The Post Office Electrical Engineers' Journal

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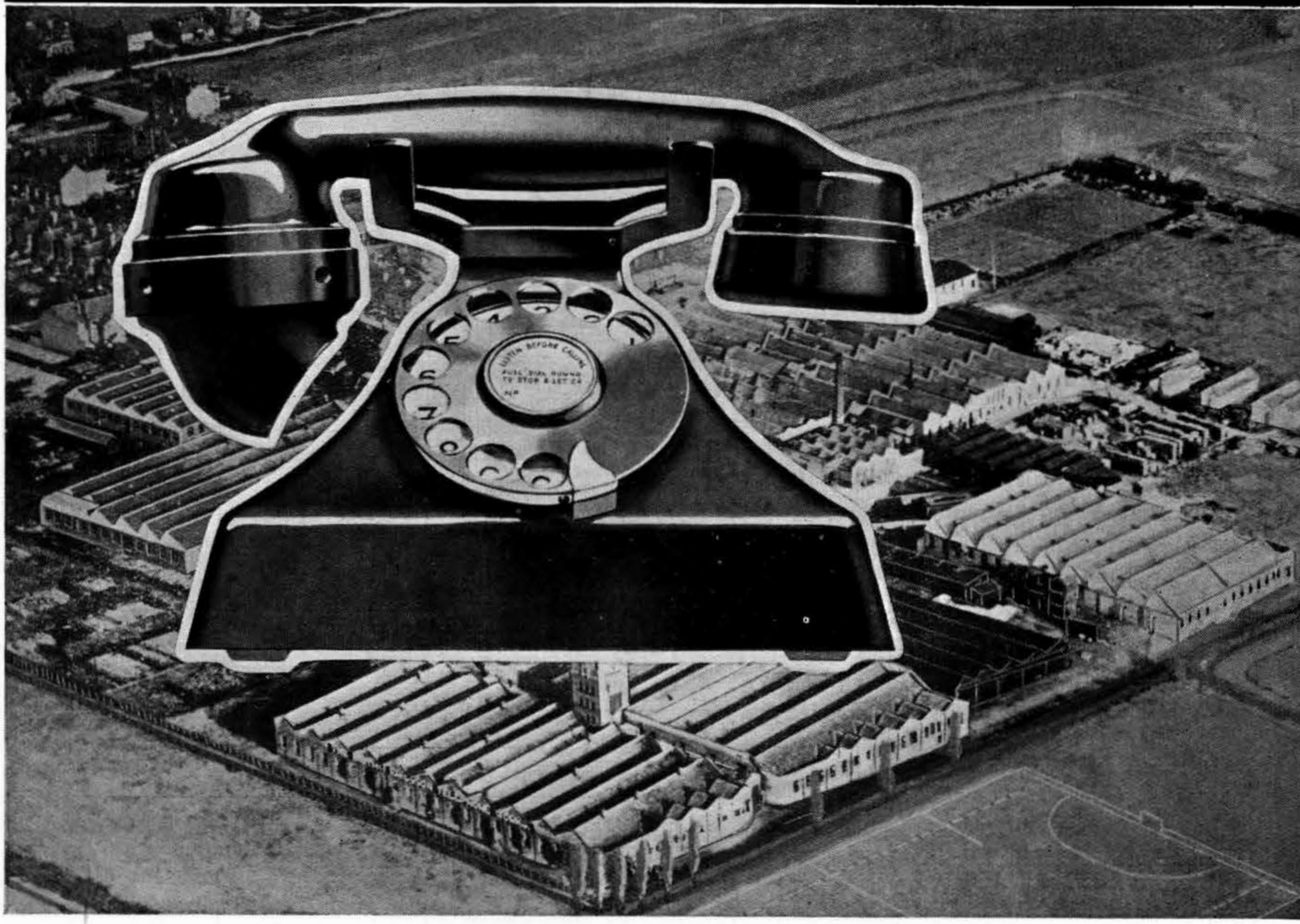
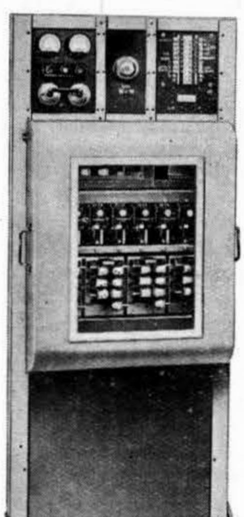




Ericsson Automatic Switch Board.

THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

Vol. XXIX April, 1936 Part I

Death of His Majesty King George V. Telephone and Telegraph Arrangements

C. RILEY

The Post Office Electrical Engineers' Journal regrets to have to record the death, at midnight on Monday, January 20th, of His Majesty King George V. His death coming with tragic suddenness, for the first public announcement of his illness was made but two days before, cast a cloud over the whole nation. In public places and in private dwellings a sad quiet reigned.

Behind the scenes, however, the little village of Dersingham in Norfolk, normally the most peaceful of Britain's hamlets, was transformed into a hive of activity. The funeral arrangements, telegrams of condolence and their replies, and the requirements of the press threw an enormous load on the telephone and telegraph staff. How these demands were met successfully and circuits provided with the minimum of delay is told in the following article.

THE illness and death of His Majesty King George V at Sandringham House caused scenes in the neighbouring village of Dersingham, the like of which have never before been witnessed. At The Feathers Hotel there were crowded together reporters and photographers of many nationalities representing newspapers in all parts of the world. The invasion started on Saturday, the 18th January. On the Tuesday, there were over 100 newspaper men in the hotel and many more arrived the following day. By 6.0 p.m. on Thursday the hotel was again empty. During those six days The Feathers was a Tower of Babel. Where the visitors slept or how they fed remains a mystery to those outside the hotel. How they telephoned their news and pictures to London is probably a greater marvel and will be told briefly in the following article. It is the story of the transformation for one short week of a sleepy village into the telephone centre of the world.

Before going into details of the week's activities, however, some idea of the normal conditions prevailing must be given. In Sandringham House itself is a complete Post Office for the use of the villagers on the Sandringham estate. In this post office is a P.B.X. to which are connected three exchange lines to King's Lynn, the Buckingham Palace private line and the extensions in the House. Other extensions from houses on the estate, such as Appleby House and the farm, also appear on the switchboard. The nearest village to Sandringham is Dersingham, about 10 miles from King's Lynn. It is a sleepy little hamlet and its 35 subscribers' lines are accommodated on a CBS 1 switchboard mounted on the wall in a corner of the passage at the post office. The post office itself is typically rural, being one room in the Sub-Postmistress's house. So much for normal conditions.

On Saturday, the 18th January, the first bulletin of His Majesty's illness appeared in the newspapers. It was obvious that a certain amount of press activity would take place in the district and there were only six trunks between London and King's Lynn. Officers from Headquarters therefore went to King's Lynn to ascertain traffic requirements and assist the local staff in setting up new circuits. The London-King's Lynn Trunks are amplified at Cambridge, Ely and King's Lynn. Press photographers were waiting to send pictures to London, but the residual mains hum on the circuits made satisfactory transmission of pictures impossible. The amplifiers were therefore connected temporarily to the standby batteries which were float-charged by metal rectifiers. Extra rectifiers were telephoned for urgently and Messrs. Westinghouse put some on the Cheltenham Flier. The train was met at Paddington at 5.0 p.m. by a Stores Department van and the rectifiers were hurried across London to catch the 5.40 p.m. train from Liverpool Street. So started the rush. While extra London-King's Lynn trunks were being lined up (Fig. 1), utilizing unloaded telegraph pairs in the London-Cambridge cable, a teleprinter circuit was arranged between the C.T.O. and Dersingham Post Office. The Sub-Postmistress gave up her sitting-room and the teleprinter was installed. Since the only illumination was oil lamps, electric light points had to be installed for driving the teleprinter. This was accomplished within two hours of the request being made to the company. Before the staff went home at 2.0 a.m. on Sunday, three additional London-King's Lynn trunks were working.

By 8.0 a.m. on Sunday telephone traffic was very heavy from Dersingham and two additional King's Lynn-Dersingham junctions were set up. A strip of jacks was screwed to the top of the small wall-mounted CBS 1 switchboard to accommodate the new lines. During a visit to Dersingham in connexion with this work, the alarming discovery was made that all the reporters were staying at the one hotel—The Feathers. The hotel had one exchange line to Dersingham, the instrument being in a cabinet illuminated by a candle. Extra outlets were obviously necessary. The King's Lynn-Hunstanton aerial route was ¾ mile distant. The Clerk-in-Waiting in London gave authority for any expenditure which might be incurred. It was decided to connect The Feathers direct with King's Lynn Exchange.

Every possible King's Lynn-Hunstanton trunk was released and ¾ mile of 12 pr/20 lb. aerial cable was ordered to connect The Feathers to the Hunstanton trunk route and so into King's Lynn. The Birmingham Stores Department was telephoned on Sunday evening. The first available passenger train would arrive at King's Lynn at 11.0 a.m. on Monday. A snow storm was raging in the Birmingham District and the Automobile Association reported the roads to be almost impassable. Exceptional measures were called for. The Stores Department chartered, from a Birmingham contractor, a fast lorry with instructions to get through at any cost, and in the event of a breakdown to hire another lorry locally and transfer the cable. The contractor estimated that the cable would be delivered by 4.0 a.m. on Monday. As a precautionary measure a further ¾ mile of cable was put on rail. After considerable difficulty on the ice-bound roads the lorry arrived in King's Lynn at 3.55 a.m. on Monday, and was held in readiness to depart for Dersingham at 6.0 a.m. Meantime the number of King's Lynn-London trunks had been increased to twelve.

At daybreak on Monday work was commenced on laying the cable and extra telephones were installed in the Smoke Room of The Feathers. Electric light poles, hedges, fences and houses were utilized to get the cable laid. (Fig. 2). By late afternoon one additional subscriber's line was working from The Feathers into Dersingham, and three were dialling direct into King's Lynn, making a total of five outlets from the hotel.

Even while the cable was being run, however, it was apparent that many more reporters were arriving at The Feathers and that the five outlets would

Fig. 1.—Setting up Additional Circuits at King's Lynn.

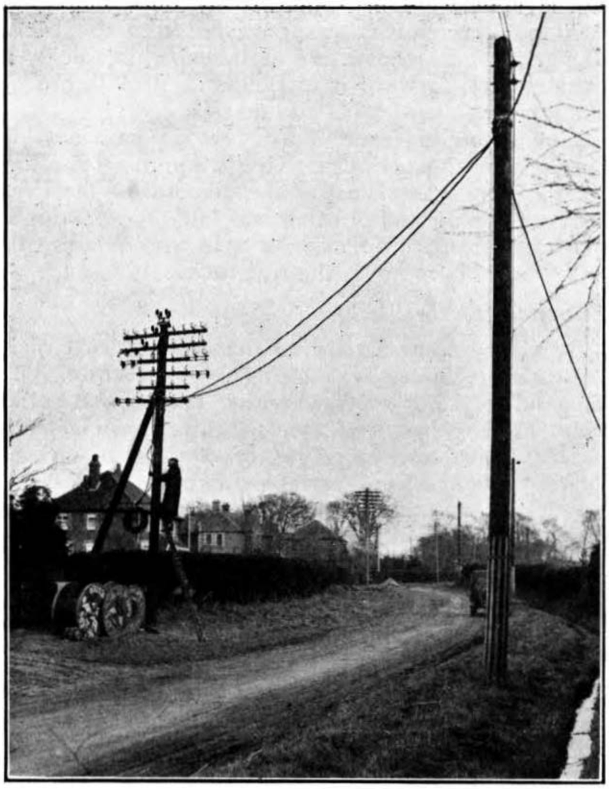


Fig. 2.—Temporary Cable being run.

be insufficient. Every possible junction on the Hunstanton route had been released or would be required during the day for additional teleprinter circuits. There remained only the King's Lynn-Flitcham cable which had eight spare pairs. The Flitcham T.P. is 4½ miles from The Feathers. Arrangements were made for 4½ miles of aerial cable, varying from 12 pr/20 lb. to 19 pr/20 lb., to be sent by passenger train from London. This arrived on Monday evening and was loaded into lorries ready for a start at daybreak.

The decision to provide these extra outlets made it possible to offer private wire facilities. Accordingly, on Monday morning, a joint visit of Traffic and Engineering Staff was paid to the hotel and the matter was laid before the reporters. By the afternoon authority was received for four private wires for the Press Agencies. Meantime, one additional Dersingham-C.T.O. teleprinter circuit, and two additional King's Lynn-C.T.O. teleprinter circuits had been provided, making, with the original two King's Lynn-C.T.O. circuits, a total of six teleprinters working for the Press in addition to the two working into Sandringham.

At midnight news was received of the death of the King, and in the early hours of morning the private wire arrangements were cancelled. It was still necessary, however, to provide the hotel with as many subscribers' lines as possible.

At 6.0 a.m. on Tuesday, the lorries and three gangs started out with the 4½ miles of aerial cable. There were many farm gateways to be negotiated and over a section of about 1 mile the lane was so bad that the lorries became stuck and the cable had to be hauled by hand. Fig. 3 gives some idea of the country which had to be negotiated. Extra telephones were installed in the passage in The Feathers. A visit to Sandringham House in the morning, disclosed the vast volume of traffic being dealt with, and an additional Sandringham-London Trunk circuit was set up, making in all one Sandringham-Buckingham-Palace private wire and two Sandringham-London Trunks. It was also arranged to open two manholes on the King's Lynn-Flitcham cable and joint four additional pairs from Sandringham House to King's Lynn. These were terminated on the Sandringham House switchboard as a precautionary measure.

By Tuesday evening 3,500 telegrams of condolence had been received at Sandringham, the average length of the telegrams being 70 words. As each of these had to be replied to it was decided to take two of the four spare pairs joined to the switchboard to set up an additional Sandringham House-C.T.O. teleprinter circuit. This was working by Tuesday evening. By 9.0 p.m. the same day the 4½ miles of cable had been run and five extra telephones at The Feathers were dialling in to King's Lynn. This made a total of 10 outlets from the hotel, but such was the volume of traffic that calls were restricted to three minutes. Fig. 4 shows reporters using the telephones in the passage. By Tuesday night the total number of King's Lynn-London Trunks had been increased to 18.

On Wednesday, movements of the Court necessitated frequent changes in the arrangement of circuits. At times when the traffic for Sandringham

Fig. 3.—Hauling Temporary Cable by hand.

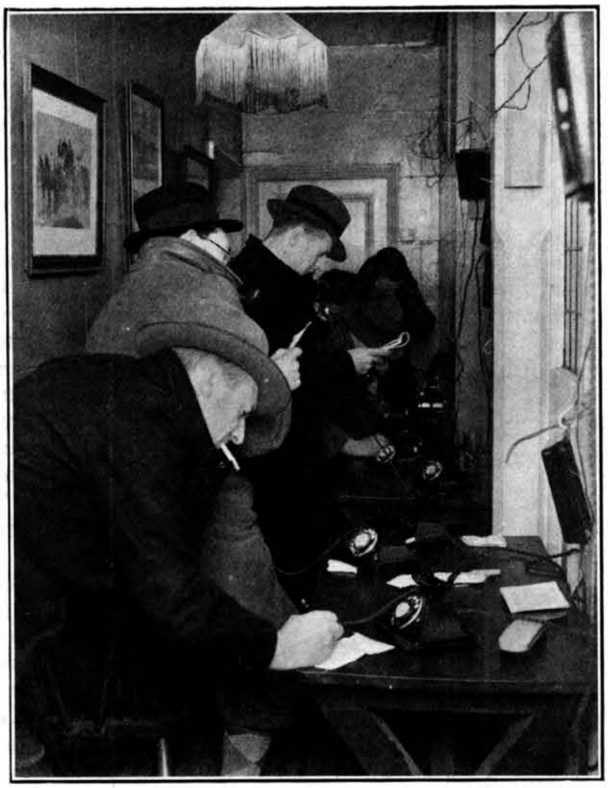


Fig. 4.—Reporters at work at The Feathers.

House was light, circuits were diverted to make additional public trunks. At the first sign of increased Court activity the circuits had to be restored. Three of the four extra pairs which had been jointed into Sandringham House the previous day were jointed through to Flitcham and three additional outlets were provided from The Feathers into King's Lynn, making a total of 13 outlets from the hotel. Throughout the day and on Thursday the aerial cable route was patrolled by a lineman and a jointer in a car, and a gang was held in readiness for any emergency at Hillington.

By the evening, with a total of 21 London - King's Lynn Trunks, no further circuits could be provided. There were no spare pairs in any of the cables and no more circuits could be diverted without risk of disorganizing normal traffic. At Cambridge, terminal amplifiers had been modified for through working to London and low frequency correctors had been hastily fitted to the unloaded cable pairs between Cambridge and London.

On Thursday, 23rd January, there was intense activity at The Feathers after the departure of the funeral procession from Sandringham House. Having telephoned their last reports, the press men left and by 6.0 p.m. Post Office staff were breathing freely once more. At 6.30 p.m. a request was received from the Stores Department to recover the aerial cable as quickly as possible and forward it to Belfast. By 9.0 a.m. on Friday one mile of cable was on rail.

Four mobile picture sets were in constant use throughout the period at King's Lynn. The linemen's room was placed at the disposal of the Press and developing and printing was done there. Fig. 5 shows picture transmission sets in use. Pairs were run from this room to the test rack.

Summary of Circuits.

It will be appreciated that the demand for circuits of various classes was changing constantly. The demand for King's Lynn-London Trunks and outlets from The Feathers increased steadily, but movements of the Court and messages of condolence on teleprinter circuits were variable factors. In order to anticipate the various demands it was necessary for the Engineering Staff to keep in touch daily with :—

The Telephone Traffic Staff at King's Lynn and Dersingham;
The Telegraph Traffic Staff at Dersingham;
The Sandringham officials, and
The reporters at The Feathers.

The Chief Constable of Norfolk was also consulted as to road traffic conditions and special personal and car passes were arranged. Fig. 6 gives a day to day summary of the circuits in use and an idea of the magnitude of the work involved. The figures, however, are approximate, since it is difficult to decide when one day's work finished and another's commenced.

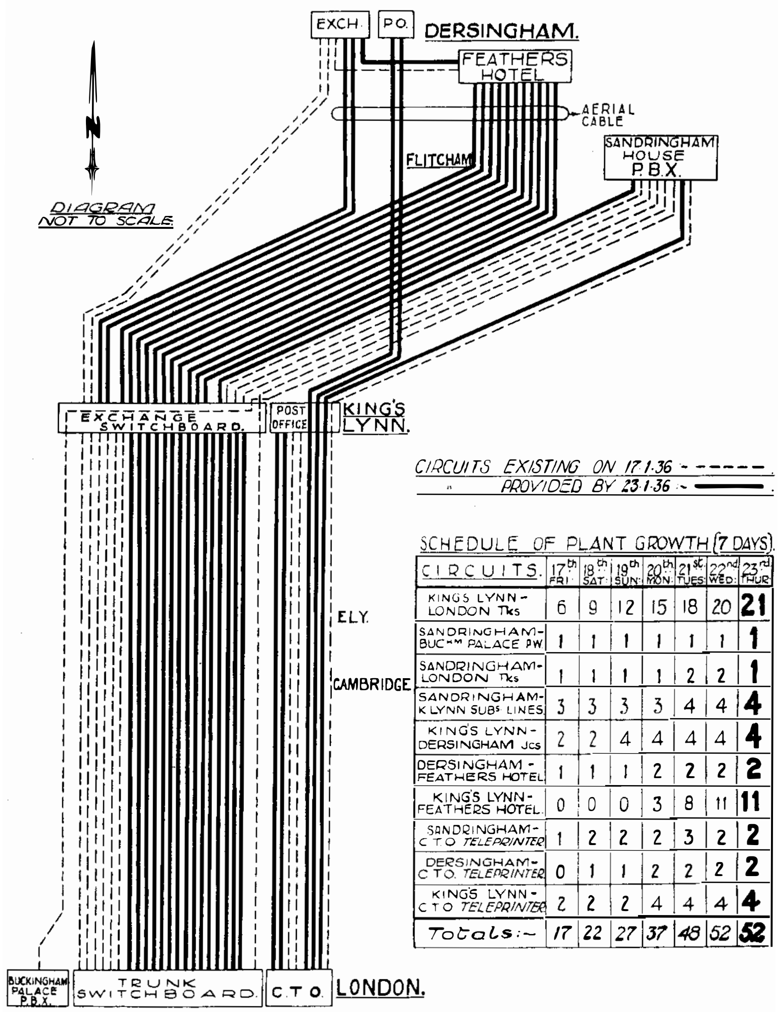
During the whole period no complaint was registered against the telephone service. The reporters expressed their great appreciation of the work done by the Post Office and more than one stated that he had never before witnessed such mushroom-like

Fig. 5.—Linemen's Room in use for Picture Transmission.

telephone development in a village in any country.

