength for this particular metallic substance. If the conductor is made thicker while keeping the diameter of the active surface (that is, the surface of the greatest current density) fixed, the electric current in the added metal will flow in opposition to the original current and if the same total current is to be maintained, the current density must be raised throughout the conductor, thus resulting in increased energy losses and increased effective resistance. (A somewhat different picture of this phenomenon is presented by S. A. Schelkunoff in "A Skin Effect Phenomenon," *Bell Laboratories Record*, volume 11, Dec. 1932, pp. 109–12.)

## *Interference and Cross-Talk*

There has now been established a sufficient background for approaching the important problem of interference and cross-talk. Consider a coaxial pair above the ground (Fig. 4). The ground, together with the outer conductor of the coaxial pair, forms a parasitic transmission line so that in effect the system is comprised of two continuously coupled transmission lines, one carrying current $I$ and the other $I_g$.

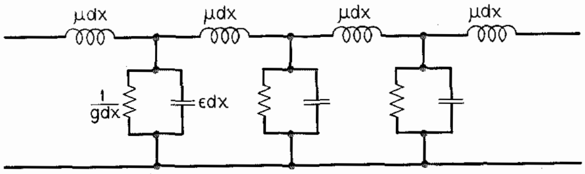



*Figure 3—This Equivalent Circuit of a Transmission Line with Distributed Constants is a Model of a Plane Wave Traveling Through a Homogeneous, Isotropic Medium.*

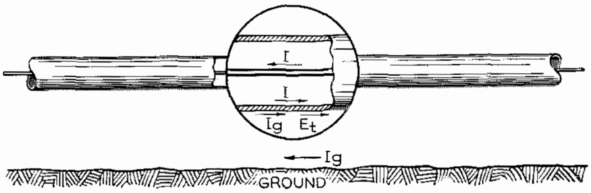



*Figure 4—The Outer Conductor of the Coaxial Pair and the Ground Form a Parasitic Transmission Line Playing an Important Role in Interference Phenomena.*

The electromagnetic field of a radio station or of static is impressed upon the ground circuit and produces in it current $I_g$, which in its turn produces the voltage drop $E_t$ along the outer surface of the outer conductor of the coaxial pair. However, because of the rapid attenuation previously discussed, this gives rise to only an exceptionally weak "induced" voltage drop along the inner surface of the conductor. Besides, on the inner surface, the abrupt change in the properties of the medium causes almost a complete reflection, practically annihilating the magnetomotive intensity and doubling the voltage drop.

This matter of interference can also be considered from a somewhat different point of view. For all practical purposes the field of the coaxial pair does not extend beyond the outer surface of its outer conductor, and, similarly (except at very low frequencies) the field of the ground return line is limited by the inner surface of that same conductor. The outer conductor, therefore, represents the entire distributed mutual impedance between the two transmission lines. At zero frequency, this mutual impedance is the d-c. resistance of the conductor, but otherwise it has a reactive component due to the magnetic interlinkage taking place within the space occupied by the outer tube. The mutual resistance between two coupled circuits can be measured by that average amount of dissipated energy which is proportional to the product of the electric currents flowing in those circuits, and similarly the mutual inductance can be gauged by that average amount of stored magnetic energy which is proportional to the product of those same currents. (The self-resistance of the circuit can be measured by that amount of dissipated energy which is proportional to the square of the current in the circuit. An analogous statement applies to the self-inductance.) As the frequency increases the electric current $I$ of the coaxial pair tends to concentrate on the inner surface of the outer conductor and the current $I_g$ of the ground return line moves toward the outer surface. The two currents become more and more separated, the regions of high density of one overlapping the regions of low density of the outer, and the mutual energy of dissipation as well as the mutual electromagnetic energy are thereby diminished.

The problem of cross-talk between two coaxial pairs is quite similar. Besides the two given transmission lines there is a parasitic line comprised of the outer conductors of the two pairs. The induction takes place from one pair into this parasitic line and thence into the second pair. Obviously, this cross-talk is exceedingly small. It is largely because of this freedom from interference that the coaxial pairs have been used as lead-ins between antennae and radio stations and seem to be promising as broad band transmission systems.

# The Centralisation of Control of Power Networks

By E. M. S. McWHIRTER, A.M.I.E.E., A.C.G.I.

*Standard Telephones and Cables, Limited, London*

SYNOPSIS:—*Industrial development towards connected and coordinated effort under one control has given considerable impetus to the design of systems which will provide automatic indication and sometimes control of power units separated by many miles. Such systems are not confined to electrical power, but embrace gas producers, water supply and power undertakings.*

*The diversity of conditions and requirements renders it economical to consider each problem on its merits, using standard apparatus whenever possible rather than developing a standard form of equipment. Such recent installations include the Central Indicating and Telephone Systems supplied to the Central Electricity Board for their Mid-East and Northeast England Areas; the control and indication of all the contactors for lighting one of the largest of London's stores; the control and indication of water conditions at the weirs, reservoirs, pipe lines, etc., of a large hydro-electric undertaking; and the indication at headquarters of the quantity and quality of coke oven gas being fed into the city's supply main by five coke ovens. These are described in brief, and the special features of each and the method adopted to meet the particular requirements are given.*

## *General Survey of Developments of Remote Control System*

ORIGINALLY the systems employed by the Standard Telephones and Cables were briefly:

The Selector System utilising the train despatching selector as its basic unit and notably employed in the G.I.P. Railway equipment previously described in *Electrical Communication*.[1] Several other equipments using this type of selector were installed in England and on the Continent, the most recent being for the control of the second largest switching station of the Central Electricity Board's system at Norton in County Durham. Three line wires are required for control and indication, whilst remote meter indication over the same wires has not yet been applied to this system.

The Distributor System which employed a distributor as the only piece of apparatus other than relays for each operation and a few common relays. Such an equipment has been supplied to Christchurch City Council, but in general the design has not been found to be sufficiently flexible for universal application. The necessity for four line wires also limits the application of the system to comparatively short distances. Metering over the same pilot wires as used for control and indication was not attempted with this system.

Until the requirements of the Central Electricity Board were made known, few, if any, manufacturers in England had developed a successful scheme of control, indication, metering, and telephony over two wires. One of the earliest equipments which met all such requirements was that supplied for the Mid-East England Area by Standard Telephones and Cables, Limited, in collaboration with the British Thomson-Houston Company, Limited, and with the Consulting Engineers to the Board, Messrs. Merz & McLellan. This installation, which was put into service in February, 1933, has been completely successful, and it is noteworthy that no change has been found necessary in the operating procedure originally adopted.

A second system for the Central Board's Northeast England Area has been operating since the early part of 1934. It is basically identical in design and principle to the equipment in the Mid-East Area, but is interesting inasmuch as it includes the indication of switches, transformer tap positions, and meter readings from three switching stations, together with automatic telephony between ten subscribers' points located at the various stations, the whole of these services being conducted over one communication chan-

[1] "The Selector System of Supervisory Remote Control as Applied to the Great Indian Peninsula Railway," *Electrical Communication*, January, 1931.

nel interconnecting the stations and extending to the control room.

A development of this system, embracing the control of circuit breakers as well as their indication and metering, has been supplied for several smaller equipments, and mention is made herein of the equipment at Queen's Park, Manchester, for the complete remote control and indication of the Corporation's largest unattended substation.

Other systems which have been supplied in the last two years have not all followed the same fundamental principle adopted for the Central Electricity Board's equipments. Examples of these systems, mentioned hereinafter, are:

The system supplied to Messrs. Balfour Beatty and Company, Limited, for the control and indication of two sets of sluice gates, the pipe line valves, and the indication of water levels and velocities at various points in the loch, river, aqueduct, and tailrace, constituting the water supply system feeding their new 17,000 kva. hydro-electric power station at Tummel Bridge, Perthshire, Scotland.

The equipment installed for the Sheffield Gas Company for indicating at their head office the total quantity and the calorific value at any instant of the gas passing into their mains from the five coke ovens which supply the city.

The remote control and indication equipment for the contactor equipment switching 2000 kva. of heating and lighting load for the Duke Street extension to Messrs. Selfridge's, Oxford Street store.

## *Central Electricity Board's Equipment*

In order to appreciate the remote indicating and telephone systems that have been installed in the Mid-East and Northeast England Areas, it is necessary briefly to examine the power network controlled. For the Mid-East Area the

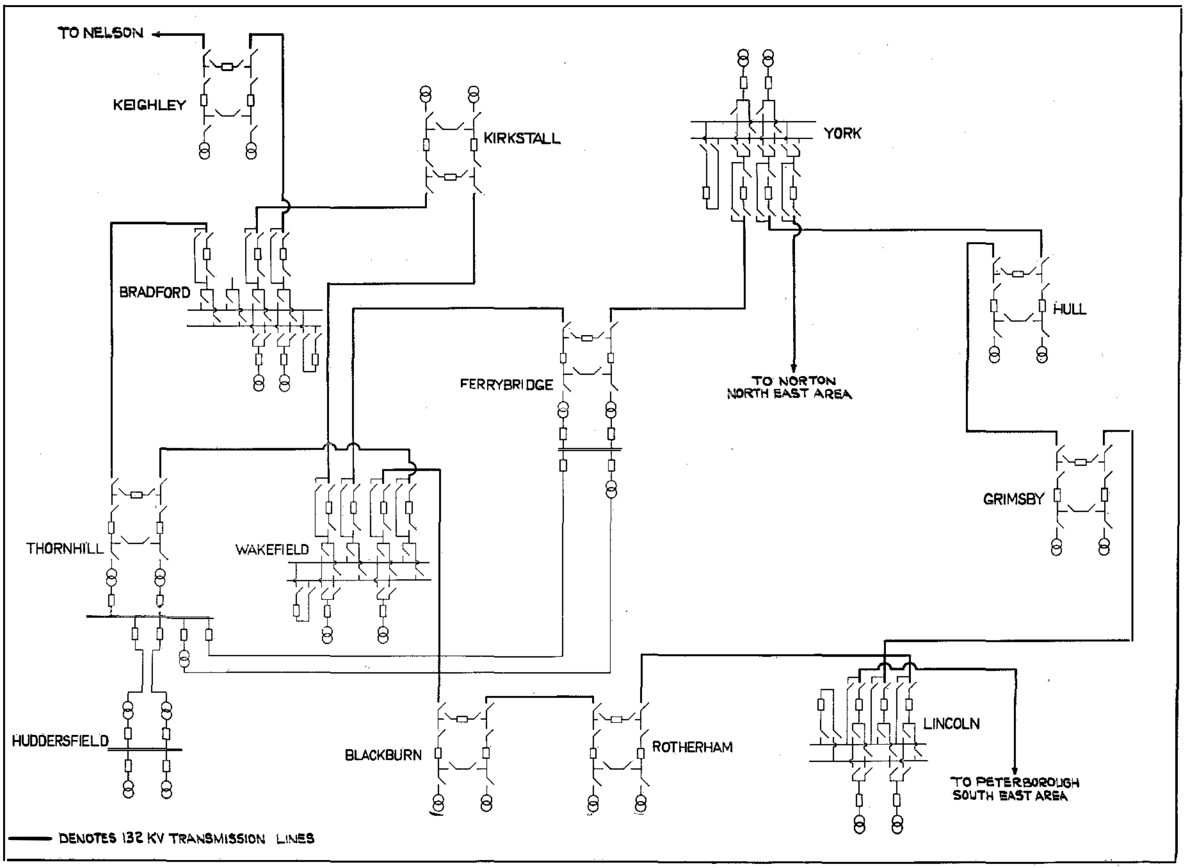



*Figure 1—Power Transmission System for the Mid-East England Area of the Central Electricity Board.*

control is located at Leeds, and for the Northeast Area at Newcastle.

