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Annales des Postes, Telegraphes et Telephones.

The French Administration of Posts and Telegraphs publishes a technical journal entitled "Annales des Postes, Telegraphes et Telephones."

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THE
Post Office Electrical Engineers' Journal

LOWESTOFT TELEGRAPH REPEATER STATION (L W V).

J. A. S. MARTIN.

LOWESTOFT Telegraph Repeater Station, which is the relaying point for three Dutch and two German cables, is situated within 200 yards of the beach on Lowestoft Ness, the most easterly promontory in the British Isles. Unlike the majority of other such stations, its situation cannot be commended from the scenic point of view, as its surroundings consist of gas works, fish-curing premises, net factories and all the various businesses connected with fishing, the staple industry of the town. One Dutch and two German cables leave the shore at Lowestoft, while the remaining two Dutch cables enter the sea at Benacre, 7 miles south of Lowestoft. One German cable reaches Germany *via* Norderney Island and the other *via* Borkum Island. From these points both cables are connected to Emden, the relaying station on the German side (Vol. VI., Part 4, Page 323 of January, 1914). The three Dutch cables are landed at Zandvoort, a small village on the Dutch coast, and are extended from there to Amsterdam, Rotterdam and the Hague.

Prior to the transfer, in 1889, the Lowestoft-Zandvoort and the Benacre-Zandvoort No. 1 cable were owned by The Electric and International Telegraph Co. This company also leased the Lowestoft-Norderney cable from Reuters. It was worked under a concession from the Prussian Government, which gave Reuters the exclusive right to lay and work cables between Prussia and England.

The Borkum cable and the present instrument room were the property of the German Union Telegraph Co., who worked the cable up to the time of the transfer to the Post Office.

In 1898, the cable hut adjoining the office was enlarged to give facilities for terminating the three cables and to allow of the installation of a battery of Leclanché cells for Wheatstone Bridge tests. The instrument room was enlarged to its present dimensions seven years later. To-day, the accommodation is entirely inadequate for the amount of apparatus contained and it is hoped that in the near future a building more suitable to present day needs will be made available. As the facilities existing to Holland

FIG. 1.—LOWESTOFT REPEATER OFFICE.

at the time of transfer were inadequate for the large and increasing volume of traffic a new cable was laid between Benacre and Zandvoort in 1900. This is known as Benacre 2. No more telegraph cables have since been laid to Holland, as the number of available channels has been considerably increased by the introduction of Double and Triple Duplex Baudot installations.

The three cables leaving Lowestoft are terminated on special terminals in the cable hut and from there are connected to the test board in the instrument room. This arrangement allows of tests being taken and given from the cable ends without loss of insulation. Special cable protectors are not installed as there is no open line between the repeaters and the cable hut. For the purpose of terminating the Benacre cables, a hut was erected on the Denes within a few yards of the beach. Similar terminals to those used in the Lowestoft hut are installed, but as the lines connecting Benacre to the Repeater Station are open wires on poles to within a mile the usual cable protectors are therefore necessary.

Communication between London (TSF) and Lowestoft Repeater Station (LWV) is by underground cable as far as Ipswich. From this point sixteen wires are carried on the L. & N.E. Railway open route to Lowestoft Railway Station, and thence by

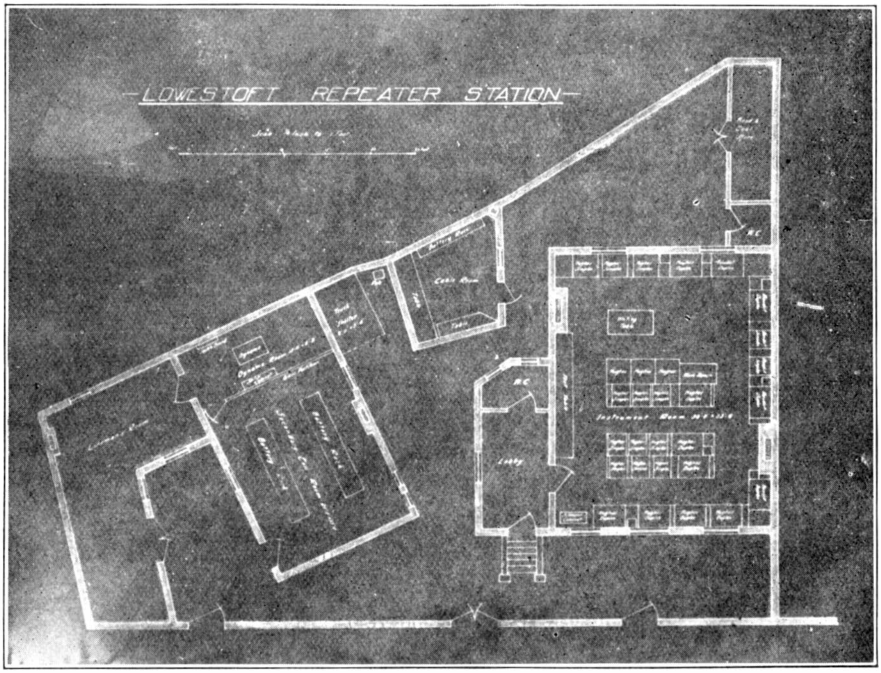

FIG. 2.—PLAN OF STATION.

underground cable to the Repeater Station. The remaining four wires are carried on the Post Office aerial line route *via* Wickham-Market, Saxmundham and Wangford, joining the Lowestoft underground at the same point as the Benacre wires. A start has already been made to complete the underground cable between Ipswich and Lowestoft, so that in the near future all lines between TSF and LWV will be in underground cable. This will considerably add to the efficiency of the service now given, as the present open sections are liable to frequent interruptions owing to the heavy gales that sweep across the flat country of East Anglia.

A schedule of the cable circuits, with the lines and apparatus in use, is given below: —

ANGLO-DUTCH CABLES.

English Land Line.	Cable.	Towns served.	Apparatus used.
		LOWESTOFT—ZANDVOORT. (Laid 1858).	
33	A	London Stock Exchange and Amsterdam Bourse.	Hughes Simplex.
34	B	London—Amsterdam.	Hughes Simplex.
35	C	Western Union Coy., London—Western Union Coy., Amsterdam.	Western Union Co.'s Multiplex (Triple Duplex).
36	D	London—Rotterdam.	Baudot Double Duplex.
		BENACRE—ZANDVOORT 1. (Laid 1884).	
37	E	London—Hague.	Hughes Simplex.
38	F	London—Amsterdam.	Baudot Triple Duplex.
39	G	London—Amsterdam.	Baudot Triple Duplex.
40	H	London—Hague.	Baudot Double Duplex.
		BENACRE—ZANDVOORT 2. (Laid 1900).	
59	J	London—Rotterdam.	Baudot Double Duplex.
60	K	London—Amsterdam.	Hughes Simplex.
61	L	London—Amsterdam.	Hughes Simplex.
62	M	Commercial Cable Co., London—Commercial Co., Rotterdam.	Wheatstone Duplex (Creed printers used).

ANGLO-GERMAN CABLES
(*via Lowestoft* LWV).

English Land Line.	Cable.	Towns served.	Apparatus used.
		LOWESTOFT—NORDERNEY. (Laid 1866).	
41	1	Station put through by Emden according to facilities and requirements.	Hughes Simplex or Duplex.
42	2		Hughes Simplex.
43	3		,, ,,
44	4		,, ,,
		LOWESTOFT—BORKUM. (Laid 1871).	
45	5	Stations put through by Emden according to facilities and requirements.	Hughes Simplex or Duplex.
46	6		Hughes Simplex.
47	7		,, ,,
48	8		,, ,,

With regard to the German cables, it is not possible to give the towns served, as no definite allocation since their restoration after the war has yet been made. Stations are put through each morning by Emden, according to requirements and facilities existing in Germany at the time. Recently the Siemens Automatic Fast Speed Printing Telegraph system has been worked simplex on the Borkum cable with satisfactory results.

A view of the office is given in Fig. 1, and a plan of the whole station is shown in Fig. 2. Fig. 3 gives a view of the interior of the instrument room from the S.E. window. Fig. 4 is a view of the instrument room taken from the N.W. window.

The repeaters are accommodated on tables round the walls of the instrument room and three tables across the centre. The tables round the room carry the repeaters proper to the Dutch circuits, while two of the centre tables are occupied by those proper to the German circuits. The remaining table carries four spare repeaters, one Hughes Duplex and Simplex, and three Hughes Simplex. At the present moment the Duplex and Simplex board

Fig. 3.—Interior of Instrument Room from S.E. Window.

is converted to Double Current, for use as an emergency set for Baudot or other Double Current systems.

For the purpose of observing signals passing on the Hughes circuits, three complete Hughes instruments are provided and furnished with wiring to the Test box for connecting to any Repeater Board.

A Silencer Cabinet of the type invented by Mr. A. Eden gives silencing facilities for 10 Hughes repeaters. Of the remaining repeaters, 14 are fitted with Alarm Repeaters No. 2 and two with the Megohm Resistance type.

Battery power is supplied from Secondary Cells, charged from a motor-driven generator. The current for the motor is obtained from the Corporation supply. Battery distribution is effected by means of two cut-outs, one $\frac{100}{100}$ and the other $\frac{80}{80}$. The larger feeds the repeaters on the Dutch circuits and the smaller the repeaters and Hughes instruments in the centre of the room.

Up to the present time it has not been necessary to introduce Anti-induction Condensers. As, however, all repeaters are equipped with these, it will be a simple matter to bring them into use should circumstances necessitate their re-introduction. The absence of this Anti-induction device renders the repeaters more flexible, as circuits can be changed from one board to another by simply making the necessary crosses at the test box.

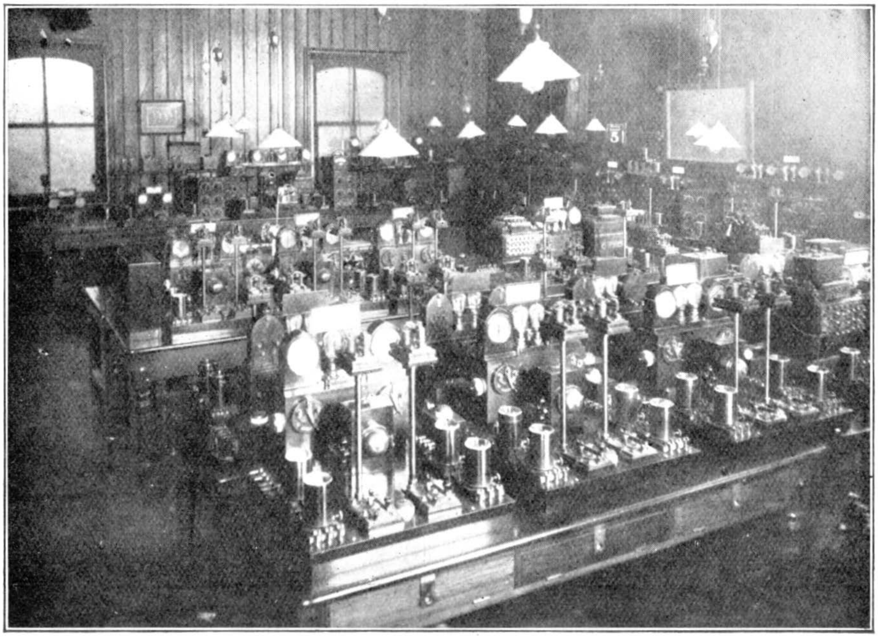

FIG. 4.—INSTRUMENT ROOM FROM N.W. WINDOW.

In conclusion, it may be of interest to add that Lowestoft Repeater Station stood through the war without suffering any damage whatsoever from the many air raids and two bombardments by enemy ships. Considering its situation, this is indeed remarkable, especially as other buildings in the near vicinity were severely damaged. Providence, however, relented of her kindness, as in January, 1916, the sea flooded the Denes and a certain amount of inconvenience and damage was caused by the flooding of the battery room and short-circuiting of the Motor-Generator. The instrument room being built several feet above the ground level escaped damage.

THE ROMANCE AND HISTORY OF THE ELECTRIC TELEGRAPH.

A. H. ROBERTS.

PART III.

HAVING proved that the direction of the magnetic force was tangential to the wire, Ampere and Arago proceeded to increase the deflection of the magnetic needle by twisting the insulated conductor into a spiral coil, and in this manner they obtained a sufficiently strong magnetic field to attract iron filings to the coil and to magnetise a steel bar placed within its hollow centre. All this, and much more on the theoretical side, was done in the short space of a week. Never before nor since has any science progressed with such rapidity in so short a period. Franklin and his co-workers had previously communicated magnetism to small bars of steel by the discharge of a battery of Leyden Jars, and the employment of a similar battery to reverse or destroy the polarity of a magnet was also known.

Following on his experiments with the magnetic needle, the coil of wire and voltaic battery, Ampere, adopting a suggestion made by La Place, proposed the use of this combination for the purpose of telegraphing, but as the system was to include a separate wire for each letter of the alphabet and a current of considerable strength was required to operate the magnetic needles the method cannot be considered a practical solution of the problem. It was not until 1824, when Schweigger introduced his "multiplier" coil, which was an extension of Ampere's spiral, that a sufficiently sensitive instrument was made available. Schweigger wound a large number of turns of insulated wire round a frame enclosing a magnetic needle and, by that device, so greatly increased the delicacy of the instrument that the needle was strongly deflected by a comparatively weak current. This arrangement formed the basis of the galvanometer and from the time of its introduction the electro-magnetic telegraph was rendered possible, but some years elapsed before the principle was successfully applied to that purpose.

Fechner, of Leipsic, is stated, by some authors, to have suggested, in 1822, the use of two wires and a single magnetic needle, which, by deflection to the right or left, could be used to signal the letters of the alphabet in accordance with a prearranged code, but that at the time the method could not be tested as a sufficiently constant battery was not available. If anything more than the bare idea of the possibility of such a plan existed in Fechner's mind, it is remarkable that he did not develop the system. The production of better batteries was occupying the attention of many capable electricians and a successful issue was only a matter of time. In his Handbook of Galvanism, which was published in 1829, Fechner proposed using 24 wires for a telegraph circuit between Leipsic and Dresden.

The next notable advance to the progress of telegraphy was:—

The discovery of the electro-magnet.—Mr. William Sturgeon, of the Royal Military Academy at Woolwich, made the notable discovery, in 1825, that when a bundle of soft iron wires was surrounded by a coil through which a current was flowing the iron became intensely magnetised, and that on stopping the current the magnetic effect also ceased. To bring the poles of the electro-magnet into the same plane, Sturgeon bent the iron into the shape

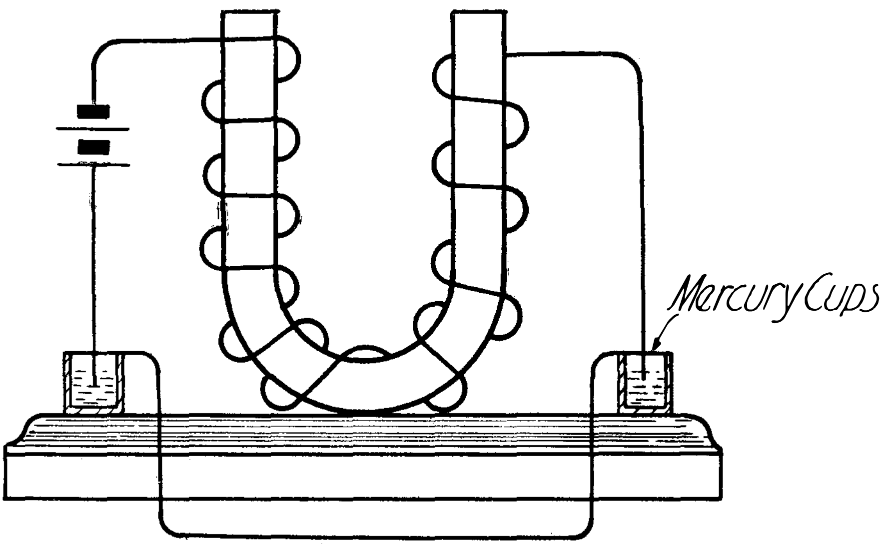

FIG. 7.—STURGEON'S ELECTRO-MAGNET.

of a horseshoe. The iron was varnished to insulate the coils of bare conducting wire which were wound spirally round it. The above illustration shows the arrangement.

This discovery aroused great interest, and although the apparatus used to demonstrate the effect was somewhat crude, it was at once recognised that important developments would soon follow the introduction of such a ready means of producing and releasing magnetic action. Sturgeon was a distinguished worker in the scientific world who did much to stimulate the growth of knowledge, and especially of electricity in this country.

The electro-magnet was perfected in America by a professor of Mathematics at Albany Academy, named Joseph Henry. He applied the principle of Schweigger's multiplier and by insulating the conducting wire with silk was enabled to place the spirals of wire close together and to wind layer on layer in order to increase the magnetic strength at the poles. At first, Henry followed Sturgeon's plan of covering the whole of the iron with windings of the conductor, but when it was found that the central part of the iron did not require to be covered, as the magnetic effect at the poles was not thereby increased and that the current passing through the conductor was unnecessarily weakened by the ineffective turns of wire, the practice was discontinued.

That Henry produced very efficient electro-magnets may be judged from the fact that in 1831 he exhibited a magnet that supported a weight of over a ton.

Professor Henry's researches into the laws of electro-magnetism placed him in the front rank of scientific investigators and his memory is honoured by the unit of inductance being named after him, thus continuing the commendable practice of associating the electrical units with the names of distinguished electricians.

We now reach what may conveniently be termed the second stage of the electric telegraph. So far, the systems referred to were chiefly operated by frictional electricity, but from this time onward voltaic electricity was generally adopted as the actuating medium.

The first electro-magnetic telegraph was known as:—

Schilling's Telegraph.—The apparatus consisted of five horizontal magnetic needles surrounded by coils of wire. The signals were read from combinations of deflections to right and left. For sending purposes, a kind of piano keyboard was used. The call signal was provided by a bell, driven by clockwork, the action being started by the fall of a metal ball which was released when one of the needles was deflected. This instrument was invented in 1830, and it is said that models were inspected by the Emperor Alexander of Russia, in April of that year, and at a later date by the Emperor Nicholas, who witnessed experiments performed through a great length of wire. Shortly afterwards, Schilling left Russia for China, but on his return in 1832 he continued his telegraphic experiments and simplified the instruments.

In some accounts of Schilling's inventions, reference is made to an instrument comprising thirty-six needles, and it is possible that he devised such an instrument at an earlier date. It is known that Schilling was well acquainted with Sömmering's method and he probably followed the plan of using a separate wire for each signal in the earlier stages of his investigations.

In September, 1835, Baron Schilling exhibited at Bonn a single needle instrument on which the signals were read by a code of deflections, to right or left, representing the separate letters of the alphabet. At that meeting, Professor Muncke, of Heidelberg

University, presided, and was so charmed with Schilling's apparatus that he at once decided to obtain a set to illustrate his own lectures. The realisation of this desire was indirectly responsible for the introduction of the first practical telegraph to this country, as will be related in due course. It is to be deplored that Baron Schilling, who was a Russian Counsellor of State, died before he had an opportunity of placing his apparatus in actual service.

For some years after Ronalds was treated with such scant courtesy in official quarters, there is no evidence that the electricians of this country pursued the subject of the development of the electric telegraph with any marked degree of enthusiasm. It

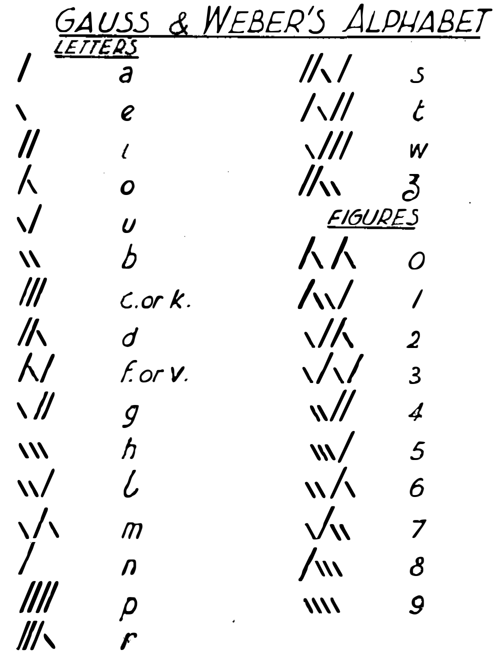

FIG. 8.—GAUSS AND WEBER'S ALPHABET.

is true that Dr. Ritchie, of Edinburgh, exhibited a model to illustrate the working of Ampere's telegraph at the Royal Institution and that Alexander, at a later date, gave demonstrations in London and Edinburgh of a telegraph in which small screens were attached to vertical needles in such a manner as to normally obscure a printed letter of the alphabet. When any needle was deflected under the influence of a current, the letter was exposed to view. As a separate wire was necessary for each symbol, the system was suitable only for laboratory use.

Gauss and Weber's System.—With the discovery made by Faraday, in 1831, that currents may be induced in a closed circuit by the relative movement of a magnet and a coil of wire, another possible means of transmitting signals by electricity was brought to light.

The first application of the method to that purpose is due to Gauss and Weber, who, in 1833, erected a double line of copper wires one and a quarter miles in length between the Physical

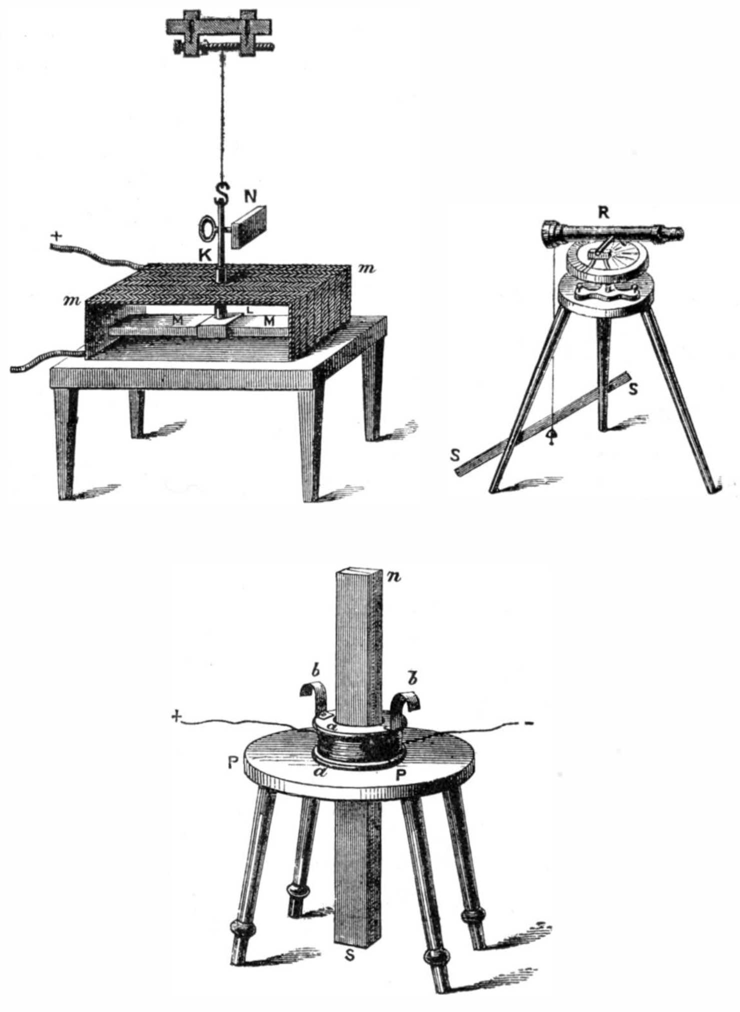

FIG. 9.—GAUSS AND WEBER'S TELEGRAPH.
(From Sabine's "The Electric Telegraph.")

Cabinet and the Observatory at Gottingen. At first they employed voltaic electricity and the line was used for the purpose of research work in connection with the laws of current strength. At a later date the magneto-electric system was adopted for the regulation of clocks and other scientific purposes, but the inventors were also alive to the fact that the apparatus was applicable to ordinary telegraphic transmission and, with the object of proving this, experiments were undertaken and short sentences exchanged over the wires with complete success.

The lines were in use for 11 years and were finally destroyed by lightning in 1844.

Gauss and Weber's telegraph is notable for two important reasons. Firstly, because a commutator was used for reversing the direction of the current—an entirely new idea at that time—and secondly on account of the introduction of a code of signs which permitted a letter of the alphabet or any single numeral to be signalled by four or less right and left deflections of the needle. This ingenious code may be represented as follows:—

It will be seen that the signals for C and K are alike, and also F and V, while J, Q, X and Y are omitted. With a five unit alphabet all the letters could be included and a separate formation given to each.

It will, perhaps, be interesting to explain the working of the apparatus as described in Sabine's "Electric Telegraph."

At the sending station, two or three large permanent magnets, each weighing 25 lbs., were vertically supported with their similar poles, *n*.S., in the same direction, by a stool-like structure. (See Fig. **9**).

Over the end of the upper pole, *n*., a loosely fitting wooden bobbin, which in the ultimate form of the instrument was wound with 7000 turns of insulated copper wire, was formed to slide easily over the poles of the magnets. A pair of handles, *b b*, were fixed to the bobbin on opposite sides to enable it to be lifted with both hands, from its position of rest on the stool, to the top of the projecting magnet. On rapidly raising the bobbin, an induced current was generated in one direction, passing out to line and through the receiving instrument. On lowering the bobbin, a current was generated in the opposite direction. The ends of the bobbin marked + and − were connected to line through the commutator, which was brought into use when more than one deflection in the same direction was required to be given to the receiving magnet. If the raising of the bobbin caused a deflection to the right, and it was necessary for the succeeding deflection to be in the same direction, the commutator was operated between the raising and lowering of the bobbin.

The receiving instrument consisted of large coils of insulated copper wire, *m.m.*, wound on a copper frame, the free ends + and − being connected to the line wires. A steel permanent magnet, M M, 18 inches in length, was suspended inside the coils of wire by a number of silk fibres supported by an attachment fixed to the ceiling of the room.

It will be readily understood that such a ponderous needle would only be deflected through a small angle and its movements would not be easily discerned by the naked eye. To assist the operator, therefore, a mirror N was attached to the suspension K of the magnet and the signals were read from the reflected figure of a horizontal scale S S by means of a telescope R, fixed at a distance of 10 or 12 feet from the mirror.

The copper frame round the needle was introduced to make the instrument dead-beat, the checking action of a metallic bobbin in the vicinity of an oscillating needle having been discovered by Arago and described by Sir William Snow Harris in 1831.

Whatever merits this system may have possessed as an aid to muscular development, it is quite clear that 8 hours' duty on the "key" would be a task not to be lightly undertaken.

Although the receiving apparatus may appear to be extremely cumbersome and crude as compared with the instruments in general use to-day, it is interesting to note the many points of similarity in principle with that very delicate instrument, the mirror galvanometer, which was devised by Lord Kelvin for the purpose of signalling through long submarine cables.

Following up the idea of its evident suitability for telegraphic purposes, but being unable to devote the time necessary to the improvement of the apparatus, Gauss applied to Professor Steinheil, of Munich, for assistance in carrying out the necessary research work to render the system suitable for practical use. Steinheil took up the task with such enthusiasm and made so many improvements that his ultimate production may be almost said to constitute a separate invention, for not only did he increase the rapidity of transmission by using mechanical rotation as a means of generating the induced currents, but he also invented an effective recorder which printed the signals on a moving band of paper kept in motion by the action of a train of clockwork. Messages were sent by this system at a speed of 6.13 words per minute. In another form, by substituting small hammers for the ink tubes of the recorder, an acoustic telegraph was constructed, the two hammers each striking a bell of glass or metal, which were of different tones. This apparatus was working in July, 1837, through a length of 12 miles of wire with an intermediate as well as terminal stations in circuit.

It is worthy of mention that by the arrangement of the commutator springs contact with the line was only permitted when the current was at its maximum strength. The samė principle is to-day adopted in the receiving distributor plate of the Baudot multiplex.

Up to this time, it was assumed that frictional electricity and voltaic (or galvanic) electricity were different in their essential characteristics, and although, as has already been shown, the earth return had been freely used for the transmission of frictional electricity, a complete metallic circuit had invariably been utilised for voltaic electricity, until Steinheil, by experiments conducted on the Nuremburg and Fuerther Railway for the purpose of endeavouring to use the railway lines for telegraphic purposes, discovered that the earth return could also be applied to voltaic and magneto-electric systems, thereby reducing the wire necessary to one half its former length. In proof of this, Steinheil removed the return wires and connected his apparatus to plates of metal buried in the earth without decreasing the efficiency of the working.

So far, we have only been considering those systems which were used for private or semi-public purposes, for the regulation of clocks or for transmitting messages between different departments of the State. None of these installations was available for the conveyance of public telegrams, although Steinheil's telegraph was well adapted to the purpose if used within a limited distance. We now come to the commencement of what may be described as the era of public telegraphs.

In the month of March, 1836, Mr. William Fothergill Cooke, who was formerly a military officer in India and had resigned his commission on account of ill-health, was engaged in the study of anatomy at Heidelburg in connection with his employment as an anatomical modeller. On or about 6th March, 1836, he happened to be attending a lecture by Professor Muncke, who exhibited the effect of electric currents in deflecting a magnetic needle at the end of a length of wire. The apparatus consisted of two galvanometers, each fitted with a single magnetic needle and two batteries, presumably voltaic piles; the two instruments, which were duplicates of Baron Schilling's telegraph, were installed in separate rooms and connected together by copper wires. Only two elementary signals were transmitted; they were represented by a cross and a straight line marked on the opposite sides of a cardboard disc attached to a straw supported by a silk thread which also carried a magnetic needle suspended inside a coil of wire by means of a silk thread, as shown in the diagram.

When the distant battery was connected to the line wires and the free ends were dipped into small mercury cups in which the galvanometer windings terminated, a deflection of the needle resulted and the card was turned exposing either the cross or the line to view according to the direction of the current.

This elementary experiment so strongly impressed Mr. Cooke with its possibilities of extension in connection with the transmission of intelligence by telegraph that he at once entirely abandoned his former pursuits and with keen imagination and indomitable perseverance applied all his energies to the practical realisation of his ideas.

Knowing little or nothing of electrical matters, beyond what has just been described, Cooke imposed upon himself the task of producing a really efficient telegraph system which could be applied to every-day uses. Truly Fortune favours the bold, for the laboratory toy of eminent scientific authorities was transformed by this new-comer into a complete telegraph apparatus in the course of a few days.

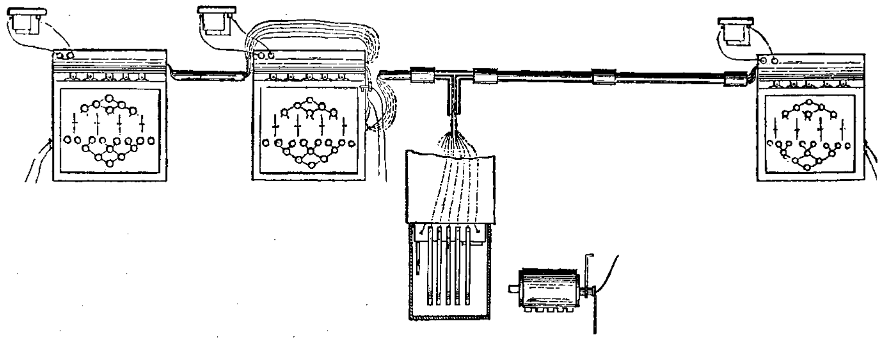

FIG. 10.—COOKE'S INTERMEDIATE AND PORTABLE TELEGRAPHS. (Second Patent, April, 1838).

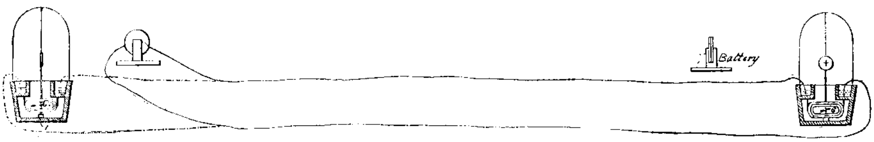

FIG. 11.—COOKE'S SKETCH OF SCHILLING'S NEEDLE EXHIBITED BY PROF. MUNCKE.

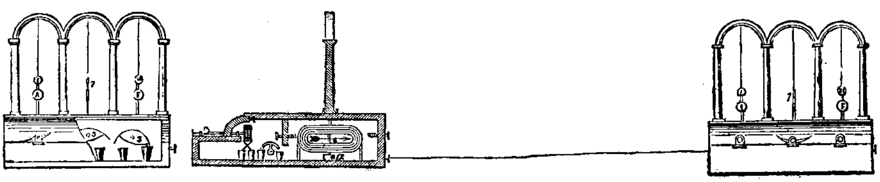

FIG. 12.—COOKE'S FIRST MAGNETIC NEEDLE.

Within three weeks of witnessing Professor Muncke's demonstration, Cooke had completed the construction of his first electric telegraph, which consisted of three magnetised needles worked by six wires. The sending portion of the instrument comprised a series of keys to be depressed in a given order for the formation of the 26 separate signals which could be transmitted, but his greatest triumph was in solving the difficulty of leaving the instrument in a position to receive signals immediately after the sending of a message was completed. By this device the apparatus was capable of being used for sending and receiving without making any alteration in the connections and the operator at the outgoing office could also read the signals he was transmitting to line. In addition to these remarkable advances on previous practice, Cooke had further invented a " Detector " for testing the line and apparatus in the case of faults occurring on the system. Before the end of the month, a clockwork alarm was added to the instrument, which then formed a complete and practical telegraph. The alarm was set in motion by means of an electro-magnet, the armature of which, on being actuated, removed a detent and allowed the clockwork to ring a bell. Not content with the phenomenal speed with which his first ideas had materialised, Cooke also commenced the construction of a mechanical telegraph, in which a dial, revolved by clockwork, was stopped at any part of its revolution, when the selected signal on the dial was exhibited opposite to an aperture in a fixed plate. It will be seen that this is very similar to Ronalds's telegraph, but Cooke adopted voltaic electricity for operating purposes, whereas Ronalds used frictional electricity, which was not so suitable for telegraphic transmission. There is no suggestion that Cooke adopted Ronalds' dial; in fact the evidence points to his having invented it quite independently. The idea of a mechanical telegraph which would require a smaller number of wires for its operation than the three needle system occurred to Cooke on 17th March, 1836. He was travelling from Heidelburg to Frankfort and happened to be reading Mrs. Somerville's work on the Physical Sciences. While doing so, the thought that a simple telegraph on the clockwork dial principle would possess many advantages over the magnetic needle method flashed across his mind. To think was to act and he at once set about the work of devising a new instrument.

Almost the only piece of mechanism with which he was at the time familiar was contained in a musical snuff-box. He immediately used the model of the musical-box barrel as the basis of a telegraph instrument and so well did he succeed that within six weeks of the date of Professor Muncke's lecture, Cooke was on his way to London for the purpose of making a mechanical telegraph from drawings which he had then prepared. So certain was he that the magnetic needle system could not compete with his later invention that he did not trouble to carry his needle instruments and models with him, but left them with other personal property in the care of his relatives at Berne. On reaching London, Cooke worked almost night and day on the construction of his apparatus, which he describes as follows:—

" It will be found that my earliest mechanism closely resembled that of a musical snuff-box. Pressure on keys completed the electric circuit, which magnetised the temporary magnet; which attracted the tail end of the detent, thereby drawing its upper end out of the train of wheels and allowing the mechanism to move by its own maintaining power, till the intervention of an appropriate pin upon the cylinder or barrel struck up the key, broke the circuit, caused the magnetism of the temporary magnet to cease and therefore put an end to the attraction of the tail end of the detent; and thus allowed the reacting spring to replace the detent in its resting position, and by so placing it to stop the mechanism, at the time when the revolving dial was presenting before an opening in the frame of the apparatus at each terminus, the requisite letter, figure or symbol."

During the months of June and July, 1836, Cooke occupied his leisure moments by drawing up a pamphlet or sketch of "Plans for establishing on the most extensive scale, and at trifling expense, a rapid telegraphic communication for political, commercial and private purposes, especially in connection with the extended lines of railroads now in progress between the principal cities of the Kingdom, through the means of electro-magnetism." After alluding to the many advantages of national importance which such a system would possess, the author discusses the method to be adopted to keep the underground line wires in good order.

To form testing points at short intervals, it was proposed to take branches off the main lines opposite to turnpikes on the public roads and at station houses on railways. The testing instrument was the Detector, which consisted of a magnetic compass needle fitted inside a coil of wire. The anticipated causes of faults were a gradual decomposition of the metal after burial for many years and the actual fracture of the conductor. What proved to be the most frequent cause of difficulty, viz., the failure of the insulation, was not mentioned, as it was thought the laying of the wires in separate grooves formed in the surface of strips of baked wood, covered by a thin wood capping and placed in semi-circular earthenware troughs in which the space between the wood and the trough was filled with waterproof cement. would be a satisfactory and durable arrangement for underground work. Needless to say, experience proved the contrary to be the case, for the insulation soon broke down under the ordeal of practical trial.

Towards the end of 1836, when the mechanical dial instrument was nearly completed, the inventor's funds were running low and he was faced with the necessity of either drawing upon the resources of his friends or endeavournig to turn his apparatus to immediate profitable use. He chose the latter course, and in January, 1837, submitted his proposal to the Liverpool and Manchester Railway Company, who required a ready means of signalling through the tunnel between Edge Hill and Lime Street, Liverpool. Cooke's instrument, which was designed to give 60 symbols, was inspected and considered to be too complex for the work as only a few elementary signals were necessary to meet the Company's requirements. In these circumstances it was suggested that the mechanical telegraph should be modified to give fewer signals, and immediately on his return to London Cooke ordered four instruments of more simple design to be constructed. Two of these were ready in the following April, but were not accepted by the Railway Company as they had, in the interval, installed a pneumatic signalling system in the tunnel.

Undeterred by this disappointment, Cooke continued his labours with characteristic vigour. In the course of an experiment which he undertook for the purpose of proving through what length of wire the electro-magnet would act in operating the detent, Cooke was astonished to find that the effect was unreliable even with only one mile of line in use. Recognising his own limitations in the theoretical branch of the subject, Cooke thereupon sought the assistance of Dr. Faraday, with whom he was acquainted, and by following that leader's advice a partial improvement was secured. Dr. Roget was also consulted in the matter and he referred the inventor to Professor Wheatstone as one who had an expert acquaintance with the subject and who also possessed a large quantity of wire at King's College, which, it was suggested, might be suitable for further experiments with the electro-magnet. The first meeting of Messrs. Cooke and Wheatstone took place at the latter's residence in Conduit Street on 27th February, 1837, and the acquaintanceship thus started resulted in a partnership extending over many years, which had an almost immediate and intense effect on the development of telegraphy in this country. Professor Wheatstone had long been engaged in conducting electrical experiments to ascertain the distance to which signals could be conveyed with the ultimate view of applying his knowledge to the purposes of an electric telegraph. He had shown a reproduction of Schilling's telegraph at King's College to illustrate his lectures on the subject as early as 1835 and had invented a "permutating Keyboard." Wheatstone also contributed largely to the general knowledge of the laws of electrical action and especially gained distinction by his brilliant researches into the determination of the velocity of the electric discharge, to accomplish which he introduced the revolving mirror which has since proved of the utmost value in solving many physical problems.

Charles Wheatstone (afterwards Sir Charles), was the son of a music-seller and was himself a musician of no mean order. He came to London at the age of 21 with the intention of setting up as a maker of musical instruments, for which purpose he studied the science of acoustics and in 1823 published a paper entitled

"New experiments in sound."

Curiously enough, Wheatstone attempted to turn to account the discovery that mechanically produced sounds might be transmitted to a considerable distance through solid wires or rods by suggesting the establishment of communication through very long lengths of wire between distant towns, and he refers to his limited experiments in this direction as "telephonic" trials. A memoir on the subject of the "Transmission of sound," by Professor Wheatstone, was published in the Journal of the Royal Institution for 1831. Realising at length that his ideas on the matter were not practicable, he turned his attention to the application of electricity to methods of telegraphing.

In 1834, Wheatstone was appointed Professor of Natural Philosophy at King's College, London, where he at once established a reputation as an investigator of exceptional genius.

Messrs. Wheatstone and Cooke applied for their first patent in May, 1837; this was sealed on 12th June following and a specification of the apparatus was filed on 12th December, 1837. The system was explained to Mr. Robert Stephenson and the Directors of the London and Birmingham Railway Company, who were so impressed with the adaptability of the invention to railway needs, that they decided at once to give all facilities and to bear the expense of practical trials on a small scale. For the purpose of the experiment early in July, 1837, they placed a large building at Euston Square, 165 feet long by 100 feet wide, at the disposal of the inventors. The wires were run round and round the walls to add length to the circuit and then a route was taken to the Stationary Engine House at Camden Town, a distance of about 1¼ miles. The instruments used in this trial were an improved mechanical telegraph and a needle instrument with horizontal needles. The result was so satisfactory that within three months the London Directors recommended the adoption of the telegraph and proposed to lay the wires from London to Birmingham, but opposition on the part of the provincial Directors caused the scheme to be abandoned.

In the following year a line of telegraphs, which was the first system used for commercial purposes, was installed between Paddington and West Drayton, a distance of a little over 13 miles. Five wires were insulated with cotton and indiarubber and drawn through iron pipes, which, on some parts of the route, were buried, and at others were raised above the ground. During wet weather, insulation faults developed and caused so much difficulty that other means of connecting the stations had to be devised. This led to the introduction of overhead lines supported by poles and insulated at the points of suspension, thus following, with little variation, the methods adopted by Dr. Watson in his Shooter's Hill experiment. The Paddington-West-Drayton circuit was subsequently extended to Slough.

It is unnecessary to refer in detail to the many improvements that rapidly succeeded each other during the next few years. Suffice it to say that the multiple needle telegraph was soon rendered obsolete by the introduction of double needle and single needle instruments, which were more efficient and less costly. Instruments of these types were first used on the Blackwall railway in 1839.