It is difficult, after the event, to retain a clear impression of the many activities during the week. The staff worked an average of 18 hours per day and had no proper meal except breakfast. The thoughtfulness of the Clerk-in-Waiting alleviated hardship somewhat when he authorized the provision of supper at the Department's expense; and if hotel managers could have sent in something other than sandwiches, the meal would have been a more welcome change.

The job could not have been carried through without the fullest co-operation of all concerned. It is a pleasure to add, therefore, that the Traffic and Engineering staff worked in the fullest harmony and the Stores Department did everything in their power at great inconvenience to supply the vast quantities of stores required in the minimum of time. In one respect fortune favoured the work. Seven weeks before the emergency arose, King's Lynn exchange was converted to automatic working and transferred to a new building. If the conditions obtaining in the old exchange had been encountered, a less satisfactory account would undoubtedly have been rendered.



SCHEDULE OF PLANT GROWTH (7 DAYS).

CIRCUITS.	17th FRI.	18th SAT.	19th SUN.	20th MON.	21st TUES.	22nd WED.	23rd THUR.
KINGS LYNN - LONDON Tks	6	9	12	15	18	20	**21**
SANDRINGHAM - BUC'HM PALACE P.W.	1	1	1	1	1	1	**1**
SANDRINGHAM - LONDON Tks	1	1	1	1	2	2	**1**
SANDRINGHAM - K LYNN SUBS LINES	3	3	3	3	4	4	**4**
KING'S LYNN - DERSINGHAM Jcs	2	2	4	4	4	4	**4**
DERSINGHAM - FEATHERS HOTEL	1	1	1	2	2	2	**2**
KING'S LYNN - FEATHERS HOTEL	0	0	0	3	8	11	**11**
SANDRINGHAM - C.T.O TELEPRINTER	1	2	2	2	3	2	**2**
DERSINGHAM - C.T.O. TELEPRINTER	0	1	1	2	2	2	**2**
KING'S LYNN - C.T.O TELEPRINTER	2	2	2	4	4	4	**4**
Totals:-	17	22	27	37	48	52	**52**

FIG. 6.—DIAGRAM OF CIRCUITS PROVIDED.

(Information regarding the work involved in other districts will be found under District Notes.—Ed.)

A New Subscriber's Loudspeaking Telephone

L. E. RYALL, Ph.D. (Eng.) Lon., A.M.I.E.E.

The first part of this article describes the problems associated with the design and operation of any form of loudspeaking telephone intended for use on Post Office circuits and capable of working one to another over commercial lines. A description of the principles employed in producing a satisfactory instrument is then given. This is followed by a detailed description of the actual loudspeaking telephone that has been developed at the Post Office Research Laboratories, at Dollis Hill, including its performance characteristics.

Introduction.

THE new loudspeaking instrument is intended to be an adjunct to the subscriber's telephone and a small desk unit, only slightly larger than a table instrument with a hand microtelephone, contains the microphone and the loudspeaker. When using the instrument, the subscriber is not called upon to make any " adjustments " whatever. The exchange is called at the touch of a key (and perhaps the operation of an auto-dial) and he is connected to the telephone network of the country. He then has complete freedom of both hands and is relieved of almost all the fatigue attendant upon prolonged use of the hand telephone. He can move around, find and refer to papers and take notes with a much greater ease than hitherto. It is more comfortable and hygienic to use, particularly in hot climates. The volume of speech from the loudspeaker is automatically regulated to the right level for any line which may be connected to the equipment. More than one person can join in the conversation which is made available for all in the room to hear. Thus conferences can be conducted by these means. Should the conversation be of a particularly private nature, however, the ordinary telephone is available instead. The user obtains a more efficient service with the loudspeaking telephone since, during waiting and holding-on times, other business can be transacted more readily. It is a means of creating an impression (either real or imaginary) of power associated with the user and thereby increases his prestige. At the same time it will appeal to the subscriber who makes social calls and will no doubt tend to lengthen the duration and number of such calls since the art of telephoning is made so easy.

The description of the loudspeaking telephone given below is divided into three sections as follows :

Section 1 deals with the various problems that arise in connexion with the successful design and operation of any form of loudspeaking telephone intended for use on all lines in place of the normal telephone.

Section 2 describes the principles and operational features of the loudspeaking telephone that has been developed.

Section 3 gives the circuit and design details together with the performance characteristics of the commercial loudspeaking telephone which embodies the principles and features described in Section 2.

SECTION 1. SOME DESIGN PROBLEMS AND FEATURES OF ANY LOUDSPEAKING TELEPHONE.

Switching to prevent Self Oscillation.

In any form of loudspeaking telephone, acoustic coupling will occur between the loudspeaker and the microphone. If the instrument is connected to a 2-wire line—as in the normal telephone system—the coupling path is completed at the connexion to the 2-wire circuit. If the speech signal strength from the microphone to the line is comparable with that obtained from a standard or normal telephone, and the sensitivity of the loudspeaker and its amplifier is sufficient to deal with incoming attenuated telephone speech, then the coupling path is such that oscillation will occur. This can be avoided only if some form of switch is arranged to prevent the simultaneous operation of the microphone and loudspeaker or of their associated amplifiers.

Theoretically the switch can be manually operated by the subscriber, but this method is not acceptable to most potential users who require the operation of a loudspeaking telephone to be at least as easy as a normal telephone, and it is practically impossible during an ordinary conversation to carry out the switching in phase with the to and fro speaking.

A " control " circuit must be associated with each of the " transmit " and " receive " circuits. The need for the " control " circuits with their own switches will be seen from the following description of their operation :—

Fig. 1 shows diagramatically the circuit from the

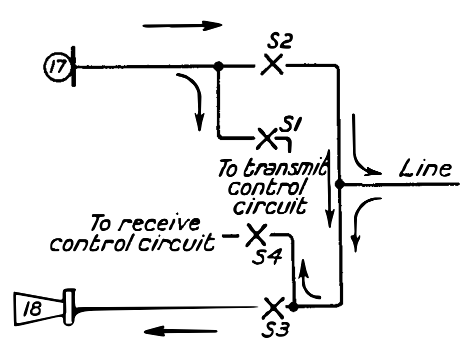


FIG. 1.—ARRANGEMENT OF SWITCHES.

microphone to the line *via* switch S2 and the line to the loudspeaker *via* switch S3. In the quiescent state at least one of these switches must interrupt the circuit to prevent singing, and it will be shown later that both switches must interrupt the circuit.

Speech incoming from the microphone passes *via* switch S1 to a control device actuated by the speech and thus closes S2 so that the speech can pass to the line. At the same time, or immediately prior to S2 closing, S4 opens and so interrupts the associated " control " path circuit and since switch S3 remains open, circulating or " out of balance " transmit signals from the line are not reproduced in the loudspeaker to cause oscillation, neither do they pass into the receive control circuit to operate the switches in the reverse manner. When the " transmit " speech has ceased the switches restore to normal. Received speech can now pass through the " receive " control circuit *via* switch S4 to close the switch S3 so that the speech can pass to the loudspeaker. At the same time, or immediately prior to S3 closing, switch S1 opens to interrupt the associated " control " path circuits. It will be seen that the control circuit switches S1, S4, must both be closed in the quiescent state to be ready to pass an incoming operating signal. If either of the switches S2, S3, in the speech signal circuit be also closed, incoming speech can pass through it without first interrupting the control signal circuit in the complementary path and echo signals are liable to cause false operation.

The requirements of the voice operated switches are :—

(*a*) Adequate sensitivity so that they are operated by the weakest telephone speech signals.

(*b*) Very fast operating speed so that no apparent initial " clipping " of the speech occurs.

(*c*) Sufficient hangover time so that they do not restore between words and syllables.

(*d*) They should preferably be less sensitive to room noise than to speech signals.

(*e*) They should be cheap and require no maintenance.

A " break-in " facility must be provided so that incoming speech can obtain control of the switches that are operated by speech in the reverse direction. At the same time side tone and echo signals must not " break in " and interrupt the circuit.

Location of the Microphone.

The microphone should be close to the loudspeaker and embodied in one unit so that the user only has to give attention to one instrument when talking.

Room Conditions.

The best operation can only be obtained in reasonably quiet surroundings. The listener at the distant end otherwise tends to be distracted by the unwanted and unaccustomed noises picked up by the microphone. In general it is not convenient to instal a loudspeaking telephone in a room or office normally occupied by more than one person.

Room reverberation or echo influences the character and intelligibility of the speech transmitted and limits the speaking distance from the microphone. For average office use a speaking distance of two to three feet is quite satisfactory, but if the room is well damped the speaking distance can be increased. The effect of reverberation is very much emphasized if the microphone and its amplifier have non-uniform response characteristics.

If the distant end subscriber is listening with a bell receiver (or a hand microtelephone) the non-linear frequency response characteristics of the receiver exaggerate the reverberation effect present at the transmitting end.

Sensitivity.

The overall sensitivity of the microphone and its amplifier should be such that the level of speech signals to the line from speech about two feet from the microphone is approximately equal to that obtained from a telephone used normally and speaking at the same level.

For the loudspeaker and its amplifier the maximum overall sensitivity should be such that signals received from a telephone, through a reasonably long line, are reproduced from the loudspeaker at an adequate volume to be easily heard, when listened to at a distance of about two feet.

Volume Control on the Receiver Amplifier.

A hand operated volume control is unsatisfactory because the user cannot know where to set it until after the call has commenced. Also, he may forget to use it. An automatic volume control device should be provided to give a maximum amplifier sensitivity until the incoming signal arrives and then it should reduce the sensitivity instantaneously so that the received volume is normal. At the end of the call the sensitivity should restore to a maximum.

Liability to " Lock Out."

If two loudspeaking telephones with voice operated switches are connected together through a line having a high attenuation and both subscribers talk simulaneously, each will operate his local switch and transmit speech to the line, but the incoming speech received will be too weak to break in at the distant end and a " lock out " condition is obtained. Neither subscriber hears the other talking if he himself is speaking. This condition should not be met with, using normal telephone circuits having attenuations up to at least 20 db.

First Cost and Maintenance.

The loudspeaking telephone must contain " transmit " and " receive " amplifiers, together with their voice operated switches and break-in devices. A suitable power supply must be available. Since it is luxury service the standard of performance must be high, but neither the first cost nor the maintenance should be excessive.

Section 2. The Principles and Operational Features of the P.O. Loudspeaking Telephone.

A new voice operated switching system has been developed to meet the requirements of the loudspeaking telephone.

The Rectifier Attenuation Network as a Switch.

A rectifier attenuation network is introduced into a signal transmission circuit so that the attenuation of the circuit, due to the introduction of the network, can be changed from less than 1 decibel to over 40 and 60 decibels when a control current changes by 0.5

and 2.0 mA respectively. Thus when the network has a high attenuation, it effectively interrupts the circuit in the same manner as a switch. It has no moving parts, is very compact, and has a large sensitivity with a very small operating time.

The four switches, shown in Fig. 1, consist of four rectifier attenuation networks, the attenuations of which are varied by a common control current. The derivation of the control current and the manner in which it is used to operate the switches in a predetermined order are very important to the successful and economical operation of the system.

The following features and principles employed have been developed primarily in association with the rectifier attenuation network,[1] but some of these features could be applied with any other suitable form of switch. For example, two polarized relays could be used in place of the four rectifier attenuation networks.

The Derivation of the Direct Control Current.

The control current is derived from a valve bridge circuit, shown in Fig. 2. The four rectifier attenuation networks 1 to 4 have low attenuations to speech signals when their control currents flow in the direction of the enclosed arrowhead, and large attenuations when these currents reverse in direction. The anode impedances of the valves 9, 10 and the resistors 5, 6 form the four arms of a bridge of which the power supply is the anode battery. In the quiescent state the points 7, 8, are given equal potentials by adjusting the value of the resistor 6. The resistors 21, 22, 23 provide steady biassing currents to the attenuation networks in the directions shown by the dotted arrows so that the networks 1 and 4 normally have low attenuations and networks 2 and 3 have high attenuations.

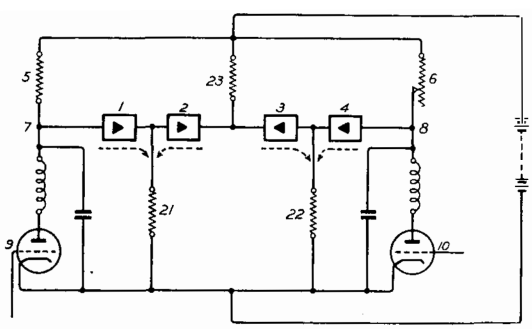


FIG. 2.—DERIVATION OF CONTROL CURRENTS FROM BRIDGE NETWORK.

It is seen that a change in control current is obtained when the anode impedance of either of the valves 9, 10 is changed. It will also be observed that if the impedances of both valves alter due to changes in the supply voltages no change in the control current occurs. This feature is particularly important where the supply voltages are derived from a " mains " power supply, which in general is subject to appreciable voltage variations. Also, if the supply is suddenly switched on to the valves, the bridge quickly comes into balance as the anode impedances of both the valves immediately after switching on have the same characteristic changes. The change in the control current is obtained by changing the grid bias voltage of one of the valves 9, 10.

The speech signal that is required to control the operation of the attenuation networks or switches is rectified, and this rectified voltage is applied to the grid of the valve 9 or 10 to reduce its normal negative grid bias potential.

The Hangover or Restoring Time.

The rectified speech control signal circuit incorporates condensers which provide a hangover period so that during the time between the words and slight pauses in the speech the additional grid bias voltage is maintained across the condensers. This hangover time should be approximately 0.5 secs.

The amplitude of the rectified voltage obtained is limited by the grid current so that the time taken for the grid voltage to restore to normal when the speech signal ceases is practically independent of the amplitude of the speech signal.

The valves 9, 10 used in the control current bridge can also be used as speech amplifiers. The block schematic diagram of the system so far developed is shown in Fig. 3, and the operation is as follows :—

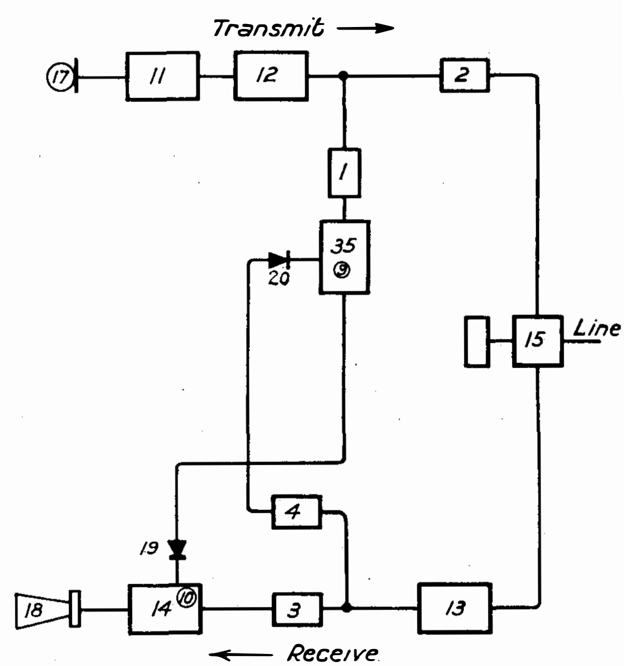


FIG. 3.—SIMPLE SCHEMATIC DIAGRAM OF SYSTEM.

[1] The use of the dry plate rectifier as a variable A.C. impedance controlled by a direct current has been known in this country since the early part of 1930. The Société d'Etudes pour Liaisons Téléphoniques and Télégraphiques à Longue Distance of Paris has used this type of attenuation network since December, 1930, and has obtained French Patents for this arrangement. The manner in which the control of the attenuation network is obtained and many other features of this loudspeaking telephone design form the subject of British Patents Nos. 413,383, 415,767, 416,372, 430,158 and 430,567, and corresponding Foreign Patents in many countries.

Speech from the microphone 17 passes through the amplifiers 11, 12 and *via* the rectifier network 1 (low attenuation) to the amplifier 35. It then passes to the signal rectifier 19 and so charges a condenser in the grid circuit of the valve 10 of the amplifier stage 14.

Since, while speaking in the transmit direction, no speech can be received from the loudspeaker, the change in grid bias voltage of the valve 10 in the receiver amplifier under these conditions, does not affect any speech reproduction. The change in control current resulting from the change in anode current of the valve 10 causes the attenuation networks 3 and 4 to become (or remain) of high attenuation and the network 2 to become of low attenuation so that the speech passes out to the line *via* the differential transformer 15. After speech has ceased and the control current and the network attenuations restore to normal, received speech from the line can pass *via* the differential transformer 15 and the amplifier 13 and so through the attenuation network 4 (low attenuation). After being rectified (20) the resultant direct voltage charges a condenser in the grid circuit of the valve 9 and so alters the grid bias voltage. The resultant change in control current (in the reverse direction to that obtained when speech passes through the transmit amplifier to line) causes the attenuation networks 1 and 2 to become (or remain) of high attenuation, and the network 3 to change to low attenuation so that the speech signals can pass *via* amplifier 14 to the loudspeaker 18.

The " Break-in " and Anti-side-tone " Break-in " Features.

It has been shown in Section 1 that some form of " break-in " feature is essential to the satisfactory operation of a voice operated switching system.

In Fig. **3** the signals used to change the control currents which flow through the attenuation networks operate by charging a condenser C (after suitable rectification) in the grid circuit of a thermionic valve, thereby changing the steady anode current. To operate the " break-in " feature the condenser C is discharged by the rectified " break-in " signal. This is shown in Fig. **4**. As previously stated signals from the transmitter 17 pass *via* the rectifier network 1 and the rectifier 19 to change the control current by charging a condenser C at point 33. Signals from the line pass through the amplifier 13 to the path 31 and after rectification supply a discharge current to condenser C at point 33. Thus, if the signal from the transmitter ceases, the discharge time of the condenser C is accelerated by the discharge current *via* the path 31 so that the reply from the line can operate the switching system *via* the network 4 immediately. This enables the speech signals from the line to break in during the interval between words, which is normally covered by the hangover period of the condenser at point 33. If the signal from the transmitter 17, however, does not cease, the signal from the line can still break in if it is large enough to supply a discharge current, *via* path 31 greater than the corresponding charging current *via* rectifier 19. When these conditions

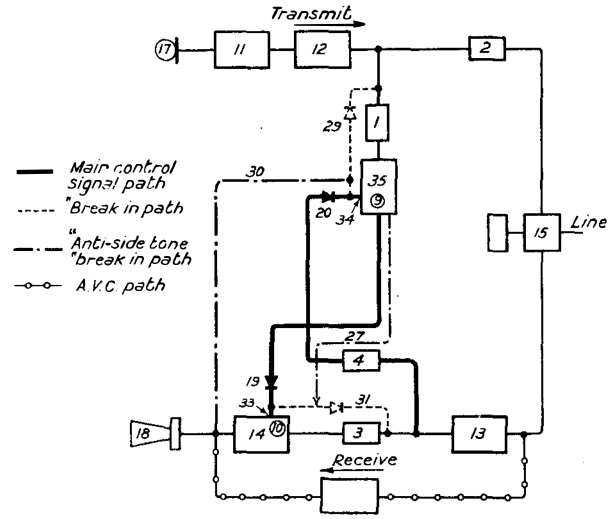


Fig. **4**.—Schematic Diagram showing " Break-in " Paths and Automatic Volume Control.

apply in practice, the unbalance or side-tone currents of the transmitted signals *via* the differential transformer 15 to the loudspeaker amplifier will be sufficient to discharge the condenser C at point 33 and so cause " clipping " of the speech transmitted to the line. To avoid this a path 27 is provided so that signals from the transmit amplifier *via* transformer 15 and path 31 are prevented by corresponding simultaneous signals *via* path 27 from discharging the condenser C at point 33. The magnitudes and the effects of the signals in the paths 31 and 27 are proportional for any particular balance condition of the hybrid transformer 15. Thus if there is a large out-of-balance signal in path 31 it will be opposed by a correspondingly large signal in path 27. A signal from the line will add to the out-of-balance signal from the transmit amplifier and if it is sufficiently large will overcome the effect of the signal in path 27 and discharge the condenser C at point 33.

