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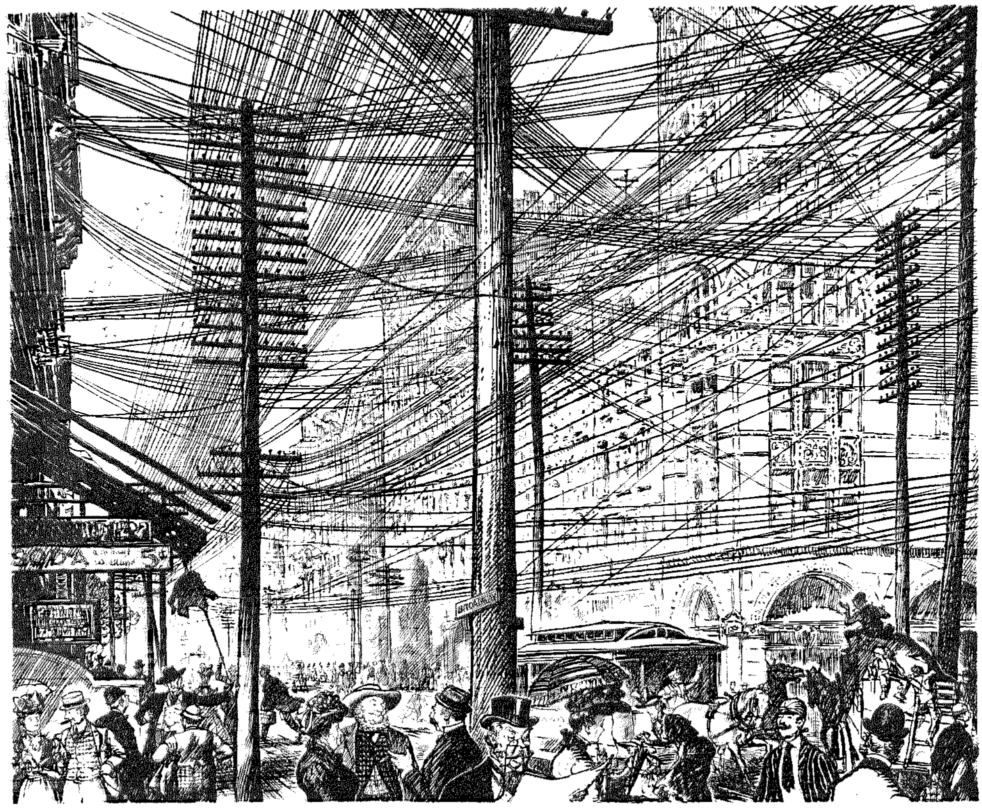

NEW YORK CITY IN 1890. TODAY NINETY-FOUR PER CENT OF THE BELL SYSTEM'S 80,000,000 MILES OF WIRE IS IN CABLES; SIXTY-FIVE PER CENT OF IT IS BENEATH THE GROUND

Electrical Communication in 1935

General Trend of Development

INCREASING development activity has characterised the year 1935, and substantial progress has been achieved in the technique of communication along lines foreseen some years ago in the two broad divisions of the field—switching and transmission.

Switching development is following its logical course in the progressive extension of automatic switching systems for large cities or restricted areas, to automatic systems designed for larger areas with the ultimate aim of nation-wide automatic service. National dialing or direct dialing from any one subscriber to any other subscriber presents the problem of long distance transmission of dial impulses and of various signaling impulses. A two-frequency system has been developed and will probably find wide application in Europe. The 50 cycle system, extensively used in Europe, has been improved to reduce sending voltages.

The switching equipment for national networks includes many new developments, such as alternate routing of calls, time and zone metering.

Private Branch Exchanges are now developed to give many new facilities[1].

The wire transmission art, after a period of relative stabilisation with the loaded and repeatered cable systems, is now in process of active development due to the introduction of non-loaded cable systems operating on a multi-channel carrier basis. Development is proceeding along two broad lines: (1) Multi-conductor cable systems where a number of channels are carried over each pair; and (2) The coaxial cable systems[2] where all channels are carried over a single coaxial line. These developments have been proceeding for some years, but the point of outstanding importance in 1935 is that two experimental cable installations, one of each of these types, have been decided upon by the British Post Office. Both cables are being manufactured by Standard Telephones and Cables, Limited, and their installation has commenced. Two 19 pair cables (one go and one return) are being installed in one duct between Bristol and Plymouth, the cable and associated repeaters being designed on the basis of 12 channels per pair. One cable, comprising four coaxial lines, is also being installed between London and Birmingham. This cable is designed for the ultimate transmission of a large number of telephone channels or for the transmission of television.

In the United States, plans have been completed for an experimental installation of a coaxial cable between New York and Philadelphia.

Teishinsho have been conducting highly interesting experiments with cable carrier equipment between Osaka and Nagoya; and the Manchukuo Telephone and Telegraph Company, in conjunction with Teishinsho and several Japanese manufacturers, have developed a carrier system for use on non-loaded cables. The trial use of this system will be on cable circuits between Antung and Mukden in Manchukuo; it is expected that it will be opened for service early in 1936.

Carrier and other improvements in transmission systems offer the possibility of cheap long distance circuits, and the combination of cheap long distance circuits together with automatic ticketing of toll calls, may be the next important stage in telephony in many countries.

In the radio field, also, active development is taking place. The broadcasting of speech and music is imposing a demand for generally higher power and higher quality at minimum annual cost. These requirements are being met in various ways. The power generally used in Europe for large new stations on medium waves is 100 kW. carrier. Two principal types of station are being called for: one uses the penultimate stage series modulation with floating carrier, for example, the new Swiss installation at Sottens; the other uses high power modulation on the last stage with a class "B" low frequency amplifier. A station of the latter type is under construction for the British Broadcasting Corporation.

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

Higher power, also, is being used for short wave broadcasting. A high power short wave station employing high power plate modulation is being constructed for the British Broadcasting Corporation.

In the medium and short wave point-to-point field, changes in design have been of comparatively minor importance. One requirement which appears to assume importance in many services is that of the automatic wave change of transmitters. On the Cunard White Star R.M.S. "Queen Mary," four radio transmitters will have dial-controlled, instantaneous wavelength change devices.

Considerable development work has been done during the year in the ultra-short wave point-to-point field, and applications are being made, among them a telephone circuit for the extension of the Spanish telephone network to the island of Majorca.

In view of the general adoption of high definition for television systems, medium power ultra-short wave transmitters now represent the recognised method for broadcasting the wide bands required for television signals. Television broadcasting transmitters are now in experimental operation in France and Germany. In England, at the recommendation of the Television Advisory Committee, preparations are nearing completion to give regular programmes by means of two television systems.

Progress in Communication Systems

The European long distance telephone systems have been extended in several countries and many of the international circuits already provided between the various capitals have been increased in number, particularly where spare circuits were available in the cable and the additional circuits were obtainable merely by the installation of more repeater equipment.

In Great Britain, the Liverpool-Glasgow portion of the new London-Glasgow cable was completed early in the year, thus providing many additional high grade circuits to the north. A successful demonstration of single channel carrier telephony was given over the cable which had been specially designed to make this possible, and circuits of this type will be installed as the traffic demands warrant. The London-Liverpool portion of this cable was completed by the end of November.

A considerable amount of terminal equipment for use on underground cables has been installed.

A very great extension in trunk line facilities has taken place during the past year. The provision of additional circuits during the last quarter of 1934, necessary to meet the great increase in trunk traffic resulting from the reduced evening charge for telephone calls, constitutes a record in Great Britain. During this period 499 additional trunk circuits were set up, comprising 159,000 miles of wire with 831 repeaters or amplifiers. In some instances, carrier sets were made use of to provide additional circuits.

A long distance cable was cut into service in France between Dijon and Mulhouse (272 km).

In Norway, the first section of the new long distance telephone cable system was completed between Sande and Sandefjord. The electrification of the railways in Norway has necessitated the provision of several telephone cable systems, a number of which were completed during the year.

The Czechoslovakian long distance telephone system, which is already very extensive, was further extended towards the east by a cable between Brno and Uh. Hradiete. Provision has been made in this cable for very long distance communication by means of high velocity circuits. Very lightly loaded pairs are included for this purpose; and, from each two pairs, one voice frequency and three carrier circuits will be obtained.

In Italy, additional equipment was added to provide more circuits over the main backbone route and new cables were installed between Turin and Modane, and between Milan and Casteggio. The former cable now links the Italian long distance telephone system to the French network.

The Australia-Tasmania submarine cable was laid towards the end of the year. During the year, the complete terminal equipment was manufactured by Standard Telephones and Cables, Limited, and is now in course of erection. This equipment comprises not only the cable terminal stations on the mainland of Australia and Tasmania and a repeater station on the intermediate island in the Tasman Sea, but also the open wire carrier equipments for the extension of the telephone and broadcast programme channel circuits to Melbourne on the mainland, and to Launceston and Hobart on Tasmania. Many features of the cable terminating equipment are new, including, for instance, feed-back controlled amplifiers capable of handling simultaneously the many telephone and broadcast channels transmitted over the submarine cable.

In China, installation is now proceeding of the equipment for the large open wire toll network covering nine provinces.

The use of carrier systems over open wire lines in Europe has continued to expand and a large number of installations have been put in service. It is interesting to record that, in Argentina, the first 3-channel system (with voice frequency telegraphy on one channel) was installed over railway train despatching circuits.

The Republic of Paraguay and the northeastern part of Argentina—comprising the Provinces of Entre Rios and Corrientes, and the Territories of Chaco and Misiones—have had telephone connection with the rest of Argentina since July, 1935, by virtue of an interconnection agreement with the United River Plate Telephone Company, Ltd. As a result of this interconnection, international telephone service to other countries in South America, to North and Central America, Europe, and other parts of the world, has been made available to 18,500 subscribers in 169 towns.

During the year the circuit between Capetown and Johannesburg, which covers a distance of approximately 1,000 miles, was brought into service. This circuit provides three carrier telephone channels, in addition to the normal voice channel, one of which is used to obtain 18 V.F. telegraph channels.

Substation Equipment

The Bell Telephone Manufacturing Company, Antwerp, has started the manufacture of a new type three-piece moulded handset, replacing the five-piece type microtelephone. The new type also is fitted with a capsule type receiver.

The development has also been completed of a 25 station impulse sender for three digits, intended for use in P.B.X. installations.

In the moulded type of subscriber set, a wall and table set has been designed in Antwerp for use in very severe tropical climates, including protection against attacks of insects.

A new scheme for transmission testing of subscribers' apparatus in the course of ordinary maintenance duties, is about to be launched by the British Post Office. A noise of standard volume, produced by a clockwork device contained in a small box, is applied to the telephone. The output is measured, either at the line terminals of the telephone or at the exchange, according to circumstances, by a decibel meter. The visual indication of the performance of the subscriber's telephone thus obtained is more reliable than the oral method using artificial cable, hitherto employed.

Intercall and Signaling

The Bell Telephone Manufacturing Company, Antwerp, during 1935, completed the development of a 50 cycle intercall railway system for secret service, giving selective calling by ordinary dialing, facilities for interconnection with an automatic central office, and provisional emergency means for calling in case of mains supply failure. This system provides greater possibilities for use and is cheaper than the intercall railway system, using the No. 50 type a-c. selector.

A directional axle counting system has been developed by Standard Telephones and Cables, Limited, and installed at Liverpool Street Station (L.N.E.R.) which caters for shunting movements and terminal roadworking. Similar equipments are being produced for Reading and Harrow.

An automatic reset arrangement for railway signaling has been developed by Standard Telephones and Cables, Limited. In case of false alarms, the apparatus is reset.

A new train describer system has been developed by the Standard Telephones and Cables, Limited, and installed at the Manchester Central Station. The design is such as to enable the train despatcher at the terminus or at any other point where trains are originated, to transmit descriptions simultaneously to any number of stations or signal cabins on the track. Illuminated displays automatically apprise signalmen or passengers, or both, of the identity of approaching trains in the order in which they will arrive. The system incorporates the safety features of block working, with the speed and convenience of a modern train describer.

The Certophone System, recently developed by Standard Telephones and Cables, Limited, provides for communication between an engine driver who is held at a danger signal, and the signalman who controls that signal. The signalman receives positive advice as to the location of the train and may recall the waiting engine driver.

Telegraph

In June, 1935, the British Post Office introduced the sixpenny telegram. In the first ten weeks following this tariff reduction, the number of telegrams handled increased by 30% and orders were placed with Creed & Company, Limited, for additional teleprinters.

In 1935, Creed teleprinters were installed at all the principal employment exchanges in London to expedite the interchange of information regarding vacancies and available labour.

In the summer, a Ticker Service, operated by means of Creed teleprinters, was inaugurated by the Union of South Africa in Johannesburg and Pretoria, and it is proposed to extend the service to Capetown. Similar services are being set up in Sydney and Melbourne, Australia.

An interesting development has been the modification of the model 3-R Creed teleprinter to enable it to be used as a multiplex tape printer. Several of these modified machines have been supplied to the New Zealand Government. It is of interest also to note that this Government has standardised the use of automatic tape transmission, and that special Creed teleprinter equipment has been supplied to equip the circuits feeding the main multiplex channels.

Increased use of teleprinter apparatus is being made by police forces in Great Britain and in other countries.

The Swedish Telegraph Administration purchased fifty teleprinters, and extensions have been made to the Tidningarnas Telegrambyra News Distributing Service.

A long distance teleprinter communication service of special interest was introduced by the Agence Havas between Paris and Madrid, the circuit being an international telephone line with single channel voice frequency equipment.

In Spain, steady progress was made during the year in extending the teleprinter network of news services. Six agencies are at present employing thirty-seven receivers for these services over Telephone Company lines. The Telegraph Administration also increased its use of teleprinters.

In line with the established practice of other European Administrations, the Latvian Telegraph Administration is introducing teleprinter systems; the first order for equipment having been placed with Creed and Company, Limited.

Teleprinter Developments by General Post Office

An automatic transmitter which will send continuous repetitions of a message containing a total of not more than one hundred characters has been developed. The transmitter, which is arranged for 7½ unit working, is of the brush and distributor plate type and therefore sends out essentially perfect teleprinter signals. It can be arranged for sending out a test message for testing on teleprinter circuits, and also can be adapted for sending out operating instructions on teleprinter exchange circuits.

Experience gained with the synchroscope for measuring teleprinter speeds, has shown it to be a valuable adjunct to the telegraph equipment for testing and maintenance work, and also for the rapid diagnosis and elimination of speed faults on teleprinter circuits.

A 50 cycle per second valve-maintained tuning fork unit has been developed for checking the speed of teleprinter motors in localities where 50 cycle frequency-controlled a-c. mains are not available. The fork is intended for use in conjunction with a synchroscope or a telegraph distortion and margin tester, and a special unit has been developed to enable the synchronous motor of the synchroscope to be driven from the fork. In order that any number of synchroscopes or telegraph distortion and margin testers may be operated from one fork, its output is arranged to drive a telegraph relay and the energy required for the various units is taken from the tongue of this relay.

Teleprinter Broadcast Systems

A system suitable for use over Tariff A circuits has been designed, with the switchboard and apparatus rack similar to those used for short lines. Special clearing facilities had to be provided in view of the fact that double current working is used for transmission as well as for reception.

Teleprinter Exchange (Telex)

A facility has been introduced for the purpose of enabling a Telex operator to attract the attention of a Telex subscriber who is continuing to teleprint although the other party has been cut off. For this purpose a special jack, to which the operator connects the subscriber, is provided on the Telex position. The insertion of a plug in this jack starts up an automatic teleprinter transmitter which sends out signals designed to attract the attention of the Telex subscriber.

Teleprinter trials have been carried out by a number of European telegraph administrations to explore the possibility of introducing person-to-person teleprinter services; also, in connection with the establishment of international teleprinter services.

Voice Frequency Telegraphs—Developments

A voice frequency system, designed to provide for a maximum of four 2-way channels over a 2-wire telephone circuit between a voice frequency main centre and a voice frequency sub-centre, has been developed for use in cases where it would not be economical to install 12 or 18 channel equipment. The equipment at the sub-centre is arranged for "all-mains" working, and thus requires connections only to the mains supply and to the local lines. The equipment, consequently, is transportable.

A transmitting unit, incorporating copper-oxide rectifiers, has been designed to replace the sending relay on the multi-channel voice frequency systems. The unit has no moving parts and enables the carrier frequency to be modulated in accordance with the transmitted d-c. signals. All systems will eventually be equipped with these units.

British Broadcasting in 1935

The British Broadcasting Corporation has continued the development of its scheme of distribution and, in order to obtain more even coverage of the British Isles, the London, North and West National transmitters have been synchronised on 1149 kc., thus freeing a channel for the Newcastle station.

New high power stations are in course of construction for the North of Ireland and for the North of Scotland. Sites have been purchased for a similar station at Newcastle and for a low power station at Bangor, North Wales. When this programme is completed there will be a total of thirteen high-power transmitters in operation, providing an alternative programme service to about 85% of the population and a single programme service to about 98%.

New orchestral studios representing the latest advances in studio technique have been constructed at Maida Vale, London, in a large building which was formerly a roller-skating rink. Studio No. 1, which has a volume of 230,000 cubic feet, is the largest yet constructed in England.

Considerable attention has been paid to recording methods and a recording van has been equipped to tour the country and obtain records of interesting events on the spot. The van is useful also for the collection of natural effects for feature programmes. The recording section is now centralised at Maida Vale, where there are three steel tape recording rooms each containing two steel tape recorders as well as three disc recording rooms each equipped with two sets of disc apparatus.

The Empire Service

The Empire Service, which is now in its third year, continues to grow, both from the programme and the technical points of view. A transmission from 0300–0400 G.M.T. directed to Western Canada was started experimentally and brought forth so much appreciation that it was made a regular transmission—Transmission 6.

Further experiments with aerial systems have resulted in improved general reception throughout the Empire. The aerial system at Daventry is being reconstructed and extended in the light of the experience gained.

Two new high power short wave transmitters have been ordered, one each from Standard Telephones and Cables, Limited and Marconi's Wireless Telegraph Co., Limited. Work is proceeding on these transmitters and the new aerial system.

Broadcasting

In the design of broadcasting transmitters the year has been characterised by a continued interest in a return to high power modulation. This is exemplified in the British Broadcasting Corporation's new long wave station at Droitwich. Operating on a wavelength of 1,500 m. with an aerial output of 150 kW., this station uses high power modulation by the series method on the penultimate stage.

The desire to improve the power efficiency of broadcasting stations has also led to continued development of high power modulation systems taking advantage of class B audio frequency amplifiers, and it is now possible to handle up to 80 kW. of audio frequency energy in this way without appreciable distortion. A contract has been placed by the British Broadcasting Corporation with Standard Telephones and Cables, Limited, for a "Regional" transmitter incorporating high power modulation on the last stage from such a class B modulator using valves in push-pull.

C. Lorenz have completed the so called Elevated Dipole to reduce fading in broadcasters. A number of these dipoles are now in use with broadcasting stations of the German Reichspost. The elevated dipole comprises wooden masts carrying a specially adjusted dipole.

The development of broadcasting in Australia has been placed on a systematically planned basis and the year has witnessed the completion of several of the group of seven medium wave stations constituting the present programme of the Administration. The equipments used vary in carrier power from 7 kW. to 10 kW. with facilities for increase in power at a later date to 25 kW. and 60 kW., respectively. High efficiency antennae are used in all cases, either of the umbrella or the insulated tower pattern with a capacity crown connected to the tower through inductance.

The firm of Lorenz has built most of the common wave equipment for the German Radio Broadcasting, and recently has made important improvements in the field of frequency control for common wave broadcasters.

Two 1 kW. broadcasters have been delivered to the Norwegian Administration, and two of the same type to the Swedish Administration. The Norwegian broadcasters are arranged for remote control so that they can be started and attended from a point outside the station.

An important order was secured in November, 1935 from the Czechoslovakian Administration covering a complete broadcasting and transmission system intended for the southwestern part of Czechoslovakia.

The antenna power of the existing Kosice broadcaster has been raised from 2 kW. to 10 kW.

In Japan, in 1935, an order for two 150 kW. broadcasting units for Tokyo was placed by the Japan Broadcasting Company. Consideration is being given to the provision of a similar station in Osaka, and also to a high power short wave regional broadcaster.

Television

A significant development in 1935 was the recommendation of the Television Advisory Committee set up by the Postmaster General for the inauguration of a high definition television service by the British Broadcasting Corporation. While it will not be placed in operation for some months, a site has been chosen at Alexandra Palace, some six miles north of Broadcasting House, and orders for one transmitter each have been placed with the Baird Television Company and the Marconi E.M.I. Television Company. The Baird Company's apparatus will use 240 lines, 25 frames, and 25 pictures; that supplied by the Marconi E.M.I. Television Company 405 lines and 25 pictures, interlaced to give 50 frames per second. Vision signals will be radiated on a frequency of 45,000 kc. and sound signals on 41,500 kc.

British Broadcasting Corporation News Service

For the purpose of broadcasting eye-witness accounts of important news events, arrangements have been made to place spare or working telephone circuits of the highest quality available on the route concerned, at the disposal of the British Broadcasting Corporation.

This scheme, which was inaugurated on October 7, 1934, applies to all towns in which there is a British Broadcasting Corporation studio and, in addition, to Liverpool and Southampton. The Corporation has agreed to give two hours (minimum) notice of its requirements and, since eye-witness accounts are usually broadcast in the second News Bulletin, requests may be received as late as 7:30 P.M.

Broadcast Interference

A portable interference locator has been designed for the tracing of sources of wireless broadcast interference. The instrument consists of a 5-valve superheterodyne receiver and has a specially designed search coil, connected by means of a flexible lead. If necessary, the search coil can be replaced by the usual external aerial and earth arrangement.

Picture Transmission Equipment

The Tokyo Asahi, the Osaka Asahi, the Tokyo Nichinichi, and the Osaka Mainichi now have picture transmission stations at Fukuoka, Moji, and Nagoya, in addition to Tokyo and Osaka which were started in 1928. All this equipment is of Nippon Electric manufacture. There is an evident movement to combine press activities between various newspapers for the formation of joint press agencies on the lines of the United Press (U.S.A.).

Commercial Radio

In addition to the existing physical circuit, a radio telephone link was put in operation between Paris and Moscow. By means of transmitting and receiving stations located near Saint Nazaire, France, a direct ship-to-shore service has been made available with liners in the North Atlantic.

Direct radio telephone service between the United States and France, it is expected, will be opened about the middle of the present year.

In 1935, the Bell System overseas telephone service was extended to include Honduras, Republic of Paraguay, Iceland, The Dominican Republic, and the City of Antofagasta, Chile, the latter, by means of a radio station installed by the Chile Telephone Company.

Radio telephone circuits between Japan on the one hand, and Berlin, London, Holland, and Brazil on the other, were opened in 1935. The latter circuit, incidentally, is one of the longest direct radio telephone circuits in regular operation in the world—over 12,000 miles.

The Spanish International telephone service was extended during the year, to include Turkey, Greece, North and South Rhodesia, Japan, Iceland, as well as ships on the high seas (via Berlin).

Ultra-Short Wave

The ultra-short wave radio equipments which were designed to provide six 2-way telephone circuits and which were tested experimentally across the Bristol Channel (England), have been transferred to provide additional circuits across the North Channel. The equipments utilise individual transmitting and receiving apparatus on each channel and hence twelve frequencies, six in each direction, are used. All the wavelengths lie between 4 and 6 metres. The power output of each transmitter is about 5 watts and small directive arrays, with reflectors suspended from 40 foot telegraph poles, are used to concentrate the transmitted energy in the desired direction.

The ultra-short wave link, placed in service in 1934 between Green Harbour and Provincetown, Massachusetts (U. S. A.), continues to give good service. This is a single channel link, operating on a wavelength of 4.5 metres over a distance of approximately 40 miles. The terminals are located to secure optical visibility over the path. The equipment is designed for unattended operation and is mounted in metal cabinets on the poles supporting the antennae. The latter are horizontally polarised. The carrier output is approximately 15 watts and is crystal controlled.

There is also the previously mentioned Spain-Majorca ultra-short wave link opened on September 1, 1935 with terminals at Barcelona and Mt. Alfabia (Soller). The distance in this case is much greater than in either of the two preceding cases—120 miles. The stations are so positioned that optical visibility is just secured. A single channel service is provided using a wavelength of 5 metres polarised vertically in the direction Barcelona-Mt. Alfabia, and 4.5 metres polarised horizontally in the reverse direction. The equipment is designed for unattended operation and incorporates AT-cut crystals for frequency control of the transmitter and receiver; the former has a carrier output of approximately 10 watts.

Aviation and Marine Radio

In Europe, in the Americas, and in the Far East, the continued extension of air transport facilities has maintained interest in all forms of radio navigation. Practice in Europe has not been standardised to anything like the extent to which it has been in the United States, and there is no agreement as yet as to the most advantageous type of radio equipment for navigational purposes. This is reflected in the multitude of experimental equipments now on trial, including several types of homing beacon, ultra-short wave blind landing gear of the Lorenz pattern, and automatic direction finders for use in aircraft as embodied in the Le Matériel Téléphonique R.C.5 equipment. The latter gives a steady compass card deflection when tuned in to a transmitting station and may be used either for position finding by the normal triangulation method, or for homing purposes along lines similar to those already in use or for homing with deliberate correction for wind drift—a feature which does not seem to be incorporated in any other system.

The Lorenz blind landing system has been developed in cooperation with the German authorities. The first equipment of this kind has been in operation on the aerodrome of Berlin-Tempelhof for some considerable period, and other German aerodromes are being similarly equipped. Outside of Germany, various countries have the Lorenz blind landing system on test.

Eight Lorenz long wave transmitter-receivers for telegraphy have been installed in Norwegian and Swedish civil planes.

The International Marine Radio Company, Ltd., London, has equipment installed on 417 British and other ships, and is also completing the contracts for 27 naval vessels placed during the past two years.

The biennial Shipping, Engineering, and Machinery Exhibition was opened at Olympia, London, in September. The International Marine Radio Company exhibit included one of the short wave radio receivers to be installed on the R.M.S. "Queen Mary." Very satisfactory demonstrations were given on this receiver.

Other features which were of special interest were a bridge radio direction finder, an automatic key for the transmission of the alarm signal, and the auto alarm itself. All of these devices are calculated to add materially to safety of life at sea.

Attention also was directed to a short wave unit for world-wide communication. This equipment is master oscillator controlled, with optional crystal control or two "spot" waves, an arrangement which has contributed not a little to the successful maintenance of long range communication under difficult conditions.

In Spain, Standard installed five coastal radio stations and four radio beacons; it also equipped four large ships, ten coast guard stations, and a number of fishing ships.

In Norway, twenty-five ships were furnished with International Marine Radio Company equipment.

National Dialing

Continued progress has been made in the design of equipment for automatic exchanges of capacities ranging from 50 to 10,000 lines and suitable from the outset for large network operation and national dialing. Improvements in long distance signaling systems have been made, and a new 50 cycle signaling system has successfully passed field trials.

A new pay station, which is a departure from existing practice, has been designed. It operates on alternating current of different frequencies supplied from the central office.

Toll Line Dialing

In order to improve efficiency on short haul toll circuits to automatic centres, Compañía Telefónica Nacional de España has installed 78 additional direct current toll line dialing equipments in 13 exchange areas, making a total of 300 installations of this type in its offices.

Two-Frequency System of Voice Frequency Signaling and Dialing Over Trunk Networks

The two-frequency (V.F.) signaling and dialing scheme has now been developed far enough to be applied generally to the trunk network in England. It will provide manual signaling between manual positions of the standard sleeve-control type, and dialing from sleeve-control positions into distant automatic networks—Director and Non-Director. Through-dialing is not contemplated at present; access to an intermediate operator will be provided by the "O" level trunk circuits.

Rotary

The type 7-District system has been developed further by the Bell Telephone Manufacturing Company and the new feature of partial combined line finders and finals now makes it suitable and economical for exchanges with calling rates of 1.7 equated busy hour calls (E.B.H.C.). This system will be used for urban exchanges where the refinements of the 7-A.2 are not required.

Eight new automatic exchanges numbering 58,000 lines were cut into service in Paris. At the present time, more than 95% of Paris subscribers are provided with automatic equipment. An automatic branch exchange was brought into operation in Lyons (Croix Rousse, 1,000 lines). Moreover, more than 1,000 rural offices were converted to automatic operation in addition to over 1,200 previously converted.

Time service, secured by means of the talking clock, already available in Paris, was extended to Lyons and Marseilles.

In October, 1935, collect calls, with some restriction, were inaugurated in the French internal service.

Automatic equipment was installed at Oran, Constantine, and Mostaganem (Algeria), also Saïgon (Indo-China), and Beirut (Syria).

In Spain, a total of 4,000 lines of 7-B Rotary equipment was installed in new offices at Burgos, Almeria, Castellon de la Plana, and Badajoz. Additional equipment for 7,000 lines was installed in the 7-A offices at Madrid and Barcelona, while an extension of 500 lines of 7-B equipment was provided in Vitoria and Logrono. The Compañía Telefónica Nacional de España is now utilising a total of 165,600 lines of 7-A Rotary and 27,000 of 7-B Rotary equipment, with a total of over 329,000 stations at the end of the year.

As certain sections of Budapest have developed at a greater speed than was anticipated when the Budapest automatic telephone area was planned, the Hungarian Administration decided to increase the number of lines of the Budapest automatic area and placed a first order for the 2,000 line extension of the Krisztina Exchange with Standard Villamossági Részvény Társaság.

The Administration is also commencing the introduction of the combined full automatic and semiautomatic rural system in Hungary. The trial installation of this equipment[3] was made five years ago. The district of Szentendre—a small town in the neighbourhood of Budapest—has been chosen for the next installation early in 1936. The network will comprise four full automatic exchanges with semiautomatic tandem circuits, and eight smaller semiautomatic exchanges, together with two 10-party lines. The semiautomatic service will be given by the Budapest toll exchange. An order for the four full automatic exchanges and the tandem circuits has been placed with the Standard Villamossági Részvény Társaság.

The Copenhagen Telephone Company has placed an order for 18,000 lines of semiautomatic equipment for the Copenhagen area, with Standard Electric Aktieselskab.

The Danish State Telegraph and Telephone Administration has adopted the 7-D Rotary rural system for its Sønderjylland and the island of Møen networks.

It is of interest to note, incidentally, that the 7-D rural system is used extensively by the Copenhagen Telephone Company in the districts surrounding the City of Copenhagen. This system is used also by the Lolland-Falster Telephone Company; and the Jytland Telephone Company has one 7-D tandem office in operation.

Step-by-Step Systems

In England, circuits incorporating a ballast resistor have been introduced, in order to reduce the effect of variation of feeding current on subscribers' lines of varying resistance. By this means it is possible to increase the feeding current on long lines without obtaining an excessive current on short lines. Circuits have been developed for all purposes in both Director and Non-Director exchanges and the scheme will be specified shortly for all new equipment.

It has been found that the average time during which subscribers listen to the busy tone is nearly 30 seconds, which may be due to some uncertainty as to the significance of the tone. In order to reduce this period, arrangements were made to develop a verbal signal to replace the busy tone. The equipment has been installed for a field trial in the Folkestone area, where it has worked satisfactorily and resulted in a definite reduction in the time of holding switches.

In order to provide telephone service for a small number of subscribers in remote districts in England, country satellite systems are to be installed. These systems employ a hermetically-sealed box of apparatus (mounted on a telegraph pole or other structure) at the centre of the district served. This is connected by a 2-wire junction to a special relay set installed at a suitable parent exchange, through which all calls are passed. Local intercommunication calls engage the junction over which the electrical power necessary for operating the local apparatus is installed. Provision is made for a maximum of ten subscribers when working to manual parent exchanges, and eight subscribers when working to automatic exchanges.

A new form of alternative trunking has been developed which, under certain conditions, results in the more efficient use of junctions and in a substantial saving in switching plant.

A dial tester has been developed to check the ratio as well as speed of a dial from the subscriber's premises. The device is located at the central office.

A regenerative repeater circuit has been designed to receive dial impulses which may be at the limit of permissible distortion and to retransmit them at correct speed and ratio. Work has also been done in connection with two-frequency signaling for bothway trunk lines, the main feature being protection against false operation.

Station Gain

The net station gain of the Bell System for the year 1935 was 461,156 as compared with 298,000 for 1934.

Net station gain of the operating telephone companies in the International Telephone and Telegraph group appreciably exceeded budget estimates. With the exception of the Shanghai Telephone Company, which recorded a small loss, gains were reported by all the companies in the group. Preliminary figures show that the gain was 57,000 stations, or over 6% of the more than 900,000 telephones now in service.

In Japan a special telephone expansion budget for 1935 of Yen 39,000,000 was approved for the equipment for 38,000 new telephones. Applications for telephones totaled 215,000. The Communications Ministry have under consideration an allotment of Yen 44,000,000 for the fiscal year 1936 to cover additional equipment for 39,000 lines.

Telephone Development

An interesting study of the development of the telephone in France appeared in the "*Revue des Téléphones, Télégraphes et T.S.F.*," July, 1935 issue, in an article entitled "Le développement du téléphone en France." It indicates quite plainly that there are very great possibilities for expansion of the telephone in France. Coming at this time, the study is especially pertinent, inasmuch as all indications point to great expansion in communications during the next period of world prosperity, even in countries most highly developed telephonically, such as the United States and Canada.

Around the World Telephone Conversation

The human voice traveled around the world for a new distance and time record, in April, 1935, when Mr. Walter S. Gifford, President of the American Telephone and Telegraph Company, talked over a 23,000 mile telephone and radio circuit that originated in the Long Distance building at 32 Sixth Avenue, New York City. In this first demonstration of a 2-way telephone call all the way around the world, Mr. Gifford used the longest telephone circuit ever established.

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A Cable Code Translator System*

By A. F. CONNERY

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By means of specially devised translators, described in this paper, 3-element cable-code signals may be translated into 2-element signals suitable for transmission over ordinary landline telegraph plants; by means of retranslating circuits, also described, the signals may be restored to their original 3-element form. Signals in the 2-element form may be monitored without the aid of retranslators. Synchronism is not required between the translators and retranslators.

EVER since its first cables were laid, The Commercial Cable Company, which owns and operates several submarine telegraph cables between North America and Europe, has used a 3-element code for signaling. In this code a dot is represented by a positive potential applied to the cable for one unit of time, a dash by a negative potential applied for one unit of time, and a space between letters by a ground potential applied for a similar length of time. The combinations assigned to the letters of the alphabet are in accordance with the continental code.

This method of signaling is used quite generally by other administrations over long submarine cables. It has, among other advantages, the marked advantage of greater accuracy than the 5-unit 2-element code which is in general use in landline systems and on some cables. In the 3-element cable code practically all mutilations of signals that might occur are detected readily by the receiving operator, and necessary corrections can be made before delivery of the message to the customer. In the 5-unit code, however, it is not possible for the receiving operator to detect most errors, except in plain language messages, and consequently the number of undetected errors is much greater. Because a large proportion of cable traffic is in unpronounceable code words, it is desirable to use a code that offers a means for readily detecting errors.

The disadvantages that previously have been held against the 3-element cable code have been that it would not directly operate an automatic printer and that it was not suitable for transmission over landline systems equipped to repeat only 2-element signals.

An automatic printer operated directly from 3-element cable-code signals is now in general use both in the Commercial Cable and All America Cable systems.[1] It is the purpose of this paper to describe a system of automatically translating 3-element cable-code signals into a special higher frequency 2-element code suitable for transmission through ordinary landline equipment, and nonsynchronous retranslating circuits for restoring the signals into their original form.

Translator System Comprises Four Units

The need for a suitable translator has been felt for some time, but the announcement of the British Post Office that it soon would be unable to lease metallic underground conductors between the cable landing at Weston-super-Mare and the main cable office in London made the need more pressing. The British Post Office proposed to lease channels of its voice frequency carrier system in place of the metallic conductors. The voice frequency system, however, was capable of transmitting only a 2-element code and therefore was unsuited for cable code working. Unless a translator were made available it would be necessary to lease two channels, one for dots and one for dashes, to transmit the signals from each submarine cable.

In response to this demand a complete translator system has been developed and is now in successful operation in England as well as on an

*Published in *Electrical Engineering*, November, 1935, and scheduled for discussion at the A.I.E.E. Winter Convention, New York, N.Y., January 28–31, 1936.

[1] "Direct Printing Over Long Nonloaded Cables," by M. H. Woodward and A. F. Connery, *Electrical Engineering*, v. 51, Feb. 1932, p. 132.

overland line between New York City and Canso, Nova Scotia. It is believed that the present development offers a better solution to the translation problem, especially on landlines of moderate length, than previously developed systems. The various units comprising the complete translator system are as follows:

Type 32*XM*. With this translator a tape perforated in accordance with the 3-element cable-code is used to transmit 2-element signals into a landline.

Type 23*RY*. This unit retranslates the 2-element signal received over a landline into the 3-element cable code. The output of this translator comes from relays and is suitable for direct transmission into a short cable, or may be regenerated and then sent into a long cable.