It will be necessary only to describe one of the power networks as they are very similar in principle. Fig. 1 shows a line diagram of the 132 kv. transmission lines and the switching stations erected in the Mid-East Area, whilst Fig. 2 shows the telephone channels rented from the General Post Office by the Electricity Board and interconnecting each of the switching stations with the Leeds Control Room.

Some of the stations form interconnection points with neighbouring areas, and therefore have more oil circuit breakers than others which serve only to connect an undertaking to the Board's network.

The control facilities specified to be carried out over the single G.P.O. channel, in the order of precedence, are as follows:

1. Telephone communication between the control room and all important points on the system, with the additional requirement that priority calling between the control room and the operator at each power station may be exercised in case of emergency.
2. The automatic indication of the position (open or closed) of all oil circuit breakers of first grade importance on a system diagram.
3. The automatic indication of the position of the on load tap change equipment of all transformers connected to the 132 kv. transmission system and the lower voltage transmission system already mentioned.
4. The automatic transmission from the control room to certain power stations of routine instructions, together with the automatic acknowledgement from the power station back to the control room of the instruction, in order to facilitate speed of operation and to relieve the traffic on the telephone system.
5. The indication of meter readings of load transfer through the main transformers and to and from the Mid-East England Area to the other interconnected areas, together with the indication of the system voltage at certain selected points; also, at certain main generating stations, the indication of the total generator load.

Table I gives the numbers of these various facilities required at each station. In addition to these facilities, certain other power stations required telephone connection with the system. This was accomplished by means of an automatic telephone exchange installed at the stations marked in Table I with an asterisk.

System design difficulties were increased by the necessity for protecting the Post Office pilot

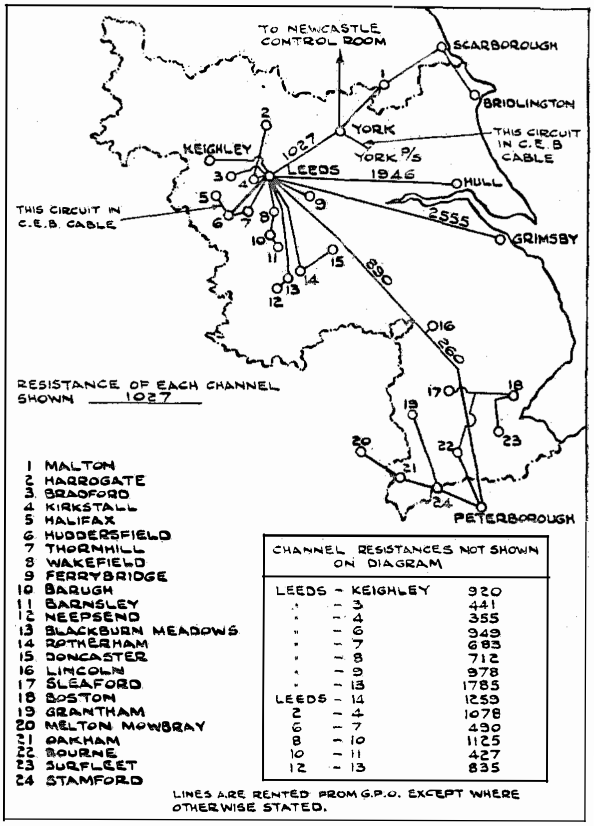



*Figure 2—The Mid-East England Area Showing Geographical Layout of the Stations and the General Post Office Lines Used for Supervisory and Telephonic Services.*

wires at all primary stations against the danger of connection under any conditions with high voltage or with the earthing system of the power stations. Part of the approved protection system was a high insulation transformer which provided the main barrier between the Post Office lines and any extraneous voltages. This transformer, connected across the pilot wires, ruled out any possibility of using a d-c. impulsing system, and a further imposed limitation entailed a recourse to reverse current signalling with a potential not greater than 50 volts, whilst any alternating current signals were limited to 2 volts and 2 milliamperes.

With these conditions in mind, a system was developed which reduced all indications and signals to a basic coding principle, including meter readings. Further, the length and resistance of some of the Post Office circuits, the longest being more than 80 miles of underground loaded cable, coupled with the importance of the correct, and only the correct, signals being transmitted, made it imperative to design a system which would be proof against faulty operation by induced line surges and all extraneous impulses, whilst at the same time employing very sensitive receiving relays.

To meet these very onerous conditions, the Constant Total Code System was produced and it has been proved to possess all the desired safeguards whilst remaining extremely robust and reliable.

In the Constant Total Code System a series of codes, one for every different signal that it is required to transmit in any one direction, is used. This system possesses the unique feature that the arithmetical sum of the impulses constituting the digits in any code is a constant number. The choice of this constant number and the decision whether three or four digits are to be used in the code are made arbitrarily to suit the total number of different signals necessary to cover the ultimate requirements of the particular system. Thus, for the Central Board's equipments where the maximum number of different signals to be transmitted to a switching station from the control station did not exceed twenty-eight, a coding series of three digits totalling ten and giving an availability of 33 codes was used, the maximum digit comprising seven impulses. For the signals sent from a switching station or power station to the control station, a constant total of thirteen impulses divided into four digits with the maximum size of seven impulses for any one digit was chosen, giving an availability of 186 codes for a maximum requirement of 124 codes for the largest station on the system.

To illustrate such a series, the table of codes for three digits totalling ten is given hereunder:

| | | | | | | |
|---|---|---|---|---|---|---|
| 1-2-7 | 2-1-7 | 3-1-6 | 4-1-5 | 5-1-4 | 6-1-3 | 7-1-2 |
| 1-3-6 | 2-2-6 | 3-2-5 | 4-2-4 | 5-2-3 | 6-2-2 | 7-2-1 |
| 1-4-5 | 2-3-5 | 3-3-4 | 4-3-3 | 5-3-2 | 6-3-1 | |
| 1-5-4 | 2-4-4 | 3-4-3 | 4-4-2 | 5-4-1 | | |
| 1-6-3 | 2-5-3 | 3-5-2 | 4-5-1 | | | |
| 1-7-2 | 2-6-2 | 3-6-1 | | | | |
| | 2-7-1 | | | | | |

It can be seen that this type of coding system will provide against any stray line pulses changing one code into another and so transmitting an incorrect signal, since an induced surge which tended to add an impulse to any digit of a code would make that code total one impulse too many and the receiving circuits are designed to reject any codes which do not total correctly. Similarly, a surge so occurring as to give the effect of losing an impulse, or any incorrect counting on the part of the receiver itself, will total less than the desired number and again be ineffective. It is true that line conditions giving the effect of any additional impulse to one digit, and then after

TABLE I—TABLE SHOWING FACILITY REQUIREMENTS AT EACH STATION IN MID-EAST ENGLAND AREA

| Station | Telephone Points Required | Oil Circuit Breakers | | Transformer Indication | | Load Meters for Transference between Stations and the Central Electricity Board System. Each meter is arranged for summating the unbalanced 3-phase load of two circuits. | | Load meters for Inter-Area Transference. Each meter arranged for 3-phase unbalanced load of a single circuit. | | Volt Meter | Total Generator Load Meter | Routine Instruction Signals Required |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 132kV. | Lower Voltage | No. of Trans. | Tap Positions of Each | Wattmeters | Reactive kVA | Wattmeters | Reactive kVA | | | |
| Bradford | 3 | 6 | – | 2 | 15 | 1 | 1 | – | – | 1 | 1 | 1 |
| Blackburn Meadows | 3* | 3 | 4 | 2 | 15 | 2 | 2 | – | – | – | 1 | 1 |
| Ferrybridge | 3 | 3 | – | 2 | 15 | 1 | 1 | – | – | – | 1 | 1 |
| Grimsby | 3 | 3 | – | 2 | 15 | 1 | 1 | – | – | – | – | – |
| Hull | 3 | 3 | – | 2 | 15 | 1 | 1 | – | – | – | 1 | 1 |
| Huddersfield | 2* | – | 4 | 2 | 11 | 1 | 1 | – | – | – | 1 | 1 |
| Keighley | 3 | 3 | – | 2 | 15 | 1 | 1 | 1 | 1 | – | – | – |
| Kirkstall | 3* | 3 | – | 2 | 15 | 1 | 1 | – | – | – | 1 | 1 |
| Lincoln | 3 | 6 | – | 2 | 15 | 1 | 1 | 1 | 1 | 1 | – | – |
| Rotherham | 3* | 3 | – | 2 | 15 | 1 | 1 | – | – | – | 1 | 1 |
| Thornhill | 3 | 3 | 4 | 2 | 15 | 2 | 2 | – | – | – | 1 | 1 |
| Wakefield | 3* | 7 | – | 2 | 15 | 1 | 1 | – | – | 1 | – | – |
| York | 3* | 6 | – | 2 | 15 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