A similar " break-in " device is provided for signals from the microphone.

Application of the " Break-in " Principle.

The arrangements used to charge and discharge the condensers in the grid circuits of the valves in the D.C. bridge providing the control current are shown in Fig. **5**. The main operating signal from network 1 passes *via* the rectifier 19 and charges the condenser C so that the grid potential of the valve 10 (corresponding to the like numbered valve in Fig. **2**), becomes less negative with respect to the potential of its cathode. Condenser C can normally discharge through resistance 25 and the backward impedance of rectifier 19 in approximately 0.5 seconds. The " break-in " signal *via* path 31 is derived from a winding of the output transformer of the 1st stage receiver amplifier 13 and passes through the rectifier 37 and the resultant direct current discharges the condenser C. The signal in path 27 is also rectified and used to charge a condenser 38. This condenser is also associated with the rectifier 37. The voltage

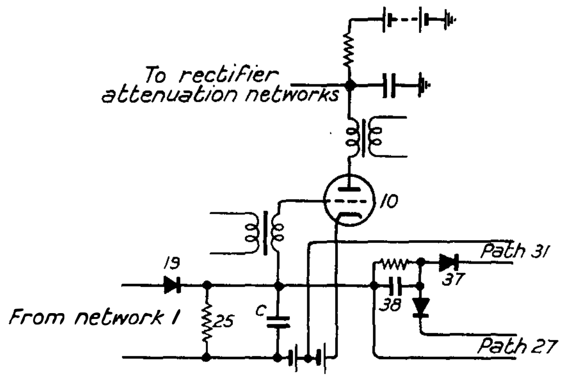


FIG. 5.—CHARGE AND DISCHARGE CIRCUITS OF CONDENSER IN VALVE GRID CIRCUIT.

developed across the condenser 38 biasses the rectifier 37, thereby preventing it from rectifying the signal in path 31 if the latter signal is due to side-tone or out-of-balance signals derived from the transmit amplifier. The discharge time of the condenser 38 is very short and need only be slightly greater than the echo time of the line, so that the voltage across the condenser 38 preventing the rectifier 37 from operating will follow the fluctuations of the signal level in the transmit amplifier. Any reply signal from the line applied to the rectifier 37 not only adds to the side-tone signal already received, but will occur during the periods between words and syllables of the speech from the transmit amplifier, in which periods there will be little or no voltage across the condenser 38, so that the rectifier 37 will become operative, the condenser C will be rapidly discharged, and " break-in " will occur.

Automatic Volume Control.

This device consists essentially of a pair of rectifier units connected across the input terminals of the receive amplifier 13. The A.C. impedance of these units decreases as the direct current through them increases, thereby providing a variable shunt across the input of the associated amplifier. The steady control current is derived from the anode circuit of a three electrode valve 40 (see Fig. 6), the normal

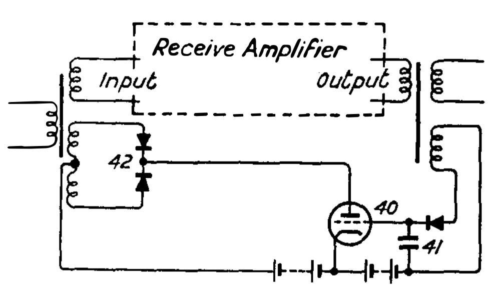


FIG. 6.—AUTOMATIC VOLUME CONTROL CIRCUIT.

negative grid-filament potential of which is approximately four times that required to reduce the steady anode current to zero. A portion of the output signal voltage from the amplifier is rectified and used to charge a condenser 41 in the grid circuit so that the grid-cathode potential becomes less negative and ultimately anode current will commence to flow. This current passes through the rectifier units 42, and by lowering their impedance causes a shunt to be applied across the receive amplifier input. A reduction in the amplifier gain of 30 decibels can be obtained when the rectified output voltage increases approximately 3 decibels.

To preserve the modulations in the speech the charge across the condenser 41 must be retained during pauses and between words, so that the reduction in gain is sensibly constant while speech is being received. The reduction in amplication that takes place as soon as an initial loud signal is received must be practically instantaneous. An effective operating time of about 5 millisecs. and a restoring time of 2 to 4 secs. is obtained in practice.

Non-linear distortion must be produced in the amplifier if the gain is changed by an alteration in the current through any portion of the amplifier which is also used to transmit speech signals.

To obtain the minimum distortion over the operating range the shunt resistance of the rectifier should be inversely proportional to the control current. This is approximately the case if copper-cuprous oxide rectifiers (Westinghouse) are used.

Calling Operations.

The following calling requirements are desirable and are met in the calling circuit design :—

(1) The line should be looped either when the telephone is lifted from its cradle (normal condition), or when the calling key on the loudspeaking set is thrown, in which case the ordinary telephone can remain untouched.
(2) The line should be looped immediately the calling key is thrown so that the heating up time of the valves coincides with, and does not add to, the normal reply time of the operator.
(3) If the subscriber is using the ordinary telephone and changes over to the loudspeaking telephone during a call, he should retain the use of the hand-instrument until the valves in the loudspeaking set have heated up and the set is " live."
(4) With automatic systems, the dial associated with the ordinary telephone should be capable of being used satisfactorily after the line is engaged by throwing the key on the table unit, as well as in conjunction with the hand-microtelephone.
(5) The dialling impulses must not be reproduced by the loudspeaker, nor should they affect the subsequent operation of the automatic volume control.

Installation and Maintenance Requirements.

The amplifier can be installed up to 200 yds. from the table unit. The set is only energized when in use and the valves are under-run with respect to their anode dissipations so that maintenance is very small.

Section 3. The Design and Circuit Details of the Loudspeaker Amplifier and Telephone Unit.

The Loudspeaker Amplifier.

This consists of three parts :—

(1) The power unit.
(2) The transmit amplifier.
(3) The receive amplifier.

The circuit diagram for the complete amplifier is shown in Fig. **7**.

The complete amplifier is housed in a metal case, with a suitably ventilated cover. The power unit occupies both sides of one end of the panel and is separated from the amplifier by a screen. The microphone and speaker amplifiers are mounted one on each side of the remaining panel space.

The Power Unit. The amplifier operates from the A.C. mains. The power transformer T12 provides the following supplies :—

(*a*) *A.C. filament heating* for valves V3, V4, V5.
(*b*) *D.C. filament heating* for valves V1, V2 and V6 to reduce mains hum.
(*c*) *An Anode Supply Voltage* of 240 volts (approx.) after smoothing with a discharge current of 130 mA.

The full voltage is only obtained when relay B operates when the valve V4 becomes live and anode current flows.

(*d*) *Grid Bias Voltages and Indicator Lamp Supply.* The various grid bias voltages required are derived from a 24 volt winding of the transformer T12. When the set is switched on, the contact B1 does not close until the valves become operative. Thus the indicator lamp does not glow until the circuit is live and the user should not speak before this occurs.

The set must be switched on when the user throws a key on the loudspeaker table instrument. Since it is impractical to switch on the mains supply directly with this key, it is arranged that the key operates a relay A which connects the transformer T12 to the mains *via* its contact A1. The power to operate the relay is derived from the secondary winding (4v) of a small transformer T13 permanently connected across the supply mains. When, after about three seconds, the valves become live and anode current flows, relay B operates and the indicator lamp lights showing the set is ready for use.

If a D.C. mains supply only is available, a motor

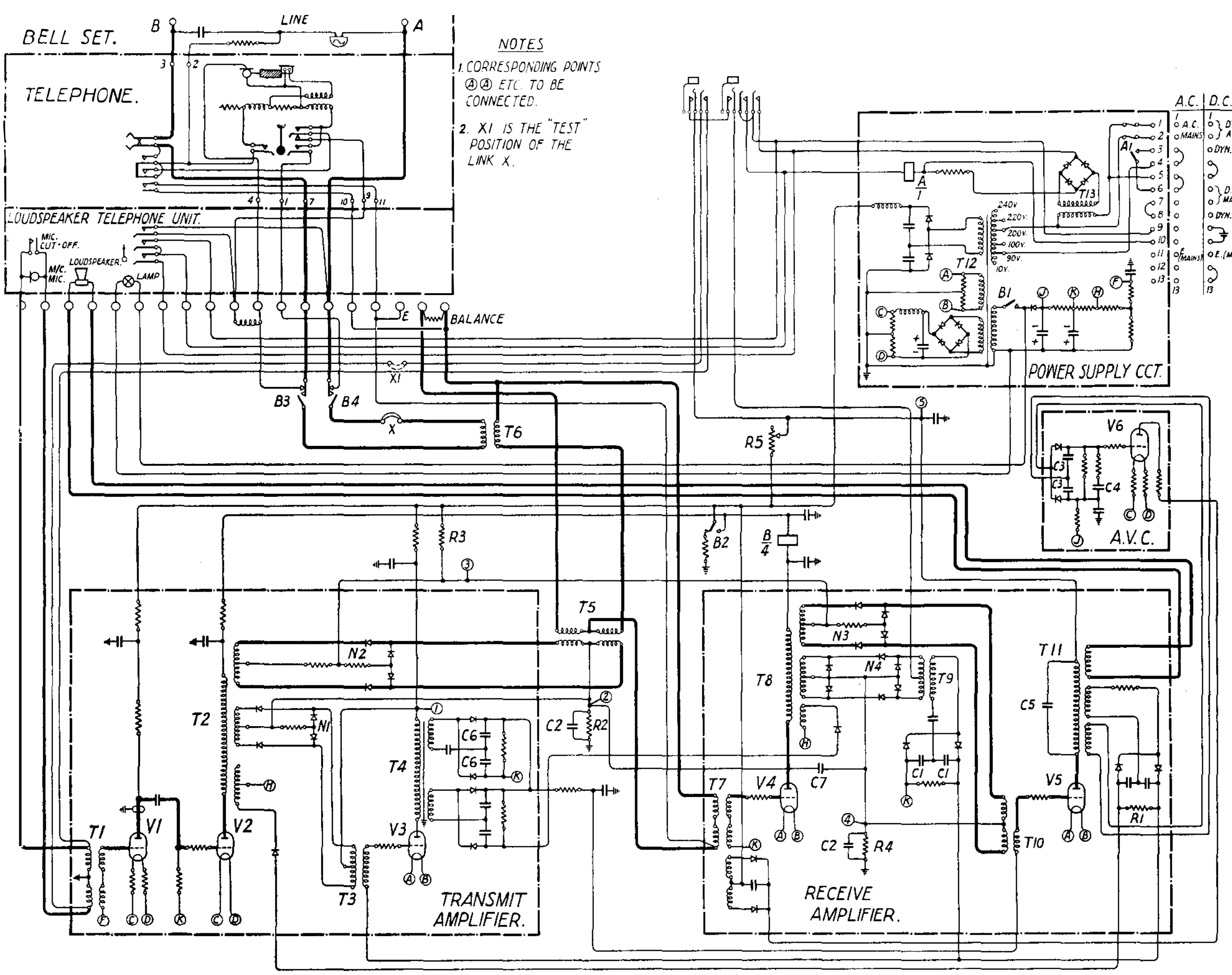


Fig. 7.—Circuit of Complete Loudspeaking Telephone.

converter is associated with the equipment to supply the necessary A.C. power to operate the amplifier. The D.C. power consumption is approximately 250 W. Smoothing units are fitted to both the D.C. and A.C. supplies.

The Transmit Amplifier. This is shown schematically in Fig. **4**, and the circuit diagram is given in Fig. **7**.

The Receive Amplifier. (Fig. **7**). The input from the line passes *via* the line transformer T6 and the peaks of the differential transformer T5 to the input winding of transformer T7. The mean signal voltage across the grid winding of this transformer is controlled automatically by the variable impedance rectifier shunt across the intermediate winding. The speech signals pass *via* valve V4 to the transformer T8, and then through network N3 to valve V5 and the output transformer T11.

The Voice-Operated Switching Circuits.

Referring to the receive circuit amplifier, the speech signal from the transformer T8 passes to the rectifier attenuation network N4.

When the network is in the transmitting condition, the signal passes to transformer T9 and a voltage doubler rectifier. The condensers C1, C1 discharge, when a signal ceases, with a discharge time of approximately 0.5 secs. The rectified voltage is connected in the grid bias feed of the valve V3, so that when signals from T8 pass through the network N4 and are rectified, the negative grid bias voltage is reduced and the anode current of valve V3 increases.

The transmit amplifier control signal circuit can be traced from transformer T2 through the rectifier attenuation network N1, the transformer T3 and the valve V3 to the transformer T4. The signals are rectified and the resultant voltage obtained across condensers C6, C6 reduces the negative grid bias voltage of the valve V5.

The Control Current Path.

The control current path can be traced from the H.T. end of the primary of the transformer T4 in the anode circuit of valve V3 through networks N1, N2, N3, N4 to the H.T. end of the primary of transformer T11.

The resistors R2, R3, R4 provide the bias network control currents so that in the quiescent state the network attenuations are as follows :—

Attenuation Network.	Control Current through rectifier network.	Attenuation.
No. 2. Microphone speech circuit.	+ 1.15 mA	high
No. 1. Microphone control signal circuit.	− 0.3 mA	low
No. 3. Loudspeaker speech circuit.	+ 0.95 mA	high
No. 4. Loudspeaker control signal circuit.	− 0.5 mA	low

When normal level speech signals are passing through either the " transmit " or " receive " amplifiers the control current is between 10 and 20 milliamps.

The " Break-in " Signals.

The " break-in " signal of the transmit amplifier is derived from the transformer T2 and from the transformer T8 in the case of the receive amplifier.

The transmit circuit anti-side-tone " break-in " signal is derived from the transformer T4 which follows the attenuation network N1, and the receive circuit anti-side-tone " break-in " signal is derived from transformer T11, also following an attenuation network, N3.

The Hangover Time of the Anti-echo or Anti-side-tone " Break-in " Circuit.

A hangover time of approximately 70 millisecs. is used in both transmit and receive circuits. This time is sufficiently short to enable the fluctuations of the rectified anti-side-tone signal voltage to follow the speech fluctuations, so that between words it falls to zero and " break-in " can then occur with relatively small signals as compared with the echo signal occurring immediately before.

The Automatic Volume Control (A.V.C.) Circuit.

The signal voltage operating the automatic volume control circuit is derived from transformer T11. The normal grid bias voltage of valve V5 of 33 volts is approximately 24 volts in excess of that voltage required to reduce the anode current of the valve to zero.

The operating time, during which the signal exceeds its controlled level by more than 2 db., is less than 5 millisecs. for all input levels. The amplification of the set increases to a maximum in 2 to 4 seconds when a signal that has previously operated the A.V.C. ceases.

The rectifiers used to shunt the transformer T7 each consist of eight elements of " H " or 10 mA type. The regulation of the automatic volume control device is shown in Fig. **8**. The harmonic introduced by the polarized shunt rectifiers is less than 35 decibels below the main signal level under all conditions of use.

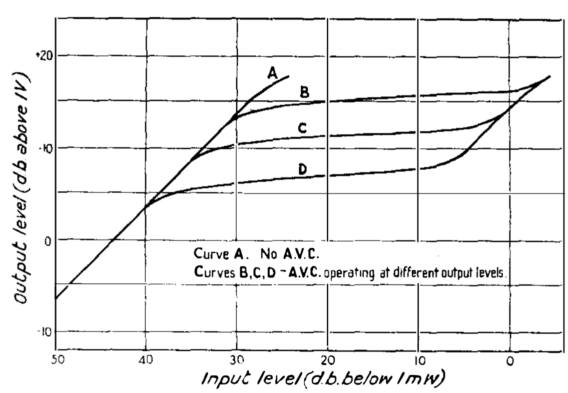


FIG. **8**.—REGULATION CURVES OF AUTOMATIC VOLUME CONTROL DEVICE.

The Loudspeaking Telephone Unit.

This is shown in Fig. **9**. The overall size is 12 ins. long, 6 ins. high and 4¾ ins. deep. On the face of the bakelite case are two openings for the micro-

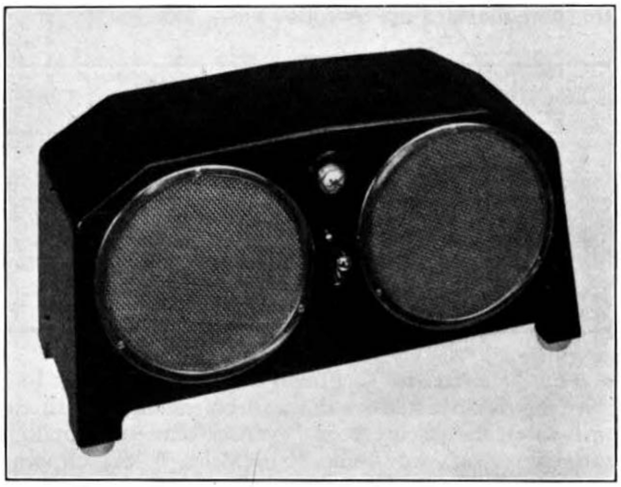


Fig. 9.—Loudspeaking Telephone, Table Unit.

phone and loudspeaker on the right and left respectively. In the centre there is the pilot lamp, which glows when the unit is in operation, and the operating key. Similar type permanent magnet, moving coil units shown in Fig. **10** are used as the microphone

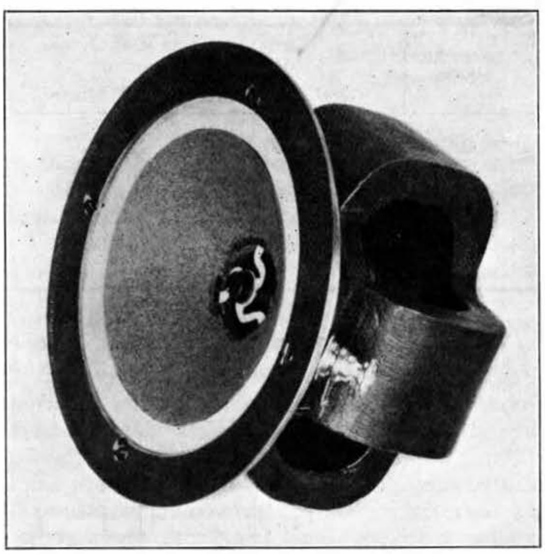


Fig. 10.—Moving-coil Microphone.

and speaker. As a microphone the unit is intended for use without any case or baffle. To avoid box resonance, the back and bottom of the microphone half of the case are open and the unit is mounted set back from the front of the case to reduce the baffle effect of the case. As a loudspeaker, the unit requires a baffle. A cylindrical lead case 1/16" thick is fitted around the back of the loudspeaker unit. The interior walls of the case are packed with layers of felt and "sorbo" rubber leaving a small air space behind the cone. The frequency response characteristics of the complete unit used as a loudspeaker are then very uniform. The design of the units themselves and frequency response characteristics have already been given in a previous article in this journal.[2]

The Performance Characteristics of the Loudspeaking Telephone.