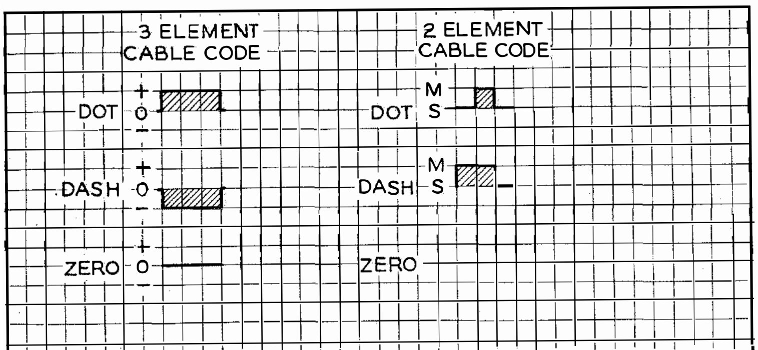
Type 23*DW*. This unit retranslates the 2-element signals received over a landline into the 3-element cable code in form suitable for recording on an ink writer. It is somewhat simpler than the type 23*RY*, but it is not suitable for operating printers or transmitting into another cable.

Type 32*RG*. This translator operates in conjunction with a regular cable code regenerator and translates the 3-element cable-code signals received over a submarine cable into 2-element signals for transmission into a landline.

2-Element and 3-Element Codes

The 2-and 3-element codes are shown in Fig. 1. It may be noted that the 2-element signals are not of the standard continental code. In this 2-element code, each dot, dash, or space occupies the same amount of transmission time. A 2-element dot consists of one unit of spacing, one unit of marking, and one unit of spacing, thus making a total of three units. A dash consists of two units of marking and one unit of spacing, or a total of three units. The zero signal consists of three units of spacing. In the 2-element code three units occupy the same period of time as one "center hole" or unit in the 3-element cable code. There is, therefore, no need of storing any signals at the translator station.

When recorded by an ink writer, the 2-element code may be easily read and therefore may be readily monitored. It is not intended, however, that messages shall be written up regularly from this code. Before recording or writing up the signals they will be retranslated into their original 3-element form. It should be noted that the third or last unit of each 2-element cable code signal is always spacing. It should be noted also that the ending of the marking interval on both dots and dashes occurs at regular intervals. On the letter *C*, for example, the interval of time between the end of the dash marking and the end of the dot marking is exactly three units. A similar interval of time separates the end of the dot marking and the end of the dash marking. These equal intervals of time are utilized in translating the signal into the 3-element form.



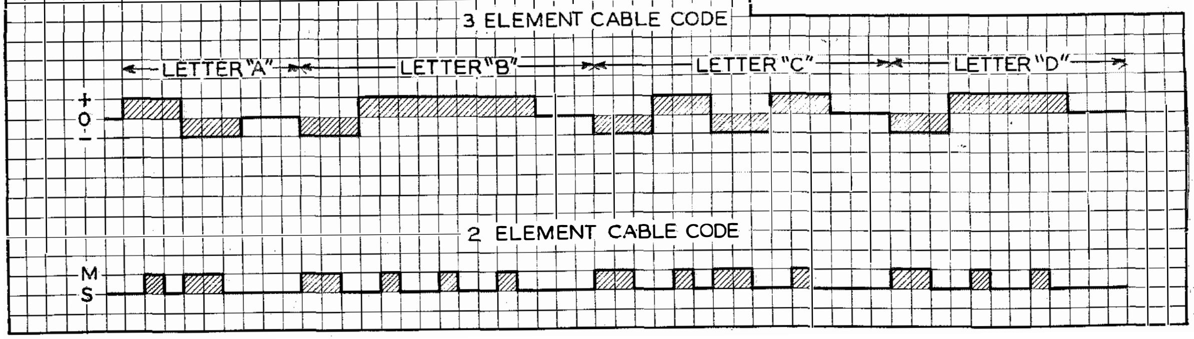


Figure 1—Comparison of 2-Element and 3-Element Codes (M—Marking S—Spacing).

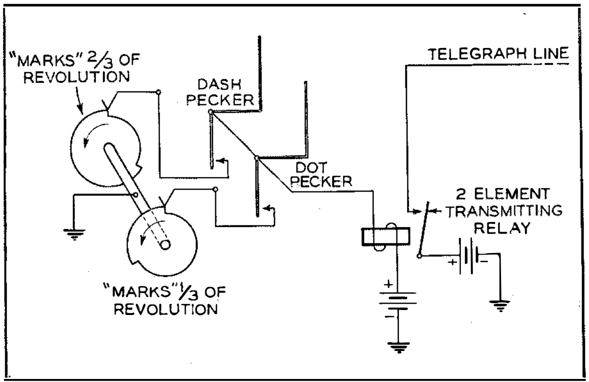


Figure 2—Schematic Diagram of Translator for Transmitting 2-Element Signals from 3-Element Cable-Code Tape.

Transmitting 2-Element Signals from 3-Element Cable-Code Tape

In Fig. 2 are shown the circuits of translator 32 *XM*, a tape controlled automatic transmitter that has been adapted to transmit 2-element code signals from a 3-element cable-code tape. This may be a standard form of automatic transmitter that operates at a constant speed. Dot and dash contacts are shown which are controlled by the dot and dash peckers under the control of the perforated tape. The two commutators are mounted on the same shaft of the automatic transmitter and revolve at the rate of one revolution per center hole or feed hole of perforated tape. During the first third of the revolution the circuit through both cams is open and the transmitting relay during this time is invariably on spacing. It is during this interval that the peckers "feel" for and assume their new positions as determined by the holes in the perforated tape. When a dot pecker has been selected, it is obvious that the circuit to the transmitting relay will be open for two-thirds of a revolution and closed for one-third of a revolution. When a dash pecker has been selected, the circuit to the transmitting relay will be open for only one-third of a revolution and closed for two-thirds of a revolution. When a zero signal is to be transmitted, neither pecker will be operated and there will be no marking of the transmitting relay for a full revolution of the commutators. The type of signals that will be transmitted, therefore, will be in accordance with the 2-element cable-code signals shown in Fig. 1.

Translating 2-Element Signals to 3-Element Cable-Code Form

Means for translating the 2-element signal back into its cable code form is shown in Fig. 3, which is a schematic diagram of translator 23*RY*. Two adjustable timing circuits are required: One of these circuits is for distinguishing between dots and dashes by the duration of the marking time of the received signal; the other is to space the dot and dash transmitting relays when no marking signal has been received for a predetermined time interval.

Each valve, together with its anode relay and shunted grid capacitor, merely acts as an easily adjusted, reliable, "slow-operate quick-release" relay. The cathode of each valve is tied to the main power battery in such manner that the cathode potential is approximately midway between the positive and negative potentials of the

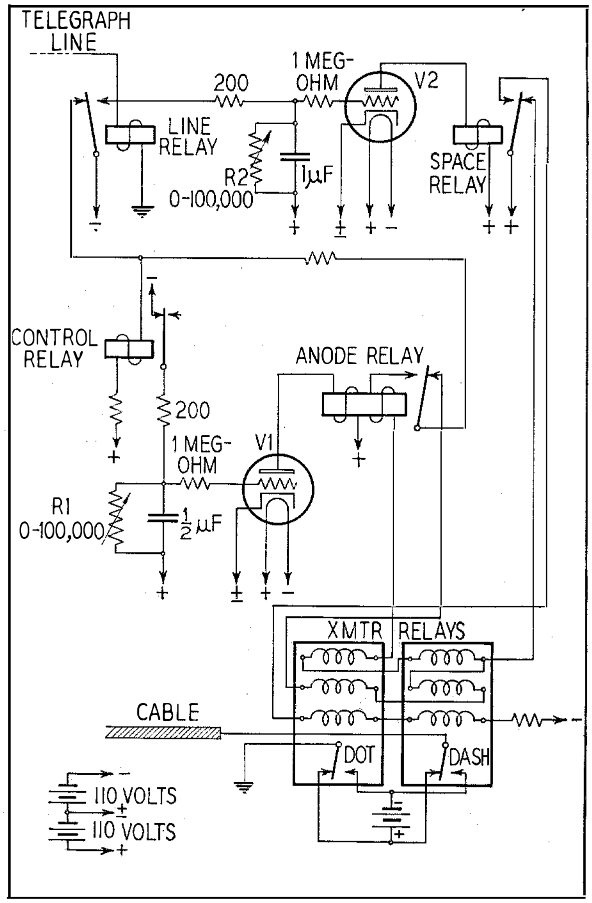


Figure 3—Translator for Converting 2-Element Signals to 3-Element Form (Resistances are shown in ohms).

main power battery shown in the figure. The actual connection usually is made by means of a potential divider. When the control relay is in a marking position as shown, the shunted ½-microfarad capacitor has a negative charge and the grid of *V*1 is highly negative with respect to the cathode. When a marking signal is received over the telegraph line the control relay releases and the negative connection is removed from the capacitor. The negative charge leaks off the capacitor through resistance *R*1 and the grid finally becomes positive with respect to the cathode. At some definite time after the marking signal has been received, anode current flows and the anode relay operates. The shunt resistance *R*1 of the capacitor will have been adjusted so that the anode relay is not operated when a dot is received, but is operated when a dash is received. When the line relay restores to the spacing position, a circuit is completed from the line relay tongue, back contact, and thence to the tongue of the anode relay. For a dot signal the anode relay is unoperated and the circuit is completed from the anode relay tongue, through the back contact, through the dot and dash transmitting relays in such direction as to "mark" the dot transmitting relay and "space" the dash relay, thereby sending out a dot cable-code signal. The dot and dash transmitting relays are polarized and remain in the positions in which they have been set. For a dash signal the anode relay will have been operated and the circuit from the plate relay tongue is completed through a holding winding on the anode relay, through the dot and dash transmitting relay, and "marks" the dash transmitting relay and "spaces" the dot transmitting relay, thereby sending out a dash cable-code signal. Each time the line relay restores to the spacing position, a cable-code dot or dash is retransmitted. At the same time the control relay operates and negatively charges the capacitor connected to the grid of *V*1. If the line relay has been "marking" for only a short time a dot is retransmitted. If it has been "marking" for a longer period of time a cable-code dash is retransmitted.

It should be noted that all the valves used in the different types of translators have a grid resistor of at least one megohm value. The purpose of this grid resistor is to prevent the grid from becoming highly positive with respect to the cathode, which would result in excessive anode current. As soon as the grid becomes positive with respect to the cathode the grid current produces an *IR* drop across the grid resistor of sufficient value to prevent excessive anode current.

The purpose of valve *V*2 and associated circuits is to restore the dot and dash transmitters to their spacing positions so as to send a zero or ground potential signal into the cable whenever no 2-element marking signals have been received for a certain time. While the line relay is not on the marking contact the charge on the capacitor associated with *V*2 is slowly leaking off. The rate at which the charge leaks off is controlled by the adjustable shunt *R*2. When the grid of *V*2 attains a certain potential with respect to the cathode, the space relay is operated. When the tongue of the space relay leaves the back contact the dot and dash operating circuit of the dot and dash transmitting relays is opened, and when the space relay tongue reaches the marking contact a circuit is completed that restores the dot and dash transmitting relays to "spacing" in the event either one had been "marking." The restoration of the dot and dash transmitting relays to "spacing" results in zero or ground potential being applied to the cable, thus indicating a space between letters.

Translating 2-Element Signals to 3-Element Ink-Writer Records

The following is a description of the translator (23*DW*) designed for use at a station where it is desired to produce cable-code ink-writer records only, from a received 2-element signal. The circuit is simpler and has some advantages over translator 23*RY*, which produces cable code signals on a pair of relays. The principal advantage is that a small misadjustment of the dot-dash adjusting rheostat will not result in recording dots for dashes or *vice versa*, but instead will result in either the dots or dashes, as the case may be, sometimes failing to reach their full amplitude, thus indicating the necessary adjustment to be made.

Referring to Fig. 4, it may be noted that the ink writer is connected in the plate circuit of valve *V*1. Being a sensitive device, the writer is shunted so that only a portion of the plate current passes through its operating coil. Resistances $R1$ and $R2$ are used as a voltage divider or potentiometer to apply a reduced voltage to the anode of the valve. The resistances in the plate circuit are so proportioned and arranged that when the grid is negative with respect to the cathode, there is no anode current and therefore no deflection of the ink writer pen. This condition is maintained while a dot is being recorded. When the grid is positive with respect to the cathode, there is maximum current in the anode circuit and the ink writer pen has maximum deflection. The ink writer is connected so that this deflection is in the dash or downward direction on the tape. This condition is maintained while dashes are being recorded. In order to record the spaces it is necessary, of course, for the pen to assume a position midway between the dot (zero anode current) and the dash (maximum anode current) line. The grid of $V1$ is maintained at a suitable potential with respect to the cathode so that the ink writer pen assumes a position intermediate to the dot and dash positions and thus records spaces. The zero adjustment potentiometer, shown in the schematic diagram, supplies the required grid potential for recording a space.

Assume that spacing is being received over the line. The line relay tongue remains against its spacing contact (S) thus energizing relays $PF1$ and $PF2$. When the line relay tongue has remained away from its marking contact (M) for a sufficient length of time the grid of $V2$ becomes positive with respect to the cathode. The anode current energizes $VR2$ thus rendering the grid of $V1$ the same potential as the zero adjustment potentiometer slider. A zero or spacing signal therefore is indicated on the ink writer. Suppose a marking signal of dot duration now actuates the line relay. When the line relay tongue reaches its marking stop, capacitor $C4$ is quickly charged negatively thus stopping the anode current flow of valve $V2$. Relay $VR2$ leaves its marking contact and disconnects the zero adjustment potentiometer from the grid of $V1$. The small grid capacitor $C3$ maintains the intermediate voltage on the grid for as long as required. The departure of the line relay tongue from its spacing contact results in relays $PF1$ and $PF2$ being deenergized. When the tongue of relay $PF1$ reaches its spacing contact, capacitors $C1$ and $C2$ are paralleled, their charges mix, and voltages equalize. Since the capacitance of $C2$ is only a small fraction of that of $C1$, the potential of $C1$ is changed only slightly. Capacitors $C1$ and $C2$ now slowly take up a positive charge through the dot-dash adjustment rheostat. At the end of the marking period of the line relay, relays $PF1$ and $PF2$ again are operated. When relay $PF1$ operates, capacitors $C1$ and $C2$ are separated and $C1$ is charged negatively. The operation of relay $PF2$ joins or parallels capacitors $C2$ and $C3$. The capacitance of $C2$ is much larger than that of $C3$; therefore the potential of $C2$ is altered only slightly when the charges mix. Capacitor $C3$ is now of the same potential as $C2$ and the grid of $V1$ is of a similar potential. For the dot signal just described $C3$ does not have sufficient charge to render the grid positive with respect to the cathode; the grid becomes negative; there is no

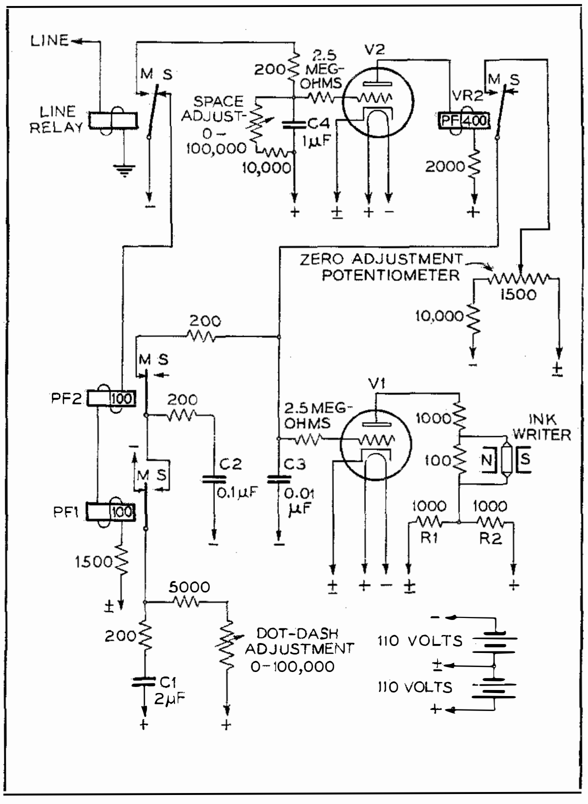


Figure 4—Translator for Converting 2-Element Signals to 3-Element Ink-Writer Records (Resistances are shown in ohms).

anode current flow, and the ink writer therefore records a dot. Had the marking interval of the line relay been of dash length, capacitor *C*1 would have received a greater charge and *C*2 and *C*3 would have had a proportionately greater potential. The potential of *C*3 for a dash would have been sufficient to render the grid positive with respect to the cathode, and therefore maximum anode current would flow and the ink writer would record a dash.

The space adjustment rheostat is adjusted so that if the line relay does not "mark" for an interval of time equal to one "center hole," the grid of *V*2 becomes positive with respect to the cathode and anode current flows. Relay *VR*2 operates and thus makes the grid of *V*1 assume a potential, determined by the setting of the zero adjustment potentiometer, that results in the ink writer recording a cable code space. Several ink writers in parallel may be actuated simultaneously.

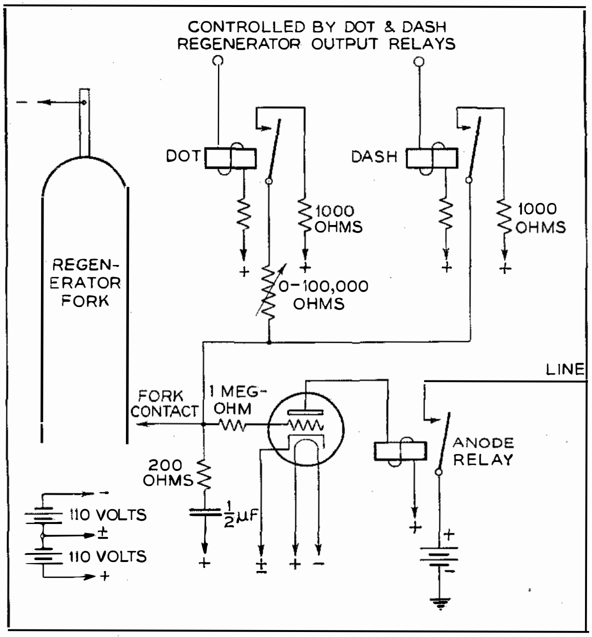


Figure 5—Translator for Converting 3-Element Signals Received Over Long Cables to 2-Element Form.

Translating Signals Received Over a Long Cable to 2-Element Form

When it is necessary to translate the signals received over a long cable into the 2-element form, a circuit similar to that shown in Fig. 5 (translator 32*RG*) may be used. A standard cable code regenerator, not shown in the figure, is used to regenerate the cable code signals, and the regenerator tuning fork is used also in connection with the translator. Referring to Fig. 5, the two neutral relays, marked "dot" and "dash," are controlled by the output signal of the regenerative repeater. The fork contact shown is one that makes contact at the same time as the fork pick-up contact so that movement of the tongues of the dot and dash relays occurs only while the fork is making contact. The marking contact of the fork is adjusted to make for one-third of the time.

While the fork is "marking," the grid of the valve is negative with respect to the cathode and there is no anode current. The anode relay, of course, will be unoperated, and a spacing signal is sent to the line. The capacitor is charged negatively. The cathode of the valve, it should be noted, is connected to the midpoint of the battery. When the fork leaves the contact the negative charge remains on the grid capacitor, provided neither dot nor dash input relay is "marking," and the output relay continues to send "spacing" to the line. If the dash input relay is in an operated position when the regenerator fork leaves its contact, then the grid capacitor is quickly discharged. The resulting anode current operates the output relay thus sending "marking" to the line. If, however, when the regenerator fork leaves its contact the dot input relay is in an operated position, it will take another one-third "center hole" time interval, when the high resistance adjustable rheostat is set correctly, before the condenser is discharged sufficiently to operate the output relay and send a marking signal to the line.

Bakelite Moulding and Its Application in the Telephone Industry

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The advantageous properties of synthetic resin mouldings are briefly enumerated with particular reference to their application in telephone apparatus. The requirements of the telephone industry have created a number of new moulding problems which are solved by means of the injection or extrusion process now in use by the Bell Telephone Manufacturing Company on a commercial basis in producing interesting parts. A description of this process as well as the conventional moulding process is given. Illustrations of various moulded parts as well as the presses and moulds employed in their production are included.

IN recent years the synthetic resin base mouldings have found an increased application in electrotechnics. Compared to the insulating materials previously known, the synthetic resins undoubtedly have many advantages. The mouldings are mechanically strong, possess high insulating properties, and are non-hygroscopic. They do not oxidise and they are practically unaffected by most chemicals or sunlight. They do not soften or flow under the most extreme climatic conditions. Steam and oil have little effect upon them. As the characteristics of synthetic resin mouldings are retained indefinitely, there is no "age" effect.

The degree of accuracy with which mouldings can be pressed is relatively high. Tolerances of ± 0.1 mm. can be easily attained and, with special care, an accuracy of ± 0.05 mm. is possible.

Synthetic resin mouldings are neat and clean in appearance; and can be produced in lustrous black or other colour, which faithfully reproduces the surface polish of the mould. Metal inserts can be embedded in the insulation during the moulding process. Screw threads of great strength and accuracy can be moulded in the material. Not only has the use of the synthetic resin mouldings dispensed with many manufacturing and assembly operations; but, also, mass production, efficiently coupled with beauty, uniformity, and simplicity, have been made possible. These advantageous properties and the progress made in the composition and in the moulding of the phenolic plastics have stimulated the rapid and extended introduction of this product.

The phenolic plastics possess the property of becoming plastic and mouldable with moderate heating; in this condition they are soluble in certain solvents, such as acetone and alcohol. A very brief exposure to greater heat, however, sets up a further chemical reaction and causes hardening to such an extent that a return to plastic conditions is no longer possible, either by chemical reaction or by a relatively high temperature, while the solvents which served to dissolve the plastic in its primary state are powerless to affect it.

The production of the reaction in synthetic resins occurs in two definite states and an intermediate state which is somewhat indefinite. The two definite states are: (1) the soluble resin, called "A"; and (2) the insoluble and infusible resin, often called "C". In the intermediate form (3), termed the "B" state, the material is still fusible but not soluble. The raw moulding material is usually obtained in the "A" state and by the moulding process, it is converted into the "C" or hardened state.

Due to these valuable properties, the synthetic resin stands out fundamentally from other plastics which are mouldable by heating. It is produced in large vessels by heating phenol, commonly called carbolic acid, and formaldehyde, the volatile constituents being drawn off by evaporation. Formaldehyde is obtained from methyl alcohol, a constituent of wood tar; pehnol is a constituent of coal tar. Chemically, bakelite is a phenol formaldehyde. It is a solid resin-like substance, different in every way from the ill smelling liquids from which it is made; it is

Figure 1—Subscriber Set Housing with Cradle.

odourless and tasteless, a distinctly new product with unique chemical and physical characteristics.

The synthetic moulding powder is obtained by mixing the phenol resin with a filler. The filler is a cheap, preferably fibrous material giving body and strength to the resin binder. The latter serves the double purpose of holding the filler together and rendering the article waterproof and durable. Typical fillers are wood, flour, asbestos, slate dust, mica, etc.

To mix the binder and filler perfectly, the slabs of resin are broken into coarse fragments and tumbled with alcohol in a drum until the resin is completely dissolved. This solution of resin is then thoroughly mixed with the wood flour filler, usually equal parts of resin and filler being employed. The product is dried to eliminate the solvent and then ground and sifted to the required degree of fineness. The intimate mixture of resin and filler obtained in this way, when ready for moulding and not artificially coloured, has a yellow grey appearance.

For the moulding of phenol plastics, a pressure of from 150 to 600 kg./cm.^{2} is needed. The presses required for large mouldings, therefore, must be powerful and of generous dimensions. They generally are hydraulically operated, since the fluxion of the material under the influence of heat results in decreased volume, and it is necessary to follow up changes of volume with a constant pressure. The mould consists generally of two parts: the top stamp or punch, and the bottom stamp or die in which the plastic is put. To withstand high working pressures, the moulds are made of a good grade of specially selected non-oxidisable alloy steel, and are hardened, with their working surfaces highly polished. The required moulding temperature being between 160° to 180° C., the moulds are usually steam or electrically heated.

The moulding process consists in placing a correctly weighed charge of moulding material in the cavity of the hot mould, either in the form of powder or of a preformed tablet. The use of preformed tablets is sometimes considered an advantage, since they obviate the necessity for weighing charges and simplify handling by the moulder. When pastils of various colours are

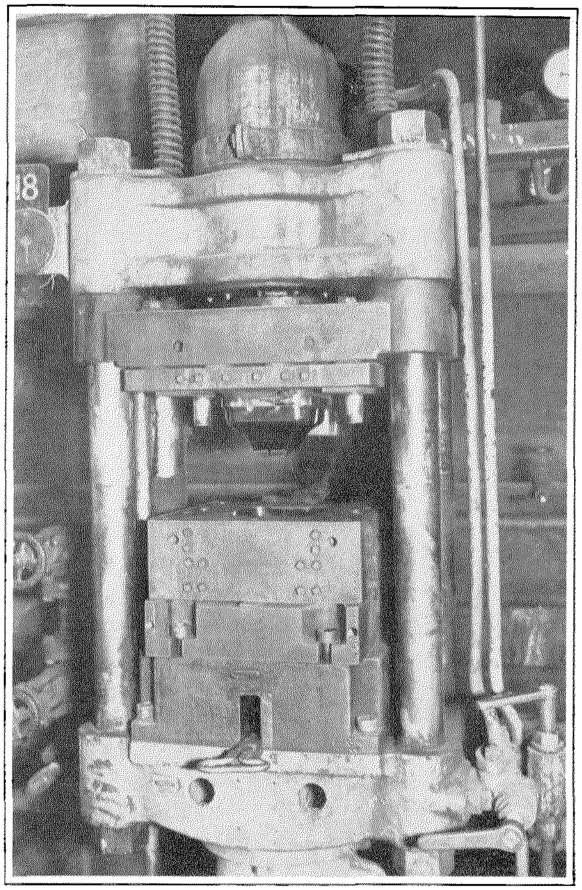

Figure 2—Positive Mould for Making the Subscriber Set Housing, Mounted on a 50 Ton Semiautomatic Inserted Ramrod Press.

used, it is possible to obtain very original colour effects.

The powerful hydraulic ram compresses the powder or pellet and closes the mould. The part must remain in the press for a sufficient length of time to ensure that the chemical changes (commonly called curing) take place in the moulding material. This time varies according to the bulk of material in the mould and the kind of material used. Quick curing powder requires about one minute for a 3 mm. wall thickness.

The moulded part may then be removed immediately from the mould. It is a faithful positive replica of the negative contour with even the smallest scratches and marks reproduced. The shrinkage of synthetic resin mouldings is on an average from four to six thousandths of an inch per inch of length or diameter.

Laboratory tests made on synthetic resin mouldings with wood flour filler gave the following results for physical and electrical properties:

Tensile strength	4,500 to 6,000 pounds per square inch
Compressive strength	25,000 to 36,000 pounds per square inch
Traverse strength	10,000 to 15,000 pounds per square inch
Hardness (metal scale)	70 to 110 Shore scleroscope
Coefficient of expansion	0.00003 inch per degree C
Specific gravity	1.35
Dielectric strength	250 to 700 volts per mil
Dielectric constant	4.5 to 7.5
Volume resistivity	3 by 10^{10} ohms per cm.^{3} at 20° C
Power factor	1 per cent to 6 per cent at 10^6 cycles per second

Moulded parts of the synthetic resin type withstand continuous temperatures up to 150° C, and up to 300° C for short periods, provided they are not exposed to rapid and radical changes in temperature and extreme dampness. These conditions tend to spoil the surface, at least for electrical insulation purposes.

Very high temperatures, such, for instance, as occur in arcing or "flash-over," cause superficial carbonisation. Hence, phenol plastics are not suitable for parts which are subject to arcing effects.

The accompanying illustrations show articles moulded in phenol plastics by the Bell Telephone Manufacturing Company of Antwerp, and indicate the progress that has been made in the production of moulded parts for the telephone industry.

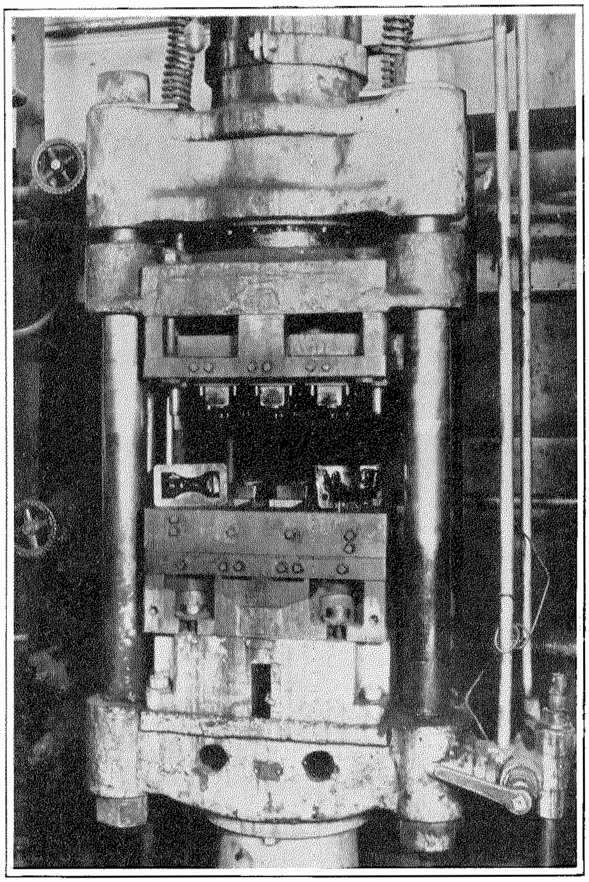

Figure 3—Mould for Cradle Mounted on a 50 Ton Semi-automatic Inserted Ramrod Press.

Fig. 1 shows a subscriber set housing with cradle. These parts replace metallic parts which were formerly used and which required considerable machining. The application of the moulding process makes it possible to reduce costs and to improve the product. One of the principal reasons for its use is the time and labour saved by reducing the multiplicity of operations and finishings which are often required to produce a metallic article to only one operation for moulding.

When they leave the mould, the parts possess a high surface lustre requiring little or no polishing. The tapped fixing holes are obtained by embedding brass inserts in the insulating material at the time of moulding.

Fig. 2 illustrates the mould for producing the subscriber set housing. It consists of a body

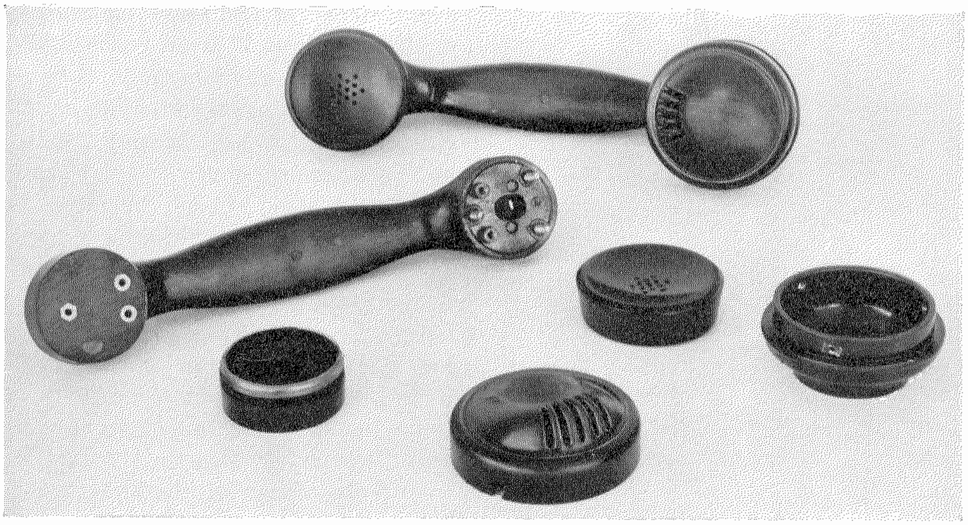

Figure 4—Different Parts Composing the Moulded Microtelephone.

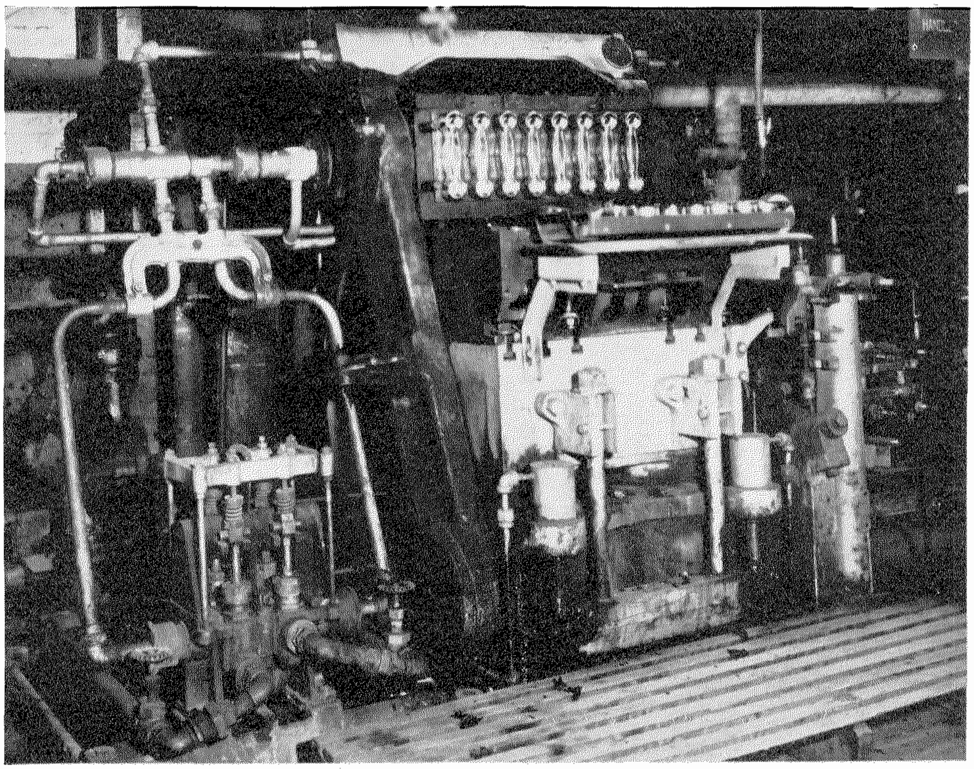

Figure 5—Burroughs Automatic Tilting Head Press for Microtelephone Handles.

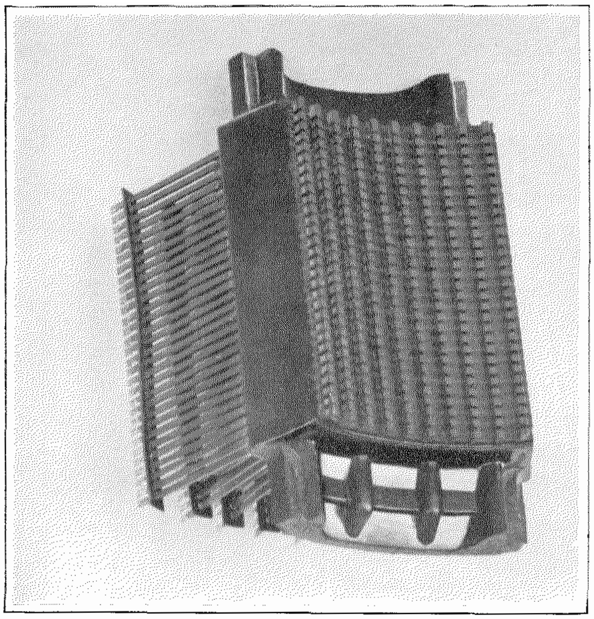

Figure 6—Selector Terminal Block (7-A.2 Rotary System).

portion or die cavity and a movable punch, conforming in shape, respectively, to the outer and inner surfaces of the part to be moulded. The pressure for causing the material to flow and take the necessary shape is supplied by the punch. The body portion is provided with a knockout or ejector to facilitate the removal of the moulded article. The mould is heated directly by means of high pressure steam, which is circulated through cores in the mould itself. It is mounted on a 50 ton semi-automatic inverted ramrod press.

Fig. 3 shows the mould used for making the cradle. It is a multiple impression mould constructed with six interchangeable body moulds in the form of inserts. Two of these inserts can be seen resting on the lower portion of the mould. They are ejected, together with the moulded parts, from which they are subsequently separated.

Fig. 4 illustrates the different parts composing the moulded microtelephone. The handle is provided with five inserted brass parts in addition to three studs and the conductors connecting the transmitter and the receiver, all of which are moulded in the insulating material. The receiver case is provided with a brass cup which is embedded in the composition during moulding. The earpiece is provided with an accurately and strongly moulded screw thread.

The press shown in Fig. 5 is intended for mass production of the microtelephone handles. With every stroke of the press, eight handles can be made at a time. It is an automatic tilting head press made by the Burroughs Company, and is shown in open position. The mould is direct steam heated; and the heating, cooling, and press movements are controlled by valves on the column at the right of the press. On the left-hand side is a hydraulically operated steam and water control which automatically admits steam to the moulds for fluxing and curing the moulding material. The backward tilting of the top half considerably facilitates the cleaning of the mould, the putting in place of the inserts, the filling of the mould, and the removal of the parts and the inserts within the shortest possible time. Fig. 5 also shows at the right, on the working table of the press, three empty mould inserts and, next to these, three which include the moulded parts.