Cooke's "dial," or mechanical telegraph, never came into general use, but Wheatstone invented a pointer telegraph, in dial form, examples of which still survive on minor circuits. Before

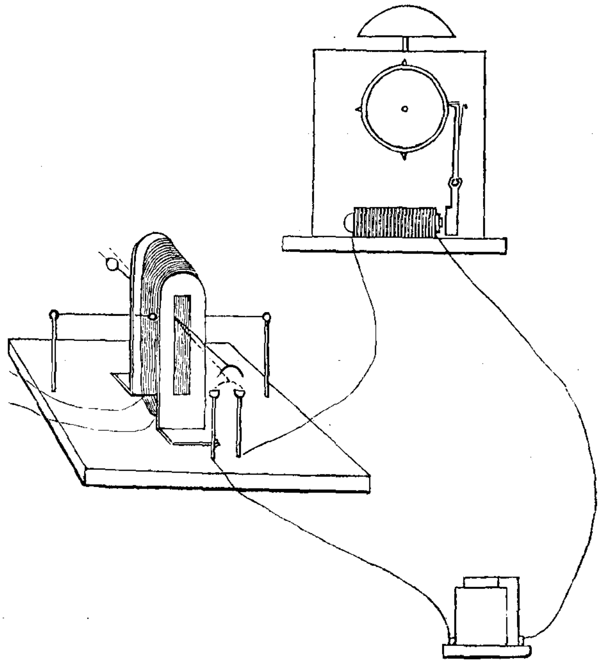

FIG. 13.—WHEATSTONE'S RELAY.

leaving the subject of dial telegraphs, it may be mentioned that the difficulty experienced in working the alarm signal electro-magnets over long distances resulted in the invention of the first relay, the weak line current being caused to deflect a needle, extensions of which dipped into small cups of mercury and closed a local circuit. The arrangement is shown in Fig. **13**.

The drawings which accompany Messrs. Wheatstone and Cooke's first patent prominently show a diamond-shaped dial with five needles. This has, not unnaturally, been assumed to represent the actual apparatus used in the early applications of telegraphy, and authors have reproduced the drawing in that connection, but from Mr. Cooke's own writings it is clear that this "hatchment" dial, as it was called, was never used on any of the working circuits.

In 1850, a law suit was tried at the Guildhall between the Electric Telegraph Co. (who were the purchasers of Messrs. Wheatstone & Cooke's patents), and Messrs. Brett and Little. The defendants in the case made it one of their chief arguments that the "hatchment" dial and permutating keyboard had never been used. This is confirmed by Mr. Cooke's statement that "Wheatstone's 'hatchment' instrument and the permutating keyboard, to be seen at King's College, and only there, never came into practical use."

In April, 1838, just before the Paddington to West Drayton experiment commenced, Messrs. Cooke and Wheatstone patented, in addition to other inventions, another four needle telegraph in which the keys were simplified, and the apparatus made suitable for intermediate station working. A sketch, copied from Mr. Cooke's drawing, is given below.

It is a matter of regret that the two partners, so eminently suited by their varied qualifications, to assist each other in developing their electrical plans, had several unfortunate controversial exchanges during the course of their collaboration. The principal cause of contention was the conflicting claims of the inventors as to the relative importance of the part played by each in introducing the electric telegraph into this country. In 1841, it was decided to refer the questions to the arbitration of Professor Daniell and Sir M. I. Brunel. Their award stated that:

"Whilst Mr. Cooke is entitled to stand alone, as the gentleman to whom this country is indebted for having practically introduced and carried out the Electric Telegraph as a useful undertaking, promising to be a work of national importance; and Professor Wheatstone is acknowledged as the scientific man, whose profound and successful researches have already prepared the public to receive it as a project capable of practical application; it is to the united labours of two gentlemen, so well qualified for mutual assistance, that we must attribute the rapid progress which this important invention has made during the five years since they have been associated."

The first joint patent, No. 7390, dated 12th June, 1837, comprised:—

(1) A five needle telegraph, using 5 wires (or 6 if each needle is to be separately deflected).

(2) A four needle telegraph, using 5 wires (the fifth being a common return).

(3) Methods of insulating wires.

(4) Sounding alarms in distant places.

(5) ,, ,, ,, ,, ,, by the aid of an additional voltaic battery. (Relay).

(6) Fault detector.

The April, 1838, patent No. 7614 covered—

(1) The addition of intermediate stations with facilities for transmitting and receiving telegraphic sgnals.

(2) Portable telegraph instruments for temporary connection to line wires.

(3) Protecting wires by drawing into tubes or pipes, and other less important matters.

In September, 1842, a patent was granted to Mr. Cooke for methods of suspending and insulating wires on posts of wood or wood and iron. The insulators consisted of glass tubes, glazed pottery ware or split goose quills fastened to the wire with white lead and twine.

The specification also included a proposed method of communication between any carriage in a railway train and the engine driver.

Other patents relating to dial telegraphs and auxiliary apparatus of various types were from time to time secured by the inventors.

The national importance of the work performed by Messrs. Cooke and Wheatstone was fittingly recognised by the Society of Arts, who presented an albert gold medal to each of the inventors in 1867.

The Morse System.—To keep in view the development of telegraphs in other countries we must go back to the year 1832 when Dr. Jackson, of Boston, and Mr. Morse, a New York artist, were returning to America as passengers on board the packet ship Sully. Jackson had been attending lectures on electricity at the Sorbonne in Paris and was taking home an electro-magnet and two small batteries, which, however, were stowed away with the baggage and could not be used during the voyage. In the course of conversation among the passengers, Jackson mentioned some of the wonders of electrical action and described methods by which it might ultimately be possible to convey intelligence to a considerable distance. Morse became interested in the subject and conceived the idea of employing an electro-magnet, which, by the use of a suitable code of signs to represent letters and other symbols, would enable a movable armature, controlled by the current to record the transmitted signals on a strip of paper. There was nothing new in the suggestion, for in 1830 Booth, of Dublin, proposed a means of telegraphing by causing marks to be made by the fall of the armature of an electro-magnet. Jackson does not appear to have been acquainted with the many systems of telegraphs that had been invented prior to that time, consequently the information he supplied to Morse was absorbed by the latter as being applicable to entirely new purposes. The many proposals for using voltaic electricity for the transmission of signals were all limited in their application by the want of a battery which would remain constant for more than a few hours under working conditions. This fundamental requirement was well known to electricians, and it was generally recognised that until a more constant source of energy was discovered there was no prospect of establishing a successful system of voltaic telegraphs for business purposes. Morse was not an electrician, and he had little or no knowledge of the subject beyond what was communicated to him by Jackson, but on his arrival in America he occupied his leisure hours, in the intervals of his duties as an artist, in the construction of the various parts of his projected telegraph. The first model was roughly fashioned out of a canvas stretcher, such as is used by artists, and the works of a clock which served to pass a strip of paper underneath the pen or pencil, which, under the influence of an electro-magnet, was contrived to produce the signals of the code adopted. An illustration of the instrument is shown in Fig. **14**. Morse was at first of the opinion that the signals could not be formed with sufficient regularity by hand. He therefore devised a series of types which were set up in a narrow frame M. and carried along by a hand-operated roller L.L., which caused a transmitting key to close the battery circuit as each projection of the type came into position.

It will be observed, on reference to Fig. **14**, that the types consisted of two series, the upper row representing the numerals 1 to 5 with a small type used for spacing, and the second row representing numerals 6 to 0. The types had from one to five projecting cogs on the upper surface, the figure selected being governed by the length of the space between one group of signals and the next. The longer spaces separated complete groups of figures. When the circuit was closed, an electro-magnet armature attached to the swinging pendulum, which carried the recording pencil, was attracted and marked V-shaped signals on the moving paper tape, as shown in the lower part of the illustration. To translate the message, which had been coded in figures for transmission, a special dictionary was used, in which each word was indicated by a separate number.

Morse completed this working model of his recording instrument in 1835, but did not progress very rapidly with its development, as two years later, in October, 1837, when he made out a caveat he described it as a " rude apparatus " and stated that the invention was not sufficiently advanced to enable him to apply for a patent. It may be explained that under the American patent laws, an inventor, by disclosing the distinguishing features of his invention could claim protection of his right and be given time to mature the same. In the caveat, Morse claimed protection for one year for a "method of recording permanently electrical signs, which, by means of metallic wires or other good conductors of electricity, convey intelligence between two or more places."

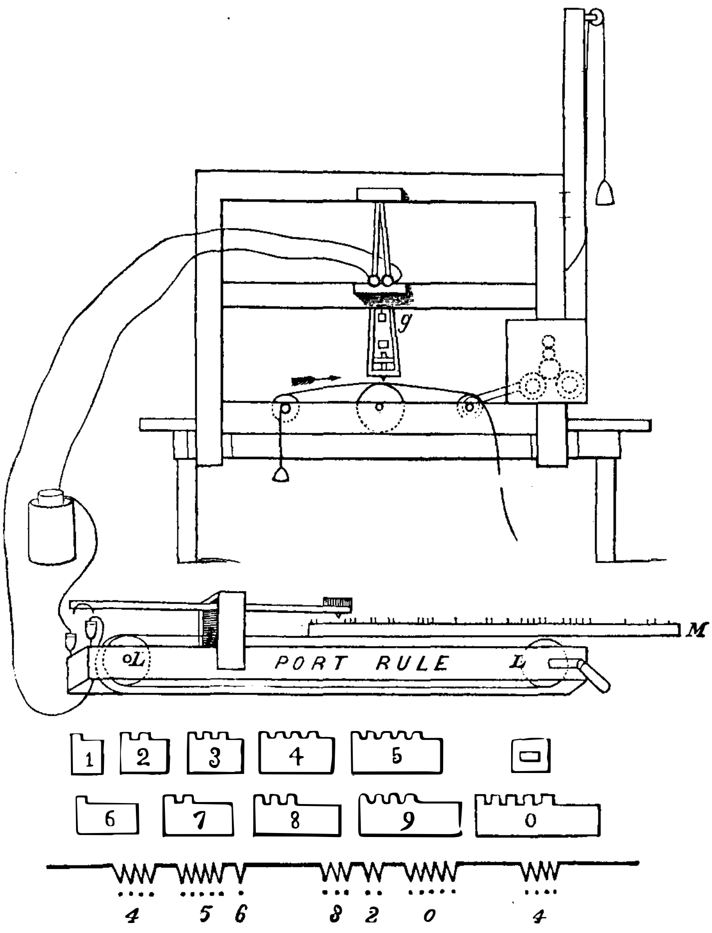

FIG. 14.—MORSE'S FIRST ELECTRIC TELEGRAPH.
(From Turnbull's Treatise on the Electro-Magnetic Telegraph).

There is no reference to any system of strengthening the current by the employment of a local battery introduced by the action of a relay or other apparatus, although certain writers state that Morse invented a form of relay in 1836, *i.e.*, prior to Cooke and Wheatstone's arrangement. If such were the case, it is inconceivable that no reference to such an important and valuable instrument should appear in the original application for protection, but it is doubtful if anything more material than the bare idea existed.

Even if such a claim had been made, Messrs. Cooke and Wheatstone, by the filing of their patent in June, 1837, would still be entitled to the credit of being first in the field with the published description of a working apparatus. Professor Henry, of Washington, stated that he saw Cooke and Wheatstone's instrument in actual use at King's College, London, early in April, 1837. Henry was especially interested in the apparatus, as he had himself devised a method on a different plan for achieving a somewhat similar result in connection with the ringing of church bells from a distance. It will therefore be seen that the idea of using a relay was not confined to one or two brilliant minds but was generally

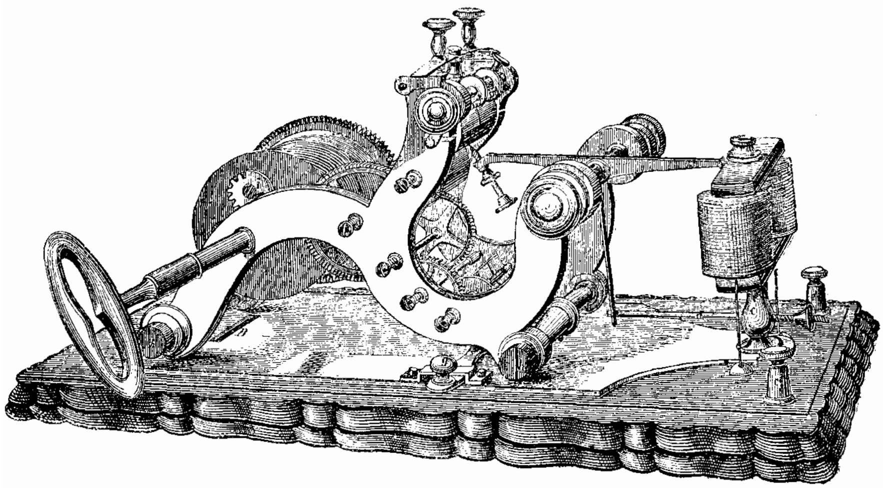

FIG. 15.—MORSE'S EMBOSSING TELEGRAPH.

known to be an essential to long distance electrical working, and the title to be regarded as the originators of the earliest practical method in respect to telegraphic use rests with the British inventors. Morse's American patent for the relay and local circuit was not granted till 1846.

By the autumn of 1837, Morse's telegraph instrument was sufficiently improved to admit of its being exhibited at the Cabinet of the New York University, where it was operated through 1,700 feet of wire, the first word transmitted being "Eureka." The American telegraph was not brought into practical use until June, 1844, when, after surmounting numerous difficulties, a circuit was successfully worked between Baltimore and Washington, a distance of 40 miles, Congress having meanwhile appropriated a sum of $30,000 for the purpose of testing the telegraph. The opening sentence on that occasion was "What hath God wrought?"

Morse's first patent was taken out on 20th June, 1840, the invention was called the "American Electro-Magnetic Telegraph." On 15th January, 1846, the patent was surrendered on account of alleged defects in the specification and a new patent was also surrendered on similar grounds.

In his later apparatus, Morse ceased to use the type-setting method and introduced a hand-worked key, by the manipulation of which the dots and dashes of a code were transmitted to line; the pencil in the receiving instrument also gave place to a style which embossed the signals on the paper strip. When the apparatus came into general use, it was not long before the telegraphists found that they could read all the signals from the clicking of the armature and it became the practice to receive messages by sound and to ignore the recording apparatus. At first this method of reception did not commend itself to the supervising officers, but when it was found that the business was conducted equally well by sound reading as by transcription from the paper tape the system was developed and instruments were manufactured without the recording portion.

It is said that Morse's earlier relays weighed 158 lbs. each and required two men to carry them. The reason for using such huge electro-magnets arose from the assumption that as fine wire windings caused the current in the circuit to be weakened this effect would be avoided if the wire used for winding the bobbins was made of equal cross-section to that of the line wire. These large relays were only used for a few weeks and were then replaced by smaller instruments wound on the plan introduced by Professor Henry.

Reviewing Morse's work in the development of telegraphy, it may be said that although he made no original discovery in electricity or magnetism, he was endowed with all the qualities of a successful inventor, including imagination, foresight, constructive ability, enthusiasm, perseverance and business acumen. In addition, Morse was fortunate in receiving much valuable assistance from such eminent scientific experts as Professors Gale and Henry, and also from his partner, Mr. Vail.

There has been much controversy as to the position occupied by Professor Morse in connection with the introduction of electric telegraphs. Some writers boldly assert that Morse was the one and only inventor of the first electric telegraph. This opinion is epitomised in the doggerel lines which appeared in an American paper at a time when the subject had become a national topic:—

"That steed called 'Lightning' (say the Fates),
Is owned in the United States.
'Twas Franklin's hand that caught the horse;
'Twas harnessed by Professor Morse!"

Against this may be quoted the generous statement of Dr. Turnbull, of Philadelphia, who, writing in 1853, said:—

"A strong instance of the popular delusion in this country (America), on the subject of the invention of the electric telegraph, is to be found in the abstract of the seventh census in Mr. Kennedy's report on Railroads and Telegraphs in the United States (p. 107):—

"It is to American ingenuity that we owe the practical application of the magnetic telegraph for the purpose of communication between distant points, and it has been perfected and improved mainly by American science and skill. While the honour is due to Prof. Morse for the practical application and successful prosecution of the telegraph, it is mainly owing to the researches and discoveries of Prof. Henry and other scientific Americans, that he was enabled to perfect so valuable an invention."

One hundred thousand copies of this report were published by order of the House of Representatives.

Commenting on the extract quoted above, Dr. Turnbull justly adds:—

"Now it has never even been pretended that American ingenuity has supplied anything towards the practical application of the needle or pointing telegraph, which is one of the various forms of the "magnetic telegraph," and confessedly the earliest of them all."

"The electric telegraph has been a long time in advancing to its present state. It is not the invention of one man or any set of men, nor of one nation, but of many nations, each adding their mite to the noble structure. Its history is based upon two of the most interesting of the physical sciences, those of electricity and magnetism. Had not these sciences been fully investigated, and thousands of labourers spent centuries upon them, we should never have seen an electric telegraph. Had not such men as Oersted, Ampère, Arago, Faraday and our own Franklin, spent their days in experimenting and nights in studying we should never have reaped the rich reward of their labours."

(*To be continued*).

DUNDEE AND BROUGHTY FERRY AUTOMATIC EXCHANGES.

By W. IRELAND, A.M.I.E.E., and F. A. ELLSON, B.Sc.,
Engineer-in-Chief's Office.

Introductory.—A new automatic telephone system, based on that of the North Electric Coy., of Galion, Ohio, U.S.A., has been developed by the General Electric Coy. for use in this country. The Post Office decided to give the system a trial at Dundee and Broughty Ferry, and some notes on it may be of interest. Of the requirements and facilities recently introduced as standard for automatic exchanges, only those which are incidental to the special features of this system are given..

The automatic switches with the associated relays were manufactured in America, but the Frames, Racks, Manual Switchboard and Desks, with their equipment and much of the auxiliary apparatus, have been manufactured by the General Electric Co. at their Peel-Conner Telephone Works at Coventry. It is expected that the exchanges will be brought into use early this year. They replace equipments of the flat board type, working on the call-wire and call-key ring-through systems, which have long been obsolete.

Multi-Exchange Area.—It will be seen from the numbering scheme for the area given below, that Dundee and Broughty Ferry contain the bulk of the lines in the area.

	Nos.	Present dialling code
Dundee	2000—6499	—
Broughty Ferry... ...	7000—7799	—
Wormit	8100—8199	81
Downfield	8200—8299	82
Invergowrie	8300—8399	83

	Nos.	Present dialling code.
Newport	8400—8599	85
Tayport	8600—8699	86
Tealing	8700—8799	87
(New Exchange about to be opened).		

Nos. for special services:—

Phonograms	90
Enquiry	91
Rural Party Lines (not used initially)...	93
Test Clerk	99
Trunks and Junction records	0

The present equipments and ultimate capacities for subscribers' lines of the two exchanges are as follows:— ...

Dundee	3340 (present)	4230 (ultimate).
Broughty Ferry ...	550 (present)	730 (ultimate).

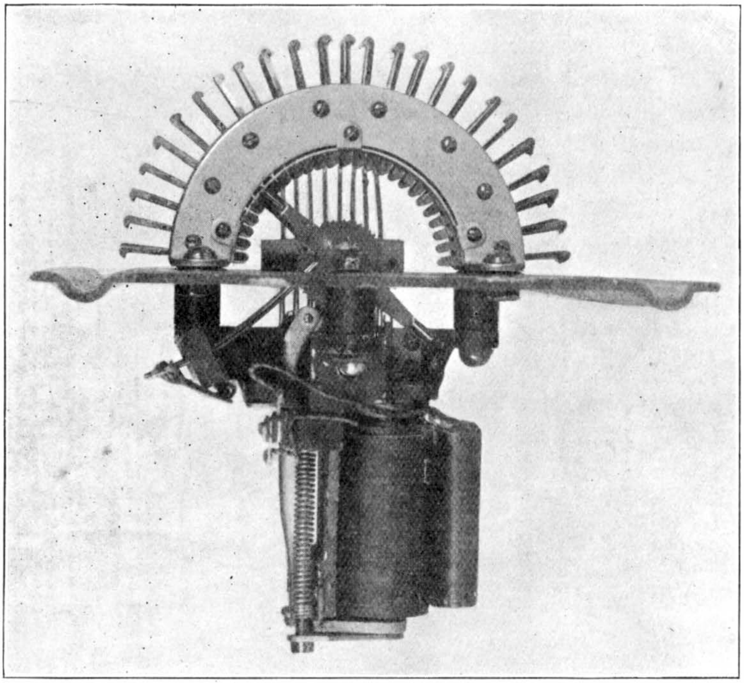

Fig. 1.—Pre-selector.

The manual board at Dundee serves also Broughty Ferry and will ultimately serve the whole area when all the sub-exchanges are converted. Full automatic working will obtain initially between Dundee and Broughty Ferry, but the other exchanges in the area will remain manually operated for the present. The latter will dial into and be dialled out from both automatic exchanges, the dialling-out codes being as shown above.

With the exception of a few of the longer lines, which will be

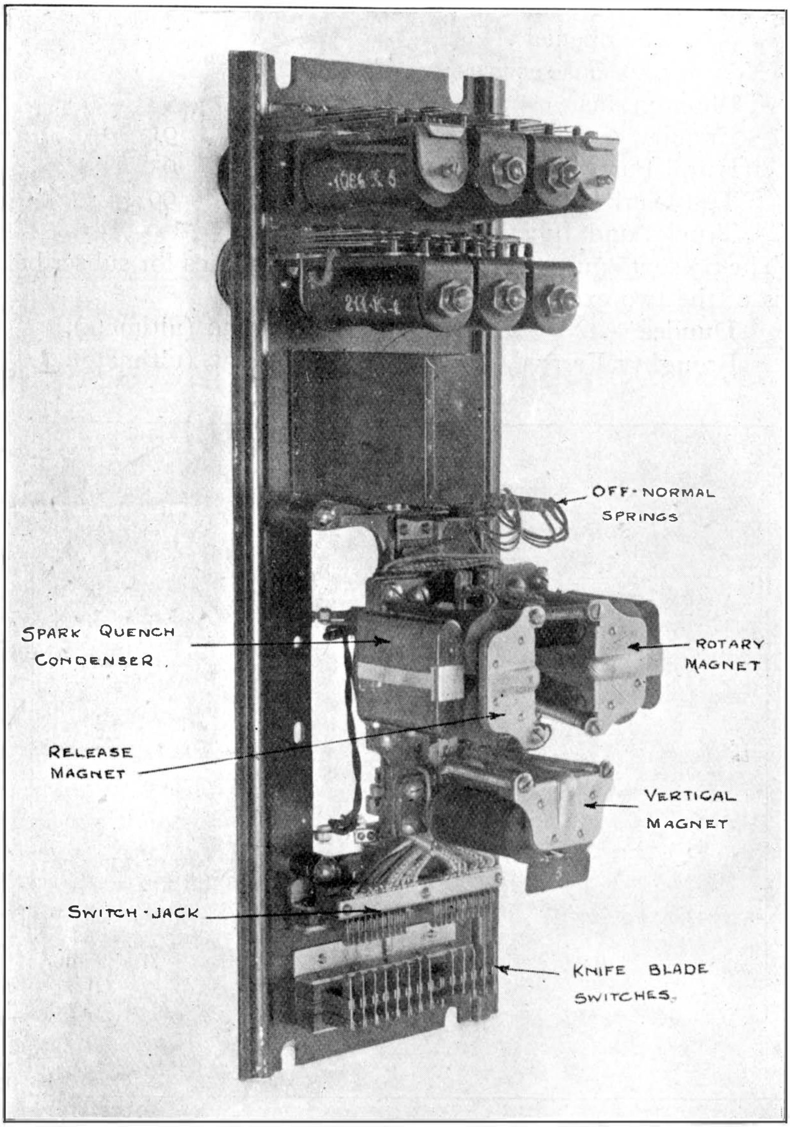

FIG. 2 (a).—2ND SELECTOR (FRONT VIEW).

worked manually and terminated on trunk signalling positions, all exchanges outside the local area will dial into and be worked outgoing manually.

Broughty Ferry will be an unattended exchange, the testing being carried out from the Test Desk at Dundee in accordance with the intention to have centralised testing for the whole of the local area ultimately.

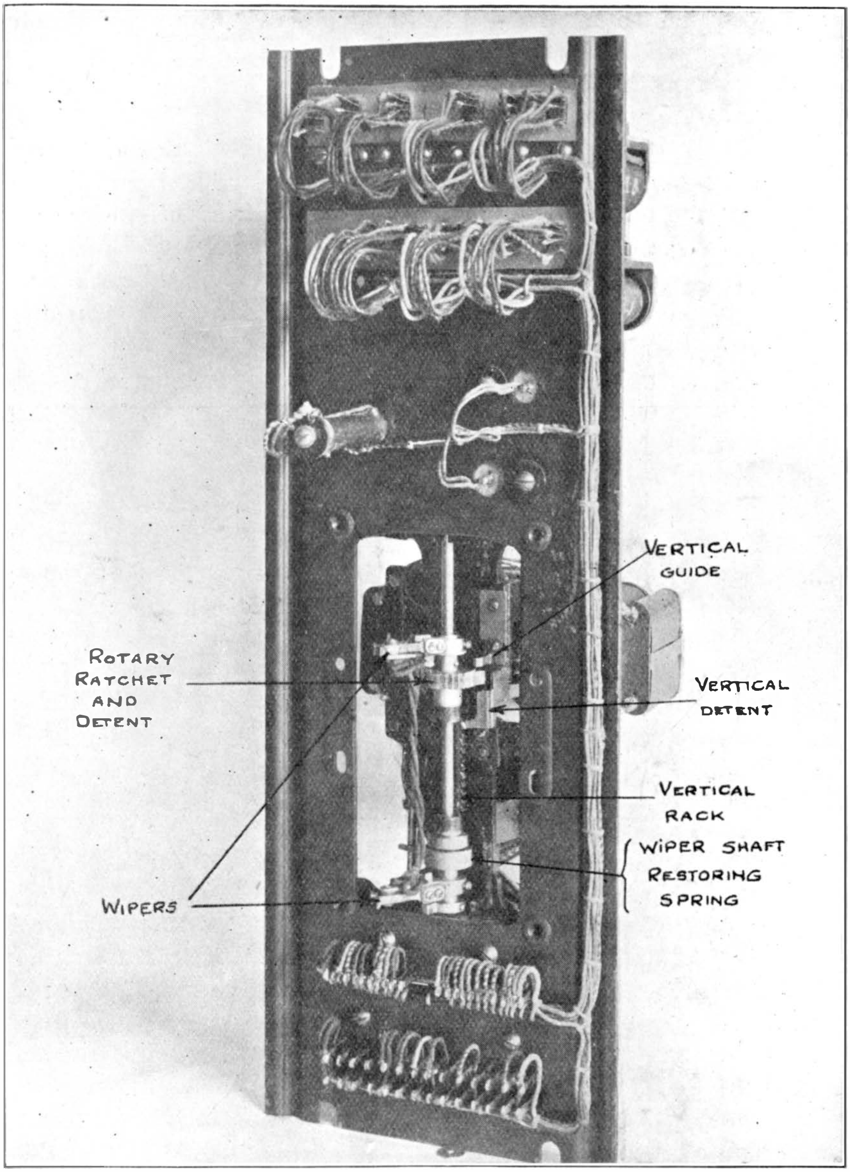

FIG. 2 (*b*).—2ND SELECTOR (REAR VIEW).

FEATURES OF SWITCHES.

The system works on the step-by-step principle. A 25-point pre-selector is employed, having 25 outlets direct to 1st selectors without grading. A view of this switch is shown in Fig. 1. The bank is of semi-circular shape, so that only two sets of wipers are required to ensure continuous contact with the bank.

The wipers are moved over the contacts at a rate of 55 steps per second by a self-interrupting drive magnet, the armature of which operates a ratchet on the wiper shaft. After release of the connection, the wipers remain on the contacts of the trunk used and do not return to a normal position.

One of the chief features of the selector-switch is that the bank contacts are placed vertically, the movement of the wipers being first horizontal and then vertical. It is claimed that this arrangement is effective in preventing faults due to accumulation of dust. The vertical, rotary and release magnets are easily removable and interchangeable. Coiled springs are used in place of flat springs for all armatures.

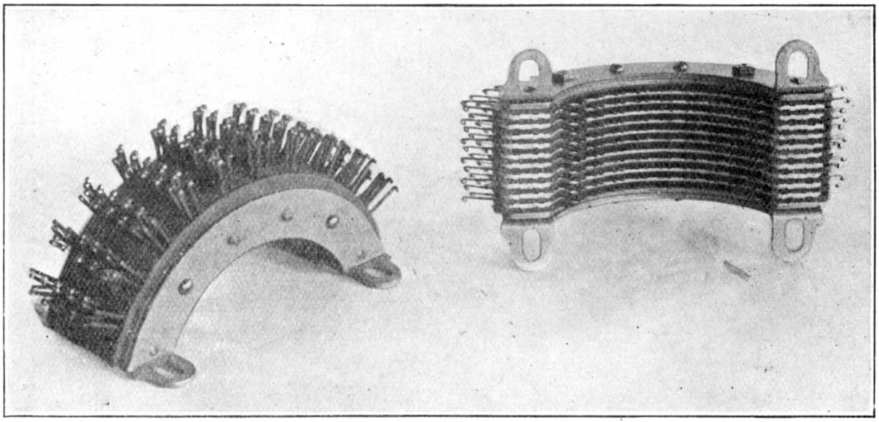

FIG. 2 (c).—2ND SELECTOR BANK.

The dog, or detent, engaging with the rotary ratchet becomes disengaged as soon as the vertical motion commences, but another detent (designated "vertical guide" in Fig. 2) holds the wiper shaft until the wipers enter the bank. After this the wiper shaft is held by the pressure of the wipers on the bank against the force of the coiled spring (at the bottom of the shaft), which, on release, returns the wipers to normal. The switching mechanisms are identical for all classes of selector, and are readily removable by means of jacks from the plate, without interfering with the wiring of the associated relays. Pre-selector mechanisms are similarly removable, and the magnets are similar to those fitted on selector switches.

Small knife-blade switches, fitted at the bottom of the switch plate, are provided to enable the circuit of the switch to be opened at various points to facilitate testing. Selectors hunt at the rate of 40 steps per second.

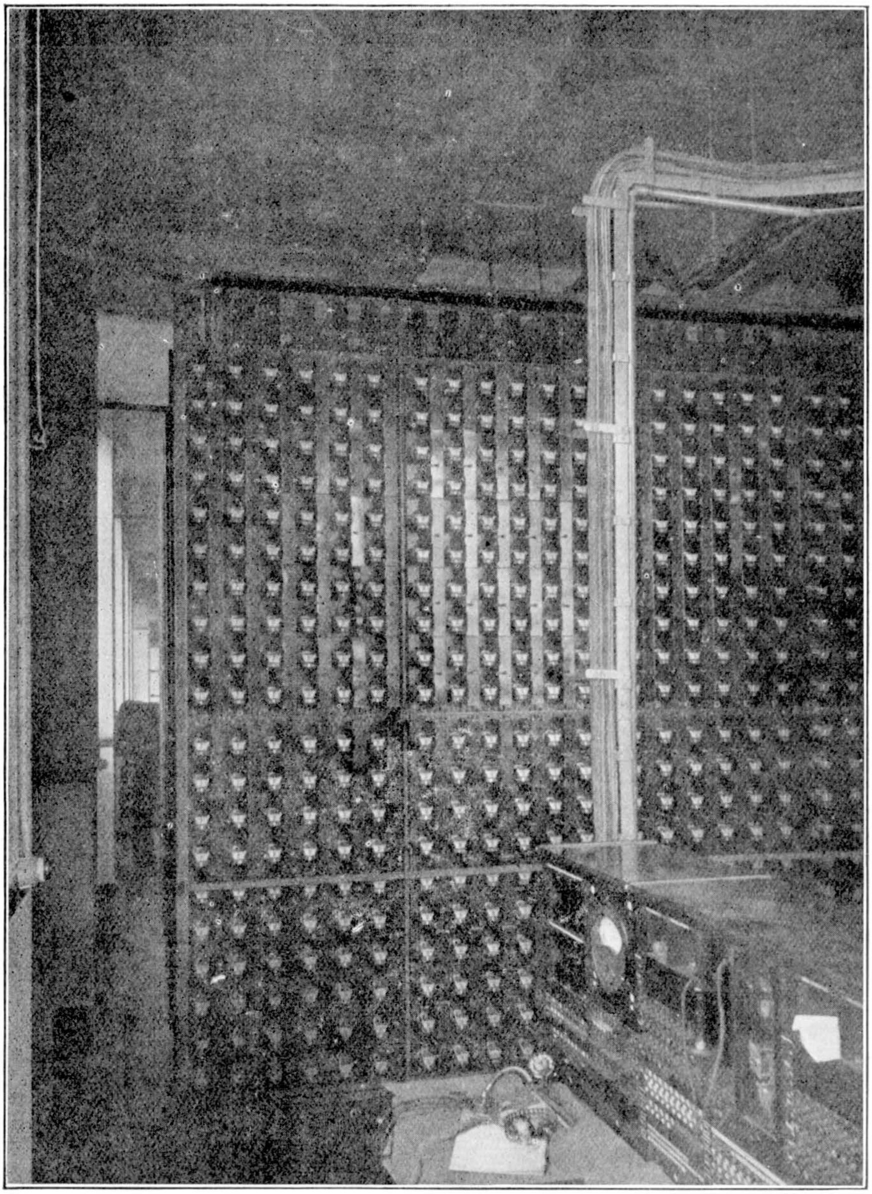

FIG. 3 (*a*).—PRE-SELECTOR RACK (FRONT VIEW).

Fig. 2 shows front and rear view of a 2nd Selector Switch with bank removed.

FRAMES AND RACKS. M.D.F. AND I.D.F.

The Main Frame is similar in construction and equipment to that fitted at a manual exchange. The exchange side of this

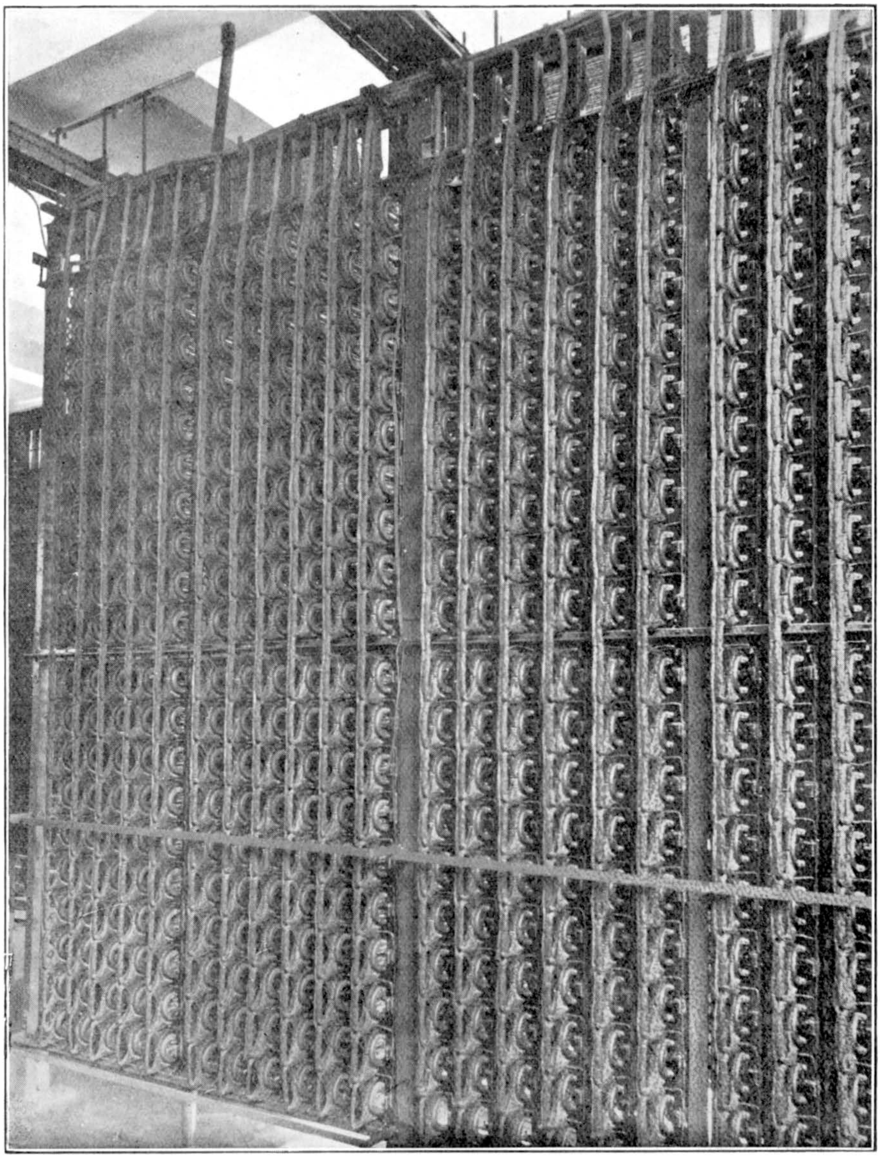

FIG. 3 (*b*).—PRE-SELECTOR RACK (REAR VIEW).

frame, however, is equipped in accordance with standard practice at automatic exchanges, with Protectors, H.C. and Test, which give facilities for testing without the necessity of removing the heat coils.

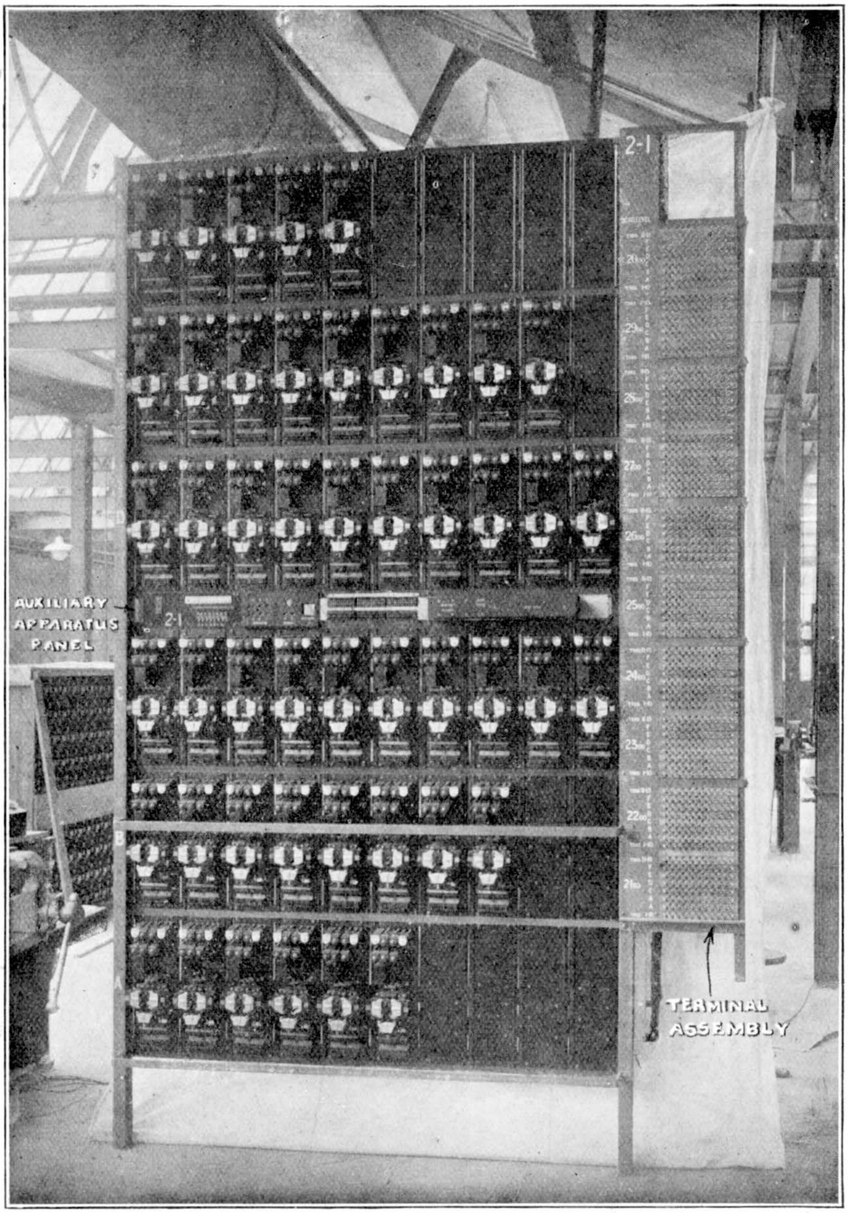

FIG. 4.—2ND SELECTOR RACK.

A full Intermediate Distributing Frame is provided to which the subscribers' lines, as well as the junction and miscellaneous lines, are cabled. The subscribers' lines are cabled from the multiple side of this frame to the protector side of the main frame and also to the final selector banks. The terminals on the answering side are cabled to the pre-selector switch terminals direct and the two sides of the frame cross-connected in the usual way.

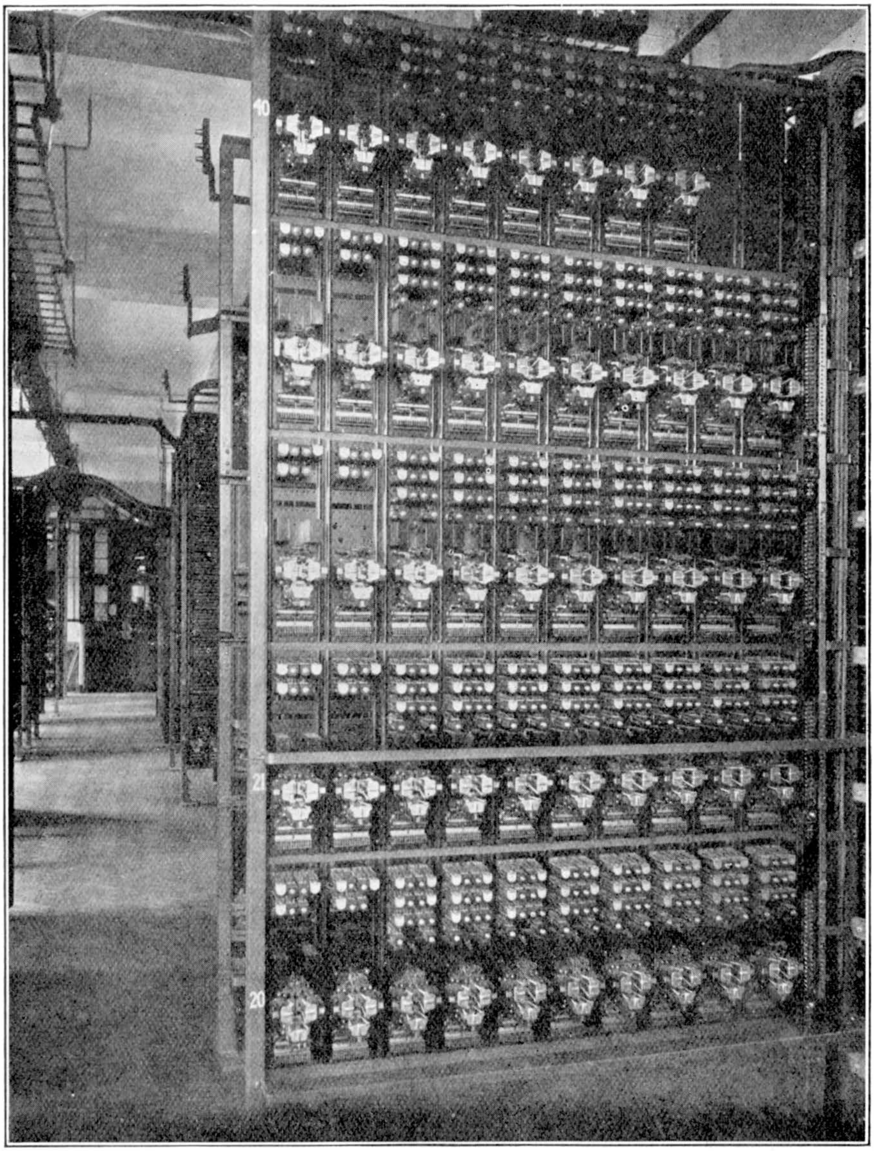

FIG. 5.—GENERAL VIEW SHOWING FINAL SELECTOR RACK (RELAY COVERS REMOVED).