Typical performance characteristics are given below.

The Characteristics of the Microphone and its Associated Amplifier.

The Microphone Amplifier Gain-Frequency Characteristics. The overall gain-frequency characteristic between the microphone amplifier input terminals and the line is as shown in Fig. **11**. The input impedance

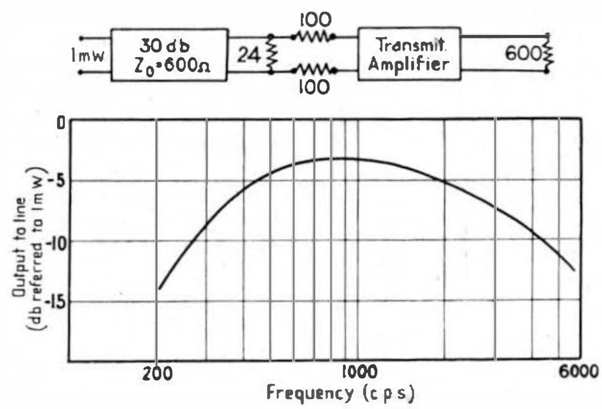


Fig. 11.—Gain Frequency Characteristic of Microphone Amplifier.

of approximately 200 ohms corresponds to the impedance of the microphone. Over-loading does not occur until the level to line is +10 db. referred to 1 mW.

The characteristic of the amplifier in association with the microphone mounted in the telephone unit is shown in Fig. **12**. The maximum change in output

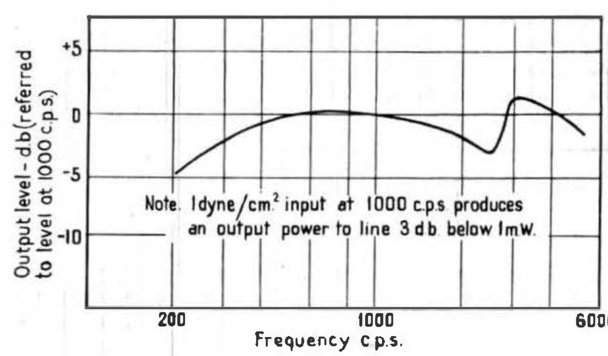


Fig. 12.—Overall Characteristic of Microphone and Associated Amplifier with Uniform Sound Pressure Input.

[2] McMillan. *P.O.E.E.J.*, 1935, Vol. 27, p. 284.

level between 300 and 5000 c.p.s. is less than 5 db. The harmonic distortion introduced into the output circuit with various input pressures (1000 c.p.s.) is given in the following table :—

Sound pressure input. Dynes/cm².	Harmonic in output signal to line (db. below fundamental).	
	2nd Harmonic.	3rd Harmonic.
4	29	38
2	32	42
1	42	45
0.5	46	> 50

A sound pressure input of 4 dynes/cm² corresponds to very loud speech at a distance of 2 ft. from the microphone and produces a signal to line 9 db. above 1 mW.

The Microphone Switching Sensitivity. The normal microphone switching sensitivity is such that for frequencies above 800 c.p.s. the switch is operated with sound pressure inputs 35 db. below 1 dyne/cm². Provision is made for increasing or decreasing this sensitivity.

With the normal microphone switching sensitivity the total operating time of the switch ranges from 2 to 5 milliseconds for sound pressure inputs from +10 to −10 db. referred to 1 dyne/cm².

The Characteristics of the Loudspeaker and the Associated Amplifier.

Overall Gain-Frequency Characteristics. The response characteristic of the receive amplifier is caused to fall off at high frequencies so that the reproduction of speech from a carbon transmitter is rendered more pleasing to the ear.

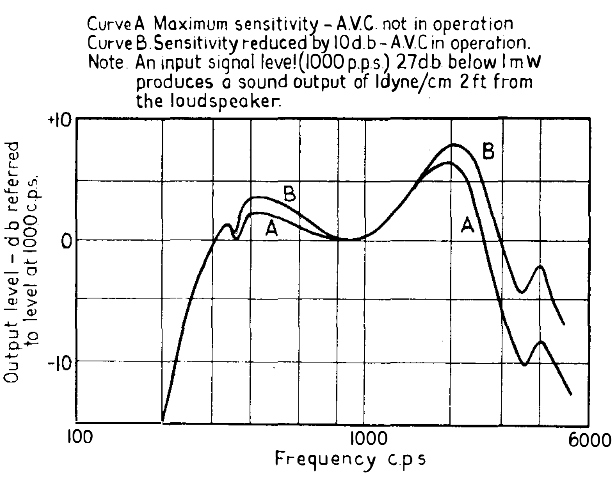


FIG. 13.—RELATIVE OVERALL CHARACTERISTIC OF LOUDSPEAKER AND ASSOCIATED AMPLIFIER.

The resultant overall frequency characteristics are shown in Fig. **13**, curve A for the condition when the A.V.C. is inoperative and curve B when the A.V.C. is reducing the 1000 c.p.s. amplification by 10 db.

The switching sensitivity of the receive amplifier is such that at frequencies near 800 c.p.s. an input signal 60 db. below 1 mW. operates the switch.

The speed of operation and the hangover times with an input of 1 mW. (800 c.p.s.) through various line attenuations are as follows :—

Line Attenuation.	Operating Time (millisecs.).	Hangover or Restoring Time (millisecs.).
0	1	340
10	2	340
20	5	340
30	8	340
40	15	340
50	40	200
55	60	100

The "Break-in" Facility. The "break-in" winding is adjusted so that, in conjunction with the anti-side-tone "break-in" from the microphone amplifier, no side-tone "break-in" or clipping occurs with speech passing from the microphone to line with the latter either open or short-circuited.

The Non-Linear Distortion introduced in the Amplifier. The total non-linear distortions introduced by the amplifier valves, the various rectifier loads and the action of the A.V.C. are expressed as harmonic content in the following table for various line attenuations with 1 mW. input (1000 c.p.s.) :—

Line Attenuation db.	Harmonic Content of Output. (db. below fundamental).	
	2nd Harmonic.	3rd Harmonic.
0	26	37
5	34	38
10	34	38
20	36	39
30	38	40
40	43	40

The Combined Performance Characteristics of two Loudspeaking Telephones operating together.

Frequency Response Characteristics. The relative frequency-response characteristics of the system, including the microphone, loudspeaker and the associated amplifiers are shown in Fig. **14**. Curve A shows the relative output pressures measured 2 ft. from the loudspeaker. The input pressure to the microphone at 1000 c.p.s. is equal to the output pressure 2 ft. distance from the speaker with a line attenuation of 24 db. between the two loudspeaking telephones.

Curve B shows the corresponding overall characteristics that are obtained when the A.V.C. is reducing the amplification of the receiving amplifier by 10 db. Increased operation of the A.V.C. has but a very slight additional effect on the frequency characteristic.

Allowing for the reduction in the overall response at the frequencies below and above 300 and 2500 c.p.s. respectively, the average speech output volume

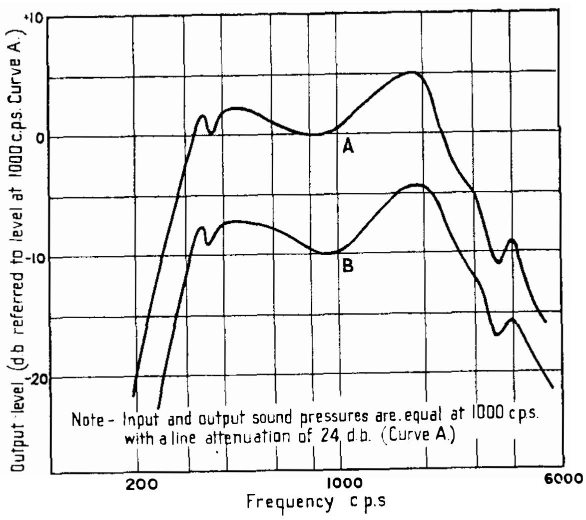


FIG. 14.—RELATIVE OVERALL SOUND PRESSURE CHARACTERISTICS—MICROPHONE TO LOUDSPEAKER.

2 ft. from the loudspeaker is at least equal to the input volume to the microphone with a 24 db. line attenuation between the two sets.

" Switching," " Break-in " and " Lock-out " (by speech tests). The danger of locking up the line, which occurs when both talkers succeed in getting to line, but neither to loudspeaker, increases as the overall line attenuation increases. Real danger of lock-out occurs after the break-in limit at the distant end is reached and before the minimum switching limit at the near end is reached. These limits are not accurately determinable and will vary with different speakers.

The following results of tests carried out can be considered typical. The rooms can be regarded as reasonably quiet offices, there being no other talkers in the rooms or machine noise. The windows which faced on to a drive were open, however, and the rooms were by no means silent.

With all lines having total attenuations ranging from zero to 20 db. two-way conversation is practically perfect and the presence of the switches cannot be detected nor can any appreciable operating time be observed. Lock-out does not occur on lines up to 20 db. attenuation.

As the attenuation of the line is increased above 20 db. the efficiency of the " break-in " from the line decreases, but satisfactory two-way conversation is possible with line attenuations up to between 25 and 30 db. depending on the voices of the speakers. The possibility of lock-out occurring with line attenuations greater than 25 db. becomes real, so that satisfactory conversation is only possible if the speakers do not attempt to interrupt one another.

Calling Operations—Circuit Details.

The connexions for auto systems are shown in Fig. 7. Corresponding circuits for manual systems (CB, CBS1, 2, and 3 and magneto) have been developed.

Installation of Equipment at Subscribers' Premises.

Installation. The amplifier should be installed in a reasonably dry room with a small clearance between the cover and the wall for ventilation purposes. A jack is provided to make connexion to the cable leading to the loudspeaker unit and telephone.

General maintenance. Since the amplifier is only switched on for the time the equipment is actually in use maintenance is small. Voice operated switching equipment of a similar design has been in continuous use (24 hours a day) in a trunk telephone circuit for over a year with no attention whatsoever.

Room echo or reverberation. The installation of a loudspeaking telephone in certain rooms may be unsatisfactory due to room echo. Simple means have been formulated in which the chief absorption units present in a room can be determined. The calculation takes into account the area of the walls of the room and the types of surface, the effects of curtains, carpets, articles of furniture and persons normally present in the room. The ratio of the absorption units to the volume of the room (in cubic feet) should be as high as possible. If it falls below about 20 absorption units per 1000 cubic feet of room volume, the reverberation effect, as observed by a distant end subscriber using an ordinary telephone, appears excessive and reduces intelligibility. The amenities of the private office of the potential business user generally include a carpet, easy chairs, and sufficient other absorbent material to reduce the reverberation effects to satisfactory proportions.

Conclusions.

The loudspeaking telephone that has now been developed has been enthusiastically received by all who have used it and the foregoing description indicates that a very high standard of performance has been achieved. The problem of obtaining satisfactory operation in association with lines of widely varying impedance and attenuation, and under conditions of room and line noise that may be present has only been successfully solved by new methods, especially developed for the purpose.

A close inspection of the fundamental feature of the design shows that both the apparatus and the maintenance are a minimum for the high standard of performance that is considered desirable for this equipment, and it would appear very difficult to obtain a more economical arrangement to give a comparable standard of performance.

The design features can be applied to simpler forms of loudspeaking telephones, such as house telephones, where the line attenuation is small and its impedance known, and thus very cheap two-way loudspeaking telephone systems can be obtained which will operate under any practical noise conditions. The methods may be applied equally well to obtain full loudspeaking conference facilities between two or more bodies of people separated by many hundreds of miles.

The Transorma Letter Sorting Machine

W. T. GEMMELL, B.Sc. (Eng), A.M.I.E.E.

The methods by which the difficulties associated with the mechanical sorting of letters have been overcome are described in this article, which gives details of the machines recently installed in the Brighton Sorting Office.

THE completion of two Transorma letter sorting machines at Brighton Sorting Office, in October last, marked a further stage in the development of mechanical sorting machines for postal work. It is now about 25 years since the first experiments in mechanical sorting were made in the British Post Office and the intervening period has seen many attempts, both in this and other countries, to produce a machine or installation to meet the exacting requirements of postal sorting.

The problems involved are intricate owing to the non-uniformity of material dealt with, the irregular flow of traffic, and the need of flexibility to cope with special postings, etc.

The Transorma machine has been developed in Holland and the installation of these machines at Brighton, which was selected as a suitable office for the trial of such machines, will enable practical experience to be gained to determine whether such machines best meet postal traffic requirements in this country. The various articles which have appeared in the Press and elsewhere will no doubt have aroused considerable interest, and the purpose of this article is to give a brief description of the method for the benefit of those whose interest is mainly in the technical details.

Historical Notes.

The idea of this method of machine sorting originated with Mr. L. Marchand, a former Official of the Dutch Post Office, and the present Transorma machine represents the result of over 20 years' development work by Mr. Marchand in collaboration with Professor Andriesson, of Delft Technical College. The first complete machine was installed in Rotterdam Post Office in 1931 and the second machine in 1933, and it is understood that both machines have come up to expectations.

The machines are built to meet requirements of the particular office in which they are installed. After study of the operation of the Rotterdam machines, and consideration of postal requirements and lay-out of the sorting office at Brighton, the requirements at Brighton were specified and the order for the machines was placed in September, 1934, the installation being completed in October, 1935.

General Description.

The machine and the mechanisms employed are extremely ingenious although the broad principle of the working of the machine is simple. A series of carriers forming an endless chain run on a horizontal track. At a part of their travel they pass in front of the operator seated at a combined keyboard and letter despatching mechanism. The letter placed in the slot by the operator is ejected into a carrier, one letter per carrier, and the depression of keys by the operator at the same time as the letter is placed in the slot sets selectors on the carrier. The carrier discharges the letter into a chute at another part of its travel, the particular chute being determined by the position of the selectors.

The chutes end in box receptacles of which, in the case of the Brighton machines, there are 250, so that letters can be sorted into 250 divisions at one operation. A numerical keyboard is used and consequently each address has to be coded according to its intermediate or final destination. This necessity for coding rather limits the number of divisions into which letters can be sorted at one operation as there is a limit to the average operator's capacity for memorizing codes.

The complete installation at Brighton consists of two identical machines with a continuous elevated operating platform. The photograph in Fig. 1 gives an idea of the general arrangement. There are five keyboards on each machine and these can be seen with the operators' chairs in position.

The letters are sorted into two sections of 250

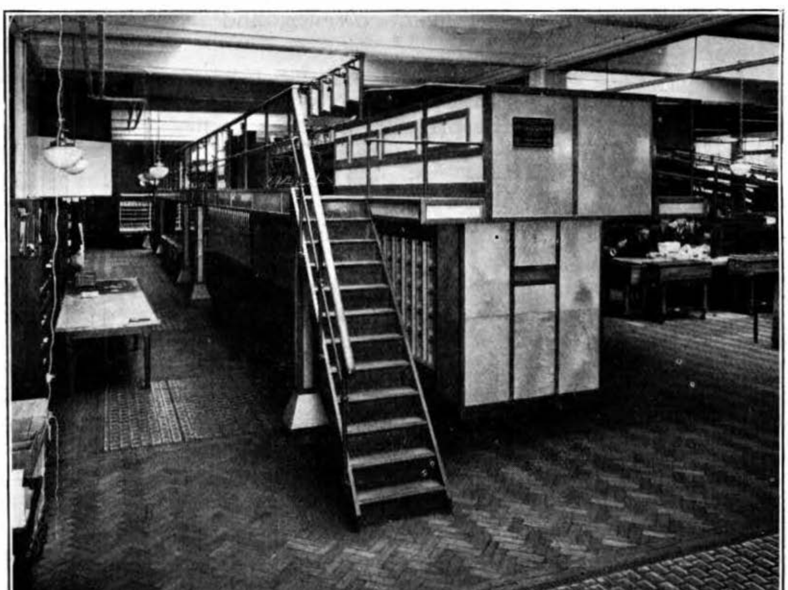


FIG. 1.—GENERAL VIEW OF MACHINE.

receptacles each, one section taking the mail from 5 of the keyboards and the other section from the other 5 keyboards. The designed speed is 50 letters per minute per keyboard, *i.e.*, 30,000 letters per hour for the complete installation. The maximum dimensions of the letters which can be handled by the machine are length 7″, width 5½″, thickness 5/16″.

The box receptacles are built under the operating platform and the 250 receptacles per machine are built into two walls of 125 receptacles each. Each wall consists of 25 vertical rows of 5 receptacles. The numbering is 0—124 on one side and 200—324 on the opposite side, the receptacles being so arranged that No. 0 is back to back with No. 200, 1 back to back with 201 and so on.

The structure is supported from the floor by 12 steel columns standing on pressed cork plates. The total weight is approximately 20 tons and the disposition of the columns is such that they stand on existing floor beams and no structural alteration to the building was necessary to take the weight.

The track and carriers, together with the keyboard mechanisms, are totally enclosed with wood covers lined with cellotex to reduce noise as much as possible.

Constructional details are shown in the general arrangement drawing in Fig. **2**. The cross section through the chutes shows how the letters are delivered into receptacles, the relative positions of the two walls and the receptacles.

The main parts have been numbered for easier identification.

The Keyboards.

The mail which is to be machine sorted is passed through the stamping machines at the ends of two facing tables on the sorting office floor level and then stacked into metal trays and taken by conveyors rising directly over the facing tables to the Transorma operating platform level. The trays are there turned at right angles on to a conveyor running along the length of the machine just below the handrail level. The trays of letters are taken by hand from the conveyor and the letters pushed into the letter troughs feeding each keyboard. Spring loaded hinged ends to the trays enable this to be done without actually lifting the letters. The letters are carried on leather bands in the bottoms of the troughs and the bands are moved forward automatically. The motion of the band in any particular trough is determined by the pressure of the foremost letter on a small lever carrying a ball race. This can be seen in Fig. **3**. Thus if letters are not being removed from the trough the motion of the band is stopped. The keyboards and troughs are shown in Figs. **3** and **4**, from which it will be seen that the foremost letter in a trough comes readily to the right hand of the operator. The keys are operated by the left hand. After reading the address the operator drops the letter into the slot immediately in front of the feeding trough and simultaneously depresses the keys corresponding to the number of the receptacle into which the letter is to be discharged. It should perhaps be noted in passing that the keys are depressed together and not one after the other as in typewriting or key sending. The lay-out of keys is shown in Fig. **5**. The resetting key is for use in cancelling a previous setting should this be in error and the mistake be realized in time. When the resetting key is used, or keys are not depressed, the

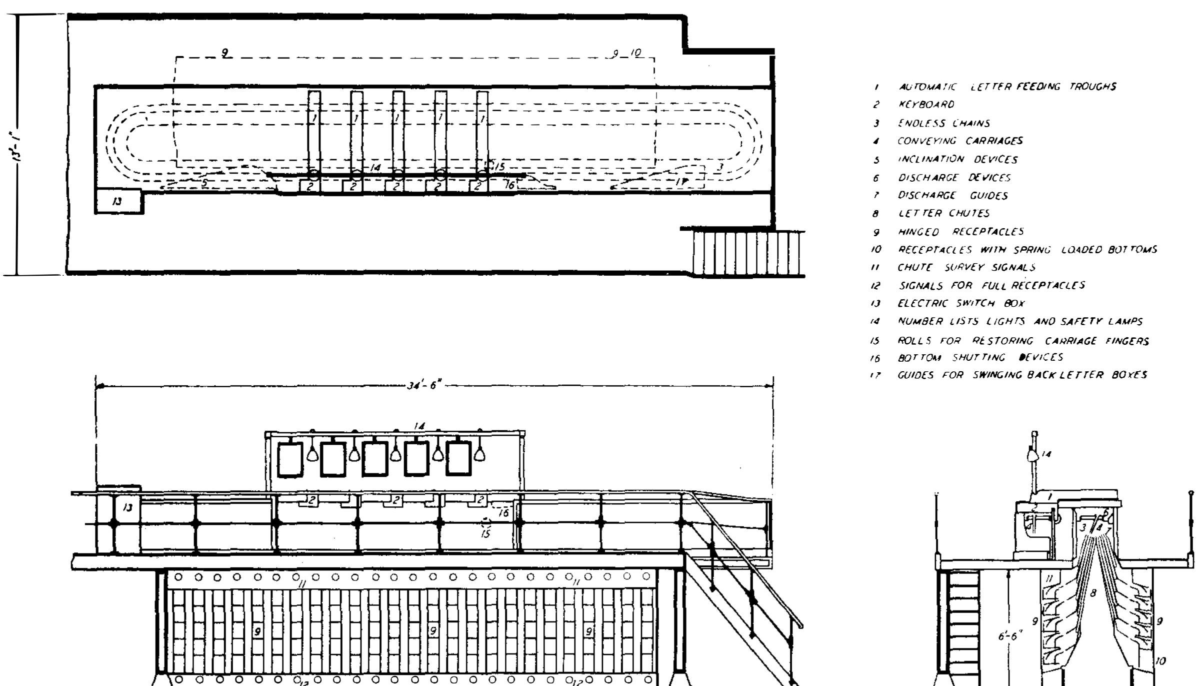


FIG. 2.—GENERAL LAY-OUT OF ONE MACHINE.