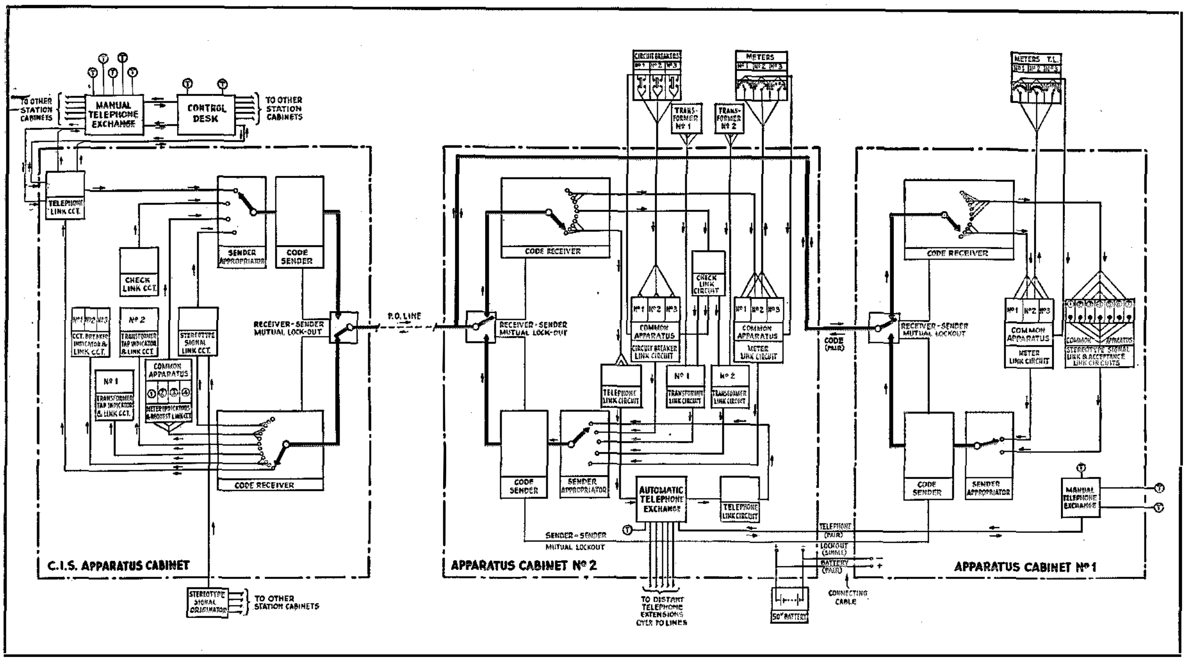



*Figure 3—Block Circuit Diagram of Constant Total Code Signalling System for Two Stations Operating to a Central Control Over a Single Pair of Wires.*

the correct lapse of time producing the opposite effect so as to lose one impulse in the succeeding digit, would give an incorrect indication, but it can be safely assumed that such an occurrence is beyond the bounds of probability. Thus a coding system was conceived which provided an inherent safeguard against wrong signalling.

Considerations of the link circuits required to interconnect the common sending and receiving equipment at either end of an equipment determined that universal relays in combination with sequence switches would provide the most robust and adaptable system and also were found to be most suitable for counting, sending, and storing the coding digits. The choice really lay between the use of stepping switches of various types as against motor driven sequence switches, and the latter were selected for the following important reasons:

1. A motor driven sequence switch for generating the various codes of impulses could obviously be controlled much more accurately than a relay controlled stepping switch to give accurately timed impulses with a nearly exact make-to-break ratio. By creating closely controlled impulses a system was obtained in which the line attenuation could be allowed the maximum degree of variation without jeopardising satisfactory operation.
2. The greater clearances between successive rotary positions of the sequence switch when compared with a stepping switch were felt to be an advantage when dealing with circuits connected to high voltage switchgear and metering transformers.
3. In the event of a breakdown of the insulation between power circuits and supervisory circuits causing a flashover between adjacent contacts, the damage to a sequence switch could be very easily cleared because probably only one brush nest and cam would be affected, whereas any flashover in the bank of a stepping switch would involve complete replacement, with all the attendant wiring affected.

### *The System in Mid-East England*

There is not space in this article to attempt any detailed circuit description. Fig. 3, however, illustrates the interworking between the link circuits and the common equipment for the arrangement of a switching station and a power station a few miles away interconnected by private cables and both signalling to and from the control station over a single Post Office channel. The diagram is given in some detail and is pictorially self-explanatory, the arrows indicating the direction of connection between the circuit units.

A view of the apparatus cubicle at Kirkstall Power Station is given in Figs. 4 and 5, which show the compact arrangement adopted, the whole of the equipment for the power station being enclosed in a steel cubicle. Fig. 5 shows the sequence switches and relays mounted on a rack, together with the fuse panel, line sending and receiving relays, which are of the telegraph type in order to deal with the 50 volt reversals to line for transmitting, and the 3 milliampere incoming impulses from the distant control station. A routine test panel can be seen, with five rotary multi-point switches, four vertical type keys, a manual impulse generator, and a small impulse counter (under dust cover). By using this equipment, the maintenance man can send into the main receiver any code that can be transmitted from the remote station, and can count any code which can be transmitted to the remote station from the main code sender. Thus he can completely test the code sending and receiving equipment without the aid of another man at the distant station and also without interrupting the normal functioning of the equipment. This feature has proved to be of immense importance in contributing to efficient and easy maintenance.

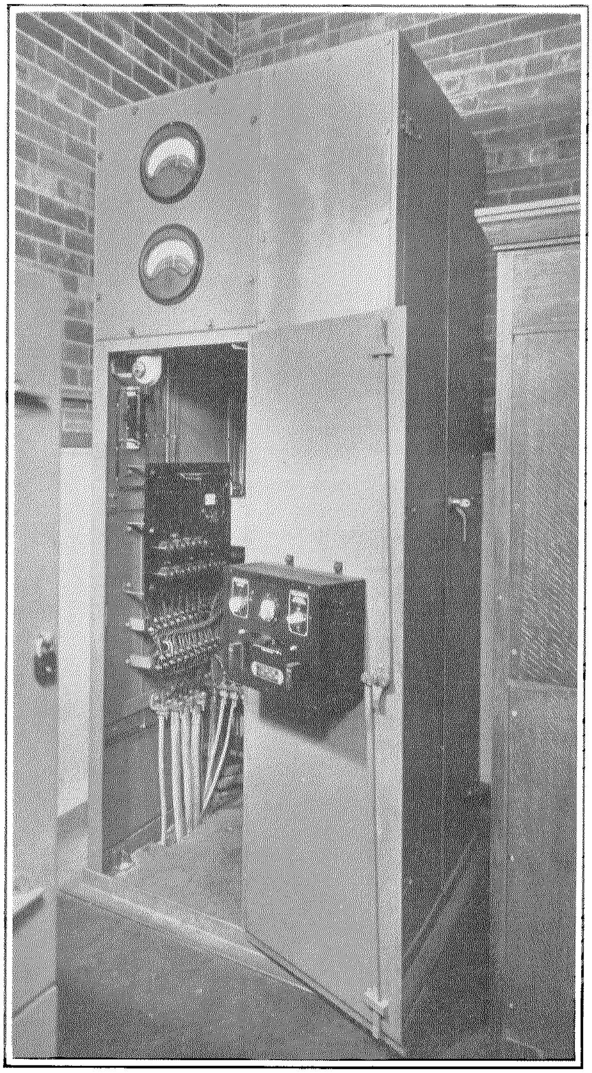


*Figure 4—Power Station Equipment as Supplied to the Central Electricity Board, Showing Cubicle Construction Adopted.*

Towards the top of the cubicle (Fig. 4) are the transmitting meters. These comprise a megawatt (scaled in 1000 kw. units) and a megavar (scaled in 1000 reactive kva. units) and transmit the summated load import or export of two unbalanced three phase 132 kv. transmission circuits to the Central Control Station. The method adopted is to divide each meter scale into 49 divisions with a separate contact in each. The needle normally floats clear of the contacts, being depressed momentarily to touch the contact over which it is standing at the instant when a reading is due to be transmitted. With each contact a separate code is associated, an economy in codes being effected by utilising the same 49 codes for all meters and using the meter reading request code to discriminate relative to the indicator affected at the control station by the incoming code.

Equipment in the Control Room at Leeds is shown in Figs. 6, 7 and 8, and includes a set of station panels carrying the meter and transformer tap position indicators surmounted by a diagram of the 132 kv. lines equipped with lamp indicators showing the circuit breaker positions, all indications being operated by the remote control equipment. In addition, a large control desk surmounted by a complete miniature system diagram stands in the centre of the room and is so positioned that the control engineers sitting at it, face the station panels.

All transmitting and receiving of signals from any of the stations can be carried out from the desk, with the exception of requests for meter readings and the "check" or automatic request for repeat of all signals. These latter operations are performed at the station panels.

The miniature diagram on the desk shows all circuit breakers, isolators, and earthing switches

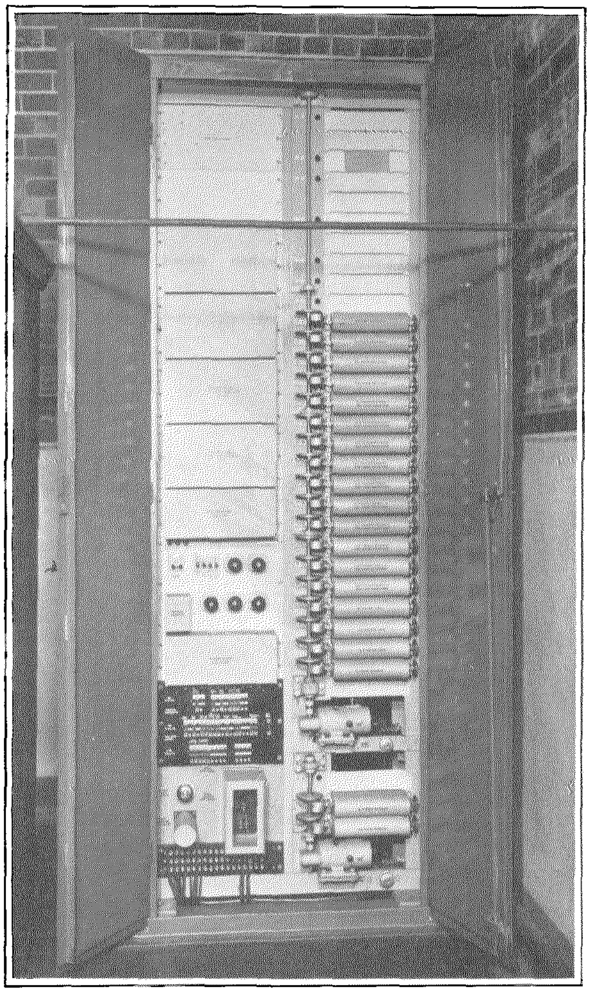


*Figure 5—Power Station Equipment Showing All Sequence Switches and Relays Mounting on a Single Rack as Supplied to the Central Electricity Board.*

on every part of the transmission system in the area, including all voltages from 132 kv. down to 6.6 kv., whether of the Board's property or otherwise. Associated with the circuit breakers, which are automatically indicated, are small signal lamps which light up during a change and assist the engineer to select quickly the unit affected. Both this indication on the desk and the simultaneous one on the station panel are "accepted" by operating the twist key, representing the particular switch set in the desk diagram to the new position.

In a similar manner changes in transformer tap position, although indicated on the station panels, are also shown on the miniature diagram by means of a pilot lamp. The control engineer accepts the change by depressing the transformer key.

Other features included in the control desk are the duplicate telephone equipments, which are completely key-sending in order to give the maximum speed of operation in an emergency; the routine instruction signal transmitting and receiving panel, whereby any of seven signals such as "Standby," "Raise Speed," etc., can be sent to any or all of the eleven generating stations simultaneously; and the manually set generator station panels which flank the main diagram upon which the engineer can set up all essentials of the operating conditions at the power stations, such as machines on load, under repair, boiler capacity steaming and banked, etc.