Pre-selector and Selector Racks.—The pre-selectors are mounted in vertical panels of 20 on racks having a capacity of 6 panels per bay (see Fig. 3). The bank wiring for each panel is connected to a terminal strip at the top of the rack. By strapping together these terminals the number of pre-selectors having outlets to each group of twenty-five 1st Selectors may be grouped in accordance with the originating traffic and altered as required to meet variations. At Dundee the pre-selectors are arranged in groups of 240.

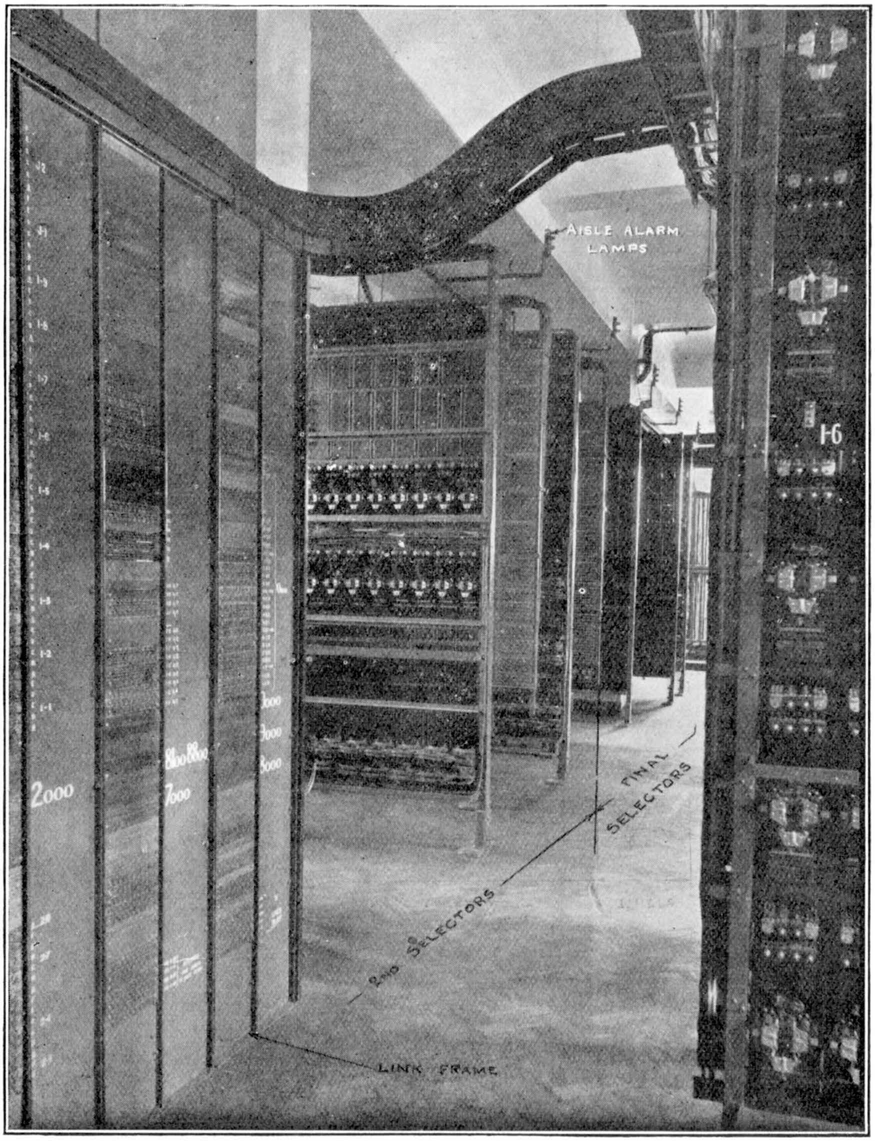

FIG. 6.—GENERAL VIEW SHOWING LINK FRAME AND SELECTOR RACKS.

1st Selectors are mounted in bays, each bay accommodating 5 shelves of 10. Fuses, alarm lamps and other auxiliary equipment are fitted on a shelf about the middle of the rack.

The cabling to the wiper side of the switches is taken direct to terminals on the switch plates, and the bank wiring is connected to terminal strips of the I.D.F. type fitted at the side of the

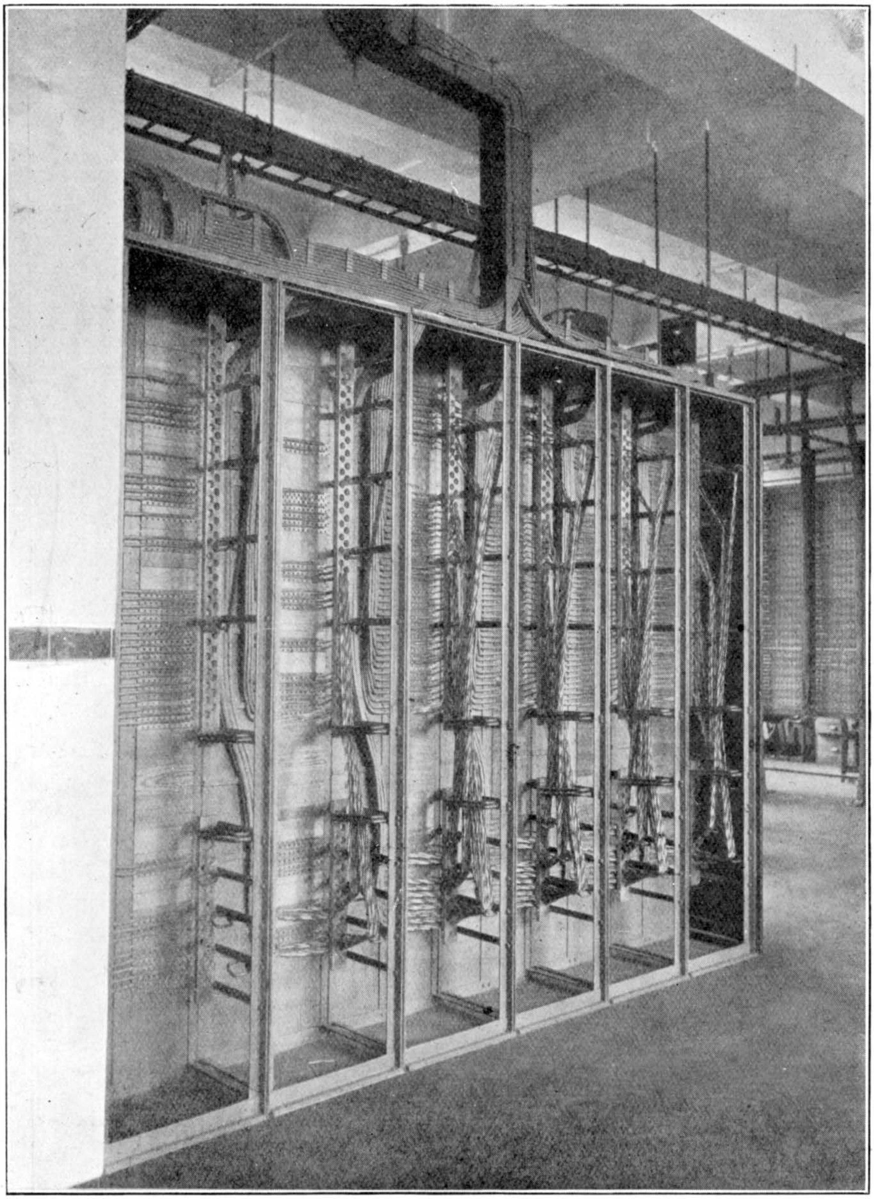

FIG. 7.—LINK FRAME (REAR VIEW).

rack, the terminals being grouped according to levels and not to shelves.

DUNDEE AND BROUGHTY FERRY AUTOMATIC EXCHANGE.

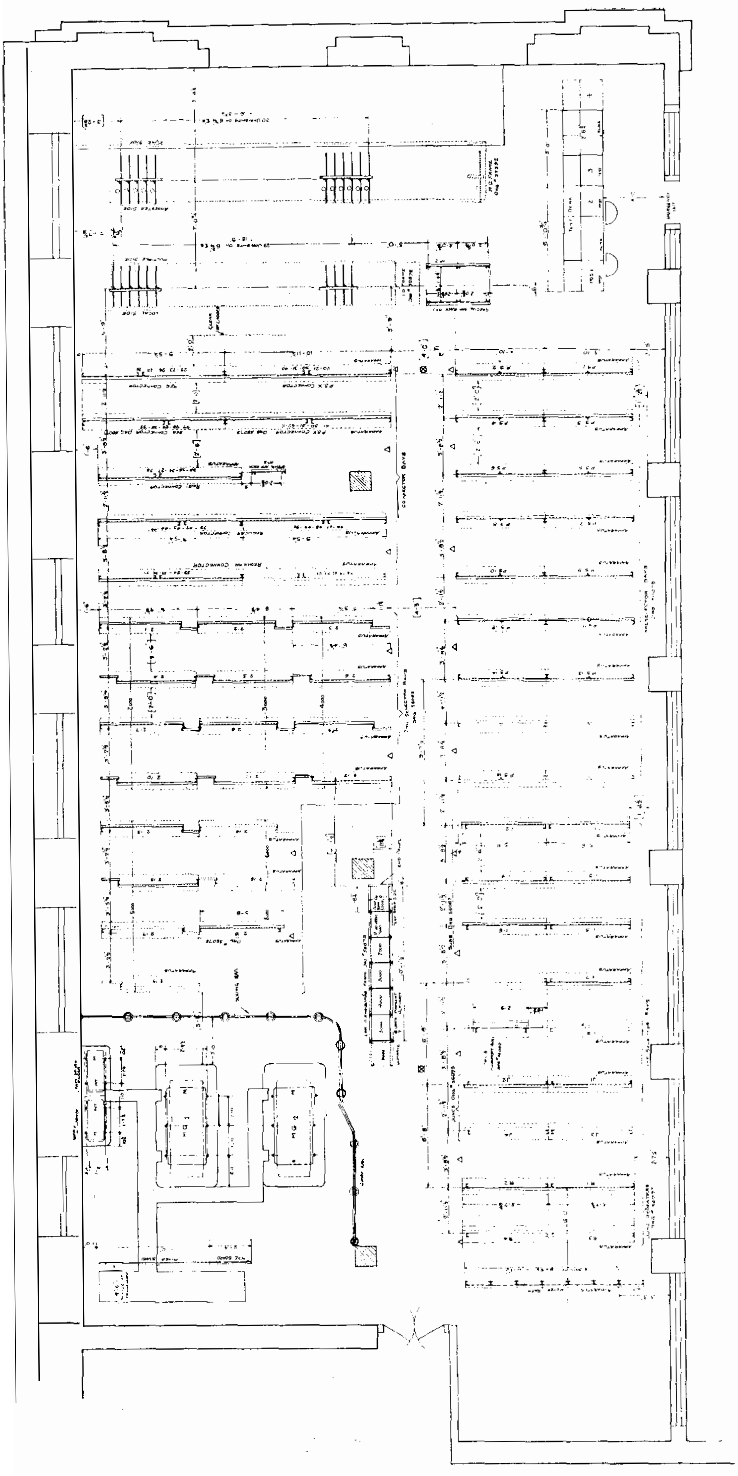

FIG 8.—FLOOR PLAN OF DUNDEE AUTOMATIC APPARATUS ROOM.

Second Selector racks (see Fig. **4**) are similar to 1st Selectors, except that they accommodate 6 shelves of 10 switches and that the bank terminals are of the link-frame type and are arranged in groups of 100, corresponding to the final selector units. This provides for grading without taking the cabling to final selectors through the link frame.

A Final Selector rack (see Fig. **5**) has capacity for 5 shelves of 10 or less than 10, suitably sized racks being combined according to the number of switches per 100 lines.

The auxiliary equipment and bank cabling terminals are here mounted at the end of the shelves, the terminals being of the I.D.F. type.

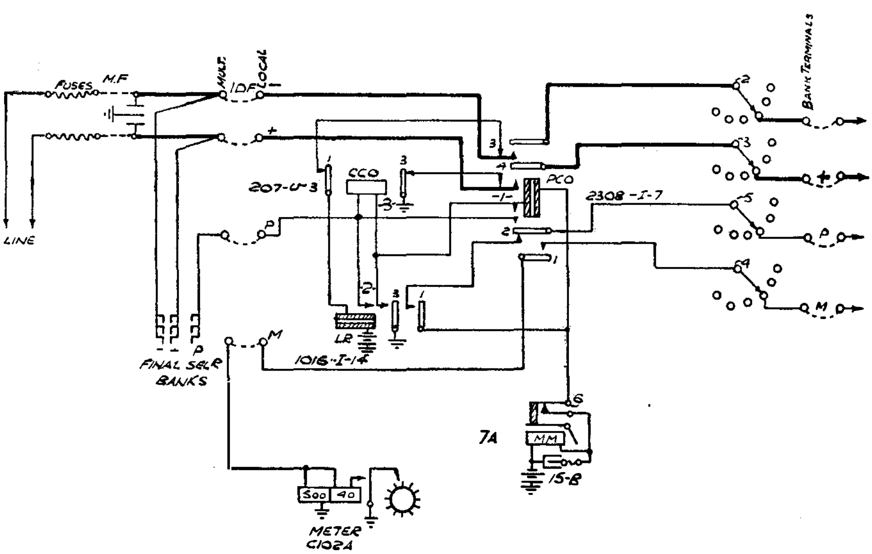

FIG. **9**.—PRE-SELECTOR CIRCUIT.

Link Frame.—This has recently been introduced at automatic exchanges to enable a grading scheme to be used between different ranks of switches and to facilitate the rearrangement of groupings. The selector bank multiple cabling at Dundee and Broughty Ferry is "straight," *i.e.*, without "slip," which is necessary if the full efficiency due to the use of graded groups is to be realised.

As will be seen in Fig. **6**, the frame consists of a number of bays or panels fitted with terminal strips, which are divided into upper and lower sections. The groups of outlets from the preceding rank of switches are cabled to the upper section and are formed into a graded group by bare wire commons on the front. The lower section terminates cabling switches of the following rank, upper and lower portions being connected by flexible jumpering at the back of the frame (see Fig. **7**).

A floor plan of the Dundee Automatic Apparatus Room appears in Fig. **8**. Two general views of this room, looking from each end of the aisle, are shown in Figs. **5** and **6**.

CIRCUITS.

The following are descriptions of the principal circuits, viz., pre-selector, first, second and final selectors:—

Pre-Selector (Fig. **9**).—When a subscriber lifts his telephone to call, line relay L.R. is operated over loop and relay C.C.O. is short-circuited. If the switch wipers are resting on bank contacts leading to an idle first selector, there will be no "earth" on P. and relay P.C.O. will operate from battery through coil of motor magnet "M.M." (which does not operate in series with

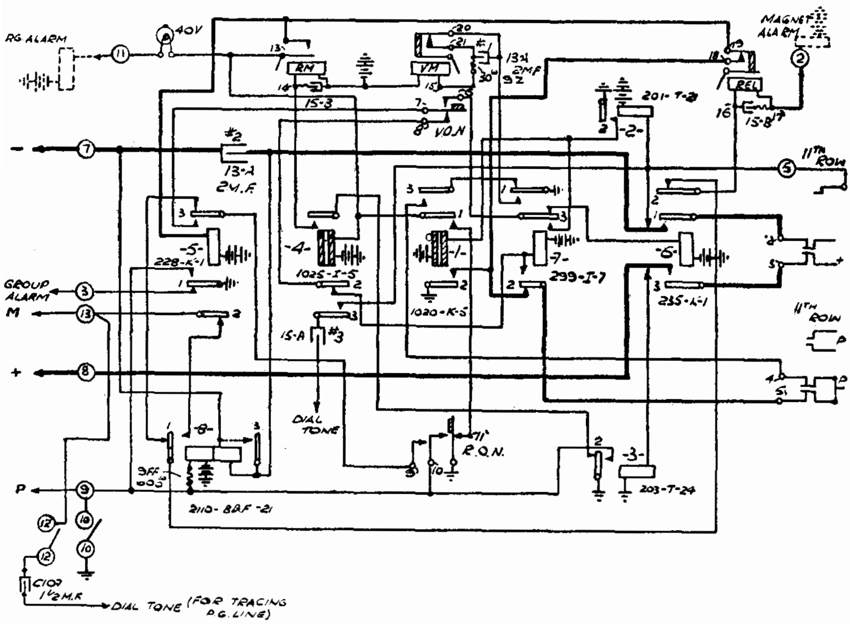

FIG. **10**.—1ST SELECTOR CIRCUIT.

"P.C.O.") and earth at contact of "L.R." The line is now put through to a 1st selector (Fig. **10**) in which relays 2 and 3 immediately operate, putting earth on P. Relay P.C.O. is retained and relay L.R. released. Relay L.R. is made slow releasing to ensure that earth is maintained on private bank contact until relay 3 in the 1st selector circuit has operated.

The connector bank is made busy to incoming calls by earth on P.

If the switch wipers are resting on contacts leading to a busy 1st selector, there will be earth on P and motor magnet "M.M." will operate from battery through its coil and contact, front contact of relay L.R., and back contact of relay P.C.O. and step the switch to the next set of contacts. "M.M." breaks its own circuit and so keeps stepping the switch forward until an idle 1st selector is picked up, *i.e.*, with no earth on P. Meanwhile P.C.O. is short-circuited., earth being on each side of the coil. When an idle 1st selector is found, the operation is as already described.

In the case of an incoming call the connector earths the private bank contact, causing relay C.C.O. to be operated through coil of relay P.C.O. and motor magnet M.M., thus cutting relay L.R. and earth from line. M.M. and P.C.O. do not operate in series with C.C.O.

First Selector (Fig. **10**).—As soon as the pre-selector picked up the 1st selector, relays 2 and 3 operated; relays 1, 4 and 5 then operate. Relay 4 puts on the dialling tone, to let subscriber know that he may now dial, and prepares the rotary magnet (R.M.) circuit. Subscriber dials thousands digits and relays 2 and 3 respond, but relays 1 and 4, which are slow releasing, are maintained. Every time armature of relay 3 falls back the rotary magnet R.M. steps forward. At the first step the rotary off normal contacts "R.O.N." are operated, breaking the circuit of relay 4 which, however, is held during dialling by the back contact of R.M. In the interval which follows the dialling of the thousands digit, relay 4 releases and relay 7 operates, the circuit of the latter being made through contacts of relay 4 V.O.N. contacts, contacts of relay 5, R.O.N. contacts to earth, and retains as long as earth is found by the private wiper. Relay 7 closes circuit of vertical magnet (V.M.) which steps up the switch wipers until a free line is found (*i.e.*, with no earth on private), when relay 7 releases; V.M. circuit is broken and the switch comes to rest.

At the first step of V.M., V.O.N. contacts operated and prepared the circuit of relay 6.

On the release of relay 7, relay 6 operates and puts the line through to the 2nd selector. Relays 2, 3 and 1 release. Relay 1 is slow to release and ensures that earth is held on private until relays 2 and 3 in the 2nd selector circuit operate. If all the bank contacts are busy the switch wipers will be stepped up to the 11th level and busy tone given to the subscriber.

Relay 8 prepares the meter circuit. Normally the currents in its two coils oppose and it does not pull up. When, however, the called subscriber answers the feeding current on the line is reversed (see final selector circuit—Fig. **12**) and the currents in the two coils assist one another. The relay operates, short-circuiting its line coil and the line condenser, and retaining by current in one coil. While the connection is set up, the meter circuit is broken at contacts of relays 5 and 6 and is completed only on release, at which time relays 5 and 6 fall back, the circuit being from battery through coils of release magnet, contacts of relays 6, 8 and 5, line switch contacts, contact of relay P.C.O. (see pre-selector circuit—Fig. **9**) and 500ω coil to earth. The meter now operates and brings into circuit its 40ω coil.

In the case of calls to the manual board metering is not required and there is no reversal of line current, hence relay 8 does not operate. The circuit of the release magnet is then though contacts of relays 6, 8, 5, and R.O.N. to earth.

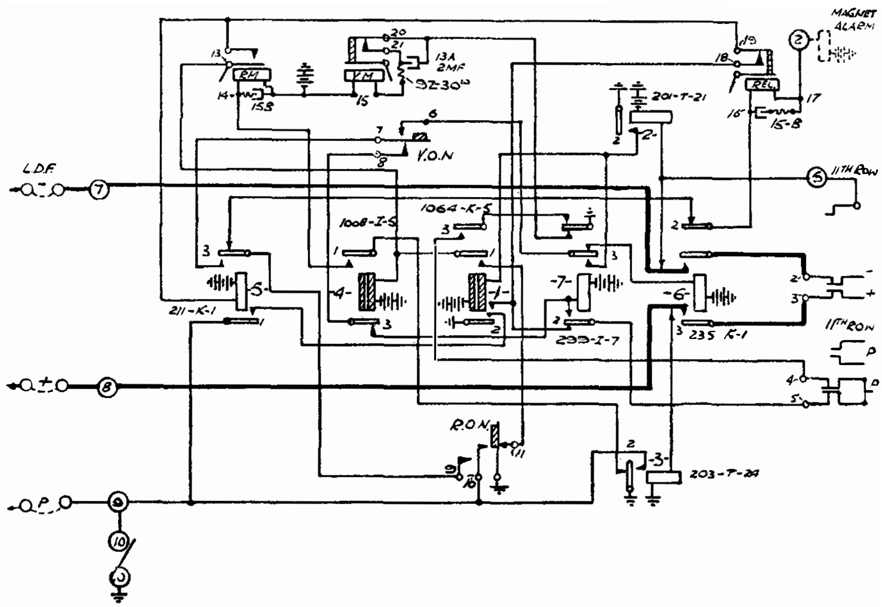

Fig. **11**.—2nd Selector Circuit.

Second Selector (Fig. **11**).—The operation of this switch is similar to that of the 1st Selector but without dialling tone and metering relay. The calling subscriber on dialling the hundreds digit is put through to a final selector.

Regular Final Selector (Fig. **12**).—When the 2nd selector picks up a final, relays 2 and 3 operate, then relays 1, 4, 12 and 8. Relay 2 puts earth on private before relay 4 (Fig. **11**) releases, thus maintaining the connection.

The subscriber now dials the tens digit, operating the rotary magnet (R.M.), the circuit being from earth through contacts of relays 3, 1 and 5, V.●.N., R.M. coil to battery. At the first step of the switch R.O.N. contacts operate and earth is taken off relay 4, but during dialling this relay, which is slow acting, is maintained by the contact on R.M. The operation of R.O.N. causes relay 10 to actuate, which prepares the ringing circuit and disconnects the line wipers, preventing them in their vertical motion from interfering with other circuits. In the interval which follows the dialling of the tens digit, relay 4 releases and relay 5 operates, preparing the circuit of the vertical magnet. The units digit is now dialled, the vertical magnet V.M. responding, the circuit being from earth through contacts of relays 3, 1, and 5, V.M. coil to battery. At the first step of the switch, V.O.N. contacts operate. During the dialling, relay 4 again operates through contact of V.M., and when V.O.N. operates the circuit of relay 5 is thus maintained. When dialling ceases, relay 4 releases, then relay 5.

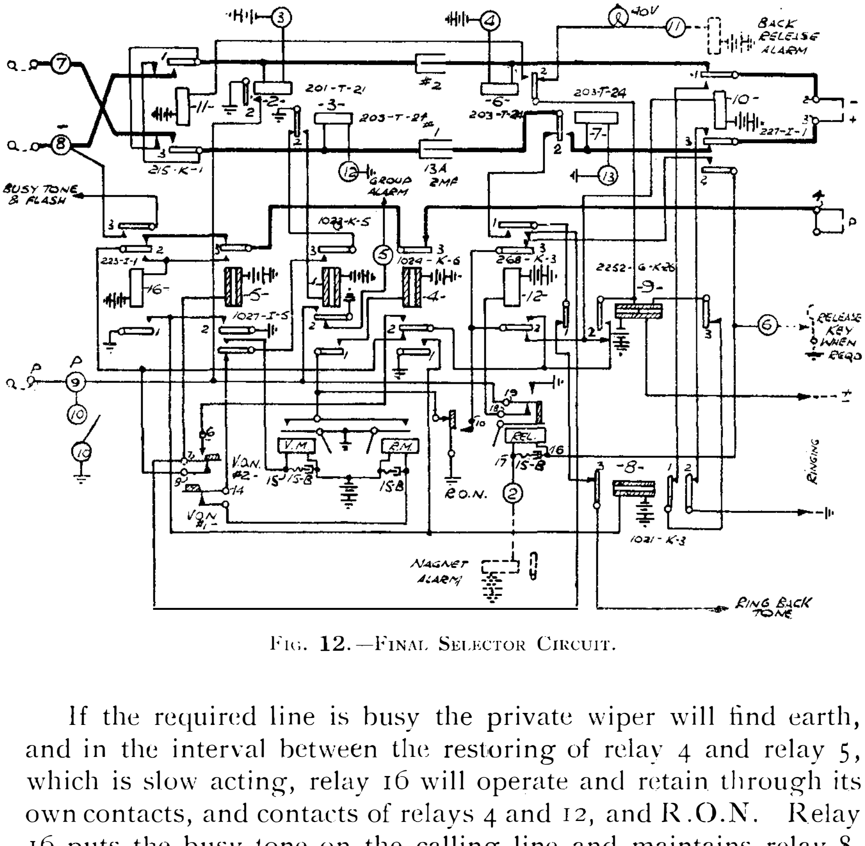

FIG. 12.—FINAL SELECTOR CIRCUIT.

If the required line is busy the private wiper will find earth, and in the interval between the restoring of relay 4 and relay 5, which is slow acting, relay 16 will operate and retain through its own contacts, and contacts of relays 4 and 12, and R.O.N. Relay 16 puts the busy tone on the calling line and maintains relay 8, which breaks the ringing circuit. If the called line is not busy, the private wiper will not be earthed and relay 16 will not operate; the releasing of relay 5 will then release relay 8, thereby closing the ringing circuit. The left hand contacts of relay 8 put on "ring-back tone," which indicates to the calling subscriber or telephonist that the called subscriber is being rung. When the called subscriber answers, relay 9 trips by the ringing current and retains, at the same time breaking the circuit of relay 10, which now releases and establishes the speaking circuit. Relays 6 and 7 operate over the subscriber's line, relay 6 closing the circuit of relay 11, which actuates and reverses the line. This reversal causes the metering relay No. 8 (Fig. **10**) to operate and prepare the metering circuit as described under " First Selector."

Release.—When the calling subscriber, who controls the connection, clears, relays 2 and 3 (Fig. **12**) release, then relays 1, 12 and 9; relay 10 operates through contact of relay 12 and R.O.N. The release magnet now operates and the switch returns to normal. In doing so it restores V.O.N. and R.O.N. The latter breaks the circuit of relay 10 and the release magnet. The final selector circuit is now restored to normal.

When earth is taken off the private at the final selector, relays 5 and 6 (Fig. **11**) release. The release magnet of the second selector circuit now operates, releasing the switch, which returns to normal and restores V.O.N. and R.O.N. The second selector circuit is now fully restored. Earth being taken off the private at the 2nd selector, relay 5 (Fig. **10**) releases, then relay 6. The circuit of the release magnet is now completed from battery through R.E.L. coil, contacts of relays 6, 8, 5, contact of relay P.C.O. (Fig. **9**), and 500$^{\omega}$ coil of meter to earth. The meter operates, and when its 40$^{\omega}$ coil comes into circuit the release magnet (Fig. **10**) operates due to the reduced resistance and the switch returns to normal, restoring V.O.N. and R.O.N. The latter takes earth off the private and relay 8 (Fig. **10**), relay P.C.O. and meter (Fig. **9**) release, the whole connection having been now restored to normal.

The pre-selector wipers do not return to the commencement of the bank contacts, but remain on the contacts on which they were last in use.

In addition to the tones already referred to, " Number Unobtainable " tone is given to the subscriber when connection is made to dead levels, dead numbers and to lines out of order.

Tracing of Connections.—When a pre-selector of the rotary type has no normal position, it is necessary, in the case of a permanent loop, to have some means of quickly locating the pre-selector concerned, as the pre-selector wipers are scattered indiscriminately over the outgoing banks. It is impossible to do this by inspection, other than by examining the condition of the cut-off relay, which would require the removal of the cover, and by the examination of a large number of switches. In the Dundee equipment, by throwing knife-blade switch No. 12 on the 1st selector, dialling tone is connected to the meter lead, and thus by searching with a telephone over the I.D.F. terminals the picking-up of the tone gives a ready means of location.

Another example of the usefulness of the knife-blade switches on selectors is in tracing the connection in the back release condition; without such switches it would be necessary to examine all 2nd selectors on the particular 1000's level concerned, as all these switches would have common outlets to the group of final switches containing the one in question. Similar difficulty would be experienced in tracing back to the 1st selector.

Fig. **13** shows the method adopted at Dundee to avoid this. Knife-blade switches 7, 8 and 10 are thrown; 7 and 8 to open the positive and negative lines, and 10 to earth the private and hold the connection.

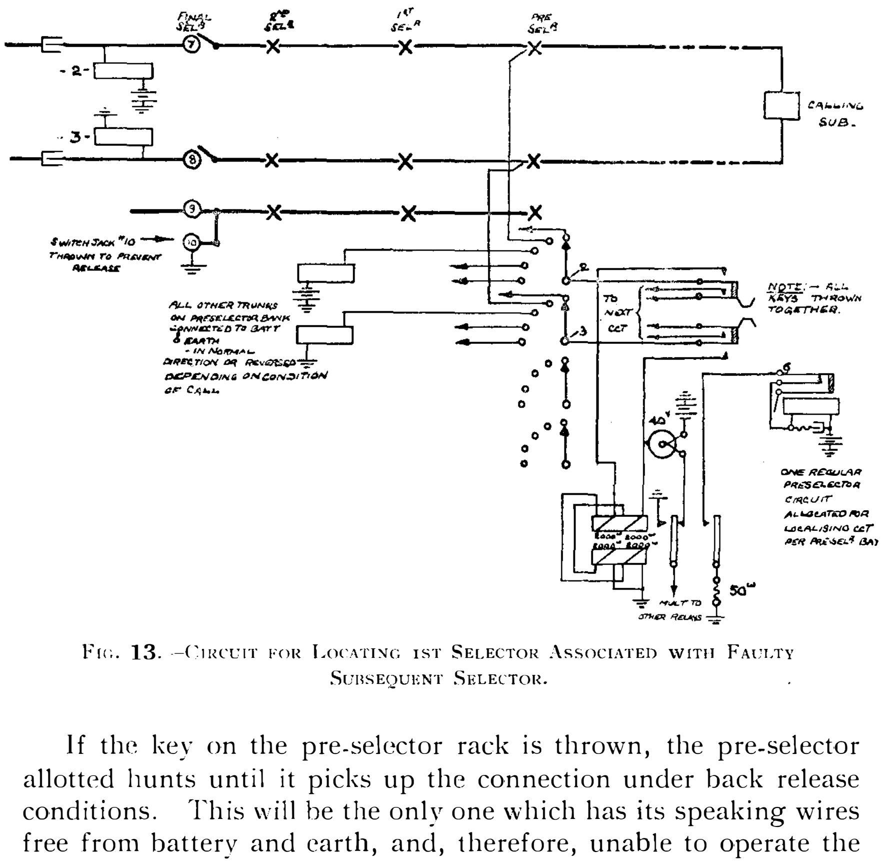

FIG. **13**.—CIRCUIT FOR LOCATING 1ST SELECTOR ASSOCIATED WITH FAULTY SUBSEQUENT SELECTOR.

If the key on the pre-selector rack is thrown, the pre-selector allotted hunts until it picks up the connection under back release conditions. This will be the only one which has its speaking wires free from battery and earth, and, therefore, unable to operate the 8000ω relay which closes the circuit for the rotary magnet.

The release of the 8000ω relay lights a lamp, indicating the group of pre-selectors, and cuts the circuit of the rotary magnet. The position of the wipers indicates at once the outgoing trunk and 1st selector. It only remains to find the 2nd selector, which is readily done by referring to a trunking chart.

Alarms.—A complete system of alarms on the usual lines is provided to call attention to the various classes of faults as follows:—

(*a*) Blown fuses.
(*b*) Ringing failure.
(*c*) Permanent loop on 1st selectors.
(*d*) Back release.
(*e*) Failure to release.
(*f*) Group congestion on 1st and final selectors.
(*c*), (*d*), and (*e*) are retarded alarms.

To enable the faults to be readily located, lamps are provided as follows:—

Ceiling lamps to indicate the rank of switches.
Aisle ,, ,, ,, ,, rack.
Shelf ,, ,, ,, ,, shelf.
Switch ,, ,, ,, ,, switch.

These lamps are of different colours to indicate the class of fault as well as to locate it.

Faults (*a*), (*b*) and (*c*) are capable of extension to the manual board.

Fault alarms at Broughty Ferry are extended to Dundee.

For the retarded alarms a pre-selector is used which, as soon as the circuit conditions causing the fault are set up, steps round one step every 6 seconds by means of an interrupter on the ringing machine. By suitably wiring certain contacts the desired period of delay is obtained.

TRAFFIC CONGESTION.

An Esterline graphic recorder, or 10-pen meter, has been supplied by the installers for recording the overflow calls. It consists of a moving chart, driven by clockwork, upon which records are made by 10 movable pens under control of 10 electro-magnets. The recorder is fitted near the Test Desk and the 10 electro-magnets connected by 10 switches to cabling multipled over the 11th row contacts on the respective levels of all selector shelves. Both the number of calls and their duration are indicated and the diagram can be opened out if the traffic is heavy by altering the gearing and so increasing the feeding speed of the paper.

A test jack per shelf of selectors on the auxiliary panel of each rack permits of any level on any shelf being isolated from the 11th row multiple to the recorder magnets, and it is, therefore, possible to locate the group of switches on which congestion is occurring.

The circuit is so wired that a meter may be fitted and connected on each rack to record the overflows on all levels of all switches on the rack. This would supplement the 10-pen meter. The recorder is portable and will be available for periodic use at Broughty Ferry.

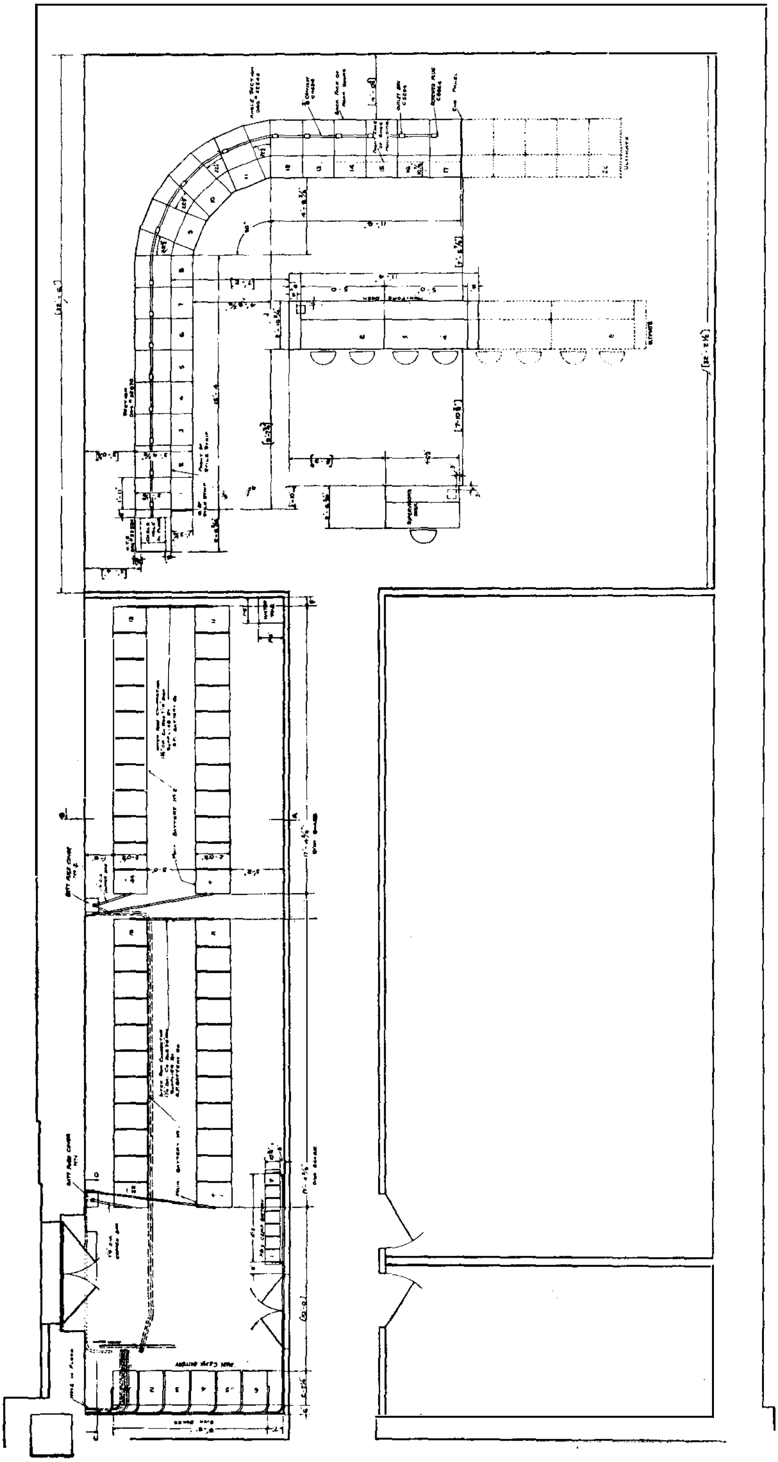

Fig. 14.—Floor Plan, Dundee Manual Switch Room and Battery Room.

Manual Board.—Fig. **14** is a plan of the Manual Switch Room and Battery Room. The manual switchboard consists of 17 one-position 2-panel sections similar in type to those used in C.B. No. 10 exchanges. Sections 1 to 6 accommodate jack-ended junctions, "0" lines from 1st selector levels and coin box lines. Positions 7 to 17 are equipped for lines working on a trunk signalling basis.

The outgoing junctions are multipled over all the sections and are divided into two groups, viz., for lines to manual exchanges and lines to the automatic equipment. The latter are equipped

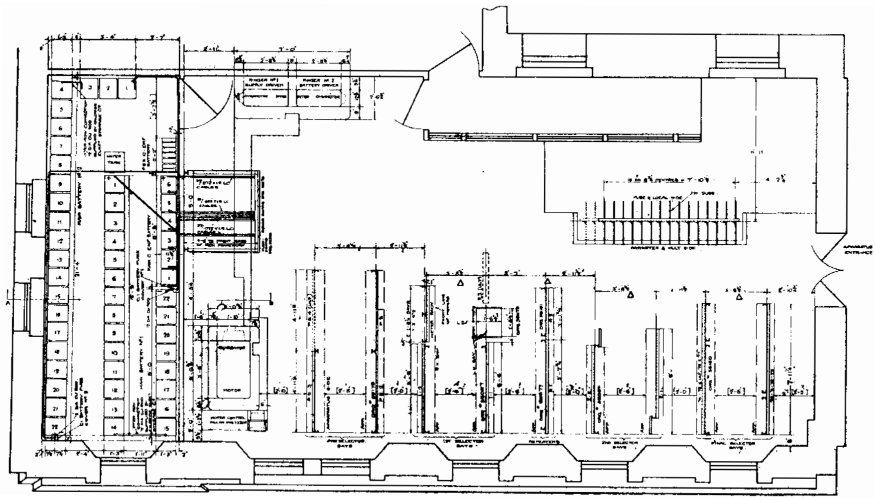

FIG. **15**.—FLOOR PLAN, BROUGHTY FERRY EXCHANGE.

with duplicate jacks and visual engaged signals and are cabled direct to 2nd selectors. The operators at the manual switchboard select the 1000's groups on the jacks and are required to dial only the last three digits. The number of 1st selectors is thus reduced.

Desks.—The following desks of standard type having the usual service equipment are provided for:—

Chief Supervisor	(1 position)
Monitors	(4 position)
Test-Clerks	(2 position)

Power Plant.—There are no special features calling for description. The main items are enumerated below:—

Power Board.

Batteries.

2 Main batteries (22 cells): box capacity 1680 AH: plate equipment 1374 AH.

1 Counter E.M.F. battery (6 cells): to carry 300 amps. continuously: for regulating discharge voltage.

1 Counter E.M.F. battery (7 cells): to carry 15 amps. continuously: for providing a voltage of 30 for P.B.X. power leads.

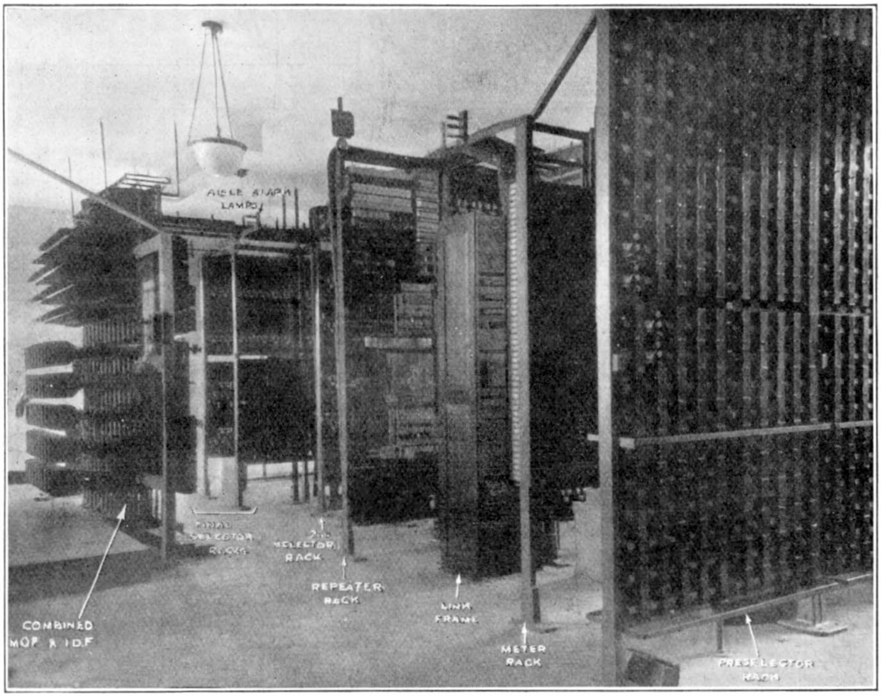

FIG. 16.—BROUGHTY FERRY EXCHANGE: GENERAL VIEW FROM ENTRANCE.