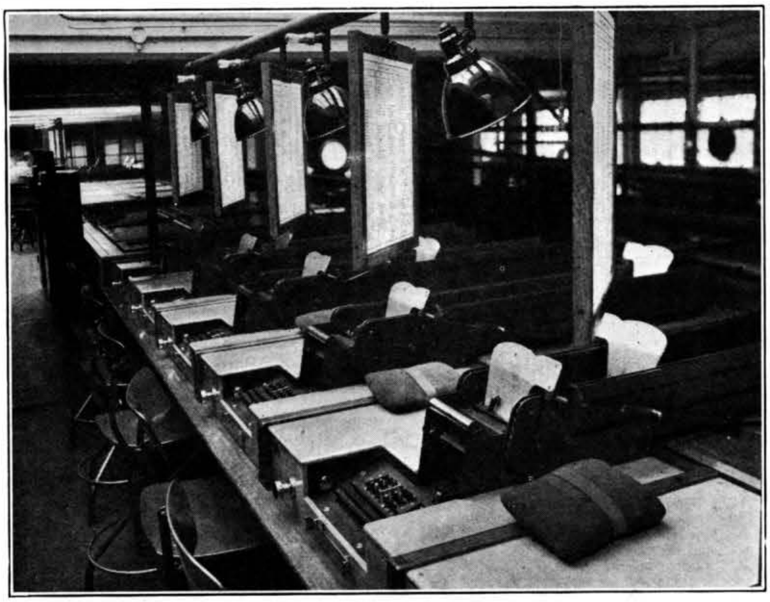


FIG. 3.—KEYBOARDS AND LETTER FEEDING TROUGHS.

FIG. 4.—KEYBOARDS.

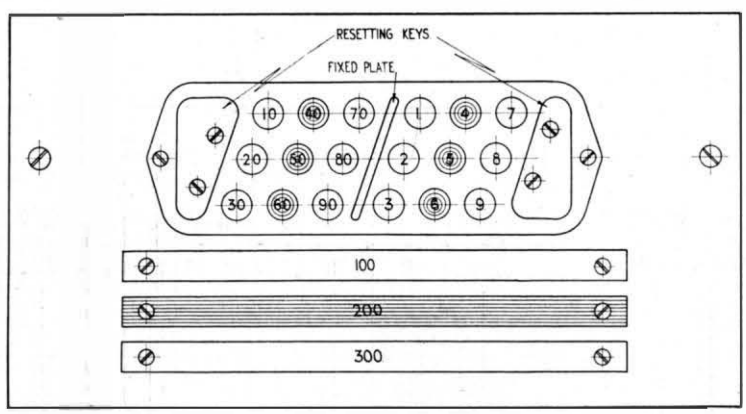


FIG. 5.—ARRANGEMENT OF KEYS.

letter is discharged to receptacle No. [illegible]. After the letter is in the slot and the appropriate keys depressed all further operations are carried out automatically.

The carriers with the bottoms closed run in a vertical plane immediately under the slots in the keyboards. As there are five keyboards it follows that each keyboard has access to every fifth carrier and the timing of the mechanism of the keyboard is synchronized with the passing of the carrier to which that keyboard has access. This is accomplished by a cylinder having five helical slots which are engaged by ball races on the carriers. The passage of five carriers gives the cylinder one complete revolution and the keyboard drive is taken from this cylinder.

The slot into which the letter is dropped has a movable bottom and at the correct time this bottom opens allowing the letter to fall into a glass fronted receptacle, having two inclined rollers at the bottom. Fingers are situated in slots in the rollers and the pressure of the letter on these fingers brings the rollers into gear. The rollers rotating discharge the letter into the appropriate carrier. The inclination of the rollers is necessary to discharge the letter in a down and a forward direction to ensure the letter arriving in the carrier and arriving without being turned round. The glass front to the receptacle enables the operator to see when a letter has been discharged.

The depression of the keys actuates a combination of links and bars and permits cams to drop in the path of the selector bars on the carrier. There are nine cams in all and the number and position of those allowed to drop is determined by the number keyed. The cams which are in the down position push the corresponding selector bars down. Thus in addition to the letter the carrier also carries the setting necessary to discharge the letter into the correct receptacle.

Each keyboard is driven through a clutch which is disengaged by the operator pulling a knob when work on the keyboard is finished. The keyboard is also inoperative unless the marking device is in position. This marking device, the position for which can be seen immediately in front of the letter feeding trough, impresses a symbol on the letter immediately before it is discharged into the carrier. Each operator has his own marking device which he puts in when taking over duty and the symbol on the letter enables the sorting of a letter to be traced back to a particular operator and a particular keyboard. In addition a counter is associated with the keyboard, this is resettable by key and the number of items sorted on the keyboard during any period can be easily ascertained. As it is essential that oversize letters shall not be placed in the machine a gauge is fitted immediately in front of the keys. This enables the operator to gauge the length, width and thickness of any letter about which there may be a doubt.

Carriers, Track and Drive.

Before describing how a letter is discharged into the correct receptacle it will be as well to deal with the carriers and the way in which they are driven.

Figs. **6** and **7** are photographs of one of the carriers. It consists of a fairly substantial steel top frame supporting the carrier proper which is of aluminium alloy. The total weight of one carrier is about 21 lbs. The top frame carries the rubber-tyred wheels on which the carrier runs. Each carrier is joined to the next by steel pins and links on one side only to form an endless chain. The pins are on the inner track side and enable carriers to turn at the ends of the track. The carrier proper can swing about a horizontal axis in the steel frame, the axis being parallel to the length of the carrier. The carrier may be held in any one of the inclinations to the vertical by a pawl engaging with a toothed quadrant. If the pawl is held off a spring pulls the carrier to the extreme left hand inclination. The pawl is held out of engagement by a trigger and downwards pressure on this trigger permits the pawl to engage with a tooth on the quadrants.

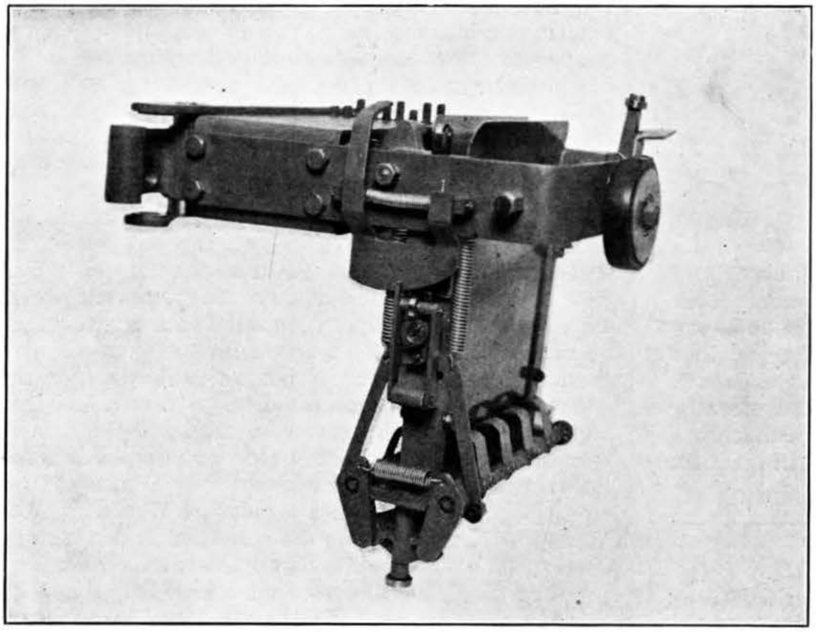


Fig. 6.—Carrier—Central Position.

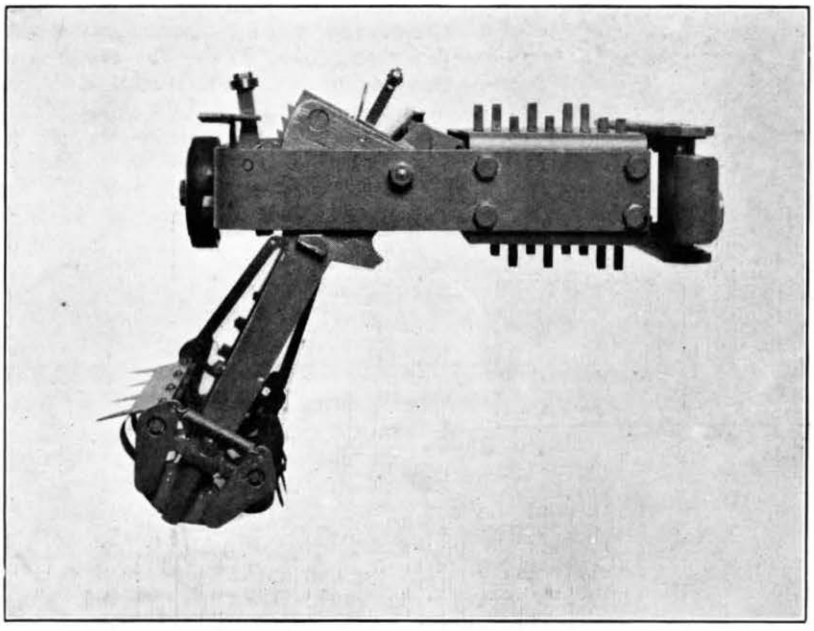


Fig. 7.—Carrier—Inclined Position.

The bottom of the carrier consists of fingers and springs. When the bottom is closed the springs press against each other keeping the letter in. Downward pressure on a trigger opens the bottom by spring action and the springs forming the bottom then grip the letter and definitely eject it from the carrier. The bottom is closed again by pushing down the bar carrying a ball race, which can be seen in the photograph. The selector bars are simply square bars of steel held by flat springs so as to be a push fit in the holes. Fig. **6** shows the carrier in central position and bottom closed. Fig. **7** shows some of the selector bars depressed, the carrier inclined and the bottom open, the conditions obtaining after a letter has been discharged.

The chain of carriers is driven at one end by a 2 H.P. 3-phase 1420 r.p.m. motor through worm reduction gear. The axis of the worm wheel is vertical and carries at its top end a solid steel plate having slots in its periphery. These slots engage with the pins connecting adjacent carriers. Fig. **8** shows the arrangement and from this it will be appreciated how the turning of the carriers is effected. The track itself is of steel with a machined surface. The speed of the motor is variable within limits to give sorting speeds between 34 and 53 letters per minute per keyboard.

An electro-mechanical brake is incorporated so that when the supply to the motor is interrupted the brake is applied and the machine stopped quickly. For maintenance purposes the machine can be turned by hand through a chain and spocket wheel.

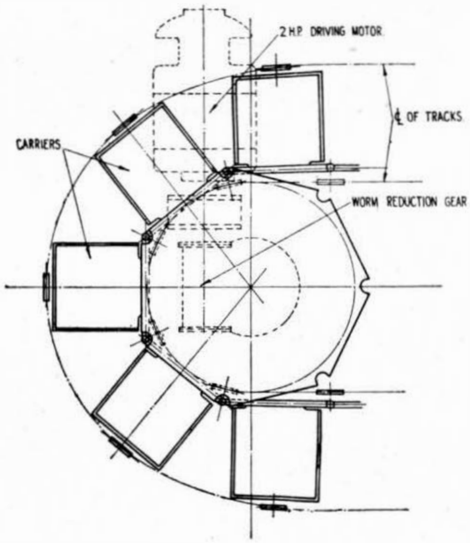


Fig. 8.—Arrangement of Driving End.

When being turned by hand the supply to the motor is cut off, but the brake magnet is left in circuit. This obviates the disadvantages of having to hold the brake off by hand and also leaves the safety devices in circuit so that in the event of a fault in the carrier mechanism the carriers cannot be inadvertently forced round with consequent damage to the machine. The driving end with the hand drive chain in position is shown in Fig. 9.

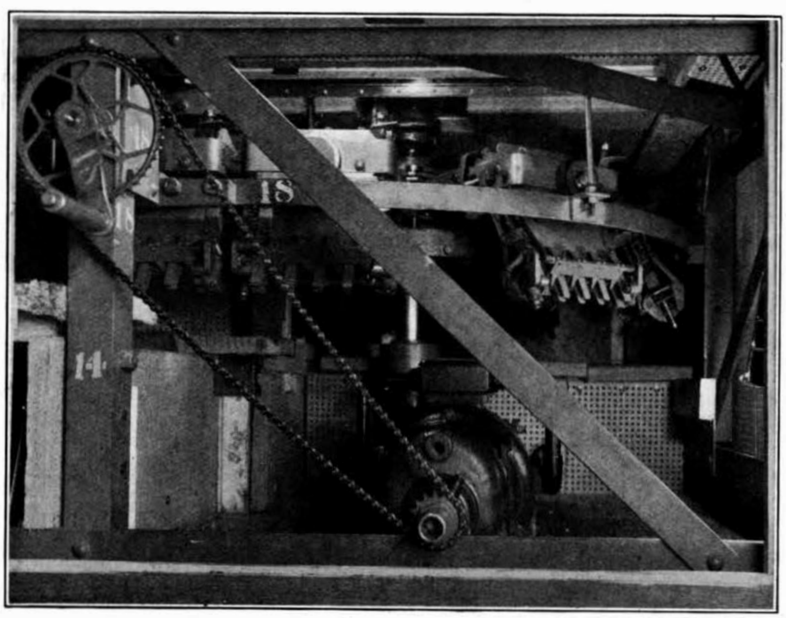


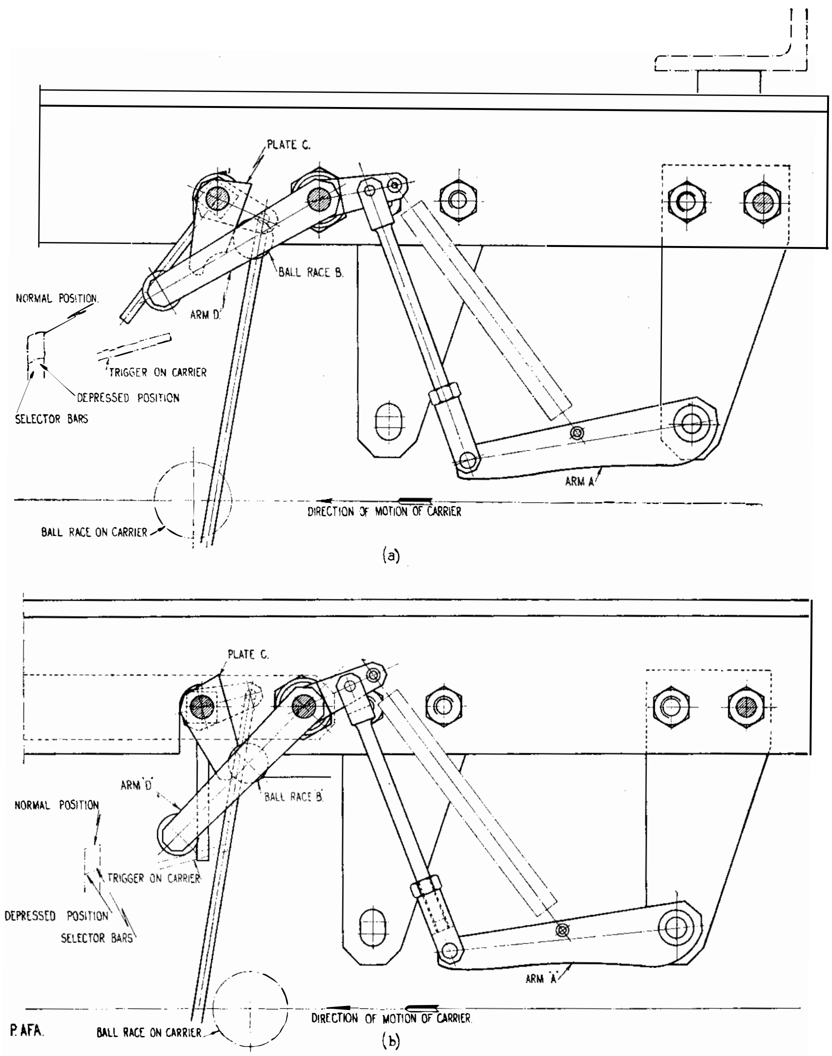
Fig. 9.—Driving End.

Discharge of Letter from Carrier.

After receiving the letter and having the selector bars set at the keyboard, a carrier has to be locked in the requisite inclined position and then opened so that the letter is discharged into the desired receptacle.

It will be seen from Fig. 2 that the inclination device is situated immediately to the left of the keyboards, the direction of motion of the carriers at that part of their travel being from right to left. When travelling under the keyboards the carrier (*i.e.*, the swinging portion) is free, but is maintained in a vertical plane by the ball race on the bottom of the carrier bearing on a straight track, being held there by the spring previously referred to. The inclination device consists of a cam, which is a part of a cylindrical plate, and locking mechanism. The ball race on the bottom of the carrier runs on the cam and thus the carrier is pushed out to the extreme inclination on the right hand side, the motion being against the action of the spring. After the position of extreme right hand inclination is reached the cam is shaped to allow the carrier to return, by the action of the spring, to the position of extreme left hand inclination. The shape of the cam, as will be seen from Fig. 2, is such that the first part of the motion is quick while the second is relatively slow. It is during the second part of the motion that the carrier is locked at the inclination corresponding to the setting of the selector bars and the ball race then leaves the cam contour. The mechanism by which this is accomplished is shown diagrammatically in Fig. 10. The carrier in its motion lifts arm A which permits a ball race B to drop into engagement with the recess in the plate C. Thus the ball race on the end of arm D is held in the down position. This happens every time a carrier passes and the arm D would be permanently in the down position but for the fact that the rocker bar carrying D also carries light fingers which are directly in the path of the selector bars in the carrier. If the particular selector bars concerned have not been depressed at the keyboard then they knock the fingers from the vertical position so knocking the ball race B out of engagement and D returns to the up position. If, however, the selector bars concerned have been depressed then, during the passage of the particular carrier, D is held locked in the down position. In this position it depresses the trigger on the top of the carrier which allows the pawl to engage with the quadrant ratchet, thus locking the carrier in the inclined position which it has then attained. Four selector bars are used to give the inclination, there being a total of ten inclinations, five to the right and five to the left. The last position is the extreme left inclination and carriers which reach this position are locked by a fixed ball race operating the trigger.