The requirements of the telephone industry

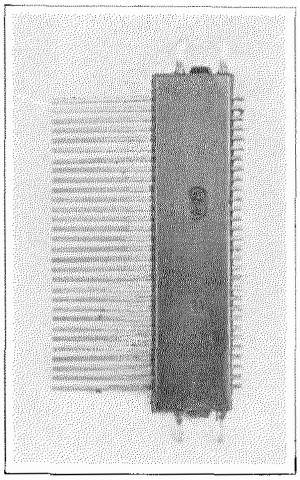

Figure 6-A—Old Style Terminal Block used in 7-A.1 Rotary System.

have created a number of new moulding problems for which the usual moulding process, as just described, is not suitable. These problems can be solved only by the application of the injection or extrusion process, which represents the latest development in the moulding art. It is a radical departure from the standard practice of thermoplastic moulding, in that heat and pressure are applied to the moulding compound before it reaches the mould.

The Bell Telephone Manufacturing Company has made much progress in this line of development, and is now producing, on a commercial basis, a number of very interesting parts by the thermo-plastic injection process. A moulding of this kind is illustrated by Fig. 6. It is a selector terminal block (of the 7-A.2 rotary system) made with phenol plastic in which three hundred terminals are embedded, all radially lined. These terminals must withstand a breakdown test of 500 volts alternating current between adjacent terminals.

The manufacture of this part, with its slender, closely spaced terminals, could not be accom-

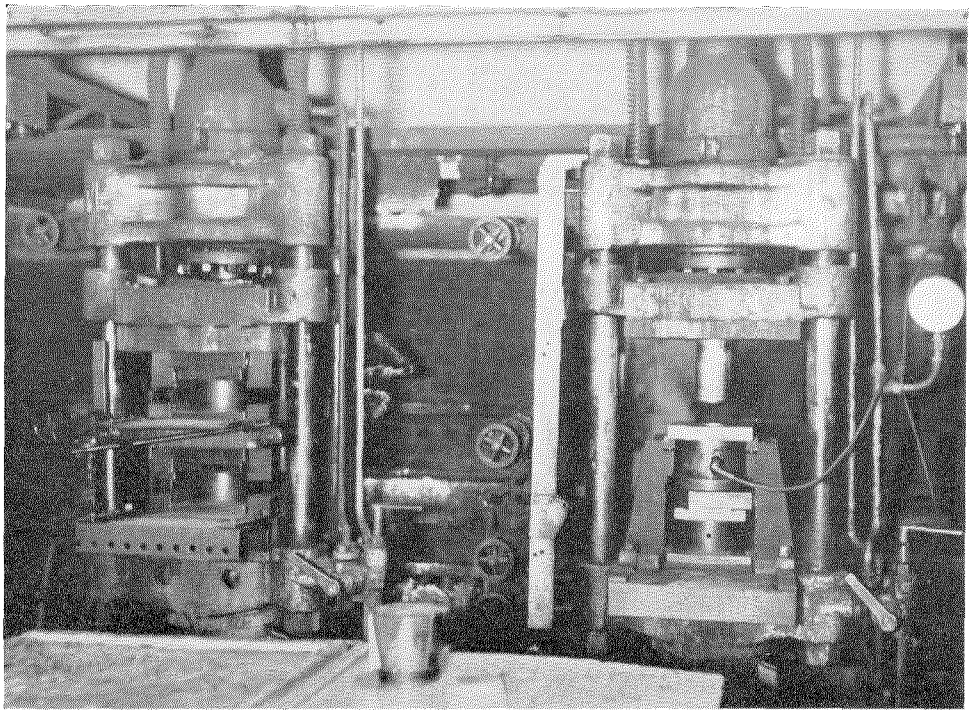

Figure 7—Moulding Equipment for Selector Terminal Block, Shown on Fig. 6.

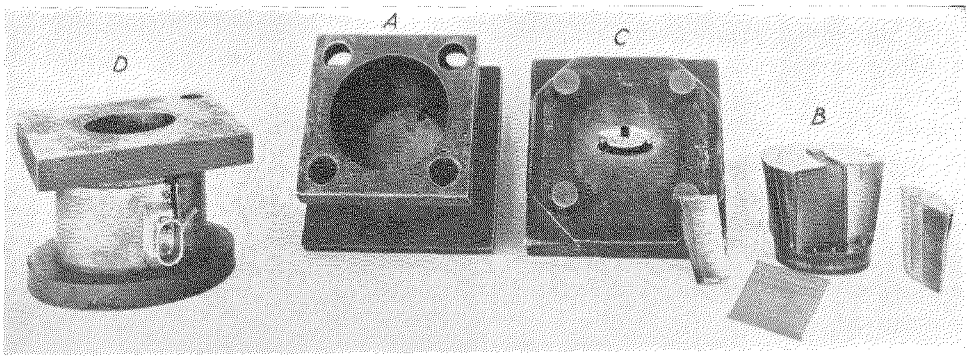

Figure 8—Mould for Terminal Block Shown on Fig. 6.

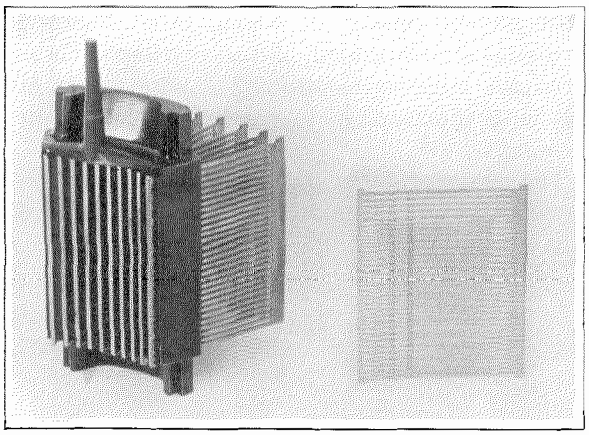

Figure 9—(Left)—*Terminal Block as It Leaves the Mould.*
Figure 10—(Right)—*Terminals as They are Placed in the Mould.*

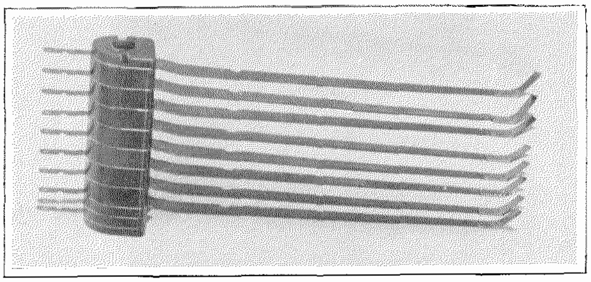

Figure 11—Feeder Brush for 200 Point Line Finder Type Switch.

plished by the conventional moulding process, as the unequal pressure would cause displacement, collapse, or breakage of the terminals. In the injection process, a more favourable hydrostatic condition prevails in the mould cavity, so that pressures are nearly the same in all directions.

The normal moulding compounds are not suitable for this process because they set too quickly and usually cure before the mould is completely filled. The injection process requires a compound that possesses extra good fluxing properties; that remains plastic for a longer time than the common powders when heated to a suitable temperature; and, finally, that sets quickly when heated to the curing temperature.

Another important point is the method of operation. Dimensions of gate and channels must be calculated in relation to the injection pressure applied, in order to prevent, as far as possible, the plastic or semi-liquid materials from entering the cavities of the mould before the composition has reached its maximum flux

If these conditions are well observed, injection moulding becomes very simple and feasible. The most friable inserts or cores remain intact under the pressure needed to fill the mould. Complex parts with thin or slender walls which do not lend themselves to the usual moulding process are readily moulded by the injection process.

Synthetic resin injection moulding is carried out on conventional vertical hydraulic presses. Fig. 7. illustrates the equipment used for the moulding of the terminal block shown in Fig. 6. The press on the left is used for the injection process, that on the right for the curing after the injection.

The mould is constructed as seen in Fig. 8, and consists of a holder or bolster "A" provided with a tapered cavity to coincide with the conical formed mould inserts "B". It will be noted that the mould inserts are constructed in such a way that, when assembled, they form a perfect frustum of a cone. A cover "C" provided with gate and injection channels closes the mould.

A separate injection cylinder "D" is set on top of the mould, so that its outlet registers with the gate of the mould. It is provided with an electrical heating element to insure the right temperature for injection. The plunger is fixed on the upper bolster of the press. It is not heated, in order to prevent the material from fluxing high up in the container and escaping.

The assembled mould is kept in operation at a temperature between 80° and 100° C. The speed of the working cycle is arranged so that the time needed for dismoulding and assembling of the mould allows it to cool off from the curing temperature to the required injection temperature.

The container placed on the top of the assembled mould is charged with the required quantity

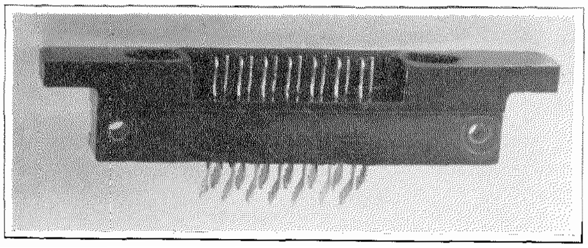

Figure 12—Jack Panel.

of powdered or pelleted composition. The whole is then placed in the injection press and the heating element turned on. After a few seconds, the material becomes plastic or semi-liquid, whereupon it is rapidly forced into the mould before curing can take place.

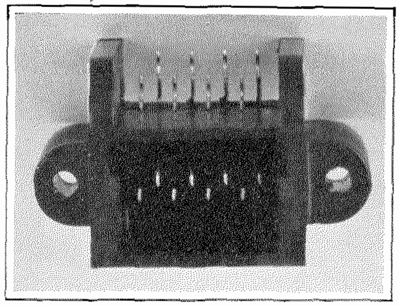

Figure 13—Terminal Strip.

The mould having been completely filled, the press is opened to remove the container for cleaning. The flash formed in the bottom of the cylinder must be taken away before charging the cylinder for the following operation. The mould is then placed in the curing press and subjected to a temperature of about 180° C for its normal cure. This press is a double story one in which the plates are steam heated. This arrangement permits leaving the moulds in the press sufficiently long for complete setting of the composition.

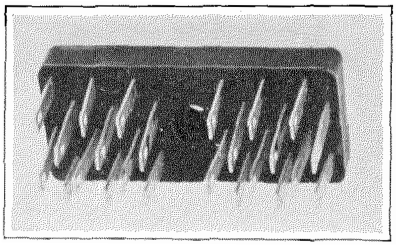

Figure 14—Terminal Strip.

On completion of the curing, the mould is removed from the press and the moulded part, together with the steel inserts, is ejected from the holder, after which it is freed from the inserts. The moulded parts leave the mould in exceptionally good condition; all portions are perfectly filled out, flashes and fins are very fine and can be readily removed. This is chiefly due to the fact that the mould is tightly closed before the moulding composition enters it; the projection area of the mould cavity being less than the section of the piston, the opening of the mould is completely prevented.

Fig. 9 shows the terminal block as it leaves the mould. Gate and connecting channels are visible at the top of the terminal block. They can easily be broken off by hand. It will be noticed that the terminals are connected at both ends.

Fig. 10 shows the terminals, punched from profiled phosphor bronze strips, as they are placed in the mould. The completed terminal block comprises ten terminal brushes, each brush containing thirty terminals. The separation of the terminals, after moulding, is done at the inside by means of a multiple milling cutter, and, at the outside by means of an automatic cutting-off operation. The soldering ends are then slotted by means of a multiple sawing operation. The soldering ends are kept well separated by means of a perforated phenol fibre strip.

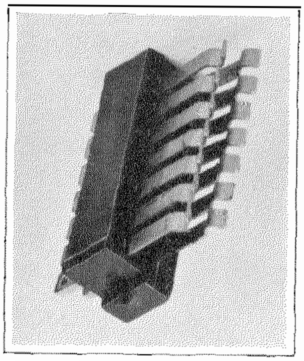

Figure 15—Spring Combination.

Fig. 6 illustrates the finished terminal block. This terminal block embraces several new features not obtainable with the ten flat terminal blocks formerly used (see Fig. 6-A). In addition to a noticeable saving in manufacturing and assembling cost, and a sensible increase in accuracy, a remarkable reduction in dimensions was effected. The dimensions of the selector, consequently, could be decreased in the same measure, so that a bay of given height will now accommodate twenty selectors in place of fifteen.

Figs. 11, 12, 13, 14, and 15 illustrate some other parts which are produced very successfully by the synthetic resin injection process.

Fig. 11 shows a feeder brush for a 200 point line finder type switch with phosphor bronze brushes moulded in the composition. The mould for this part is made so that different sizes of similar parts can be made in the same form. The steel inserts of the mould are interchangeable and are available in the quantity required for making it possible that each desired distance between each level, and each desired number of brushes, can be obtained for the different types of line finder switches made.

The steel inserts in the mould in this case are relatively thin, but, since no dry powder or stiff compound enters the mould cavity, these parts do not suffer from the required high pressure, which in this process varies from 600 to 1,000 kg. per square centimeter, according to the shape and size of the part.

Fig. 12 illustrates a jack panel in which fourteen brass terminals are embedded. The injection process makes possible the production of these parts with a minimum of rejections, whereas, by applying the normal moulding process, the inserts would be pushed out of place or collapse due to the stiffness of the compound.

Figs. 13 and 14 show terminal strips, and Fig. 15 illustrates a spring combination made in the same manner as the foregoing part. Another advantage of this process consists in the fact that for parts having nearly the same dimensions, a large part of the mould equipment, as for instance the holder, the cover, the container, and the plunger, can be made interchangeable for the different inserts so that, for various similar parts, only the steel inserts need be made specially.

From this brief outline it can be seen that the synthetic resin injection process, for numerous parts, has many important advantages as compared with the conventional moulding method. The Bell Telephone Manufacturing Company is seriously pushing the development of the injection process for some new intricate parts, the moulding of which is only possible with this kind of process.

The Design of 2-Pole Networks Containing One Positive and One Negative Reactance

By L. C. POCOCK, M.Sc., A.M.I.E.E.

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THE steady development of network theory and the importance of the subject in the art of electrical communication have led to the publication of a number of methods of designing a network for a specified frequency-impedance characteristic. In most cases the specified impedance-frequency data is assumed to be given in the form of an algebraic function of the frequency; in practice, however, the initial data are in the form of a curve or its equivalent, and the determination of a frequency function that will approximately fit the curve is, even in the simplest cases, a difficult matter.

Method

The networks falling within the scope of the method to be described are any that can be represented by the formula

$$|Q| = \sqrt{\frac{\alpha x^2+\beta x+1}{\gamma x^2+\delta x+\varepsilon}} \qquad (1)$$

where $x=\omega^2=(2\pi f)^2$ and Q is the impedance of the network.

This formula applies to eleven networks (Fig. 1), each containing one inductance, one capacity, and three resistances, as well as to their equivalent networks and a range of networks with a mutual inductance and one capacity. The formula also applies to mutual impedances within these networks, that is, impedances defined by the ratio of the volts at one pair of terminals to the current flowing between another pair of terminals.

An expression of the form (1) can be transformed into a curve with two *symmetrical* branches by a suitable substitution of the form

$$y = \frac{x-\eta}{x-\xi} \qquad (2)$$

after which (1) takes the form

$$|Q| = \lambda\sqrt{\frac{\pm 1 \pm B^2y^2}{\pm 1 \pm A^2y^2}} \qquad (3)$$

so that the constants α, β, γ, δ, and ε are replaced by the constants ξ, η, λ, A, and B.

The data for Q being given in the form of a curve, a simple graphical construction enables it to be determined whether there is a substitution (2) which will transform the original curve into a *symmetrical* curve; if this can be done ξ and η are immediately known from the construction.

The remaining three constants, λ, A, and B can be found by fitting the transformed impedance curve into a family of standard curves (Fig. 2) drawn on log-log paper. In this operation the transformed Q curve is drawn on transparent paper with the same scales as the family of standard curves; laying the transparency over the standard curves so that the scales at first coincide, the transparency is displaced without rotation until the curve drawn on it coincides with one of the standard curves. The constants λ, A, and B are then determined from the parameter defining the particular curve with which coincidence has been obtained, and from the displacements of the transparency scales with respect to the abscissae and ordinates of the standard curves.

By a purely algebraic calculation, the original constants appearing in (1) are derived from the five constants, ξ, η, λ, A, and B that have been evaluated.

Procedure

The procedure corresponding to the foregoing outline of the method will now be described in detail and in order, it being supposed that an impedance curve $|Q|$ is given and its equation in the form of (1) is required.

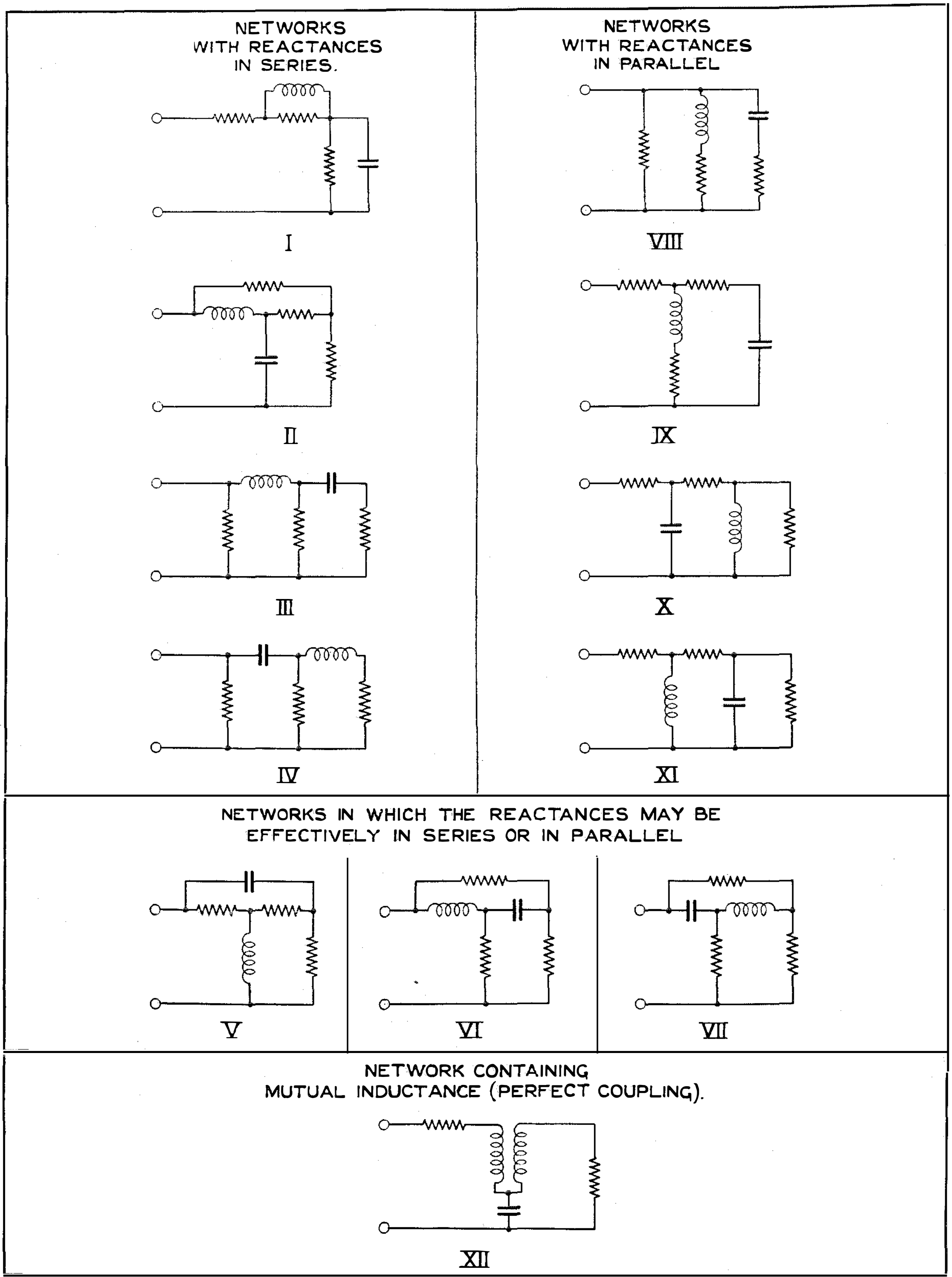
NETWORKS
WITH REACTANCES
IN SERIES.
I
II
III
IV
NETWORKS
WITH REACTANCES
IN PARALLEL
VIII
IX
X
XI
NETWORKS IN WHICH THE REACTANCES MAY BE
EFFECTIVELY IN SERIES OR IN PARALLEL
V
VI
VII
NETWORK CONTAINING
MUTUAL INDUCTANCE (PERFECT COUPLING).
XII

Figure 1

The variable in (1) is proportional to ω^2 and therefore the first step is to replot the given impedance curve with an abscissa of ω^2. It will be assumed that the curve thus plotted shows a minimum value and extends to ω^2 values (*i.e.*, x values) considerably removed on both sides from the value x_0 at which the minimum is located.

The substitution (2) affects the x scale only; graphically, a substitution of this form can be effected by projecting the x scale from any fixed pole on to any line. The inclination of the projected scale is of no importance provided proper oblique coordinates are used (see Appendix I), and for convenience of space on the drawing paper an oblique axis for the projected scale is often convenient; the obliquity of the axis is determined when fixing the pole O, for the axis must be parallel to Ox_0.

In order to procure a y scale such that the Q curve replotted as a function of y appears as a symmetrical curve, the pole must be chosen with the same x (oblique) coordinate x_0 as the minimum of the curve (see Fig. 3). This at once determines the value of ξ, for $\xi = x_0$. The distance of the pole from the x axis is entirely arbitrary and a matter of convenience.

Lines are then drawn through the pole and pairs of values of x for which Q is equal in value; let these paired lines be called a a′, b b′, c c′, etc. The y scale is now to be drawn by trial as a line parallel to Ox_0, intersecting the x axis at x′ and in such a position that the intercepts between x′ and the intersection of the y scale with the lines a and a′ are equal; similarly, the intercepts between x′ and the intersection of the y scale with the lines b and b′ are equal, and so on. If such a position for the y scale cannot be found the given impedance curve cannot be represented by equation (1).

If the requirements can be met with sufficient accuracy for the purpose in hand $x' = \eta$ and η is therefore determined.

Having placed the y axis, a uniform scale should be marked upon it, taking as unit distance, the distance of the pole of projection from the x axis measured parallel to the y axis. The transformed Q curve may now be plotted on the y scale by transferring the Q value appropriate to each point on the x scale to the corresponding (projected) point on the y scale. This operation is, however, unnecessary as the curve (or rather one of its two equal branches) has to be plotted on transparent paper to the same scale as the standard curves to which reference must now be made.

The family of standard curves required is suggested by the consideration that expressions of the form (1) can be rationalised in terms of elliptic functions[1]; these are symmetrical functions and therefore the first step is a substitution of the form (2) which converts (1) into the form (3).

There are three cases to distinguish, corresponding to the three forms of (3) which represent curves having a stationary (minimum) value of Q. The appropriate substitutions are shown in Table I[2].

TABLE I

	$\lambda\sqrt{\frac{1+B^2y^2}{1+A^2y^2}}$	$\lambda\sqrt{\frac{1+B^2y^2}{-1+A^2y^2}}$	$\lambda\sqrt{\frac{B^2y^2-1}{A^2y^2-1}}$
y	$\frac{1}{A}$ sc (u, k)	$\frac{1}{A}$ nc (u, k)	$\frac{1}{A}$ ns (u, k)
Q	λ dn (u, k)	$\frac{\sqrt{A^2+B^2}}{A}.\lambda.$ds (u,k)	$\frac{B}{A}.\lambda.$dc (u,k)
k	$\frac{1}{A}\sqrt{A^2-B^2}$	$\frac{A}{\sqrt{A^2+B^2}}$	$\frac{A}{B}$

Corresponding to these, three sets of curves are required, k being the parameter distinguishing the different curves in each family. The curves are drawn on log-log paper; in Fig. 2 all three families are drawn to the same scale. For practical use appropriate scales should be used for each set; curves are required for smaller differences of k^2 than can be shown in Fig. 2.

[1] Bibliography: 7 Chapter X.

[2] Readers who are unfamiliar with elliptic functions or who do not have access to tables of their values should note that the standard curves can be set up by plotting abscissae and ordinates for corresponding values of θ in the following expressions:

For sc u use tan θ
For nc u use sec θ
For ns u use cosec θ
For dn u use $\sqrt{1-k^2\sin^2\theta}$
For ds u use cosec $\theta\sqrt{1-k^2\sin^2\theta}$
For dc u use sec $\theta\sqrt{1-k^2\sin^2\theta}$

where k^2 is the parameter for each curve of a family.

Returning now to the original data which has been subjected to the transformation (2), one branch (the longer) of the transformed Q curve must be plotted on transparent log-log paper similar to that on which the standard family is drawn. The transparency is superposed on the standard curves and manoeuvred (without losing parallelism of the respective axes on the two sheets) until the curve on the transparency coincides as well as possible with part of one of the standard curves. If the coincidence is sufficiently exact a solution to the problem is possible and the ensuing calculations can be undertaken with confidence. It should be noticed that up to this stage almost no calculation has been necessary.

It is necessary to note the k value of the standard curve with which the other curve agrees, and also a pair of coincident values on the superposed abscissae and on the superposed ordinates.

Let y′ and Q′ be coordinates of the curve on the transparency that coincide with values of coordinates on the standard sheet denoted by a bar. Then from Table I it is clear that the three constants λ, A, and B are determined as shown in Table II.

TABLE II

	dn-sc family	ds-nc family	dc-ns family
λ	$\frac{Q'}{\overline{dn\ u}}$	$\frac{kQ'}{\overline{ds\ u}}$	$\frac{k\,Q'}{\overline{dc\ u}}$
A	$\frac{\overline{sc\ u}}{y'}$	$\frac{\overline{nc\ u}}{y'}$	$\frac{\overline{ns\ u}}{y'}$
B	$A\sqrt{1-k^2}$	$\frac{A}{k}\sqrt{1-k^2}$	$\frac{A}{k}$

Having determined in this way λ, A, and B, with ξ and η already determined, it is only a matter of algebra to reverse the substitution (2) and secure an expression of the form (1) which is the required data for the curve Q. Thus the con-

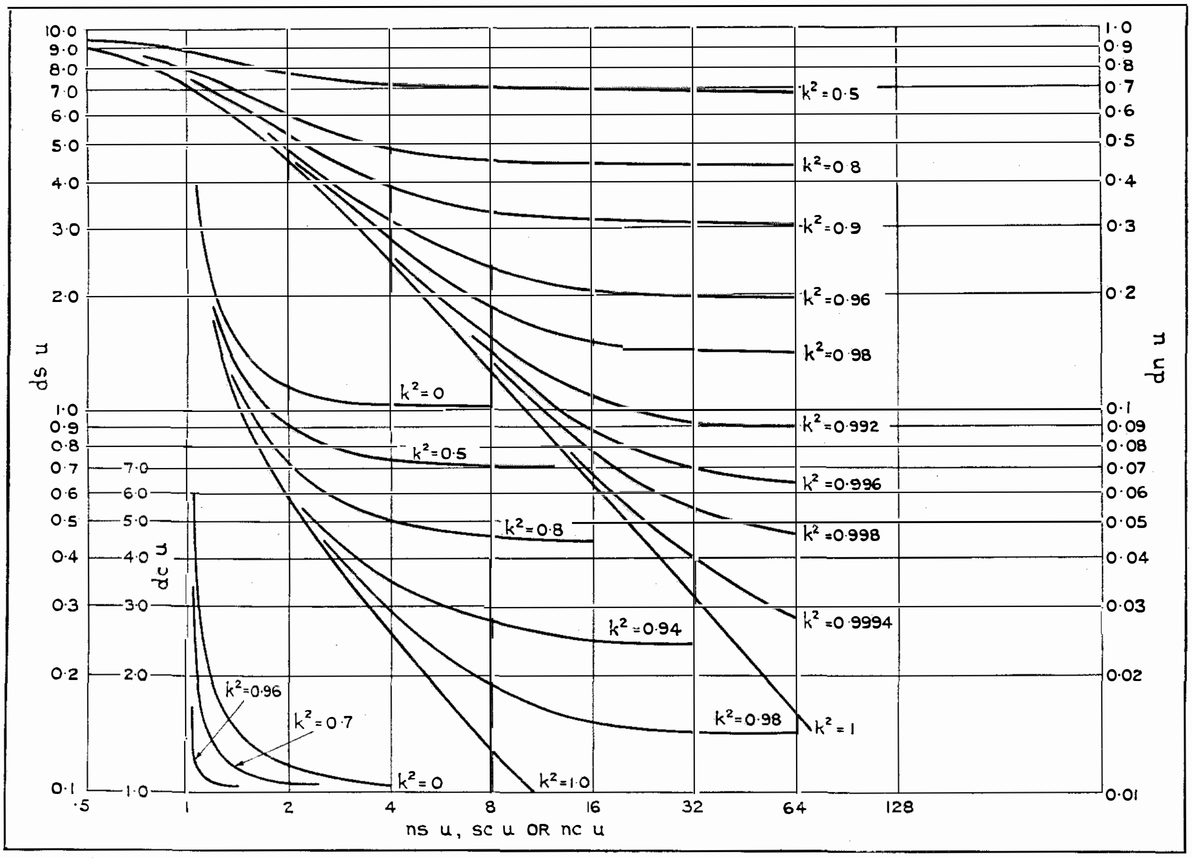

Figure 2

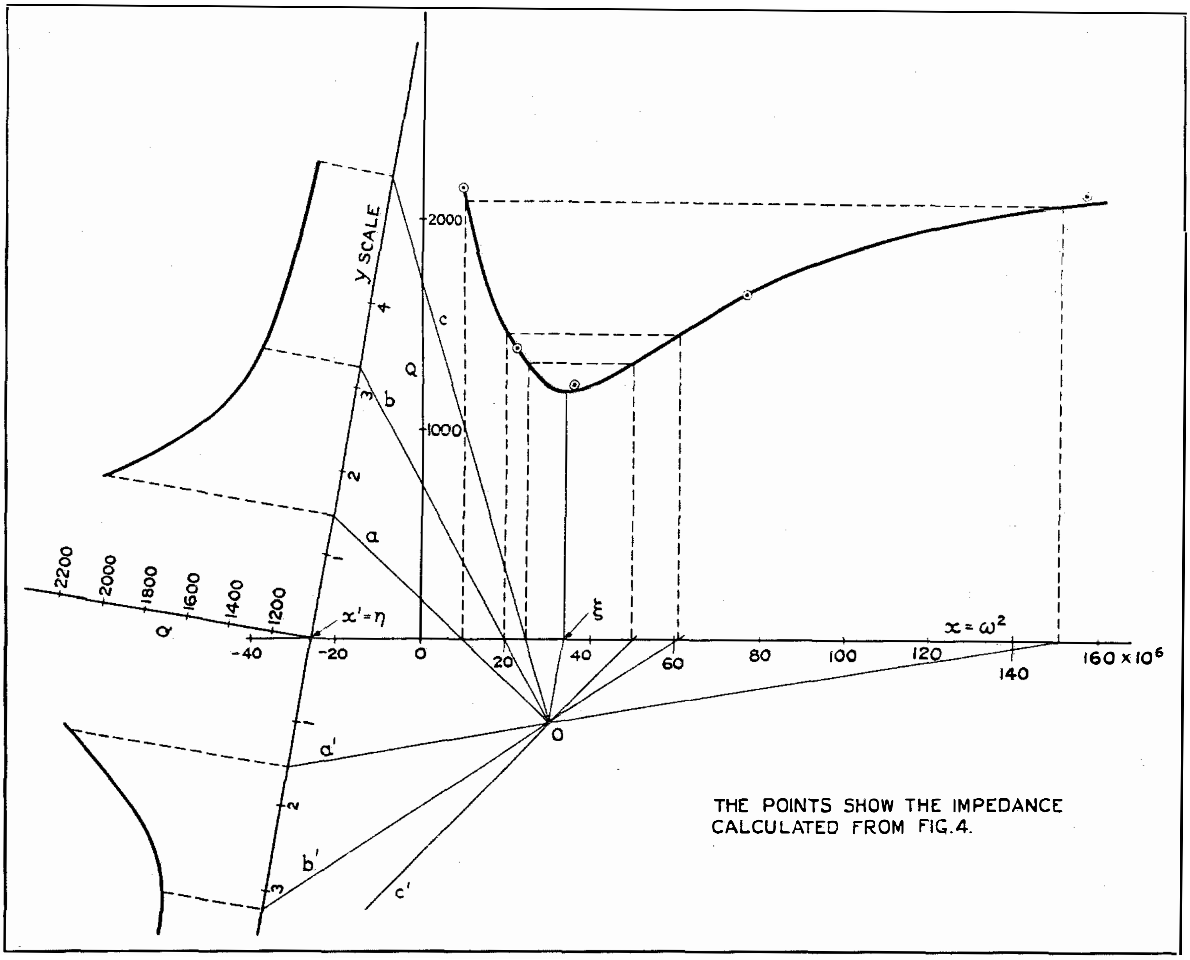

Figure 3

stants, α, β, γ, δ, and ε are determined from the following:

$$\left.\begin{aligned}\alpha &= \frac{m+B^2}{m\xi^2+B^2\eta^2}\\ \beta &= -2\frac{m\xi+B^2\eta}{m\xi^2+B^2\eta^2}\\ \gamma &= \frac{1}{\lambda^2}\frac{p+A^2}{m\xi^2+B^2\eta^2}\\ \delta &= -\frac{2}{\lambda^2}\frac{p\xi+A^2\eta}{m\xi^2+B^2\eta^2}\\ \varepsilon &= \frac{1}{\lambda^2}\frac{p\xi^2+A^2\eta^2}{m\xi^2+B^2\eta^2}\end{aligned}\right\} \quad (4)$$

where m and p have the following values according to the set of standard curves used:

$$\left.\begin{aligned}&\text{dn-sc family:} \quad m = p = +1\\ &\text{ds-nc family:} \quad m = +1;\ p = -1\\ &\text{dc-ns family:} \quad m = p = -1\end{aligned}\right\} \quad (5)$$

The following substitutions are often convenient for the expression of the network solutions:

$$\left.\begin{aligned}a &= \sqrt{\alpha}\\ b &= \sqrt{\beta+2\sqrt{\alpha}}\\ c &= \sqrt{\gamma}\\ d &= \sqrt{\delta+2\sqrt{\gamma\varepsilon}}\\ e &= \sqrt{\varepsilon}\end{aligned}\right\} \quad (6)$$

These permit (1) to be expressed in the form:

$$Q = \frac{b+ja\omega+1/j\omega}{d+jc\omega+e/j\omega} \quad (7)$$

Should the given curve be smoothly rising or falling without showing a minimum, a solution may be possible by choosing ξ at a point that is a reasonably possible minimum; η is then still arbitrary and trial values must be used in the attempt to get a y scale on which the single branch of the curve available will plot in a shape that can be fitted to the standard curves. Obviously, the method is not as well adapted to this case.

When the given curve shows a maximum, the simplest procedure is to plot the reciprocal of Q, thus producing a curve with a minimum; when the solution has been obtained in the form (1) or (7), it must, of course, be inverted.

The construction of a network that realises the given Q data when the constants in (1) have been obtained is outside the scope of this paper. The method of partial fractions[3] or one of the other methods noted in the Bibliography may be employed; a direct solution of one of the networks (Fig. 1) is always possible but there is little to guide one in determining which network will meet the case, although some can generally be discarded. For example, the constants in (1) enable it to be stated whether Q is greater at $\omega=0$ or at $\omega=$infinity; it is evident that network IV has Q smaller at $\omega=$infinity than at $\omega=0$, while for III the contrary holds good.

Examples

I. Let the Q data for which a network is to be constructed be as follows:

f	Impedance	f	Impedance
500	2,120	1,200	1,410
750	1,400	1,400	1,640
800	1,330	1,500	1,770
1,000	1,210	2,000	2,090

The impedance is plotted against $x=\omega^2$ in Fig. 3 and the minimum is taken as $x=33.7\times10^6$ which is therefore the value of ξ. The projection of the x scale is carried out and it is seen that the required equality of intercepts is secured when $x = -25.4\times10^6 = \eta$. The y scale is then numbered and the Q curve replotted on this scale to illustrate its appearance. Replotting the Q-y curve on log-log paper and comparing with the standard dn-sc curves, coincidence is obtained with the curve $k^2=0.96$. The sc u scale values are found to be 2.22 times the y scale values on which they are superposed so that $A=2.22$. The ratio of the Q values to the dn u values on which they are superposed is 6,200 which is therefore the value of λ. B is 0.444 (Table II).