Machines.

2 Motor Generator Charging Sets: Motor side 440 Volts D.C.: Generator side 260 amps. at 50 volts.

2 Ringing dynamotors: output 1 amp. at 75 volts: (one is run off supply at 200 volts D.C. and the other off main battery). Each ringer is equipped with interrupters, high and low speed, to give the necessary tones and interruptions.

BROUGHTY FERRY EXCHANGE.

The apparatus is of the same type as at Dundee, except that a combined M.D.F. and I.D.F. of the type used at C.B. No. 10 exchanges is used. A floor plan is shown in Fig. **15** and two general views of the exchange in Figs. **16** and **17**.

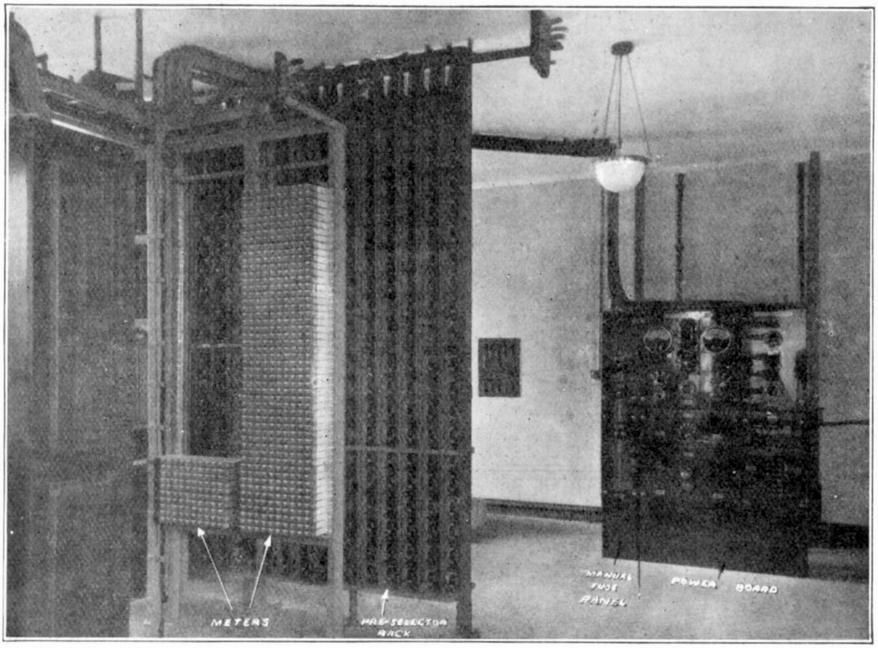

FIG. **17**.—BROUGHTY FERRY EXCHANGE: GENERAL VIEW LOOKING TOWARDS ENTRANCE.

The writers are indebted to the Contractors, who kindly supplied photographs and lent tracings of floor plans and circuit diagrams.

THE TRUNK EXCHANGE AND HEAD TELEGRAPH OFFICE IN CHRISTIANIA.

(From *Tehnisk Tidskrift*).

THE exchange was installed last year (1923). It contains 69 trunk sections, 1 transfer section, 4 enquiry sections, 4 repeater sections, 2 supervisors' sections, 1 test section, 12 record sections, 4 junction sections and 5 night concentrator sections. All the sections are two position. The Elektrisk Bureau Co., of Christiania, supplied the main portion of the plant; Mix and

Genest supplied the pneumatic tubes; Siemens and Halske the power plant and repeaters; the Western Electric Co. supplied the apparatus for intercommunication with the Christiania Telephone Company. From the cable chamber there are 24 56-pair cables going up to the main frame on the fifth floor, and 560 telephone lines and 240 telegraph lines are taken through test jacks on the testing panel.

Power Plant.—The power supply Company have led in 230-v. 3-phase A.C., and a three-wire 220—440-v., D.C. supply. A 230-v. 3-phase supply is given from a reserve oil-driven plant belonging to the Department. The only batteries are two sets of 24-v., 508-Ah capacity. The telegraphs use 30, 60, 90, 120, 150, 180 volts and the supply is given from 6 shunt generators, coupled on a single shaft driven by a 3-phase motor. There is a similar spare machine. For machine telegraphs there are duplicate 6 kw. 110-v.—55 volt machines. For the conveyors there are 2 sets giving 6 kw. at 55-v. For telephones there are duplicate sets giving 3.2 kw. at 24-v., each with two telephone type generators. One generator is over-compounded 5% and supplies the electric clocks and calculagraphs, the other generator can charge the battery. There are three ringing machines. For the repeaters there are duplicate sets, having a 12-v. generator at one end, the motor in the middle, and a 220-v. generator at the other end. The power switchboard has 12 panels. The telegraph instrument room is on the fourth floor and the trunk telephone room on the fifth floor.

Each trunk position controls three trunk lines ordinarily, but a fourth can be joined up if necessary. There is a 500 junction multiple, a 400 trunk multiple, and a 240 service multiple, and above this the strip of jacks which are used to give the " delay " on trunk lines.

The concentration sections are in a room near the rest room. Each position has jacks for 150 trunks, a strip of 10 jacks for records, and 8 pairs of cords.

The Christiania Telephone Company has its junction centre in the same building on the third floor. On the second floor are the 2nd group selectors for trunk records, phonograms, etc. The subscribers dial 01 for records, 02 for junction calls, 03 for phonograms.

The record operators have the band conveyor in front of them, the tickets being conveyed to the distribution table, operated and then distributed by tube to the trunk positions. The record operator can find the delay being experienced on any one of 60 trunks by means of voltmeters. On each trunk position are fitted 10 jacks, 5 for delay on ordinary calls, and 5 for delay on express calls (which pay three times as much as ordinary calls). The trunk operator by putting a dummy plug in one of these jacks sends 2, 4, 6, 8, or

10 volts respectively over a line to the I.D.F., and thence to the record table, where the line is multipled. If the record operator inserts a peg in the jack corresponding to the trunk whose delay she wishes to know, she will read on the voltmeter the relative pressure sent from the trunk position; this pressure represents delay. These " delay " lines are also led to the supervisor's desk.

For traffic from the trunk positions into Christiania automatic system, pre-selectors are used so that when the trunk operator presses her O.W. key, she is connected to an idle cordless B telephonist in the junction room, who states what junction the trunk operator shall use. The pneumatic tube installation is equipped with tubes of dimensions 70 × 8 mm. A tube goes from the central distribution table to each section. The tube at the central table divides into two; one end is used for sending the other for receiving. A small flap in the tube struck by the incoming ticket diverts the ticket into the receiving tube at the central distribution table. At the trunk positions the one open end is used for both sending and receiving.

There are 24 4-wire repeaters terminating on plugs and cords so that they can be introduced into any one of the required lines. When a trunk operator needs a repeater she plugs into the transfer multiple and a lamp lights on each of the four repeater positions. A free operator replies and sets up the required connection in the multiple of 60 trunk lines and 60 artificial lines. Above the trunk multiple is fitted a service multiple of 240 numbers.

SOME NOTES ON THE USE OF THE PROBABILILITY THEORY TO DETERMINE THE NUMBER OF SWITCHES IN AN AUTOMATIC TELEPHONE EXCHANGE.

By DR. M. MERKER,

International Western Electric Co., Antwerp.

PART I.

1. In any automatic exchange the number of trunks or switches is, for economical reasons, always inferior to the number of subscribers, and the following problem may therefore be proposed: What number x of lines or switches is needed to give a good service, *i.e.*, to obtain that the number of calls, which cannot go through because all the switches are in use, be very small and equal, for instance, to 0.001?

It is obvious that the number of switches x will depend on the number of subscribers, the duration of the calls and the intensity of the traffic. Experience has shown that the probability theory may be applied to calculate the number of switches in an automatic exchange. The problem may therefore also be stated in the following way: How many switches x are needed to have a probability of, say, 0.001 of finding all switches engaged simultaneously?

The number of subscribers is given and the duration of the calls and the traffic are estimated from observations on existing installations.

The determination of the traffic intensity or the counting of the number of calls is usually made during the "busy hour."

2. At present it seems that three formulæ obtained by means of the probability theory are used to calculate the number of switches in an automatic exchange.

If we represent by:

N the number of *subscribers* or subs. lines.

t the average time during which a *subscriber's line is in use* during the busy hour and expressed as a fraction of this hour.

P_r the probability that r lines will be engaged simultaneously.

We will have the formula:

$$P_r = \frac{N(N-1)\ldots\ldots\ldots(N-r+1)}{r!} t^r (1-t)^{N-r} = C_N^r \; t^r (1-t)^{N-r} \ldots (1)$$

which is obtained by applying the laws of the combinatorical analysis by considering that N events happen in the unity of time and that P_r is the probability that r of them occur in a time t, expressed as a fraction of the adopted unit. (C_N^r means the number of combinations of N things taken r at a time).

When the time t is smaller than 0.05, *i.e.*, smaller than 3 minutes, the value of P_r in the formula (1), supposing P_r is smaller than 0.01, remains practically constant when t is decreased and N increased in the same proportion, so that the product Nt remains constant.* In this case the formula (1) is also correct when we represent by:

N the number of *calls* during the busy hour (usually greater than the number of subscribers' lines).

t the average duration of *one call*.

* See E. C. Molina, The Am. Math. Monthly, Vol. XX., June, 1913, and F. Lubberger, E.T.Z., Sept. 14th, 1922.

When N is increased indefinitely and t reduced so as to keep $Nt = m$ constant, by using the well known formula:

$$\lim_{n=\infty} \left(1 + \frac{x}{n}\right)^n = e^x$$

and by writing the expression

$$N(N-1)\ldots\ldots\ldots(N-r+1)$$

in the form

$$N^r - [1+2+3+\ldots(r-1)]\,N^{r-1} + \ldots\ldots = N^r\left(1 - \frac{r(r-1)}{2N} + \ldots\right)$$

we will have for $N = \infty$

$$\lim. \frac{N(N-1)\ldots(N-r+1)}{r!}\, t^r\,(1-t)^{N-r}$$

$$= \lim. \frac{N^r}{r!}\left(1 - \frac{r(r-1)}{2N} + \ldots\right)\left(\frac{m}{N}\right)^r \left(1 - \frac{m}{N}\right)^N \left(1 - \frac{m}{N}\right)^{-r}$$

$$= \lim. \frac{1}{r!}\,\frac{N^r}{N^r}\left(1 - \frac{r(r-1)}{2N} + \ldots\right)\left(\frac{m}{1 = \frac{m}{N}}\right)^r \left(1 - \frac{m}{N}\right)^N$$

$$= \frac{m^r}{r!}\,e^{-m}$$

and the formula (1) becomes:

$$P_r = \frac{e^{-m}\,m^r}{r!} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

which is usually given as an approximation of formula (1). It is, however, understood that to obtain these formulæ the *number of switches* used to complete the calls *was assumed to be unlimited* (*i.e.*, equal to the number of subscribers' lines).

By starting from another principle (that of the statistical equilibrium) Mr. Erlang gives another formula and considers the case where the number of switches is limited to a value x (Elektroteknіren, Jan., 1917; P.O.E.E.J., Jan., 1918, Vol. X., Part 4; E.T.Z., 19th Dec., 1918; A.P.T.T. Juillet-Aout, 1922).

This formula is:

$$P_r = \frac{\dfrac{m^r}{r!}}{1 + \dfrac{m}{1!} + \dfrac{m^2}{2!} + \ldots + \dfrac{m^x}{x!}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

and the probability that all switches are engaged is:

$$P_x = \frac{\frac{m^x}{x!}}{1 + \frac{m}{1!} + \frac{m^2}{2!} + \ldots + \frac{m^x}{x!}}$$

Mr. Erlang proposes also the formula (2) as an approximation which can be deduced from (3) by considering an infinite number of switches.

3. In his theory, Mr. Erlang assumes that the number of calls is independent of the number of connections already established. It is easy to show that if we take the opposite hypothesis, *i.e.*, if we assume that the traffic depends on the number of free subscribers and is proportional to it, and by taking the number of switches as unlimited, Mr. Erlang's theory gives the formula (1). The probability that a call happens in a time dt, when r switches are engaged, will be $m \frac{N-r}{N-m} dt$ by assuming that the average number of calls m ($m = Nt$ is usually considered as representing the average number of calls during the time t) will be changed in the proportion $\frac{N-r}{N-m}$ and be equal to $m \frac{N-r}{N-m}$.

If therefore P_r is the probability that r switches will be engaged in the time t, $P_r m \frac{N-r}{N-m} dt$ will be the probability that in the time dt the number of engaged switches passes from r to $r+1$. Further, if P_{r+1} is the probability that $r+1$ switches are engaged in the time t, the probability that one of the $r+1$ connections ceases will be $(r+1) P_{r+1} dt$

The principle of the statistical equilibrium will give

$$P_r m \frac{N-r}{N-m} = (r+1) P_{r+1}$$

for any value of r from $r=0$ to $r=N-1$ (the number of switches being supposed to be unlimited).

We will therefore have a series of equations:

$$P_0 m \frac{N}{N-m} = P_1$$

$$P_1 m \frac{N-1}{N-m} = 2 P_2$$

$$P_2 m \frac{N-2}{N-m} = 3 P_3$$

$$P_3 m \frac{N-3}{N-m} = 4 P_4$$

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$$P_{N-1} m \frac{N-(N-1)}{N-m} = N P_N$$

and we may write:

$$P_0 = P_0 = \qquad P_0$$

$$P_1 = P_0 \frac{m}{1} \frac{N}{N-m} = \qquad P_0 C_N^1 \frac{m}{N-m}$$

$$P_2 = P_0 \frac{m^2}{1 . 2} \frac{N(N-1)}{(N-m)^2} = \qquad P_0 C_N^2 \left(\frac{m}{N-m}\right)^2$$

$$P_3 = P_0 \frac{m^3}{1 . 2 . 3} \frac{N(N-1)(N-2)}{(N-m)^3} = P_0 C_N^3 \left(\frac{m}{N-m}\right)^3$$

.
.
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$$P_r = P_0 \frac{m^r}{r!} \frac{N(N-1)\ldots(N-r+1)}{(N-m)^r} = P_0 C_N^r \left(\frac{m}{N-m}\right)^r$$

.
.
.

$$P_N = P_0 \frac{m^N}{N!} \frac{N(N-1)\ldots(N-N+1)}{(N-m)^N} = P_0 C_N^N \left(\frac{m}{N-m}\right)^N$$

The sum of the probabilities $P_0 + P_1 + \ldots\ldots + P_N$ is certainty and equal to 1, therefore

$$P_0 = \frac{1}{1 + C_N^1 \frac{m}{N-m} + C_N^2 \left(\frac{m}{N-m}\right)^2 + \ldots\ldots + C_N^N \left(\frac{m}{N-m}\right)^N}$$

$$= \frac{1}{\left(1 + \frac{m}{N-m}\right)^N}$$

and $$P_r = \frac{C_N^r\left(\frac{m}{N-m}\right)^r}{\left(1+\frac{m}{N-m}\right)^N} = C_N^r\left(\frac{m}{N-m}\right)^r\left(\frac{N-m}{N}\right)^N = C_N^r\left(\frac{m}{N}\right)^r \left(1-\frac{m}{N}\right)^{N-r}$$

From the above we see that all three formulæ, obtained by different authors by means of different mathematical theories, may be deduced from a single theory (that of Mr. Erlang) by making different assumptions. By assuming that the number of subscribers is limited and the number of switches is unlimited we obtain the formula (1), while the formula (3) of Mr. Erlang results from the contrary assumptions: an unlimited number of subscribers (the hypothesis that the traffic is independent of the number of calls in progress corresponds to an infinite number of subscribers) and a limited number of switches.

The formula (2) is obtained by supposing that both the number of subscribers and switches is unlimited.

Thus the formula (2) has been deduced from (1) (where the number of switches is already unlimited) by assuming that the number of subscribers is infinite. The formula (2) is also obtained from (3) (where the number of subscribers is infinite) by assuming that the number of switches is unlimited.

If we consider now the case where both the number of subscribers and switches is limited, which corresponds more than the other cases to the practical conditions, we will find by the theory of Mr. Erlang, as shown previously, the formula:

$$P_x = \frac{C_N^x\left(\frac{m}{N-m}\right)^x}{1 + C_N^1\frac{m}{N-m} + C_N^2\left(\frac{m}{N-m}\right)^2 + \ldots + C_N^x\left(\frac{m}{N-m}\right)^x} \quad \ldots\ldots(4)$$

which is, however, much less convenient for calculation than the other formulæ.*

Practically the difference between the values obtained by these four formulæ is very small and does not affect the number of switches x calculated

The following table illustrates this fact:—

Table of the probabilities of finding 10, 11, 12 *or* 13 switches engaged when $m=5$ and $t=\frac{1}{30}h=2$ minutes. obtained with 4 different formulæ.

* See O'dell: "Theoretical principles of the traffic capacity of automatic switches," *P.O.E.E.J.*, Oct., 1920. Vol. 13, Part 3.

Formula	Conditions	P_{10}	P_{11}	P_{12}	P_{13}
$P_x = C_N^x t^x (1-t)^{N-x}$ ....(1)	N limited, x unlimited	0.01722	0.007557	0.0030185	0.0011049
$P_x = \dfrac{C_N^x \left(\frac{m}{N-m}\right)^x}{1 + C_N^1 \frac{m}{N-m} + C_N^2 \left(\frac{m}{N-m}\right)^2 + \dots + C_N^x \left(\frac{m}{N-m}\right)^x}$ ......(4)	N limited, x limited	0.01742	0.00759	0.00302	0.001105
$P_x = \dfrac{e^{-m} m^x}{x!}$ ....(2)	N unlimited, x unlimited	0.01813	0.00824	0.00343	0.00132
$P_x = \dfrac{\frac{m^x}{x!}}{1 + \frac{m}{1} + \frac{m^2}{2!} + \dots + \frac{m^x}{x!}}$ ....(3)	N unlimited, x limited	0.01838	0.00829	0.00344	0.00132

From this table it appears that for a given probability of say 0.01, the number of switches x obtained by any of the formulæ is 11, with a probability 0.001 the number of switches would be 13. The manufacturer of an automatic exchange may therefore take the formula which is the easiest for calculation.

4. We may now further examine if these formulæ correspond really to the problem the manufacturer has to solve.

The probability P_x given by the above is the probability of finding x lines simultaneously engaged. For instance, the value of P_{10} found with the formula (1) and which is equal to 0.01722 for $m=5$ and $t=\frac{1}{30}$ $h=2$ minutes (N = 150), means that if somebody comes, during the busy hour, in the central office an infinite number of times at infinitely small intervals to take note of the number of lines engaged simultaneously, he will find 1,722 times in 100,000 that 10 lines are engaged.

This value of the probability is obtained by an outside observer; for a subscriber this value would be different. It seems that the manufacturer is really interested to know the probability for a subscriber to find a certain number of lines simultaneously engaged and this is not given by any of the four above formulæ.

It seems that it was Mr. Lely's purpose to take care of this (Waarschynlykheidsrekening by automatische Telefonie—Den Haag, 1918), by his formula:

$$P_x = C_{N-1}^{x} \quad t^x \ (1-t)^{N-x-1} \ldots\ldots\ldots\ldots (5)$$

which gives the probability for a subscriber, when he takes his receiver from the switchhook, to find x lines engaged, and where N is the number of subscribers and t the time one subscriber uses his line during the busy hour (expressed in parts of an hour). It is also the probability for a stranger to find the same number of lines x engaged simultaneously when the number of subscribers is $N-1$.

But even this formula does not give entire satisfaction because it gives the probability that a call, *when it comes in, finds x lines engaged*, while the manufacturer is precisely interested to know the *probability that a call comes in* when x lines are engaged. This may also be expressed as follows: it is the probability for a stranger to find simultaneously $x+1$ lines engaged.

To resume this question, the problem to be solved by the manufacturer may be stated as follows: When the number of subscribers is N and each subscriber uses his line during a time t (during the busy hour) what number of switches x has to be used in order that the probability of surplus calls coming in would be, say, $P=0.001$ (*i.e.*, in the above mentioned conditions a stranger would find once in a 1000 times at least $x+1$ calls).

As the number of switches is equal to x, it is therefore necessary to make the sum of the probabilities of having $x+1$, $x+2$, etc., simultaneous calls. The required formula will be

$$P = P_{x+1} + P_{x+2} + \ldots = \Sigma P_{x+1} \ldots\ldots\ldots\ldots (6)$$

where P_{x+1}, P_{x+2}, etc., are the probabilities of having $x+1$,

$x+2$, etc., lines simultaneously engaged when the number of switches is unlimited. This is the method of the W.E. Co., which uses the approximate formula:

$$P = e^{-m}\left(\frac{m^{x+1}}{(x+1)!} + \frac{m^{x+2}}{(x+2)!} + \ldots\ldots\right)$$

5. The meaning of P_{10} given in the above paragraph may also be expressed in another way. If the observer mentioned previously had measured the time during which 10 lines are engaged, during the busy hour, he would have obtained a time equal to 0.01722 hours, or $0.01722 \times 3600 = 62$ seconds. These 62 seconds are obviously the sum of the times, usually separated by intervals, during which 10 lines are engaged during the busy hour.

As stated above, we may assume that to calculate P_x, the number of switches is unlimited. The influence of this assumption, which is contrary to the real facts, is very small. If, however, it is desired to take care of the limitation of the number of switches, two cases have to be examined.

Amongst the automatic systems we may indeed distinguish those where the surplus calls wait till a switch becomes free, *i.e.*, where the call goes through immediately after one of the engaged switches becomes free and those where the surplus calls are lost, *i.e.*, where the subscriber has to call again. The first may be represented by the W.E. Co. system and the second by the Strowger system. In the system of the W.E. Co. type, when the number of switches is as usual sufficient to reduce all waiting times to very small values, it may be assumed that no call will be lost and started again afterwards, and that all surplus calls find their way through the first switch which becomes idle. The time during which x lines will be engaged will in this case be

$$\pi_x = P_x + P_{x+1} + P_{x+2} + \ldots = P_x + \Sigma P_{x+1} \quad \text{.........................(7)}$$

where P_x is the time x lines would be engaged if the number of switches was not limited. On the other hand in the systems of the Strowger type if we suppose that all surplus calls are lost and will be postponed a certain time, the time x lines are engaged will be smaller than in the systems of the W.E. type and will be

$$\pi_x = P_x + P'_x \quad \text{...(8)}$$

where P_x is as previously the time x lines would be engaged if the number of switches was not limited, and P'_x the difference between the times that x lines are engaged when the number of lines is limited and unlimited. This value of P'_x may therefore be expressed by the difference between the formulæ (4) and (1)

$$P'_x = \frac{C_N^x \left(\frac{m}{N-m}\right)^x}{1 + C_N^1 \frac{m}{N-m} + C_N^2 \left(\frac{m}{N-m}\right)^2 + \ldots + C_N^x \left(\frac{m}{N-m}\right)^x} - C_N^x t^x (1-t)^{N-x}$$

or by the difference between the formulæ (3) and (2).

$$P'_x = \frac{\frac{m^x}{x!}}{1 + \frac{m}{1} + \frac{m^2}{2!} + \ldots + \frac{m^x}{x!}} - \frac{e^{-m} \cdot m^x}{x!}$$

And we have seen above that these differences have a very small value when the number of switches is sufficiently great.

The above assumption that the lost calls are postponed a certain time is, however, not correct. Usually the subscriber will restart his call immediately. The time during which x switches are engaged being very small, the subscriber will already find a free line. But this new call coming in, just after x lines were engaged, will certainly have an influence on the value of the time during which x lines are engaged, so that we may write:

$$\pi_x = P_x + P'_x + P''_x \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

where P''_x is the time x lines are engaged due to the renewed calls.

It appears, therefore, that in the systems of the Strowger type two sorts of calls are lost: (*a*) those which are renewed immediately and increase the time during which x lines are engaged by a quantity P''_x and (*b*) those which are renewed later and which have no influence on this time.

The first may be considered as a sort of delayed calls, but where the duration of the delay is longer than in the W.E. type systems.

It is evident that the increase of P''_x reduces the number of calls properly lost and from the formula (9) it may also be seen that the increase of the time x lines are engaged in a Strowger system reduces the number of calls properly lost.

All this is, however, only true in case the number of switches x is sufficiently great, and when the increase of π_x is due to the increase of P''_x alone.

As we have

$$P'_x + P''_x < \Sigma\ P_{x+1}$$

the formulæ (7) and (9) show that the time when x lines are engaged is greater in the systems of the W.E. type than in the Strowger type.

Remark:

The formula (6) $P = \Sigma P_{x+1}$

may in accordance with the above be considered as the maximum waiting time in a system of the W.E. type. The expression $P = \Sigma P_{x+1} = 0.001$ means that the number of switches must have a value such that the maximum waiting time of a surplus call should not be greater than 0.001 hour or 3.6 seconds. This maximum is, however, obtained only exceptionally, because the time ΣP_{x+1} that the $(x+1)$th line is engaged does not elapse in one continuous period, but is the sum of different times (of the busy hour) separated by intervals during which the $(x+1)$th line is not engaged. To obtain this maximum it would further be necessary that the first waiting subscriber would find an idle switch after all others have found one. If this maximum presents itself exceptionally it cannot occur a second time during the busy hour.*

6. It has sometimes been stated† that the Strowger systems have an advantage upon the W.E. systems due to the fact that the total time x switches are engaged is smaller for the 1st than for the latter systems.

Before considering the mathematical theory it is, however, necessary to point out that the fact that all switches are engaged during a longer time can only be disadvantageous when some calls have still to go through. The disadvantage of such a long time does not consist in the value of this time itself, but in the fact that new calls would not find free switches. When the formulæ (7) and (8) or (7) and (9) are used the total time x lines are engaged includes also the influence of all surplus calls so that these calls have already come in. As all calls were considered there can be no question of an advantage because there are no more subscribers who are interested in this question. (See also paragraph 8, Remark III.).

To calculate the average waiting time of a delayed call in the W.E. type systems, the following reasoning has been made.‡ If M is the total number of calls for N lines during the busy hour the product $M\,P_x \cdot \frac{N-x}{N-m}$ will be the average number of calls during the time P_x when x lines are engaged. As the x switches are en-

* P_x is usually considered as representing the percentage of surplus calls, but according to the above, this meaning should be abandoned. Moreover this interpretation is sometimes in contradiction with the one according to which P_x represents the time x lines are engaged during the busy hour. When, for instance, the number of subscribers belonging to one group is equal to 50 and with $P_x = 0.01$ we will obtain according to the 1st interpretation that on 1 day in 2 no surplus call will occur, while according to the 2nd interpretation, P_{x+1}, P_{x+2}...being the engaged time of $x+1$, $x+2$...lines during the busy hour, $\sum P_{x+1} = 11$ seconds, which means that surplus calls occur every day.

† Milton: "Calcul du nombre de selecteurs ou de lignes auxiliares" Annales P.T.T., September, 1921, p. 484.

‡ Idem, p. 482.

gaged during a total time ΣP_x the total probable number of surplus calls will be

$$S = \frac{M}{N-m} \Sigma P_x (N-x) = M \frac{N-x}{N-m} P_x \frac{1}{1 - \frac{m}{x+1}} \text{ (approx.)}$$

and by calling

$$T = \Sigma P_{x+1} + \Sigma P_{x+2} + \ldots . = \Sigma\Sigma P_{x+1} \frac{1}{\left(1 - \frac{m}{x+2}\right)^2} \text{ (approx.)}$$

the total waiting time of all delayed calls, we will have:

$$\frac{T}{S} = \frac{Nt}{M} \frac{1}{x+1-m}$$

which means that the average waiting time of one delayed call is equal to the average duration of a conversation multiplied by $\frac{1}{x+1-m}$

This formula, even if considered as approximate, cannot give the average waiting time of a call, because

$$S = M \Sigma P_x \frac{N-x}{N-m} = M \frac{N-x}{N-m} \Sigma P_x$$

does not give the probable total surplus calls. This may be shown as follows. If M P_x represents the average number of calls during the time P_x and M $P_x \frac{N-x}{N-m}$ this average reduced proportionally to $\frac{N-x}{N-m}$, S represents only this average reduced proportionally to $\frac{N-x}{N-m}$ of the number of calls occurring during the time ΣP_x. When an average figure is used it is assumed that the calls are uniformly distributed between the times ΣP_x of the busy hour; but in practice this is not the case. During certain of these times no calls may come in, and during some other times several may occur and just these latter are important when we want to calculate the total number of surplus calls.

To illustrate the incorrectness of the above formula, which should give the average duration of a delayed call, we may consider the following example,* where

$N = 200 \quad t = 0.03 = 108$ sec. $\quad x = 16 \quad m = 6$

The formula, gives an average waiting time of one delayed call equal to $\frac{1}{x+1-m} = 1/11$ of the average time of a communication. This latter being 108 seconds (if $M = N$) we will have ***an average waiting time of***:

* Idem, p. 485.

$$\frac{108}{11}=9.8 \text{ seconds, or}$$

$$\frac{72}{11}=6.5 \text{ seconds for } M=300.$$

The total waiting time for all calls will, however, be:

$$1 \times P_{17}=1 \times 0.000118=0.000118 \text{ h.}=0.4248 \text{ sec.}$$
$$2 \times P_{18}=2 \times 0.000039=0.000078 \text{ h.}=0.2808 \text{ ,,}$$
$$3 \times P_{19}=3 \times 0.000012=0.000036 \text{ h.}=0.1296 \text{ ,,}$$
$$4 \times P_{20}=4 \times 0.000004=0.000016 \text{ h.}=0.0576 \text{ ,,}$$
$$5 \times P_{21}=5 \times 0.000001=0.000005 \text{ h.}=0.0180 \text{ ,,}$$

0.9108 sec.

or according to Mr. Milon's approximate formula*:

$$T=\Sigma\Sigma P_{x+1}= P_{x+1}\frac{1}{\left(1-\frac{m}{x+2}\right)^2}=\frac{0.000118 \times 9 \times 3600}{4}=0.9558 \text{ sec.}$$

and we see that *the total waiting time of all delayed calls does not yet reach one second.*

It is therefore interesting to examine the true signification of the formula

$$S=M\,\Sigma P_x\frac{N-x}{N-m}$$

We will have

$$P_x\frac{N-x}{N-m}=C_N^x\, t^x(1-t)^{N-x}\frac{N-x}{N-m}=$$

$$=\frac{N(N-1)\ldots(N-x+1)}{x!}\,t^x(1-t)^{N-x}\frac{N-x}{N(1-t)}=$$

$$=\frac{(N-1)(N-2)\ldots\ldots(N-x)}{x!}\,t^x(1-t)^{N-x-1}=C_{N-1}^x\,t^x(1-t)^{N-x-1}$$

which is Mr. Lely's formula, *i.e.*, the probability that a subscriber finds x lines busy.

We will have also

$$P_{x+1}\frac{N-x-1}{N-m}=C_{N-1}^{x+1}\;t^{x+1}(1-t)^{N-x-2}$$

and we will obtain

$$\frac{S}{M}=\Sigma P_x\frac{N-x}{N-m}=\Sigma C_{N-1}^x\,t^x(1-t)^{N-x-1}$$

or

$$\frac{S}{M}=\Sigma P_x$$

where P_x corresponds to Lely's formula.

* Idem, p. 481.

7. Another error has been made in estimating the time x lines are engaged in a Strowger type system by assuming that this time lies between P_x and $\frac{1}{2}\Sigma P_x$.* This time must always be superior to P_x, as shown by the formulæ (8) and (9). By considering again the above numerical example we obtain:

$$\frac{1}{2}\Sigma P_x = \frac{1}{2} P_x \frac{x+1}{x+1-m} = \frac{17}{22} P_x$$

The engaged time of the 16 lines in the Strowger system would therefore be smaller when the number of switches is limited to 16 than in case the number of switches is unlimited, which is obviously impossible.†

By using the other approximate formulæ of Mr. Milon we obtain for the time x lines are engaged in a W.E. system:

$$\pi_x = P_x + \Sigma P_{x+1} = P_x\left(1 + \frac{m}{x+1-m}\right)$$

and in a Strowger system:

$$\pi_x = P_x + \frac{1}{n}\Sigma P_{x+1} = P_x\left(1 + \frac{1}{n}\frac{m}{x+1-m}\right) \text{ where } n > 1.$$

This value n has to be determined.

In case of the W.E. systems we would have for the total waiting time of the delayed calls

$$T = \Sigma\Sigma P_{x+1} = P_{x+1}\left(\frac{x+2}{x+2-m}\right)^2$$

which may also be considered as giving the part of the total circuit time occupied in carrying all calls through, lost by the fact of the number of switches being limited to x. In a Strowger system the total duration of the lost calls will be:

$$P_{x+1}\left(\frac{x+2}{x+2-m}\right)^2 + \frac{n-1}{n}\Sigma P_{x+1}$$

because ΣP_x, ΣP_{x+1}, ΣP_{x+2}, etc., being the total time the xth, $x+1$th, $x+2$th, etc., line is engaged when the number of switches is unlimited, we shall have in a Strowger system, when the number of switches is limited to x, that the xth line loses a part of the above mentioned engaged time equal to

$$P_x + \Sigma P_{x+1} - \left(P_x + \frac{1}{n}\Sigma P_{x+1}\right) = \frac{n-1}{n}\Sigma P_{x+1}$$

and the total of the lost parts of the engaged time will therefore be:

$$\frac{n-1}{n}\Sigma P_{x+1} + \Sigma P_{x+1} + \Sigma P_{x+2} + \dots = \frac{n-1}{n}\Sigma P_{x+1} + \Sigma\Sigma P_{x+1}$$

* Idem, p. 483.

† Idem, p. 485, 486; where this time is taken equal to 0.00025 whereas P_x= 0.00027.

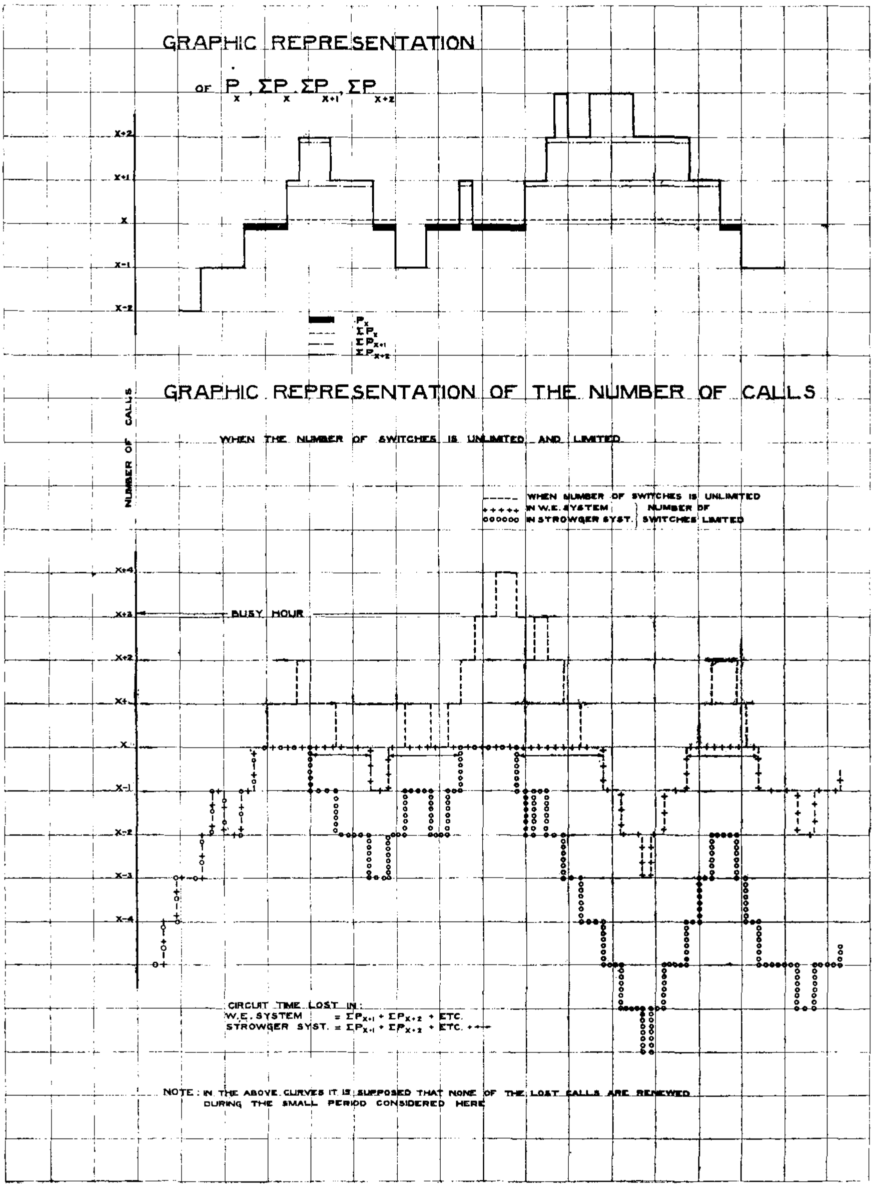
or by using Mr. Milon's approximate formula, this lost time will be:

$$P_{x+1}\frac{x+2}{x+2-m}\left(\frac{x+2}{x+2-m}+\frac{n-1}{n}\right)$$

while in the W.E. it will be:

$$P_{x+1}\left(\frac{x+2}{x+2-m}\right)^2$$

(See graphic representation)



and the conclusion is, therefore, that the engaged time lost through the limitation of the number of switches is greater in the Strowger systems than in the W.E. systems.

On the other hand we shall come to the conclusion that the number of properly lost calls in the systems of the Strowger type is smaller than the number of delayed calls in the systems of the W.E. type, but these two quantities expressed in *different units* should not be compared. The calls which are renewed immediately could moreover with reason be considered as delayed calls.*

Numerical example.

By taking the same values as used in the preceding paragraph, we have for the engaged time lost by the limitation of the number of switches to x in a W.E. system.

$$\Sigma\Sigma P_{x+1} = \frac{0.000118 \times 9 \times 3600}{4} = 0.9558 \text{ sec.}$$

and in a Strowger system by assuming $n=2$

$$P_{x+1} \frac{x+2}{x+2-m}\left(\frac{x+2}{x+2-m} + \frac{n-1}{n}\right) = 0.000118 \times \frac{3}{2}\left(\frac{3}{2} + \frac{1}{2}\right)$$

$$3600 = 1.2744 \text{ sec.}$$

It may be well to state that the difference between these systems from the point of view given above is more of theoretical than of practical interest, the difference being often smaller than the small error made by using any approximate formula.

(To be continued)

THE ANGLO-DUTCH TELEPHONE CABLE.

By E. F. PETRITSCH,

Of the Netherlands Telegraph and Telephone Service.

A COIL-LOADED submarine cable was laid between England and Holland at the end of June, 1922, by the British Post Office. The landing places are Aldeburgh on the English and Domburg on the Dutch coast. As regards construction, this cable belongs to the Anglo-Irish type, which was first used in 1913 for the connection of Nevin with Howth. (For Anglo-Irish cable see pages 381-383 of Vol. 6, Part 4, Jan., 1914, of this Journal). The same type of

* Practically the number of switches is sufficient to reduce the waiting time of all delayed calls in a system of the W.E. type to such a small value that this delay is usually not noticed by the subscriber. In the systems of the Strowger type all surplus calls have to be renewed.

cable, but somewhat improved, was used in 1918 between Dover-Sangatte II. and Dungeness-Audrecelles II. (See the article by Sir William Noble, "The Long Distance Telephone System of the United Kingdom," in the Journal of Electrical Engineers, Vol. 59, No. 300, April, 1921). The length of the three last-named cables is 63.3, 21.0 and 27.6 naut. miles respectively.

The new Anglo-Dutch cable is 82.329 naut. miles long.

It is the longest submarine coil-loaded cable that has, as yet, been laid.

Each of the four conductors of the cable weighs 160 lbs. per naut. mile, and the dielectric of each conductor 150 lbs. From the above it may be concluded that the direct current resistance per naut. mile amounts to 7.1 ohms at an average water temperature of 12°C, and the wire to wire capacity to 0.164 mfds. The two side circuits and the phantom circuit are loaded with coils placed one nautical mile apart. The first loading-point is placed exactly half a nautical mile from Aldeburgh, whereas the distance of the last, that is the 82nd loading-point, is 0.805 naut. mile from Domburg. The inductance of the coils is 100 millihenries for the side and 50 millihenries for the phantom circuit, the direct current resistance of same about 6.2 and 3.1 ohms respectively.

Taking into consideration that the capacity of the phantom is twice as great as the wire-to-wire capacity, the constants of the completed cable per naut. mile are as follows:—

For the side circuit.	For the phantom circuit.
$R_{DC} = 20.4$ ohms.	$R_{DC} = 10.2$ ohms.
$C = 0.164$ mfs.	$C = 0.328$ mfs.
$L = 0.100$ henries.	$L = 0.050$ henries.
$\sqrt{\frac{L}{C}} = 780$	$\sqrt{\frac{L}{C}} = 390$
$\omega_0 = \frac{2}{\sqrt{LC}} = 15600$	$\omega_0 = \frac{2}{\sqrt{LC}} = 15600$

$\omega_0 = 2\pi f_0$ where f_0 is the natural, *i.e.*, cut-off frequency. (See the article by J. G. Hill on pages 11-30 of Vol. 16, Part 1, April, 1923, of this Journal).

The constant $tg\delta$, which is decisive for the value of the leakance, *i.e.*, of the dielectric losses ($G = \omega C tg\delta$), can, in the present case, where the dielectric is made of specially treated gutta-percha, be taken as $tg\delta = 0.0039$.

From the landing-place on the Dutch coast, a series of measurements and tests have been made, the results of which throw a good light on the characteristics of such a cable, and, at the same time, also offer approximate means of seeing how far the observed characteristics coincide with the theory.

The following points were investigated:—

(1) The change of the velocity of propagation of the current with increasing frequency, or rather, the changes in the retardation angle (82α) prevailing over the whole length of cable—82 coil-sections.

(2) The increase in attenuation with augmenting frequency, and further the share in this phenomenon of:

(*a*) The iron-loss in the loading-coils.

(*b*) The losses in the dielectric.

(*c*) The reflection losses.

The last-named is caused by the fact that we are dealing here with a line which, similar to a filter circuit, is made up of capacities and inductances.