After being set at the required inclination the carrier makes the turn at the end and is taken over the tops of the chutes leading to the receptacles. The whole of the straight portion of the track on the side remote from the keyboards is used for discharging into receptacles. The mechanisms used to open the bottom of the carrier are similar to those for setting the inclination,



(*a*) Condition when Carrier is not to be locked in particular inclined position.
(b) ,, ,, ,, is to be ,, ,, ,, ,, ,,

FIG. **10**.

advance of the entrance to the chute. The chutes are of special shape designed to retain the facing of the letters. Incidentally it should be mentioned that good stacking and retention of facing is of utmost importance in letter sorting whether mechanical or hand.

Receptacles.

The chutes which are of aluminium, discharge into the receptacles as can be seen from the cross section in Fig. **2**. Celluloid fingers are placed at the bottom of the chutes and celluloid flaps at the entrances to the receptacles to prevent letters jumping and becoming defaced. Two hundred and thirty-five receptacles in each machine are provided with a swivelling bottom and have a height of 10″ to take a stack of letters 8″ high. The bottom three receptacles in the first three rows have spring loaded bottoms and a maximum stacking height of 16″, while the remaining twelve receptacles in the first three rows have a stacking height of 6″. The large receptacles, Nos. 4, 9 and 14, are for divisions with heavy traffic. The spring loaded bottoms fall as the number of letters in the receptacles increases and this keeps the top of the pile of letters near to the chute discharge point and tends towards better stacking. The fronts consist of hinged stainless steel bars while the backs comprise three fixed vertical bars giving a clear view of the chutes at the back. When a receptacle is full the celluloid flap at the top presses on a push button. This makes circuit for a signal lamp at the bottom of the row and also for a master lamp. Thus one signal lamp serves five receptacles and one master lamp serves each half section. The identification of a full receptacle is thus an easy matter. In addition to the receptacle full signal there is also an indication given when a letter sticks in a chute. In the bottom of the chute immediately behind the receptacle a 1″ hole is drilled. The holes in the chutes in the same row are in the same vertical line. A beam of light is directed through these holes from the base of the machine and is reflected by a mirror at 45° at the top of the receptacle to illuminate a shadow glass on the front above the row of receptacles. Should there be an obstruction in the chute the beam of light is interrupted and the shadow glass is darkened giving the necessary indication to the attendant.

Space is left between receptacles for access to the chutes and in this space are placed the label holders. A lamp is placed overhead between each row to give

but in this case there are 25 selections. It will be appreciated that every carrier sets the mechanism for the opening of the carrier at each discharge point and that the mechanism is knocked out of engagement by the carrier unless the selector bars corresponding to the discharge point have been depressed.

A view looking down on the discharge portion of the track is seen in Fig. **11**.

As previously stated when describing the carrier, the letter is ejected in a downward direction by spring action. Interposed between the bottom of the carrier and the chutes are discharge guides which consist of channels running the length of the fitting. Between the time of discharge from the carrier and the time of arrival at the mouth of the chute the letter traverses the discharge guide in an oblique direction, the resultant of the horizontal motion of the carrier and the vertical motion due to ejection by the springs. The actual point of discharge is therefore a little in

FIG. 11.—LETTER DISCHARGE MECHANISM.

the carrier travelling between guides. These guides end in springs set on a slope so that the carrier under spring action goes to its extreme left hand inclination. A cam is then used to take it to the central guides under the keyboards.

The bottom is closed by a cam plate pushing down the rod carrying a ball race at the top.

The selector bars are restored to normal by the carrier running over a cylinder in the path of the bars, the cylinder acts on the bottom ends of the bars and pushes them all back to their normal position.

Safety Devices.

To prevent damage to correspondence or to the machine in case of a fault caused either by an unsuitable (*e.g.*, too thick) letter or by failure of some part of the mechanism to function correctly, safety devices are incorporated. These safety devices check the working of the machine and if a function has not been performed correctly a relay circuit is opened, the automatic controller switches off current to the motor and brake magnet and the machine is stopped very quickly. There are nine safety devices in all.

1. At each keyboard to check correct delivery of letters into the carrier.
2. After the inclination device. This operates if for any reason a carrier fails to lock in an inclined position.
3. At the end of the discharge guides. The machine is stopped if at this point a carrier is still closed.
4. After the inclination resetting position to ensure that all carriers have been unlocked from the inclined position.
5. After the bottom closing cam. This operates if a carrier fails to close correctly.

In addition each operator has a push button so that he can stop the machine in emergency.

Signal lamps are associated with each safety device so that the trouble can be located without delay.

the necessary illumination for the inspection of chutes. The details of the receptacles can be seen in the photograph in Fig. 12.

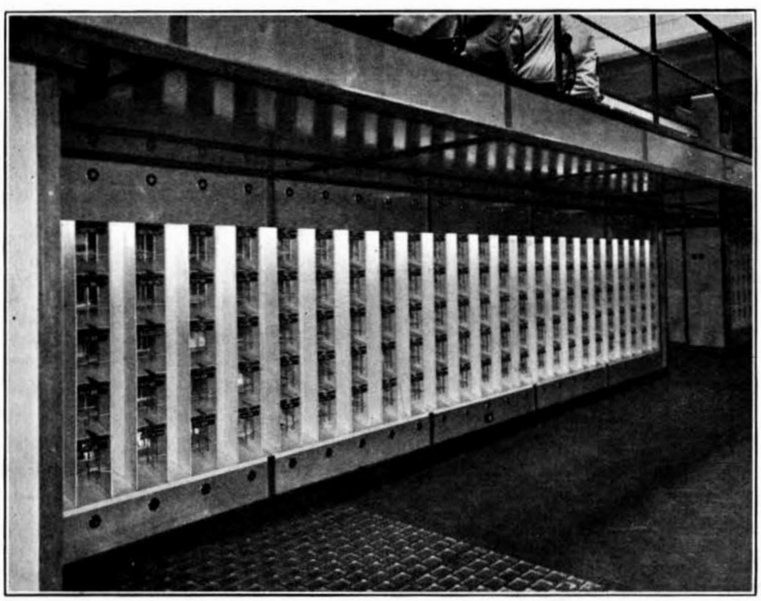


FIG. 12.—RECEPTACLES.

Carrier Resetting Devices.

After the discharge of the letter the carrier is in the condition shown in Fig. 7. After the turn at the end of the line of chutes it is reset so that before it again reaches the keyboards, it is free to swing, has the bottom closed and the selector bars normal. The carrier is freed from its locked inclined position by a fixed guide acting on a ball race, this takes the pawl out of engagement with the toothed quadrant. While this is being done the carrier is held in the inclined position by the ball race on the bottom of

Conclusion.

Considerations of space prevent a more detailed description, but it is hoped that enough has been written to give some idea of the machine and of the ingenuity shown in overcoming the many problems which beset the designer of postal sorting machines. It is interesting to note in conclusion that in the Transorma the solutions to the sorting problems have been sought in mechanical devices and that the use of electric aids is limited to the driving and controlling of the machine.

Functions of a Complex Angle

A. K. ROBINSON, A.M.I.E.E.

Instruments for calculating circular and hyberbolic functions of complex angles with a single scale setting are described. These instruments also suitable for determining the angle if the function is known.

IN a previous article[1] a description was given of a method of obtaining the functions sinh, cosh, sin and cos of a complex angle, and in concluding it was suggested that the method could, with practice, be used for the inverse process of obtaining the angle from the value of the function. It was not, however, convenient for the purpose, and with the object of making it so it has been further developed. The results of the development are described below, an incidental being a considerable simplification in the finding of the direct functions. The values of the functions are given in the form $(x + jy)$. For either direct or inverse functions the required value is obtained with a single setting, and the correct algebraic signs are indicated.

A modification is also described for cases where the hyperbolic component is greater than about 2.5-3.0, when both sinh H and cosh H become sensibly equal to $\frac{1}{2}e^{H}$ (H being the hyberbolic component). In this the functions are given in both forms, $A\underline{/\theta}$ and $(x + jy)$.

Finally, a simple construction is given for tanh, coth, tan and cot, and the inverse values $\tanh^{-1}$, etc.

Throughout the article "H" has been used to indicate an angle or component read on a hyperbolic scale, and "C" to indicate an angle or component read on a circular scale.

It must be remembered that when dealing with hyperbolic functions of a complex angle the real component of the angle must be read as "H" and the imaginary component as "C," whereas in dealing with circular functions the real component is read as "C" and the imaginary as "H."

Sinh, Cosh, Sin and Cos.

The arrangement consists of two parts, one fixed and the other rotating. The fixed part (Fig. 1) is a

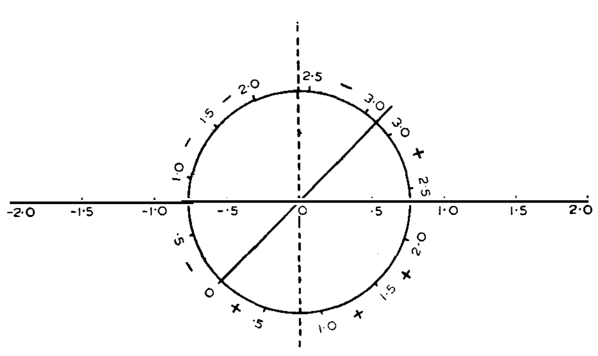


Fig. 1.—Fixed Portion of Instrument.

sheet of graph-paper with a single horizontal scale having a centre zero. It also includes a circular scale in radians with the horizontal zero as centre, of any convenient radius. As a matter of constructional convenience the zero of the circular scale is set off at $\angle 135^\circ$.

The rotating part (Fig. 2) consists of a 45° set square pivoted at the right angle. One edge is marked with values of H set off from the pivot at distances according to cosh H, and the other edge is marked similarly but at distances corresponding to sinh H. Sufficient corresponding readings are connected by straight lines to provide a guide for the eye in correlating them. Three arrows are provided on the rotating portion to indicate readings on the circular scale, and are disposed as indicated in Fig. 2.

The centre arrow is used for $\cos(C + jH)$, $\cos(\bar{C} - jH)$, $\cosh(H + j\bar{C})$ and $\cosh(-H + jC)$. The right hand arrow is used for $\sin(C + jH)$ and $\sinh(H + jC)$, and the left-hand one is used for $\sin(\bar{C} - jH)$ and $\sinh(-H + j\bar{C})$. This arrangement enables the positive "H" scales to be used for all combinations. The circular scale is, of course, half positive and half negative, and the symbol "$\bar{C}$" indicating that the normal sign of the C reading is to be reversed is simply used to avoid the provision of a duplicate but reversed C scale.

To find any function the appropriate arrow for the function required is set to the C reading. Then the horizontal distances of the two H readings from the centre zero, as indicated on the horizontal scale, are the values (x) and (y) of the function, in the expression $(x + jy)$. This is indicated in Fig. 3.

In the case of cosh, sin and cos it is the cosh H reading which gives (x), as indicated on the scale. In the case of sinh it is the sinh H reading which gives (x).

If C is large it is first necessary to reduce it to a value less than π by taking the difference between it and the nearest multiple of 2π, giving either a positive or a negative reading. A list of multiples of 2π on the corner of the graph sheet is useful.

To obtain the angles corresponding to a function whose value is $(x + jy)$, straight edges are set vertically at the values (x) and (y) and the scales are rotated until the same H reading is given by each (this being the object of the guiding lines). The corresponding angles are then read direct. One setting (when (x) is on the cosh H scale) gives six angles (two $\cosh^{-1}$, two $\sin^{-1}$, and two $\cos^{-1}$), and the other, (x on the sinh scale), gives the other two angles, $\sinh^{-1}$.

In construction the actual sizes and scale ranges are a matter of choice, the chief limiting factor being cosh H, which, of course, is never less than one. Any number of rotating members can be made to cover different ranges, using a simple multiplying factor for (x) and (y). In the original model the graph sheet used was the standard 40 × 25 cms.

[1] *P.O.E.E. Journal*, Vol. 26, Pt. 3.

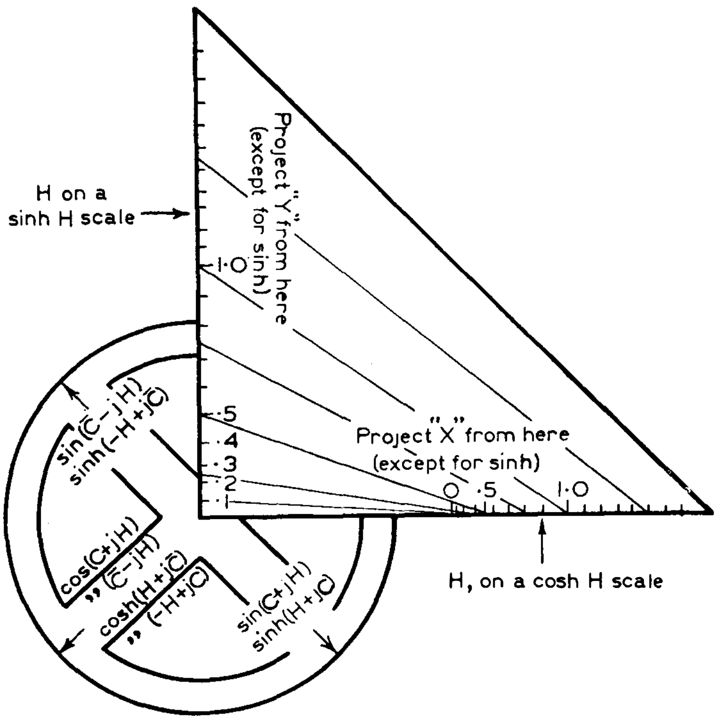


FIG. 2.—ROTATING PART OF INSTRUMENT.

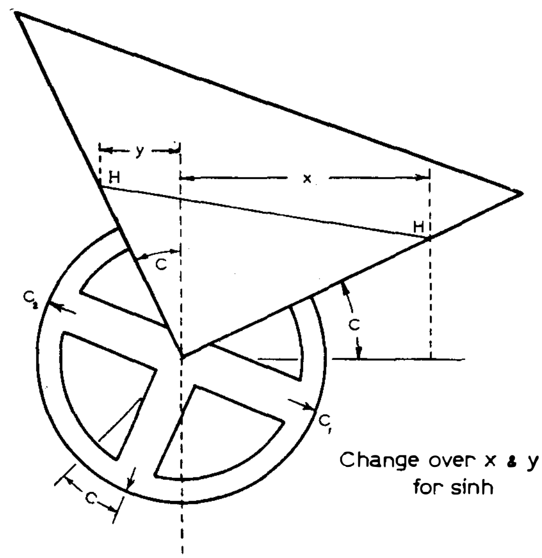


FIG. 3.—SETTING FOR READING SINH, COSH, SIN AND COS.

The horizontal scale was marked −2.3 to +2.3, and the circular scale given a radius of 7.5 cms. The set square was made with a 23 cm. side giving an H range of 0 to 1.45, cosh H being 1 to 2.249. A second set square identical with the first except for the scales of cosh H and sinh H gives an H range of 0 to 3.8 (cosh H being 1 to 22.36) and the corresponding (x) and (y) readings are, of course, multiplied by ten. (Note.—Since the arrangement is quite symmetrical the reverse of the set square can readily be used for the alternative range).

SINH, COSH, SIN AND COS IN CASES WHERE H IS GREATER THAN ABOUT 2.5, AND COSH H AND SINH H ARE THEREFORE BOTH SENSIBLY EQUAL TO $\frac{1}{2}e^{H}$.

In these cases it is possible to modify the arrangement so that (x) and (y) are at right-angles in their proper relationship, and the functions can therefore be given in the form $A/\underline{\theta}$ as well as $(x + jy)$. This is very readily adapted for use with the ordinary calculating board used for conversion between $(x + jy)$ and $A/\underline{\theta}$. The calculating board simply needs the usual (x) and (y) axes and a circular scale of any convenient radius, set off as usual from the positive (x) axis and preferably marked in both degrees and radians. The rotating member is an ordinary straight scale of lengths with a super-imposed scale of H readings set off according to the value of $\frac{1}{2}e^{H}$ (Fig. 4). The arrows indicate the appropriate C reading, the H reading gives (x), (y) and A, and the angle of the scale is θ.

The question of range is again a matter of choice. A range of H from 2.5 to 6.2 is fairly convenient ($\frac{1}{2}e^{H}$ equals 6.09 to 246), and (x) and (y) can be marked off 0 to 2 and 0 to 1.25 respectively in 10 cm. units, and multiplied by 100 when used for this particular purpose.

SECH, COSECH, SEC AND COSEC.

Although there is probably no essential difficulty in designing special constructions for these functions, it is usually desirable to restrict the number of separate items used, and it is suggested that if these

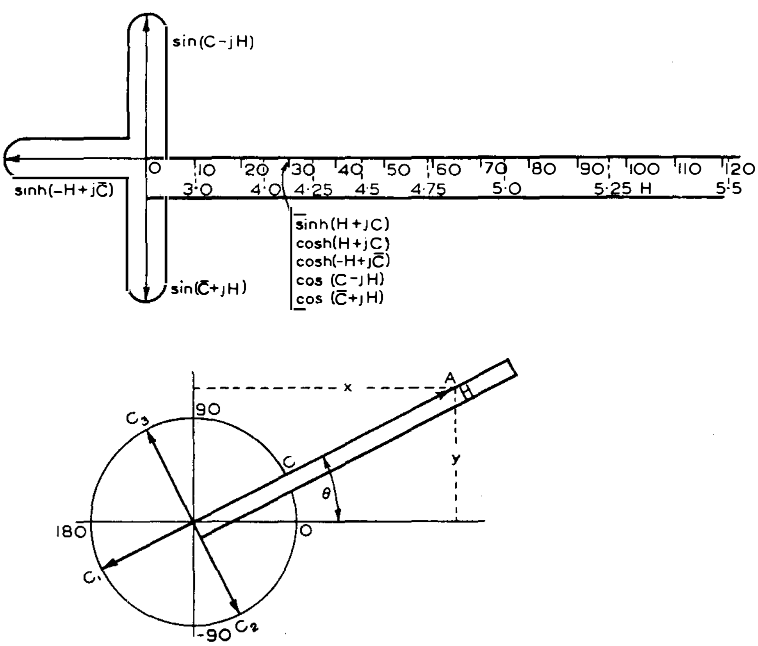


FIG. 4.—MODIFIED ARRANGEMENT FOR USE WHEN H IS GREATER THAN 2.5.

values are required they should be taken as the reciprocals of the cosh, sinh, cos and sin functions. In this connexion a useful addition to the calculating board is a simple graph of the form " $ab = 10$ " from which reciprocals can be written down direct if required. Thus, if the value required is $\frac{1}{x + jy}$ the calculating board gives $A\underline{/\theta}\,(= x + jy)$, but the required value of $\frac{1}{A}\overline{\backslash\theta}$ can be written down from inspection.

Tanh, Coth, Tan and Cot.

These functions are fundamentally more complicated than those previously discussed, consisting as they do of the ratio of two simpler functions. Many constructions are possible, but the following is probably as simple as the nature of the functions allows :—

From a point 0 mark off A and B at unit distances horizontally and set off a line OP of length e^{2H} at an angle 2C to the horizontal axis (Fig. **5**). Draw PA

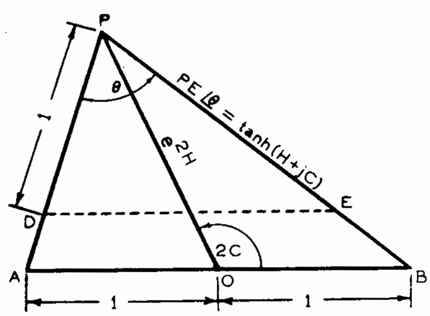


Fig. **5**.—Fundamental Construction for Tanh, Coth, Tan and Cot.

and PB, mark off PD, = 1, along PA and draw horizontally from D, crossing the line PB at E. Then PE, referred to the line PD as regards angle, is tanh (H + jC).