The supervisory equipment is located in another room beneath the control room. A rack construction similar to that used for the power stations was adopted. Thirteen bays or racks are at present equipped, there being ample room left for any additions which future expansion of the power system may require.

The system was first cut into service in February, 1933, and, within a few days of its inauguration, had to give immediate and vital service during a two-day blizzard, the worst experienced in Yorkshire for many years, during which many services and communication lines were out of action. The equipment stood the test admirably and despite several switches tripping out, the central control was enabled to maintain supply everywhere in the area during the storm.

## *The Northeast England System*

For this area, only six major switching stations were required to be equipped and the same construction was used as for the Mid-East System. One important difference lies in the fact that no control desk centralising the control and telephone facilities was required, since the Central Board in this area is working in close cooperation with one chief undertaking, the Northeast Electric Supply Company, Limited, operating from the same control room.

An interesting illustration of the adaptability of the Constant Total Code System is the operation of the Power Station at North Tees, the very large Switching Station at Norton, the Power Station and Switching Station at Darlington,

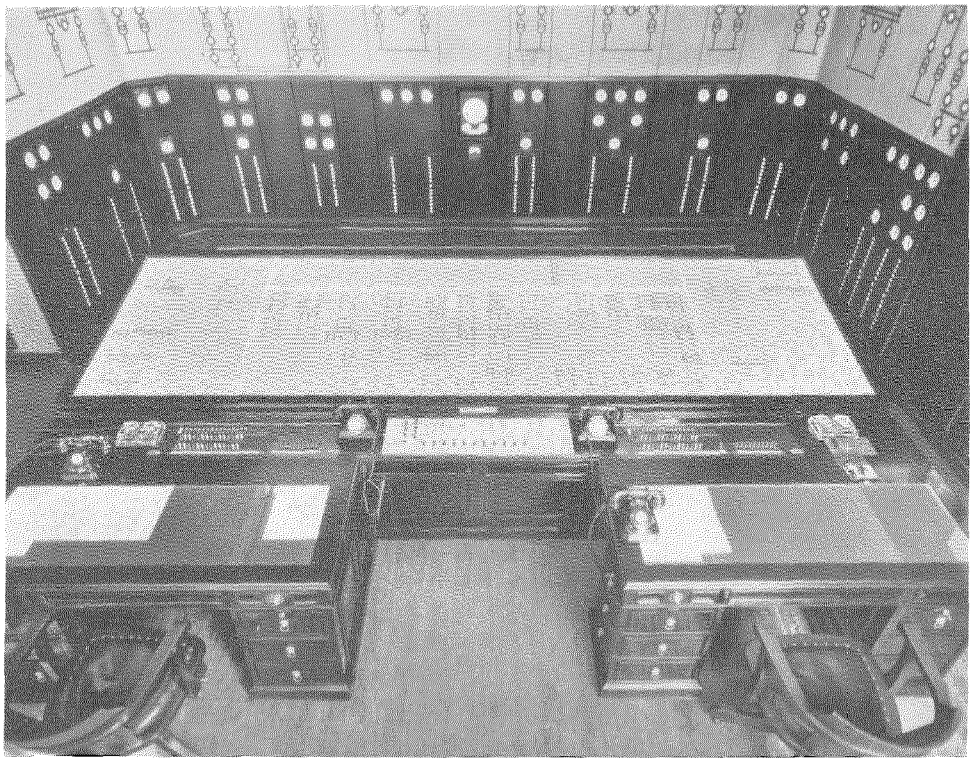


*Figure 6—The Control Desk for the Leeds Control Room.*

and a telephone connection to a power station of secondary importance at Northallerton, all of which interconnect, indicate, and communicate to the Control Room at Newcastle over one pair of Post Office wires.

Fig. 9 shows in block schematic form the facilities provided to the Northeast Area by the Constant Total Code System and the pilot channels over which they are conducted.

## *A Large Substation Fully Remotely Controlled and Indicated*

In January, 1933, Standard Telephones and Cables, Limited, cut into service a Constant Total Code System for completely indicating and controlling Queen's Park Substation from High Street Control Station on the Manchester Corporation's Power System.

The ultimate capacity of the system was designed for the control and indication of sixty-eight oil circuit breakers and earthing switches, and selection and indication of twenty-eight voltmeters or ammeters. The diagram and system are fully wired for future extensions, blanks in the diagram indicating where these will occur.

The coding system employed, as explained earlier, was determined by the size of the equipment. A series employing a constant total of sixteen divided into four digits with a maximum of eight, giving an ultimate possibility of 285 codes, was adopted.

For the control of the circuit breakers, a preselection indication was specified which, by means of a lamp signal on the control diagram, indicates to the operator that a correct selection has been made and that everything at the remote station is set up for the operation required. Depressing a common operate button then transmits one impulse to close or trip the switch. The effect of this method of working is firstly, that it gives confidence to the operator before he actually performs an important switching operation, and secondly, that it provides an easier method of exact timing, for a switch can be selected and then closed or tripped instantaneously as dictated by the indication of associated meters.

In the case of the Queen's Park equipment, four pilot wires were provided, the distance being relatively short. It was practicable, therefore, not to resort to code metering to provide spot readings but to use one pair of wires to interconnect as selected the potential or current transformers at the substation with the respective indicating

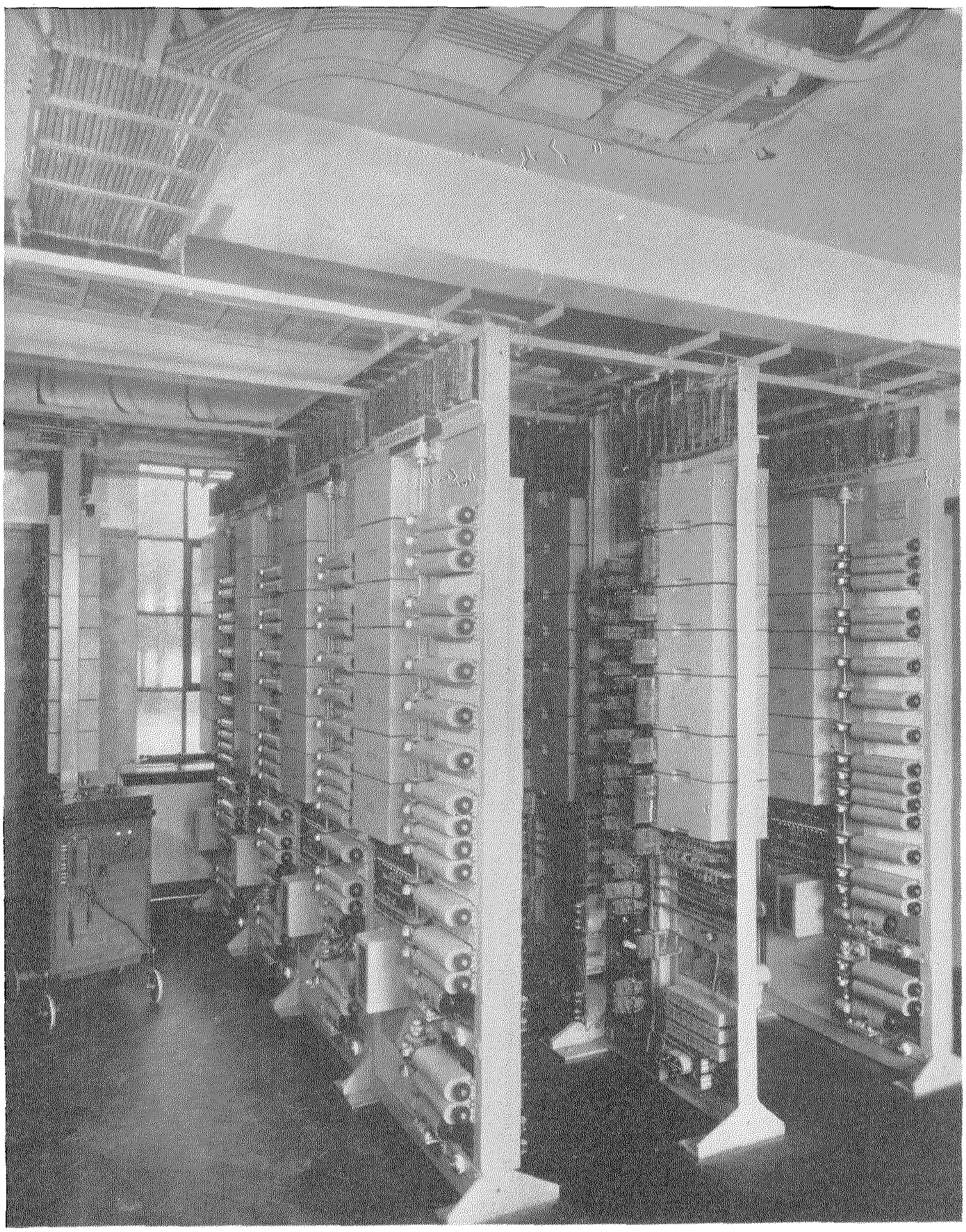


*Figure 7—General Equipment View of Apparatus Bays at Leeds Control Station.*

meters at the control station. Thus, a particular meter indication can be obtained by code selection over the pair of wires used for this purpose to connect the required transformer and meter indicator to the other pair of pilot wires. The fluctuations in the circuit selected can then be watched by the control engineer as long as he cares to leave the particular meter selection key operated. This facility has proved very useful when carrying out major switching operations, since further switch selections can, of course, be made over the coding pilot wires simultaneously with the meter indication on the metering pair.

Arrangement of the equipment at both control and substation was such that a single cubicle only was required to house the equipment. At the control station, this was mounted with the control diagram in one iron framework, the diagram surmounting the apparatus racks, the doors of which can be seen in the illustration, Fig. 10.

At the substation, interposing relays between the supervisory equipment and the switchgear proper were found to be necessary only in cases where double switch construction was employed for the main and reserve bus bars. In these cases the necessity for a relay interlock to prevent simultaneous operation of main and auxiliary units made their use essential, but in all other cases where rack-in-type switchgear is employed a direct circuit for the operation of the switches over the sequence switch brushes of the code receiver was found to be practicable and economical.

## *Remote Control and Indication of the Lighting and Heating System for a Large Store*

For a power system where contactors are used almost exclusively, a number of different points require consideration when designing a remote control system. One fundamental difference is that a contactor has to be maintained energised as long as it is closed and is not fitted with closing and tripping coils, as is the case with oil circuit breakers.

It is very desirable, particularly for the lighting circuits of a large building, that they be energised almost simultaneously. Reduced to remote control language, this implies a very large number of selections being carried out within the shortest possible time.