Substituting in 4, 5, and 6, the constants for expression (1) or the alternative form (7) are obtained:

$$\left.\begin{aligned}\alpha &= .00095\times10^{-12}\\ \beta &= -.0462\times10^{-6}\\ \gamma &= .122\times10^{-15}\\ \delta &= .0038\times10^{-12}\\ \varepsilon &= .089\times10^{-6}\end{aligned}\right\}\text{ or }\left\{\begin{aligned}a &= .0308\times10^{-6}\\ b &= .124\times10^{-3}\\ c &= .01105\times10^{-9}\\ d &= .102\times10^{-6}\\ e &= .298\times10^{-3}\end{aligned}\right.$$

The direct solution of network IV, Fig. 1, with these constants gives the network of Fig. 4b, which may, however, more easily be obtained by the method of continued fractions in the form of Fig. 4a which is convertible into Fig. 4b. Another solution may be obtained by Otto Brune's method[4] (see Fig. 5 and Appendix II).

The impedance calculated at certain frequencies from the network of Fig. 4 has been plotted in Fig. 3.

II. The impedance data are given as a single branch curve as follows:

$2\pi f$	|Q|	Calculated Impedance of Network Designed
0	2,400	2,310
1,000	2,200	——
2,000	1,920	1,910
3,000	1,600	——
4,000	1,250	1,216
5,000	920	——
6,000	630	646
7,000	400	421

The data for this curve were taken from a random curve drawn freehand.

The Q data were plotted against a scale of ω^2

[3] Bibliography: 4, 5 and 2 page 18.

[4] Bibliography: 3.

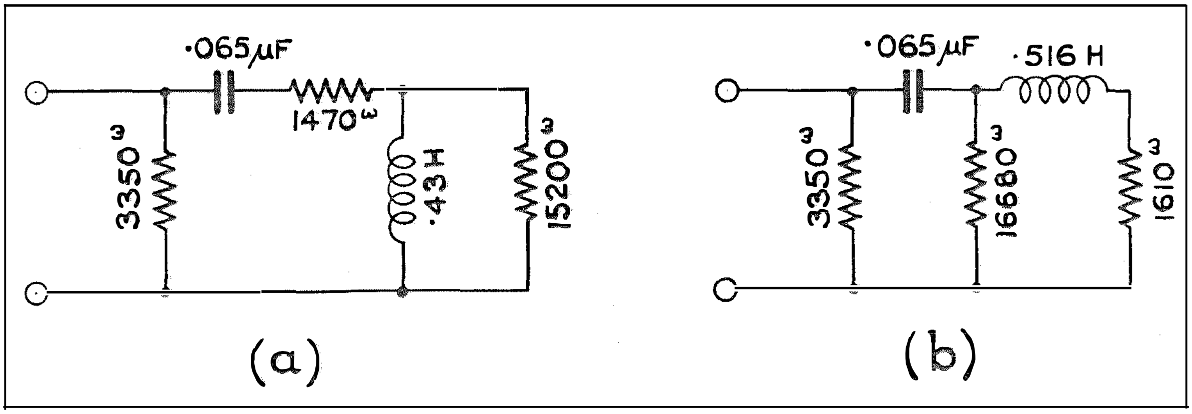

Figure 4

and then the curve was extended downwards with increasing curvature in a smooth manner; in this way a possible minimum value was found at $\omega^2 = 70 \times 10^6 = \xi$. From a pole with this value of abscissae the ω^2 (*i.e.*, x) scale was projected to y axes in various positions. Trial Q curves were then plotted on the different y scales thus formed and after a few trials it was found that, with a y scale crossing the x axis at $x = -90 \times 10^6$ a curve was obtained which agreed fairly well with one of the standard curves. The value -90×10^6 was therefore adopted for η.

Superposition of the transformed Q curve on the standard curves gave agreement in the ds-nc family with the curve $k^2 = .98$ and the values $a = 1.08$, $B = .1545$ and $\lambda = 2{,}180$ were deduced.

From equations 4, 5 and 6 the following constants were calculated:

$$\begin{array}{ll} \alpha = 2.015 \times 10^{-16} & a = 1.416 \times 10^{-8} \\ \beta = -2.67 \times 10^{-8} & b = .403 \times 10^{-4} \\ \gamma = 7.04 \times 10^{-24} & c = 2.66 \times 10^{-12} \\ \delta = 14.5 \times 10^{-16} & d = 12.97 \times 10^{-8} \\ \varepsilon = 18.8 \times 10^{-8} & e = 4.35 \times 10^{-4} \end{array}$$

By the method of continued fractions the solution shown in Fig. 6 was obtained.

The calculated impedance of this network at five frequencies is shown above by the side of the original data.

APPENDIX I

Geometrical construction (in oblique coordinates) for the bilinear transformation:

In Fig. 7, let GJ be the scale of x, G the origin and O the pole of projection.

Let DF be the scale of y.

GH is the coordinate of the pole O.

DB is the projection on the y scale of GA.

$$DA = GA - GD \text{ (GD being negative)}$$
$$AH = GH - GA.$$

By similar triangles,

$$DB = OH\frac{DA}{AH} = -OH\frac{GA - GD}{GA - GH}.$$

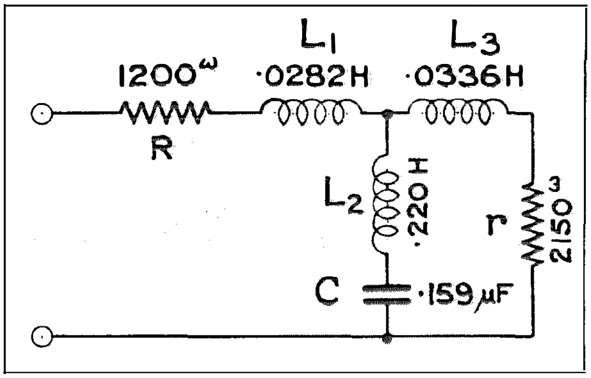

Figure 5

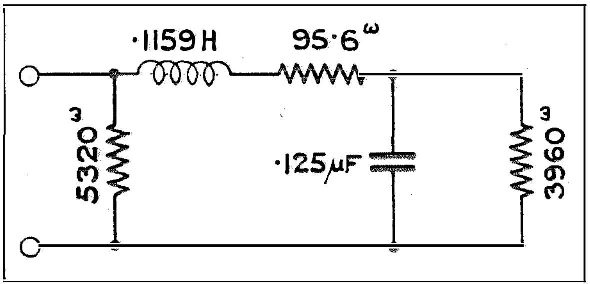

Figure 6

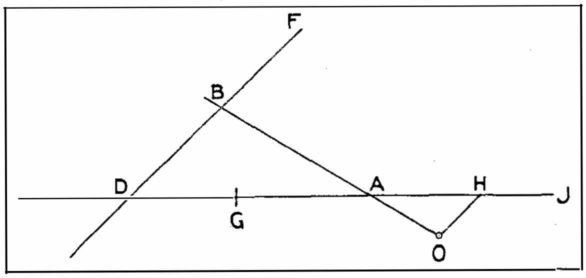

Figure 7

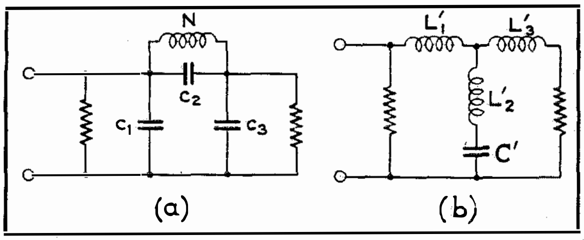

Figure 8

GA is x, therefore, choosing OH as -1 we can write,

$$DB = y = \frac{x-\eta}{x-\xi},$$

η and ξ having the meanings assigned to them in the text.

APPENDIX II

Brune's synthesis of a two terminal network leads to a solution of the form shown in Fig. 5, where L_1, L_2, L_3 are the T-representation of a perfectly coupled transformer (compare Fig. 1, No. XII).

In terms of the constants defined in equations (6), the elements of the network are:

$$R = \frac{b\,(d^2-2ce)\ -\ d\,(c+ae)}{d\,(d^2-4ce)}$$

$$\pm\ \frac{2\sqrt{ce}\sqrt{(c-ae)^2-(bc-ad)\ (d-be)}}{d\,(d^2-4ce)}$$

$$r = 1-eR$$

$$C = \frac{d}{1-eR}$$

$$L_1 = \frac{-c\,(1-eR)+(b-dR)\,d+(a-cR)\,e}{2\,de}$$

$$L_2 = \frac{c\,(1-eR)-(b-dR)\,d+(a-cR)\,e}{2\,de}$$

$$L_3 = \frac{c\,(1-eR)+(b-dR)\,d-(a-cR)\,e}{2\,de}$$

If the curve to be solved shows a maximum instead of a minimum it is inverted as in the text. The above expressions will then give the network inverse to the solution desired, and the required network is found by the rule for constructing inverse networks[5]. This leads to a fictitious network, Fig. 8a, one of the capacities being negative but Brune shows that the fictitious network of Fig. 8a can be replaced by a real network Fig. 8b in which,

$$C' = C_1+C_3$$

$$L_1' = \frac{NC_3}{C_1+C_3}$$

$$L_2' = \frac{NC_2}{C_1+C_3}$$

$$L_3' = \frac{NC_1}{C_1+C_3}$$

[5] Bibliography: 8 Chapter XVIII.

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The Radio Direction Finder on Board Ship

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THE Radio Direction Finder has always been regarded as an instrument of importance to navigation, but it is one which has been somewhat slow to reach its present stage of development and to become generally recognised as an instrument which does not require special knowledge of radio for successful operation. A recent examination (August, 1935) of the latest issue of the Berne List of Coast Stations and Ship Stations indicates that about 36% of the world's shipping is fitted with radio direction finding equipment. It is to be anticipated, however, that this figure will steadily increase, and it does not seem at all unlikely that before long the radio direction finder will be regarded as much a part of the normal navigational equipment of any seagoing vessel as the mariner's compass itself. While the advantages of directional reception gained early recognition, the insensitive receivers employed prior to the introduction of the thermionic valve made it impracticable to rotate the large aerials necessary to obtain adequately strong signals; consequently, all early direction finders were of the fixed aerial Bellini-Tosi type. Such equipments came into general use during the European War and consisted of two large fixed triangular loop aerials, suspended by their apices as high as possible above the receiver and at right angles to each other. In this type of direction finder the signals received by the loops are transferred to the small fixed loops of an instrument called a radio goniometer; the position of a third coil associated with the radio receiver and rotating within the two fixed coils, indicates the direction of the incoming signal.

When sensitive receivers employing thermionic valves came into general use, the necessity of employing large aerials disappeared and they were replaced by the small fixed frame aerials in general use today. At the same time it became possible to employ a single small rotating loop aerial which could itself be used to indicate direction by means of a pointer or index on its axis. Both types of direction finder—the single rotating frame and the two fixed loops at right angles to each other—have their uses and special application. The former is the simpler and more general type but there are many occasions when the structure of the ship renders it necessary to remove the frame some distance laterally from the position of the observer. In these circumstances the installation of a direction finder on the fixed frame Bellini-Tosi system may be desirable.

The thermionic valve came into general use about the year 1913, and for the next ten years the radio direction finder was under development but was only occasionally to be found installed on board ships of the Mercantile Marine. For instance, as late as 1924, there were only about one hundred and twenty British and forty United States ships fitted with direction finders.

About this time (1924) the United States Lighthouse authorities commenced the erection of radio beacons on which ships could take radio bearings by means of their own apparatus. Until this date, ships had either to accept bearings given by shore stations or request shore stations to send a special signal on which the ship herself could take a bearing. Either of these courses involved the services of a qualified radio operator.

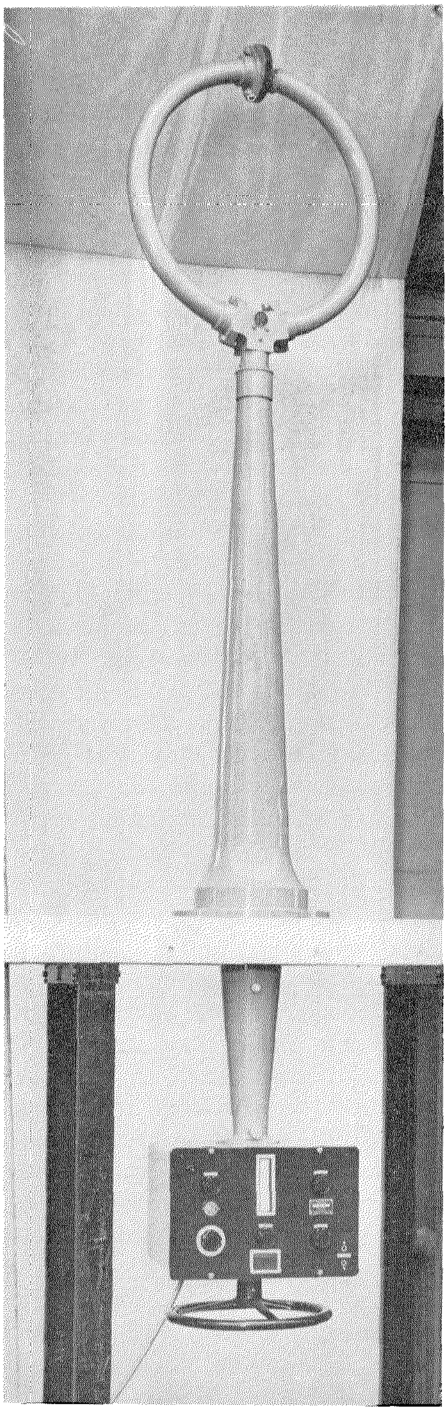
The establishment of the radio beacon marked the commencement of a fresh development in the art. These new radio beacons worked automatically to a schedule on a wavelength of about 1,000 metres and employed an extremely simple characteristic signal. Their primary object was to provide a radio station on which the average navigating officer could take a bearing himself without reference to the skilled radio personnel of the ship. Up to this time the practice had been to take bearings on 450, 600, or 800 metres wavelength; these wavelengths were in use for ordinary maritime communications and, owing to interference, it was not as a rule possible for any person, unless he were a skilled Morse operator, to make reliable observations on them. The adoption of a special wave, which at the same time happened to be comparatively free from interference, did much to simplify the operation of taking a bearing by radio direction finder by those unskilled in the reception of Morse signals.

Concurrently, with the development and simplification of the radio direction finding system, radio engineers and laboratories proceeded with the simplification of the radio direction finder itself, and endeavoured to reduce, as far as possible, its errors to a formula which could be placed at the disposal of the unskilled operator. Their efforts have been very largely successful and the average navigating officer, furnished with a radio direction finder of the type shown in the accompanying illustration, and certain simple and definite instructions, can fix his position at all times and in all weather with very great confidence when in the vicinity of a radio beacon. If he observes certain additional instructions, the instrument can be usefully employed at ranges of several hundred miles.

Readers may perhaps be interested to observe for themselves how far this ideal of simplicity has been attained, and the remainder of this article is therefore devoted to a general description of the properties of the instrument, together with an explanation of the routine errors which are always to be associated with its use.

The basis of radio direction finding is the fact that a loop of wire will receive the strongest signals from a radio transmitting station when its plane is in the direction of the station, and the weakest signals when its plane is at right angles to the direction of the station. The direction of maximum signals is ill-defined, but the direction of minimum signals (or "zero") can be made extremely sharp with well designed apparatus. Consequently, direction finders, with a few special exceptions, are designed to operate on the minimum strength of signals.

These instruments are subject to errors arising from the presence of metal employed in the construction of the ship, and these errors must be ascertained before the instrument can be used for navigational purposes. This procedure is called "calibration," and involves taking simultaneous bearings of a transmitting station by direction finder and by standard compass



Modern Radio Direction Finder

through 360° of arc. The results are compared, and from them a table or chart is prepared indicating the correction (called the "quadrantal error") which must be applied to the observed bearing by D.F. in order to obtain the true bearing by D.F.

Liability to error is greatly accentuated on short wavelengths, and though radio direction finders are usually designed to work on wavelengths as low as 450 metres, it is customary to restrict their normal operation to the signals received from stations working between 800 and 1,200 metres.

A modern radio direction finder, when used as a navigational instrument to take observations on wavelengths between 800 and 1,200 metres, is a robust and reliable instrument which, provided it is treated with the same care and attention that is accorded to the standard compass, possesses a high degree of accuracy under certain well defined conditions. Speaking generally, the accuracy of all radio bearings obtained under all conditions, day or night, at distances up to 40 miles over sea, may be relied upon, provided the quadrantal error correction already mentioned has been applied and the path of the waves does not closely follow a coast line, thus introducing an error referred to later as the coast refraction error.

Specifically, it may be assumed that radio bearings are accurate:

(a) To within ±2° of arc by day at all ranges over sea, and at all ranges up to 40 miles at night;
(b) To within ±5° of arc at night up to ranges of about 80-100 miles over sea.

Maximum accuracy is obtained at short ranges and an accuracy of ±1° is often possible for ranges of 20 miles at night and 50 miles by day.

Radio bearings should never be relied on:

(a) At night at any distance over about 80-100 miles;
(b) When bearings are partly over high land and partly over water;
(c) When bearings closely follow a coast line.

The expression "at night" means the period between one hour before sunset till one hour after sunrise.

The errors giving rise to inaccuracies may be briefly described as follows:

1. Sunrise, Sunset, or Night Effect Errors at Distances over about 80–100 Miles

During these periods the direction finder is under the influence of the direct ray which gives true bearings, and also the indirect ray which is returned from the upper layers of the atmosphere and which is liable to give a false bearing.

Very considerable inaccuracies, up to as much as 90° on observations taken at ranges of several hundred miles, have been observed during these periods, and observers should not rely on any bearings taken at night, or one hour before and after sunrise or sunset, at ranges over 80–100 miles. The presence of this error can usually be detected, as the "zero" becomes indefinite, and the strength of the observed signals often varies considerably within a short period of time.

At distances less than 80 miles there may be a small error, but it is rarely more than two or three degrees; not more, in fact, than is often experienced when taking bearings by compass.

2. Coast Refraction Error

This error occurs when the path of the waves follows the coast line, and is due to the fact that electro-magnetic waves apparently travel more slowly over land than over sea, and, consequently, when passing from land to sea, or vice versa, there is a slight distortion of their path, dependent on the angle at which the waves pass from the one to the other. The error may be as much as 5°.

3. Error Due to a Reciprocal Bearing

The actual direction of the transmitting station has a 180° ambiguity, as there are obviously two positions, 180° apart, in which the received signals are at a minimum, and it may, therefore, be necessary to ascertain in which of two possible directions the transmitting station is situated. This operation is called finding the "sense," which can be determined by several methods, but the principle is the same in all cases.

"Sense" is determined by combining in the same receiver the directional signals received on the loop with the all-round signals received on an ordinary vertical aerial or its equivalent. When a special aerial is provided it is called the "sense" aerial. The effect of this combination is to produce a somewhat ill-defined, but unmistakable, single directional "zero" which can be utilized to indicate the actual direction of the transmitting station.

4. Quadrantal Error

When the signals from the transmitting station pass through the ship, every part of the ship which is a conductor of electricity is affected by them, and the currents of electricity thus set up in these conductors combine to deflect the path of the signal to a varying extent.

The corrections necessary to allow for these deflections are a minimum at 0°, 90°, 180°, 270°, and a maximum at 45°, 135°, 225°, 315°. They also change their sign in each quadrant. If they are additive between 0° and 90° they will be subtractive between 90° and 180°, and so on. They are in fact quadrantal, and before the bearing, as observed on the D.F. scale, can be used for navigation, the radio direction finder must be "calibrated" and the ascertained quadrantal correction applied to the observation. Once calibrated, no further correction should be necessary, unless some alteration has in the meantime been made in the disposition of the metal fittings or rigging in the neighbourhood of the instrument. In some cases, however, experience has shown that cargo may have an appreciable effect on the quadrantal error, sufficient to justify calibration both when the ship is heavily and lightly laden. For these reasons, frequent opportunity should be taken to check the instrument by test bearings when within visual distance of a transmitting station.

5. Convergency Correction

This correction only becomes of importance when the observed station is more than 80 miles distant. It is necessary, due to the fact that wireless waves follow the track of a great circle, whereas bearings laid off on a chart on a Mercator's projection are on a rhumb line. Although, as already stated, this correction is negligible at short ranges, its importance increases with the distance; for example, an error of 100 miles may be introduced in the position of a ship fixing her position by radio bearings of stations 800 miles distant should the observer fail to apply the convergency correction to the observed bearings.

Esterified Fibrous Insulating Materials

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PART III

In Parts I[1] *and II*[2] *of this paper, it was indicated that a new technique of insulating materials is appearing on the horizon and that the insulation of the future will be prepared synthetically or will be chemically processed to eliminate inherent natural defects. This point is illustrated in the present installment by two cases:* (1) *The improvement of the processing of acetylated cotton* (Cotopa) *to a stage which provides insulation 10-20 times superior to any textile insulation previously known;* (2) *The development of processes for the analogous treatment of natural silk and wool to meet the demand for high grade insulation with fireproof characteristics superior to those obtainable from cellulosic materials.*

THE present and concluding part of this paper is divided into the following sections:

(1) Fuller details of the insulation resistance of *Cotopa* and its recent great improvement,
(2) Fireproofing of Textiles,
(3) Chemical and physical structure of natural silk and wool,
(4) Chemical derivatives of natural silk and wool having greatly improved insulation resistance values,
(5) Short summary of the properties of all the textiles commercially available, from an electrical manufacturing standpoint.

1. *Fuller Details of the Insulation Resistance of Cotopa and Its Recent Great Improvement*

Relation of Insulation Resistance of Cotopa to Relative Humidity Under Absorption and Desorption Conditions

Curves showing the relation of the insulation resistance of *Cotopa* to the relative humidity of the surrounding atmosphere are given in Fig. 3 of Part I and, similarly, for acetylated cottons of various degrees of acetylation, in Fig. 2 of Part II. These curves, as stated, were all obtained under absorption conditions, that is to say, the textile samples were first thoroughly dried out over phosphorus pentoxide at ordinary temperatures, then brought into an atmosphere of the lowest relative humidity at which measurements were required and kept there until no further appreciable change with time took place. They were then transferred to an atmosphere of higher relative humidity and the process repeated, and so on with atmospheres of steadily increasing relative humidity up to 100%.

If a sample be taken through the same series of relative humidities in the reverse order, i.e., under desorption conditions, a fresh curve is obtained with values lower than the first curve. Reference thereto has already been made in Section 8 of Part II, and the complete absorption-desorption curves of cotton are shown in Fig. 20 of Part II. A. C. Walker has recently published further information including more detailed curves regarding this phenomenon as it affects cotton.

This effect is due to the fact that all colloidal organic materials which absorb moisture, such as textile fibres, have different moisture contents when in equilibrium with an atmosphere of any given relative humidity, depending on whether they have reached equilibrium from a higher or a lower relative humidity. Except for minor variations, the insulation resistance of a given sample is constant for a given moisture content. Details of such variations are given in Walker's paper[3].

Cotopa is no exception to this general rule and its insulation resistance curves under absorption and desorption conditions are shown in Fig. 1, which exhibits another minor feature of *Cotopa*, namely, a slight improvement in insulation resistance either on storage for some time or on

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

being slowly taken round the humidity cycle. The curve, marked 1 starting at A, was obtained by first drying a sample of *Cotopa* thoroughly over phosphorus pentoxide, then measuring the insulation resistance at equilibrium with a series of atmospheres of increasing relative humidity up to 100%, and then taking the sample through the same series in the reverse order as indicated by the arrows. The sample was then redried over phosphorus pentoxide as before, and the series of measurements repeated when slightly higher results were obtained as shown, marked 2. This would appear to be a stable condition, since an additional repetition of the cycle did not produce any further appreciable change. The same effect is observed if *Cotopa* is stored in an atmosphere of 70%-100% relative humidity for a few weeks, improvements of the order of from 10%–50% being obtained when compared with measurements made immediately after the completion of manufacture.

This effect is, of course, of the same nature as that referred to in Section 1 of Part II and is due to a slow slight readjustment of the internal structure of the fibre.

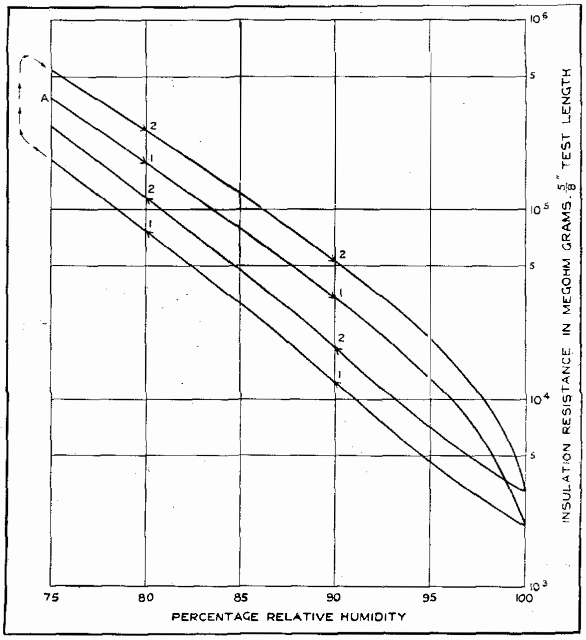


Figure 1—Relation of Insulation Resistance of Cotopa *to Relative Humidity under Absorption and Desorption Conditions.*

Improvements in the Insulation Resistance of Cotopa due to Special Washing Process

Recent studies have shown that whereas the electrolytic matter in *Cotopa*, washed in the normal manner, is such as to give a specific conductivity of water extract (for details of method see Section 9 of Part II)[2] of about 30-50 micromhos, more thorough washing with water of low electrolyte content can reduce the electrolytic matter to such an extent that water extracts of only 10 micromhos specific conductivity can be obtained, with a corresponding increase in the insulation resistance at 80% relative humidity to 1,000,000 megohm-grams.

Effect of Heat Treatment on the Insulation Resistance of Cotopa

Fig. 2 shows the effect of heat treatment on the insulation resistance of *Cotopa*. Similar curves for cotton have been published by Walker[3].

Curve 1 is that obtained with the same sample of *Cotopa* as in Fig. 1 after heating in air to a temperature of 140°C. for 3 hours. After being taken around the cycle 1, the sample was dried thoroughly over phosphorus pentoxide and taken around the cycle again. This time the absorption curve was lower than absorption curve 1, but the desorption curve was practically identical. Drying over phosphorus pentoxide again and retesting resulted in a repetition of curve 2. The dotted lines indicate the higher of the two curves previously obtained without heating.

This shows that an improvement of 200–300% in the insulation resistance of *Cotopa* can be attained by heating at 140°C. for 3 hours, that this improvement is retained only if the material is not taken to high humidities, and that if it is taken to high humidities the greater part of the improvement is lost but that a minor part is permanent. The difference between the upper dotted curve and curve 1 represents the temporary improvement and the difference between the upper dotted line and curve 2, the permanent improvement. If a lower temperature is employed, both the temporary and permanent improvement are less.

No further gain is obtained by increasing the time of heating above 3 hours when dealing with small samples; but, when larger masses of textile are concerned, allowance must be made for the slow rate of heating up and for the fact that moisture will escape more slowly, so that a somewhat longer period probably will be necessary.

By this means, samples of "super washed" *Cotopa* previously referred to have had their insulation resistances at 80% relative humidity increased to 2,000,000 megohm grams under absorption conditions, about 1,500,000 being retained even after exposure to high humidities, drying, and conditioning at 80% relative humidity.

Improvements in Insulation Resistance due to Increased Combined Acetic Acid Content

Recent research work in the laboratories of Chemical Works (formerly Sandoz, Ltd.) has made it possible to carry the acetylation process much farther without causing mechanical damage to the fibres, resulting in much higher combined acetic acid contents and higher insulation resistance values. By this means, values of the order of 60,000,000 megohm grams at 80% relative humidity can be obtained. This material when available will, of course, be rather more expensive than the 100,000–1,000,000 type of *Cotopa*.

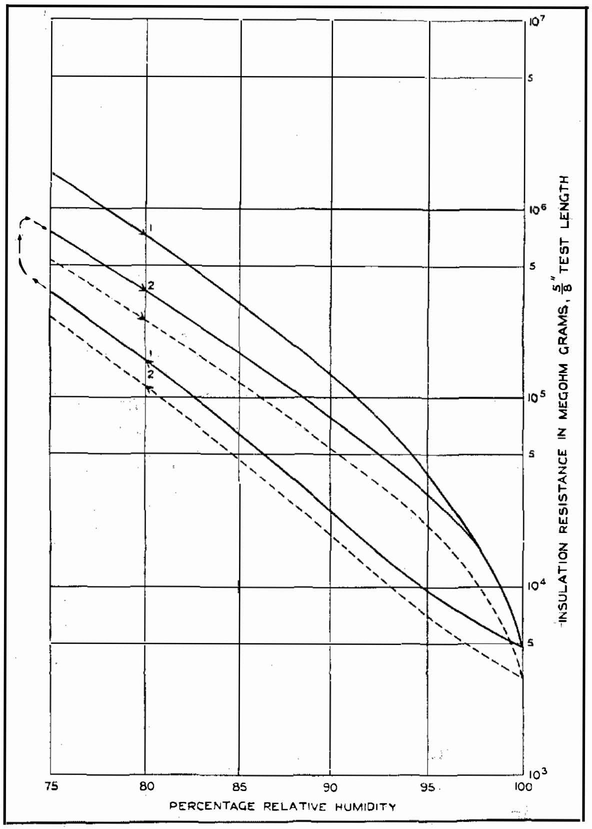


Figure 2—Effect of Heat Treatment on the Insulation Resistance of Cotopa.

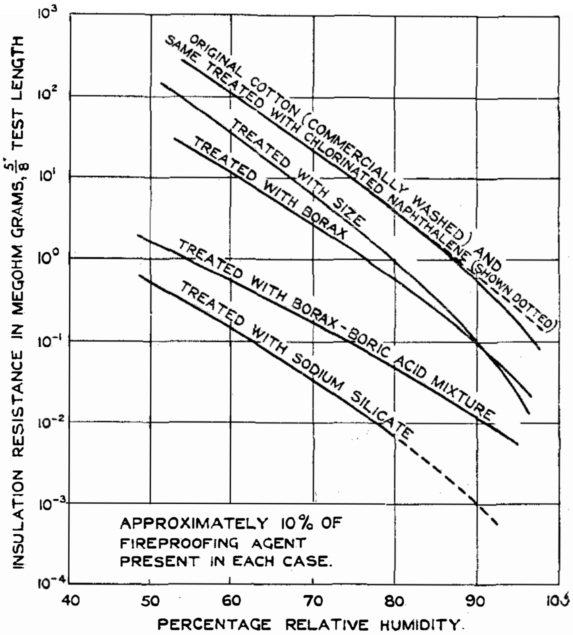


Figure 3—Effect of Fireproofing Agents on the D-C. Insulation Resistance of Cotton.

It can thus be seen that the insulation resistance of *Cotopa* is rapidly being moved up to values which are enormous, compared with those obtainable with textile insulations in the past, but in respect of its one weakness—fire resisting properties—very little progress has been made, and another line of research has been developed to supply the need for high grade insulation with improved fire resisting properties. This is described in Section 4.

2. *Fireproofing of Textiles*

The fireproofing of textiles is a very complex subject for several reasons. Chiefly, the resistance of a textile material to burning varies enormously according to the form and nature of the finished product in which it is incorporated; the manner in which testing of the fire resistance of materials is carried out greatly affects the results; and combustion can take place in at least two different ways—with and without an accompanying flame.

Inflammability of Natural Textiles

Only one fibrous material, namely, asbestos, has complete fire resisting properties in the sense that it cannot be made to burn under any circumstances. Although it is perfect in this respect, the other properties of asbestos, notably its low tensile strength and the difficulty of spinning any but extremely coarse yarns from it, reduce its application to a very limited sphere. As all the other textile fibres are organic substances containing carbon, hydrogen, and oxygen, and sometimes nitrogen and sulphur, the bulk in every case consisting of carbon, they burn when a flame is applied to them. They differ amongst themselves according to their chemical constitution in that, generally speaking, cellulosic fibres continue burning when the flame is removed while protein fibres cease to burn when the flame is removed.

The following summarises their properties in this respect:

(1) Collodion (cellulose nitrate) silk	Burns very vigorously, almost explosively.
(2) (a) Cotton Cotopa Viscose Silk Cuprammonium Silk Chardonnet Silk	Burning generally continues on removal of initial flame.
(b) Cellulose Acetate Silk	Like 2 (a), but the burning is not initiated quite so easily due to fusion of the fibres.
(3) Wool	Fuse as they burn, but burning nearly always ceases on removal of initial flame.

Fireproofing Treatments for Cotton using Inorganic Materials

The bulk of the fireproofing processes described in the literature have had as their object the improvement of the flame resisting properties of cotton, and hence are nearly all directly applicable to *Cotopa*. A publication[4] of the Department of Scientific and Industrial Research summarises the suggestions that have been made for fireproofing cotton fabrics up to 1929, and describes the work done by its authors on inorganic fireproofers.

Treatment of this kind consists of three types:

(1) Impregnating the fabric with an aqueous solution of a salt and removing the water by evaporation.

(2) As in (1), but subsequently immersing the dried fabric in the solution of another salt which by double decomposition produces an insoluble precipitate with the first one, the said precipitate being produced in the interstices and fibres of the fabric.

(3) Painting on the flameproofing material in the form of a solution thickened with starch, glue, gum, etc.

Ramsbottom and Snoad[4] consider that insoluble matter has relatively little flameproofing effect and in their work confined themselves mainly to the first of the above types. They summarise the suggested explanations of fireproofing action as follows:

(1) The fireproofer may fuse below the ignition temperature of the fabric and cover the fabric with a layer impervious to air.

(2) The fireproofer may evolve noninflammable gases which mix with those produced from the heated fabric and render them noninflammable.

(3) Endothermic changes may take place in the fireproofer which cause the flame to be extinguished.

(4) The heat of the flame may be dissipated by con duction.

They are of the opinion that of the above, only the first is of any importance when dealing with inorganic fireproofers; and, as a result of their experimental work, state that an important feature is the chemical action of the fireproofer on the fabric at temperatures a little below the ignition point of the fabric, and that the good fireproofers are substances which from their constitution would be expected to destroy fabrics readily under the action of heat.

All of the effective inorganic fireproofing materials are strong or fairly strong electrolytes and most of them tender cotton appreciably at temperatures a little above normal after six months' storage, and even at ordinary temperatures when exposed to light and air for several months. In this respect borax and boric acid stand out as producing very little deterioration. Separately they are not, however, the most effective fireproofers, but investigation of mixtures of borax and boric acid revealed the fact that whereas both these materials readily crystallise alone, a mixture containing 30% boric acid and 70% borax, on evaporation, leaves a clear syrupy mass. On applying this mixture to cotton fabric to the extent of about 6% of the weight of the fabric, it was found to have excellent fireproofing properties and to prevent the propagation of flame. The proofed material retains its softness and, when stored for 100 days at ordinary temperatures, exhibited no loss in strength; after a year at 40°C. it had lost 7% in tensile strength, and after 100 days of exposure to direct sunlight under glass had lost

27% in tensile strength, the untreated fabric losing 20% during the same period.

Fireproofing Treatments for Cotton Involving Organic Materials

The organic substances which have been proposed as flameproofing agents for cotton may be grouped as follows:

(1) Salts of organic bases with mineral acids, e.g., guanidine phosphate.
(2) Organic esters of inorganic acids, such as triphenylphosphate and tricresylphosphate.
(3) Salts of organic acids such as lead oleate and ammonium recinoleate, sodium oleate, and palmitate (soaps).
(4) Proteins such as glue, size, gelatine, and casein.
(5) Chlorinated carbocyclic compounds, such as chloronaphthalenes and chlorophenols.
(6) Miscellaneous, e.g., guanidine and urea.

Group 1 above contains several efficient flameproofers which owe their efficiency almost entirely to the mineral acid and which have all the drawbacks of the inorganic group for electrical purposes.

Group 2. The substances are claimed to be of value for incorporation in cellulose acetate, but when used externally on cotton or *Cotopa* have very little fireproofing effect and, moreover, produce large volumes of smoke and fumes, thus greatly increasing the difficulties of any one endeavouring to put out a fire.

Group 3. The substances have a very slight fireproofing effect and, like Group 2, when the treated material is once well alight the fireproofer itself burns fairly easily.

Group 4. Protein materials have a moderate fireproofing action but have the disadvantage that they readily grow moulds; this, however, can be overcome by incorporating suitable fungus prevention materials.

Group 5. The chlorinated carbocyclic compounds have a certain amount of fireproofing action due (as in the case of Group 2) to the production of heavy vapours but, nevertheless, they burn as long as a flame is applied and produce large volumes of fumes and black smoke, thus greatly adding to the difficulties of any one trying to put out a fire.

Group 6. Urea and guanidine both have a moderate fireproofing action.

None of the above organic compounds approach the good inorganic compounds in efficacy as fireproofers. However, with the exception of Group 1, they do not have any deteriorating effect on cotton yarn or fabric.