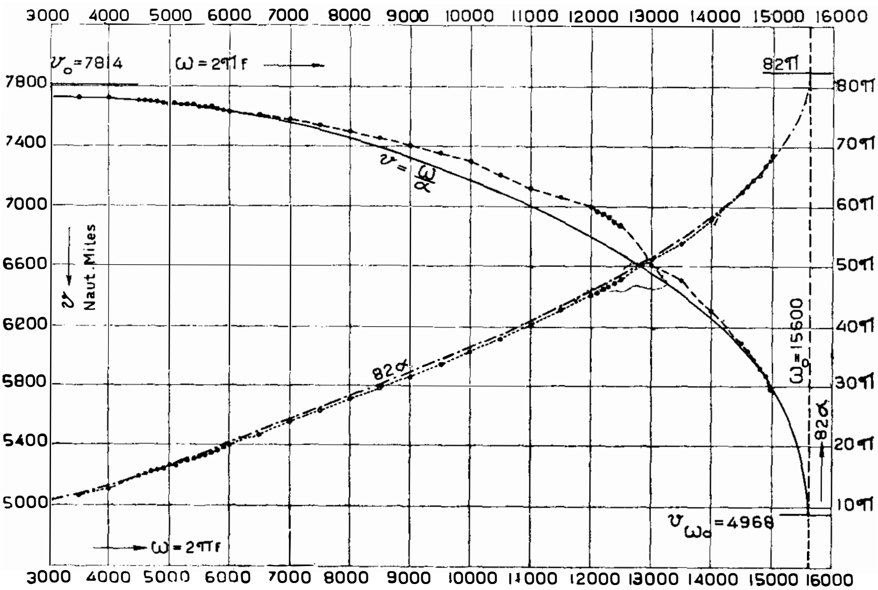


FIG. 1.

(3) The shape of the characteristic impedance curve during a run of frequency up to and over the cut-off point. In this connection tests were made to discover the causes of the irregularities in the shape of the characteristic impedance.

(4) Cross-talk and overhearing.

In taking the measurements necessary for the investigations mentioned under (1)—(3), the method described by M. A. H. de Voogt (Pupin Cable Measurements, *Electrician*, No. 2361, 17th Aug., 1923) was followed.

(1) VELOCITY OF PROPAGATION.

In Fig. 1 are plotted

(*a*) The values of the velocity of propagation $v = \frac{\omega}{\alpha}$ in naut. miles per second corresponding to the individual frequences.

(*b*) As a counterpart to the above the retardation angle 82α (which corresponds to the whole cable length) in multiples of π. The calculated values are given by the smooth curves. The frequencies at which values were measured are marked by a circle. The measurements were made on the side circuit which is formed by wires 1 and 3 of the cable in question.

The observed values show small deviations from the normal and certain irregularities.

The retardation angle per coil section α was calculated by the formula

$$\sin\frac{\alpha}{2} = \frac{\omega}{\omega_0} = \frac{f}{f_0}.$$

This relation is derived from J. G. Hill's already quoted paper formula (4), page 15, which is changed into

$$\cos\alpha = 1 - 2\left(\frac{\omega}{\omega_0}\right)^2$$

taking into consideration that θ, neglecting the losses, is a purely imaginary value.

If, however, we make use of the more accurate formula (2) in the above mentioned paper, page 14, then we get smaller values for α with a corresponding higher value for v. This coincides well with the result of measurements made within the range of frequency up to $\omega = 12500\left(\frac{\omega}{\omega_0} = 0.80\right)$. In accordance with the theory this deviation should, however, increase as we approach the natural frequency. (See the table at the head of page 18 in J. G. Hill's article.) The measurements taken do not confirm it. But the determination of α in the proximity of the cut-off point is so difficult that the results of measurements cannot be considered as reliable.

If the inductance of the coils should be distributed continuously along the whole cable line, then the current at any frequency would be propagated with the same speed $V_0 = \frac{1}{\sqrt{LC}}$ which gives in the present case a velocity of 7814 naut. miles a second.

Fig. **2** shows the variations of open and short circuit impedances of the phantom measured between $\omega = 5000$ and $\omega = 7000$. The frequencies at which the retardation angle of the whole line, 82α, should in accordance with the theory become a multiple of π, are marked in the figure. The upper part of the graph contains the imaginary and the lower the real component of the measured impedances. The characteristic impedance Z_0, resulting from the same, is also shown.

The coincidence with the theory is not particularly good in the case in question, but there are also a great many deviations and irregularities noticeable. This is chiefly due to the fact that, in the present instance, the phantom line is provided at both ends with repeating coils, and consequently reflections from the ends are observed. This matter will be gone into more fully later. Fig. **2** also shows how difficult it is to determine the angle of retardation even in the case of low frequencies.

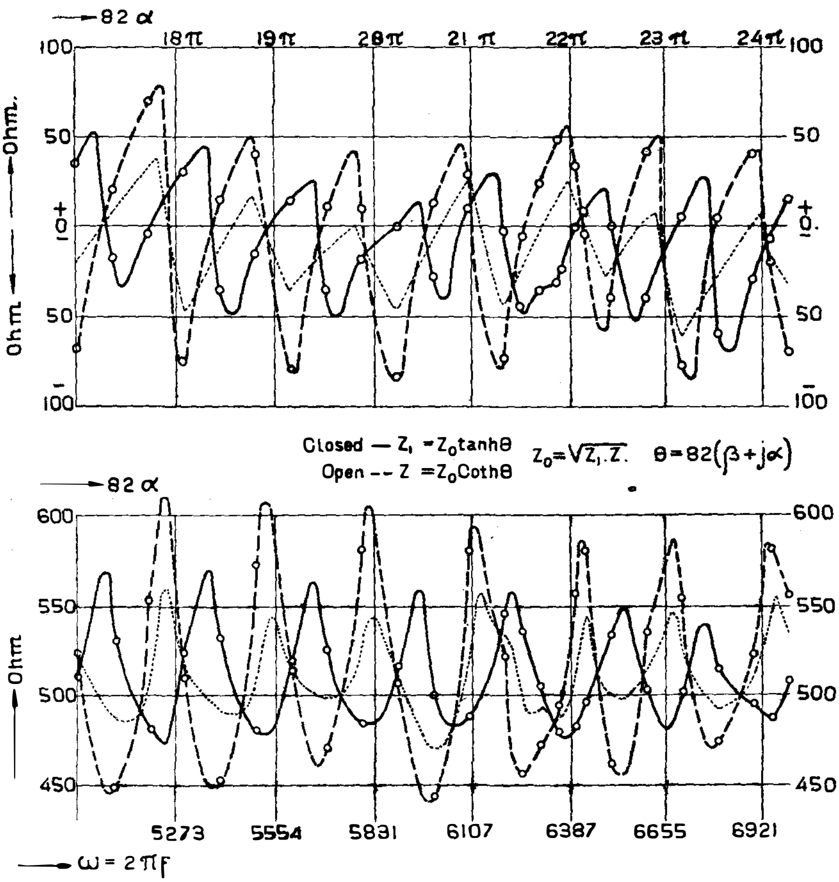
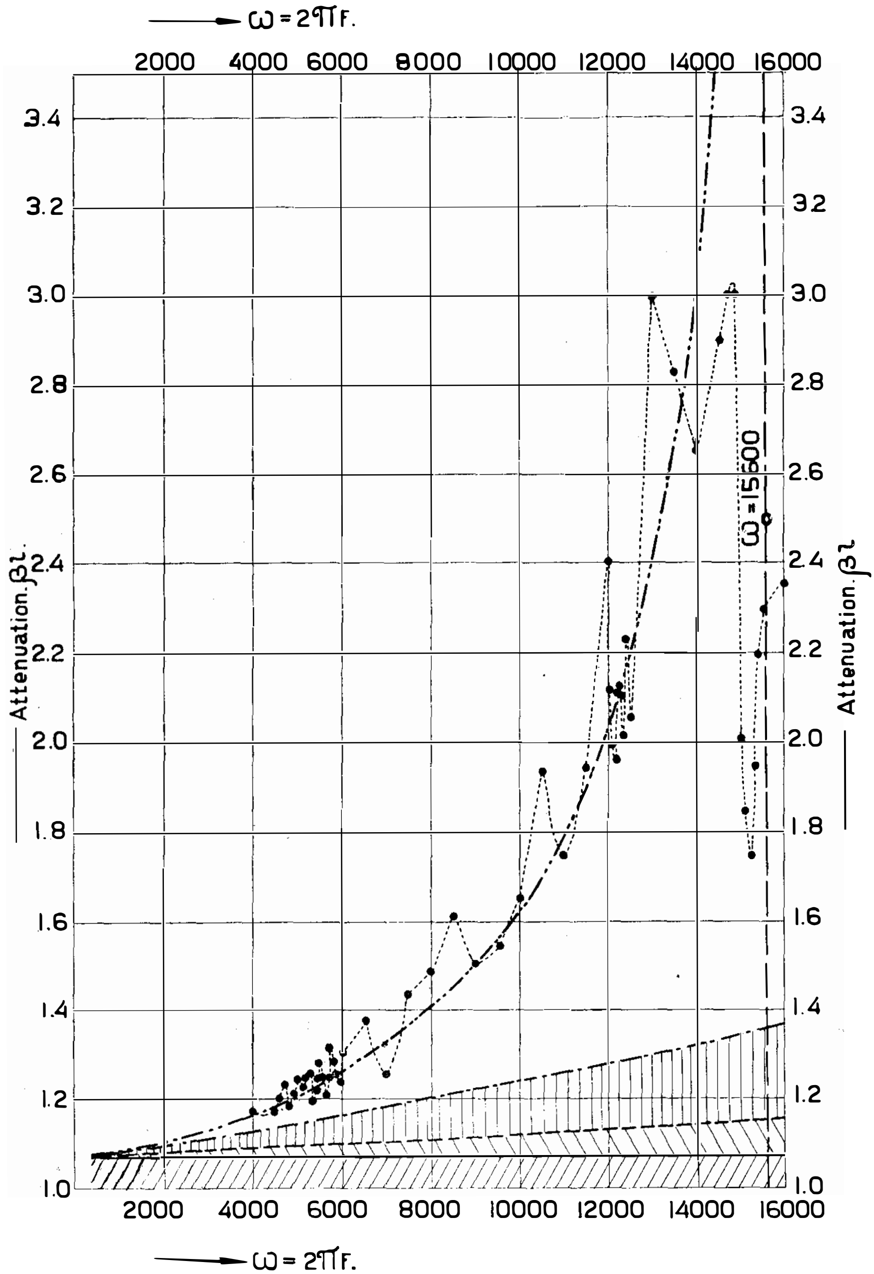


Fig. **2**.

(2) Attenuation.

Fig. **3** contains the calculated and measured values of the attenuation βl (in the present case 82 β) for the side circuit (core 1 and 3).

Further more calculations were made from the primary constants of the line:



Resistance loss ————————

Iron losses — — — — — —

Leakance loss — · — · — · — · —

Calculated total attenuation — · · — · · — · · —

Measured attenuation . . . .

FIG. 3.

$$(a)\quad 82\,\frac{R_{DC}}{2}\sqrt{\frac{C}{L}}$$

which represents the share of resistance in the attenuation, neglecting all the other losses:

$$(b)\quad 82\,\frac{\Delta R}{2}\sqrt{\frac{C}{L}}$$

which gives the iron losses to be expected in the coils. The calculation of Δ R, which increases with the frequency, is based on the formulæ given in the article by Speed and Elmen (Journal of the American Institute of Elect. Engineers, Vol. XL., No. 7, July, 1922) assuming that the flux density is very small.

As is to be seen in Fig. **3**, the iron losses play a very insignificant part in the whole attenuation.

$$(c)\quad 82\,\frac{G}{2}\sqrt{\frac{L}{C}}$$

where $G=\omega C tg\delta$. This equation represents the losses of leakance. They are somewhat larger than the iron losses, but also of little importance in the case in question.

If no further losses are to be added, the whole attenuation would consist only of the sum of these three components, and be represented by

$$82\,\beta'=82\left(\frac{R_{DC}+\Delta R}{2}\sqrt{\frac{C}{L}}+\frac{G}{2}\sqrt{\frac{L}{C}}\right)$$

But here in the case of a coil-loaded cable reflections have to be taken into account, which increase as $\sin\frac{a}{2}$ deviates from $\frac{a}{2}$.

The total attenuation to be expected would accordingly be

$$(a)\quad 82\,\beta=82\,\beta'\times\frac{1}{\sqrt{1-\left(\frac{\omega}{\omega_0}\right)^2}}$$

This is the rapidly increasing line shown in Fig. **3**.

The reflection losses are small in case of low frequencies, smaller even than the losses in iron or in the dielectric; they increase however greatly in case of higher frequencies.

If ω has the value $\omega=13550$ $\left(\frac{\omega}{\omega_0}=0.867\right)$, we find $\beta=2\,\beta'$, this means that the reflection losses will double the attenuation of the cable and in the case of the natural frequency β approaches the value ∞.

The measured values of the attenuation agree fairly well with the calculated values as long as it is not a question of frequency in the proximity of the cut-off point.

Remarkable is the circumstance that the attenuations, recorded by the measurements, are sometimes larger, sometimes smaller, than they ought to be conformable to the theory. It looks as if in reality the attenuation of such a loaded cable was subject to periodical variations. A similar picture is shown by Fig. 1 in J. G. Hill's often-quoted article. It therefore seems proper to go into the question as to what can be the cause of these variations.

According to the very detailed investigations on coil-loaded cables made by K. W. Wagner and Küpfmüller (Arch. of Elektr., Bd. IX., 1921, pages 478-479) irregularities in the construction of such cables should exercise no influence worth mentioning on the propagation constant θ, both in respect of α and of β.

It is true that through such irregularities the shape of the characteristic curve is influenced, the attenuation, however, ought to increase uniformly and not in an undulating manner. If there are actual undulations in the attenuation curve, the cause must be looked for in varying, increasing and decreasing losses of energy, occasioned likewise by induction effects on neighbouring cable conductors or on the cable covering, *i.e.*, lead sheath or iron armouring.

On investigating this matter further, one comes to the conclusion that the measured variations are much too great to be explained in this way. In the case of measurements made by the author on multicore cables at frequencies where a maximum loss of energy was to be expected on account of cross-talk, it was found that these losses of energy were immeasurably small.

And just in the case in question, it is almost impossible for the measured undulations of the attenuation to be caused by such losses. For we have a cable consisting simply of 4 wires with gutta-percha as dielectric, and it was ascertained that the induction effects of one pair of wires on the other was too small to be measured.

Overhearing from side to side circuit was found to be over 100 M.S.C., *i.e.*, over $\beta l = 10.6$, with angular velocities up to $\omega = 15000$.

It may therefore be supposed that, in carrying out the measurements, some condition necessary for the obtaining of quite exact attenuation values has been neglected.

One of these conditions is the making of the measurements at all frequencies with the same strength of current. This condition is rather difficult to obtain in making measurements by the short and open circuit method. It can accordingly happen that, in the case of the measurements with several frequencies, there is quite a different distribution of current and voltage along the cable. The characteristics of the coils are largely dependent on the strength of the current; the self-induction changes slightly and the resistance loss considerably (Speed and Elmen, Wagner and Küpfmüller, *loc. cit.*). As has been ascertained, the attenuation can, under these circumstances, be augmented by 10 per cent. (See J. G. Hill's book, "Telephonic Transmission," Fig. 103,

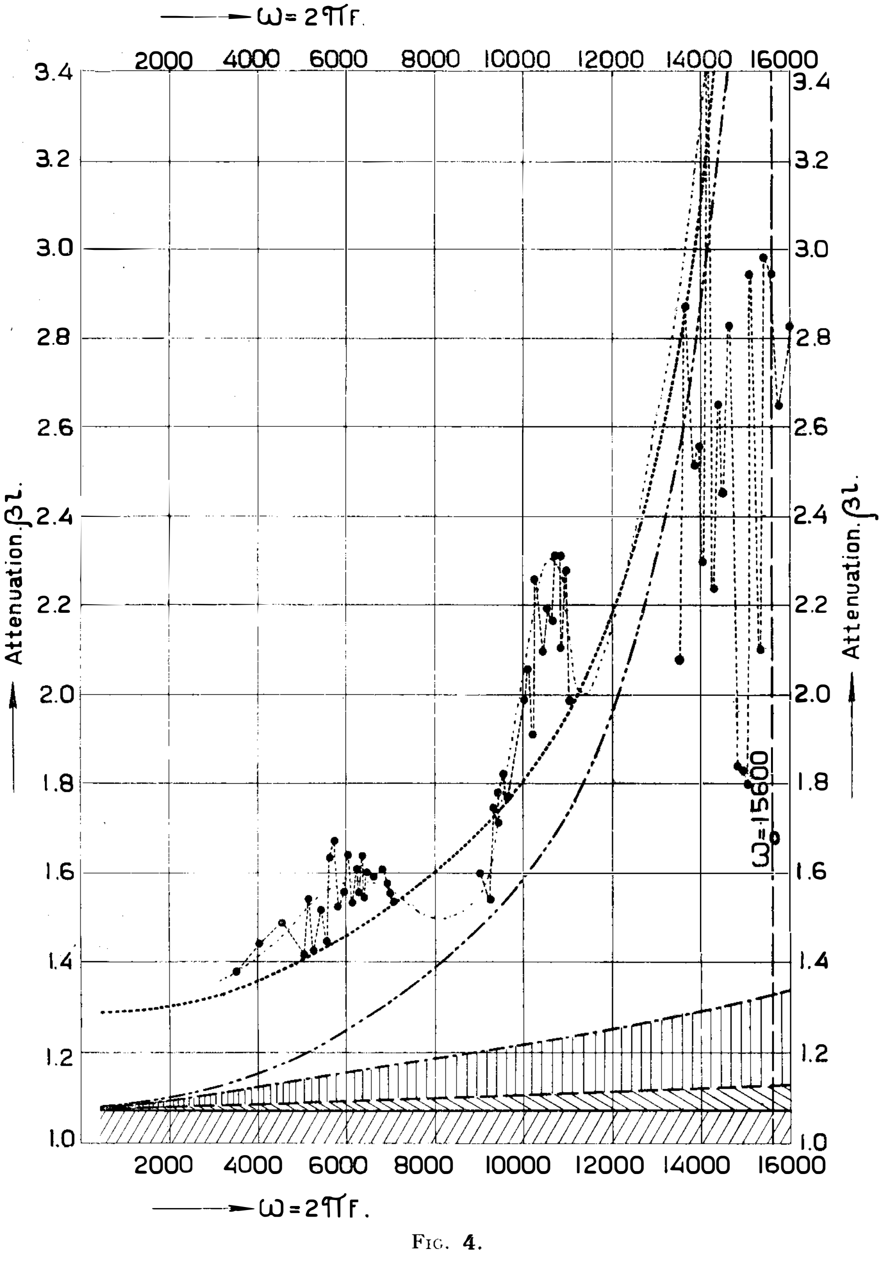


Fig. 4.

page 196.) The observed fluctuations lie all within this range. Measurements on other coil-loaded cables have shown that smaller variations in the attenuation are to be observed when greater care is taken to keep the strength of the current as constant as possible in measuring. All these circumstances confirm the supposition.

Fig. 4 gives the measured attenuation of the phantom. In addition are calculated for the phantom, in the same way as for the side circuit, the losses due to D.C. resistance, hysteresis and eddy currents, leakance and reflections, and shown in dotted lines.

As the phantom was provided on both sides with repeater coils (Western Electric Co. 4006/A), the losses in the repeating coils are to be added to the attenuation of the cable. These amount to about $\beta l = 0.065$ for each of the two-coil arrangements together, this makes accordingly $\beta l = 0.13$. From the measurements, however, the increase in attenuation caused by the termination of the cable with these coils, amounts, on an average, to $\beta l = 0.20$. Reflections are observed here in the repeating coils—of which mention has already been made in Section 1—which bring with them losses of energy to the extent of $\beta l = 0.07$. Such a loss is to be expected in a ratio of the characteristic impedance of the repeating coils Z_1 to the characteristic impedance Z_2 of the phantom $\frac{Z_1}{Z_2} = 1.65$, which also may fairly correspond to the reality. (See the article by the author, "Die Leistung ungleichartiger Fernsprechleitungen," Elektr. and Masch., 1916, Heft 45.)

The attenuation of the phantom obtained by measurements shows still greater variation than in the case of the side circuit. This is to be explained by the fact that, in the case in question, the result of the measurements is not only influenced by the variation of the properties of the loading coils due to fluctuations in the current, but that here also is to be added the same effect caused in the repeating coils. The measured attenuation values can therefore lay no great claim to exactitude. If, nevertheless, these results of measurements are published, it is done to draw attention to the difficulty one meets in making exact and reliable attenuation measurements with coil-loaded cables and repeating coils.

(3) THE CHARACTERISTIC IMPEDANCES OF SIDE AND PHANTOM CIRCUITS.

Fig. 5 shows the variation of the characteristic impedances with frequency of the two side circuits. The fully drawn line (—•—•—) has reference to the measurement made on the loop, which was formed in such a way, that in Aldeburgh, where the cable ends in a half coil section, the cores 1 and 3 were connected to cores 2 and 4 respectively. In this way a cable of 164.658 naut. miles, provided with 164 loading coils, was available for making the measurements. The whole attenuation for this loop was therefore $\beta l = 2.2$ at $\omega = 3000$ and $\beta l = 3.0$ at $\omega = 10000$. On account of this great attenuation value no influence worth mentioning of reflections from one end to the other was to be feared. To obtain reliable measurement results, it seemed sufficient to close the ends of the wires (core 1—3) over an ohmic resistance, which during every single measurement was made equal to the real component of the characteristic impedance measured at the beginning of the line (core 2—4).

The dashed line (— — —) has reference to the characteristic impedance of the side circuit Domburg-Aldeburgh, formed of core 1—3, that is nearly of 82 coil sections. The corresponding curve

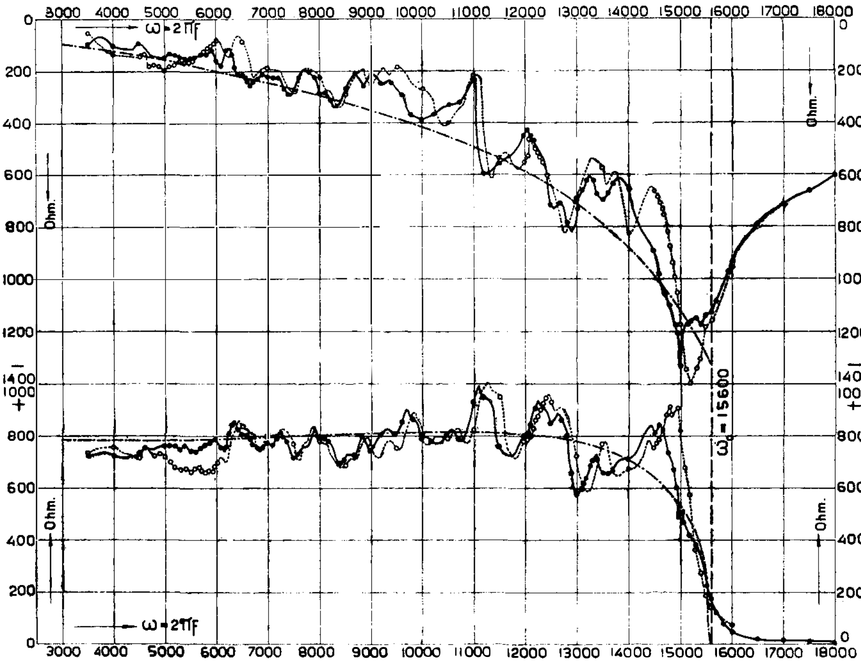


FIG. 5.

is calculated by the values obtained by open- and short-circuit measurements.

The upper part of Fig. 5 contains the imaginary, the lower the real component of the impedance; the values of both components are given in ohms.

The two characteristic impedances obtained in this way run with some variation almost parallel.

Straight through these two dotted curves, obtained by means of measurements, runs a smooth dash-dotted line (— · — · — ·). This line corresponds to the theoretical values of the characteristic impedance at various frequencies under the existing condition, *i.e.*, that the first coil is not placed at a distance of a half, but of 0.805 part of a coil-section.

The formulæ relative to this ideal impedance were first developed by R. S. Hoyt (Western Electric Co.'s British Specification 18018/1913, R. S. Hoyt and A. Taerd, American Patent Specification 1167693/1916, Siemens and Halske, German Patent Specification 330964/1920) in connection with G. A. Campbell's theory.

If $Z_0 = A + jB$ and X is the distance of the first loading-coil from the beginning, expressed in parts of a coil-section, the real component of the ideal characteristic impedance at the various circular frequencies $\omega = 2\pi f$, follows the law:

$$A = \sqrt{\frac{L}{C}} \times \frac{\sqrt{1 - \left(\frac{\omega}{\omega_0}\right)^2}}{1 - 4X\left[(1 - X)\left(\frac{\omega}{\omega_0}\right)^2\right]}$$

and for the imaginary component

$$B = \sqrt{\frac{L}{C}} \times \frac{(1 - 2X)\frac{\omega}{\omega_0}}{1 - 4X\left[(1 - X)\left(\frac{\omega}{\omega_0}\right)^2\right]}$$

Although it is here a question of merely simplified formulæ, it is to be seen from Fig. **5** that the values of the measured characteristic impedances follow very closely the theoretically calculated values. Nay, one is even in a position to determine from the measured values of the characteristic impedance with an exactitude of 1% the distance of the first loading-coil from the beginning of the cable.

Fig. **6** shows the course of the characteristic impedance of the phantom, calculated from open and short-circuit measurements. As already mentioned, the phantom was provided, both at the beginning and end, with Western Electric repeating coils 4006A. The submarine cable had to be joined provisionally at both landing-places to aerial lines, for which as usual three repeating coils at both ends of the circuit were used (one each for the two side circuits and one for the phantom). The terminals 4 and 2 of these coils were connected with the submarine cable, the terminals 2 and 5 led to the aerial wires, or rather to the testing equipment. The curve of the ideal characteristic impedance for the phantom, which was calculated from the formula given above, is also indicated in this case by a dash-dotted (— · — · —) line.

We see from this graph that the connection of the repeating-coils on the submarine cable raises the values of the real component of the characteristic impedance in the ratio 1 : 1.3 and on the other hand considerably flattens the curve of the imaginary component.

This seems to be advantageous when the question is the connection of aerial lines to the cable. The characteristic impedances at the point of junction thereby become approximately equal.

Not desirable on the other hand is another phenomenon connected with the repeating coils, to which reference has already been made in the two earlier sections: the appearance of reflections at the end of the cable.

These reflections show themselves here in the form of periodical undulations of the real and imaginary component of the characteristic impedance.

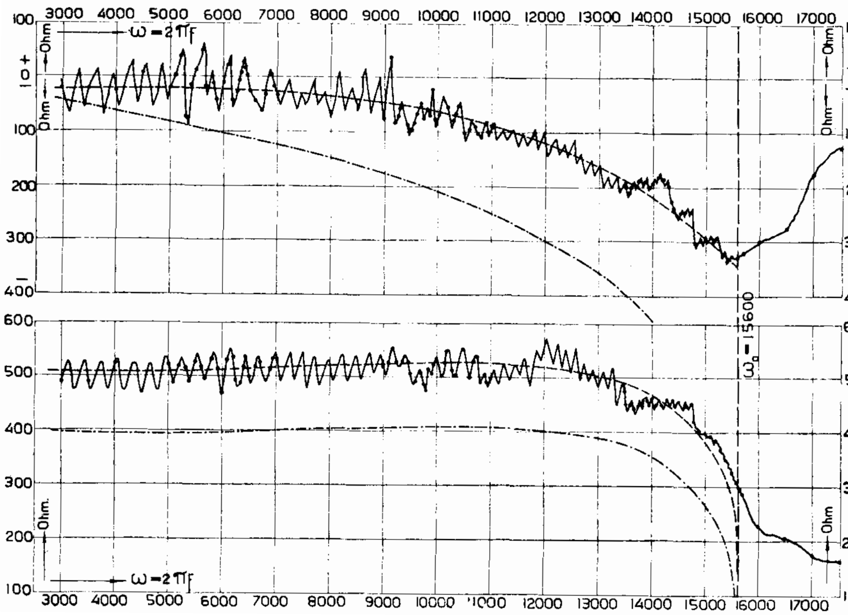


Fig. 6.

The intervals, in which these undulations follow each other, depend on the value of $m\alpha$, the retardation angle of the length of cable lying between the discontinuity which cause the reflections and the beginning of the circuit. m is therefore the number of coil-sections falling on this part of the cable. One undulation follows the other in intervals which correspond to the increase of $m\alpha$ with the amount of $\pi = 180^\circ$. In the present case a careful examination of the measured characteristic impedance shows that the intervals, in which the undulations follow each other at the various frequencies, represent an angle of about 2.2°. From this must be concluded that the discontinuity, which causes the undulations, lies behind $m = \frac{180^{\circ}}{2.2} = 82$ coil-sections, that is, in the case in question at the end of the cable where the repeating coils are connected.

The attenuation $m\beta$, which is due to the part of the circuit between the discontinuity and the place of measurement, has, of course, a great influence on the amplitude of the undulations. The variations always arise from waves, which are thrown back from the place where a discontinuity exists. The greater the attenuation experienced by the wave thrown back in covering the way from the existing discontinuity to the beginning of the cable, the smaller the influence it can exert on the shape of the impedance curve.

It is true that for the amplitude of the undulations the absolute value of α plays also a part. With rising values of α, that is with an increasing frequency, the amplitude of the variations becomes greater. In case of defects and discontinuities, lying not far from the beginning of the cable, the influence of α is predominant, and the amplitude of the variations becomes ever greater with increasing frequency. With such discontinuities, lying far from the beginning of the cable, the influence of the attenuation $m\beta$ is predominant and the amplitude of the undulations diminishes as the frequency increases. (See in this connection the article by Wagner and Küpfmüller, *loc. cit.*, and by the latter the article in Telegraphen und Fernsprechtechnik, IX., 1922, No. 6, June, 1922).

In the case in question a decrease of the amplitude of the undulations with higher frequencies is clearly to be noticed. This is evident, considering that the attenuation βl is 1.2 at $\omega = 5000$, whereas nearly 2.4 at $\omega = 1300$ and increases so rapidly that in the neighbourhood of the cut-off point the influence of the reflected waves becomes imperceptibly small.

In addition to this variation, occurring with fairly regular periodicity, the characteristic impedance of the phantom shows other small irregularities, which, in their periodicity, correspond fairly closely with the typical irregularities of the characteristic impedance of the side circuits.

Let us therefore consider again the characteristic impedance of the side circuits, and try whether, from their values, any conclusion can be drawn as to the presence of irregularities in the construction of the cable.

In this connection it seems advisable to restrict ourselves to an investigation of the real component, the shape of which is given again in Fig. 7.

At the same time are shown in this figure those frequencies which must especially be taken into consideration concerning the reflections caused by irregularities in one of the first 12 coil-sections ($m = 1, 2, 3 \ldots . 12$) being those where $\frac{m\alpha}{2} = \pi$ or a multiple of π. With these frequencies the value of cos $m\alpha$ is alternately 0 or 1, which values are indicated in the graph by white and black circles respectively.

From this survey is to be seen at first glance that the observed irregularities in the run of the characteristic impedance have a certain relation to these frequencies. In general the amplitude of the undulations with increasing frequency and increasing α becomes larger, while on the other hand the variations of smaller periodicity disappear more or less with the higher frequency. When the cut-off point is approached only a few undulations succeeding each other in large intervals remain. The variations of small periodicity are caused without doubt by reflections from the more distant coil-sections, the others from the coil-sections at the beginning of the circuit. The properties of the first loading-

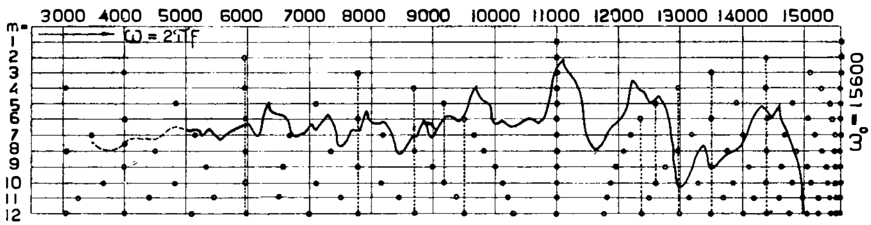


FIG. 7.

coils and loading sections are therefore chiefly responsible for the shape of the characteristic impedance curve.

On account of the small number of variations observed in the characteristic impedance, there can be no question of faults in the cable. The first variation with a considerable amplitude is observed when $\omega = 11040$, that is exactly the frequency where, for all coil-sections, $m = 1, 2, 3, 4 \ldots . 164 \; \frac{m\alpha}{2} = \pi$ or a multiple of π. Reflections, whether originating from either a loading-coil or a coil-section exercise therefore round about this particular frequency a specially great influence on the form of the characteristic impedance.

If one forms the ratio of the difference to the sum of the measured to the ideal line impedance, then all the values so obtained between $\omega = 3500$ and $\omega = 13000$ lie under 0.10. When $\omega = 13100$ the ratio rises to 0.128 and attains the highest value when $\omega = 14600$ with an amount of 0.155. These are very small values, which make it probable that the cable can be used without difficulties in connection with 22 type telephone repeaters.

The attempt to discover, by means of a detailed analysis of the observed deviations, whether these originate from small irregularities in the inductance of the loading-coils or in the capacity of the coil-sections, and still more the exact determination of the position of these irregularities in the cable, meets with many difficulties. For it is here a question of very small influences exercised by 164 loading-coils and just as many coil-sections, acting very differently.

Still, some undulations appear again and again in a similar form with such regularity that one is inclined to trace them back to one and the same cause. Thus, in the range of the lower frequencies from $\omega=3500$ to about $\omega=11000$, there appears an undulation which becomes smaller and smaller, the periodity of which corresponds to an angle of 2.8° to 3.0°. This would lead to the conclusion that here an influence prevails emanating from one of the loading-coils or from one of the coil-sections, lying about 60 to 64 naut. miles from the beginning of the cable. Now it is a fact that the 19th coil-section from Aldeburgh, that is the 61st from the test hut in Domburg, was faulty and was changed after the laying of the cable. A piece of cable 24 metres long was added. Consequently a very small irregularity in the cable really exists at this point. The observed undulation is so insignificant that it could really be traced back to this small irregularity; the circumstance that the influence of this disturbance is no more noticeable in the case of the higher frequencies also bears out the supposition that it proceeds from a faulty distant coil-section.

In the case of higher frequencies, the influence of the loading-coils and coil-sections at the beginning of the circuit seems to predominate. The great undulation round about $\omega=14600$ seems to point to an influence of the 4th or 5th coil-section, that leads one to suppose that there is a very small irregularity at the point where the joint near the coast was made. Moreover still small influences seem to make themselves felt, emanating from the 7th, 11th or 12th and from the 23rd or 24th loading-coil or coil-section. But the prevailing conditions are so complicated—as already mentioned—that only a guess can be made. Greater deviations between the electric constants than 0.002 henry for the coils and 0.002 mfs. for the coil-sections do not seem to occur.

In conclusion, it is worth remarking that, as is to be seen from Figs. **5** and **6**, the imaginary component of the characteristic impedance attains its highest value before the natural frequency $\omega=15600$ is reached, while, on the other hand, the real component only slowly approaches the value θ after the cut-off point.

(4) Over-hearing and Cross-talk.

For the determination of over-hearing and cross-talk at the beginning of the cable the connections proposed by K. Küpfmüller in his article " Abgleichverfahren " (E.T.Z. 1923, Heft 20, Figs. 30 and 31) were used. The end of the cable was terminated by Western Electric repeating coils 4006A, the secondary coils of which on the land side were closed by resistances about equal to the characteristic impedance of the side and phantom circuits respectively 800 ohms and 400 ohms.

The characteristic impedance of the artificial line used for measuring amounted to 600 ohm, a value which lay therefore exactly in the middle between that of the characteristic impedance of the side-circuit and of the phantom.

Over-hearing from side-to-side circuit—as already remarked in Section 2—was smaller for all frequencies than 100 M.S.C.,

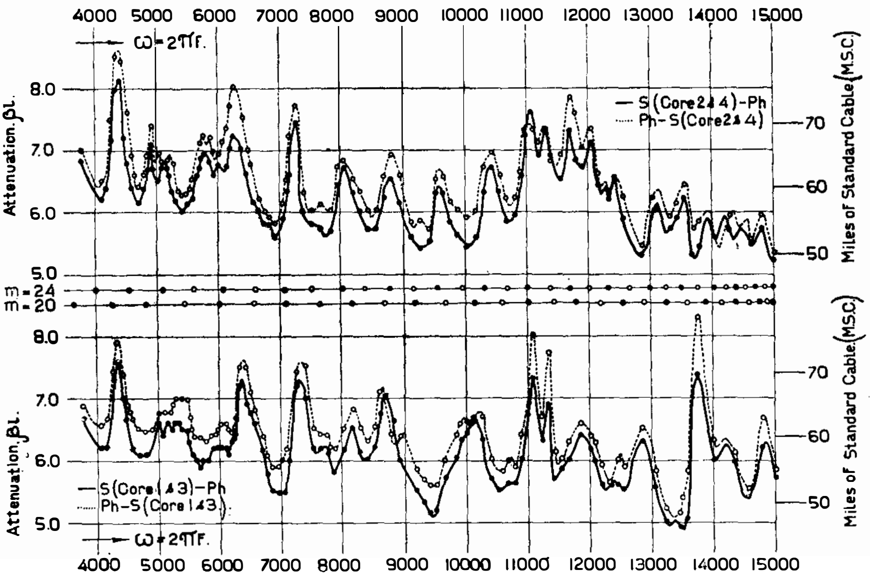


FIG. 8.

i.e., $\beta l = 10.6$. The result of the measurements of cross-talk are given in Fig. **8** from phantom to the side-circuits and *vice versa*. It will be seen that cross-talk also shows, similar to the characteristic impedance, peculiar periodically returning undulations with the various frequencies.

From the theory developed of late years relative to the various influences and circumstances which play a part in cross-talk (see Lichtenstein, E.T.Z. 1920, page 188-208, Breisig E.T.Z. 1921, page 933, Küpfmüller, Archiv. f. Elecktr. XII. 1923, 2 Vol. Wehage Zeitschrift für Fernmeldetechnik 4 Jahrg. 1923, Vol. 4) results that such variations of the cross-talk really exist. They are therefore by no means errors of testing, nor may they be traced back merely to incorrect termination of the cable at the end. The observed variations can certainly not proceed from reflections from the end of the cable. The periodicity with which the undulations appear leads one rather to conclude that they are caused by a capacity coupling in the 20th or 24th coil-section.

The frequencies at which $\cos m\alpha = 0$ resp. 1 for these two coil-sections ($m=20$ and $m=24$) are plotted and indicated by small white and black circles in the middle of the graph.

As is to be seen from Fig. **8** the cross-talk of the phantom to the two side circuits is very small, considering that we have to do with a submarine cable more than 82 naut. miles in length with gutta percha as dielectric. On an average it is smaller than 60 M.S.C. or βl 6.4.

We believe we have shown that the methods of testing at present at our disposal permit a very exact and thorough investigation of the properties of telephone circuits even if the conditions are as complicated as they are in the submarine cable considered.

In conclusion, the author wishes to thank Dr. W. Deutschmann for his assistance in making the measurements.

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM.

TELEPHONE STATIONS AND WIRE MILEAGES FOR EACH ENGINEERING DISTRICT AS AT 30TH SEPTEMBER, 1923.

Telephone Stations.	Overhead Wire Mileages.				Engineering District.	Underground Wire Mileages.				Submarine (Land miles).
	Telegraph.	Trunk.	Exchange.	Spare.		Telegraph.	Trunk.	Exchange.	Spare.	
385,906	610	4,100	60,448	479	London	20,859	36,613	1,366,369	42,455	
41,959	1,930	18,442	44,374	1,566	S.E.	3,569	14,127	75,450	14,724	
46,161	4,732	21,396	36,992	1,339	S.W.	13,233	2,412	74,178	2,441	
35,986	9,278	26,989	32,789	3,562	E.	11,350	15,128	36,481	21,715	
64,727	8,555	37,419	43,936	3,304	N. Mid.	11,064	17,230	105,291	52,595	
43,431	4,826	24,223	47,075	4,561	S. Mid.	6,607	6,561	86,659	75,719	
43,386	5,436	25,480	38,968	2,339	S. Wales	5,048	10,992	65,491	17,891	Returns made annually.
63,367	8,860	22,639	37,013	4,591	N. Wales	11,440	19,322	103,954	19,884	
105,958	3,070	15,812	45,615	3,424	S. Lancs.	11,048	45,013	253,433	37,946	
55,075	6,311	24,947	36,576	2,388	N.E.	6,026	16,138	108,940	20,491	
55,571	4,209	26,603	42,485	2,703	N.W.	8,945	19,745	103,308	15,180	
34,292	2,628	14,417	22,559	2,225	N.	2,322	7,382	52,285	3,562	
15,314	4,706	5,614	10,593	219	Ireland N.	141	57	27,464	105	
44,558	5,734	19,603	29,430	1,465	Scot. E.	1,508	5,220	75,711	3,169	
67,739	7,353	22,659	37,838	344	Scot. W.	11,742	15,351	169,175	25,943	
1,103,430	78,238	310,343	566,691	34,509	Totals.	124,902	231,291	2,704,189	353,820	
1,082,587	79,233	308,939	561,535	33,850	Figures on 30th June, 1923.	124,779	221,902	2,680,141	318,900	

HEADQUARTERS NOTES.

C.B.S. Nos. 2 and 3 SYSTEMS.

As a result of recent studies undertaken with a view to improving the C.B.S. System, a new design of equipment working on a loop signalling basis has been developed. This equipment is being standardised in two forms to be known respectively as "C.B.S. No. 2" and "C.B.S. No. 3." The former is for use in medium-sized exchanges up to 2, or at the most 3, operator's positions, while the latter is suitable for small exchanges up to 10 lines. The system that is being superseded will henceforth be known as "C.B.S. No. 1."

The need for a new design of equipment had become increasingly evident with the growing complexity of the junction arrangements necessitated by the differential earth signalling system, and it was largely on this account that a simplified system of working was sought.

Careful consideration of the problem led to the adoption of the following features:—

(1.) Standard junction signalling facilities.
(2.) "Loop" call and "disconnect" clear for local working.
(3.) Local battery speaking. Common battery speaking for the subscribers' instruments could not be justified.
(4.) High resistance signalling apparatus in order to reduce current consumption to a minimum to cover cases where the smaller switchboards are operated from primary cells.

The service conditions in the smallest exchanges do not warrant the same facilities as are provided in the larger ones and it was found economical to introduce two new systems, as follows:—

System.	Title of New Switchboard.	Title of C.B.S. No. 1 Switchboard which will eventually be superseded.
C.B.S. No. 2.	"Switchboard C.B.S. Junction and Local $\frac{5+20}{50}$."	"Switchboard Wall Junction and Local $\frac{5+20}{45}$."
	"Section Switch C.B.S. Junction and Local $\frac{30+60}{240}$."	"Section Switch Junction and Local $\frac{20+60}{140}$."
C.B.S. No. 3.	"Switchboard Wall C.B.S. Junction and Local $\frac{2+5}{22}$." *	"Switchboard Wall Junction and Local $\frac{2+4}{10}$."