In considering the new Duke Street building of Messrs. Selfridge & Company, Limited, it was required to control the contactor system from the adjacent Oxford Street building switchboard room. By this means both buildings could be controlled as regards the electrical installation by one man, and simultaneous illumination could as nearly as possible be achieved.

The distance between the two switchboard rooms was not very great, and there was consequently no necessity of economising pilot wires. Direct operation of the contactor gear over large section pilot wires was, however, out of the question on the score of cost when compared with a remote control equipment operating over telephone type pilots.

A distributor system was evolved by Standard Telephones and Cables, Limited, using sequence switches of the type employed in the Rotary Automatic Telephone System as synchronous distributors. By rotating sequence switches at each end in synchronism, a number of successive and individually associated connections between push buttons at the control station and relays at the remote station could be effected as the sequence switches revolved. Similarly, a number of individual connections between auxiliary contacts on the switchgear and associated indicating lamps on the control diagrams could be effected over other cams connected to another pilot wire using the same sequence switches.

It was found that the most economical arrangement of pilot wires and cams under the circumstances was to use six pilot wires to each pair of sequence switches, capable of controlling and indicating up to eighteen contactors.

There are thirty-two contactors at present installed, all of the three-phase type, with capacities varying from 100 to 1200 amperes, whilst the remote control system has space provided for an ultimate capacity of sixty-three contactors. A view of the control panel mounting the keys and lamps for controlling and indicating the system is shown in Fig. 11, whilst Fig. 12 illustrates the cubicle and equipment installed at the remote switchroom for controlling the contactor gear depicted in Fig. 13.

For the present requirements involving thirty-

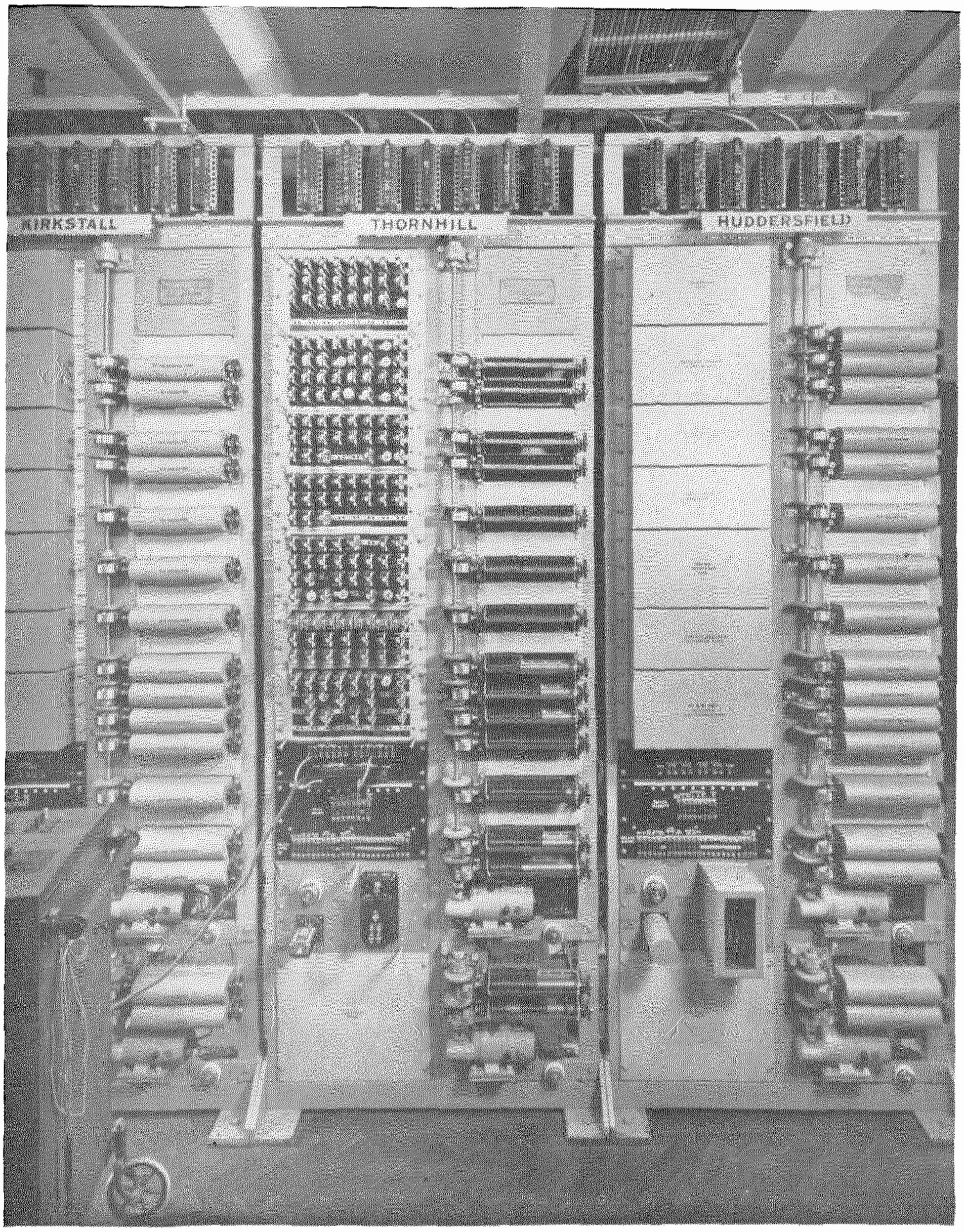



*Figure 8—Face View of Three Station Apparatus Bays at Leeds Control Station.*

two contactors, controlled and indicated, two sequence switches at each end of the equipment are used. Space for two more switches has been left, giving an ultimate maximum capacity for controlling and indicating seventy-two contactors.

The interposing relays are of the latching universal type, fitted with mercury contact tubes for operating the contactor circuits at 240 volts a-c. In addition to these interposing relays, one of which is required per contactor controlled, only seven relays per sequence switch are required by the system, in addition to a common motor start relay.

Both sets of sequence switches revolve simultaneously and, in one complete revolution taking 3.6 seconds, all the contactors can be remotely closed or opened in any combination with indications received back at the control station of all the operations performed. This time would not be extended even if additional contactor gear were installed up to the maximum for which the system is designed.

Any automatic change in the position of the switchgear, for example, releasing on fault, is immediately indicated at the control station by means of the usual indicating link circuit, which automatically starts revolving the associated sequence switches at each end.

Local control of all the contactors at the substation is possible by a simple preliminary switching operation between the supervisory control circuits and the local push button circuits; but, for local control, as well as for fault releasing, the supervisory equipment immediately and automatically indicates any changes in position.

An interesting feature of this system, which is common to all distributor systems, is that for every single operation the positions of all other switches are automatically checked.

Another interesting point is that the system operates from only one battery supply, which is located at the control station. It is a 50 volt trickle charged battery and, as a standby, a rectifier equipment has been supplied, capable of operating the system in the event of serious battery failure.

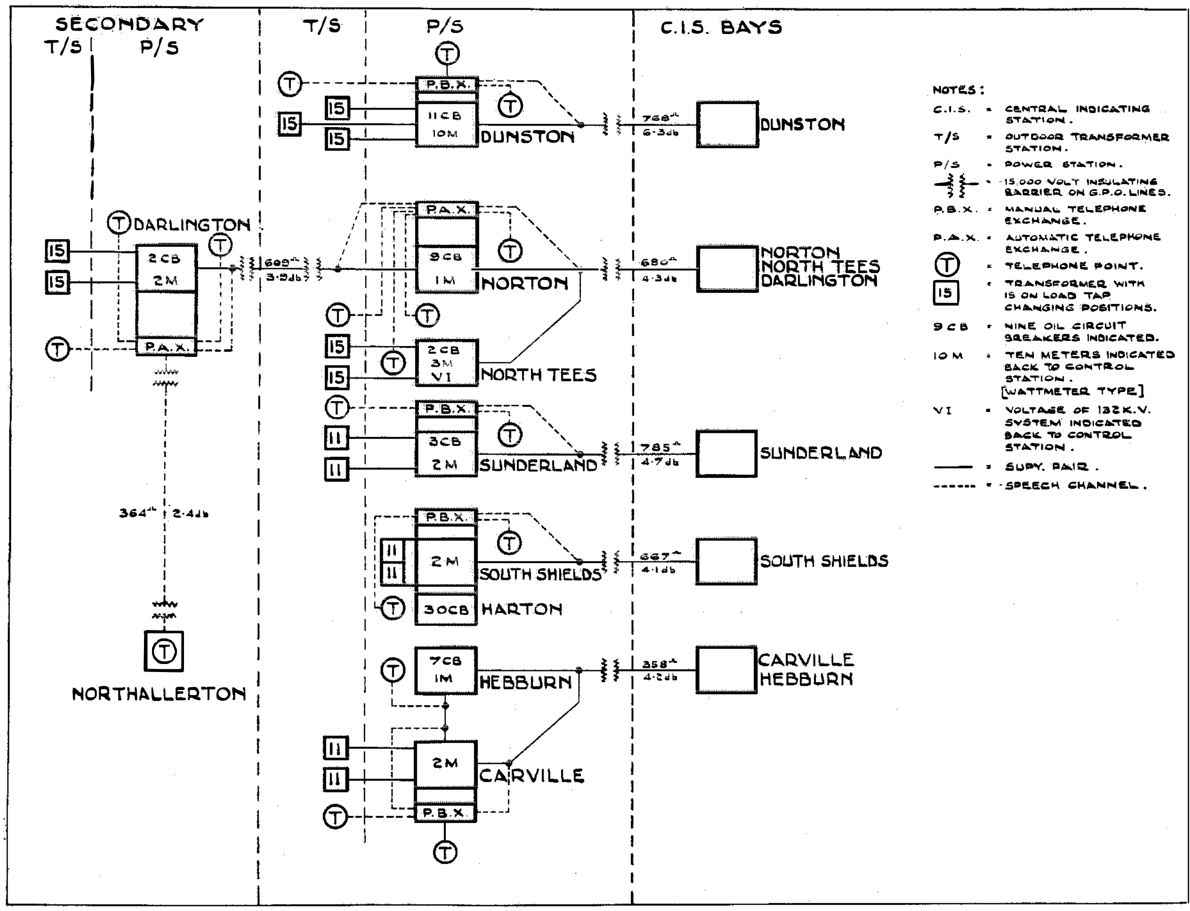



*Figure 9—Outline Diagram of Stations in the Central Electricity Board's Northeast England Area Showing in Block Form the Facilities Provided and the Interconnecting Line Available.*