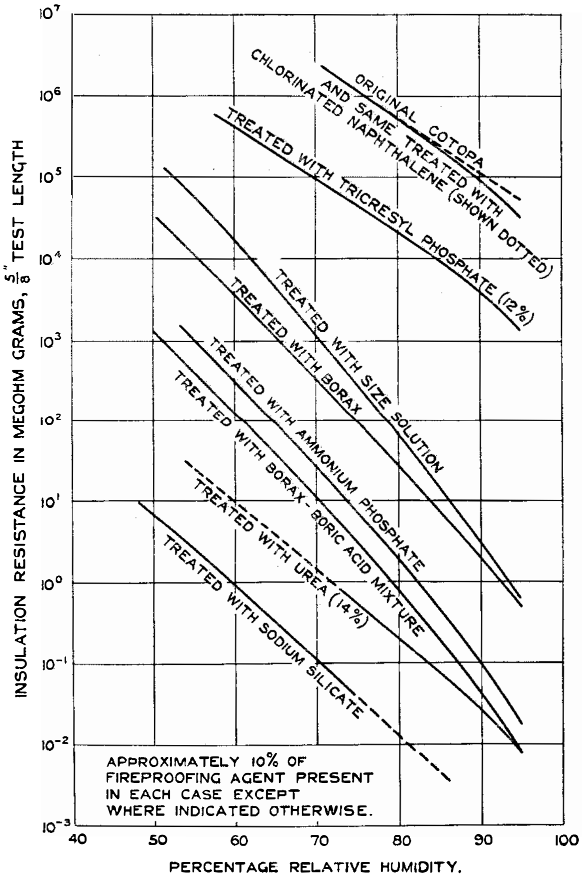


Figure 4—Effect of Fireproofing Agents on the D-C. Insulation Resistance of Cotopa.

Effect of Fireproofing Treatments on Insulation Resistance and Corrosion of Copper Conductors

Up to the present, all the suggested materials which are good fireproofers decrease the insulation resistance of yarns in which they are employed and, when applied to textiles of high insulating value such as *Cotopa* or acetate silk, produce an enormous reduction in insulation resistance. Figs. 3 and 4 show the effect of various typical fireproofing materials on the d-c. insulation resistance of purified cotton and *Cotopa*, respectively, about 10% by weight of the fireproofer being present in the yarn in each case. It will be noted that the best fireproofing agents (borax-boric acid mixture, sodium silicate, and

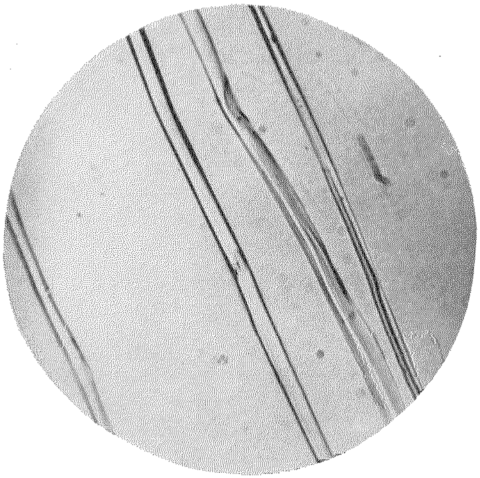


Figure 5—Mulberry Silk Fibres (Magnification 200 approximately).

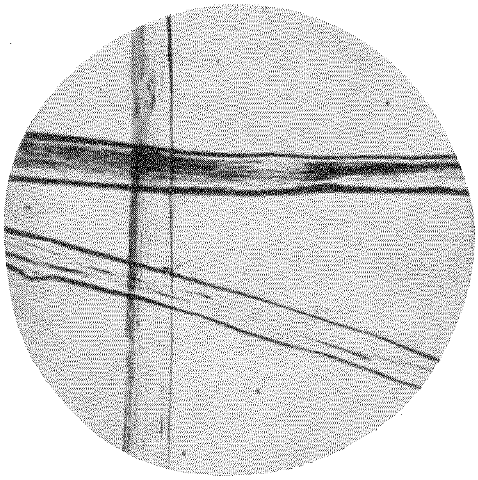


Figure 6—Tussah Silk Fibres (Magnification 200 approximately).

ammonium phosphate) reduce the insulation resistance of *Cotopa* to about the same value as that of unwashed grey cotton. The moderate ones like borax, urea, and size (fish glue) reduce the insulation resistance of *Cotopa* to the level of that of a washed cotton. Chlorinated naphthalene has little effect on the insulation resistance under equilibrium conditions, but it reduces the speed of moisture absorption, and hence retards changes in insulation resistance when the relative humidity changes, just as hydrocarbon waxes do.

Most of the good fireproofers mentioned above when used in cotton yarn have a corrosive effect on copper conductors at humidities of the order of 90%–100% relative humidity, green copper salts being formed within a few days. The borax-boric acid mixture is one of the least corrosive of this group, but material fireproofed with it should never be used next to a copper conductor; for, while it does not appear to lead to chemical corrosion very readily, electrolytic corrosion can easily be produced when a steady voltage is applied.

From the above it is obviously absurd to fireproof *Cotopa* or similar materials having high insulation resistance with any of the good or moderate fireproofers discovered up to the present. The objections to the use of the chlorinated carbocyclic compounds have already been given.

One course at present open is to use a composite insulation in which the inner layers provide the requisite insulation resistance and the outer layer provides fire protection. This can be carried out most economically on wires by using two or more lappings of *Cotopa* covered by an outer lapping of cotton fireproofed with approximately a 10% of borax-boric acid mixture. The result will be found to be fairly satisfactory, except in the rare event of a portion of the wire being soaked with water; in most cases this kind of accident only causes temporary damage while the wire is wet but, with the type of make-up described, the fireproofing medium would be dissolved and soak into the *Cotopa* lappings, producing a permanent low resistant path and possibly electrolytic corrosion.

Another possible course is to use two or more lappings of *Cotopa* and an outer lapping or braiding of wool. This combination is not quite so resistant to fire but does not suffer any permanent damage from having been wet.

A third possible course is to use two or three lappings of the wool or natural silk derivatives, described in Section 4, by means of which nearly as good insulation resistance values can be obtained as in the case of *Cotopa*, with greatly improved fire resistance characteristics.

3. *Chemical and Physical Structure of Natural Silk and Wool*

NATURAL SILK

Origin. Natural silk is the fibrous material extruded by the caterpillars of various species of moths (those artifically reared being mainly the mulberry silkworm, Bombyx Mori) in order to form a soft case or cocoon in which the creature can shed its skin and change into the pupa form. Before spinning, the substance from which the fibre is formed can be found in the silkworm in the form of a clear, colourless, sticky liquid, which is secreted from two glands placed symmetrically on either side of the body and communicating with a tiny orifice in the head. As soon as this liquid is extruded and comes into contact with the air, it solidifies and forms a uniform double fibre.

In order to obtain the silk in a form suitable for manufacture, the cocoons are collected when the caterpillars have finished spinning and have changed into pupae, and the pupae are killed by placing them in an oven or by steaming. They are then ready for reeling, which is carried out by placing the cocoons in a container of water kept at about 60°C. An operator then collects the ends of from four to twenty individual cocoons, draws them through an eye and then over various guides to a reel which steadily winds them up. As fast as one cocoon is finished, another replaces it, so that one continuous thread is obtained. The raw silk at this stage consists of two main materials called, respectively, sericin and fibroin, the first being soluble in water and the second insoluble. In the reeling process some of the sericin dissolves in the water and causes the individual fibres to cohere and form one thread, which naturally varies in thickness, according to the number of component fibres. Slight variations in the make-up give "grège," "organzine," and "trame" silks. Grège refers to a single fibre and, by combining several of these and twisting, organzine or warp silk is obtained; by using a smaller number of fibres and adding less twist, trame or weft silk is obtained. The outer portion of the cocoon, which is tangled, is used to make "floss silk." The damaged cocoons, inferior qualities, etc., are boiled with soda solution, torn to shreds, combed, carded, and spun by machinery to make "spun silk." If the boiling operation is omitted, the material is called "chappe silk."

When required, the silk is "degummed" by boiling with soap or soap and soda solutions, a process which separates the silk into its individual fibres and improves its appearance.

The individual fibres, when viewed under the microscope (Fig. 5) are seen as smooth, transparent, apparently structureless rods of approximately circular cross-section with an average diameter of about 0.01–0.02 mm.

Wild silks, generally coming on the market under the name of Tussah silk (also Tussur, Tussore, Tasar) are obtained in a similar manner from other species of caterpillars and are mainly imported from India or China. They always have a brownish colour which is very difficult to remove. The diameter of the fibres is considerably greater than that of mulberry silk, averaging about 0.02–0.05 mm. Its appearance under the microscope is shown in Fig. 6.

Composition of Silk. It has already been mentioned that the raw silk fibre consists of two substances, sericin—the external water soluble portion, and fibroin—the true fibre which is insoluble in water. These materials are proteins, and the following approximate analyses of the elements present show that they do not differ very much in ultimate composition:

	Fibroin	Sericin
Carbon	48.8%	44.6%
Hydrogen	6.2%	6.2%
Nitrogen	19.0%	17.4%
Oxygen	26.0%	31.8%

Natural silk is rapidly dissolved by concentrated mineral acids and, under certain conditions, it is broken up into much smaller molecules in a manner analogous to the hydrolysis of cellulose to glucose, but with the added complication that instead of finally breaking down to one kind of molecule, it breaks down to several different kinds of molecules, including:

Glycine 36% $NH_2.CH_2.COOH$

Alanine 21% $NH_2.CH.COOH$
CH_3

Tyrosine 10% $NH_2.CH.COOH$
CH_2⬡OH

and much smaller amounts of several other similar compounds[5]. The figures represent the percentage of each compound obtained.

The work involves considerable analytical difficulty so that it is not surprising that the whole of the silk molecule is not yet accounted for; but, fortunately, one generalisation stands out very clearly from the results, namely, that although there are several different individual molecules used to make up the silk molecule, they all belong to one class, that of the amino-carboxylic acids of general formula

$$\begin{array}{c} NH_2.\underset{\displaystyle\overset{|}{X}}{CH}.COOH \end{array}$$

where X represents some well known group of atoms. This, moreover, is true of the proteins as a class generally.

It is not desirable to go into details of the lines of reasoning employed in elucidating the structure of the proteins, but merely to state the conclusions which are as follows:

It is known that amino-carboxylic acids can react with each other, e.g., the simplest one, glycine, can react with itself under certain conditions to form glycylglycine thus:

$$\underset{\text{(Glycine)}}{NH_2.CH_2.COOH} + \underset{\text{(Glycine)}}{NH_2.CH_2.COOH} =$$

$$\underset{\text{(Glycylglycine)}}{NH_2.CH_2.CO.NH.CH_2.COOH} + H_2O$$

but the product itself is also an amino carboxylic acid and so can react with itself or any other amino-carboxylic acid to form a further compound having a yet longer molecule. It will be observed that the outstanding characteristics of these compounds will be a long molecule, a few free $-NH_2$ and COOH groups, mainly at the ends, and a large number of –CO–NH– linkages, e.g.,

$$NH.\underset{\displaystyle\overset{|}{W}}{CH}.CO.NH.\underset{\displaystyle\overset{|}{X}}{CH}.CO.NH\ldots\ldots\underset{\displaystyle\overset{|}{Y}}{CH}.CO.NH.\underset{\displaystyle\overset{|}{Z}}{CH}.COOH,$$

where W, X, Y, Z are different groups of atoms, but mainly either –H (hydrogen) or $-CH_3$ (methyl).

Work on amino acids and proteins generally has shown that CO–NH linkages (called peptide linkages) can exist in two forms in virtue of the labile (movable) hydrogen atom, the conversion from one to the other being reversible and dependent on the hydrogen ion concentration of the solution in which the protein is immersed.

In acid solutions the keto form predominates and combination with acids occurs as follows:

$$-CO.NH- + HCl = -CO.\overset{\displaystyle H \atop \cdot}{\underset{\displaystyle \cdot \atop Cl}{N}}H-$$

In alkaline solutions combination occurs with the Enol form:

$$-\underset{\displaystyle \cdot\cdot \atop OH}{C}:N- + NaOH = -\underset{\displaystyle \cdot \atop ONa}{C}:N- + H_2O$$

The above accounts for the known amphoteric character of proteins, i.e., their ability to form weakly linked compounds with both acids and bases. Since there are also present, as previously referred to, some free carboxyl and amino groups which are able to combine with bases and acids, respectively, the proteins can be said to be doubly amphoteric.

A considerable volume of empirical information is available on the other chemical properties of silk, but it cannot be claimed that the subject has yet been worked out in full detail.

X-Ray Studies of Silk. An X-ray photograph of natural silk shows at once that silk is really crystalline in spite of the complete absence of crystalline structure when viewed under the microscope; it also indicates that the invisible crystals are all pointing along the axis of the fibre.

It is known that in straight chains the linkages (or "valency bonds") are set at an angle which is equal or near to the tetrahedral angle (109° 28′) and, therefore, in a polypeptide chain built up as described above, each amino acid residue, whatever the nature of the side chain, will take up the same length along the main chain axis, a fact which can be shown from known data on the sizes of atoms to be about 3.5 A.U. If the side chains are disposed arbitrarily along the length of the main chain, there will be no strict regularity of pattern such as one obtains by the repetition of glucose residues in a cellulose main valency chain; but, if the side chains follow some periodic arrangement, then the pro-

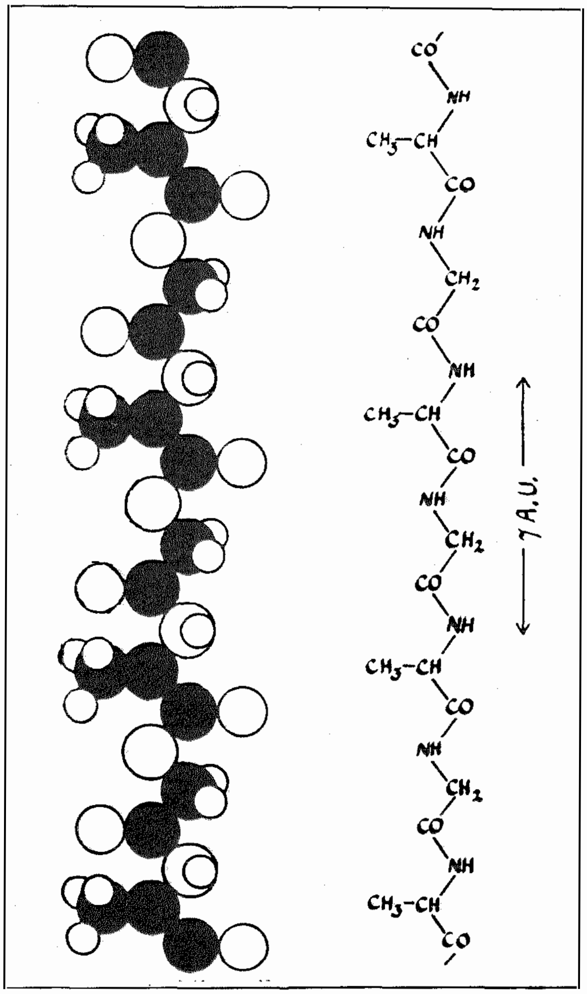


Figure 7—Atomic Arrangement and Conventional Formula of Part of the Fibroin Chain of Natural Silk.

tein chain will be a true line pattern analogous to the cellulose main chain with a repetition period of 3.5 A.U. (instead of 10.3 A.U.). This is found actually to be the case, leaving no room for doubt that the long thin crystallites of the fibroin of natural silk, lying roughly parallel to the axis of the visible fibres, are other than bundles of fully extended polypeptide chains[6]. Fig. 7 shows the atomic arrangement and conventional formula of part of the fibroin chain of natural silk based on the regular alternation of alanine and glycine residues. As a certain amount of tyrosine is obtained on hydrolysis, it is evident that about one residue in seven must be of this form and hence have a somewhat larger side chain (i.e., a $-CH_2\bigcirc OH$ group). As traces of other amino acids are also formed on hydrolysis, evidently still different side chains occur with a frequency of perhaps one in twenty. From the fact that the X-ray photograph of natural silk is by no means as perfect as, for example, that of ramie cellulose, it is probable that these additional groups are not regularly distributed.

Wool

Wool is the hair of the sheep and in its natural state contains from 10%–24% of grease and 2%–6% of potassium salts which, together with extraneous dirt, etc., have to be removed by the process of scouring, which consists broadly of washing the wool thoroughly in several baths of warm water containing soap and weak alkali.

Microscopically the cleansed wool fibre appears to have the form of a solid rod of circular or elliptical cross section from .02–.06 mm. in diameter and from 1 to 7 inches in length, and is covered with scales pointing in one direction. The scales overlap, somewhat in the manner of roof tiles (Fig. 8) and are so minute as not to be discernible to the eye, but they can be felt if a wool fibre is drawn between the fingers in the direction opposite to that in which they are set.

Composition of Wool. Wool consists of another protein substance called keratin, which is the basis of the whole of the class of epidermal growths comprising mammalian hairs, nails, spines, horn, and whalebone, but not feathers or

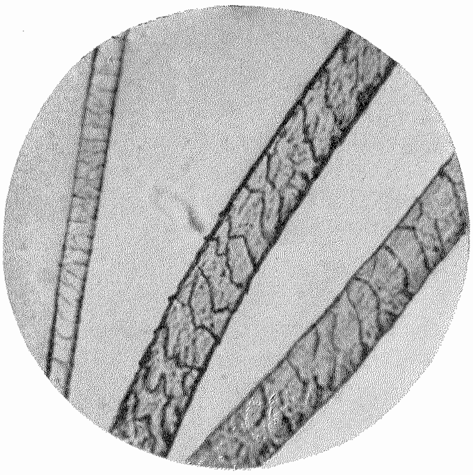
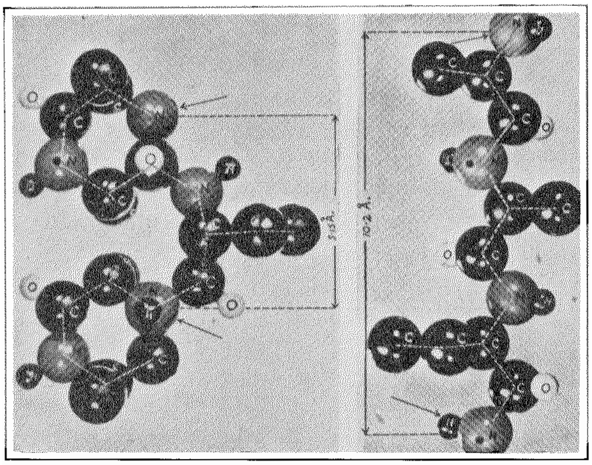


Figure 8—Scoured Wool Fibres (Magnification 200 approximately).



α Keratin β Keratin

Figure 9—Skeleton Atomic Models of the α and β Forms of the Keratin Chain.

reptilian scales[7]. The ultimate composition of wool keratin may be taken roughly as:

Carbon	50%
Nitrogen	15–17%
Hydrogen	7%
Sulphur	2–4%
Oxygen	22–26%

and is very similar to that of natural silk except that it contains a little sulphur.

Like fibroin and sericin, keratin can be broken up under certain conditions by acids to give a mixture of a considerable number of amino-carboxylic acids, but unlike them keratin yields only quite small amounts of the two simplest amino acids, the bulk being of the more complex ones. It can thus be seen that, by analogy with fibroin, keratin might be expected to be built up of extended polypeptide main chains with more numerous side chains than in the case of fibroin—in fact with a side chain attached to practically every amino acid residue.

X-Ray Studies of Wool Keratin. An examination of the X-ray photograph of wool keratin shows that like fibroin it is made up of long thin micelles or crystallites parallel with the axis of the fibre but, when a detailed comparison with that of silk is made, it is obvious that there is a considerable difference; for, in the fully extended polypeptide chains characteristic of fibroin, the pattern repeats at a distance of 3.5 A.U., whereas in the case of wool the repeat is definitely at a distance of 5.1 A.U. While wool is undoubtedly built up of long molecular chains which are almost certainly polypeptide chains, the photographs nevertheless indicate that they are different from those of fibroin. The explanation can be found by considering the elastic properties of wool and silk, respectively. Cotton and natural silk have only a limited true elasticity and their internal structure is damaged irreparably when they are stretched beyond a certain amount, but wool is extremely elastic, more like rubber than the other textile fibres. In steam it can be stretched to double its initial length but will contract to its former length when the tension is removed. On examining wool in the fully stretched state, it is found to give quite a different X-ray photograph in which the pattern repeats at 3.4 A.U., corresponding to the value of 3.5 A.U. obtained with fibroin. These two forms of wool have been named α and β keratin. Skeleton models are shown in Fig. 9 and the conventional formulae in Fig. 10, from which it can be seen that the molecular chains in the α form bend themselves into a series of hexagons of such dimensions that a sequence of three amino acid residues takes up a distance of about 5.1 A.U. in the direction of the fibre axis. On

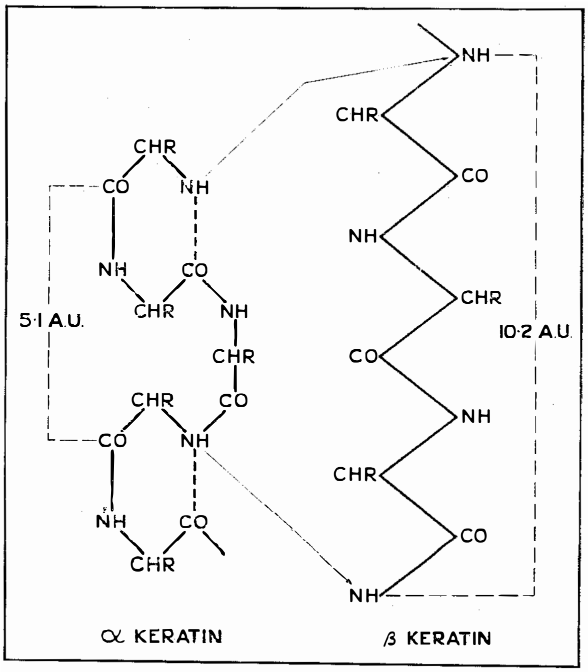


Figure 10—Conventional Formula of α and β Keratin.

pulling these chains into the fully extended β state, each trio of residues takes up a distance of 3 x 3.4 A.U., i.e., 10.2 A.U. In other words, the maximum extension before rupture takes place is about 100%[6].

The main chain structure, therefore, is the same in stretched wool and natural silk, the difference between them being that whereas the main chains in wool have many "pendants," those of silk have very few indeed.

It can thus be seen why wool possesses such a high degree of real elasticity compared with silk and cotton; in the case of the latter, most of the extension under tension is due to slipping of the main molecular chains past each other.

It remains to explain why wool tends to the contracted form of α keratin when not constrained, while natural silk does not act in this manner. This is probably due to the fact that in fibroin most of the side chains consist of non-polar $-CH_3$ groups, whereas in wool the side chains are largely acidic or basic and, moreover, the total amount of each is roughly equal. These acid and basic groups form "salt linkages" by moving together, due to the electric attraction between the groups, which are ionised, carrying negative and positive charges, respectively. Thus the oppositely charged centres of the side chains approach as closely as possible and hence cause folding of the main chains. It has also been shown that there are cross linkages between the main chains which depend on the presence of cystine,

$NH_2.CH.COOH$
|
CH_2
|
S
|
S
|
CH_2
|
$NH_2.CH.COOH$,

an amino acid containing sulphur, so that the formation of the keratin complex can be visualised as a kind of "polypeptide grid" crinkled in the normal or α state, but straight when forcibly pulled out into the β state[6].

4. Chemical Derivatives of Natural Silk and Wool Having Greatly Improved Insulation Resistance Values—Insuwools and Insusilks

Reference has been made in Section 2 above to the difficulty of treating cellulosic fibres to obtain fire resisting properties without reducing the insulation resistance to extremely low values and, despite a great deal of work on the subject, no satisfactory solution has been discovered up to the present. Another line of attack on the general problem of combining high insulation resistance with fire resisting properties has, however, been developed recently in the Dielectrics Laboratory of Standard Telephones and Cables Limited, London, with considerable success. Instead of trying to improve the fire resisting properties of fibres of satisfactorily high insulation resistances, such as *Cotopa*, the principle adopted has been to attempt the converse, namely, to improve the insulation resistance of fibres already having good fire resisting properties, the obvious ones to choose being wool and natural silk.

Methods Previously Suggested

Three methods had already been proposed for attaining this end. First, as a result of the work of the Bell Telephone Laboratories[8], the thorough washing of natural silk to reduce its electrolyte content to a minimum, whereby insulation resistance values of the order of 50 or 60 times those of the ordinary commercial product were obtained. Marsh and Earp[9] doing the same thing with clean scoured wool reported an improvement of about 10 times in insulation resistance by thorough washing, and similar results have been obtained in the course of this work, the smaller improvement in the case of wool merely reflecting the fact that wool normally possesses a smaller electrolyte content than silk.

A second method for the improvement of the insulation resistance of wool was discovered by Marsh and Earp[9], namely, that when a wool fibre is transformed by stretching from the α to the β keratin state, its insulation resistance is increased about 10 times. Samples of stretched worsted yarn were obtained by Standard Telephones and Cables, Limited, through the assistance of the Wool Industries

Research Association and examined, but were found to have an insulation resistance of only about 3 times that of ordinary supplies, although the electrolyte content was about the same. The difference was believed to be due to the fact that Marsh and Earp worked with single fibres with which they could be sure of complete stretching, whereas this condition was only partially reached with stretched yarn.

A third method described by Denham, Hutton, and Lonsdale[10] is to add just sufficient strong mineral acid (a trace only is used) to natural silk to bring it to its isoelectric point (about pH 4.2), at which it is stated that for any given electrolyte content the insulation resistance is about 5 times higher than if the silk were neutral. The authors mention, however, that the results do not give information about the resistance of silk that has been in equilibrium with water of pH7 free from electrolytes, and say that if such conditions were attainable, the silk would presumably be of high electrical resistance due to absence of electrolytes. A number of samples of "isoelectric silk" obtained commercially by Standard Telephones and Cables, Limited were found on examination to contain about the same amount of electrolytic matter and to have about the same insulation resistance values as good quality washed silks.

Insuwools and Insusilks

A large number of chemical derivatives of wool and silk have been prepared in the Dielectrics Laboratory, Standard Telephones and Cables, London, possessing improved insulation resistance properties. Those showing the greatest improvement have been called "Insuwools A," "B," and "C"; and "Insusilks A," "B", and "C". As has been shown in the previous section, the chemical structure of wool and silk is extremely complex and hence it will probably be a long time before it is possible to state definitely the exact chemical composition of each of these derivatives as certainly as with *Cotopa*, for instance, although an estimate can be made in most of the cases.

Comparing samples at equal electrolyte content (as measured by the method referred to in Part II[2]), it has been found that derivatives of wool having an appreciable improvement in insulation resistance over well washed wool can be obtained by the action of each of the following groups of reagents: Oxides or salts of many metals having acidic or amphoteric oxides, anhydrides of aliphatic carboxylic acids, acid chlorides, tannic and closely related acids, naphthol sulphonic acids, and various aldehydes. Most of these reagents also give silk derivatives of improved insulation resistance. As in the case of the acetylation of cotton to form *Cotopa*, there is in each case a decrease in the moisture content at any given relative humidity as compared with the original wool or silk, and all samples, examined up to the present, form series based on each parent material, in which decreasing moisture content corresponds with increasing insulation resistance.

The table on the opposite page gives a list of the most important of the derivatives examined, together with their moisture contents and insulation resistances.

In some of the above cases higher insulation resistance values could be obtained by altering the conditions of preparation, but in many instances this advantage would be offset by tendering of the fibre or by the extra gain not being economic.

Chemical Composition and Properties of Derivatives. In the case of derivatives formed from oxides and salts, it is probable that the oxide of the metal combines with the free carboxyl groups in the keratin or fibroin complex in the normal manner of the formation of salts. With tannic acid (Insuwool A and Insusilk A) it seems probable that a portion is chemically combined and that part is strongly absorbed. Keratin and fibroin are so complex and tannic acid has so many reactive groups that the possibilities are very numerous.

With the derivatives formed from acetic anhydride (Insuwool C and Insusilk C) the action must take place by the acetylation of $-OH$ and NH_2 groups on the side chains and at the ends of main chains. In this connection it is interesting to note that acetylated wool shows a greater improvement than acetylated silk, possibly due to the larger number of side chains containing $-OH$ and $-NH_2$ groups available in wool, as already described. Since many factors enter into the question, final conclusions cannot be reached until electrical measurements are available on a considerable number of samples of various known degrees of acetylation of both wool and silk.

By acetylating the tannic acid derivatives (Insuwool B and Insusilk B), further improvements can be attained and are probably due to acetylation of some of the hydroxyl groups of the tannic acid as well as those referred to above in the keratin and fibroin complexes.

In nearly all cases the derivatives are of a deeper colour than the original material, ranging from pale buff of Insuwool A to the old gold colour of Insuwool B. This, of course, limits the number of shades in which these materials can be dyed and makes it impossible to produce them in bright colours, although a readily distinguishable range of about five or six shades can be obtained.

Most of the derivatives, particularly Insuwools A and B, and Insusilks A and B are rather stiffer and harsher than the original material, characteristics which make them less suitable for ordinary textile purposes but which are not very important from an electrical point of view.

When examined microscopically (Figs. 11–15) Insuwools and Insusilks differ very slightly indeed from the original fibre; Insuwool fibres generally appear slightly smoother than untreated wool.

Insulation Resistance of Insuwools and Insusilks. The insulation resistance of Insusilks and Insuwools for the 60%–100% relative

Material	Moisture Regain		Insulation Resistance in Megohm-Grams using a ⅝ Inch Test Length and 500 Volts Test Voltage at 25°C.	
	At 80% Relative Humidity	At 95% Relative Humidity	At 80% Relative Humidity	At 95% Relative Humidity
Untreated natural silk	......	17.8%	350	0.3
Good quality commercially washed natural silk	......	17.7%	11,000	9.0
Tannic acid derivative of natural silk—Insusilk A	......	13.3%	100,000	1,300
Tannic acid derivative subsequently acetylated—Insusilk B	......	13.1%	600,000	3,000
Natural silk acetylated only—Insusilk C	......	13.1%	120,000	250
Good quality scoured wool	16.0%	......	185	1.6
Commercially washed wool	16.0%	......	690	8.7
Aluminium derivative of wool	14.7%	......	2,200	105
Tannic acid derivative of wool—Insuwool A	12.0%	......	17,000	760
Tannic acid derivative of wool subsequently acetylated—Insuwool B	9.8%	......	200,000	5,000
Wool acetylated only—Insuwool C	10.4%	......	120,000	2,000
Wool derivative formed with 1 hydroxy, 4 sulphonic acid of naphthalene (Neville & Winter's acid)	......	......	....	160
Acetyl chloride derivative of wool	......	......	....	100
Benzoylchloride derivative of wool	......	......	....	120
Formaldehyde derivative of wool	......	......	....	120

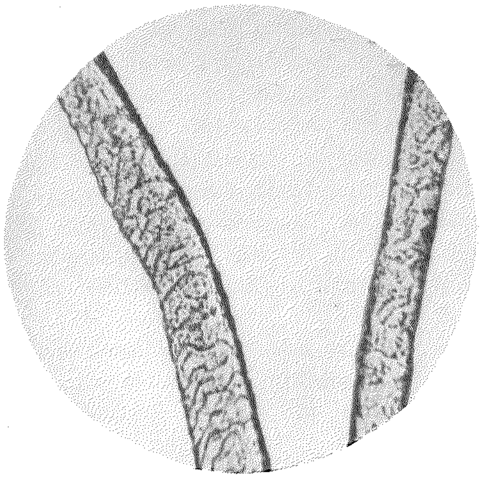


Figure 11—Insuwool A Fibres (Magnification 200 approximately).

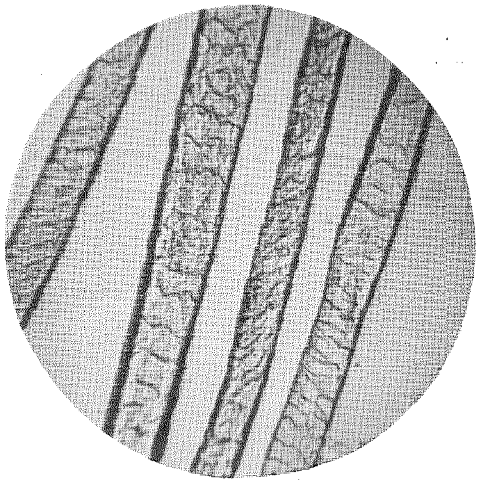


Figure 12—Insuwool C Fibres (Magnification 200 approximately).

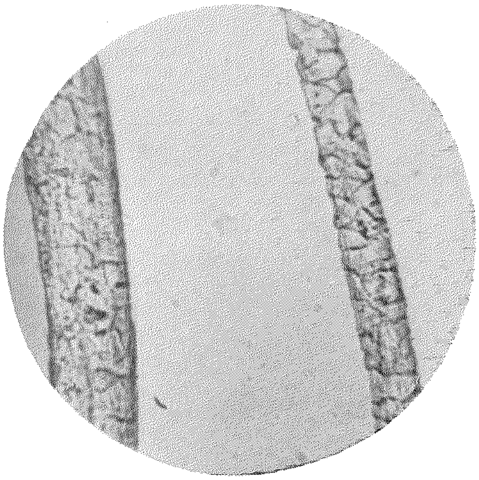


Figure 13—Wool - Aluminium Oxide Derivative Fibres (Magnification 200 approximately).

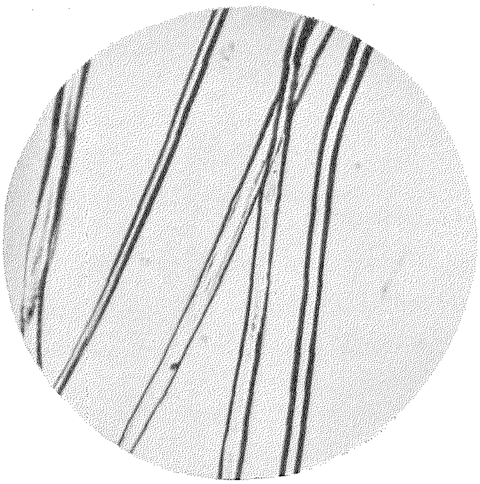


Figure 14—Insusilk A Fibres made from Mulberry Silk (Magnification 200 approximately).

humidity range are shown in Figs. 16 and 17, together with the values for untreated and washed wool and silk as normally obtained commercially. In order to simplify reference, only the absorption curves are shown, but the hysteresis loop is similar in all these cases, desorption values being about one-tenth of absorption values at 80% relative humidity. (The ratio with *Cotopa* is less, being about one-third, but that of cotton is about one-seventh). Absorption and desorption curves of washed silk and Insuwools A and B are shown in Fig. 18. Generally speaking, the shape and slope of the curves are those of the parent fibre with Insuwools B and C, and Insusilks B and C, but with Insuwool A and Insusilk A, improvement in insulation resistance is very much more marked at high than at lower humidities. Insusilk B has

Figure 15—Insusilk C Fibres made from Mulberry Silk (Magnification 200 approximately).

about 5,000–1,000 times the insulation resistance of ordinary silk, or about 300 times that of washed silk; while Insusilks A and C give less improvement at 95% relative humidity. Insuwool B has about 2,000 times the insulation resistance of ordinary scoured wool at 95% relative humidity, and Insuwools A and C show less improvement.

Comparison of Insuwools and Insusilks with each other and with *Cotopa* and cellulose acetate silk is complicated by the different shapes and slopes of each family of curves but, broadly speaking, Insusilk A and Insuwool B are about equivalent to an ordinary *Cotopa* and, therefore, are a little better than cellulose acetate silk. Insuwool A, the cheapest of these groups, is nearly equal to a cellulose acetate silk and has roughly one-fifth of the insulation resistance of an ordinary *Cotopa*. Insusilk B has appreciably higher values than ordinary *Cotopa* at 80% relative humidity and, in fact, approaches the value obtained with the superwashed *Cotopa* previously referred to. Like natural silk and all its derivatives, however, its insulation resistance falls off more rapidly than *Cotopa* above 80% relative humidity, till at 95% it is about equivalent to an ordinary *Cotopa*.

Applications of Insusilks and Insuwools. Primarily these materials have been developed in order to combine the fire resisting qualities of natural wool and silk with insulation resistances of the same order as those obtainable from acetate silk and *Cotopa*, and it is where this combination of properties is required that they can be of most value. Insusilks made from trame silk at last make available a textile of high insulation resistance for lapping on fine wires, an application for which *Cotopa* is not suitable, owing to inability to produce sufficiently fine counts.

5. *General Comparison of Textiles Available for Electrical Insulation Purposes*

During the course of this paper, detailed reference has been made to numerous textiles with occasional comparisons. A summary is given below of their outstanding features and their relative values for the purpose of electrical insulation, even though such a summary is necessarily only approximate.