If H is zero e^{2H} is, of course, 1 and the angle DPE is a right angle. If H is negative e^{2H} is less than 1, and the angle DPE is obtuse.

Though the above is the fundamental construction it is thought to be preferable to work always in terms of e^{-2H}, thus making the range from 1 to 0 instead of from 1 to ∞. This is quite practicable, because if the above construction be used for tanh $(-H + jC)$ giving a value

$$\tanh(-H + jC) = PE\,\underline{/\theta} \qquad \text{(Fig. 6).}$$

$$\text{then} \quad \tanh(\ \ H + jC) = PE\,\underline{/180^\circ - \theta}$$

$$\tan(\ C + jH) = PE\,\underline{/\theta - 90^\circ}$$

$$\text{and} \quad \tan(\ C - jH) = PE\,\overline{\backslash\theta - 90^\circ}$$

Also if PF, equals 1, is marked off on PB and a horizontal drawn, cutting PA at G then PG equals $= \frac{1}{PE}$ and therefore

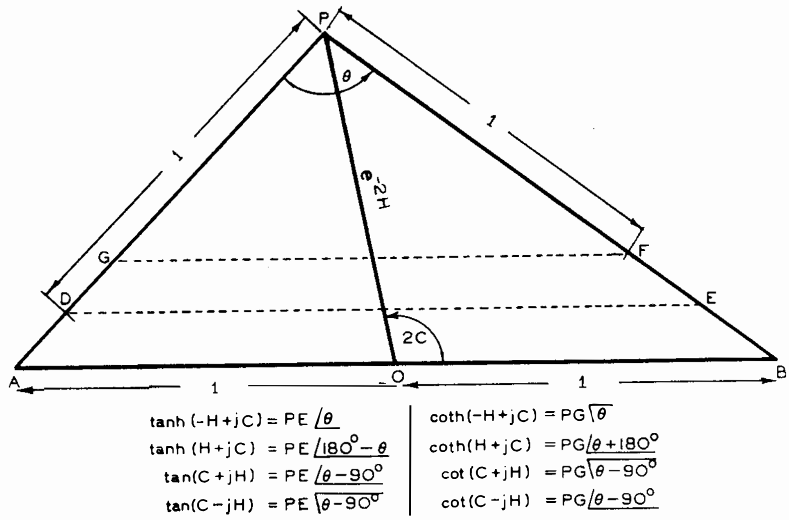


Fig. **6**.—Alternative Construction for Tanh, Coth, Tan and Cot.

$$\coth(-H + jC) = PG\,\overline{\backslash\theta}$$

$$\coth(\ \ H + jC) = PG\,\underline{/\theta + 180^\circ}$$

$$\cot(\ C + jH) = PG\,\overline{\backslash\theta - 90^\circ}$$

$$\cot(\ C - jH) = PG\,\underline{/\theta - 90^\circ}$$

In applying the method in practice to avoid drawing, the essentials are a sheet of graph paper as large as is convenient, marked with a horizontal axis and the points A, O, B, and with a circular scale marked in double radians (in order that a reading C corresponds to a physical angle 2C), plus a revolving scale giving H values set off at distances corresponding to e^{-2H}. These are shown in Fig. **7**.

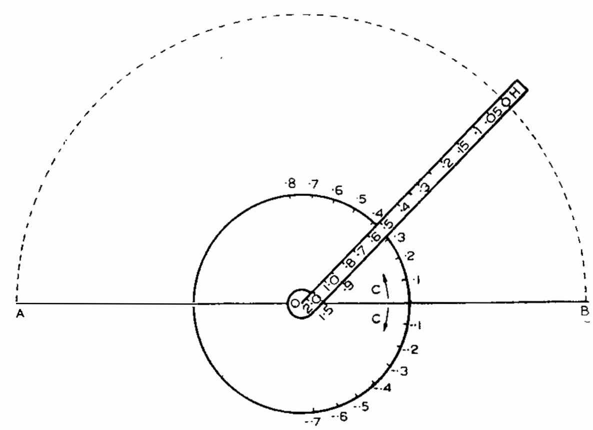


Fig. **7**.—Simple Instrument for measuring Tanh, Coth, Tan and Cot.

The length PE and PG and the angle θ may be measured with simple scales and an ordinary protractor, but it is preferable to use a concentric double protractor and scales of the form shown in Fig. **8**. This form enables all the eight functions to be read direct without having to add to, or subtract from, the measured angle, and the absence of a joint between the two scales enables the centre point

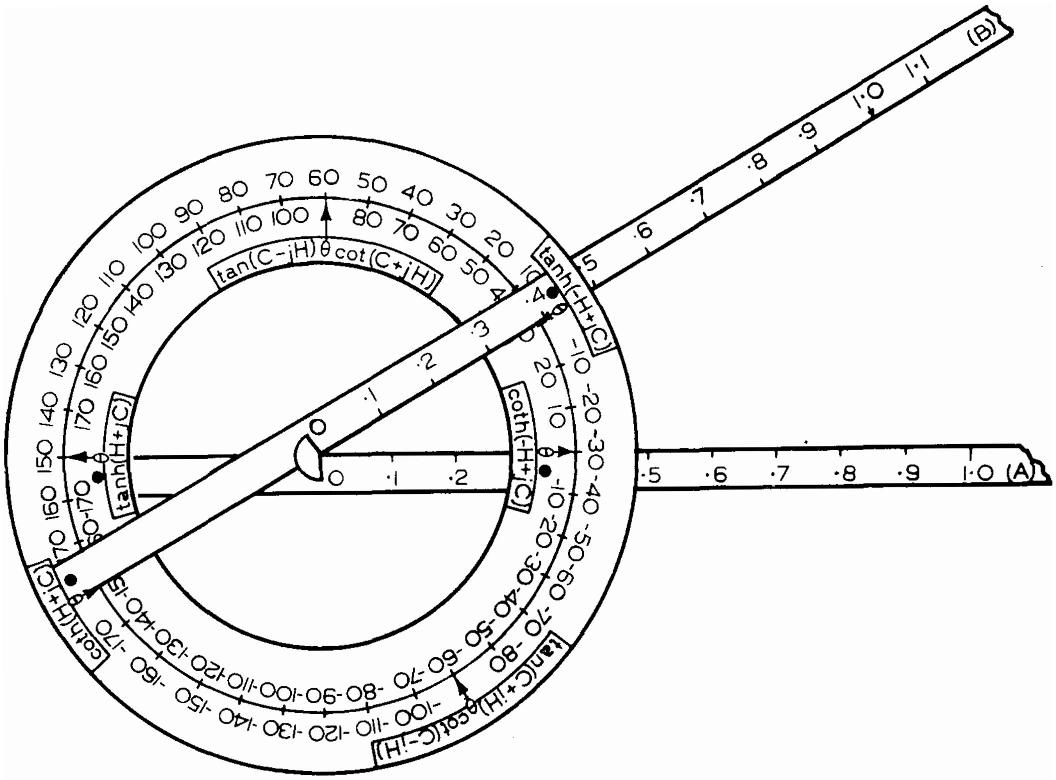


FIG. 8.—INSTRUMENT FOR MEASURING TANH, COTH, TAN COT USING CONCENTRIC DOUBLE PROTRACTOR.

readily to be set to the H value. In using, the centre point is set to the H reading and the A and B scales opened to the points A and B on the graph sheet. Then PE and PG as required are read by projecting horizontally (by eye) from the unit marks on the A and B scales respectively to the opposite scale, and the corresponding angles are read from the protractor.

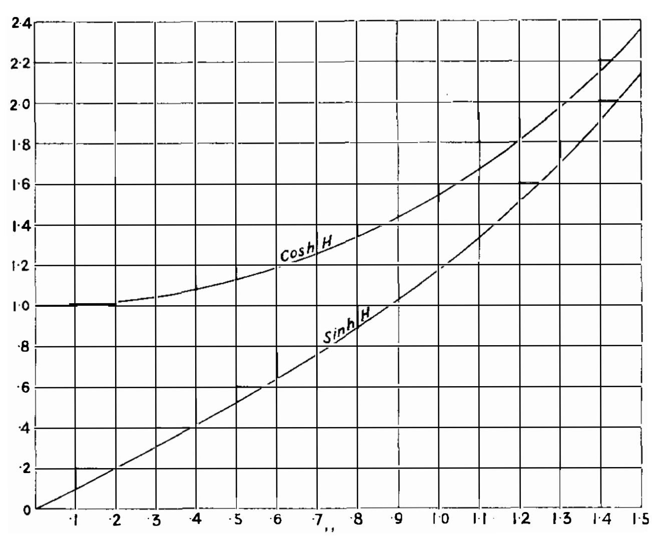
It may be pointed out that the purpose of the A and B scales is simply to provide the ratio, by similar triangles, between PB and PA. That is PB : PA : : PE : 1 : : 1 : PG. The actual value of the scales used is therefore entirely independent of that used for OA, OB and e^{-2H}, and if projection from the unit marks is impracticable, any other convenient mark such as .1 may be used. Furthermore, in some cases it may be difficult to decide on the value of PE or PG owing to the scales being nearly horizontal, but since the ratio is all that is required, once the angle θ has been read, the scales may be opened or closed to any convenient angle, so long as corresponding horizontal points are kept horizontal. For example, if $C = 90°$, $\theta = 180°$, and values on the PE and PG scales cannot be distinguished. Two known corresponding readings, however, are those coinciding with the points A and B, and the protractor is closed up to any convenient angle, with those readings horizontal, to find the correct ratio.

Although e^{-2H} is a rapidly decreasing function, it is, of course, inherent in these particular cases, and in one form or other it cannot be avoided.

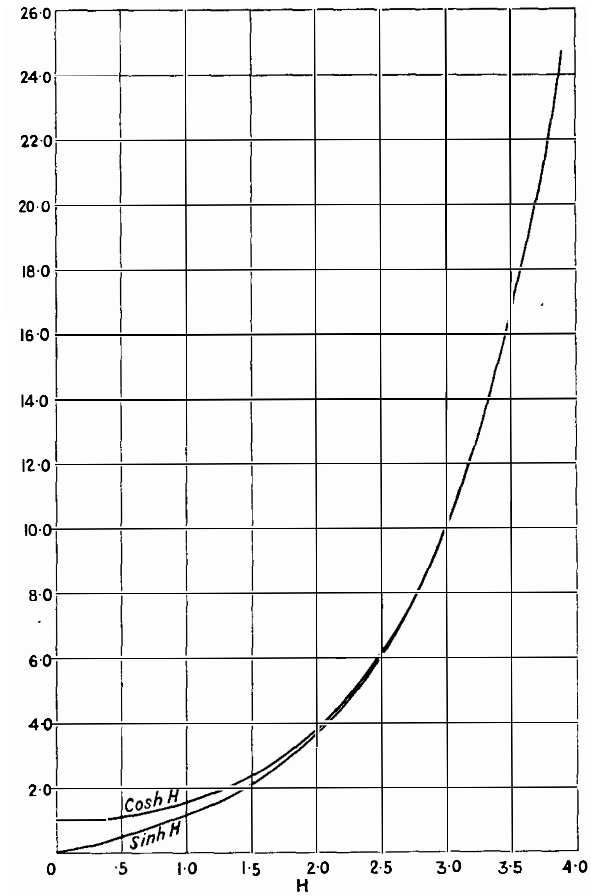
TANH^{-1}, TAN^{-1}, COTH^{-1}, AND COT^{-1}.

For these, the protractor is opened to the given value of θ and, with PE or PG horizontally placed relative to the corresponding unit mark, is moved into such a position on the board that the A and B scales meet the points A and B. Then the H scale is revolved to meet the protractor centre point, and H and C are read direct.

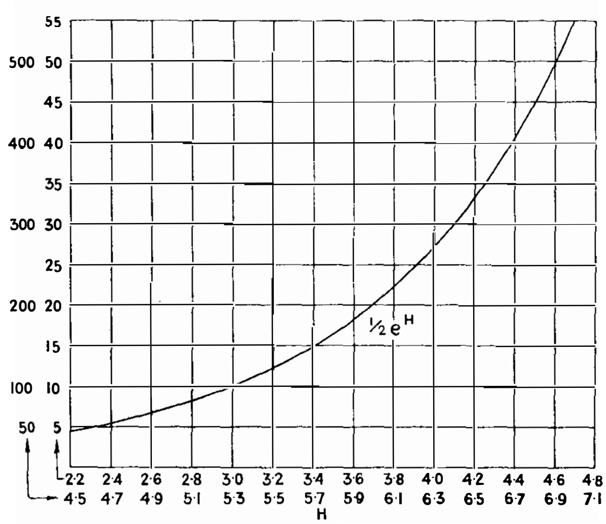
Brief proofs of the constructions involved are appended, together with graphs of the required functions, sinh H, cosh H, $\frac{1}{2}e^{H}$ and e^{-2H}.



GRAPH OF SINH H AND COSH H (H = 0 TO 1.5).



Graph of Sinh H and Cosh H.



Graph of $\frac{1}{2}e^{H}$.

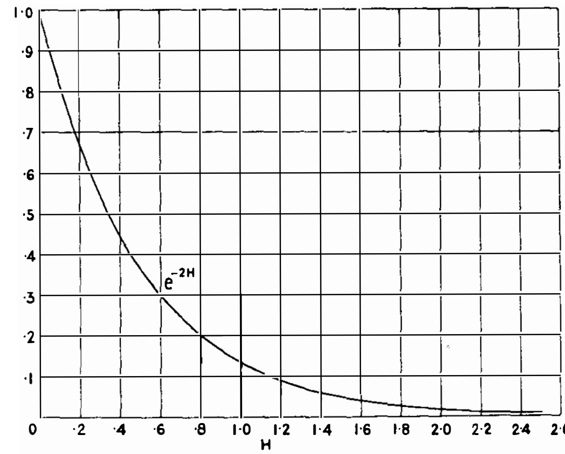
APPENDIX.

Referring to Fig. **3**, $C_1 = C + 90$, and $C_2 = C - 90$.

$\therefore \quad \sin C = -\cos C_1 = \cos C_2$

and $\cos C = \sin C_1 = -\sin C_2$.

If x is projected from the cosh H scale, then



Graph of e^{-2H}.

$$(x + jy) = \cosh H \cos C - j \sinh H \sin C$$
$$= \cos (C + jH)$$
$$= \cosh H \cos (-C) + j \sinh H \sin (-C)$$
$$= \cosh (H + j\bar{C})$$
$$= \cosh (-H) \cos C + j \sinh (-H) \sin C$$
$$= \cosh (-H + jC)$$
$$= \cos (\bar{C} - jH)$$

$$= \cosh H \sin C_1 + j \sinh H \cos C_1$$
$$= \sin (C_1 + jH)$$
$$= \cosh H \sin (-C_2) - j \sinh H \cos (-C_2)$$
$$= \sin (\bar{C}_2 - jH)$$

If x is projected from the sinh scale then

$$(x + jy) = -\sinh H \sin C + j \cosh H \cos C$$
$$= \sinh H \cos C_1 + j \cosh H \sin C_1$$
$$= \sinh (H + jC_1)$$
$$= \sinh (-H) \cos C_2 - j \cosh (-H) \sin C_2$$
$$= \sinh (-H + j\bar{C}_2)$$

Referring to Fig. **4**,

$C_1 = C \pm 180°$, $C_2 = C - 90$, $C_3 = C + 90$.

$\therefore \quad \sin C = -\sin C_1 = \cos C_2 = -\cos C_3$

and $\cos C = -\cos C_1 = -\sin C_2 = \sin C_3$.

$(x + jy) = \frac{e^H}{2} \cos C + j \frac{e^H}{2} \sin C$, which for values of H above 2.5 approximately

$$= \sinh (H + jC)$$
$$= \cosh (H + jC)$$
$$= \cosh (-H + j\bar{C})$$
$$= \cos (C - jH)$$
$$= \frac{e^H}{2} \cos (-C) - j \frac{e^H}{2} \sin (-C)$$
$$= \cos (\bar{C} + jH)$$
$$= -\frac{e^H}{2} \cos C_1 - j \frac{e^H}{2} \sin C_1$$
$$= \sinh (-H + j\bar{C})$$
$$= -\frac{e^H}{2} \sin C_2 + j \frac{e^H}{2} \cos C_2$$
$$= \sin (\bar{C}_2 + jH)$$

$$= \frac{e^{\mathrm{H}}}{2} \sin \mathrm{C}_3 - j \frac{e^{\mathrm{H}}}{2} \cos \mathrm{C}_3$$

$$= \sin (\mathrm{C}_3 - j\mathrm{H})$$

Referring to Fig. **6**,

$$\frac{\mathrm{PE}\,\angle\theta}{1} = \frac{\mathrm{PB}}{\mathrm{PA}} = \left[\frac{e^{-2\mathrm{H}} - 1\,\angle{-2\mathrm{C}}}{e^{-2\mathrm{H}} + 1\,\angle{-2\mathrm{C}}}\right]$$

$$= \left[\frac{e^{-\mathrm{H}}\,\angle\mathrm{C} - e^{\mathrm{H}}\,\angle{-\mathrm{C}}}{e^{-\mathrm{H}}\,\angle\mathrm{C} + e^{\mathrm{H}}\,\angle{-\mathrm{C}}}\right]$$

$$= \frac{e^{(-\mathrm{H}+j\mathrm{C})} - e^{-(-\mathrm{H}+j\mathrm{C})}}{e^{(-\mathrm{H}+j\mathrm{C})} + e^{-(-\mathrm{H}+j\mathrm{C})}}$$

$$= \underline{\tanh(-\mathrm{H} + j\mathrm{C})}$$

$$\mathrm{PE}\,\angle 180 - \theta = -\,\mathrm{PE}\,\angle{-\theta} = -\left[\frac{e^{-2\mathrm{H}} - 1\,\angle 2\mathrm{C}}{e^{-2\mathrm{H}} + 1\,\angle 2\mathrm{C}}\right]$$

$$= -\left[\frac{e^{-\mathrm{H}}\,\angle{-\mathrm{C}} - e^{\mathrm{H}}\,\angle\mathrm{C}}{e^{-\mathrm{H}}\,\angle{-\mathrm{C}} + e^{\mathrm{H}}\,\angle\mathrm{C}}\right]$$

$$= \left[\frac{e^{(\mathrm{H}+j\mathrm{C})} - e^{-(\mathrm{H}+j\mathrm{C})}}{e^{(\mathrm{H}+j\mathrm{C})} + e^{-(\mathrm{H}+j\mathrm{C})}}\right]$$

$$= \underline{\tanh(\mathrm{H} + j\mathrm{C})}$$

$$\mathrm{PE}\,\angle\theta - 90 = -j(\mathrm{PE}\,\angle\theta) = -j \tanh(-\mathrm{H} + j\mathrm{C})$$

$$= -\tan(-\mathrm{C} - j\mathrm{H}) = \underline{\tan(\mathrm{C} + j\mathrm{H})}$$

$$\mathrm{PE}\,\angle 90 - \theta = -j(\mathrm{PE}\,\angle 180 - \theta)$$

$$= -j \tanh(\mathrm{H} + j\mathrm{C})$$

$$= -\tan(-\mathrm{C} + j\mathrm{H}) = \underline{\tan(\mathrm{C} - j\mathrm{H})}$$

Telegraph and Telephone Plant in the United Kingdom

TELEPHONES AND WIRE MILEAGES. THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 31st DEC., 1935.