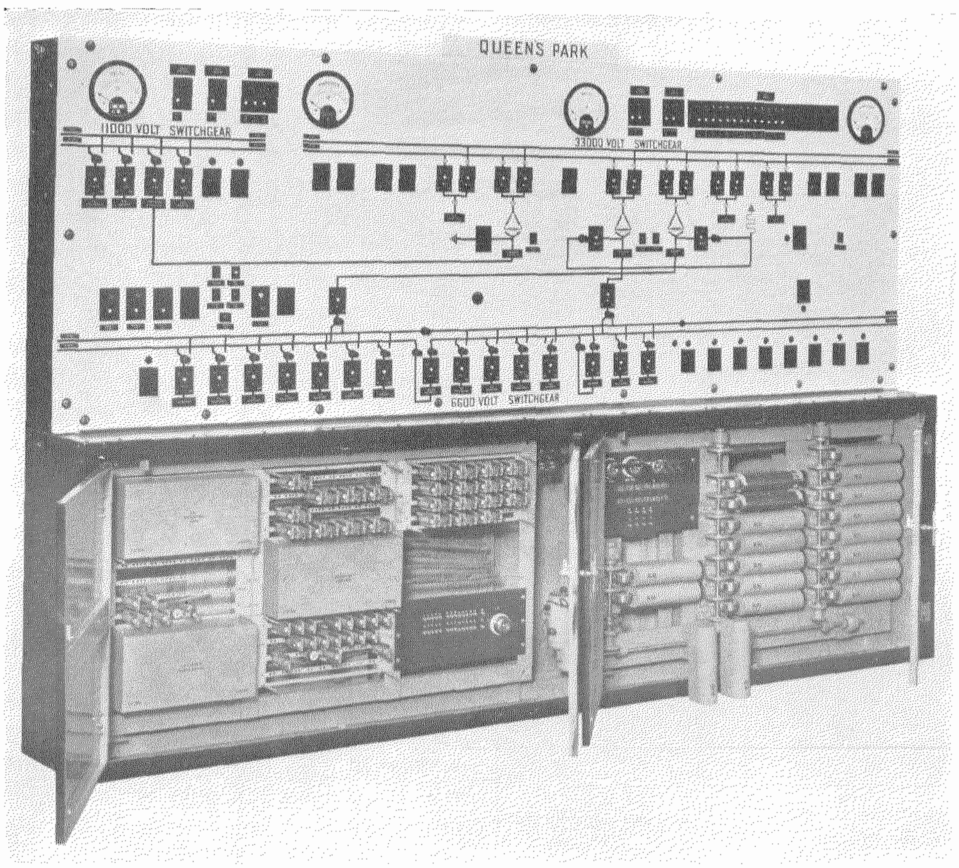



*Figure 10—The Control Equipment and Diagram for the Complete Remote Control of Queen's Park Substation.*

## *A Remote Indication System for the Sheffield Gas Company*

The Sheffield Gas Company obtains supplies of gas from a number of coke producing plants in the surrounding area. The gas produced at these coke ovens is passed into a network of pipes through which it is carried to the plant of the Company.

Unlike an electricity supply undertaking, a gas company is in the fortunate position of being able to store its product and to keep a reserve in hand. Consequently, centralised control is not so essential, but when the supply is obtained directly from coke ovens it is of first importance that, at any instant, the quantity and quality of gas being supplied by the particular coke plant should be known.

Early in 1934 a system designed to give such indications was installed by Standard Telephones and Cables, Limited, for the Sheffield Gas Company. In considering this problem, it had to be borne in mind that an indication of a six figure number of any combination was required, and therefore a series of codes for each number was out of the question. Clearly the simplest way was to transmit each digit by an equivalent number of impulses in a manner similar to dialling a six figure number, except that the impulses would have to be generated automatically from some form of electrical storage meter which counted the revolutions of the gas meter. A d-c. impulsing system, using by-path stepping switches and universal relays, was designed and operates briefly as described below.

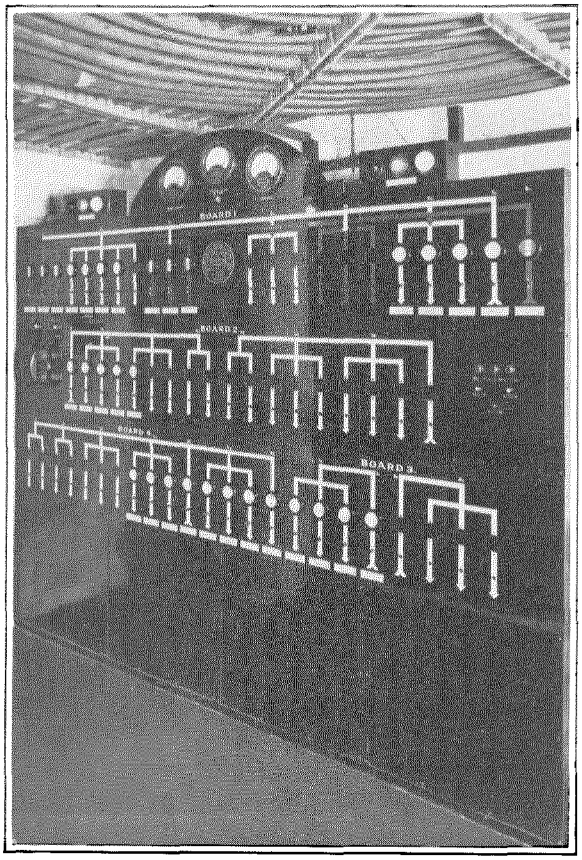


*Figure 11—The Remote Control and Indicating Diagram Board for Messrs. Selfridge's Duke Street Extension Lighting and Heating Plant.*

Gas from the coke ovens passes into a network of pipes through a volume meter at each producer plant, where its quality is measured on a recording calorimeter. The Gas Company's requirements were that a reading of the counter fitted to the volume meter and a reading of the calorific value should be transmitted on request to the control room in its central offices. Both-way telephony was also required between the control desk and the different stations, each station being connected to the control point by a pair of telephone lines rented from the Post Office for both metering and telephonic use.

At the control room, a desk (Fig. 14) on which are mounted common indicators and one key and lamp for each station, also houses the relays and switches for receiving the signals. The indicators take the form of a number of digit drums similar in appearance to the usual Veeder counter, one for indicating volume with a range of 1 to 1,000,000 thousands of cubic feet and the other for indicating the calorific value accurately to within 1 B.Th. U. for a range of 460 to 560 B.Th. U.

The equipment at a distant station is shown in Fig. 15. It consists of a number of relays and by-path switches, together with a calorific value indicator, to which reference will be made later, mounted in a small cabinet. Fifty volt batteries arranged to be trickle charged from the mains are installed at the control point and at each distant station.

When the control desk key associated with the particular station is thrown to "indication," a positive pulse is sent over the line to that station, causing the apparatus there to transmit back to the control desk a series of impulses corresponding to the readings of volume and calorific value at that instant. When the key is thrown in the other direction to "telephone," a negative impulse is sent over the line and this causes the bell in the telephone instrument at the distant station to be rung.

The volume meters used at the coke ovens are of the positive displacement type and are fitted with counters which record the volume of gas which has passed through the meter in thousands of cubic feet. A pair of contacts, attached to the counter and arranged to close every time a volume of 1,000 cubic feet has passed through the meter, operate a train of three by-path switches forming an electrical storage system which normally keeps in step with the meter counter and can record up to six digits, each switch having a 100 contact bank. It is from the position of these switches at the time a reading is requested that the digits of the code are fixed.

It is essential, however, that these switches be not moved during the transmission of the reading, despite the fact that the volume meter will still be functioning and may send several impulses into the storage group during code sending. In order that these impulses shall not be lost, an auxiliary switch is provided, to which the impulses from the volume meter are routed whilst transmitting, the circuit being arranged automatically to transfer them into the main storage group at the conclusion of sending.

The calorimeter used at the coke ovens is of the type which gives a direct reading of calorific value from the difference in temperature of two points in its water system. Resistance thermometers are fitted at these two points and connected to a bridge circuit containing a galvanometer which acts as a direct reading calorific value indicator. The galvanometer is fitted with contacts in the manner already described in connection with the scheme for the Central Electricity Board, except that it has 100 contacts instead of 49. These 100 contacts are connected to the bank of a stepping switch so that, when a reading is requested from the control station, the moving contact carried by the pointer is brought into contact with one of the fixed contacts, and the switch hunts for the point on the

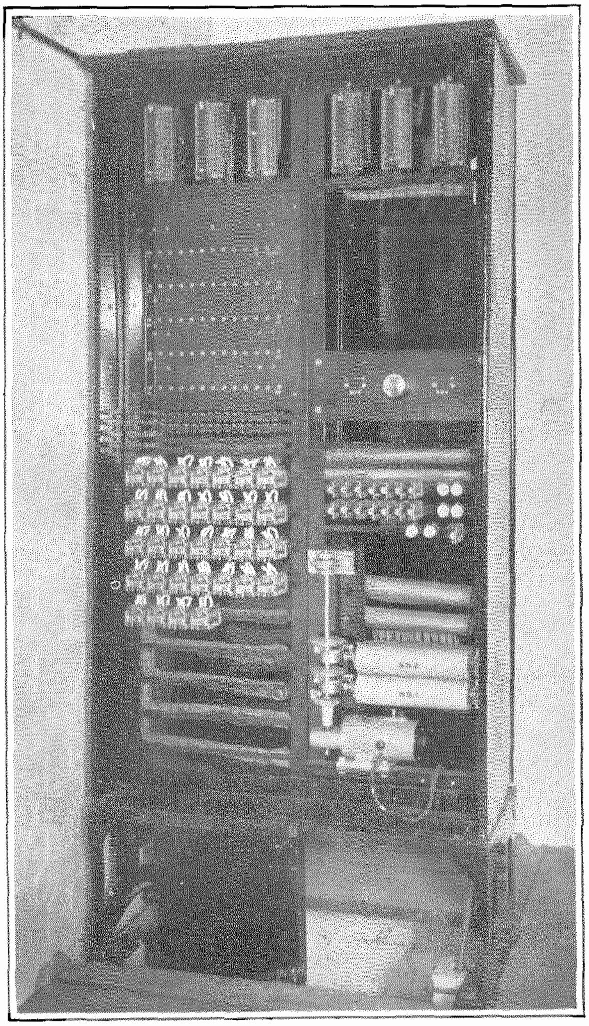


*Figure 12—The Remote Control Cubicle in the Unattended Switchroom of Messrs. Selfridge's Installation.*

bank corresponding to this contact. The position of the switch is then used to determine the code to be sent back to the control desk.

It will be realised that when a reading is requested the train of storage switches and the switch associated with the calorific value indicator mark points on their banks corresponding to the reading which is to be sent back to the control point. A further switch is arranged to hunt for these bank positions in turn, stepping under control of a pendulum relay, each step causing an impulse to be sent over the line to the control point. These impulses cause the indicators on the control desk to step in turn, thus displaying in the window of the indicator the desired readings of volume and calorific value. When the request key on the desk is restored, the indicators return to their normal positions.