* This board is primarily designed for exchanges with 1 junction and up to 10 subscribers. The extra junction equipment is provided as a "stand by" for use in case of faults and will very rarely be required for a second junction. Subscribers' line *capacity* beyond 10 is provided to meet exceptional requirements.

The accompanying photographs, for the use of which we are indebted to the manufacturers of the switchboards, Messrs. The British L.M. Ericsson Co., show clearly the general construction and disposal of the apparatus on switchboards C.B.S. Junction and Local $\frac{5+20}{45}$. (See Figs. **1** and **2**). It will be seen that the board is designed to stand on the floor against a wall and that access to its interior is gained by unlocking the front and swinging the same bodily forward from the back board, which carries the bulk of the apparatus. The relay rack is carried on a gate hinge

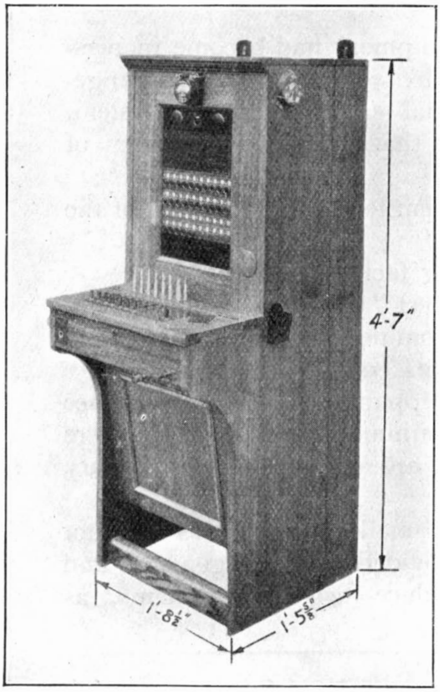


Fig. 1.—Switchboard, C.B.S. Junction and Local $\frac{5+20}{50}$. Closed.

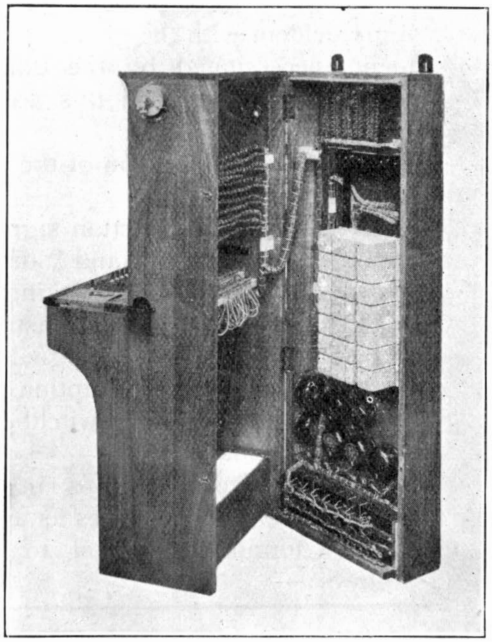


Fig. 2.—Switchboard $\frac{5+20}{50}$. Open.

and can be swung foward from the back board when access is required to the relay terminals and wiring.

The indicators fitted on the switchboard, both for the lines and for supervisory purposes on the cords, are somewhat similar to the well-known Western Electric Company's "sixpenny" signals which have been used extensively for many years as negative supervisory signals on several sizes of C.B P.B. X. switchboards. The visual shutter is practically identical, but its operation by the armature and the method of mounting the latter is entirely different.

Outlines of the indicators are shown on the accompanying sketch (Fig. 3) and photographs of the mounted items are reproduced on Figs. 4, 5 and 6. It will be seen from these illustrations that the armature is pivoted at the top end of the iron cover, to which it forms a tilted lid. A pin carrying a spiral spring passes through the core, and the spring (which is adjustable by means of a screw shown at lower end) maintains the armature in the tilted position and restores it after operation. On the top of the armature is carried an operating rod or pin which engages with a bent lug on the lower side of the shutter.

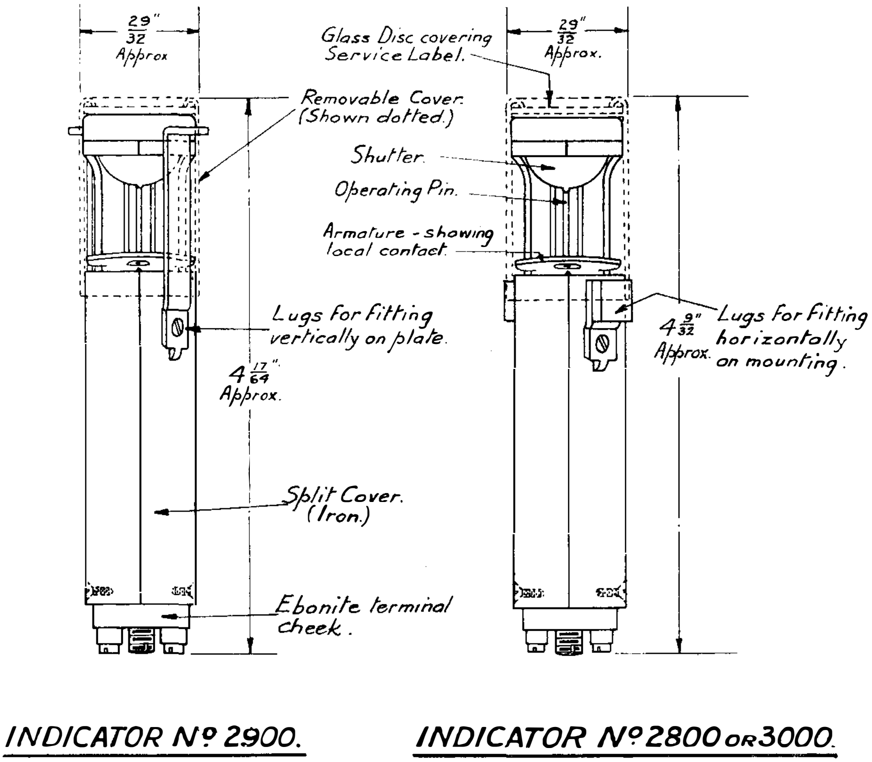


Fig. 3.

When the armature is attracted the long arm of the operating pin raises the shutter upwards and causes it to show white against the glass cover which closes the end of the slip-on cap. A label for service markings, shaped like a D, is secured between the top of the indicator and the glass.

The indicators are suitable for mounting either vertically on a plate—on the larger boards the supervisories are mounted in pairs on a common plate—or horizontally on a strip, which is fitted with lugs similar to those on a jack strip to be secured to the stile bars by standard jack fasteners. The illustration (Fig. 3) shows Indicators Nos. 2900 and 2800 or 3000. The former mounts vertically on the plate; the latter is secured to the front of the horizontal mounting by trapped screws which pass through the mounting and engage in the short lugs shown screwed to the side of the iron cover of the indicator.

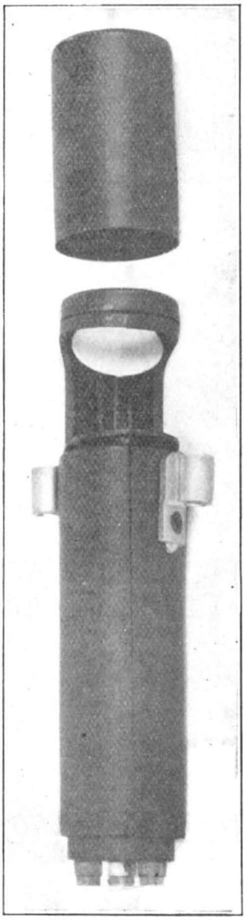


Fig. 4.—Line Signal, with Cap Removed.

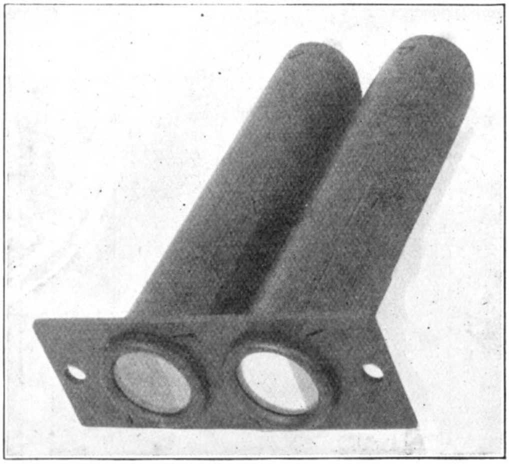


Fig. 5.—Pair of Supervisory Signals.

The operation of the circuits on the C.B.S. No. 2 system will be described first, Diagrams L 105 and 207 refer.

Standard through junction signalling conditions similar to regular C.B. manual jack-ended junction working are provided. The circuits may be adapted for working on junctions to or from Automatic Exchanges by fitting an additional relay in each cord circuit. This modification is catered for in the design of the switchboard and provision is made for a dial.

Subscribers Line Circuit. Diagram L 105 (Fig. 7).—The line signal is operated by the completion of the loop at the subscriber's

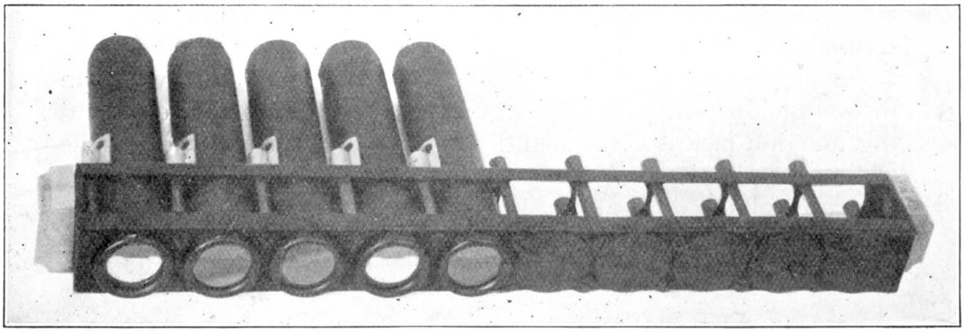


Fig. 6.—Line Signals on Mounting.

station, the active winding of the signal being included in the earth return to avoid trouble due to false signals caused by line faults.

Junction Line Circuit. Diagram L 105.—This circuit follows the same principles as standard jack-ended junction line circuits in C.B. manual exchanges.

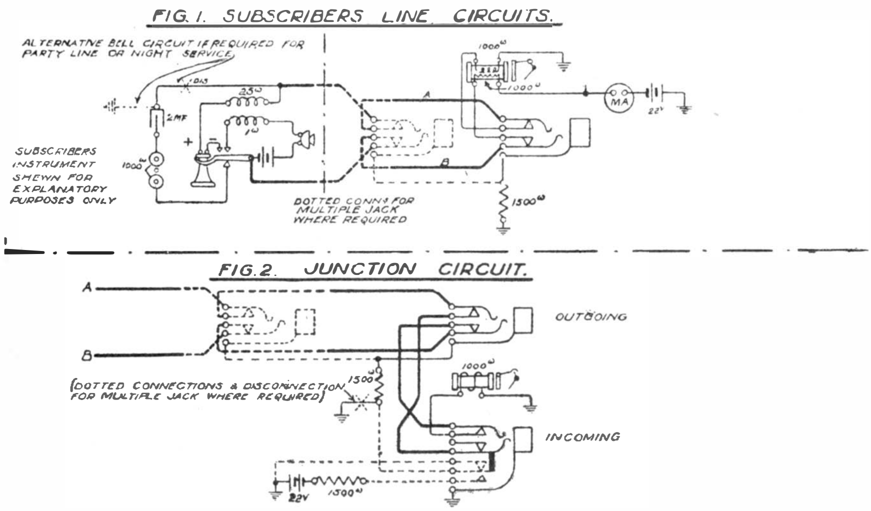


Fig. 7.

Cord Circuits. Diagram L 207 (Fig. 8).—The cord circuits employed are similar in principle to C.B. cord circuits, the supervisory signal being controlled by the subscriber's loop. They are suitable for use with any type of junction without the use of auxiliary equipment. Battery is fed to line over the "B" wire through 200ω, a higher resistance supervisory relay being used on the "A" side. This arrangement reduces the current in the subscriber's receiver to a minimum, but provides comparatively heavy current on the "B" line for junction signalling. All cord circuits on the board are universal, *i.e.*, suitable for handling both junction and subscriber's connections. This is affected by providing a relay "J" associated with the answering plug which operates only when an incoming junction jack is plugged into. The bush of the incoming junction jack is connected direct to earth. On insertion of the answering plug in an incoming junction jack, relay "J" receives the full voltage of the main battery and operates, but when the answering plug is connected to a subscriber's jack, 1,500ω is in-

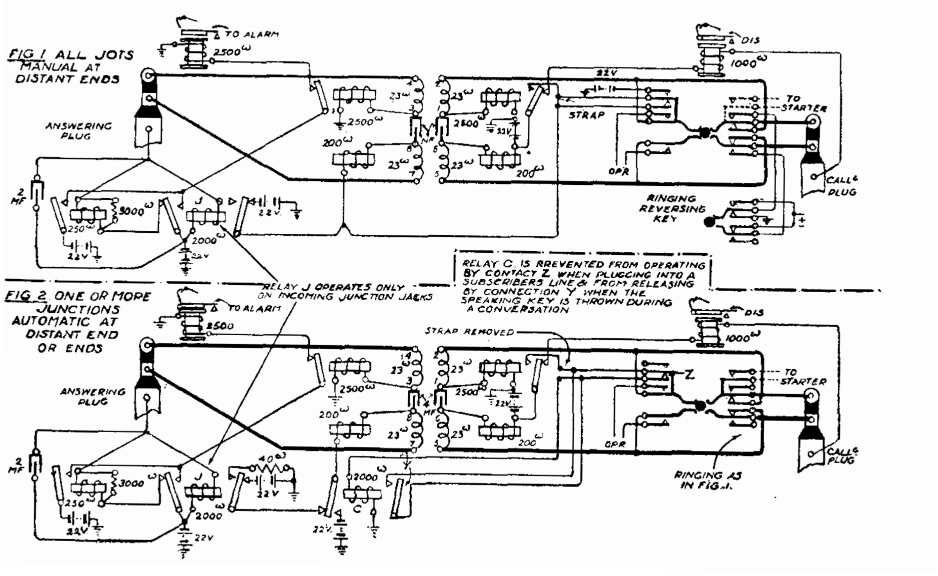
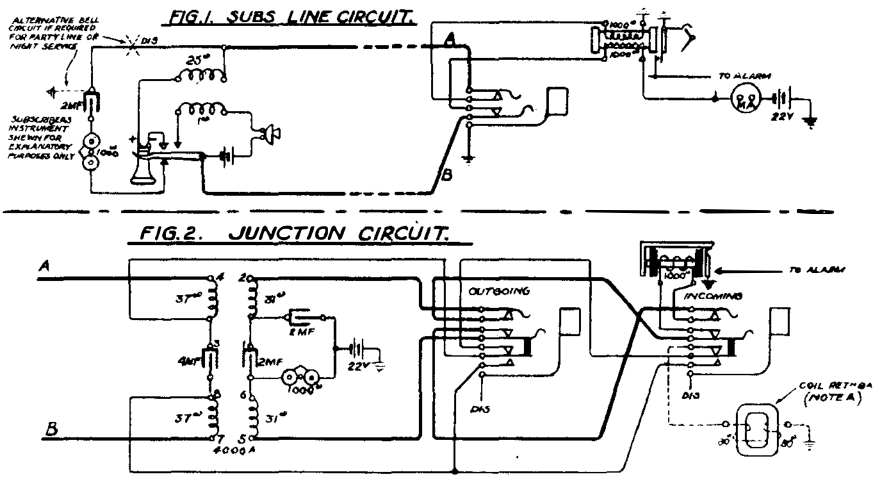


FIG. 8.

cluded in the earth connection. Relay "J" is then shunted by the 250ω relay and does not operate.

The lower part of Fig. 8 (L 207) shows the connections necessary when junctions carrying dialled out calls from automatic exchanges have to be accommodated. On such connections it is necessary for the call to be registered automatically at the automatic exchange when the called subscriber removes his telephone from the hook. Registration is effected by removing earth from the "B" wire of the junction and substituting battery. It will be seen that the circuit differs from that adopted for manual working (see upper part of Fig. 8) in that it arranges to connect earth to the " B " line when the operator answers and also provides against premature connection of battery to the " B " wire before the called subscriber answers. The method of doing this will be clear from the notes on the diagram. The latter provision is necessary to prevent wrong metering and because of the use of break jacks in the subscriber's line, which permit of battery from the calling signal being momentarily connected to the tip of the entering plug.

Ringing current is normally sent to line over the " B " wire with the " A " line earthed. When the Party Line Reversing Key is thrown to ring out on the " A " wire, earth is *not* applied to the " B " wire. This is so arranged to avoid the " tinkling " which would otherwise be occasioned by the discharge from the condensers in the " B " side bells.



NOTE A. RETARDATION COIL 9A WITH DOTTED CONNECTION IS ONLY REQUIRED WHERE JUNCTION WORKS DIRECT TO A CORD CIRCUIT OF THE C.B.S. No. 1 TYPE.

Fig. **9.**

Diagrams L 105 and 205 refer to the C.B.S. No. 3 system. It will be seen that this is similar in principle to the C.B.S. No. 2 system, except that through junction signalling is not provided, nor is provision made for junctions working to Automatic Exchanges.

Subscribers Line Circuit. Diagram L 104 (Fig. **9**).—This circuit is similar to that the C.B.S. No. 2 system already described.

Junction Line Circuit. Diagram L 104.—The repeating coil is associated with the junction line instead of the cord circuit to economise in repeating coils and also to facilitate any special arrangements on the junction which may be required for multi-office working or superposing. A 1000ω magneto bell is provided on the junction as a standby signal for calling the operator should she fail to clear a connection on receipt of the visual signal. It also provides for code ringing at multi-office exchanges. Battery is connected to the centre point of the repeating coil to maintain the operation of the answering supervisory relay when the plug is inserted in the incoming junction jack.

Cord Circuit. Diagram L 205 (Fig. **10**).—The cord circuit is similar in principle to that of the C.B.S. No. 2 system, but is reduced to the simplest possible elements. It is provided with one supervisory signal only, since the majority of calls are junction calls and no supervisory signal is received over the junction line. The night bell connection to the signal is con-

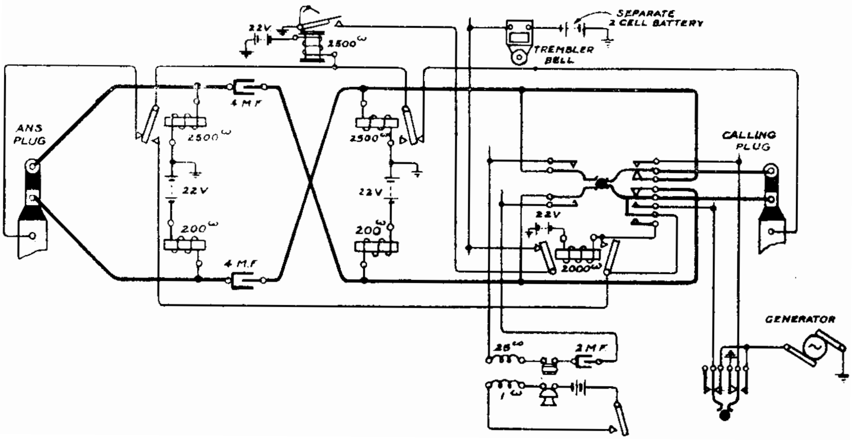


Fig. **10**.

trolled by a locking relay which remains locked until the called subscriber answers, thus preventing the night bell ringing except at the end of a call. The cord circuit is crossed between the condensers and the calling supervisory apparatus in order to balance it.

Footnote:—

Reference to previous articles in the *P.O.E.E. Journal* which have a bearing on the subject :—

"Trunk and Junction Circuit Development," by Messrs. Jenkins and White. Page 281, Vol. VIII.

"Notes on C.B.S. Telephone System," by W. O. Blight. Page 197, Vol. XI.

"A Modified C.B.S. System," by H. W. White. Page 115, Vol. XII.

EXCHANGE DEVELOPMENTS.

The following works have been completed:—

Exchange.	Type.	No. of Lines.
Birmingham South Extension	Manual	880
Bradford Central Extension	,,	2000 & conversion
Darlington Extension ...	Automatic	400
Rosendale, New	Manual	560
Royal, New (late Minories	,,	7500
Smethwick Extension ...	,,	200
Woodford, New	,,	1025
Applin & Barrett	P.A.B.X.	20
Daily News	,,	40
Glasgow Herald	,,	60
Harvey Nichols	,,	60
Heap & Sons	,,	40
L.C.C. County Hall ...	,,	600
Readhead's, Ltd. ...	,,	20
Speaight & Sons	,,	20
Woolland Bros	,,	40

Orders have been placed for new Exchanges as follows:—

Exchange.	Type.	No. of Lines.
Bolton Desk	Manual	—
British Empire Exhibition	Automatic	—
Didsbury	Manual	1660
Enfield	,,	1800
Gloucester	Automatic	1060
Leeds Satellites—		
Chapeltown	Automatic	850
Headingley	,,	1220
Roundhay	,,	800
Stanningley	,,	680
Maidenhead	Manual	1120
Mill Hill	,,	600
Palmers Green	,,	2200
Torquay ... ... }	Automatic	1274
Paignton ... ... }		296
Weston-Super-Mare ...	Manual	870
Woolwich	,,	1385
British Xylonite Co. ...	P.A.B.X.	45
Ferranti's Ltd.	,,	60
Harvey Nicholl's	,,	60
Lee & Coy....	,,	40
Lloyd & Co.	,,	30
Scottish Oils	,,	20
Star & Garter Home ...	,,	30
Ward & Goldstone ...	,,	25

Orders have been placed for extensions to existing equipments as follows:—

Exchange.	Type.	No. of Lines.
Cardiff	Manual	1500
Dudley	Automatic	300
Edgbaston	Manual	1060
Hammersmith	,,	1640
Leeds Modification ...	Automatic	—

LONDON DISTRICT NOTES.

DURING the quarter ended 28th September, 1923, 7,834 exchange lines, 3,973 internal extensions and 750 external extensions were provided; in the same period, 2,695 exchange lines, 2,302 internal extensions and 284 external extensions were recovered, making nett increases of 5,139 exchange lines, 1,671 internal extensions and 466 external extensions.

INTERNAL CONSTRUCTION.

New Exchanges have been opened during the past quarter at Royal, Woodford, Southall and Eltham.

The Royal Exchange is of the C.B. No. 1 type, and has been equipped for 7,500 lines. The plant was installed by the Peel Conner Company. The whole of the lines, which have been served temporarily by Minories Exchange, have been transferred thereto along with a certain number of Avenue and Central lines. The building, which is situated in Great Tower Street, will ultimately contain a large amount of automatic plant, and will be one of the largest exchange buildings in London.

The Woodford, Southall and Eltham Exchanges are of the C.B. No. 10 type, and were installed by the District Staff.

New buildings for the accommodation of Telephone Exchanges are in course of construction or about to be commenced at Albert Docks, Meadway (Golders Green), Woolwich, Bishopsgate, Enfield, Mill Hill, Palmers Green and Sloane.

Sites have been acquired and arrangements are in hand for the construction of new buildings at Battersea, New Malden, Warlingham, Hendon, Maida Vale, Guildhall (Wood Street, E.C.). Strand, Tilbury, Western and Walworth.

The existing Exchange buildings are being extended at Dalston, Ealing, North, Streatham and East Ham.

Exchange Extensions have been completed at Ealing, East Ham, Enfield, Hornsey and Walthamstow, and extensions are in progress or about to be commenced at Brixton, Burgh Heath, Clerkenwell, Edgware, Dalston, Elstree, Hammersmith, Hayes, Hatch End, Hendon, Hounslow, Hop, Ilford, London Wall, Kensington, Maida Vale, Reigate, Palmers Green and Wallington.

The main frame has been erected in connection with the new Holborn Exchange and the new Tandem Exchange, which will be installed in a new building provided in High Holborn.

P.A.B.X.'s to the number of 14 are now working in the London Engineering District, and 4 are in course of construction. The P.A.B.X. installed by the Relay Automatic Company at Messrs. Debenham's premises in Wigmore Street and equipped for 320 lines initially, to be extended to 400 in the near future, was brought into use in December.

Olympia.—During the Summer the wiring of Olympia has been considerably revised and extended, a new frame being erected which provides for a maximum of 400 Telephones for Exhibition purposes. Over 350 were provided in connection with the recent Motor Show. An extension at Hammersmith Exchange was completed by the Western Electric Company in order to accommodate this traffic.

Baudot Telegraphs.—Automatic transmitters of the Western Electric type, fed by keyboard perforators No. 24 (Booth-Willmott) type, have been installed and are working on the four arms of a London—Glasgow Baudot circuit.

External Construction.

During the three months ended 30th September, 1923, the following changes have occurred:—

Telegraphs.—Nett decrease of 24 miles of open wire and a nett increase of 162 miles in underground.

Telephone (Exchange).—Nett increases of 52 miles and 12,803 miles in open wire and underground respectively and a nett decrease of 1,116 miles in aerial cable.

Telephone (Trunks).—Nett increases in open and underground of 3 miles and 3,147 miles respectively.

Pole and Pipe Line.—Pole line showed a nett increase of 74 miles, and pipe line a nett increase of 42 miles, the totals to date being 4,475 miles and 5,251 miles respectively.

The total single wire mileages at the end of the period under review were:—

Telegraphs	21,469
Telephones (Exchange)	1,426,818
Telephones (Trunks)	40,713
Department's Wires on Railways ...	3,561
Spares	42,933

Pneumatic Tubes.—A new $2\frac{1}{4}''$ tube for bothway service between the Central Telegraph Office and the editorial offices of the "Daily Mail" has been completed and handed over for working.

LONDON COUNTY COUNCIL AUTOMATIC PRIVATE BRANCH EXCHANGE.

J. RADFORD, A.M.I.E.E.

THE provision of Private Branch Exchanges operated by means of automatic switching equipment is rapidly emerging from the stage of novelty into the commonplace, and descriptions of particular exchanges where this method of working is adopted will probably soon suffer the common fate of papers which, while in themselves are more or less interesting, exhibit no outstanding features which may be considered worthy of inclusion in the pages of this Journal.

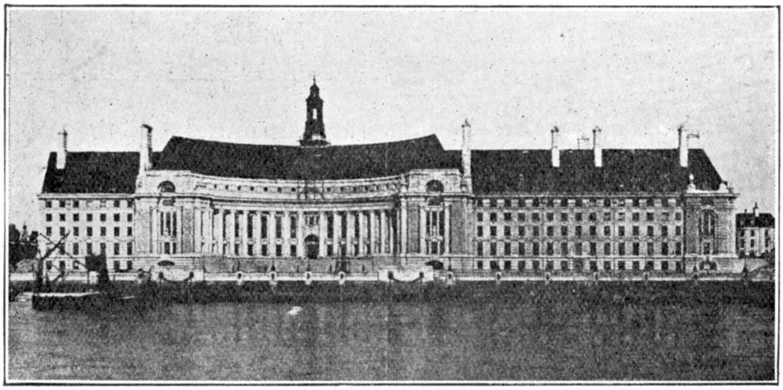


FIG. 1.—L.C.C. HALL.

In view, however, of the size and importance of the Automatic Private Branch Exchange which has been installed in the New County Hall of the L.C.C. at Westminster—this being the largest P.A.B.X. in the country—it is thought that a brief description of the equipment may not be considered superfluous.

The officers responsible for communication services of the Council considered that the many advantages of automatic working justified the recommendation for its installation in the fine new building (Fig. 1) which now houses the Council and its officers and staff, and negotiations were opened with the Department with this object in view.

As soon as the policy to adopt automatic working was decided upon precise details were obtained of the Council's requirements with regard to traffic and development, and these were incorporated in a specification prepared in the Engineer-in-Chief's Office. The order for the equipment was subsequently placed with the Automatic Telephone Manufacturing Co., of Liverpool, and the exchange was opened for service on September 8th, 1923.

The equipment provided comprises the following items of plant, viz.:—

Automatic switching equipment (Figs. 2 and 3).
Manual equipment.
Additions and alterations to the existing main frame, which is now a combined main and intermediate distribution frame.
Special apparatus rack.
Fuse board.
Test case.
Power plant, including two sets of cells, charging machine, ringers, power switchboard and fuse panels.

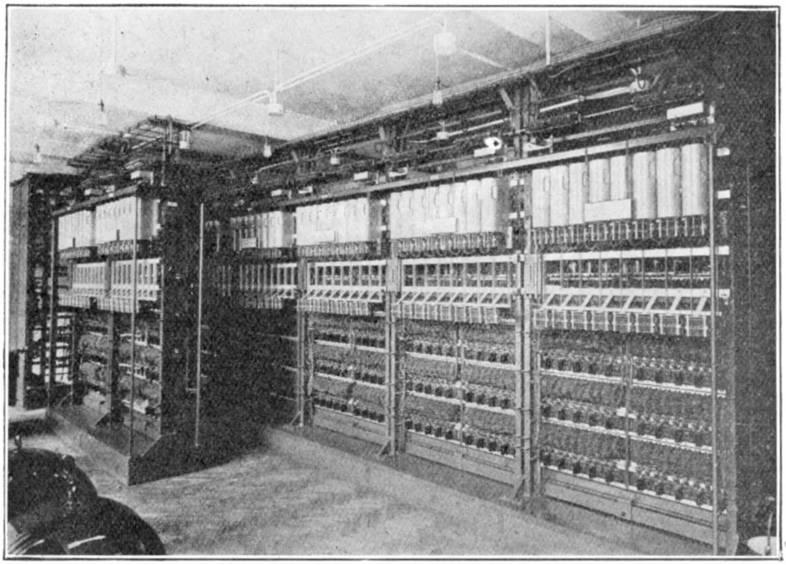


Fig. 2.

The equipment is located in the basement of the building in three rooms, containing respectively the automatic equipment and power plant, the manual board and the batteries.

Automatic Switching Equipment.—Seven 100-line units have been provided, 6 of which are equipped with 100 rotary pre-selectors, or line switches, and 1 with 50 pre-selectors.

These units are of the combined line switch and final selector type, the line switches being fitted on one side of each unit and the final selector switches on the other.

The 650 lines are divided into 2 groups, one for 350 extensions and the other for 300.

Each of these groups is provided with a suitable number of junctions or outlets to groups of first selector switches, which in turn are provided with outlets to the final selectors.

Standard traffic facilities, including dialling, ringing, busy and number unobtainable tones are provided.

A three-figure system was adopted for the initial equipment, the numbers allotted being 200 to 899, *i.e.*, the outlets from levels 2 to 8 inclusive of the first group selectors are taken direct to final selectors, and as the anticipated ultimate development is 900 extensions, provision will be made in due course for expanding the numerical scheme into a four-figure system in respect of the last 200 extensions. This will be effected by interposing second selectors in the outlets from level 9 of the first selectors, the outlets

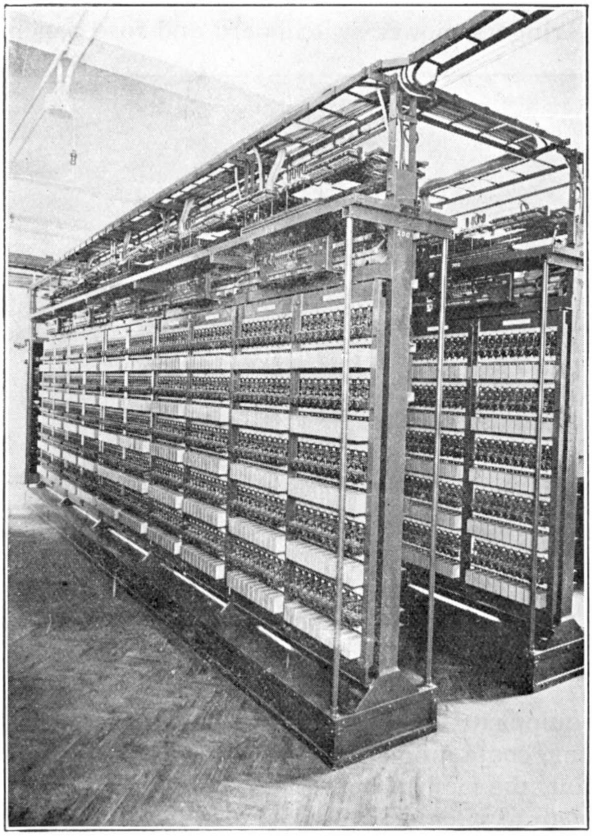


FIG. 3.

from levels 0 and 1 of these second selectors being wired to final selectors in the two last groups.

Manual Switchboard.—Automatic working at Private Branch Exchanges has not yet reached the stage where the P.B.X. manual operator can be dispensed with, although, in passing, it should be mentioned that the facility has recently been authorised whereby, under certain conditions, automatic extensions are enabled to dial out direct to the public exchange for originating exchange calls.

For calls incoming from the public exchange, however, the retention of the manual operator is at present regarded as indispensable.

In the case of the L.C.C. P.A.B.X., both originating and incoming exchange calls are dealt with by the manual operator, and in order to operate these calls a multiple of the automatic extension lines is provided on the manual board, together with individual answering equipment. Provision has also been made on the manual board for 50 extensions to be worked manually.

The arrangements are briefly as follows:—

Incoming Exchange and Tie Line Calls.—These calls are dealt with by the P.B.X. operator, who completes them by ringing on a cord circuit, the calling plug of which is inserted in the multiple jack of the requred extension.

Originating Exchange and Tie Line Calls.—These are dealt with by the P.B.X. operator.

When an extension desires to originate a call to the public exchange, or to the Tie lines, the digit "O" is dialled, and the call arrives at the manual board on individual answering equipment comprising a jack and lamp. The operator then answers and completes the call by means of a cord circuit in the usual manner.

The automatic equipment which has been taken into use for the call is released immediately the call arrives, as described later, and is thus free to deal with other calls.

Local Calls.—These are calls from extension to extension and are completed entirely automatically, thus affording the subscriber a rapid and efficient inter-communication service.

"Back release" facilities are provided for local calls, so that either the calling or the called extension may release the connection by simply hanging up the receiver.

Engaged Conditions.—The engagement of an extension line on a line switch, or on the final selector multiple, *i.e.*, for originating and incoming calls respectively, places the engaged test on the associated multiple jacks on the manual board. Similarly, the engagement of an extension line on the manual board places the engaged test condition on the associated contact in the final selector multiple.

The arrangements are such that the manual operator may plug into the multiple jack of an extension which is engaged on the automatic equipment without breaking down the connection on the automatic switch. This facility is afforded for the purpose of enabling the operator to offer an exchange or other call.

It has been previously mentioned that standard tones are provided, and as these are well known they will not be further described here.

On calls from the extensions to the manual board, the arrangements are such that the calling extension is able to release the connection, if desired, before the operator plugs in, and also that the insertion of the plug places the extension under the control of the operator and prevents the connection being released until the plug is withdrawn from the jack.

Through signalling is not provided between the extension telephone and the public exchange, *i.e.*, the manual operator controls the connection and the extension is able to flash in the operator.

Night Service.—The night service requirements are catered for by the provision on a small subsidiary manual switchboard as the main manual board is not continuously staffed.

A suitable number of exchange lines and certain selected extensions are connected to the subsidiary board, which is located in a position where one of the Council's staff is in attendance during the night and at week-ends.

Alarm Signals.—A system of alarm signals has been provided in order that the plant operating conditions may be efficiently supervised and to ensure that failures of plant may be promptly brought to notice. These alarm signals are extended to the manual board by the operation of switching keys, at times when engineering officers are not in attendance.

Circuit Operations.—The space at disposal does not permit of an exhaustive description of the circuit arrangements, but the essential features of a few of the fundamental circuits will be briefly reviewed (Fig. 4).

Rotary Line Switch.—Each extension line terminates in the exchange on a rotary line switch, and is also multipled to its associated contacts on the final selector multiple. This switch functions as follows:—

1. Automatically rotates its wipers on to an idle trunk to a first selector.
2. Switches its wipers through to the idle trunk.
3. Closes the discriminating circuit.

The switch is arranged to remain on the outgoing trunk it last used, whether the trunk has been taken by another extension or not. When the extension removes the receiver to make a call, the extension line will be immediately extended to the outgoing trunk upon which the line switch wipers rest if it is idle. If, however, this trunk has been taken by another extension, the wipers of the line switch of the calling extension will be automatically rotated until they rest on the first idle trunk to a first selector.

When the receiver at the extension is removed, the line relay operates, extending the rotary magnet circuit on to the private wiper *via* the operated contacts of the line relay and normal contacts of the B.C.O. relay.

The line relay operates a mechanical link or latch, which normally forms a stop to prevent the full operation of the B.C.O. relay. The B.C.O. relay is therefore left free to operate fully as soon as an idle trunk is found.

If the wipers are resting on a busy trunk, the private wiper finds earth on the private bank contact. The B.C.O. relay is therefore shunted and a circuit is closed for the rotary magnet which operates, opening its own circuit at the rotary interrupter

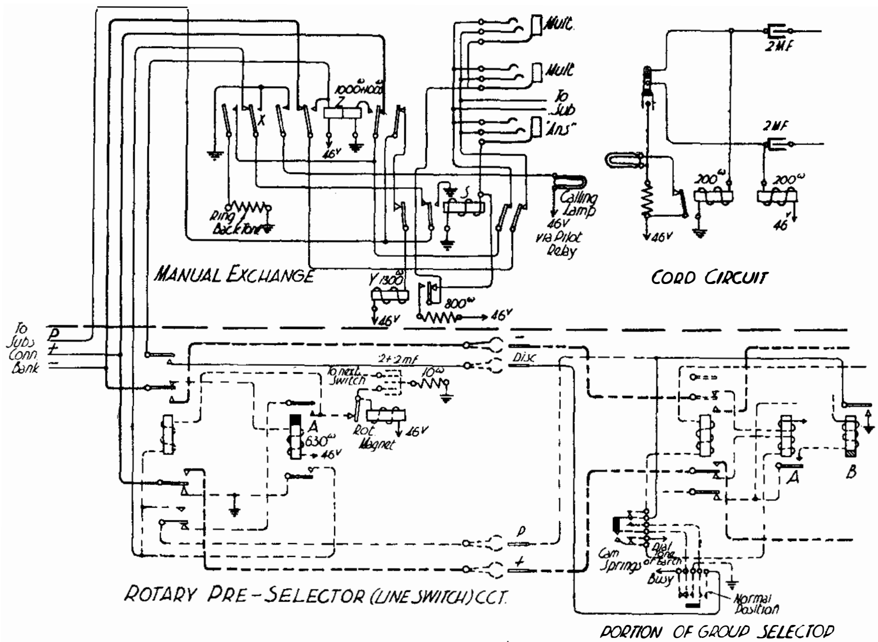


FIG. 4.—L.C.C. A.P.B.X.

springs. In falling back it moves the wipers on to the next trunk. If this trunk is also engaged, the above cycle is repeated until an idle trunk is found.

If the wipers are resting on an idle trunk, or as soon as an idle trunk is found, as explained above, the private wiper does not find earth and the B.C.O. relay is therefore not shunted, but operates to close the line wiper circuit, switching the extension line through to the outgoing trunk and connecting the discriminating wiper to the special service trunk.

The B.C.O. relay also disconnects the line relay, but this relay, being slow to release, maintains the earth on the winding of the

B.C.O. relay until earth has been placed on the release trunk by the switch ahead.

This earth "busies" the trunk on which the wipers stand, and thus prevents another line switch from using that trunk; it locks up the B.C.O. relay during the whole period of the call, and it places the busy condition on the contacts of the calling extension in the final selector multiple, thus busying the calling extension to other extensions.

When the switches ahead are released, the B.C.O. restores. The line switch wipers, however, remain on the bank contacts of the trunk, but this has no effect since the extension line is broken at the contacts of the B.C.O. relay. The trunk may be used again by the same extension, if in the meantime it has not been taken into use and thus made busy by another extension.

When an extension is called by another extension, the final selector places earth on the private bank contact and also on to the B.C.O. relay of the line switch of the called extension.

The B.C.O. relay is energised, but owing to the mechanical link or arm previously referred to it does not operate fully, but breaks its normal contacts without making, or closing, its operated contacts. The called extension line is therefore not extended to an outgoing trunk, as would have been the case if the B.C.O. relay had fully operated.

First Selector and Final Selector.—When the line of the calling extension has been extended to an idle trunk to a first selector, the subsequent operations of the first and final selector, due to dialling, are the standard automatic operations, but special provision has been made to enable the extensions to call the manual board, by dialling "O," and to be called by the telephonist for incoming exchange or tie line calls.

On a local call, the earth placed on the release trunk by the selector energises relay Y on the manual board, *via* the operated contacts of the extension's B.C.O. relay and the normal contacts of relays Z and S. Relay Y operating places battery *via* its operated contacts on to the bushes of the calling subscriber's multiple jacks, thus providing engaged test conditions.

When an extension calls the manual board by dialling "O," the first selector wipers are stepped up to the tenth level. As all the private contacts in this level are permanently earthed, the wipers will be automatically rotated to the eleventh step, where the following circuit is closed through the normal post springs on the eleventh step cam springs:—

Selector release trunk earth—operated contacts of the 11th step cam springs and of normal post springs—discriminating trunk—extension's line switch wiper—operated contacts of B.C.O. relay—one winding of relay "Z" to battery.

Relay " Z " therefore operates and performs the following functions:—

(*a*) Disconnects extension loop from the automatic switches, and places its own winding across the extension line. The automatic switches restore immediately the loop is broken.

(*b*) Places " ring back tone " on to the extension line.

(*c*) Lights calling lamp associated with answering multiple jack.

(*d*) Places busy earth on the extension private bank contacts of the extension to busy the extension to other extensions.

(*e*) Disconnects the calling extension B.C.O. relay in order to take earth off the release trunk. This earth would otherwise busy the trunk upon which the line switch wiper is resting.

The calling lamp glows while the extension is on the line owing to relay " Z " being maintained in its operated position by the extension line loop, but should the extension restore before the telephonist answers the connection will release and he will then be free to make another call.

On seeing the extension calling lamp glowing, the telephonist inserts the answering plug into the answering jack of the extension, thus placing the engaged test battery on the bushes of the extension multiple jacks, to busy the line on the manual board.

The calling extension loop completes a circuit for relay " A " of the cord circuit. Relay " A " energises and disconnects the answering supervisory lamp circuit. The cut-off relay " S " is also operated by the battery on the sleeve of the answering cord to perform the following functions:—

(*a*) Places earth on the private final selector bank contacts to busy the extension line to other extensions.

(*b*) Keeps the extension's B.C.O. relay disconnected.