As textiles are almost invariably used in electrical work in positions where there is free access for the atmosphere with its varying conditions of

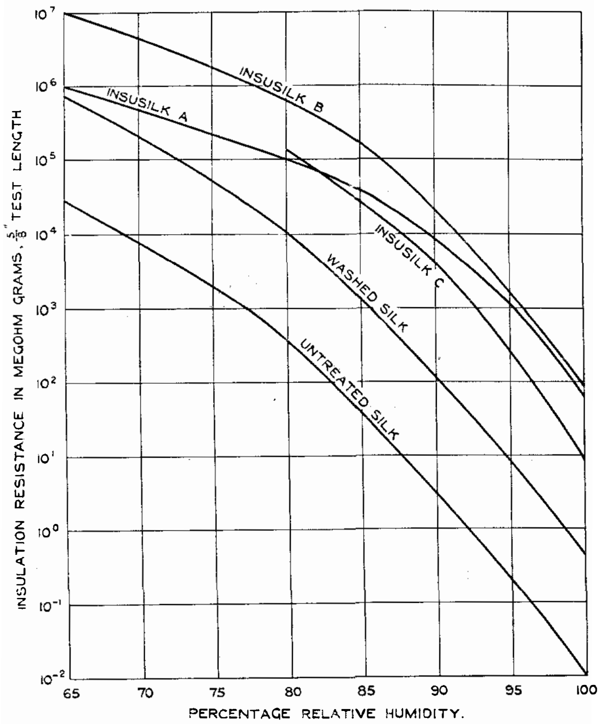


Figure 16—Relation of Insulation Resistance to Relative Humidity of Natural Silk and Derivatives of Natural Silk.

relative humidity, the subject has been discussed throughout with reference to the relative humidity range 50%–100% and the same applies to the following summaries of the properties of textiles for electrical insulation.

Cellulosic Fibres

Cotton. Is the cheapest of the available materials with good mechanical and running properties, but low insulation resistance and high electrolyte content which sometimes causes corrosion of metals. Its fire resisting qualities are negligible unless impregnated with chemicals which reduce its insulation resistance to still lower values and are liable to cause corrosion of conductors when in contact with the copper. Available in all colours.

Washed Cotton. The same as cotton, except that the removal of the bulk of the salt content by careful washing can increase the insulation resistance as much as 50 times in extreme cases. Well washed cotton cannot cause corrosion troubles. Available in all colours.

Mercerised Cotton. Its properties are like those of cotton, except that it has higher tensile strength and a semilustrous appearance. For the same electrolyte content it has lower insulation resistance values than cotton but, since its

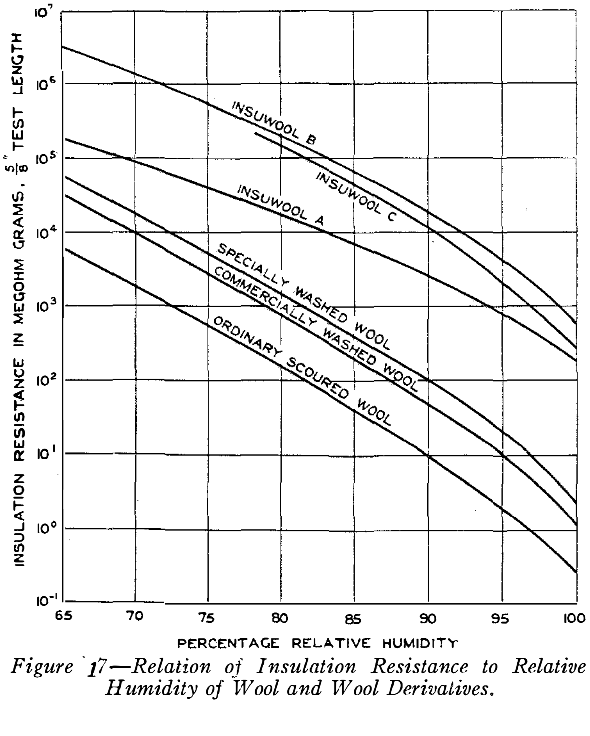


Figure 17—Relation of Insulation Resistance to Relative Humidity of Wool and Wool Derivatives.

electrolyte content is often low, it has values of the same order as unwashed cotton. Only used for braids. Available in all colours.

Glazed Cotton. Stiff, of lustrous appearance, and resistance to mechanical wear good. Otherwise similar to unwashed cotton. Only used for outer braids. Available in all colours.

Flax, Linen, and Natural Cellulosic Fibres (Chiefly Ramie). Valuable for their high tensile strength and wearing qualities. Insulation resistance of the same order as cotton; chiefly dependent on degree of washing. Available in all colours.

Viscose Silk, Cuprammonium (Bemberg) Silk, Chardonnet Silk. These are all regenerated cellulose and have insulation resistance values of the same order as cotton (at the same electrolyte content they have lower values) and their fire resisting properties are about the same as those of cotton. Their mechanical and running properties are not as good as those of cotton, but their high lustre and pleasant appearance make them suitable for some braids where there is not much mechanical wear and where appearance and not insulation resistance is the main criterion. Available in all colours.

Acetate Silk. Its mechanical and running properites are inferior to those of cotton, *Cotopa*, etc., and it has the disadvantage of melting at temperatures much lower than the working temperature of a soldering iron. Its insulation resistance is about 1,000 times that of washed cotton, and about one-quarter of that of ordinary *Cotopa.* Its flame resisting properties are slightly better than cotton and *Cotopa* in that its low melting point makes it a little more difficult to ignite, but once alight it burns as readily as the former. Available in all colours, but coloured acetate silks usually have about one-tenth of the insulation resistance values of the undyed material.

Spun Acetate Silk. Same as acetate silk, except that the slipperiness of the latter has been overcome. The tensile strength, however, is lower than that of cotton and *Cotopa.* Available in all colours, but with the same reservation with regard to insulation as in the case of ordinary acetate silk.

Cotopa. This has the good mechanical and running properties of cotton, combined with an insulation resistance several times that of acetate silk. It resists higher temperatures than cotton

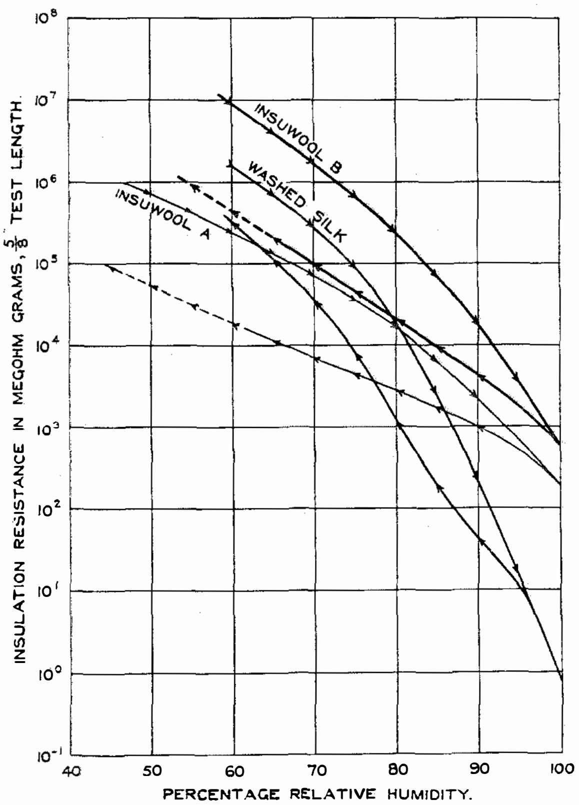


Figure 18—Insulation Resistance of Treated Wools and Washed Silk under Absorption and Desorption Conditions.

without being affected and is not likely to be damaged by heat traveling along a conductor during soldering operations. It does not melt. Its fire resisting properties are the same as those of cotton. It is available in all shades, without at the same time sacrificing insulation resistance.

Crestol (*Acetylated Mercerised Cotton*). Has the lustre and good mechanical and running properties associated with mercerised cotton. Its insulation resistance is lower than that of *Cotopa* or acetate silk, but much higher than cotton or mercerised cotton. Its fire resisting properties are the same as those of cotton. Available in all colours.

"*Superwashed Cotopa.*" Has insulation resistance values about 5 times those of normal *Cotopa* and about 20 times those of acetate silk. Available in all colours.

All the above textiles are composed of cellulose or are cellulose derivatives and their insulation resistance-relative humidity curves run approximately parallel. Hence it is reasonable to say that the insulation resistance of one is so many times that of another for the range 50%–100% relative humidity. In the group of protein fibres hereinafter referred to, however, the slopes of the curves are steeper than those of the cellulosic fibres and there is a greater tendency to fall off at the highest humidities, particularly with natural silk and its derivatives. Hence references to insulation resistance in the following must be taken as referring to 80% relative humidity unless otherwise stated: also, in any comparison with a cellulosic fibre, the comparison will usually be altered in favour of the cellulosic fibre for relative humidities above 80%, and in favour of the protein fibre for relative humidities below 80%. This effect is marked with silk and its derivatives, but is slight with wool and its derivatives.

Protein Fibres

The fire resisting properties of all of the following are much the same and are very much better than those of the cellulosic group.

Natural Silk Group. These are, of course, more expensive than any of the other fibres.

Grège or Trame Mulberry Silk. Characterised by high tensile strength but is difficult to run. It and the Insusilks made from it are the only textiles which can be used satisfactorily for covering fine wires. Its insulation resistance is generally about seven times that of washed cotton or 1/300th of that of *Cotopa*, depending of course on the actual amount of electrolyte content. With high electrolyte contents corrosion of conductors is liable to occur. Available in all colours.

Washed Grège or Trame Mulberry Silk. By careful washing the insulation resistance can be improved up to about 50 times, so that it is then about one-tenth of that of ordinary *Cotopa.* No trouble is experienced with corrosion of conductors, but the material is a little more difficult to run.

Chappe Silk. Much easier to run on machines than the last two, but not available in sufficiently fine counts for covering fine wires. Its normal colour is grey and hence only a limited number of colour shades can be obtained unless it is specially bleached prior to dyeing. Other properties similar to those of unwashed trame mulberry silk.

Washed Chappe Silk. Like chappe silk, but has insulation resistance equal to washed trame mulberry silk; no danger of corrosion troubles.

Tussah Silk. Similar to chappe silk, but of a brownish colour which makes it impossible to get more than a limited range of colour shades. In the unwashed state it usually has a very high electrolyte content and a lower insulation resistance than chappe silk.

Washed Tussah Silk. Has usually about 100 times the insulation resistance of the unwashed material and is free from corrosion troubles.

Insusilks. Mechanical and running properties are similar to those of the present material, depending on whether this is trame or spun. They are all a little stiffer than the silks from which they are made and they are all of various shades of buff or brown so that only a limited colour range is available.

Insusilk A. Insulation resistance about equivalent to an ordinary *Cotopa* and therefore better than acetate silk. Has about 100 times the value for washed silk at 95% relative humidity, but has little advantage at 50%–70%.

Insusilk B. Has appreciably higher insulation resistance values at 80% relative humidity than ordinary *Cotopa*, and about 60 times that of washed silk. At 95% relative humidity it has values 300 times those of the latter.

Insusilk C. Has an insulation resistance about twice that of acetate silk at 80% relative humidity, and about 10 times that of unwashed silk.

Insuwools. These have the mechanical and running characteristics of the wool fibres, and those having particularly good insulation resistance, namely, Insuwools A, B, and C, are all normally of a buff or brownish colour making it possible to get only a limited range of colour shades.

Insuwool A. Is the cheapest of this group, has an insulation resistance about one-fifth of that of an ordinary *Cotopa* and is nearly equal to cellulose acetate silk—in fact, its insulation resistance is better than most coloured acetate silks at 80% relative humidity. It has about the same insulation resistance as washed natural silk at 75% relative humidity, superior values above 75%, and inferior below 75%. At 95% relative humidity it has about 80 times the insulation resistance of washed natural silk.

Insuwool B. Has an insulation resistance equal to or a little better than an ordinary *Cotopa*, about 7 or 8 times that of acetate silk, and many times that of washed natural silk.

Insuwool C. Has an insulation resistance equal to or slightly less than that of an ordinary *Cotopa* and about 3 or 4 times that of acetate silk.

Esterified Paper

On the Continent, impregnated paper is a strong rival to textiles for many purposes, owing to its cheapness, and there is a growing tendency to employ esterified paper on account of the greatly increased insulation resistance values obtainable. The comparison of paper with textiles is rather difficult, but it has been found that measuring the transverse insulation resistance of cable insulating papers, i.e., a test analogous to that already described for textiles, when in equilibrium with an atmosphere of a given relative humidity, and expressing the results in megohm grams, values are obtained of the same numerical order as for cotton and that, like those for cotton, they vary with the electrolyte content and the treatment of the paper. With acetylated paper improvement of the insulation resistance of the original paper of about 150 times is taken as standard at present, but laboratory samples having an insulation resistance improvement of 2,000 times have already been made and it is probable that much higher values will be obtained in the near future, though the problem is not exactly analogous to that of acetylating cotton on account of the high content of lignin in cable papers.

The author, in conclusion, wishes to express his thanks to Mr. W. T. Astbury, M.A., and the Oxford University Press for permission to reproduce the photographs of atomic models shown in Figs. 7 and 9 from Mr. Astbury's book, "Fundamentals of Fibre Structure."

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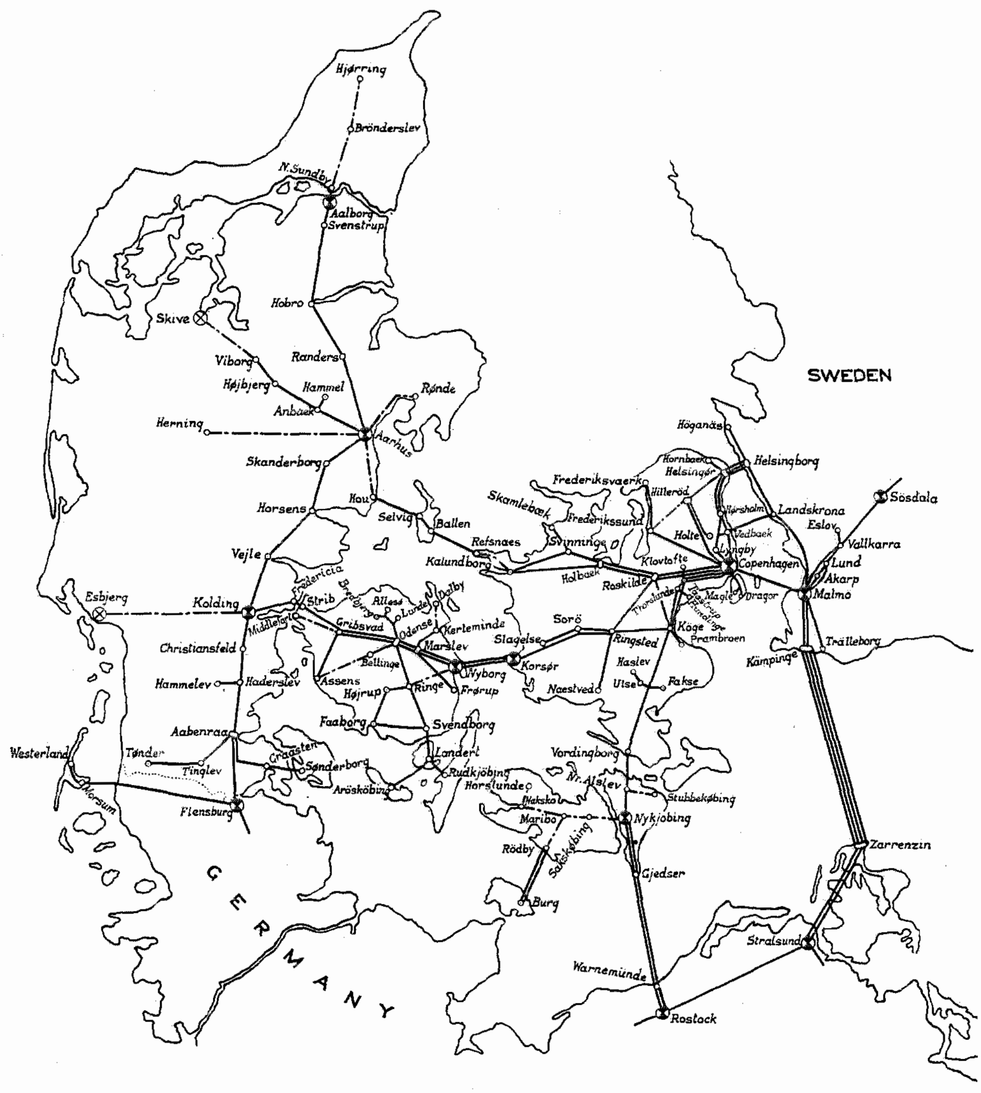
Erratum—On page 221 of Part I (*Electrical Communication,* January, 1935) the name "chardonnet silk" was inadvertently used for "collodion silk." Chardonnet silk, of course, is a regenerated cellulose made by the denitration of collodion silk. It is almost completely superseded now by viscose and cuprammonium silks. None of these, however, is of any value for electrical insulation purposes.



CONVENTIONS.

⊗ (filled)	DENOTES REPEATER STATION (EXISTING).
⊗	" " " (PROPOSED).
———	" CABLE (EXISTING).
—·—·—	" " (PROPOSED).

Telephone Cables in Denmark

The Danish Telegraph Administration's Toll Cable Network*

By N. E. HOLMBLAD

Telegraph Engineer, M. Ing. F.

DURING the spring and summer of 1934 the Telegraph Administration completed and put into operation a toll cable plant on the route Køge-Kolding. This cable plant may be said to form the completion of the first part of the Administration's toll cable programme, and it is opportune, therefore, to give a brief general description of this toll cable network.

A plan of the cable network is shown in Fig. 1, and the most important characteristics of the cables are indicated in the accompanying table. Of the routes shown in Fig. 1, the Kolding-Aalborg cable was laid on the initiative of the Jutland Telephone Company, the Telegraph Administration jointly using the cable on a permanent lease. All other cables were laid by the Telegraph Administration, and are on several of the routes being used jointly with a private telephone company. This arrangement has been advantageous to both parties when a simultaneous need has existed for providing new plant on the same route. On other routes, where it has not been possible to arrange permanent joint use, a temporary renting has, in certain cases, been arranged so as to utilize the spare circuits which, in view of extensions, it is always necessary to provide when establishing a large cable plant. In this connection it should be noted that in all of the more recent cables, specially screened and light-loaded circuits have been included for use by the Broadcasting Administration (see the table). These circuits are owned by the Broadcasting Administration. In most cases the broadcast circuits are screened by a lead sheath and, therefore, become of special importance to the Telegraph Administration as, by virtue of the special protection in the inner lead sheath, they may be used as test leads in case of faults, if water should penetrate into the outer layers of the cable. In such cases it is of great importance to have at least one sound lead available in order to make a quick and reliable location of the fault.

Considering the cross-sections of the cables for the various routes in the light of the information given in the diagram, it should be observed that, as regards the southern part of Jutland, the long distance as well as the local telephone services are operated by the State. The State Administration, therefore, has included for its own use local circuits corresponding to the circuits for the private telephone companies on those routes which are being used jointly by a private telephone company and the Telegraph Administration.

As to some of the data given in the table, it must be remembered that they may vary a great deal within the various pairs of the same type and along the cable, and are also dependent upon the temperature of the cable. The figures given must, therefore, in general be taken as representing nominal values only.

The oldest one of the coil-loaded cables shown in the diagram is the one which was laid (1926) in the Baltic between Nykøbing-F and Rostock (Cable route No. 1). A special interest is attached to this cable because the submarine connection Gedser-Warnemünde may be considered as a pioneer in the use of the coil-loaded system for submarine cables of such length and number of circuits. This cable completely fulfilled the expectations, and the Administration has not hesitated to provide more cables of the same kind for connection to Germany as well as to Sweden (Cable routes 5, 6, and 7).

After completion of the Nykøbing-F-Rostock cable there was a long pause in the laying of toll cables, the next cable, namely, Copenhagen-Nykøbing-F for connecting the earlier cable plant Nykøbing-Rostock with Copenhagen, not being undertaken until 1930. In this interval all more important connections to places abroad

* This article is a translation from the Journal of the Institute of Danish Civil Engineers "INGENIØREN," January 19, 1935.

DANISH TOLL CABLES. 1934.

	CABLE ROUTE	LENGTH km	CIRCUIT TYPE	NUMBER OF CIRCUITS	CORE DIAM. mm	RESISTANCE (INCL. COILS) OHMS/km (15°C)	CAPACITY (NOMINAL) μF/km	LOADING (COIL INDUCT. mH AND SPACING) (SEE NOTE 5.)	ATTENUATION 800 p:s NEPER/km	TOTAL ATTENUATION NEPER	IMPEDANCE 800 p:s OHMS *	CUT-OFF FREQUENCY p:s
1	NYKØBING FL.– ROSTOCK I. 1926	88·4	4-WIRE SIDE CIRCUIT	12	1·0	44·6	0·039	47 – 2208	0·029	2·54	$757 e^{-j9}$	5010
2	KØBENHAVN – NYKØBING FL. 1930	128·0	2-WIRE SIDE CIRCUIT	14 (SEE NOTE 2)	1·4	23·9	0·035	140 – 1710	0·0087	1·12	$1560 e^{-j1}$	3480
			2-WIRE PHANTOM CIRCUIT	7		12·0	0·058	56 – 1710	0·0088	1·13	$770 e^{-j1}$	4275
			4-WIRE SIDE CIRCUIT	18	0·9	54·6	0·033	140 – 1710	0·0181	2·32	$1630 e^{-j2}$	3585
			4-WIRE PHANTOM CIRCUIT	9		27·3	0·053	56 – 1710	0·0176	2·25	$810 e^{-j4}$	4475
			BROADCAST PAIR	1	1·4	22·1	0·035	16 – 1710	0·021	2·70	$550 e^{-j12}$	10300
3	SVINNINGE – SKAMLEBÆK R. 1930	17·6	2-WIRE SIDE CIRCUIT	16	1·0	43·9	0·033	85 – 2931	0·0229	0·40	$1020 e^{-j7}$	3520
			BROADCAST PAIR	2	1·0	42·8	0·043	15·6 – 977	0·0351	0·62	$670 e^{-j13}$	12300
4	KØBENHAVN – LYNGBY R. 1931	15·2	2-WIRE SIDE CIRCUIT	10	0·9	53·5	0·037	80 – 3000	0·030	0·46	$1020 e^{-j10}$	3400
			BROADCAST PAIR	3	0·9	54·1	0·044	13 – 1000	0·042	0·64	$675 e^{-j16}$	13300
			TELEGRAPH CORES	12	0·9	52·7	0·034	NON LOADED	0·062	0·95	$540 e^{-j45}$	NONE
5	YSTAD – RØNNE. 1931	72·4	2-WIRE SIDE CIRCUIT	10	1·4	22·8	0·035	60 – 3870	0·0166	1·22	$700 e^{-j7}$	3540
6	KØBENHAVN – MALMØ 1931	56·7	2-WIRE SIDE CIRCUIT	24	1·15	34·6	0·036	115 – 2464	0·0153	0·87	$1210 e^{-j5}$	3160
			4-WIRE SIDE CIRCUIT	30	1·0	43·7	0·039	18 – 2464	0·0435	2·46	$545 e^{-j23}$	7650
			BROADCAST PAIR	2	1·0	43·3	0·034	8 – 2464	0·0476	2·7	$530 e^{-j32}$	12300
7	NYKØBING FL. – ROSTOCK II 1931.	88·8	4-WIRE SIDE CIRCUIT	22	1·0	42·5	0·037	14·5 – 3295	0·0482	4·29	$515 e^{-j40}$	7590
			BROADCAST PAIR	1	1·5	18·9	0·037	5·3 – 3295	0·0318	2·83	$340 e^{-j28}$	12520
8	KOLDING – FLENSBURG (AABENRAA – SØNDERBORG) 1931	83·4 (35·0)	2-WIRE SIDE CIRCUIT	24	1·05	41·2	0·035	140 – 1725	0·0135	1·13	$1550 e^{-j3}$	3465
			2-WIRE PHANTOM CIRCUIT	12		20·6	0·058	56 – 1725	0·0134	1·12	$775 e^{-j4}$	4255
			4-WIRE SIDE CCT. MEDIUM HEAVY LDD. (SEE NOTE 1)	4	1·05	41·2	0·035	140 – 1725	0·0135	1·13	$1550 e^{-j3}$	3465
			4-WIRE PHANTOM CIRCUIT MEDIUM HEAVY LOADED	2		20·6	0·058	56 – 1725	0·0134	1·12	$775 e^{-j4}$	4255
			4-WIRE SIDE CIRCUIT LIGHT LOADED	6	1·05	39·5	0·035	30 – 1725	0·0263	2·20	$745 e^{-j11}$	7485
			4-WIRE PHANTOM CIRCUIT LIGHT LOADED	3		19·8	0·058	12 – 1725	0·0254	2·12	$385 e^{-j13}$	9200
			BROADCAST PAIR	1	1·1	39·5	0·035	16 – 1725	0·0300	2·50	$580 e^{-j10}$	10250
9	AARHUS – AALBORG 1932	113·5	2-WIRE SIDE CIRCUIT	14 (SEE NOTE 3)	1·4	24·2	0·035	140 – 1694	0·0089	1·01	$1545 e^{-j0}$	3500
			2-WIRE PHANTOM CIRCUIT	7		12·1	0·057	56 – 1694	0·0086	0·98	$780 e^{-j2}$	4340
			4-WIRE SIDE CIRCUIT	3	0·9	54·0	0·033	140 – 1694	0·0179	2·03	$1660 e^{-j4}$	3600
			BROADCAST PAIR	1	1·4	22·3	0·037	16 – 1694	0·021	2·40	$540 e^{-j11}$	10050
10	ROSKILDE – SVINNINGE 1932	47·7	2-WIRE SIDE CIRCUIT	16	0·9	53·9	0·033	130 – 1945	0·0194	0·93	$1467 e^{-j4}$	3480
			2-WIRE SIDE CIRCUIT	14	1·2	31·7	0·034	130 – 1945	0·0120	0·57	$1443 e^{-j2}$	3440
			BROADCAST PAIR	4	1·0	42·5	0·042	15·5 – 973	0·0333	1·59	$662 e^{-j14}$	12670
11	SVINNINGE – KALUNDBORG 1933	27·2	2-WIRE SIDE CIRCUIT	14	1·2	31·3	0·034	130 – 1923	0·0119	0·32	$1441 e^{-j2}$	3460
			BROADCAST PAIR	2	1·0	42·7	0·043	15·5 – 962	0·0344	0·94	$650 e^{-j12}$	12600
12	AARHUS – KOLDING 1933	100·5	2-WIRE SIDE CIRCUIT	48	1·15	34·7	0·036	140 – 1704	0·0119	1·20	$1550 e^{-j2}$	3440
			2-WIRE PHANTOM CIRCUIT	24		17·4	0·058	56 – 1704	0·0117	1·18	$785 e^{-j3}$	4285
			4-WIRE SIDE CIRCUIT MEDIUM HEAVY LOADED	6	1·15	34·6	0·036	140 – 1704	0·0119	1·20	$1550 e^{-j2}$	3440
			4-WIRE PHANTOM CIRCUIT MEDIUM HEAVY LOADED	3		17·3	0·058	56 – 1704	0·0117	1·18	$785 e^{-j3}$	4285
			4-WIRE SIDE CIRCUIT LIGHT LOADED	6	1·15	33·4	0·036	30 – 1704	0·0235	2·36	$740 e^{-j10}$	7460
			4-WIRE PHANTOM CIRCUIT LIGHT LOADED	3		16·7	0·058	12 – 1704	0·0231	2·32	$380 e^{-j12}$	9250
			BROADCAST PAIR	1	1·15	32·7	0·037	16 – 1704	0·0296	2·98	$585 e^{-j16}$	10025
13	KOLDING – NYBORG 1934	103·5	2-WIRE SIDE CIRCUIT	76 (SEE NOTE 4)	1·2	33·8	0·034	140 – 1761	0·0118	1·22	$1555 e^{-j2}$	3480
			2-WIRE PHANTOM CIRCUIT	38		16·9	0·054	56 – 1761	0·0117	1·21	$785 e^{-j3}$	4370
			4-WIRE SIDE CIRCUIT MEDIUM HEAVY LOADED	6	1·2	33·9	0·034	140 – 1761	0·0118	1·22	$1555 e^{-j2}$	3480
			4-WIRE PHANTOM CIRCUIT MEDIUM HEAVY LOADED	3		17·0	0·054	56 – 1761	0·0117	1·21	$785 e^{-j3}$	4370
			4-WIRE SIDE CIRCUIT LIGHT LOADED	4	1·2	30·8	0·034	30 – 1761	0·0216	2·24	$740 e^{-j9}$	7515
			4-WIRE PHANTOM CIRCUIT LIGHT LOADED	2		15·4	0·054	12 – 1761	0·0210	2·17	$385 e^{-j11}$	9 45
			BROADCAST PAIR	1	1·2	29·6	0·035	16 – 1761	0·0271	2·80	$570 e^{-j15}$	10150
14	NYBORG – KORSØR I 1933	26·6	2-WIRE SIDE CIRCUIT	38	1·2	29·7	0·044	NON LOADED	0·055	1·46	$368 e^{-j40}$	NONE
			2-WIRE PHANTOM CIRCUIT	19		14·9	0·071	NON LOADED	0·047	1·25	$209 e^{-j40}$	NONE
			4-WIRE SIDE CIRCUIT	5	1·2	29·7	0·044	NON LOADED	0·055	1·46	$368 e^{-j40}$	NONE
			4-WIRE PHANTOM CIRCUIT	2·5		14·9	0·071	NON LOADED	0·047	1·25	$209 e^{-j40}$	NONE
			BROADCAST PAIR	1	1·4	21·9	0·046	NON LOADED	0·046	1·22	$298 e^{-j40}$	NONE
15	NYBORG – KORSØR II 1934	25·7	2-WIRE SIDE CIRCUIT	38	1·2	29·1	0·042	NON LOADED	0·052	1·34	$367 e^{-j41}$	NONE
			2-WIRE PHANTOM CIRCUIT	19		14·6	0·068	NON LOADED	0·047	1·20	$206 e^{-j39}$	NONE
			4-WIRE SIDE CIRCUIT	5	1·2	29·1	0·042	NON LOADED	0·052	1·34	$367 e^{-j41}$	NONE
			4-WIRE PHANTOM CIRCUIT	2·5		14·6	0·068	NON LOADED	0·047	1·20	$206 e^{-j39}$	NONE
			BROADCAST PAIR	1	1·4	21·6	0·041	NON LOADED	0·045	1·16	$323 e^{-j39}$	NONE
16	KØGE – KORSØR 1934	74·1	2-WIRE SIDE CIRCUIT	72	1·2	34·0	0·035	140 – 1730	0·0120	0·89	$1560 e^{-j2}$	3465
			2-WIRE PHANTOM CIRCUIT	36		17·0	0·055	56 – 1730	0·0116	0·86	$790 e^{-j2}$	4365
			2-WIRE SIDE CIRCUIT	4	0·9	56·8	0·032	140 – 1730	0·0185	1·39	$1640 e^{-j3}$	3620
			2-WIRE PHANTOM CIRCUIT	2		28·4	0·052	56 – 1730	0·0182	1·37	$820 e^{-j4}$	4495
			4-WIRE SIDE CIRCUIT	10	0·9	56·8	0·032	140 – 1730	0·0185	1·37	$1640 e^{-j3}$	3620
			4-WIRE PHANTOM CIRCUIT	5		28·4	0·052	56 – 1730	0·0182	1·35	$820 e^{-j4}$	4495
			BROADCAST PAIR	1	1·4	22·2	0·035	16 – 1730	0·0205	1·55	$560 e^{-j11}$	10250

NOTE:-

1. AABENRAA – SØNDERBORG OVER ALL 2-WIRE, MEDIUM HEAVY LOADED, 44 SIDES + 22 PHANTOMS.
2. FURTHER KØBENHAVN – KØGE, 42·5 km, IN THE SAME CABLE AND WITH THE SAME QUALITIES: 1 BROADCAST PAIR, 72 SIDE CIRCUITS + 36 PHANTOM CIRCUITS 2-WIRE AND 10 SIDE CIRCUITS + 5 PHANTOM CIRCUITS 4-WIRE.
3. FURTHER AARHUS – RANDERS, 37·3 km, 6 SIDE CIRCUITS 0·9mm 2-WIRE
4. FURTHER KOLDING – FREDERICIA, 22·3km, 4 SIDE CIRCUITS + 2 PHANTOM CIRCUITS 1·2 mm 2-WIRE.
5. IN CASES WHERE THERE ARE VARIOUS COIL SPACINGS WITHIN THE SAME PLANT THE LONGEST ONE HAS BEEN INDICATED.

* e^{-j} DENOTES A NEGATIVE ANGLE.

Danish Toll Cables—1934.

were carried over open wire lines between Copenhagen and Nykøbing-F. The reason why this practice did not cause much trouble is accounted for by the high standard of the maintenance of the open wire lines. In the long run it was, however, not considered satisfactory to have the relatively short route, Copenhagen-Nykøbing-F, in open wire circuits forming part of the long international connections, elsewhere carried in cables. Furthermore, the existing open wire lines did not afford possibilities for growth to meet the steadily increasing international telephone traffic and, accordingly, the cable Copenhagen-Nykøbing-F was installed in 1930.

Actually, Denmark was rather late in developing a cable plant suitable for connection with the European network. This was due to various causes: divisions of long distance telephony and local telephony between the State and the concessionaire telephone companies; the relatively small area of the country with the many submarine cable routes; and the early development of a large and high quality open wire network. The late building up of toll cable plants, however, has been an advantage in one respect in that the cable plant was designed after the coil loading technique had reached a fairly high degree of perfection, so that all the cables which have been laid may even today be considered as being up-to-date. It is fortunate that the kind of coil-loading, which is used for the Copenhagen-Nykøbing-F cable and which was entirely new (140/56 mH coils spaced 1.7 km. apart) when that cable was being planned, is still considered suitable, and the result has been a fairly uniform cable network. This type of loading has, in fact, been used where special conditions, as for example, submarine cable routes or special circuits to radio stations, have not prevailed (i.e., Cable routes 3, 4, 10, and 11). It should be noted that this loading method, since its inception, when it only comprised circuits loaded with 140/56 mH coils (medium heavy loading), has been supplemented with a lighter grade of loading (30/12 mH coils) for use on a smaller number of special circuits which are more suitable for high speed transmission over very long distances. Such circuits were used in this country for the first time in 1931 on the Kolding-Flensburg cable (Cable route 8).

After the completion of the Copenhagen-Nykøbing-F cable, development advanced rapidly and the rest of the cable plant, shown on the diagram, was finished in the succeeding four years. When considering the layout of the network it will be noted that the main route between Copenhagen and Jutland passes over Seeland and Funen to Kolding, whence the circuits branch off. The main reason for selecting this route was to avoid as far as possible the more expensive and less reliable submarine cable routes, even though the circuits to Aarhus and beyond were considerably longer. A spare route to Jutland via Kalundborg, however, has been maintained, this being the former route for most of the circuits to the northern part of Jutland. One of the reasons why a cable was laid to Kalundborg was largely due to the erection of the radio station at Skamlebaek and the broadcasting station at Kalundborg. These radio stations made it desirable to have cables to Skamlebaek and Kalundborg, and in turn made it possible, without great expense, to include some cable circuits to Kalundborg for use in connection with the best of the older circuits from Kalundborg to Aarhus. In this way an additional route to Jutland has been obtained, independent of the Copenhagen-Kolding route. This will be of very great importance in case of possible cable faults on the ordinary route, even though the number of circuits in the spare route is small.

In addition to the broadcasting stations at Copenhagen and Kalundborg, the diagram shows the radio stations at Skamlebaek and Lyngby, since these may be said to form a natural link in the telegraph as well as the telephone network. These are a transmitting and a receiving station, respectively, for telephone communication with ships, and in the future will also be used for oversea connections. A connection with Iceland has recently been established.

The cost of the Telegraph Administration's part in the cables in question may be taken as about Kr. 14,000,000, and for the repeater stations as about Kr. 2,000,000. All the underground cables, except a few shorter routes which have been obtained from Germany (Svinninge-Skamlebaek, Copenhagen-Lyngby, and the route Aabenraa-Flensburg, forming part of the Kolding-Flensburg plant), have been delivered by the

Northern Cable and Wire Works in Copenhagen, with the coils from Standard Electric. The two non-loaded Great Belt cables[1] were manufactured by the Northern Cable and Wire Works, whereas all the coil-loaded submarine cables have been delivered from Germany. The jointing and installation of the underground cables has in general been carried out by the Telegraph Administration in collaboration with the factory and under the factory's guarantee for the complete plant. For this reason, testers and jointers were given special training at the factory.

[1] "Submarine Telephone Cables Across the Great Belt," by John Møllerhøj, *Electrical Communication*, January, 1935.