To call the control point from any of the substations, it is only necessary to lift the hand set of the telephone instrument at the station. This causes an impulse to be sent over the line to the control desk where the circuit is so arranged that with the request key associated with that particular station in its normal position, such an impulse will cause the bell of the telephone instrument at the control desk to be rung and will light a lamp associated with the particular station.

## *A Remote Control and Indication System for Water Power*

For the efficient control of a hydro-electric station, it is essential that the power station control engineer shall have full knowledge and control of the water power available. Generally, such schemes consist of a reservoir, one or more dams or control weirs, an aqueduct, and pipe lines feeding from the aqueduct into the power station with a tail-race for the spent water returning to the river channel.

Water power is, of course, considerably less flexible than steam power, and since it usually extends over several miles of country, a change of conditions in, for example, the reservoir, may not be felt in the power house for some several minutes. Thus a number of indications of water level and water flow at various strategic points are required to be continuously indicated in the

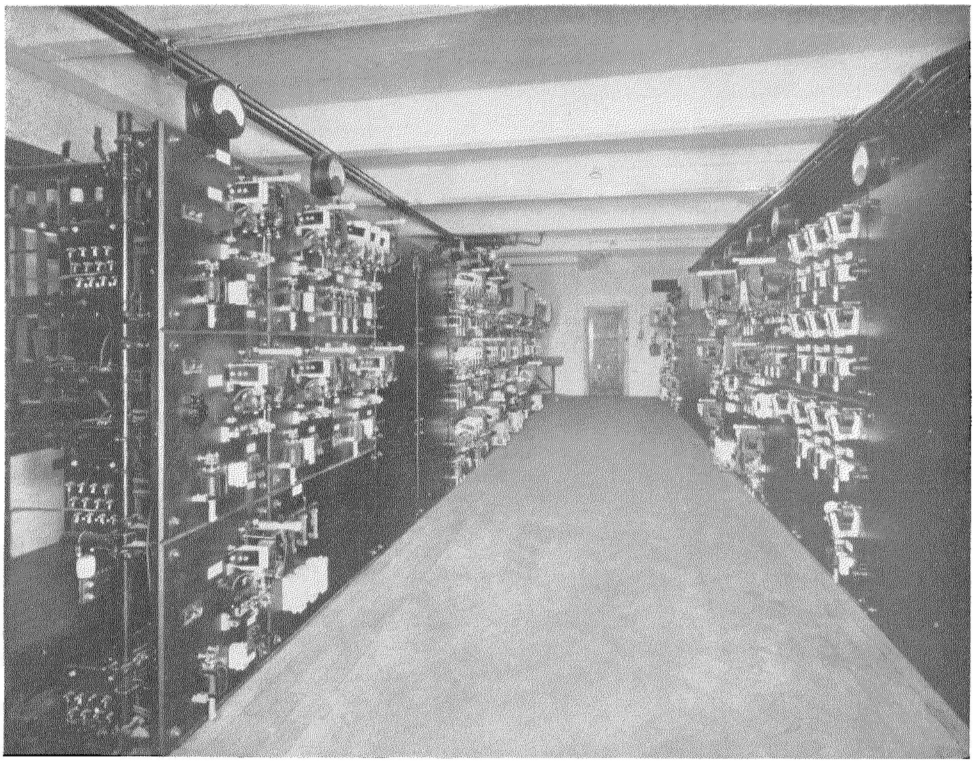


*Figure 13—View of the Contactor Switchroom of Messrs. Selfridge's Duke Street Extension which is Completely Remotely Controlled from the Adjacent Oxford Street Building.*

power house with remote control of the sluice gates and pipe line valves.

Fig. 16 illustrates the control desk designed by Standard Telephones and Cables, Limited, and installed at the Tummel Power Station of the Grampian Electricity Supply Company. On this desk are mounted the gate and water condition indicators in an outline diagram of the water system.

The Tummel scheme may be considered as starting from Loch Rannoch, a reservoir with a drainage area of 284 square miles. The outflow from the loch is controlled by three sluice gates. The original water channel is followed for 4 miles where the intake dam has been constructed to take care of the daily variation in load. At this point the water divides; that required for the operation of the power station being drained off through automatically controlled gates into an aqueduct, whilst a minimum flow passes down the river channel through two further sluice gates in order to keep the river in condition to meet the requirements of the Fishery Board. These latter gates are large enough to enable flood water to be passed down the river.

From the intake dam the water travels along a concrete aqueduct about 2½ miles long; then, passing down two pipe lines to the power house, it drives two 24,000 B.H.P. Boving turbines coupled to two 17,000 kva. British Thomson-Houston alternators. The spent water passes through the front of the power station into the tail-race and so back into the river channel.

Originally the following requirements were specified:

(1) The control and position indication of three gates at the control weir.
*(2) Water level indication at Loch Rannoch.
*(3) Water flow below the control weir.
(4) Indication of the position of the main gates in the intake dam at Dunalastair.

(5) Indication of the position of the aqueduct extension gates.
(6) Control of the aqueduct gates.
(7) Water level indications at the main dam and across the screens.
*(8) Water flow at the measuring weir below the dam.
(9) Control and position indication of the pipe line valves at the forebay.
*(10) Water levels at the forebay tail-race.

A later requirement was that those items marked with an asterisk were to be continuously recorded on chart recording instruments.

With two major considerations in view, firstly that continuous indications were required from a large number of remote locations, and secondly that to provide any facilities at all a pilot cable had to be constructed on an aerial route, it was decided to adopt a system using a separate pilot wire circuit for each function, combining only those of control and indication of any one unit over the same pilot wire circuit.

Additional features were the indication of supply failure at any of the three remote locations, namely, the Control Weir, the Dunalastair Dam, and the Forebay at the top of the pipe lines. A feature also provided was the indication by means of two lamps of the direction of movement of any of the water indicators. That is to say, if the water level in Loch Rannoch were rising slowly and steadily, the red lamp associated with the indicator would be illuminated. Similarly, if the water level were falling, an amber "falling" lamp would be illuminated. With the apparently slow movement of water under normal conditions at certain points in the system, these lamps have proved extremely useful in association with the actual indicators.

*Figure 14—Indicating Desk at the Sheffield Gas Company's Head Office for Receiving Indications from Five (maximum nine) Coke Oven Plants.*

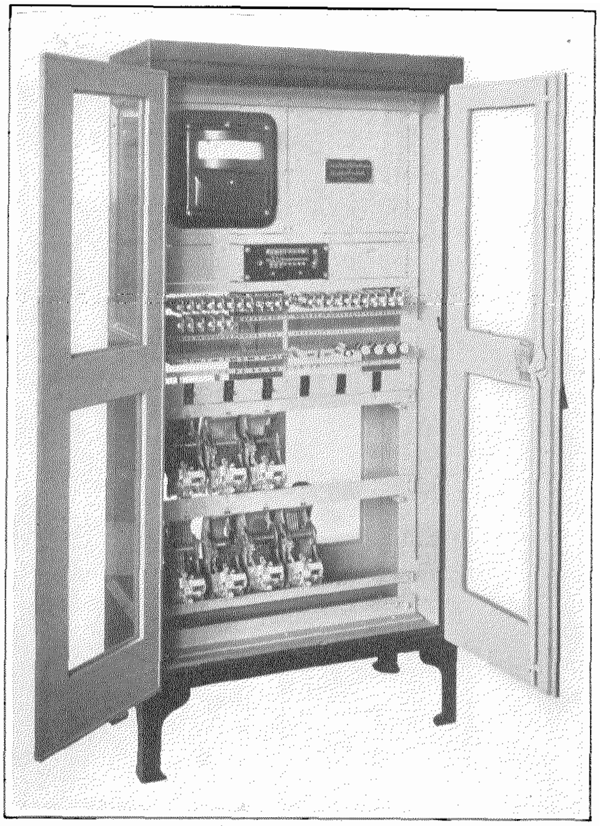


*Figure 15—A Coke Oven Plant Installation for Remotely Indicating the Quality and Quantity of the Gas Passing into the Sheffield Gas Company's System.*

It was found possible to concentrate the connection to the sluice gates and water level instruments at three points, namely, the Control Weir, the Dunalastair Dam, and the Forebay, and three cables were supplied and erected connecting the power house to each of these locations. Owing to the rocky nature of the country and the fact that an overhead transmission line at 11 kv. already existed, the pilot cables to the Control Weir and the Dam were erected underneath this transmission line on an aerial suspension wire. Considerable attention was given to the protection of these pilots and a scheme using three carbon protectors in parallel to earth for every individual wire, together with a kick coil in series with the line to cater for lightning surges,

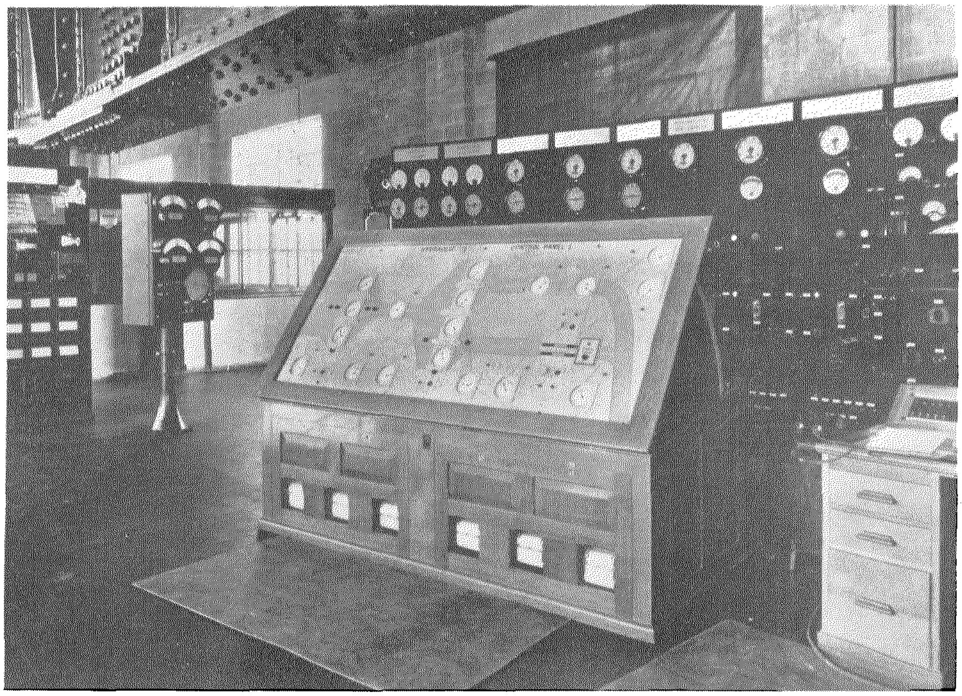


*Figure 16—The Control Desk in Tummel Power Station for the Remote Control and Indications of the Hydraulic Scheme.*

was adopted. In addition, the cable was specially constructed to withstand 2,000 volts between conductors and lead sheath, so that, with a protection system which should break down at between 400 to 500 volts and an insulation withstanding 2,000 volts, it was considered that the cable was suitably protected against all cases of surges induced by the power system.