(*c*) Disconnects the extension loop from the windings of relay " Z," which therefrom restores. When relay " Z " restores, it disconnects the calling lamp circuit and the " ring back tone " circuit, and allows the extension line switch to restore to normal.

The telephonist now completes the call manually. When the extension hangs up the receiver at the end of the conversation, relay " A " in the answering cord circuit restores and causes the supervisory lamp to glow.

Manual telephonist calls the automatic extension.

A. *Extension line disengaged.*—After having tested and found the extension line disengaged, the telephonist inserts the calling plug into the multiple jack and calls the extension by operating the ringing key.

The insertion of the calling plug into the multiple jack places the cord sleeve battery on to the bushes of the other multiple jacks, to " busy " the extension to other telephonists. The extension's cut-off relay " S " is also energised in order to:—

1. Disconnect the extension line from the automatic apparatus.
2. Place busy earth on to the extension's private final selector bank to busy the extension to other extensions.
3. Disconnect circuit of relay " Y " to prevent it from operating unnecessarily.

B. *Extension line engaged.*—Should the telephonist find, upon testing the called extension line, that it is engaged on another call, she inserts the plug into the called extension multiple jack and offers the call.

If the extension should be engaged on an automatic conversation, the telephonist requests him to hang up his receiver, when the automatic switches immediately release, and as soon as the earth on the extension private final selector bank contacts is removed by the release of the automatic final selector switch, relay " Y," which has been operated on the automatic call, immediately releases. Relay " Y " releasing, completes the circuit *via* its back contacts to the extension's cut-off relay " S," which now energises from battery on the sleeve of the cord circuit. Immediately relay " S " operates, the extension line is disconnected from the automatic equipment. The telephonist will then recall the extension by operating the ringing key.

Should the called extension be engaged on another exchange call, *via* the manual board, and decide to take the call now offered, the telephonist asks him to hang up his receiver and she immediately communicates with the telephonist controlling the existing call and asks her to take down the connection. Then the telephonist, controlling the offered call, recalls the extension and completes the connection in the normal manner.

The writer is indebted to the A.T.M. Coy. for the loan of the blocks illustrating this article. The circuit diagram is a composite one and has been included in order that the foregoing circuit descriptions may be more easily followed.

It should be mentioned in conclusion that the release of the automatic equipment immediately on the arrival of an originating exchange call at the manual board is not now insisted upon and, under certain conditions, contractors are permitted to arrange their circuits for the release of the automatic equipment when the operator plugs in.

LONDON'S OLDEST TUBE.

An underground route of a somewhat exceptional nature has recently been acquired by the Department, and perhaps a few details may be of interest to the readers of this Journal. To realise the nature of this route readers must be carried back to the year 1863 when a pneumatic dispatch tube was opened for the purpose of conveying mails between the G.P.O.; Euston Station, and the North Western District Post Office. The route is shown in Fig. **1**. This tube shaped like the letter " D " laid with the

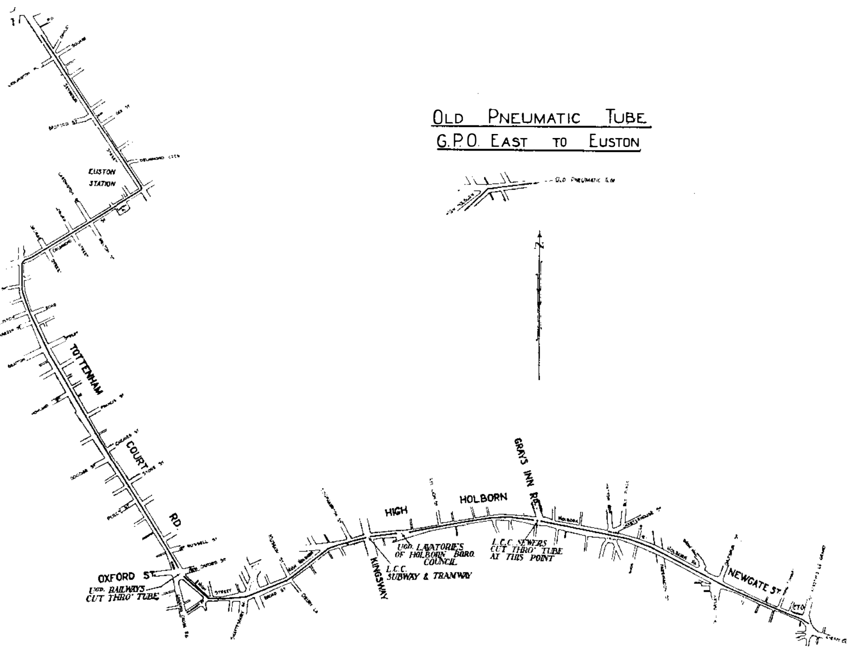


Fig. **1**.

straight line downwards is of 1″ cast iron, Fig. **2**. Its maximum dimensions, between the G.P.O. and Euston Station are 4′ 6″ high × 4′ wide and between Euston Station and N.W.D.O. 2′ 6″ × 2′ 6″, the sections being 9′ long on the straight and 6′ on the curves. Sections are joined by means of a socket and a tapered spigot, the fitting being sufficiently exact to make packing unnecessary preparatory to running in the lead. Portions of the lead recovered recently show the taper quite clearly. The completed tube was provided with rails and the motive power was compressed or rarified air. A popular description of the tube with some quaint prints can be seen in the *Windsor Magazine*, Vol. XI., Dec., 1899—May, 1900. It would appear that the tube was used intermittently for parcel traffic up to 1871-3 when, owing to difficulty in securing or maintaining air-tight joints, this huge work, costing upwards of £200,000, was abandoned.

Recent telephone requirements led to the consideration of employing this derelict tube and authority was received for exploration purposes. Fortunately, some of the local Councils had built ventilating shafts with surface covers on the derelict tube and these proved exceedingly useful in connection with the preliminary investigations. The first section examined was between the Holborn Empire and near Grays Inn Road, approximately 440 yds., which was found to be in excellent condition, the air being pure and sweet. Eventually all the secrets of the long buried tube were laid bare. Various road users had broken

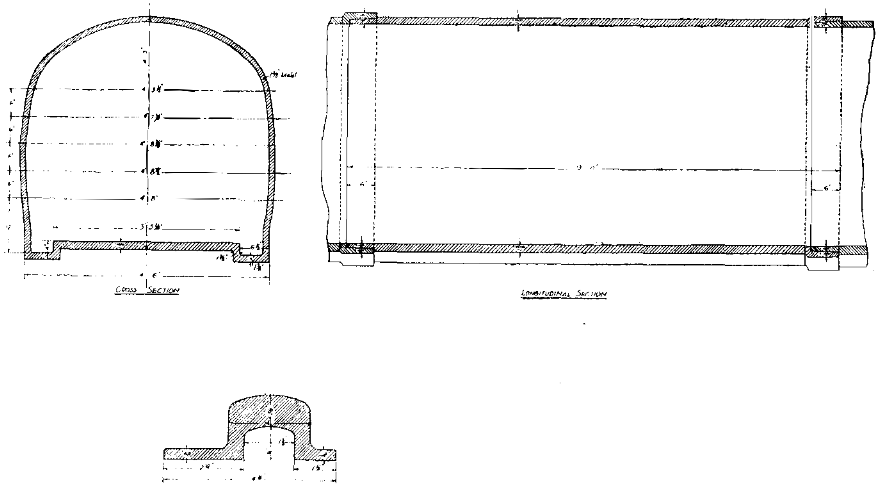


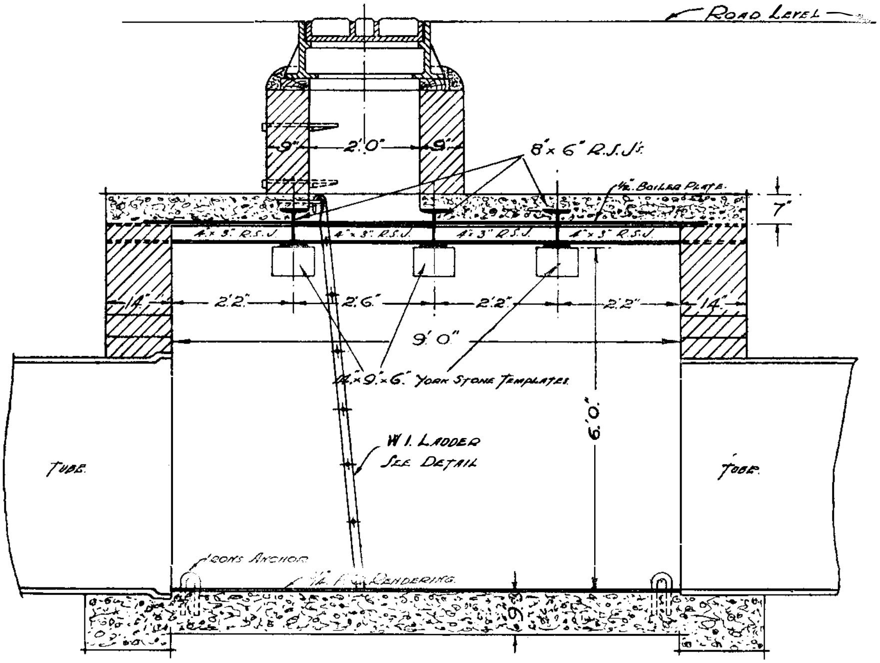
Fig. 2.

through the tube at different points. Some, repenting, had made good again by more or less efficient brick work, evidently in a hurry to avoid discovery. Others left permanent evidence of their work—notably at a point east of Kingsway and also near Grays Inn Road.

The main breakage was that at the east of Kingsway, where a length of 60 yds. had been cut away. This spot was evidently the site of the Holborn Station on the original tube. Here was located a branch tube which terminates in the cellars of a building on the south side of Holborn, and is now in use for the storage of coal. The missing 60 yds. portion has now been replaced by a brickwork tunnel of similar dimensions built of 14″ brickwork in blue Staffordshire, with a circular turned arch and resting on a 6″ concrete foundation.

An obstruction at Grays Inn Road caused by an L.C.C. sewer shaft having been built through the tube gave considerable trouble, but a satisfactory solution was found and the continuity of the tube established. In building the Southampton Row—Kingsway Subway (cutting across Holborn) the L.C.C. demolished the tube. In this case manholes were built on both sides and the Subway utilised as a connecting link.

Other small breakages were found and made good by brick sections. Suitable manholes on the route have now been provided, and the whole portion between Grays Inn Road and Kingsway electrically lighted. Constructional details of a typical manhole which has been built on the tube are shown in Fig. **3** (*a* and *b*).

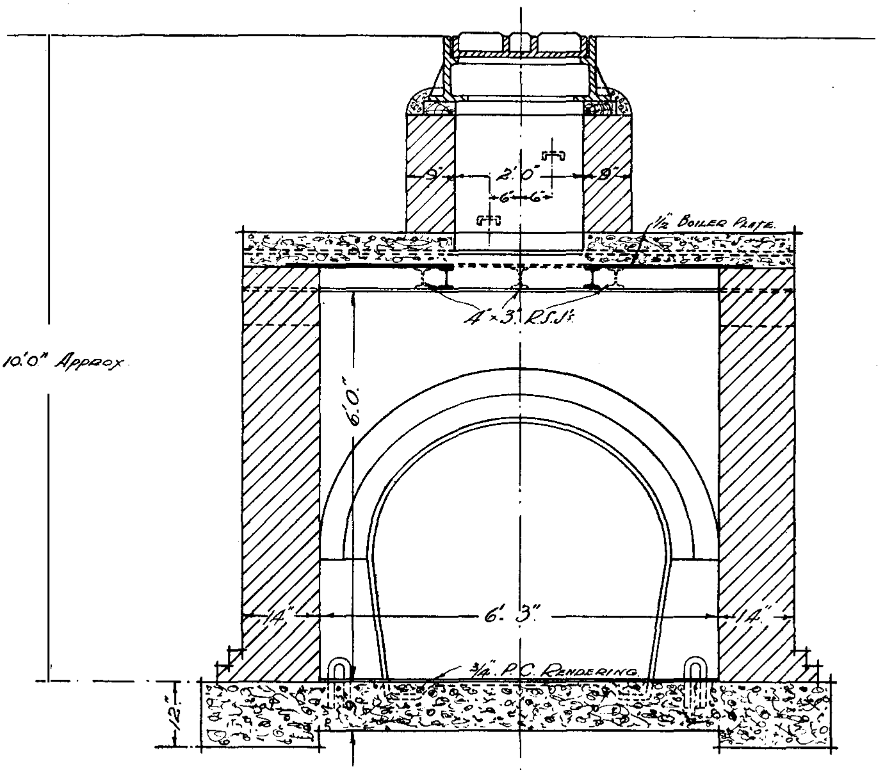


SECTION. A.A.

FIG. **3**(*a*).

The manhole outside the new Holborn Exchange connected to the Exchange vault embraces not only this old tube but the Ex-National Telephone Company's route of 12 ducts and the P.O. route of 21 ducts, and jointing operations on these routes can be carried out at this point at any time without causing street obstructions. It is interesting to note that the route of the tube West of Kingsway is *via* Broad Street and High Street to St. Giles' Circus, this being the road to the West before New Oxford Street was built. This section of tube will be electrically lighted by feeders from the West Central District Post Office, and will be largely used in conjunction with other Subways for plant required for the new Strand Exchange.

In order to facilitate investigations the Contractors constructed a trolley and in a weak moment the writer was persuaded to embark thereon. Two trap doors were discovered in the roof of the tube in High Street. As there is a considerable curve here it is probable these were provided for inspection purposes, in the event of a blockage—although no surface evidence exists.



SECTION. B.B.

(Fig. 3(b)).

At St. Giles' Circus, where the Central London and the Hampstead Junction Railways meet, the parcel tube has been entirely demolished. This, however, is not a serious matter as the portion up to this point will be utilized as part of a main westward route, and indeed it is now being connected with a new line of ducts between High Street and the Marble Arch.

Between a point at the South end of Tottenham Court Road and near Euston Station the tube has been used by the St. Pancras Electricity Department for many years. Manholes have been built by the Municipality and the mains consist of bare copper conductors suitably insulated. The remaining portion at Euston Station has been broken away at several places, although the end, and the terminating chamber, may still be seen. Part of this chamber is in use as a Mess Room for Railway employees.

So far no trace of the tube has been found northwards of Euston Station, but a portion of it is still visible at the North-western District Office, Camden Town.

So far the results can be summarised in that a valuable route is now available for probably 50 or 60 cables through the Centre of London, between Denmark Street, Charing Cross Road and a point near Holborn Circus. It would have been impossible to provide the same accommodation by means of ducts except at an abnormally high cost.

Exploration is now proceeding in the City Section between Holborn Circus and the G.P.O.

It is understood that the tube was acquired by purchase from The Pneumatic Dispatch Co. for a sum of £7,000.

X.C.T.

NEWINGTON CAUSEWAY SUBSIDENCE.

A VERY serious subsidence occurred at Newington Causeway, London, S.E., during the evening of 27th November, creating a cavity twenty feet deep and extending over the whole of the carriageway, which is 40 feet wide, for a length of about 40 feet. Newington Causeway is a very important thoroughfare, being the main artery from London Bridge to the South, over which a double tram track conduit system operates, in addition to numerous omnibus routes and other heavy vehicular traffic. The carriage-way had recently been repaved with wood blocks on 12″ reinforced concrete and this reinforcing played an important part by holding a large portion of the surface intact although the sub-soil had dropped away (Fig. 1). It is remarkable and gratifying that, in spite of the magnitude of the subsidence and the heavy traffic carried by the thoroughfare, no person suffered injury. The cause of the collapse is the subject of inquiry by the Ministry of Transport, and a full report on this aspect of the case has already appeared in the public press.

In order to give some idea of the actual happenings, without giving the sequence of events, it has to be stated that about 56 feet below the level of the surface, the City and South London Electric Tube is in course of enlargement at this particular point.

The first signs of anything unusual, so far as the tube is concerned, was the failure of the current, resulting in the stopping of the trains. Tons of debris poured into the tube, and it was necessary to conduct the passengers from a train along the railway track to the Elephant and Castle Station a few hundred yards distant. Above ground the alarm was given by a loud explosion followed by flames rising over 20 feet in height which were fed by escaping gas, and which were endangering the Southern Railway Bridge which crosses the roadway at this point. A large number of fire engines were quickly on the scene and it was soon evident that it was necessary to concentrate all engines upon the railway

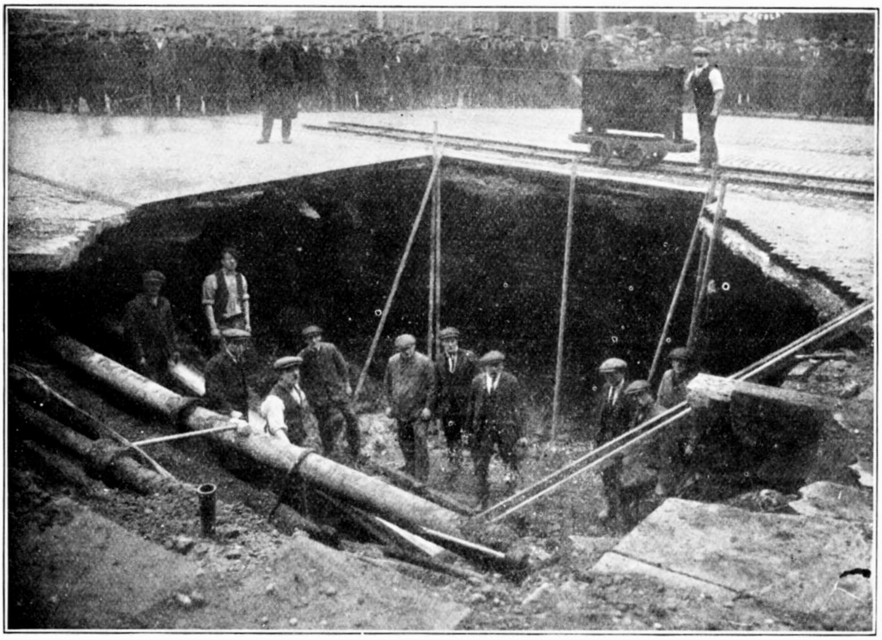


FIG. 1.

bridge if it was to be saved. Shortly afterwards a 15" water main burst, and this effectually extinguished the fire before serious damage was done to the bridge.

The site was examined as soon afterwards as possible, and the extent of the subsidence was then discovered. The disastrous effect to all mains involving gas, water, electric light, the L.C.C. main sewer, tramway duct route, and the Department's route of 12 octagonal ducts was apparent (Fig. 2). The Post Office duct line carries five 300 pr 20 and one 800 pr 10 cables. This had dropped about 6 feet for a distance of 40 feet. The work of restoration was not undertaken without great risk owing to the overhanging concrete carriageway, which was held together by the reinforcing and was likely to collapse at any moment. A large staff was engaged upon the clearing of the debris before the cables could be closely examined (Fig. 3). This work was interrupted by the Council Authorities deciding to bring down the suspended concrete carriageway, and steps were speedily taken to protect the cables by covering them with timber. When all was ready one large block of ferro-concrete road foundation, weighing about 10 tons, crashed down on the top of the timbering, and although the planks had been placed a foot above the cables it was feared that serious damage had been done. Upon inspection, however, it was

Fig. 2.

found that the cables had been safely protected—the full force of the fall of the concrete had been broken by a mass of concrete projecting partially above the cables. The next step was to clear a block of concrete which now covered the duct route, and this could only be done by breaking it up. It was then possible to deal with the cables, which were gradually raised into alignment, and lashed to a racking built up of old oak arms, the supports being placed about 4 feet apart. At this stage the Railway Engineers stopped further work as they decided to pump fluid cement several feet below the surface to form a solid foundation in order to safeguard against a further subsidence. This was carried out by driving a number of steel tubes of about $1\frac{1}{2}''$ diameter into the ground, and forcing the liquid through them under pressure. After 14 tons of cement had thus been disposed of, it was discovered that an appreciable quantity had found its way into the main sewer. This prolonged the delay to the work of restoration of the mains, and further excavation was necessary to expose the sewer and effect repairs. It was now decided to drive steel tubes to a depth of

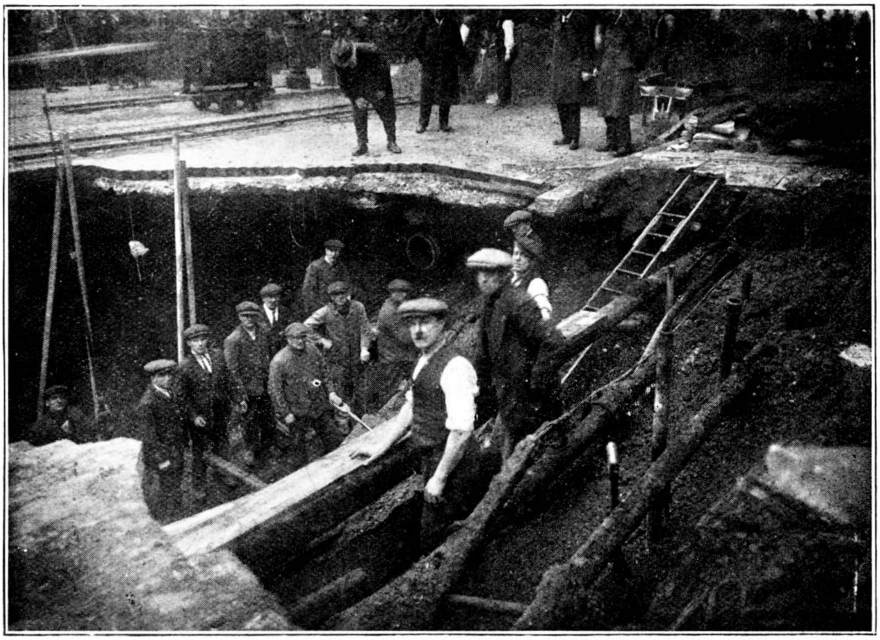


FIG. 3.

approximately 40 feet and repeat the operation. This stage of the work is still in hand at the time of writing, and consequently all work on the various mains is at a standstill.

The result of the subsidence from the P.O. point of view is remarkable inasmuch as, although the six cables carrying 2300 circuits were under great tension, only four circuits were interrupted.

P.J.C.

WIRELESS

COMMUNICATION WITH LIGHTSHIPS.

By F. TANDY, M.I.E.E.

THE problem of communicating with lightships by means of electric signalling devices has been one which, notwithstanding several attempts at solution, has practically remained unsolved on an economic basis until the advent of wireless telegraphy and telephony. In the early days attempts were made to signal:—

(A) By direct transmission of sound waves set up by mechanical means and received by submerged microphones encased in water-tight chambers.

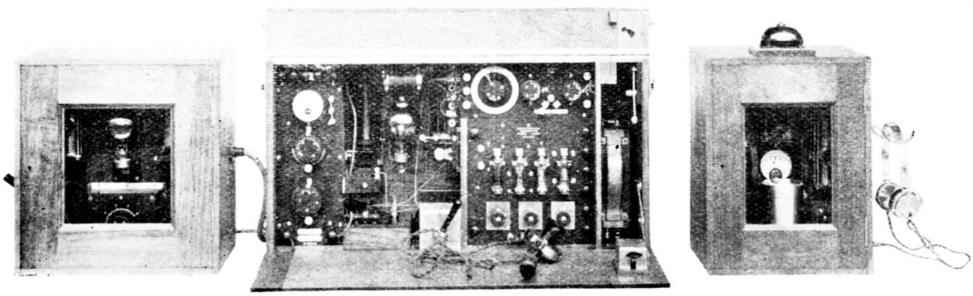
(B) By inductive methods: in these arrangements a coil was laid out at the bottom of the sea in the vicinity of the lightship moorings. This coil was connected to the shore by a cable and signalling was effected by a buzzer arrangement. A coil suspended to the lightship picked up inductively the intermittent impulses from the coil at the sea bottom connected to the communicating point on the shore.

(C) By the detection of leakage currents from one or two ends of an earthed electrical circuit with a corresponding receiving section with its ends suspended from the lightship, so that the distribution of current following various paths of conductivity would lead to a small fraction sufficient in magnitude to be picked up by a sensitive electrical receiver, provided the signals were made of intermittent components from which dots and dashes could be formed.

Even when these systems were replaced by direct telephone working the practical difficulties were not overcome. The usual chafing of cables on the Sea Coast frequently led to breakdowns such as are common to all submarine work, but one of the prime causes of difficulty was that experienced at the lightships where the veering cable has been a fruitful source of breakdown. Replacement of this latter portion of the circuit is sometimes within the range of skill of the lightship keeper, but in cases where the despatch of a cable repair ship is necessary it will readily be seen that considerable expense and delay can easily be involved.

Recent advances in the evolution of wireless telephony however appear to solve the problem on more satisfactory and reliable lines.

For some time past, communication has been established on the Mersey between the lightship at the Bar and the Offices of the Mersey Harbour Board and this system seems to have given such satisfactory results that the Trinity House authorities have elected to apply the system to the light vessels anchored in the mouth of the Thames, and at an inauguration ceremony which took place on



(*a*) FIG. 1. (*b*) (*c*)

March 20th, 1923, telephone communication was established between the North Goodwin Lightship and the Ramsgate Post Office.

The plant on the lightship was installed whilst it was in dock, the aerial being supported by the main mast which carries the "light" and a spar hanging over the stern. The aerial consists of two copper wires separated by spreaders 12′ long, and facilities are afforded for lowering and raising as required. It is insulated from the spreaders by porcelain rod insulators about 18 inches in length.

The ship apparatus installed consists of a transmitting and receiving section coupled with an arrangement for calling the Ramsgate Post Office. The apparatus is of the type usually employed where portability is concerned and has therefore not definitely been designed for either ship or permanent shore work. (See Fig. 1, showing combined speaking and calling apparatus). A similar set has been installed at the Ramsgate Post Office except that calling from the latter point is not provided for, but a "bell" apparatus to respond to the calling devices on the lightship has been installed. It is ultimately intended that four other lightships shall be so provided with calling and speaking facilities to work to the Ramsgate Post Office and other lightships will in due course be placed in communication with another depot.

The apparatus installed has several interesting features associated with it and is described in detail under the headings:—

(*a*) Aerial (Ramsgate Post Office);

(*b*) Transmitting and speaking devices;

(*c*) Calling: Transmitting and receiving apparatus.

The apparatus in both cases is extremely compact and although the wiring is mainly enclosed, the various items can be detached and the whole of the interior removed for examination with comparative ease. The ship stations differ somewhat from the shore

FIG. 2(*a*).

stations inasmuch as petrol-paraffin power plant has been installed in the former case for the purpose of charging accummulators and for supplying the necessary voltage for the excitation of the telephone transmitting device, whereas in the latter case current is available for such purposes through the medium of a small electrical generator worked from the public mains.

(*a*) *Ramsgate Post Office Aerial.*—The aerial consists of a 7/19 copper stranded wire, about 80 feet long horizontally, with down lead of about 30 feet to the roof. It is supported by a 50 feet light creosote pole on the roof of the Post Office building, the heel of the latter being 40 feet from the road level, the distant end of the aerial being connected to an existing telephone pole 120 feet from the Post Office pole. The wire is insulated by four porcelain rod insulators 18″ long, except the leading-in roof insulator, which is of ebonite composition and of the mushroom or umbrella type. The earth is provided by means of a copper net in the roof. The erection of the pole was somewhat difficult as it was essential to establish temporarily two gallows poles on the roof so that the intermediate lifting of the main pole could be carried out without inconvenience. (See Figs. **2**(*a*), **2**(*b*), **2**(*c*).

(*b*) *Transmitting and Speaking Devices.*—For the purposes of giving continuous attendance the actual speaking and receiving

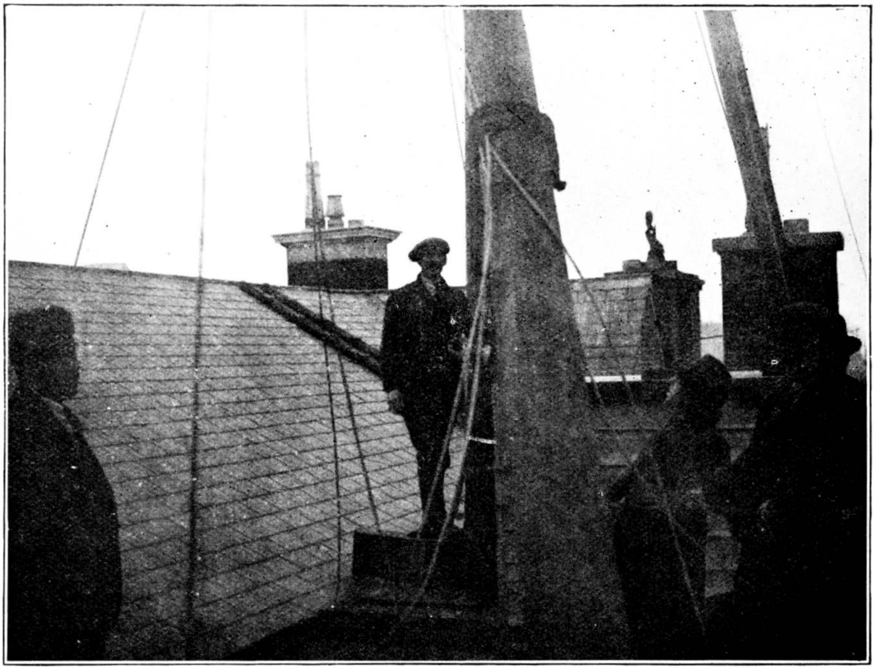


FIG. **2**(*b*).

equipment was placed in the Telephone Exchange, a starting switch for operating the motor generator and bringing into use the accumulator cells being fixed adjacent to the main apparatus The running plant and cells occupy a position in an adjacent room.

The motor is supplied with current from the public mains in the Post Office and is directly coupled with a small generator running at a speed of 2800 r.p.m. and is provided with a double armature which permits of the generation of current for high tension for the purposes of the anode current of the transmitter valve at 1500 volts, and also current at a lower voltage for the low tension accumulators. A relay operated by the turning of a "receiving and sending" switch brings into operation the circuits necessary for the running of this plant.

The motor-generator was subsequently found incapable of the practically continuous charging arrangements required at Ramsgate, and hence it has been necessary to simply use it for its H.T. transmission duty. The cells supplied with the set have been replaced by cells of equal capacity to the Exchange cells and charging is effected in series with the latter by means of suitable switching arrangements.

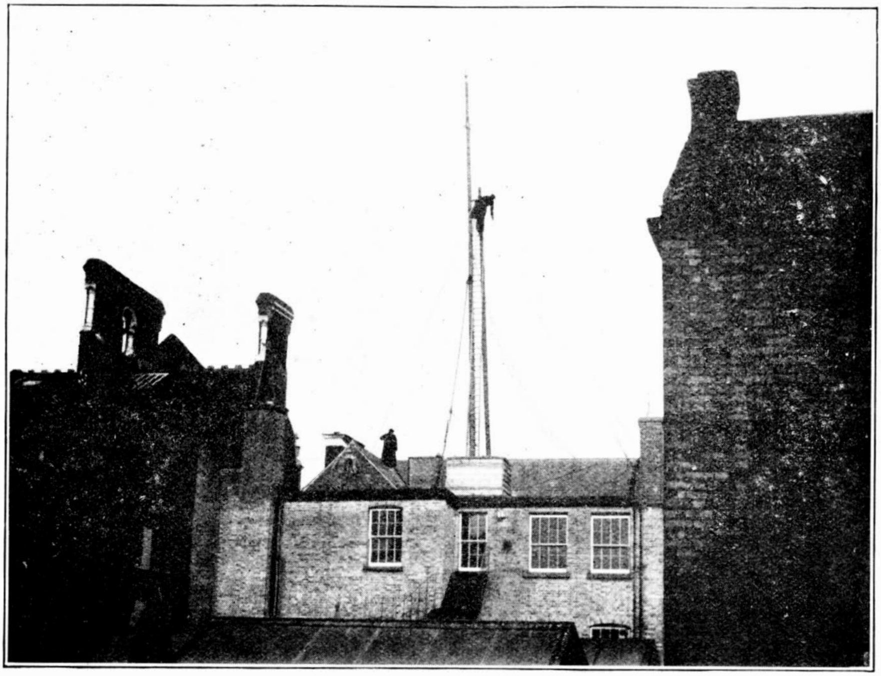


FIG. 2(*c*).

The diagrams shown in Figs. 3(*a*), 3(*b*), indicate the arrangement of the transmitting and receiving apparatus.

It is suitably divided up into compact sections grouped as follows:—

(A) For transmitting purposes: a panel containing the aerial tuning inductance (10) and ammeter for the aerial current; transmitting valve of type M.T. 3, 100 watts (9), a by-pass condenser (12) and the following supplementary apparatus:—

A reservoir condenser (5), for the purposes of smoothing the high tension current, a choke coil (6), for the purposes of preventing ripple currents from the generator, an air coil (7), to prevent high frequency oscillations reaching the generator apparatus, an aerial blocking condenser (8) for the purposes of preventing the short-circuiting the high tension current supply.

In connection with the aerial tuning inductance, which is designed on the variometer or rotating coil plan, is a reaction coil associated with the grid of the transmitting valve coupled to produce the oscillations setting up the carrier wave. The transmitting valve requires a voltage of 1500 volts on the anode circuit, the current for heating the filament being 1.2 amperes. The anode rapidly becomes of a dull red heat and care must be taken to avoid excessive temperatures at this point.

In circuit with the aerial the ammeter records the aerial current, provision being made to short-circuit the former when necessary

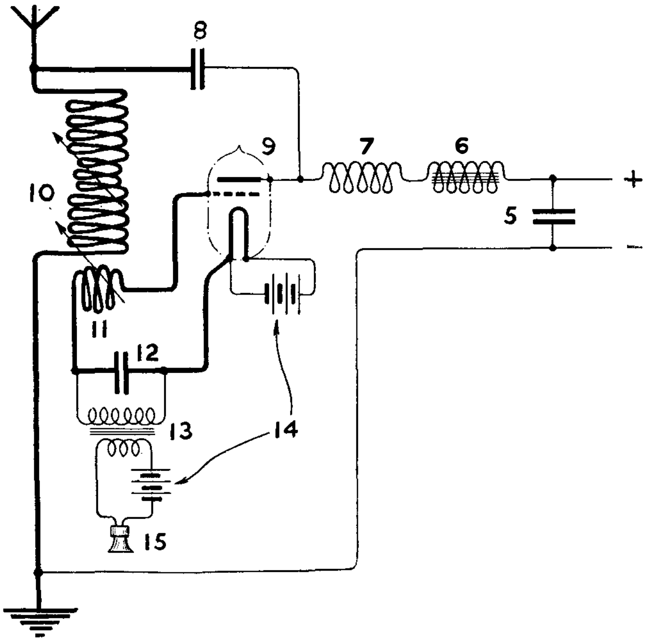


Fig. 3(*a*).—Transmitting Circuit.

The reading of the ammeter is a guide to the proper functioning of the high frequency apparatus. It is, amongst other things, a criterion of the coil adjustments determining the proper modulation of the carrier wave when speaking currents are set up in the microphone transmitter. When the transmitting valve is oscillating the reactance must be such that grid variations due to speech are not of such a magnitude as to excessively vary the potential of the grid either positively or negatively sufficiently to prevent it oscillating.

In the microphone circuit a resistance is available which can be introduced in the event of excess current flowing in the microphone circuit. Incidentally the set supplied is provided with facilities for the substitution of a morse key in place of the speaking microphone whereby telegraphic signals can be transmitted.

Contained within the same compartment as that enclosing the transmitting accessories is a small buzzer and tuning system whereby the transmitted wave-length can be pre-determined in accordance with the required standard.

(B) For reception: the second panel consists of the tuning devices required in connection with the receiver and consist of an aerial series condenser, variable inductance and reaction coil. The inductance is split into two portions so that by means of a two-way switch it can be connected up in a manner most suitable for the reception of either of two wave lengths with the maximum efficiency. The associated panel contains the various detector and amplifier valves, 4 in number, with the usual high frequency and low frequency, inter-valve and telephone transformers (see Fig.

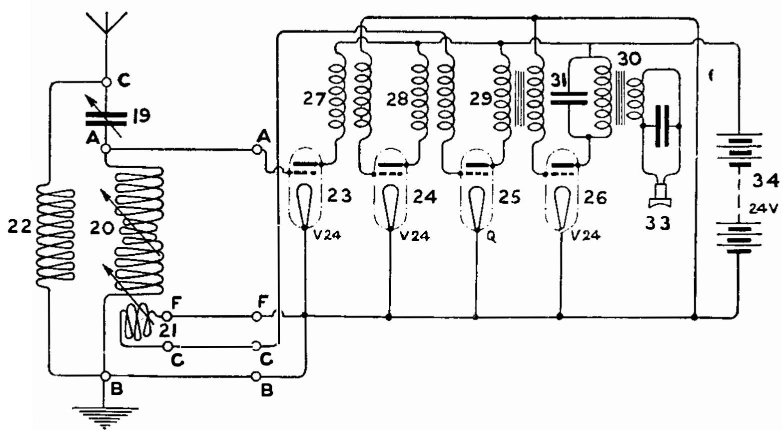


Fig. 3(*b*).—Receiving Circuit.

3(*b*). The first two valves (23 and 24) are for high frequency amplification and the last (26) for low frequency amplification and note magnification.

The grid control of the second valve is effected by means of a tap on a potentiometer resistance with an additional resistance in series to supplement that over which the contact slider passes. The filament currents are regulated by a common resistance supplemented by additional resistance in the case of the third valve. The third valve is specially adapted for rectification. It is of the " Q " type, having a maximum efficiency from the rectification point of view. In practice it is found that the elimination of jamming can best be secured by a comparatively low degree of incandescence of the " Q " valve, whereas in the case of the other three valves the temperature is fairly high.

The usual method of tuning is followed, the maximum volume of telephone speech being secured when the reactance coil is adjusted at a point just below that where oscillation would occur. The combination naturally is tuned to the transmitting system; but at the same time it should act as an eliminating device which will prevent other signals than those required being received.

The capacity and inductance in combination covers a fairly wide range above and below that of the wave length for which the apparatus is designed. It may perhaps be noted at this point that the whole of these valves are in operation in conjunction with two additional valves associated with the call receiving device, so that a total of 6 valves are in circuit to receive a call. The call device

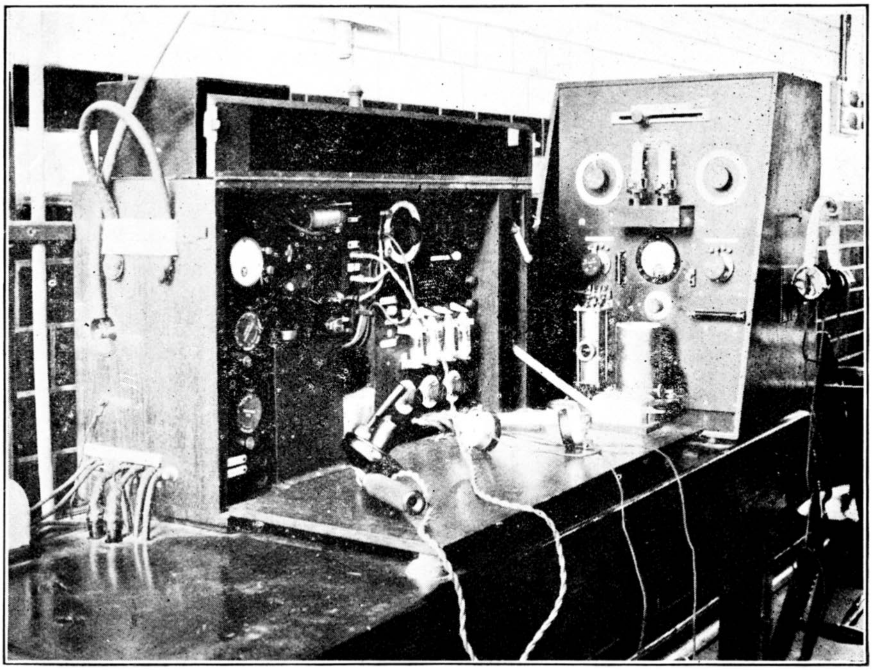


FIG. 4(*a*).

is shown in Fig. 4(*a*). Provision has also been made for the H.F. transformers to have a tap connection, so that the whole or half of the windings can be brought into operation as desired. This facility enables the set to be worked, as before stated, at its maximum efficiency on two definite wave lengths, and provision is made by means of press buttons whereby the connections can be changed for this purpose quickly. It is understood that the tuning is sufficiently flat to allow of 20% margin above or below the wave length for which the receiver is designed, with efficient reception. The potentiometer adjustment of the third valve permits of tuning very sharply. This is an essential condition in view of the proximity of the lightship to ships in the Channel, and it enables the results of jamming to be eliminated as far as is practicable. There are several other points of minor detail and interest in connection with the receiving set, but from a general point of view they need not be specifically mentioned.

(*c*) *Calling*.—Transmitting and receiving apparatus (see Fig. **4**(*b*)).

The principal novelty in connection with this installation can probably be placed under this head. At the present time the installation permits of calling in one direction only, that is to say, the lightships can call the Ramsgate Post Office only. For this reason the calling devices have been installed on the lightships

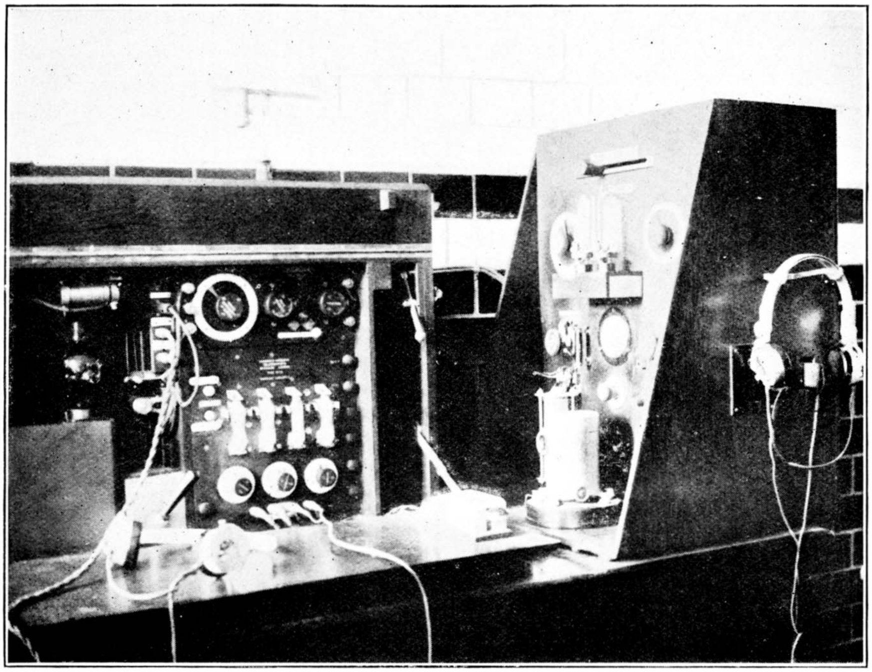


Fig. **4**(*b*).

exclusively, whereas the receiving device is located at Ramsgate Post Office only. The principle which has been followed is to utilise the carrier wave transmission of the ordinary speaking circuit, a signal of lower frequency modulating the carrier wave. Facilities exist on the calling mechanism for generating four frequencies and thus, on the assumption that receiving devices are tuned thereto, four stations can be called on a selective basis. This requirement, however, does not have to be met in the present case and only one low frequency adjustment has been necessary, the best frequency being chosen to meet the local conditions. The call transmitter comprises a valve and complete oscillatory circuit, which determines the low frequency alterations in accordance with the capacity of the circuit connected with it. Such oscillations are carried forward to the high tension circuit of the main transmitting valve ordinarily used for speaking purposes, with the result that the outgoing oscillations are modulated at a frequency determined by the control of the low frequency valve.