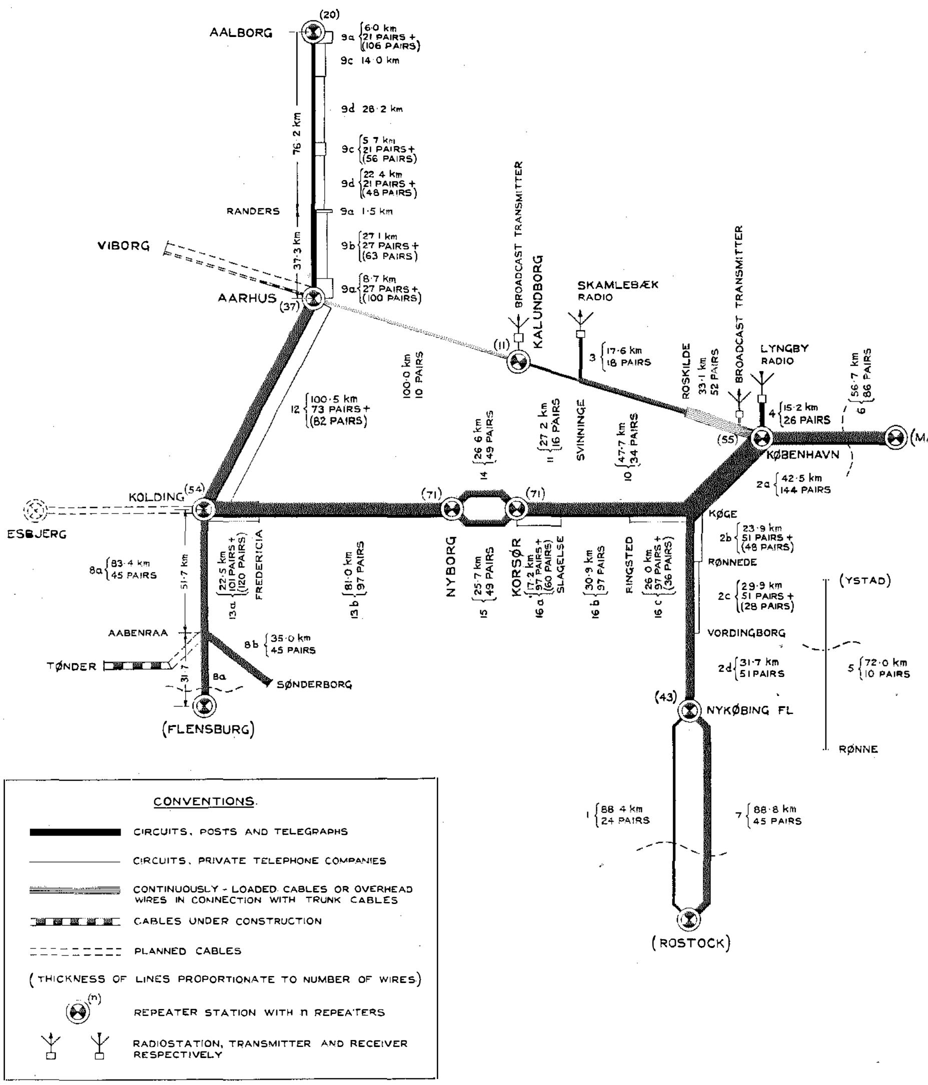


Figure 1—Danish Cable Network—1934.

Application of Minimum Net Loss Theory to the Design of International Toll Circuits

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I. *Introduction*

QUESTION 28 now before the 3rd and 4th C.R. of the C.C.I.F. reads as follows:

(a) What method can be specified for the determination of the minimum net loss for both 2-wire and 4-wire international circuits (both when used for terminal and when used for via business) from the standpoint of echo, singing margin, and crosstalk, due weight being given to the question of the variation of the characteristics of the circuit with time?

(b) What is the minimum net loss of a 2-wire or 4-wire international circuit when used for terminal and when used for via business?

As explained in a previous paper[1], the provision of a satisfactory telephone connection involves the control of two general groups of factors:

(a) Those which, regardless of their value within certain ranges, may be considered as contributing in a continuous manner to the effective transmission rating of the connection and as being mutually compensating. Such factors may be allowed to vary over ranges provided one or more of the other factors in the same class are also varied to compensate for them.
(b) Those factors which, on the one hand, have specific and individual limits which cannot be exceeded without making the circuit inoperative but which, on the other hand, have no effect whatever on the effective rating of the circuit if each is kept within its specific limit.

In the attempt to insure a satisfactory grade of service being given for any connection put up in the continental network, the C.C.I.F. has arrived at certain limiting values for the first group of effects. These limitations take the form of a limiting value for the overall attenuation; and, as a means of insuring that this value will never be exceeded, a limit for:

(a) The national transmitting loss;
(b) The national receiving loss;
(c) The loss in the international circuit.

Up to the present, other effects such as cut-off and noise, have been given specific limiting overall values but, under the new concept of effective transmission, studies are under way to weight such effects in terms of their effective contribution to the overall performance. When these studies of the equivalent weighting of such effects are completed, the standards (a), (b), and (c) above will be replaced by new standards which will include all of these effects, and if adhered to will insure keeping all factors which contribute to the effective rating of a given connection within allowable limits.

The solution of the limitation of the second group of effects (i.e., echo, singing margin, and intelligible crosstalk) has, however, progressed but little beyond the stage of acceptable overall limits. The problem of determining and limiting the contribution of the three portions of the circuit (i.e., the national transmitting, the national receiving, and the international networks) to these overall limits has not been touched. Question 28 is an attempt to reach a solution of this problem in an indirect way based on the fact that all three of these effects—echo, singing margin, and intelligible crosstalk—are for a given type of circuit dependent on the transmission loss at which the circuit is worked.

The wording of the question, however, especially part (b), is somewhat unfortunate; for although there is for a given circuit or combination of circuits a definite minimum transmission loss below which the circuit or combination of circuits cannot be worked without

[1] "Some Considerations Regarding a Toll Fundamental Plan for Europe," *Electrical Communication*, October, 1935.

exceeding the accepted limits of crosstalk, singing margin, and echo, there is, in theory, no such thing as an inherent minimum net loss assignable to a circuit or part of a circuit when used as part of a built-up connection. A wording which would more accurately express the problem being attacked would be the following:

> (b) In what way can the relation between transmission loss and the three factors—echo, crosstalk, and singing margin—be used to control echo, crosstalk, and singing margin on the built-up connections met with in the general European network?

In addition to stating more specifically the objective in view, such a wording would eliminate much of the difficulty and theoretical hair-splitting which would be encountered in attempting to define and determine the "minimum net loss" of a circuit when used in transit.

In a paper entitled "Certain Factors Limiting the Volume Efficiency of Repeatered Telephone Circuits," contained in *The Bell System Technical Journal*, October, 1933, Mr. L. G. Abraham has outlined the general theory of minimum net losses and presented methods of determining *for any given circuit* the minimum loss at which such a circuit can be worked before the allowable limit for any one of the three factors under discussion is surpassed. As an answer to part (a) of Question 28 now before the C.C.I., this paper provides an adequate method of procedure. By gathering the necessary data as outlined in the annexes to Question 28 and proceeding as outlined in the L. G. Abraham paper, curves of minimum net loss versus length could be calculated for all accepted types of circuits in use in Europe. Likewise the minimum net loss for any given combination of circuits could be calculated. This still leaves us, however, a long way from the real objective: the control of echo, crosstalk, and singing margin for the general case of built-up connection.

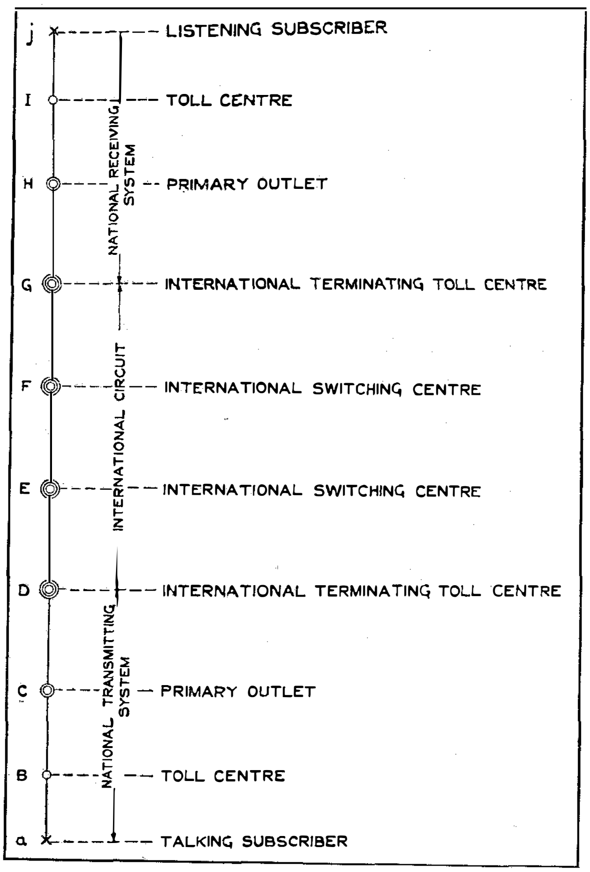

Figure 1

In order to be perfectly clear as to the final objective of our consideration of minimum net loss, let us for a moment examine the practical engineering phases of the problem as it arises in practice. In Fig. 1 we have the present standard international circuit. Tentative rules have been laid down for the allowable transmission loss in each part of the network.

When studies now under way on effective transmission are completed, we will have available for the international network standard design limits which probably will take the following form:

$$a_t + BC\ (\text{effective}) + CD\ (\text{effective}) = S_t = GH\ (\text{eff.}) + HI\ (\text{eff.}) + j_t$$

$$a_r + BC\ (\text{effective}) + CD\ (\text{effective}) = S_r = GH\ (\text{eff.}) + HI\ (\text{eff.}) + j_r$$

$$DE\ (\text{effective}) + EF\ (\text{effective}) + FG\ (\text{effective}) = S$$

$$S_t + S_r + S_i = S_o$$

where a_t and j_t = effective transmitting rating (performance loss) of subscribers' set and loop.

a_r and j_r = effective receiving rating (performance loss) of subscribers' set and loop.

S_t = maximum allowable national transmitting loss (performance loss)

S_r = maximum allowable national receiving loss (performance loss)

S_i = maximum allowable international toll circuit loss (performance loss)

S_o = maximum allowable overall transmission loss (performance loss)

With such standards available, the various administrations can proceed to design their networks in accordance with the needs and economies involved within their own system. As long as the above standards are met, any overall connection set up will meet the effective transmission requirements for satisfactory communication.

There remains only the question of guaranteeing that echo, singing margin, and intelligible crosstalk will be kept within the established limits for the overall connection. If some practical method, based on transmission loss, similar to that which applies in the case of uniform terminal circuits, can be found, the complete control of the general international built-up connection then resolves itself into one of meeting the limits above noted, plus the added restriction that the transmission loss of any links BC, CD, etc., be not less than a certain given value for any given type and length of circuit.

The form in which the limits for effective transmission will be given allows a very considerable latitude in the design of the various national systems. This is very desirable, since local conditions, methods of operation, types of equipment, etc., will vary so from country to country that any more specific limits might very well force types and grades of circuits which would be uneconomical when viewed from the standpoint of the local administration. In order to obtain full advantage of this latitude in design practices, such rules as are laid down for the control of echo, crosstalk, and singing margin should be in the same general terms. This latitude in the allowable range of factors contributing to the effective rating of the circuit, and the desirability of having the same latitude in controlling the group of factors contributing to echo, crosstalk, and singing margin does, however, complicate the problem since it greatly restricts the use of solutions based on "average cases," but does not mean that such approximate solutions are thrown entirely out of consideration; quite the contrary. As previously mentioned, there is theoretically no factor inherent in a given circuit of given type and length which may be considered as a measure of the contribution made by that circuit to the overall echo, crosstalk, and singing margin limits; consequently, some approximate method must be utilized. In determining the approximations to be used, however, the aim should be to select practicable methods which will give the best balance between accuracy and the maintenance of such latitudes in local design practices as appear to have specific meaning and application in the European network.

II. Possible Procedures

As has already been noted, the application of minimum net loss to control echo, crosstalk, and singing margin on built-up connections, at best, will be an approximation. It remains to be seen whether or not a practicable working method can be found in which the approximations do not involve too great chances for error.

There are two general methods that might be followed: (a) the net loss factor method, and (b) the inherent net loss method. Before, however, discussing either method, it would seem desirable to mention one practical consideration which may permit some simplification and possible reduction in the factors which must be taken into account. This consideration is the relative unimportance of the nominal transmission loss of the individual links which make up the overall connections.

Whereas, theoretically, the distribution of gains over the circuits involved has a distinct bearing on the minimum net loss of a circuit or combination of circuits, in actual practice there exists today such uniformity in design practices, in repeater spacings, allowable levels, etc., that it can safely be said that the overall transmission loss rather than the nominal transmission loss of the individual links is the controlling factor. It was partially on account of this fact that the author suggested a change in the question, eliminating the phrase "minimum net via loss." Possibly, we may return to something which we may call the "minimum net via loss," but, in this event, it should be kept in mind that the term is merely a relative weighting factor assigned to a given circuit and need have no relation whatever to the nominal transmission loss at which the circuit is worked in the via connection.

The possible application of this point in the development of a method of using minimum net loss in the design of via connections may be seen from the following illustration;

Let us assume a network utilizing combinations of circuits whose minimum net loss curve is of the form shown in Fig. 2. Let us further assume that the built-up connections whose minimum net loss we are attempting to determine are in the range X to Y. Now, under the net loss factor method, a very close approximation to the actual curve of minimum net loss in this range X to Y can be obtained by drawing the straight line LM. Such a straight line provides us with a very simple method of establishing design standards such that any built-up connection in the range X to Y will be within the allowable transmission loss limits as determined by the curve shown. All that is required is that

$$E = (\sum ln) + L,$$

where E is the effective transmission loss, (not including the toll terminal loss), l is the length of each individual circuit, n is the slope of the line LM, and L is its intersection with the vertical axis (in the case shown L is negative). For any particular circuit, ln or (ln+L) does not lie on the true minimum net loss curve nor should it be considered as imposing any restriction on the actual transmission loss at which any individual circuit of the overall connection is worked. In fact, when we come to assigning limiting values of nominal transmission loss for portions of the network such as the national transmitting system (B-D of Fig. 1) or the international circuit (D-F of Fig. 1) we may even assign values such that $E-(ln+L)$ may be negative. As long as $\sum E$ for the *combined connection* lies on or above the actual curves of minimum net loss, the connection will meet echo, crosstalk, and singing margin limits. This point will be touched on further, in discussing actual procedures under the two plans.

II. 1 The Net Loss Factor Method

From the standpoint of practical application, the net loss factor method probably provides the most simple and direct method developed of controlling echo, crosstalk, and singing margin through the medium of minimum net loss. As

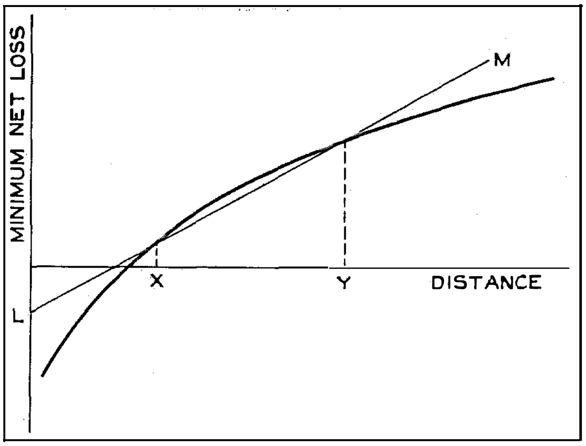

Figure 2

mentioned in the previous section, this method assumes an equal distribution over the circuit of the relative contribution made to the factors being controlled. Its applicability in the case of uniform facilities and the method of keeping the error involved in the straight line assumption within reasonable limits in the critical range has also been indicated. The extension of this method to cover built-up connections, involving different types of facilities in the different links, involves the drawing of a family of straight lines through the same point in the vertical axis so chosen that they approximate closely the actual minimum net loss curves for the corresponding type of facility in the critical range.

The assumption is then made that the minimum net loss, N, of any combination of circuits is $\sum ln + L$, where l is the length of circuit of a given type, n is the net loss factor for that type of facility, and L is, as above, the intersection of the family of straight-line curves with the vertical axis. Theoretical justification of this assumption is somewhat difficult due to the complex interrelation of the various effects involved. However, if we take typical cases in which the total lengths of circuits involved are within the ranges where the straight line closely approximates the actual curve of minimum net loss and compare the value of minimum net loss obtained from the assumption that $N = \sum ln + L$ with that obtained by actual calculation as explained in the L. G. Abraham paper, we find that in all cases the loss is sufficiently close for all normal engineering.

A full application of this method requires two steps:

(1) Determining the actual net loss factors and the value for L, by

(a) Calculating the actual curve of minimum net loss for all accepted types of circuits involved in the European network;

(b) Studying the probable range of lengths which might be involved for all types of international connections and selecting the family of straight-line curves which give the best approximation to the actual curves in the critical ranges.

(2) Establishing limiting values for the two portions of the international network, i.e., the national transmitting or receiving network and the international circuit proper. In the latter, it will be more convenient to establish limits in terms of margins rather than of actual transmission losses. Thus the limit for the national portion of the network (BC+CD or GH+HI. of Fig. 1) will be a certain value $M_N = E_N - (\sum \ln + L)$ and for the international circuit $M_I = E_I - (\sum \ln + L)$ where M_N and M_I are the limiting margins established for the national and international portions, respectively, of the international network, E_N and E_I the nominal working transmission loss of the national and international portion, respectively, while l, n, and L have the same significance as previously indicated.

The selection of M_N and M_I will involve further study in connection with the European Fundamental Plan. The characteristics of the international portion of the network are gradually becoming crystallized so that, once the nominal working transmission loss of the international portion of the network is fixed, M_I can be determined. M_N would then be chosen such that $2 M_N + M_I = 0$.

Such a method would provide a very simple and practicable way of limiting echo, crosstalk, and singing margin on built-up connections and would be in sufficiently broad terms to allow the operating engineers considerable latitude in designing their own systems to meet most economically the local conditions of use since the network would be limited only by the following (See Fig. 1):

a_t + BC (effective) + CD (effective) = S_t = GH (eff.) + HI (effective) + j_t

a_r + BC (effective) + CD (effective) = S_r = GH (eff.) + HI (effective) + j_r

$M_{BC} + M_{CD} = M_N = M_{GH} + M_{HI}$

III. *The Inherent Net Loss Method*

A second method which may possess some advantages both in accuracy and ease of application is what may be termed the inherent net loss method. This method is based on a factor termed the inherent net loss which is the actual allowable net loss for a circuit or combination of circuits when used against its mirror image.

In developing this method the assumption is made that, converging at each center of transit, there is a radiating network of lines as shown in Fig. 3. Thus, at C, there will center a group of

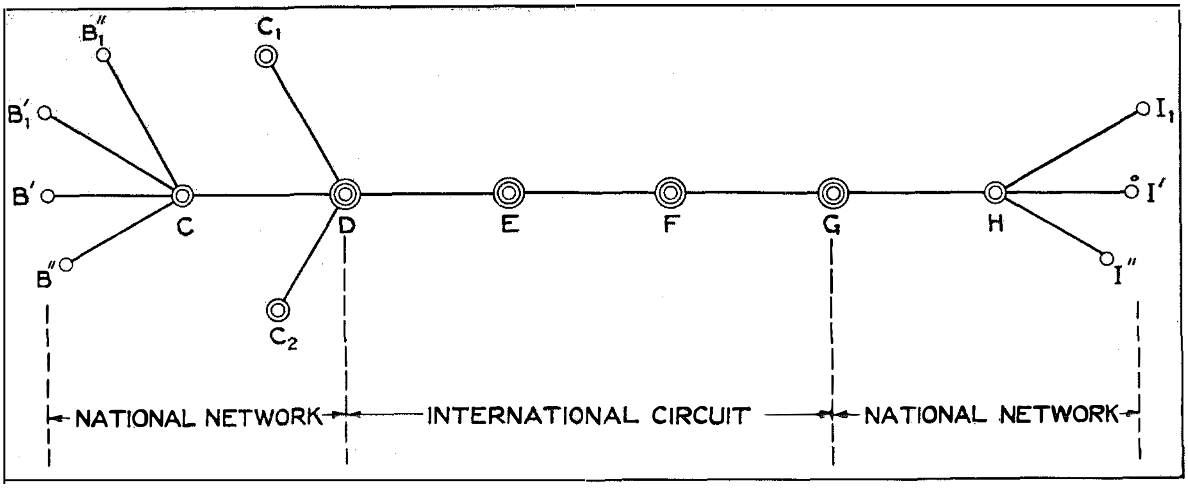

Figure 3

circuits such as B′, B″, etc. The effective transmission limit for all circuits centering at any point will be the same. They will be of varying lengths and, in order to meet the requirement of echo, crosstalk, and singing margin, they may vary as to type of facility. The problem is to choose the most economical grade of facility that will enable this value of effective transmission to be met and, furthermore, a type whose contribution to the overall echo, crosstalk, and singing margin will not exceed a certain fixed value. What it in reality comes down to, is fixing a limit of length for each type of circuit when used in a certain part of the connection.

Now, if we take a circuit of a given type and length, we may calculate by the L. G. Abraham method the transmission loss, which we may term $2E_i'$, at which this circuit plus its mirror image may be worked. Since the two portions of the circuit from the mid-point are identical, we may say that the relative contribution of each part to the allowable net loss is E_i'. If in the network centering at C, we find that for a given type of facility we need a certain working transmission loss, E_0, we may use this type of facility up to the length where $E_i' = F_0$. If this distance is not exceeded for any circuit of the given type of facility, any connection put up of the type B′CB″ will always meet echo, crosstalk, and singing margin limits. The same holds for circuits of any other type of facility when used with the same type in a connection B′CB″.The question then arises as to what happens in the case of a circuit B′C working at the limiting distance when used with a circuit B_i'C of another type to form the connection B′CB_i'. If we take a circuit B′CB″ working at its limiting point, we have the following condition for

(a) *Echo.* B′C contributes to the echo effect a certain weighted echo W_{BC}'. It further adds delay to the echoes coming from CB″. It is the combined weighted echo at B′ which must be kept within 100%. Now if in place of CB″ we substitute a second circuit CB_i' we find that the echo effect at B′ is made up as before of

(1) Weighted echo of the portion B′C.
(2) Weighted echoes for each return path from CB_i' each increased in delay by the delay in B′C.

Now these paths from CB_i' may be different in delay and amount of return power from those in the former case of CB″. However, since E_0 for CB_i', will be very nearly the same as for CB″ (under the assumption of uniform effective standard to C for all circuits centering there) and since the terminal echo is by far the most important, it can be shown that the actual return currents and delays are such that, when corrected for the additional delay in B′C, the result will be almost identical with that obtained for CB″.

(b) *Singing Margin.* The same general case holds for singing margin. If we take two circuits B′CB″ and B_i'CB_i'' both working at the same overall transmission loss $2E_0$ and of such length that they are at the limiting point from the standpoint of singing margin, it can be shown, provided both have been designed according to the same standards for repeater spacings, taper, etc., that the return loss from the mid-point in either direction is practically identical. Hence, either half may be substituted for the other without upsetting the singing margin limit. Actually, with a given limiting standard for effective transmission, it is not absolutely accurate to assume that E_0 for one type of facility will be the same as that for another. The difference will be slight, however, and the inaccuracy involved in assuming a constant value for E_0 is within the limits of normal engineering calculations involved in such a case.

(c) *Crosstalk.* A somewhat similar analysis can be made in the case of crosstalk. That is, if we substitute for circuit CB″ a second circuit CB_i'' *when each of these circuits is working at the same transmission loss and is of the limiting length allowed by the net loss curve* for crosstalk for that type of facility, the overall crosstalk condition for B′CB″ is the same as for B′CB_i''.

In other words, in considering the case of a group of circuits switching at a central point, such as C in the illustrative case, there is good engineering justification for assuming and using this so called "inherent minimum net loss" in via connection engineering.

In extending this method to the whole national network, the procedure is somewhat similar. Curves of inherent minimum net loss are drawn for various types of facilities used in the portion CD of the above network in association with each of the limiting types of circuit BC working at this inherent minimum net loss. That is, a circuit BCD is set up against its mirror image and, for varying lengths of CD, the minimum net loss N_i is determined for each of the limiting cases represented by each type of facility used in the BC network. The inherent minimum net loss for BC is known. The inherent net loss for each length of CD is then the difference between the value of N_i for BCD and that already obtained for the limiting case for BC.

So far the problem is strictly national, and limiting lengths for the BC and the CD networks will be determined by the engineers designing the national networks. In extending this method to the international circuit DEFG, the procedure would be to obtain a series of curves of inherent minimum net loss for such types of circuits as are found in the international network. The procedure is the same except that, in place of the mirror image, we utilize a circuit having as end links the limiting cases for BCD and GHI.

As in the case of choosing the family of straight-line curves giving the greatest accuracy under the net loss method, the development of the inherent net loss curves requires close coordination with the design of the form of the European network as a whole—a coordination only attainable through the medium of a well formulated European Fundamental Plan.

IV. General Conclusions and Suggested Method of Procedure

(1) By gathering data as outlined in either, or both, the American Telephone and Telegraph Company or the German Post Office appendices to Question 28, it will be possible to trace curves of minimum net loss versus length for all accepted types of facilities used in the international network. This data will give the answer to part (a) of Question 28.

(2) Although theoretically there is no such thing as a "minimum net via loss" for any circuit as such, there are two general methods whereby echo, crosstalk, and singing margin may be practically controlled. These are:

(a) The net loss factor method;
(b) The inherent net loss method.

Both of these need close investigation of the inherent form of the national networks as indicated by the European Fundamental Plan. With such a plan as a basis, one or the other of the above methods can be adapted, within certain ranges, to yield results sufficiently broad to allow full latitude in design and, also, an accurate control of echo, crosstalk, and singing margin. Thus, undue restriction in local design practices will be avoided.

(3) From the standpoint of international service a subcommittee on minimum net loss might well be set up to study in detail the method best adapted to European conditions and, when all data are at hand, to issue working rules, curves, etc., for general adoption throughout Europe.

Private Automatic Branch Exchanges

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General

WHILE it is true, in a broad sense, that the development of automatic switching in private exchanges has followed central office practice, private telephone service includes a number of special requirements and facilities which are necessary for its efficient operation, but which are not applicable to public exchanges. Private telephone service, in bringing to the home and the office full automatic intercommunication, saves a great deal of time by reason of its invaluable aids to efficiency.

Private telephone exchanges give service under three headings, namely, Internal, External, and Special. Under this last heading, most of the development work of recent years has been carried out and it is these special features that constitute the principal difference between private exchange and other forms of telephone equipment.

Try to picture to yourself the exasperation of a business man who, having been connected with Mr. Smith in an organization served by a private exchange, finds it is Mr. Jones in an entirely different office to whom he must speak. What must he do in this case? The modern private exchange provides the answer. Mr. Smith can transfer the call to Mr. Jones by pressing the transfer button on his set and dialing Mr. Jones.

Again it frequently happens that Mr. Smith, having been called up from the city, finds he needs information from Mr. Jones and would like to communicate with him while holding the city connection. This facility is also possible by means of the same transfer button, as indicated in the schematic of city connections (Fig. 1).

Internal Service

Private exchanges vary in size. At one end of the scale there is the small exchange suitable for doctors, lawyers, dentists, etc., and also the private home installation for which from four to ten stations are usually sufficient. At the other end, there is the large organization, public buildings, municipal offices, government departments, hospitals, and large factories where one thousand or more internal stations may be required.

Different units, designed to meet these varying conditions and capacities, have been manufactured by the Bell Telephone Manufacturing Company, Antwerp, and are listed in Table I. The 4- and 6-line units are of the all-relay type and the others are of the single motion switch type. The No. 7055 and the 7-D types are power driven and employ the well known gear driven finder. In all cases, the equipment is suitable for tropical climates—black enamelled, cellulose acetate covered wire being used when necessary.

External Service

It is an indubitable fact that some kind of attendant is desirable to handle incoming calls. In some countries full automatic in-service is given, but it is admittedly not a commercially sound practice. There is always the danger that calls will all be directed to the manager. The most expeditious manner of handling incoming calls is by means of a cordless type of attendant's board. Not only is the work of the attendant simplified, but secrecy is more easily attained than with the older plug and jack type of switchboard. An example of a modern cordless board suitable for a part-time attendant is shown in Fig. 2. For comparison, the familiar plug and jack type of switchboard is shown in Fig. 3.

Special Services

Under this heading, private exchanges provide conference facilities, preference service, tie lines, and code calling. Special arrangements are also made for handling incoming city connections during the night or when the attendant is absent.

Types and Capacities

4- AND 6-LINE UNITS WITH ONE JUNCTION. TYPES 7005 AND 7006 (SEE FIGS. 4 AND 5).

These are all-relay units and replace the old fashioned intercommunication systems. They have the advantage of secrecy on all classes of calls, and are considerably cheaper to install. The capacity of these small units makes them particularly suitable for private residences and small offices of all kinds.

Field experience gained with this type of unit furnishes conclusive evidence that there exists a real demand for this class of service. The Belgian Régie has installed over twelve hundred No. 7005 P.A.B.X's. on a rental basis in a little more than one year—a striking example of the importance of the small P.A.B.X. field as an additional source of revenue.

The 7005 and 7006 boards are fed from an all mains power unit (no battery), consisting of a metal rectifier, transformer, and filter. This current supply unit is suitable for connection to a-c. mains of 110, 130, 160, or 220 volts.

The method of operation is simple, a local call being obtained in the same way as in a dial city office. The standard dialing, busy, and ringing tones are given.

An outgoing city call is obtained by momentarily depressing the transfer button on the set after having received local dialing tone. Access to the city trunk is thereby obtained and, when the city dialing tone is received, the full number of the wanted party is dialed.

An incoming city call may be received by any local party by depressing momentarily the trans-

TABLE I

Antwerp Code No.	CAPACITY			Numbering	Operating Voltage	Operating Features
	Station Lines	Links	Junctions			
7005	4	1	1	1 to 4	24 V.	1 connection at a time
7006-A	4	1	1	1 to 4	24 V.	1 local plus 1 city connection at a time
7006-B	6	1	1	1 to 6	24 V.	
7011-A	10	2	–	1 to 0	24 V.	
7011-B	10	2	2	1 to 0	24 V.	Method of operation same as for all relay boards.
7015-A	12	2	–	1 to 8 91 to 94	24 V.	
7015-B	10	2	2	1 to 7 92 to 94	24 V.	"0" for automatic out; "8" for answering incoming calls.
7015-C	10	2	3	idem	24 V.	
7025-A	25	3	2	1 to 8 92 to 99 901 to 908	24 V.	"0" for automatic out; "1" to attendant.
7025-B	25	3	3	idem	24 V.	
7025-C	25	3	5	idem	24 V.	
7025-D	25	3	–	idem	24 V.	
7035	100	any	–	01 to 99	24 V.	
7035	80	any	any	10 to 89	24 V.	"0" for automatic out; "9" to attendant
7035	99	any	any	101 to 199	24 V.	3 digit numbering
7055	400	any	any	100 to 499	48 V.	3 digit numbering
7-D	900	any	any	100 to 999	48 V.	3 digit numbering
7-D	1,800	any	any	1,000 to 1,999 2,000 to 2,799	48 V.	4 digit numbering

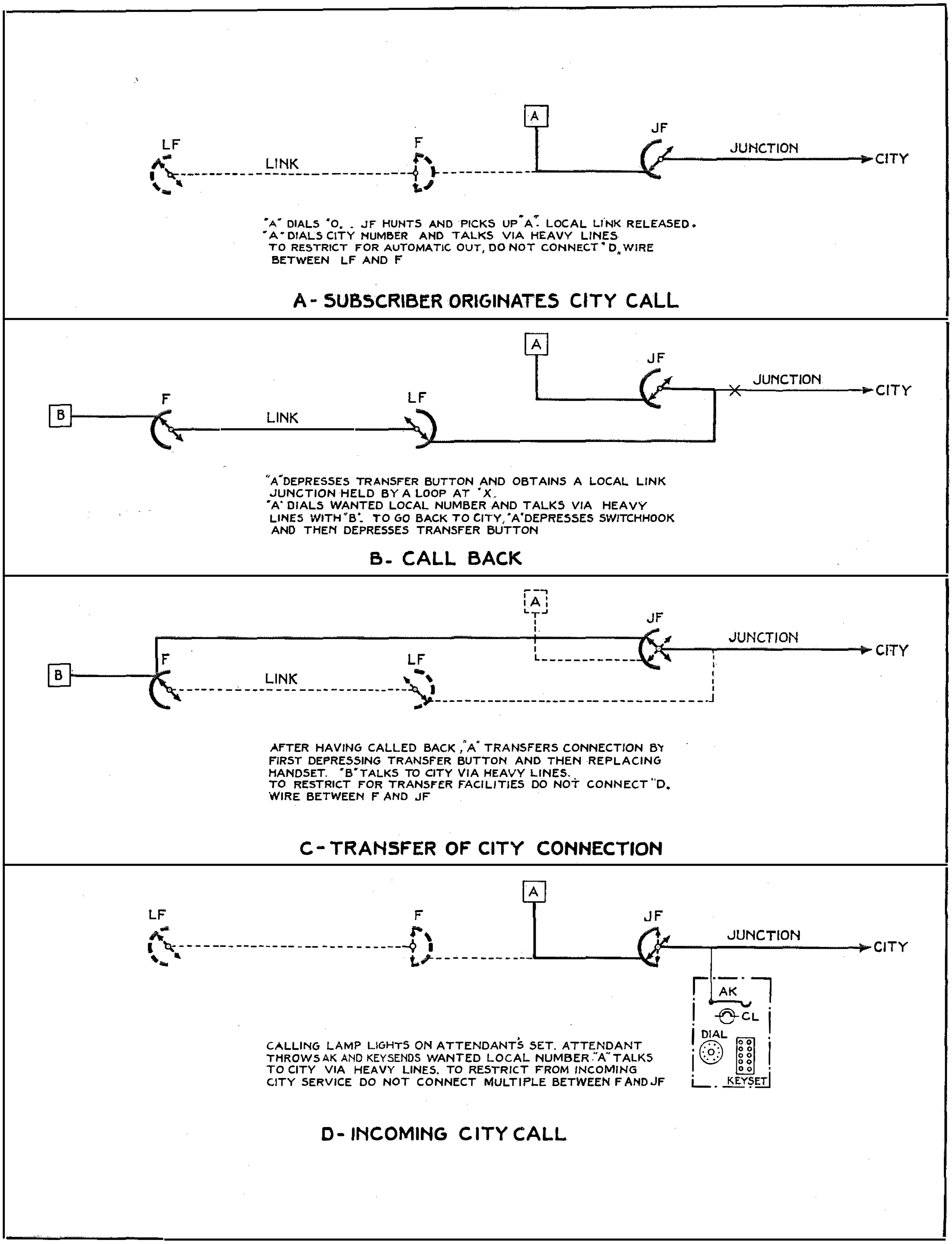


Figure 1—Schematic of City Connections.

fer button after having received local dialing tone.

If the answering party desires to transfer the city call to another local party, he again depresses the transfer button and, after having received local dialing tone, dials the required local party's number. If the latter does not accept the connection, the first party may go back to the trunk by momentarily depressing the switchhook and thereafter depressing the transfer button. This is a regular "call back" operation.

If the second local party accepts the city call, the first party depresses his transfer button and then replaces the handset, after which the city connection is automatically transferred to the second party.

From the above, it is clear that no special attendant or attendant's equipment is required with this particular type of P.A.B.X.

Fig. 4 shows a front view of the 7006-B P.A.B.X. with cover removed, and Fig. 5 shows the all mains supply unit for the 7005 and 7006 types.

Units Employing Single Motion Switches

For reasons of economy, different types and capacities of single motion switches are necessary, for it is evident that a 20-line unit would not be economical if it employed a 50-point or a 100-point switch.

The smallest type of switch has eleven points, and the brush carriage is rotated by means of the conventional pawl and ratchet drive. This type of drive is also used on switches with 30-point and 50-point arcs.

Figure 2—Cordless Attendant's Set.

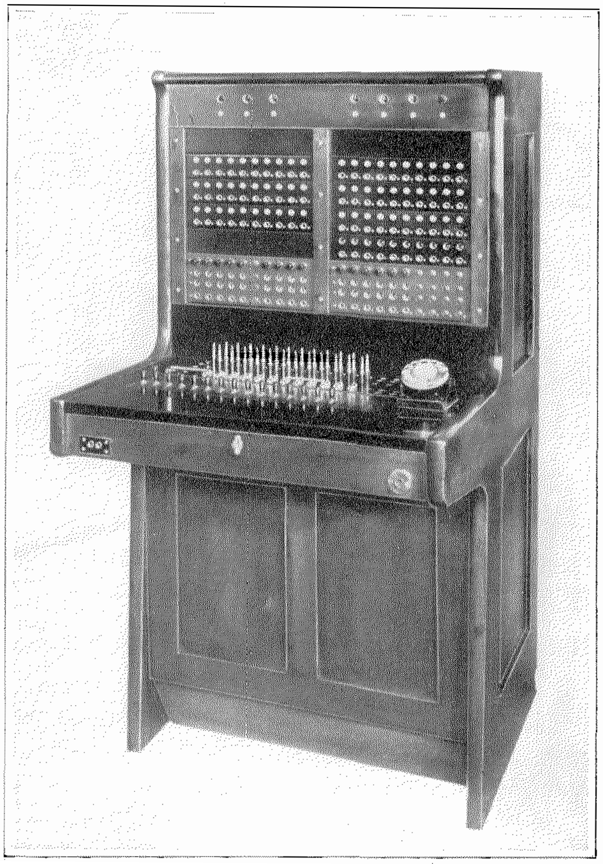


Figure 3—Pedestal Type Manual Attendant's Board.