Telephone communication between the power house and each of the three remote locations was also provided, a simple arrangement of magneto ringing being adopted with an additional protection to the telephone user by including a 15,000 volt isolating transformer at the pilot cable termination of the telephone circuit.

The actual circuit arrangement for the indications is a balanced bridge circuit operating over two wires individual to each indication and using a common return wire to avoid the necessity for batteries at the remote locations.

Each bridge consists of a potentiometer operated by the water meter or sluice gate mechanism at one end, and a similar potentiometer divided into 50 steps connected to the bank of a line switch arranged to step either backwards or forwards at the other.

The wipers of the line switch and the moving arm of the remote potentiometer are connected over the common return wire and through the 110 volt battery at the power station. A sensitive polarised relay, adjusted to a centre or neutral balance, is connected into the line circuit with two equal windings, one in each line. The contacts of this relay operate the stepping line switch, moving its wipers forward for one direction and backward for the other direction of operation of the relay.

Such an arrangement, it can be seen, provides an automatic self-balancing bridge, since any movement of the remote potentiometer is taken up by an equal and opposite resistance change by the line switch potentiometer until the polarised relay receives equal and opposite currents, and is restored to its neutral contact position.

In the case of the sluice gates, remote control is effected by reversing the above arrangement. In other words, the raise and lower push keys on the control diagram, when operated, step the line switch out of position and preset it to the desired position. This upsets the relay balance and, upon operation of a common operate button, the contactor circuit is closed to start the gate motors at the remote location, the motors continuing to operate until current balance is restored to the relay. An additional key on the control desk for each set of gates can transfer the control from the power house to the remote site.

Each indication on the control desk is obtained by direct gearing between the needle of the instrument and the rotating wiper assembly of the associated both-way line switch which is mounted directly at the rear of the panel.

The equipment arrangements for such a system are very simple and consist of the control desk (Fig. 16) at the power house, in which are mounted all the relays and switches, whilst at each location a wall mounting steel box housing the contactors for the remote control of the gates, together with the cable terminations and telephone set, comprise all the equipment necessary.

In the control desk, Duralumin panels finished by sand-blasting and colourless lacquer were used. The water panels were engraved approximately 1/32 inch deep and filled in with blue enamel, resulting in a well balanced and pleasing diagram.

The system was cut into service in February, 1934.

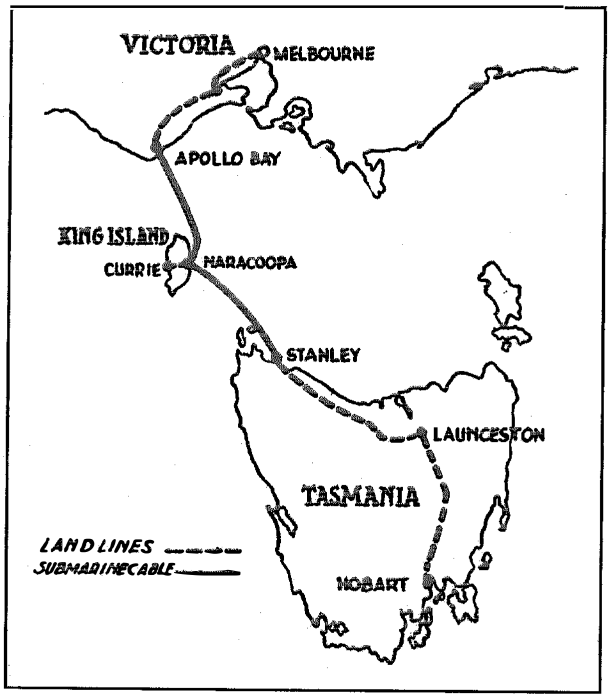
# Recent Telecommunication Developments of Interest

FOR some time provision of telephone service, either by means of a radio telephone link or a submarine cable, from the Australian mainland to Tasmania has been under consideration. On the recommendation of the Commonwealth Public Works Committee, Parliament decided that the cable plan should be adopted.

The two existing telegraph cables between the mainland and Tasmania are not suitable for providing telephone channels, but they will be retained for telegraphic service, and provision has been made in the new cable to meet all telegraphic requirements in the event of the failure of either or both.

The cable will contain a single central conductor with special dielectric insulation and a concentric type return conductor, the channels being obtained by superimposed carrier telephone systems. It will be similar to the 1930 Key West-Havana cable, and will consist of two lengths of 81 nautical miles, or 162 nauts. overall.

The central copper conductor will be surrounded by a dielectric of mixed para rubber and gutta-percha or balata. The cable return conductor will consist of five tapes wound concentrically around the insulation. As a protection against the teredo worm a copper tape will be wound continuously around the cable, which will then be armored in the usual manner with steel wires embedded in jute.




The dielectric to be used is called para gutta, the use of which will very considerably reduce dielectric losses.

The equipment it is proposed to install ultimately will provide six telephone circuits and one single direction, reversible broadcast program circuit. The telegraphic circuits will be obtained from a voice frequency carrier telegraph system to be used on one of the six telephone circuits. The channels will be obtained over the cable by means of a telephone carrier system, operating on the following frequencies:

FREQUENCY OF CARRIER CHANNELS

| Channel | Frequency, Cycles per Second |
|---|---|
| No. 1 | 0 to 3,000 |
| 2 | 3,000 to 6,000 |
| 3 | 6,000 to 9,000 |
| 4 | 11,000 to 14,000 South to North<br>21,000 to 24,000 North to South |
| 5 | 14,000 to 17,000 South to North<br>25,000 to 28,000 North to South |
| 6 | 17,000 to 20,000 South to North<br>28,000 to 31,000 North to South |
| Broadcast Program Channel | 34,000 to 42,500 |

The associated land lines will employ Standard carrier telephone systems.

The carrier system to be used over the cable will differ slightly from the land line system, in that for two of the channels on the cable the same frequency will be used in both directions, whilst the general arrangement on land lines will be to use different frequencies in each direction.

Initially it is proposed to install four telephone channels only over the cable.

The broadcast program channel equipment will provide a flat transmission characteristic from 35 to 7,500 cycles per second; and, since the velocity of propagation will be high over the whole system, there will be practically no appreciable phase shift.

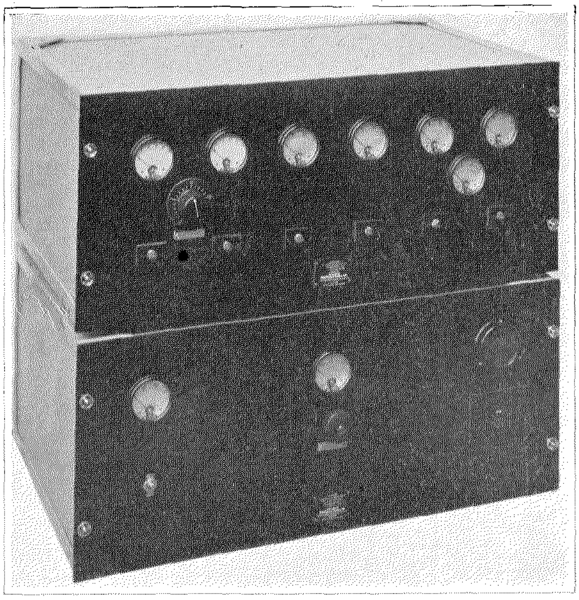
The cable terminal equipment at Apollo Bay and at Stanley will be similar to that provided in the Standard carrier telephone systems. The various channels transmitted over the cable at carrier frequencies will be transformed to voice frequencies at these stations and therefore may be monitored by the mechanics operating the equipment.

The voice frequency telegraph equipment to be supplied at Melbourne and at Launceston will provide five channels initially but, if developments warrant it, the number of channels which can be provided over this system is eighteen duplex channels working at a speed of 33 cycles per second.

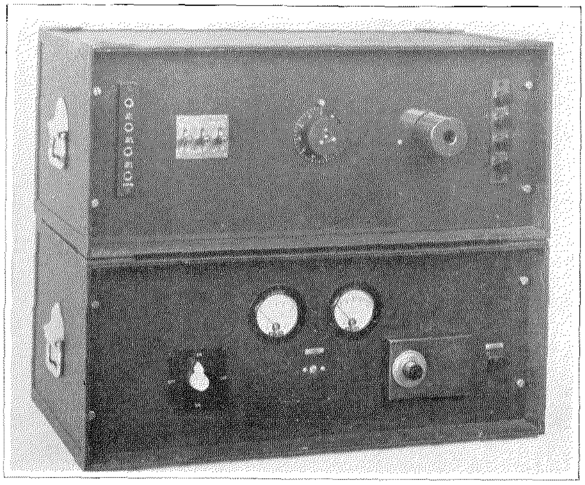
The submarine cable is to be manufactured and laid by Siemens Bros. and Co., Ltd. of Woolwich, England, which is represented in Australia by Siemens (Aust.) Pty., Ltd. The short equipment will be supplied by Standard Telephones and Cables, Ltd., London, which is represented by Standard Telephones and Cables (Australasia), Ltd. The service will be in operation towards the end of this year.

NOTE: Abstracted by permission from The Electrical Engineer and Merchandiser, September 15, 1934.

THE 28.LU.2C 100 watt compact type amplifier, shown in the accompanying illustration, represents a type used in connection with the broadcasting of the Eucharistic Congress held in Buenos Aires in October, 1934. Its characteristics are: anode dissipation, 40 watts at no-load and 200 watts at full-load; power handling capacity, 90 watts for 5% harmonic and 100 watts for 10% harmonic; gain, 36 db.; minimum input, 50 milliwatts; input impedance, 500 ohms; optimum-load impedance, 24 ohms; and frequency range, 30 to 10,000 cycles with a deviation of 2 db. within the frequency range. The amplifier is driven by the MS.3029-3 amplifier.



THE 28.LU.1B portable amplifier, operating from a-c. supply mains, is similar to a type used in connection with the Eucharistic Congress at Buenos Aires. Its characteristics are: anode dissipation, 120 watts; power handling capacity, 30 watts for 5% harmonic and 40 watts for 10% harmonic; gain, 105 db.; minimum input power, $1.5 \times 10^{-3}$ microwatts; input impedance, 400 or 25 ohms; optimum-load impedance, 128, 32, or 8 ohms; and frequency range, 30 to 10,000 cycles with a deviation of 4 db. within the frequency range.



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