A mechanical device is associated with the low frequency transmission circuit whereby, by means of a dashpot and plunger system, the low frequency currents can be established for periods dependent on the time constant of the dashpot, which can be made to vary from a period of 5 to 45 seconds. The operation consists

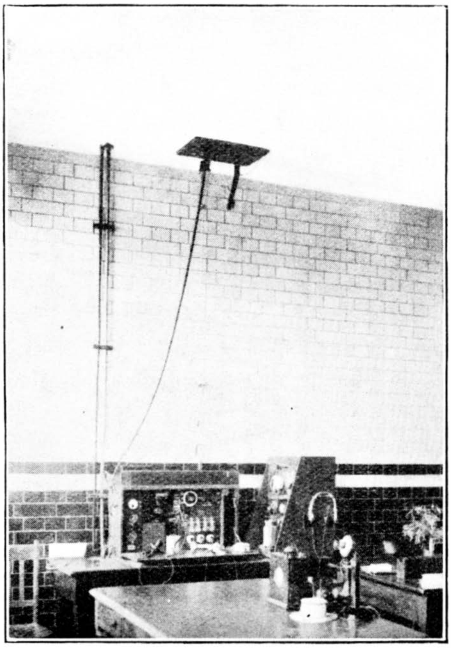


FIG. 4(c).—LEAD-IN.

in pulling down a handle which is held by an electro magnet, a circuit of the latter passing through the dashpot. The duration of the signal is thereby controlled, at the termination of which, and at the end of the allotted period, it automatically cuts the circuit and the calling magnet is de-energised. The working operation therefore consists of starting the normal transmitting valve with the switch at "send" and subsequently operating the automatic calling device, which in turn modulates the transmitted waves.

For the purposes of receiving, the modulated waves are received in the normal telephone transmission and receiver amplifier circuits, but at the end of the amplifier system they are carried into a supplementary item of apparatus known as the "call" receiver, where further amplification and tuning takes place. There are two receiving valves in circuit with a loosely coupled variable inductance, the secondary of which is connected with the grid circuit of the first valve of the call receiver. Accurate tuning by means of a variable condenser to the particular note frequency allocated is here arranged for and in practice the transfomer is coupled so loosely that selection can be of a very refined character, the object being to eliminate unwanted wave lengths. The plate circuit of this first valve is inductively coupled to the grid circuit of the second one, which contains a grid condenser, and leak together with the secondary of a reaction transformer.

It will be observed that this reaction transformer is intermediate between the grid condenser and grid and that its primary coil is associated with the anode circuit. The transformer has an iron core, and in the ordinary conditions there would be a definite time lag between the operation of the secondary circuit and the variation in grid due to its original potential changes, but it will be seen that no detrimental effect arises in this connection for the reason that speech is not involved at this point and any want of phase will not interfere with the character of the received signal which eventually operates the relay. In practice it is found that the reaction introduced in this manner affords a considerable increase to the working margin of the apparatus. As the filament is made incandescent permanently under working conditions, it will be seen that there is a continuous flow of current to the anode and this current is arranged to hold over the tongue of the relay against the spacing stop. When, however, a signal is received and the grid is rendered so negative that the current through the valve is reduced it is therefore not sufficiently strong to hold over the tongue of the relay, which passes to the marking stop, thus completing the circuit through the dashpot relay. This dashpot is timed in the same manner as the one which controls the duration of the signal at the transmitting end and once set in motion by the relay it completes its travel and operates the bell. The dashpot consists of a cylindrical tube with paraffin as the viscous medium determining the rate of rise and fall of the armature, the latter being regulated by means of a cam giving the necessary adjustment of play over a wide period of time. The operation of this apparatus therefore depends largely on the fact that in the ordinary operation of other transmitting systems, the transmitting key would not be held down for a sufficiently long period as would interfere with the working of the call device at the Ramsgate Post Office, and it remains to be seen to what extent in practice this condition holds good. The system is undoubtedly complex, but in the hands of reasonably skilled operators there should perhaps not be any unusual maintenance difficulties. It is without doubt much more complex than the installations of ordinary telephones which have hitherto been relied upon and it remains to be seen how far experience indicates that the system will be sufficiently reliable to justify its extension in other directions. It obviously eliminates the necessity for skill so far as regards the transmission of communications with ordinary telegraphic symbols, but on the other hand it involves such a degree of scientific and electrical skill that the period taken to acquire the latter may not be, comparatively speaking, much greater than that required in the ordinary course in acquiring a knowledge of telegraphic manipulation.

Noise and Interference.—The set was originally designed to work on the 320-metre wave-length. A considerable amount of noise and jamming occurred on this wave-length, however, and investigation was necessary into both cases of trouble.

As regards noise, this arose largely from the proximity of the Exchange charging plant, both the Exchange generator and dynamotor causing noise through sparking, with additional noise arising from ripples in the mains. The motor generator sparking was practically cured by alteration to the angle of commutation, the best position being found by trial. The dynamotor was changed for a new item, sparking on the old one being due to wear and tear.

Condensers of the value of 1 M.F. across the mains reduced, to a practical value, the noise due thereto.

A further source of noise arose in earthing the frame of the High Tension Generator. The direct connection to earth brought a strong noise into the receiving part of the apparatus. This was overcome by inserting an air core choke in the direct earth connection after experimental trials had decided the correct value of the choke.

Interference was found particularly bad on the 320-metre wave, due to much shipping in the Channel working on or near this wave length. So much interference arose that it was eventually decided to reduce the wave length to 285 metres, on which interference was found to be to a minimum. The aerial system needed modification to work well on the smaller wave length. A subsequent permanent change to 250 metres has also been adopted.

The work of installation has been carried out by the Marconi Company's officers and the information contained in these notes has, in the main, been supplied through the courtesy and kindness of the Marconi Company.

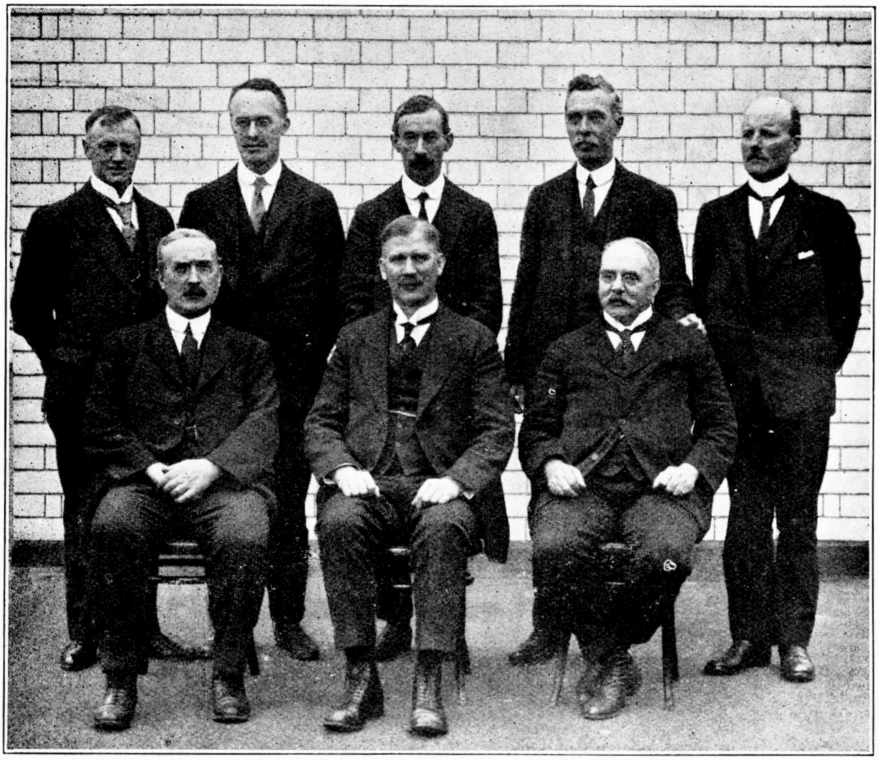
The specification for the installation was prepared by the Trinity House Authorities with the assistance of Officers of the Engineer-in-Chief.

Oct., 1923.

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS.

THE BOARD OF EDITORS, P.O.E.E. JOURNAL.

(Taken on the occasion of Mr. Hill's retirement).



Back row, left to right: E. J. WILBY, B. O. ANSON, J. W. ATKINSON, A. O. GIBBON, A. C. BOOTH.

Seated, ,, ,, ,, W. CRUICKSHANK, E. H. SHAUGHNESSY, J. G. HILL.

LOCAL CENTRE NOTES.

LONDON CENTRE.

1923-24 SESSION.

The Session was opened by a visit to Messrs. Johnson and Phillips' Cable Works at Charlton on July 30th. This was followed by a visit to Messrs. Siemens' Works at North Woolwich on October 4th. The parties numbered 70 and 90 respectively, and the Members much appreciated the arrangements made by the respective firms for their benefit.

The first General Meeting of the Session was held at the Institution of Electrical Engineers on Oct. 9th. The President, Col. T. F. Purves, took the chair, and after a few words of praise for the work done by the Centre in the past and of encouragement for the future called upon Mr. A. B. Eason to read his paper on "Power Plant in C.B. and Automatic Telephone Exchanges." The paper described the evolution of the present practice and showed that there was no finality in design; at some period of the growth some parts of the system now in use were in the trough of the wave and almost lost to view and at other times they were on the crest; but each movement is faithfully recorded in the Department for the guidance of those responsible for the design of plant. A good discussion followed.

On the 13th November, Capt. J. G. Hines read a paper on "Some Considerations Affecting the Lay-out of Telephone Plant in a Multi-Exchange Area." The subject is of great importance from the traffic standpoint as well as from that of engineering cost. The author has been engaged on the work for several years and his experience shows that the problem of the best lay-out of external plant cannot be solved without the systematic investigation of many factors to which otherwise arbitrary—and generally inaccurate—values would have to be assigned; and these investigations must of necessity be conducted by the Engineering Department. The paper was followed by a long and interesting discussion.

Mr. J. G. Hill, who took part in the discussion, will have retired from the service by the time these notes are in print and the opportunity is taken to wish him long life and prosperity in his retirement and to assure him a warm welcome to our future meetings.

R.T.R.

SOUTH WESTERN CENTRE.

SESSION 1923-24.

With reference to the current session, it has been decided that the full pre-war activities of the Institution should be attained, and that full Centre Meetings should be resumed in those cases where divided meetings have been the practice during recent sessions.

Meetings are therefore being held at:—

The Royal Hotel, College Green, Bristol.

and not at Bristol and Plymouth as hitherto.

The following programme has been arranged:—

16th October, 1923.—Annual General Meeting with Presidential Address by E. J. Eldridge, M.I.E.E.

13th November, 1923.—" Standardisation in the Engineering Industries." A. J. Stubbs, M.I.E.E. (late Assistant Engineer-in-Chief).

11th December, 1923.—To be arranged.

15th January, 1924.—" The Suitability of C.B. Signalling v. Magneto Signalling in Scattered Areas." A. T. Kinsey, A.M.I.E.E.

12th February, 1924.—To be arranged.

11th March, 1924.—" Electrolytic Action in Lead Covered Cables." B. J. Smith.

It is probable that Headquarter Officers will address the Centre on :—

" Automatic Telephony " and " Machine Telegraphy with special reference to present day Baudot working,"

on 11th December and 12th February respectively, but arrangements have not yet been completed.

Reference Libraries.

A catalogue showing the recent additions to the Central Library was recently circulated.

Special attention is drawn to the books held for reference purposes at Bristol which are listed therein. It is hoped that members will take full advantage of these new books.

The period of loan is indefinite—unless a book is required by another member, when the maximum period is 14 days—but there is no restriction as to the number of works which a member may borrow at one time.

The same procedure applies to books borrowed from the Central Library.

Technical Periodicals.

Complaints are being received that these are often " out of date " by the time the last member on the list receives the publication which he has selected.

Will members kindly circulate as quickly as possible these periodicals and not retain them unduly. If, for any reason, the particular periodical cannot be read when received a note opposite the member's name " To me later " will ensure its return when it has circulated to other members.

Election of Hon. Librarian and Hon. Secretary.

With reference to the nominations called for for these posts, Mr. J. E. G. Burt was elected Hon. Librarian and Mr. R. G. Alexander Hon. Secretary, both unopposed.

Annual General Meeting.

This will take place, as will be seen by reference to the programme, on the 16th inst. Members are urged to make a special effort to attend and to bring forward any proposals or suggestions for discussion with a view to making the session a great success. The time of the meeting will be notified later.

R. G. ALEXANDER,
Local Hon. Sec.

Bristol, 3/10/23.

SOUTH MIDLAND CENTRE.

At the first meeting of the 1923-4 session held on the 31st October, 1923, the Chairman, in presenting to Mr. Peck a three-tier sectional bookcase subscribed for by the members, briefly eulogized Mr. Peck's work as local Secretary during a period of seven years. The recipient thanked the Chairman and his fellow members of the Centre for their gift, and made a graceful acknowledgment to them of their generous spirit of co-operation which he had received in arranging the programmes session after session.

Mr. B. O. Anson, M.I.E.E., of the Engineer-in-Chief's staff, then commenced an illustrated lecture on "Automatics."

It is understood that Mr. Anson's lecture is also to be delivered in other Centres, but possibly if space can be found in the Journal for a report of the proceedings at Reading, other Centres may appreciate the great educational value of the lecture.

The lecturer at the outset demonstrated the possibilities of development in this country by the display on the screen of curves which showed that the numbers of telephones per thousand inhabitants in the U.S.A. was about six times as large as it was in this country, whilst the population was only about three times as large.

He continued by exhibiting photographs of Subscribers' apparatus and Exchange plant suitable for small, medium and large Exchanges, and explained by the aid of a skeleton diagram how the apparatus was actuated when a call was made.

After the working in broad outline of the Automatic systems at Accrington and Blackburn linked Exchanges, and of the new plant at Sheffield and satellite Exchanges had been explained, Mr. Anson showed the method evolved in order to surmount the problems which demanded solution before the numerous Exchanges in London and other very large cities could be converted to the automatic system.

The lecturer demonstrated the manner of determining the economic capacity of the plant to be installed by means of statistical graphs, which related the number of switches to the estimated traffic units.

Possibly owing to the promise—if time permitted—of sugar plums consisting of the display of additional slides, the questions were of unusual brevity. Mr. Halton congratulated the lecturer and sought further information concerning the possible variation in the "busy hour" load under automatic conditions. Mr. J. S. Brown asked about the battery capacity at Southampton Exchange and also appealed to the members to make a close study of automatic telephony and expressed the opinion that the system had come to stay.

The additional slides put through the lantern were of a distinctly propagandist flavour, and some of them evidently originated in the land of Abraham Lincoln. One gruesome exhibit purported to demonstrate that even in the home of sky-scrapers the span of life itself might on occasion fail to compass the time required to obtain a telephonic connection—presumably through a *manual* exchange.

* * * * * *

We had the pleasure at the meeting on the 28th November of hearing three short papers. Mr. J. H. Haynes' lecture was entitled: "The Transposition of Wires."

He outlined the difficulties of grafting the newer arrangement of running wires on the transposition system on to the superseded "twist" system, and gave some details of the organisation evolved to overcome the interregnum between uniform dispositions of the conductors.

Mr. Haynes drew attention to the economies in first cost and in maintenance resulting from the introduction of the transposition system and the reduced liability to error on the part of the workmen erecting wires, but he feared that in certain atmospheric conditions snow might cause contacts between wires run "on the straight."

The problem encountered in selecting "S.O." poles in areas where the routes are numerous were stated, and suggestions to overcome the difficulties were enumerated.

Early experiments were described, and questions asked and opinions given by Messrs. Beasley, Halton, McInnes, Atkins, Beaumont, and the Chairman. Mr. Haynes replied to the six members, but it was evident that Mr. Halton curtailed his questions owing to the fact that two other papers were to follow.

The subject of Mr. B. J. Beasley's paper was: "Terminating Loaded and Balanced Cables."

The lecturer emphasized the necessity of securing for conductors in main cables a very high insulation resistance and that it was therefore very important to give close attention to the terminations. He detailed the methods devised for terminating main cables (1) which are and (2) which are not phantom loaded, gave practical hints about the procedure, and described difficulties in actual practice.

Mr. Beasley contended that it was imperative that the cotton wool used in packing should be thoroughly dry and that neither the cotton wool nor the Compound No. 2 should come in contact with the paper.

Several slides were shown which were very helpful in enabling the audience to follow Mr. Beasley's points more easily.

Messrs. Beaumont, Campbell, Halton, and Atkins' questions were answered and the lecturer thanked Mr. J. S. Brown for his information about the effects of humidity in cotton waste.

Mr. A. H. Brown made himself responsible for the last of the trinity of increments to our vocational education by introducing the topic: "Electrolytic Action: Use of Tester Number 36."

The construction of the tester was described and we were fortunate in being able to see the actual apparatus as the details of its mechanism were adumbrated.

The use of the instrument when detecting stray currents in cable sheaths was explained, and the method of ascertaining the strength and direction of the flow was described. Mr. Brown inferred that sometimes owing to variations during a short period of time in the flow of the unwanted current, before the wavering records of the tester are accepted by Officers of other undertakings, it might be necessary to supplement the results by verbal persuasion.

The lecturer closed with useful advice about the preparation of reports in case of suspected electrolytic action.

Replies were given to the questions raised and comments made by Messrs. Haynes, Beaumont, Atkins and Halton.

Members might be excused if they carried away from the meeting a pathetic mind photograph of a Post Office officer on the roadside shielding from a deluge a piece of Departmental apparatus, the delicacy of which is apparent from the symptoms of feminine uncertainty it betrayed in making up its electrical mind.

A.W.L.

NORTH WALES CENTRE.

The first meeting of the Session was held at Shrewsbury on 23rd October, 1923, when Mr. H. W. Powell read a paper on "Maintenance Tests and Fault Localisation on Main Underground Cables." The Chairman of the Centre, Mr. T. Plummer, presided.

The lecturer exhibited several items of apparatus and numerous diagrams and, after explaining the necessity for monthly tests, followed with references to the degrees of urgency in taking up faults. Reference was also made to the first tests of cables, the past history of which is unknown, the types of terminations, and the time and place for the tests to be carried out. The desirable standard of insulation was touched upon and particulars of the various localising tests given.

On 27th November, 1923, a meeting was held for the purpose of hearing Mr. C. G. A. McDonald read a paper on "Illumination."

He referred to the various systems of lighting and the physiological effects of lighting in general, and described the effect of the use of different types of lamps and reflectors. He also dealt with the question of intensity of illumination and in this connection compared the standards laid down in the British and American Post Offices. He expressed the opinion that as additional lighting had been proved to result in greater speed of working an increase in illumination could be proved to be a paying proposition. The lecture was illustrated by lantern slides.

The present Session promises to be a successful one and the membership has recently been increased to 138.

RETIREMENT OF Mr. J. G. HILL.

It will come as a surprise to many that on 4th December, 1923, Mr. Hill attained the age of 60, and it will be a matter of regret not only to his colleagues but also to his numerous friends in the larger telephone engineering world that he elected to retire—though, if we may be confident of anything, not into inactivity.

As James Greaves Hill he entered the service of the Postmaster-General in 1877, and during a period of 14 years, whilst engaged as a telegraphist at Sheffield, he was an ardent student of mathematics and physical science, the result being his promotion to a Junior Clerkship in the Engineering Department on 1st August, 1896. The further steps in his official career were to an Engineership in the Engineer-in-Chief's Office on 9th December, 1901; to a 1st Class Engineership in charge of the then Leamington Section on 30th April, 1909; and, on 8th November, 1910, to the (then) equivalent of an Assistant Staff Engineership in the Research Section of the E.-in-C.O., which position he occupied until he retired.

In these pages it is almost unnecessary to state that Mr. Hill has been closely associated with the development of the science of Telephone Transmission for the past 20 years and that he ranks as one of the leading authorities on the subject; but even among ourselves relatively few are aware of the investigations and researches in which he has played a prominent part.

In 1902 he assisted in the first Continental speech investigation;

in 1904-5 he co-operated with the National Telephone Company in transmission tests, designed the first standard cable equipment used by the P.O. (as distinct from the N.T. Co.) and conducted the first standard cable tests; in 1906-8—when "loading" was in its infancy and there was a strong leaning towards "air-core" coils—he made the first P.O. investigation into the then novel and somewhat suspect, "iron-core" coils of the Western Electric Company and reported favourably, subsequently assisting the late Mr. A. W. Martin in a long investigation into the relative merits

Mr. J. G. Hill.

of the two types of coil installed on underground circuits between Manchester and Liverpool; in 1909 he also assisted Mr. Martin in special tests of the Krarup system of continuous loading in Denmark; whilst since that date he has conducted or co-operated in practically every transmission test or investigation of any consequence, including, of course, the extremely important tests on the results of which the range of telephone communication with the Continent has been continuously increased without lowering the standard of speech.

In carrying out the various Continental investigations Mr. Hill's unusually good knowledge of the French language placed him in an exceptional position, and both the British P.O. and the various Foreign Administrations benefited to an extent which can hardly be exaggerated. His qualifications as a linguist also made him a very valuable delegate to the International Conference of Telegraph and Telephone Experts, held at Buda Pest in September, 1908, the Joint Conference of the Institution of Electrical Engineers and the Société Internationale des Electriciens de Paris in May, 1913, and the Conference on International Telephony at Paris in March last.

Mr. Hill's contributions to the literature of Telephone Engineering cover a period of 17 years, and he has good reason to be proud of the high standard, both literary and technological, of all of them. No apology is needed for presenting our readers with a list (apart from contributions to the technical press):—

1906—Paper on "Telephone Transmission." Contributed to the Institution of P.O. Electrical Engineers. Awarded Senior Bronze Medal.

1914—Paper on "Loading of Aerial Lines." Institution of P.O.E.E. Awarded Senior Silver Medal.

1916—Paper on "Loading of Underground Cables for Phantom Working." Institution of P.O.E.E. Awarded Senior Silver Medal.

1922—Paper on "Phantom Circuits and Combined Telegraph and Telephone Circuits." Contributed to the Institution of Electrical Engineers and awarded the Institution Premium of £25.

1922—Book, "Telephonic Transmission: Theoretical and Applied."

The last-named, which has already attained a world-wide circulation, is, of course, the *magnum opus* of the series; but the first is of special interest as being also the first of the scientific and technological papers contributed to the Institution of P.O.E.E.

It is also a matter of special interest that Mr. Hill has acted as Chairman of the Board of Editors of this Journal, of which he has been a member for several years; and we are deeply indebted to him for the whole-hearted support, valuable advice and personal work which he has contributed.

Blessed with a modest but genial personality and a mind of high integrity it is not surprising that, at the end of his official career, his numerous friends decided that he should not be allowed to "steal silently away," and in the G.P.O. Deputation Room on December 3rd, at one of the most pleasurable functions of the kind ever convened, he was presented with several tokens of esteem, including some jewellery for Mrs. Hill. The Chair was taken by

Colonel Purves who, after one of those felicitous contributions of which we are always sure when we see him on his feet, called on Mr. S. A. Pollock to make the presentation. This was done in happy vein, reference being made to many of the facts related above, and it was equally pleasant to hear the remarks of Mr. E. H. Shaughnessy, Mr. B. S. Cohen, Mr. A. B. Hart, Mr. C. Robinson, Mr. W. S. Mountain and Mr. W. E. Twells, all concurring in the wishes already expressed by Col. Purves and Mr. Pollock that Mr. Hill in his retirement would be granted long life, good health and all prosperity.

J.W.A.

BOOK REVIEWS.

"The Inspection and Testing of Materials, Apparatus and Lines." By F. L. Henley. Price 21*s*. nett. Published by Longmans, Green & Co.

This is the third of the series of Manuals of Telegraph and Telephone Engineering published under the Editorship of Sir Wm. Slingo.

The book is written primarily for the Inspector of Materials, and contains considerable information upon manufacturing processes in addition to detailing the tests on the finished products. The author rightly points out that the more the Inspecting Officer knows of manufacturing processes, of the properties of materials and of craftsmanship, the better able he will be to form an accurate judgment.

The subject is an extraordinarily difficult one to write up satisfactorily with a readable book, and to this end the author adopts what he calls the "narrative" form. In this he has been fairly successful in the earlier portions of the book, but in many cases the "narrative" merely results in the absence of proper paragraphing. It is somewhat confusing to the general reader to find a number of different subjects dealt with in one paragraph, and greater attention to this, and to the classification of the headings, would considerably improve the readability of the book.

Another general criticism of the book is that while the author has included a vast amount of interesting information on the properties of materials, the subject of testing is rather scantily handled. The testing of materials is a profession which has its own specialization, and while there are numerous text-books in existence which give the theories underlying the various tests, very few of them deal with the practical points which occur in this work. For example, the author mentions, in connection with the electrical tests on cables, "that the leads from the galvanometer to the cable should not be of the concentric rubber dielectric type, otherwise the apparent wire-to-wire capacity of the cable will be low." He does not, however, give any explanation on the point, and, if my recollection on the subject serves me rightly, there are also cases where the use of leads whose capacities to earth are unequal may even make the apparent wire-to-wire capacity higher than the true wire-to-wire capacity.

The first portion of the book deals with the properties and testing of the ordinary engineering materials, such as copper, wood, clay and clay products, indiarubber, gutta-percha and balata, paints and creosote. In this portion are included the various telegraph construction items, such as cast-iron and earthenware pipes, poles, copper wire, paper and other cables, etc. The subjects are well handled, except for the unduly long extracts from British Standard Specifications, the cheap price of which and their ready accessibility to the reader, might well have led to their exclusion from the book, even if other grounds, *e.g.*, the impossibility of converting them into "narrative" form, had not persuaded the author to omit them.

The latter portion of the book deals with apparatus. Batteries, telephone transmitters and receivers, telegraph apparatus, exchange apparatus and switchboards are included. There are also chapters dealing with testing at audio frequencies, and with the tests on thermionic valves. Finally, a chapter on maintenance testing of lines concludes the book.

The author lays considerable stress on the details of the mechanical examination of apparatus and to the points of workshop finish which receive attention in the inspection.

Several pages are devoted to the mathematics of the Wheatstone bridge used with alternating currents, which in view of the scope of the book could have been equally well explained by some of the simplex mathematical solutions which are available. It might also have been desirable to call attention to the fact that the Wheatstone bridges given will only balance with real sinusoidal currents and will not balance, or will give incorrect balances, with approximate sinusoidal currents such as those which can be obtained from a buzzer. Buzzer testing with suitable currents used to be standard practice at one time.

The present tendency is, however, to use sinusoidal currents and the author gives on page 267 a description of the triode oscillation generator used by the Post Office for testing work. A point worth noting in connection with this oscillator is that it is of a type which tends to produce strong harmonics, and means should be taken to eliminate them in certain tests of telephone apparatus where resonance effects are liable to be present.

In the chapter on maintenance testing of line the author gives an account of the modern Post Office method of locating incipient faults in paper cables, before they occur. In past times, the desiccator was too frequently used indiscriminately at this early stage, with the result that many cables have been irretreviably spoilt by the dispersion of moisture along their whole length.

A.G.L.

"The Poulsen Arc Generator." By C. F. Elwell, M.I.E.E., M.A.I.E.E. (London; Ernest Benn, Ltd.). 192 pp. 18*s*. nett.

Mr. Elwell's book is a most valuable contribution to Wireless literature and the first work devoted entirely to this subject. The author in his preface states that the book is not intended to be a technical treatise but rather the account of a machine which, in the twenty years of its existence, has rendered great services to mankind. In spite of this disclaimer the book is full of sound practical engineering information.

The matter commences with a short history of the Poulsen Arc. Following chapters deal with the theory of the Duddell and Poulsen Arcs and with the design of commercial arcs. The author then passes on to descriptions of commercial arc generators. The essential differences between Danish, English, German and American arcs are here described. Methods of keying are next treated and a chapter follows in which types of actual keying apparatus are illustrated. Auxiliary apparatus is next dealt with. Included under this heading is the D.C. control apparatus, and also the High Frequency apparatus such as Aerial Inductance, Condensers, Antenna Entrance and Wave-Changing Switch.

An interesting chapter follows on the application of the arc to Radio Telephony. There has been such a rapid development in the use of valve transmitters for Radio Telephony that one is apt to overlook what has been done in the way of telephony by arcs. At present there are two Radio Telephone services acting as links in public telephone services. One of these links is between the island of Santa Catalina and the mainland of California and is worked by valves, while the other link is between the islands of Bornholm and Zealand in Denmark and is operated by Lorenz Poulsen Arcs.

The two concluding chapters deal with high frequency measurements and descriptions of typical arc installations.

Perhaps the most valuable feature in the book is the very complete bibliography which contains references to practically every article or paper of importance on the Poulsen Arc. Throughout the work Mr. Elwell has been careful to give references to all sources of information which he has utilised. It is pleasing to notice that much of Dr. Fuller's valuable paper on the Poulsen Arc has been rescued from oblivion by inclusion in Chapters IV. and V. of this work.

The book is well printed and contains a large number of excellent diagrams and half-tones. It will be accepted as a valuable and standard work of reference on this subject by Radio Engineers.

A.J.G.

"Principles and Practice of Wireless Transmission." By G. Parr. (London: Ernest Benn, Ltd.). 163 pp. 5*s*. nett.

This book is stated to be intended for those who wish to be informed of the principles on which wireless transmission is based but who is neither able nor inclined to acquire a knowledge from books in which it is treated as part of the general science. It seems questionable whether there is any justification for splitting up the subject of wireless telegraphy in this way when the subject is handled in such an elementary manner.

The writer commences with the principles of electricity and magnetism. The first three chapters of 60 pages deal with this part of the subject, while Chapter IV. describes waves and wave motion. In this chapter the writer does not appear to be as clear as he might have been in describing the use of graphs to represent waves in one case and oscillatory currents in another. Chapter V. deals with Electric Oscillations while Chapter VI. is devoted to Spark Transmission. Continuous Wave Transmission by alternators and arcs is next dealt with in Chapter VII. An error occurs here in describing arc keying. On short-circuiting the keying inductance the wavelength is decreased not increased as stated. The remaining portion of the book is devoted to methods of valve transmission and modulation.

The book as a whole contains much useful information, but it is a work which will have a very limited appeal.

A.J.G.

"Time and Weather by Wireless." By W. G. W. Mitchell, B.Sc., F.R.A.S. (London: The Wireless Press, Ltd.). 125 pp. 3*s*. 6*d*. nett.

This little volume fills a distinct vacancy in popular wireless literature. The book is divided into two sections, the earlier portion dealing with time signals while the latter portion deals with weather reports. The section on time signals describes the different codes used for distributing time signals. Sidereal time is explained and a description is given of the scientific or vernier time signals sent from Eiffel Tower. This section contains a table of all stations throughout the world which send time signals.

The second portion of the book on meteorology deals first of all with the factors which decide the weather. The organisation of a meteorological service is here described. The various codes used in sending weather reports are mentioned, although full particulars for decoding such reports are not given. The preparation of synoptic charts is described and some useful hints on forecasting are given. The book concludes with a time table of the principal European transmissions of weather reports to aeroplanes.

The work forms a handy and useful little reference book on these subjects.

A.J.G.

"Wireless Telephony—A Simplified explanation." By R. D. Bangay. (London: The Wireless Press, Ltd.). 134 pp. 2*s*. 6*d*. nett.

Mr. Bangay's little book follows the lines of his previous works in which the principles underlying Radio Telegraphy are explained by reference to mechanical analogies.

This method dispenses with the necessity of any mathematical treatment, yet it enables persons who have no previous knowledge of electrical and physical phenomena to obtain a grasp of the fundamental principles involved. The author appears to have achieved his purpose very successfully.

The book is clearly printed and contains a large number of diagrams which help to illustrate the author's meaning. The explanations given are very ingenious and are likely to appeal specially to persons who have a mechanical turn of mind.

"The Wireless Experimenters Diary and Note Book." (London: The Wireless Press, Ltd.). *2s. 6d.* nett.

This is a handy little diary for the wireless enthusiast. In addition to the usual diary pages it contains notes of general information, together with a list of European Broadcasting Stations and a list of call signs of amateur transmitting stations. There are also a number of useful tables and formulæ.

"The Wireless Amateurs Diary and Note Book." (London: The Wireless Press, Ltd.). *1s.* nett.

This is similar to the Experimenters Diary, but is in a cheaper binding and is abridged. The list of amateur call signs is omitted, but about 37 pages of useful notes and data on receiving circuits is included instead.

A.J.G.

ARTHUR WEST HEAVISIDE, I.S.O.

WITH the death of A. W. Heaviside there has gone not only the last survivor of the original band of Superintending Engineers, but one of the most remarkable men of the Post Office Engineering Service. He was born on the 30th June, 1844, "within the sound of Bow Bells," and commenced his career with Sir Charles Wheatstone—whose relative he was. At the age of 17 he became Assistant Engineer to the Universal Private Wire Company, of which Sir Charles was the Chief Engineer, and he was afterwards placed in charge of that Company's operations at Newcastle-on-Tyne. The Wheatstone A.B.C. was in considerable use between colleries, shipping offices, coal staithes, etc., and Heaviside devised an Exchange System by which these various A.B.C. renters could be put in communication with each other. At the transfer in 1870 he was Superintendent at Newcastle, and with the revision which followed after the transfer he was appointed Superintending Engineer of the District—which bore the somewhat clumsy title of the "North Eastern (Northern) District." The invention of the telephone at once attracted his attention, and he is believed to have possessed the first pair of telephones in England, they being made in the P.O. Workshop at Newcastle from descriptions of Graham Bell's invention, and proved successful, before Mr. (afterwards Sir W. H.) Preece arrived with a pair of telephones from America.

He threw himself with great seal and energy into the work of transforming the A.B.C. System into a telephonic one, being greatly assisted by Messrs. G. M. Carr and W. R. Smith; and during this time he devised the Bridge System of telephony, which was of considerable service on circuits with intermediate offices. The first multiple exchange possessed by the Post Office (and the only one for many years) was at Newcastle, being authorised in 1889 and opened in 1891. He carried on competition with the

The late A. W. Heaviside, I.S.O.

National Telephone Company so vigorously that for many years, and, in fact, until the Post Office started telephoning London, the Newcastle Exchange was the only Post Office one of any considerable size.

The "N.E.N." System, as many of our readers are aware, was a secret one, the operator being able to speak to either subscriber in turn, but cut out of circuit when the two subscribers were put through to each other. A permanent current was sent from each subscriber's office to the Exchange, and deflected an indicator needle to the right. The lifting of the left-hand receiver cut off the current and gave the call signal, and the lifting of the second receiver restored the current in the reverse direction, so that the indicator needle at the Exchange and at any intermediate office showed that the circuit was engaged. This system continued until his retirement, when it was replaced by one of the C.B. type.

Heaviside was not only one of the leading pioneers in telephone working but also took great interest in the development of wireless telegraphy, and some of the earliest experiments were made on the Newcastle Town Moor. He also devoted considerable attention to the development of electric light and power, and was largely instrumental in forming the Newcastle Electric Supply Company, which is now probably the largest supplier of electric power in Europe. He was a notable pioneer in the early days in the use of underground wires for telephones, the cables then being, of course, of the G.P. type.

Heaviside always took great interest in the training of young men, and was able to infuse his own enthusiasm and energy into them, and to obtain the last ounce out of willing workers. The devotion of the members of his staff to himself was a most remarkable feature. Among those who were under his control during some portion of their career were Messrs. G. M. Carr, T. Harrison, A. Moir, T. J. West, J. F. Lamb, T. E. P. Stretche, T. B. Johnson, and J. R. M. Elliott (Superintending Engineers), and J. G. Holdsworth, W. R. Smith, H. Wilson, W. J. Bailey, and D. H. Kennedy (Assistant Superintending Engineers, or Assistant Staff Engineers).

Even telephony, electric light, and wireless telegraphy did not exhaust Heaviside's interests, and on the formation of the Tyne Submarine Mining Volunteers he took a commission, and held it for some years. He was a prominent member of the Newcastle Literary and Philosophical Society, on the Council of which he served, and before which he gave a lecture on Telephony so long ago as July, 1881.

He was elected an Associate of the Institution of Electrical Engineers in 1872, and a Member in 1877, and won a Fahie premium. When the Institution decided to establish Provincial Centres, Newcastle was one of the first, if not the first, to be opened in 1899, and Heaviside was unanimously elected the first Chairman on the nomination, I believe, of Mr. (afterwards Sir John) Snell. He was invested with the I.S.O. in 1903.

On his retirement, on the 1st September, 1904, he went to live at Ealing, and was for some months employed in connection with the transfer of the National System to the Post Office. After some years he went to live at Torquay, where his brother Oliver already resided.

He was a rare fighter, both in pressing his demands on the Treasury and at Headquarters, and in defending the Department's rights, being particularly strong in pithy sentences, many of which might be quoted as maxims. He was as invariably courteous to the humblest member of his staff or one of the public as to the Postmaster-General or a peer of the realm.

T.B.J.

10th December, 1923.

STAFF CHANGES.

POST OFFICE ENGINEERING DEPARTMENT.

APPOINTMENT.

Mr. H. P. Brown, Assistant Staff Engineer, has been appointed by the Government of the Commonwealth of Australia as Permanent Head of the Postmaster-General's Department in Australia, from 18th December, 1923.

PROMOTIONS.

Name.	Grade.	Promoted to	Date.
Robinson, C. ...	Executive Engineer, Research Section, E.-in-C.O.	Asst. Staff Engineer, Research Section, E.-in-C.O.	5-12-23
Leigh, J. H. ...	Assistant Engineer, South Lancs. District.	Executive Engineer, Technical Section, Eastern District.	1-1-24
Savory, D. C. ...	Chief Inspector, North West District.	Assistant Engineer, South Lancs. District.	1-1-24
Emlyn-Jones, J ...	Chief Inspector, South West District.	Assistant Engineer, South West District.	20-12-23
Woods, E. J. ...	Chief Inspector, S. Eastern District.	Assistant Engineer, Lines Sect., E.-in-C.O.	To be fixed later.
Hambleton, J. W.	Chief Inspector, Testing Branch.	Assistant Engineer, Designs Section, E.-in-C.O.	do.
Brown, G. ...	Chief Inspector, Scot. West District.	Assistant Engineer, Equipment Section, E.-in-C.O.	do.
Armitage, D. ..	Chief Inspector, Wireless Section, E.-in-C.O.	Assistant Engineer. Wireless Section, E.-in-C.O.	do.
Reed, F. L. ...	Clerical Officer. Submarine Branch.	Executive Officer Accounts Section, E.-in-C.O.	1-4-21
Henderson, G. J.	Clerical Officer, S. Lancs. District.	Executive Officer, S. Lancs. District.	13-11-23

TRANSFERS.

Name.	Grade.	Transferred.		Date.
		From	To.	
Jefferyes, G. C.	Executive Engr.	Irish Free State.	Scot. East Dist.	5-11-23
Golding, F. ...	Executive Officer.	S.Lancs. District.	N. Wales Dist.	9-9-23

RETIREMENTS.

Name.	Grade.	District.	Date.
Hill, J. G. ..	Asst. Staff Engineer.	Research Section, E.-in-C.O.	4-12-23
Brown, J. L. ..	Executive Engineer.	London District.	31-12-23
Brown, F. G. ...	Assistant Engineer.	do.	31-12-23
Allin, W. W. ...	Executive Officer.	S. Eastern District.	20-11-23

DEATH.

Name.	Grade.	District.	Date.
Cowie, F. E. W.	Executive Engineer,	Scot. East District.	23-9-23

COMMUNICATIONS.

All Remittances and Communications should be addressed to the MANAGING EDITOR, P.O.E.E. JOURNAL, Engineer-in-Chief's Office, G.P.O. West, London, E.C.1.

Binding covers and copies of the Contents Index for Vol. 3 to 15 are available, and may be obtained from the local agents for 1*s.* 6*d.* and 3*d.* respectively. Subscribers can have their copies of Vol. 15 bound, with index included, at a cost of 3*s.* by sending the JOURNALS to the local agents. Orders should indicate whether the original binding with black lettering, or the later pattern in gold, is required.

The Council of the Institution of Post Office Electrical Engineers has decided to raise the price of the JOURNAL to 2*s.* (2*s.* 3*d.* post free) per copy. This price applies also to annual subscribers, the subscription being 9*s.* per annum, post free. The price to P.O. subscribers is 1*s.* 6*d.* per number. All back numbers 2*s.* each.

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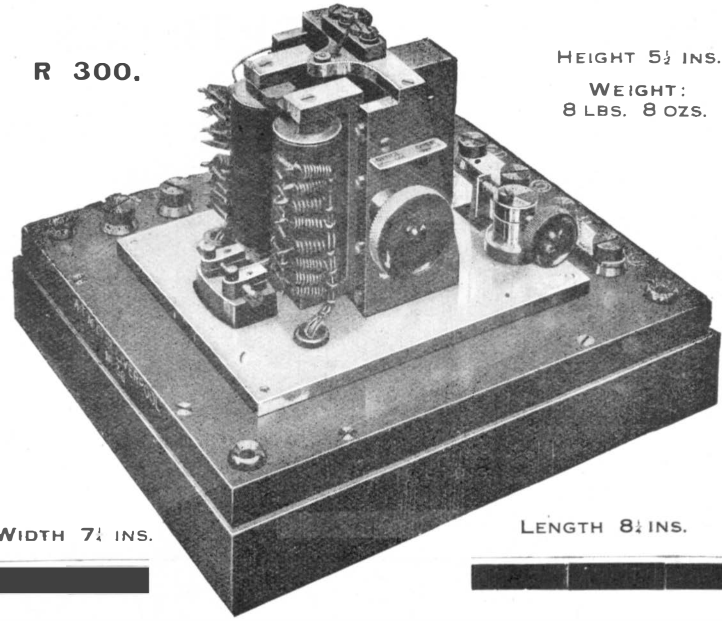

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