The 100-point switch is the standard rotary gear driven finder[1].

10-Line Unit with Two Junctions. Type 7011 (Fig. 6).

The 7011 type of P.A.B.X. employs a 12-point switch which gives a capacity of ten local stations and two junctions. To maintain uniform single digit numbering for local calls, a method of operation, similar to that of the 4-line units, has been adopted. An outgoing city connection is originated and an incoming city connection replied to by removing the receiver, awaiting the local dialing tone and then depressing the transfer button. With this method of operation no special attendant is required.

Power is obtained from an all mains supply unit similar to that used with the 4- and 6-line

[1] "The 7-D Rotary Automatic Telephone System," by W. Hatton and J. Kruithof, *Electrical Communication*, April, 1935.

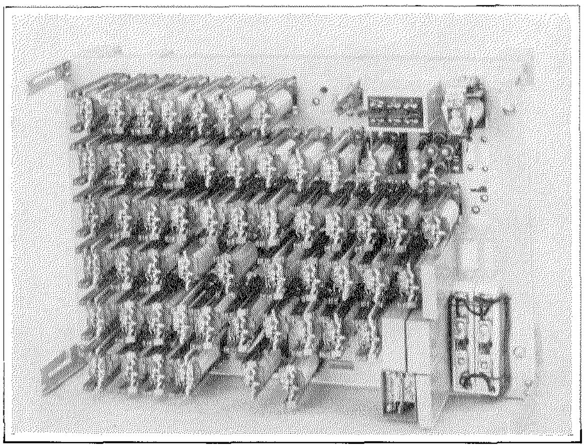


Figure 4—7006-B P.A.B.X.

types. Fig. 6 shows the 7011-A P.A.X. with cover removed.

10-LINE UNIT WITH THREE JUNCTIONS. TYPE 7015 (FIG. 7).

This unit employs a 14-point switch which gives a capacity of ten local stations and three junctions. The method of operation is as follows:

An outgoing city call is originated by dialing "O," after having received the local dialing tone. Access to the outgoing trunks is thereby given and, upon hearing the city dialing tone, the full city number is dialed.

An incoming city call may be received by any local station by dialing "8" after having received local dialing tone.

An incoming or outgoing city call may be transferred to another party in the same manner as described above for the all-relay boards.

A given station may act as an attendant without using the usual attendant's answering equipment. This arrangement requires a modification in the subscriber's line circuit, and allows the station to answer an incoming call by simply removing the handset. Call-back and transfer are performed in the usual way.

The attendant may be provided with two keys mounted in a neat little box outside the telephone set for the purpose of listening-in on, and eventually breaking down, existing local connections.

Power is obtained from an all mains supply unit.

25-LINE UNIT WITH FIVE JUNCTIONS. TYPE 7025 (FIG. 8).

This unit employs a 30-point switch which gives a capacity of twenty-four lines, five junctions, and one attendant's line.

The equipment is mounted on a floor type rack provided with covers both at the front and at the rear, and is therefore dustproof.

The 7025 P.A.B.X. and all the larger units are arranged for "automatic out" and "attended in" city service.

An outgoing city call is originated by dialing "O" after having received local dialing tone.

An incoming city call is received by an attendant who dials the wanted local party and extends the city connection to him.

Transfer of both incoming and outgoing city calls may be performed any number of times.

The attendant's cabinets and the detailed method of handling incoming calls are described hereinafter.

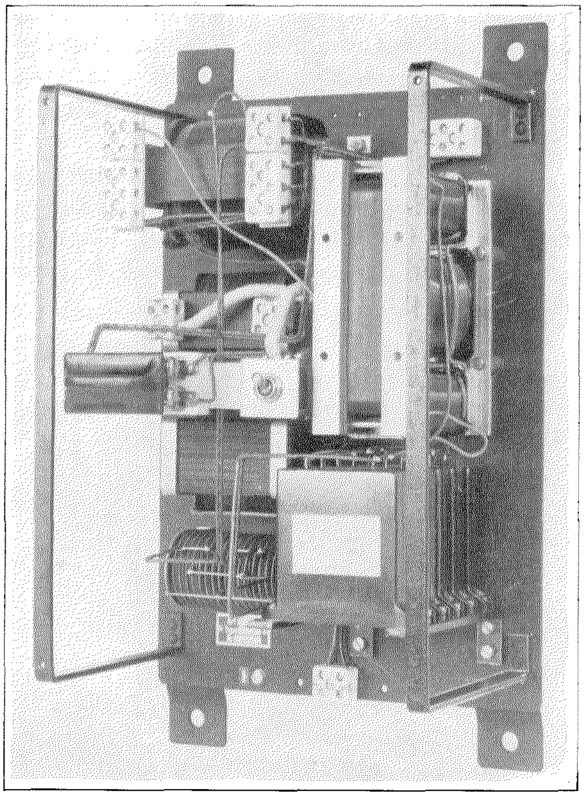


Figure 5—All Mains Supply Unit PLA-1072.

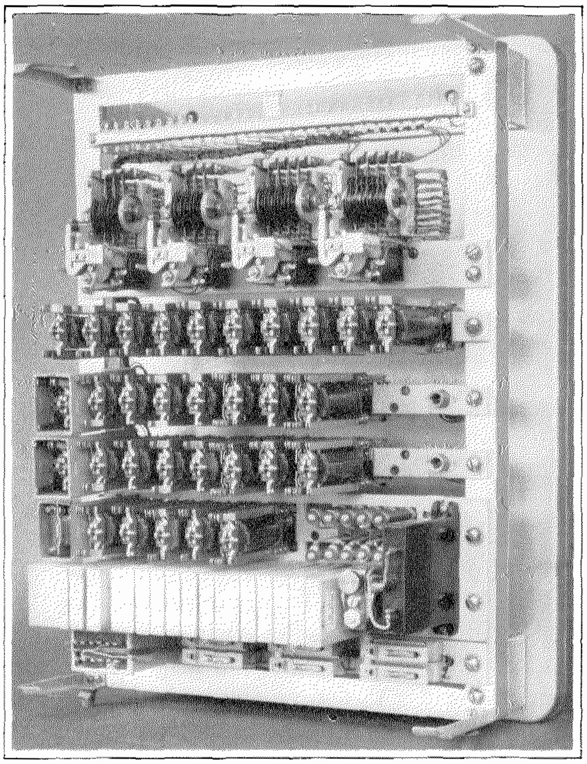


Figure 6—7011-A P.A.B.X.

50- AND 99-LINE UNIT. TYPE 7035 (FIG. 9).

The 7035 P.A.B.X. employs a 50- or 60-point switch. The ultimate capacity of this type is ninety-nine local lines with any number of links and junctions.

The equipment is mounted on one or several floor type racks, which are entirely shielded front and rear. Two different equipment layouts have been designed, known as the "unit" and the "non-unit" type, respectively.

The "unit" type is based on the "circuit unit" principle, i.e., one or several complete circuits are mounted on a small frame, forming a self-contained, completely wired unit. A certain number of such units, depending on the quantity of circuits required, are mounted on a floor pattern rack, and the different units are then interconnected by means of a small tie cable.

Fig. 9 shows a typical "unit" type equipment, comprising fifty lines, six links, and four junctions. The top unit is a combined line and common circuit unit. Then follow three units, each with two link circuits, and finally two junction units, each with two junctions. The illustration also shows one of the shields.

The great advantage of the "unit" type design is that it enables operating telephone companies to keep a number of different kinds of circuit units in stock and to build up equipments themselves according to actual requirements. The unit principle also permits extensions to existing installations to be made rapidly and without disturbing the equipment in service.

The justification for the "non-unit" type is low initial cost. All switches are mounted together in order to simplify the multiple cabling, and the entire circuit cabling is included in one cable form. This reduces the number of terminal strips and soldering points to the minimum. The self-contained type of equipment has the drawback that extensions require more installation and testing work on site.

The outgoing and incoming city traffic is handled in exactly the same manner as for the 7025 P.A.B.X.

Since the arc capacity of the switch used is fifty or sixty points, it is evident that an additional selector is required for capacities above

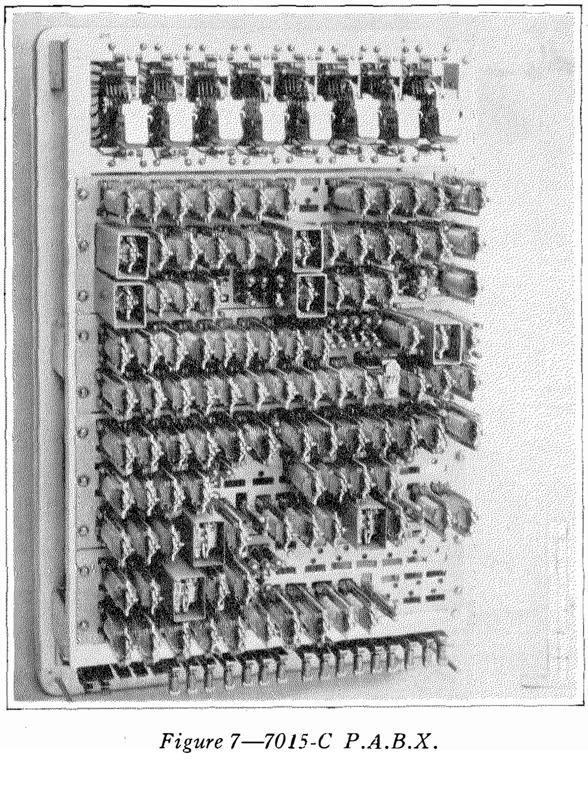


Figure 7—7015-C P.A.B.X.

fifty lines. Such equipments would comprise two groups of links, each giving access to fifty lines, and each having a home selector, and an additional selector.

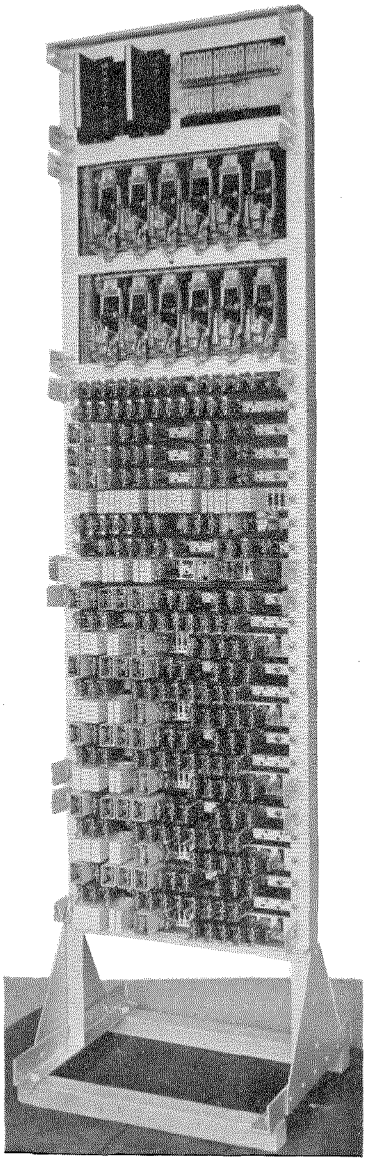


Figure 8—7025-C P.A.B.X.

100- TO 400-LINE UNIT. TYPE 7055 (FIG. 10).

This is a rotary type of unit designed for a maximum capacity of four hundred lines and has been fully described in *Electrical Communication*[2]. Recently, the 7055 equipment has been improved to reduce cost and simplify installation. The equipment is now arranged in units, comprising relay and line finder bays completely wired and tested in the factory. Each unit is entirely shielded.

With this arrangement the local unit, for instance, would comprise the complete equipment for one hundred local stations, namely nine (or twelve) links, three (or four) registers, and the starting, ringing, and tone circuits. For 200-line equipments, the second local unit would comprise a second finder bay with auxiliary switches. Junction circuits and special service circuits would be mounted in separate units.

The units are placed on a floor channel with a 1/30 H.P. switchrack motor, and the whole equipment is braced to the walls or to the roof in the most convenient way.

All finder arc cabling is made in the factory, the multiple cables being given sufficiently long tail ends so that the installer has only to form out and solder the terminal strip side.

The 7055 equipment is designed in two standard heights, arranged to accommodate nine or twelve link circuits per one hundred lines. This corresponds to calling rates of 1.2 and 1.8 E.B.H.C., respectively.

The outgoing and incoming city service is handled in the same manner as explained for the 7035 P.A.B.X., using one or two attendant's sets, as the case may be.

The incoming traffic may also be handled by means of a floor type plug and jack manual board, or by means of key sender equipment as described below.

100- TO 900-LINE AND 100- TO 1800-LINE UNIT. TYPE 7-D.

This type takes its title from the 7-D Rotary System[3] because of the similarity of its fundamental design. Its components are single motion switches and flat relays which form link circuits, finals, control circuits, and registers. Naturally, the design is much simpler than the 7-D Rotary System, features such as time and zone metering being unnecessary for private exchanges.

The capacity is nine hundred lines with three digit numbers, two digit numbers being reserved

[2] "400 Line P.A.B.X.—7055 Type," by M. A. Biske, *Electrical Communication*, January, 1935.

[3] "The 7-D Rotary Automatic Telephone System," by W. Hatton and J. Kruithof, *Electrical Communication*, April, 1935.

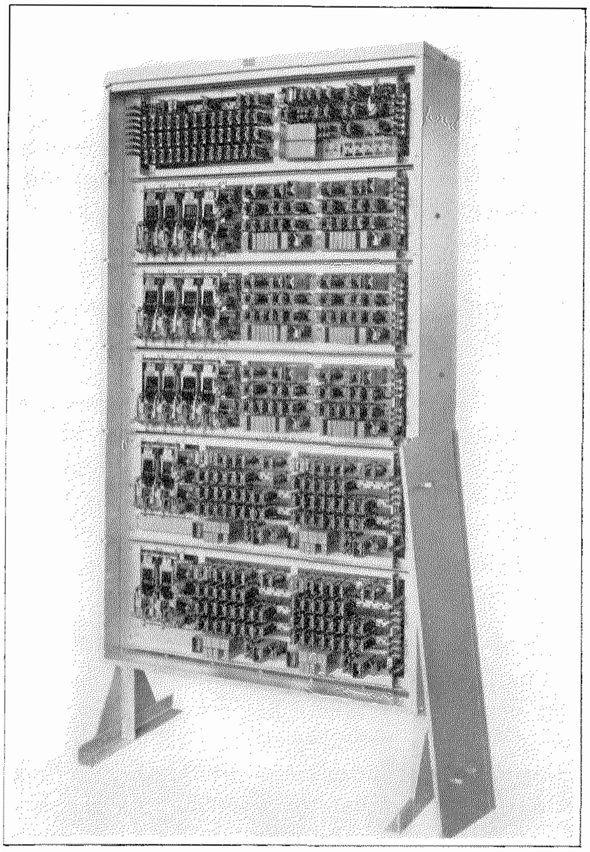


Figure 9—7035 P.A.B.X. Unit Type.

for ten special services. If four digit numbering is used for the local lines, the capacity is eighteen hundred lines.

The link circuits are extremely simple and comprise two gear driven finders and one relay. The final stage is similar to the 7-D Rotary System, the final being a gear driven finder associated with a control circuit. The register is designed to meet the following requirements:

(a) Numbering, three or four digits as required.
(b) City and special services, as required.
(c) Network operation, i.e., the exchange may form part of a net work of private exchanges with open or closed numbering.
(d) Restricted and unrestricted city service.

The equipment of the 7-D P.A.B.X. has been designed with particular regard for easy installation and maintenance. As far as possible, the circuits have been assembled in self-contained units. The local unit for instance, comprises all the apparatus associated with a group of one hundred lines, including line finders, finals, and control circuits. The register circuits, with corresponding link choosers, are also shipped as complete units.

The city traffic may be handled in two different ways:

The first method is illustrated in the junction diagram shown in Fig. 11, from which it will be seen that the whole outgoing city traffic is taken over the regular links. The incoming traffic is handled by one or several operators on a plug and jack type attendant's board. This method is particularly economical with a large number of junctions, due to the very cheap one-relay link circuit.

The second method is based on the use of a high speed key sender equipment. The city junction terminates in a group selector, and the local final selectors serve both for local and for incoming calls.

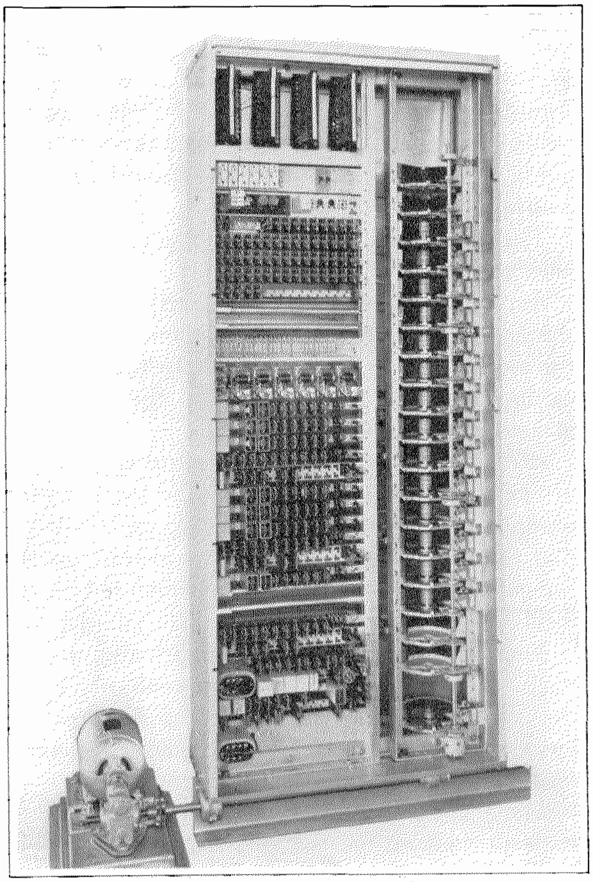


Figure 10—7055 P.A.B.X.

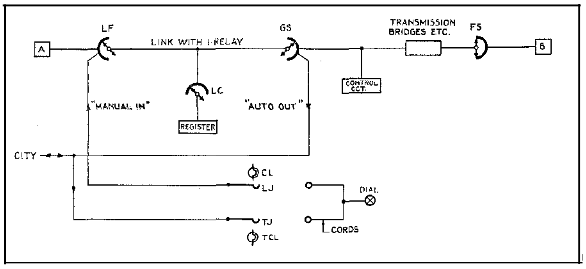


Figure 11—Junction Diagram for 7-D P.A.B.X.

Attendant's Set (Fig. 2).

The attendant's set used in connection with the 7025, 7035, and 7055 P.A.B.X's. comprises a moulded handset and cradle mounted on a small desk turret, arranged to accommodate the necessary keys and lamps for each junction, together with a small number of common keys. The set is made in two sizes, one for five and one for ten junctions.

The apparatus required per junction is mounted as a unit on a key mounting frame provided with a special terminal plug, which fits into a corresponding jack assembly which is fixed to the frame of the set. The key unit is completely wired and can easily be removed for readjustment without disturbing the service.

Fig. 2 shows the cordless attendant's set equipped with three junctions.

The method of handling incoming calls is briefly as follows:

An incoming call is signaled by the lighting of the junction calling lamp. The attendant throws the answering key and removes the handset. The calling lamp is extinguished and the attendant is connected to the city party.

After having ascertained the requirements, the attendant dials the number of the local station without further manipulation of keys. While the dial is being operated, a hold is placed on the junction and the attendant is connected to the local side.

The local party is rung automatically, a ring-back tone being given to the attendant. When the party answers, the attendant restores the answering key, after which the through connection is established.

The attendant may restore the answering key without waiting for the subscriber's reply. The calling lamp then glows dimly until the party answers.

If the local party is busy, the attendant receives busy tone. She may listen-in and offer the city call, and eventually break down an existing local connection, if desired.

If a city call is not accepted, the attendant releases the established connection by depressing a release button, and the call may then be extended to another subscriber.

Each junction is provided with a holding key, which enables the attendant to park an incoming city call which cannot be completed immediately.

The attendant may be called in on any city connection by "calling back" in the usual way and dialing the single digit reserved for the attendant (one or nine). This causes the trunk calling lamp to light, and the attendant may answer and treat the connection as a regulator incoming call.

Attendant's Set with Key Sending (Fig. 12).

The Bell Telephone Manufacturing Company has recently produced a key sending equipment for completing incoming city calls on P.A.B.X's. Whereas the attendant's set previously described makes use of a dial for selecting the required P.A.B.X. station, the new equipment employs a key set comprising a set of ten push button type keys numbered 1, 2, 3, . . . 9, 0.

Two different designs of attendant's sets are available, one desk type set as illustrated in Fig. 12 for a maximum capacity of ten junctions, and one floor type set for larger capacities. A dial

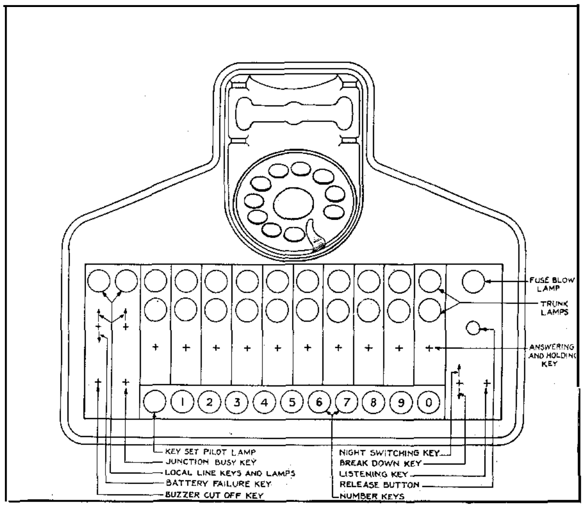


Figure 12—Key Sender Attendant's Set.

is, of course, still required by the operator for setting up calls to the city exchange.

Since key sending is introduced mainly for the purpose of saving the operator's time, the new trunk circuit has been so designed that the number of manipulations is reduced to a strict minimum. Each trunk has a combined answering and holding key and two lamps, one associated with the trunk side (trunk calling lamp), and the other associated with the local side (supervisory lamp).

The method of operation is briefly as follows: An incoming call is signaled by the lighting of the trunk calling lamp. The attendant throws the answering key, extinguishing the calling lamp. After having ascertained the requirements, the attendant depresses the number keys corresponding to the wanted party, one at a time. The answering key is then released, and all subsequent stages of the connection are indicated by the supervisory lamp, which flickers during selection, lights fully while a free party is being rung, or flashes if the party is locally busy. If the P.A.B.X. party is exchange busy, both lamps flash.

This method of supervision does away with the necessity of audible (tone) signals to the attendant, who can determine at a glance the exact condition of every incompleted call.

The keyset, with the common marking relays, is associated with the trunk until the selection is completed. When an answering key is depressed, a keyset pilot lamp is lit, indicating that the common relays are free and that key sending may be started. This avoids false operations in case the selection should be delayed for any reason.

Some interesting new features have been introduced in the key sender equipment, namely, parking on busy calls, splitting of a trunk connection, and continuous hunting over night switching lines.

An important incoming city call, which is extended to a busy P.A.B.X. party, may be left parked until the local station becomes free. In the meantime, one or both trunk lamps flash. When the local station hangs up, it is immediately rung and the supervisory lamp lights fully. This feature is very useful in cases where the attendant has been instructed not to interrupt the conversations of certain executives. Offering and breakdown facilities are, of course, also embodied in the key sender design.

It has often been found desirable to enable the attendant to talk to the city subscriber without being heard by the local party and vice versa. This feature has been incorporated by the provision of a common splitting key.

During the absence of the regular attendant, the incoming traffic may be handled by a group of local stations, the so-called night attendants. A common night switching key is provided for use when the operator leaves duty. The arrangement is such that each trunk may be switched over to a predetermined P.A.B.X. party, or one group of night attendants may be common for all trunks. In the latter case, continuous hunting takes place until a free attendant is found, or until the call is abandoned.

Key sender equipments are furnished only with the 7035, 7055, and 7-D P.A.B.X.'s.

Auxiliary Link Circuits

Since a local link is temporarily engaged when an outgoing city call is originated, it may happen that all local links are occupied while one or several junctions are available. In order to enable a subscriber to obtain a city connection in such cases, a so-called auxiliary link is introduced.

When a call is originated and all local links are engaged, the auxiliary link finds the calling line and gives busy tone, indicating that a local call cannot be obtained. An outgoing city call, however, may be obtained in the usual manner by dialing "O."

An auxiliary link is always furnished with the 7015 and 7025 boards. In the 7011 board a similar arrangement is introduced. For the 7035 P.A.B.X. an auxiliary link is not usually provided because of the greater number of links, but may be supplied, if required.

Night Switching

For unattended P.A.B.X's. the problem of night switching does not arise, since any subscriber may answer and handle incoming calls.

For attended P.A.B.X's., it is necessary to provide means to handle incoming traffic during the absence of the regular attendant. A night switching key is therefore added to each junction on the attendant's set. These keys are thrown when the regular attendant goes off duty.

Two different schemes for night switching have been developed. Under the first scheme, each junction is connected through to a given local party who receives the incoming call and transfers it to the wanted subscriber. Under the second scheme, a group of local stations, maximum number five, is common to all the junctions on an incoming call. The first free station in the group is picked up, and the call may be transferred to the desired party in the usual way.

Manual Attendant's Board (Fig. 3)

It frequently occurs in P.A.B.X. installations of some importance that several types of trunks are connected, for instance trunks to a dial or manual city office, ring-down trunks to distant offices, or manual P.B.X's. and tie lines to other P.A.B.X's. The total trunk traffic may then be too high to be handled by one operator.

It is also common in large installations to provide for several classes of city service, allowing some stations automatic out service, whereas others must obtain a city connection by means of the operator.

In many such cases a floor type attendant's board with one or several positions, equipped with a jack and lamp per subscriber and with a certain number of manual cord circuits, is desirable.

In order to identify the calling station, one or several so-called lamp lighting finders are provided. When a station dials the single digit reserved for the operator, a lamp lighting finder seizes his line and lights the lamp in the multiple. When the operator plugs in, the automatic apparatus is released. It is possible to call in the operator on such manual city connections by flashing one of the supervisory lamps in the cord circuit, and is accomplished by calling back the operator in the usual way.

Figure 13—Supervisory Set.

Special Services

The special services most frequently requested in connection with P.A.B.X. equipments are code calling, conference and preference calling, fire alarm facilities, and tie line service. All these special services have been described in detail in connection with the 7055 P.A.B.X.[4] It may be of interest, however, to make a brief reference to two additional features which have met with considerable success in the field.

Supervisory Sets

It is often necessary in a private telephone installation for an executive or secretary to be able to supervise incoming and outgoing city office traffic. This requirement is sometimes extended to include local communications. To provide for this kind of control, a small supervisory set has been developed, very similar in appearance to the attendant's set previously described. It includes a key and lamp per junction and one common key. If required, a key and lamp per local link can be added.

When the common key is thrown, all engaged junctions and links are indicated by the lamps, and the supervisor can listen-in on any connection by throwing the corresponding listening key. These keys are connected in series so that it is not possible to listen-in on more than one connection at a time. The supervision is secret, but the supervisor may enter the communication by throwing a separate common key.

The supervisory set may be connected as a regular station to the P.A.B.X. and can then receive and originate calls in the usual way. Fig. 13 shows the set for the 7015-C P.A.B.X. with star type signals instead of lamps.

Personal Call Key Sender (Fig. 14)

In most organizations it will be found that an

[4] "400 Line P.A.B.X.—7055 Type," by M. A. Biske, *Electrical Communication,* January, 1935.

Figure 14—Key Set.

executive regularly calls a selected number cf persons; and various devices have been developed and marketed for the purpose of calling a limited number of stations without using the dial. The aim is, of course, to save the time and trouble of consulting the directory and of dialing a three or four digit number.

It is not only quicker but less fatiguing to simply press a button marked with the name of the desired person. A busy executive, maintaining contact with his organization by telephone, may frequently originate twenty or more calls per hour. True, they may all be of short duration but, nevertheless, each call requires the selection of the required department or person. Calling directly by name, combined with the transfer and call back features, gives unprecedented flexibility and rapidity. Call back on incoming and outgoing city connections may be effected by depressing the button belonging to the required station, and on toll calls the time saved thereby is invaluable.

The arrangement comprises a key box and an individual circuit and switch for each station given this service. The key box, Fig. 14, is placed on the desk near the telephone set and is equipped with fourteen non-locking buttons, each designated by name. The individual circuit and switch mount on the P.A.B.X. unit, and the arc of the switch is jumpered to the required stations (Fig. 15).

The circuit is simplicity itself. The key box and telephone are connected over four wires to the switch and its associated relay group. Each key connects ground to one or more of the wires and as a result of the combinations possible, the switch can be positioned to the required line. A release button is included which permits successive connections to be made without restoring the handset, a feature which is particularly useful in conjunction with call back. The individual circuit is arranged to park on busy lines and, if required, breakdown and preference facilities can be included.

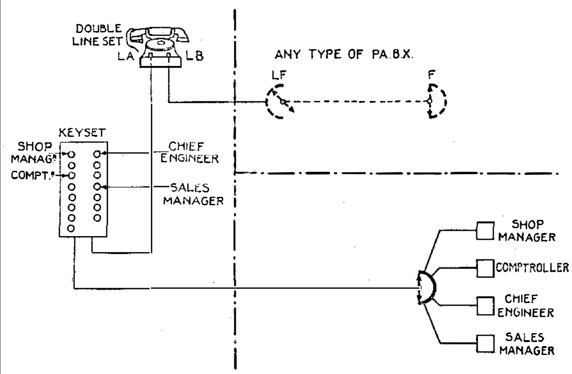


Figure 15—Personal Call Key Sender Schematic.

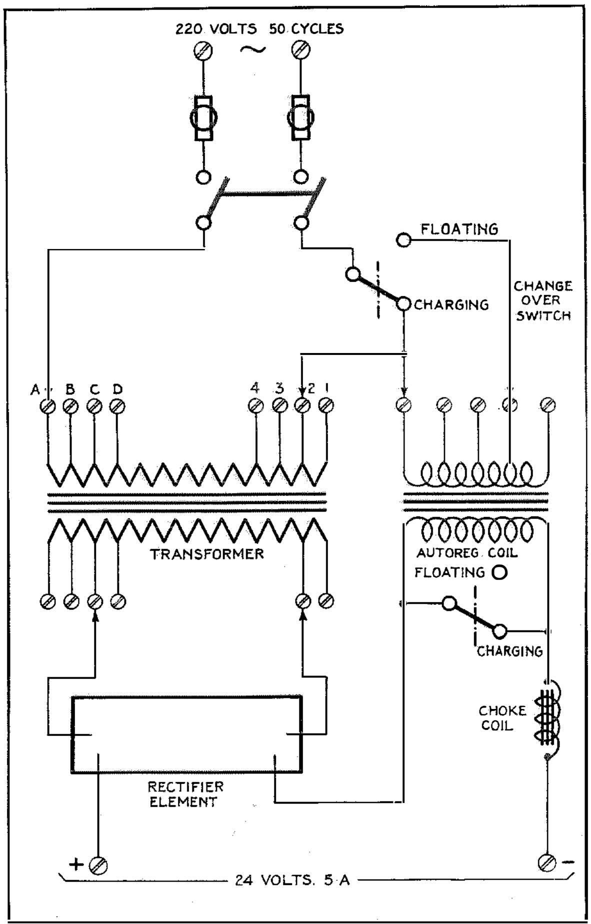


Figure 16—Metal Rectifier Circuit.

This method of reaching particular persons with the minimum of time and effort can be added to any type of private exchange and, moreover, each individual circuit unit can be connected to its own group of selected stations.

Power Plant

Considerable effort has been expended during the last few years on the improvement of power plants for private telephone installations. This is, of course, quite justified, since both initial cost and subsequent maintenance of the equipment depend to a certain extent on the simplicity and, reliability of the power plant.

The tendency in modern design is to eliminate the use of batteries or, when these are indispensable, to operate them under conditions which make regular attendance unnecessary.

In areas with alternating current main supply, it is comparatively easy to achieve this result by the use of metal rectifiers, which now have reached a high grade of perfection.

Rectifiers delivered by the Bell Telephone Manufacturing Company are of the selenium type, which consists of iron discs with a thin layer of selenium, using a special alloy as a second electrode. These discs are made in various sizes and may be connected in series or in parallel, in order to obtain the voltage and amperage required. These rectifiers have a practically unlimited life and do not require any maintenance.

Fig. 16 shows the circuit of a typical selenium rectifier designed for floating a battery. The tappings on the primary of the transformer permit adjustment of the output within certain limits, in accordance with the actual load.

An auto-regulation coil limits the floating current to such a value that the battery voltage during floating will never exceed the permissible limit for satisfactory operation of the P.A.B.X. If for some reason the battery requires complete charging, this coil may be eliminated by means of a switch. Fig. 17 shows the characteristic curves of a 48 volt, 15 ampere rectifier, from which the effect of the auto-regulation coil can be clearly seen.

The choke coil, in connection with the filtering action of the battery, is sufficient to remove all humming or noise from the P.A.B.X. equipment.

As previously mentioned, all mains power units have been developed for use with the smaller P.A.B.X's. The requirements of an all mains unit are, of course, quite severe, since it

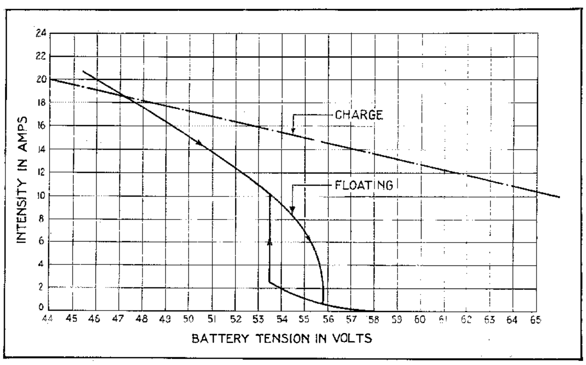


Figure 17—Characteristic Rectifier Curves.

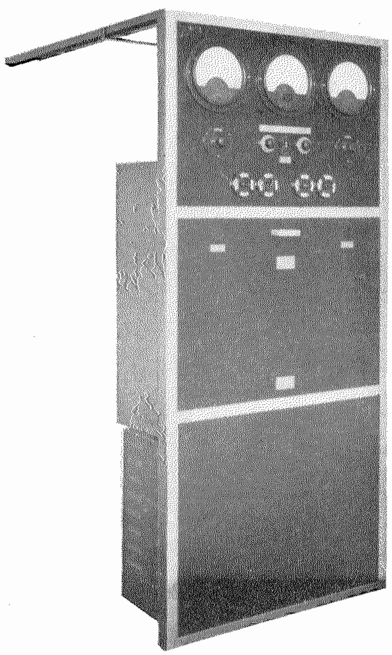
must supply d-c. current between minimum and maximum load while keeping the d-c. voltage within the permissible operating limits without the regulating effect of a battery. The auto-regulation coil of these units is especially designed to give the desired characteristics.

An all mains unit should never be used in connection with a battery. The reason is that the rectifier might have to recharge the battery, for instance after a main supply failure, and carry the P.A.B.X. load at the same time. This increased load might sericusly damage the rectifier elements.

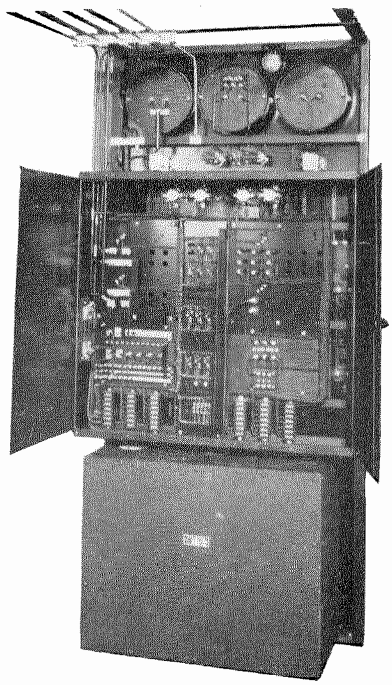
The elimination of noise and cross talk from an all mains unit is, of course, not an easy problem. It has been solved by using two filters, each consisting of a combination of choke coils and condensers, in series. One of these filters is used in the signaling leads, and both filters are used in the talking leads.

Recent Telecommunication Developments of Interest

THE growing trend towards complete automatisation of rural and suburban areas with small unattended exchanges makes essential full automatic battery charging equipment capable of operating for long periods without supervision. The illustrations show a new type of equipment which has been developed by the Bell Telephone Manufacturing Company and which gives automatic full float operation. The equipment comprises a constant potential dry rectifier and a voltage control circuit which maintains the exchange voltage between the limits of 46 volts minimum and 52 volts maximum. The maximum output of the equipment illustrated is 20 amperes. A 24 cell battery of 90 amperehours capacity and 3 C.E.M.F. cells will supply the requirements for an 800 line exchange handling a medium traffic load.



Front View



Rear View

All Metal Flush Type Power Unit

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