Number of Telephones owned and maintained by the Post Office.	Overhead Wire Mileages.				Engineering District.	Underground Wire Mileages.			
	Telegraph.	Trunk.	Exchange*	Spare.		Telegraph.	Trunk.	Exchange.†	Spare.
933,883	428	5,134	50,744	6,949	London	37,948	240,914	3,937,942	95,001
116,832	2,066	16,083	50,718	8,087	S. Eastern	5,778	100,651	391,204	51,977
134,668	4,449	36,613	86,686	6.324	S. Western	24,970	73,204	309,391	80,713
93,569	4,068	37,723	78,729	13,421	Eastern	15,958	97,910	189,486	34,317
144,390	4,607	35,343	65,138	24,162	N. Midland	6,148	213,140	353,979	104,216
117,259	3,240	21,708	71,312	14,881	S. Midland	9,362	90,847	352,529	60,534
78,450	2.936	25,721	64,348	9,539	S. Wales	6,361	66,178	171,369	33,548
156,865	4,412	20,374	65,380	17,165	N. Wales	8,796	114,215	486,208	132,775
200,099	1,194	4,090	29,592	10,198	S. Lancs.	7,598	131,838	710,853	73,261
131,624	5,082	22,660	44,628	7,814	N. Eastern	11,942	108,718	368,726	37,561
85,484	1,141	12,086	31,044	16,601	N. Western	5,957	84,284	267,185	83,572
66,449	1,232	12,996	24,237	7,328	Northern	4,462	59,130	204,979	24,595
32,950	3,154	11,234	14,002	1,450	N. Ireland	435	7,863	83,177	21,383
96,498	4,520	27,166	46,146	9,230	Scotland E.	2,019	69,267	187,442	55,470
119,968	3.963	19.512	38,200	9,141	Scotland W.	10,651	90,028	291,967	101,964
2,508,988	46,492	308,443	760,904	162,290	Totals.	158,385	1,548,187	8,306,437	990,887
2,451,781	47,398	313,921	741,739	157,434	Totals as at 30th Sept., 1935.	157,938	1.468,184	8,252,112	961,852

* Includes low gauge spare wires (*i.e.*, 40 lb. bronze in open routes and 20 lb. or less in aerial cables).
† Includes all spare wires in local underground cables.

Modern Cable Layout in Manholes and Cable Chambers

L. MEEK

In this article the author shows how recent new designs for manholes have enabled improved accommodation to be provided therein for cables. Easy access to all joints is afforded and the result is neat and efficient. He suggests that similar methods might, with advantage, be applied to cable chambers.

Introduction.

UNTIL comparatively recently, the general practice in this country was to construct manholes which, in plan, were either square or only a little greater in length than in width. In most cases cables were placed centrally across such manholes, support being afforded to the joints either by long wall brackets or by structures built upon the floor. The entrance was usually placed at one corner of the manhole and access gained by steps fixed to the wall.

This design, which is illustrated in Fig. 1,

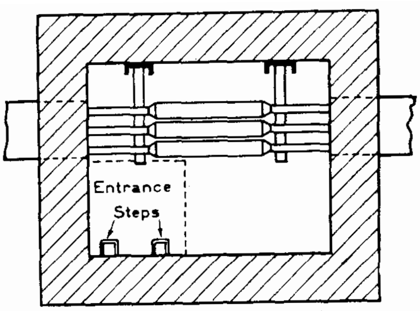


FIG. 1.—PLAN OF OLD TYPE OF MANHOLE.

possessed serious disadvantages, especially at junctions and where a large number of cables had to be accommodated. Considerable congestion occurred; inadequate space was available for jointing operations; the lower joints eventually became inaccessible —or almost so; cables were liable to damage through being stepped on; the provision of adequate support was sometimes impracticable, and often the general arrangement was very untidy and inefficient.

About seven years ago a modified type of manhole, in which all the cables are supported upon the side walls, following the lines of American practice, was designed and constructed in connexion with the Newcastle Auto-Conversion scheme. The features of this manhole were described in an article by Mr. F. G. C. Baldwin, entitled " Accommodation for Cables in Manholes and Subways," which was printed in *The Post Office Electrical Engineers' Journal* for October, 1932. Two years ago this method was standardized and introduced generally throughout the country.

The present article deals with certain important considerations which have arisen in the London Engineering District as a result of the experience with the new manholes and the placing of cables therein. Reference is also made to the subject of cable chambers.

The New Standard Manhole.

The various sizes of the new type of manhole and their uses are shown in Table I.

With the exception of design No. 11, which has not been altered appreciably, the new types are longer and narrower than those which they supersede. Experience may show that the width of design Nos. 1 and 2 can be further reduced to 3 ft. 6 ins. and still leave ample space for jointing operations.

Design Nos. 0, 1 and 11 provide for the entrance above the centre of one of the side walls. Access is afforded by steps fixed to the wall, all cables being supported on the opposite wall.

A central entrance is provided in the No. 2 design and an iron ladder gives access to the manhole, both walls being used to support the cables.

The ladder in the larger manhole represents a distinct advantage over the steps previously used,

TABLE I.

Number of Conduits.	Type of Manhole to be used. Footway.	Carriageway.	Internal Dimensions. Length.	Width.	Height.
3	RF.0	RC.0	6 ft. 6 ft.	3 ft. 6 ins. 3 ft. 6 ins.	4 ft. 5 ft.
4 to 9	RF.1 or BWF.1	RC.1 or BWC.1	6 ft.	4 ft.	5 ft. 6 ins.
10 or more	RF.2 or BWF.2	RC.2 or BWC.2	10 ft.	4 ft.	6 ft., minimum
For Loading Pots ...	RF.11	RC.11	13 ft. 6 ins.	5 ft. 6 ins.	7 ft.

NOTE:—F = Footway. C = Carriageway. R = Reinforced Concrete. BW = Brickwork.

but a lighter type of iron-work would probably serve the purpose equally well.

The present type of cable bearer, consisting of vertical steel channel and horizontal wrought iron brackets, is also, perhaps, somewhat heavier than is necessary, as the maximum weight of a full-size cable to be supported does not exceed 11 lbs. per foot. Moreover, when it is desired to remove a bracket, there is the inconvenience of having to lift the cable about three inches or take out the bolt carrying the bracket. The new type of pressed steel bearer in experimental use is lighter, but the brackets cannot be removed without taking out the bolt holding them, which is difficult when the cables are in position. Apart from these details the new type of manhole has been found to possess many advantages, as the longer wall ensures adequate accommodation for cables and their joints, easy access to the joints, and a very neat appearance.

The standardization of the new design of manhole has, moreover, reduced the number of types from 8 to 3 in each of the four categories (*i.e.*, brick, concrete, footway and carriageway).

Special Manholes.

The standard drawings so far provide for manholes on through routes only, but by suitable modification excellent provision can be made for right angle turns and junctions of three or four routes of conduits. Various conditions commonly met with are shown in Fig. **2**. Type A is the standard No. 2 manhole,

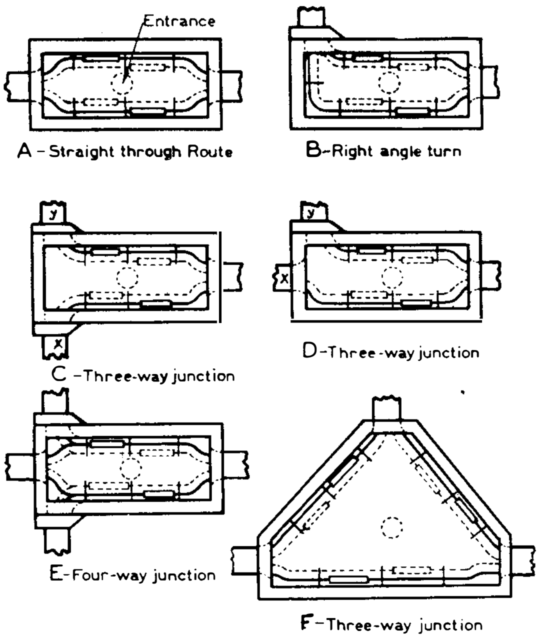


Fig. **2**.—Plans of new type of Manholes, with Adaptations.

and types B, C, D and E show adaptations which provide for the different requirements indicated. Type F is an alternative to C or D where the number of cables required between ducts x and y is in excess of two. In types C or D such cables need to be taken round the manhole. Other designs of standard manholes can be similarly adapted. Conduits should be laid in vertical tiers of not more than four abreast and they should be recessed into the walls of the manholes to facilitate the bending of cables into position.

Cable bearers must be fixed before cabling operations begin to ensure that cables and joints are correctly placed. The channels should be long enough to carry the ultimate requirements, but the brackets need be supplied only as required.

Placing Cables in Manholes.

Careful planning is necessary to secure a proper arrangement of cables on the walls of manholes, particularly at junction points where the number of cables is large. Consideration should not be limited to cables to be provided initially, but should include ultimate requirements. Except in simple cases a drawing of each manhole should be prepared on tracing linen and the positions of cables and joints clearly indicated. Prints should be supplied to the Inspector and workmen concerned. The linen tracing should be filed as a record and the positions of additional cables and joints marked as required, prints being issued to the officers carrying out the work. A typical drawing will be seen in Fig. **3**.

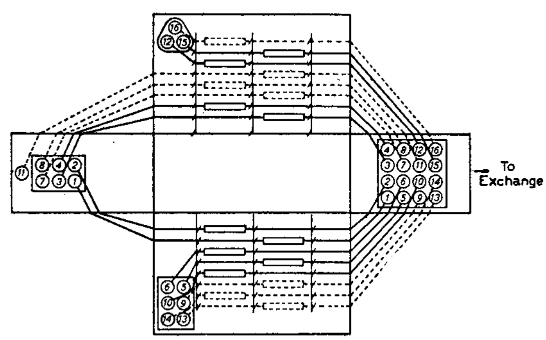


Fig. **3**.—Cable Lay-out in Junction Manhole.

An important departure from previous practice will be observed in the method of allocating conduits. Instead of filling the conduits systematically from the bottom upwards, it is necessary on the exchange side of a junction manhole to allocate the conduits in such a manner that cable crosses are avoided in the manhole. The setting of the cables round the walls prevents any of the conduits from being blocked by this procedure. It is desirable to number the conduits on the records, as shown in Fig. **3**, from the exchange to a suitable point on each main route.

Three principles should be carefully observed when planning cable lay-outs in manholes :—

(1) Cable bearers between which joints will be made should be placed three feet apart.

(2) No more than two cables should be accommodated on one bracket.

(3) Seamed joints should be avoided.

The three feet spacing of cable bearers referred to in (1) is necessary to accommodate joints on full sized cables, using a 30 inch sleeve in accordance with standard practice. The introduction of "balloon" joints, with three banks of sleeves in the centre, may lead eventually to the use of shorter

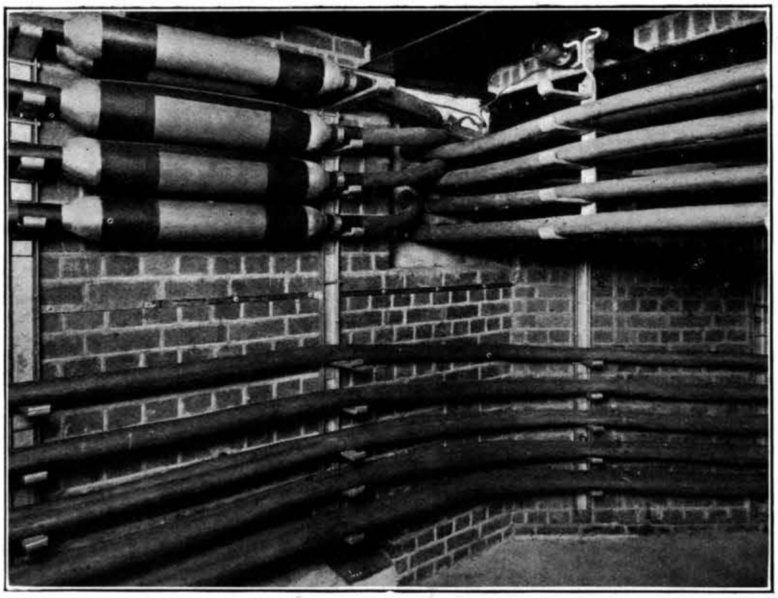
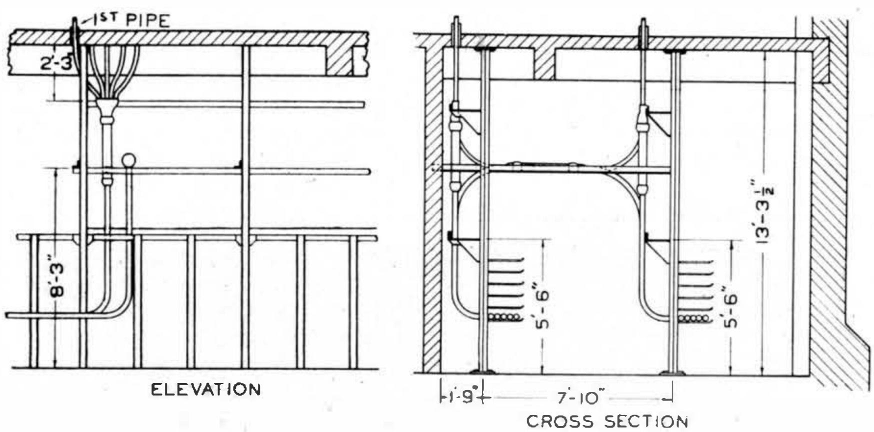


Fig. 6.—East and South Walls, London Wall Manhole.

between the cable chamber and the floor upon which the main distribution frame is situated. In this case the terminating joints are made in a trench provided along the length of the frame and joints in the cable chamber are usually avoided.

Drawings of the racking recently provided at the new Royal automatic exchange, London, are shown in Fig. 7, and they indicate the present practice in the London Engineering District. Two main distribution frames are installed in this instance and two lines of racking are provided. The cables are carried on horizontal cantilevers from the conduits and normally they rise at the appropriate positions to vertical terminating joints, from which smaller units



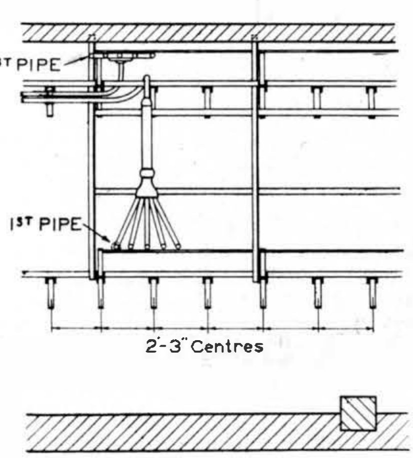


Fig. 7.—Cable Chamber, Royal Exchange, London.

of E.S. and W. cables connect with the points of termination on the main distribution frame. Horizontal members are provided on the racking for cables to cross over from one side to the other where necessary, and in these cases a horizontal terminating joint is made.

A view is given in Fig. **8** of similar racking and cables installed in the cable chamber at the City and Central automatic exchanges in London in 1935. Instead of horizontal cantilevers, iron shelving was used to give additional strength.

In many cases cable chambers may be regarded as large elongated manholes and it is considered that methods somewhat similar to those adopted for supporting cables in manholes may be applied with advantage to cable chambers. Economies in the cost of cable chambers and racking may thus be secured, together with improved accommodation for, and accessibility to, cables and joints.

Fig. **9** shows how the improved methods could be applied in the case of the Royal automatic exchange, and comparison with Fig. **7** will indicate the saving in accommodation and racking. With only two cables per bracket, lighter steel sections can be used. All joints are horizontal, which is an advantage, as they are easier to make and plumb. An experiment along these lines would indicate whether it would be advisable to adopt this method as standard practice.

The developments described in this article undoubtedly represent a notable advance in external plant practice which will have a beneficial effect upon the general efficiency and reliability of the plant.

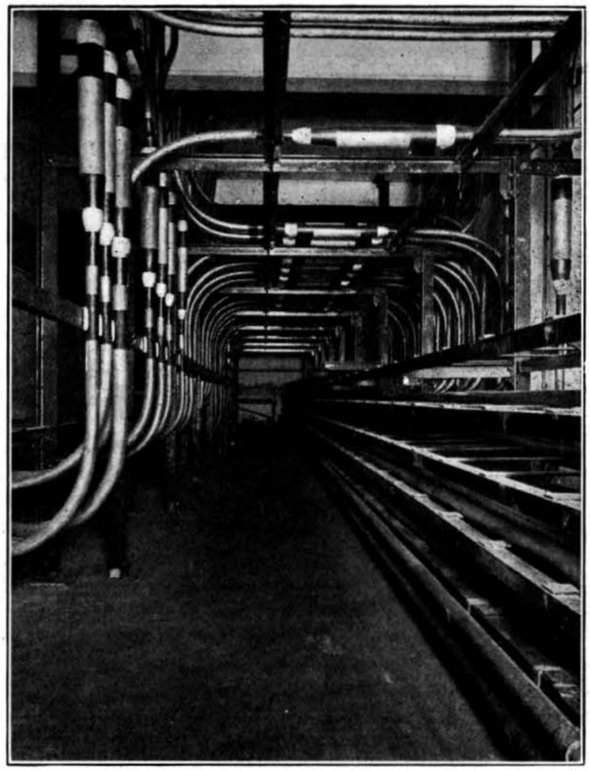


Fig. 8.—Cable Chamber, City and Central Exchanges, London.

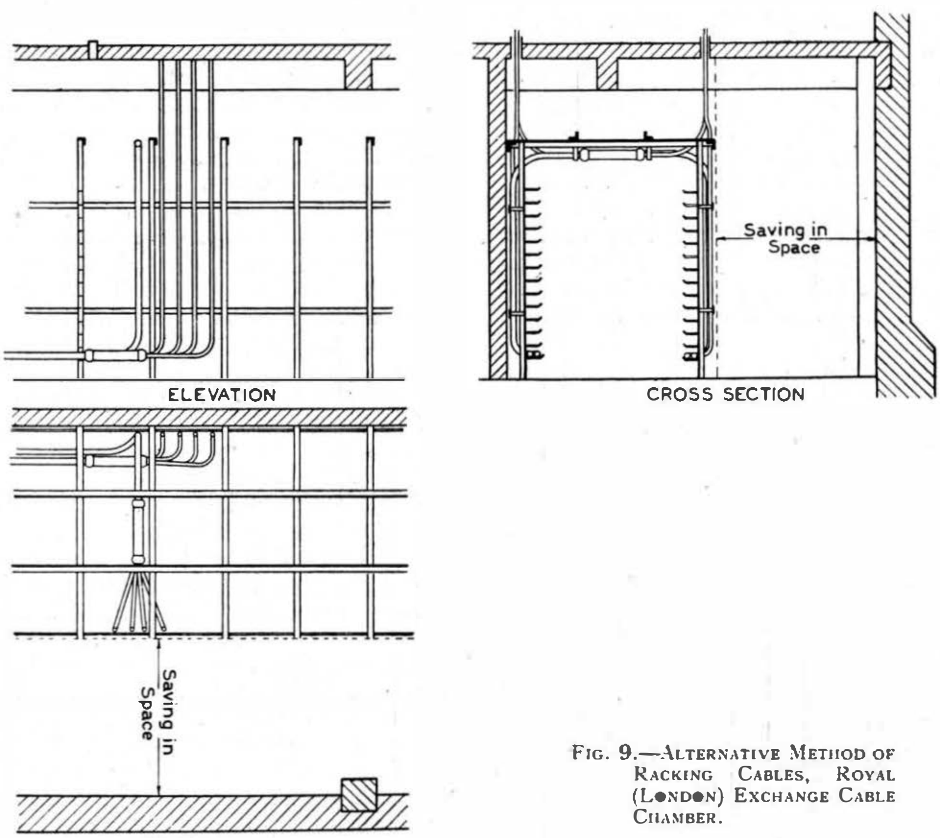


Fig. 9.—Alternative Method of Racking Cables, Royal (London) Exchange Cable Chamber.

Carrier Telephony I

G. J. S. LITTLE, B.Sc., A.M.I.E.E.

In this first article of a series dealing with Carrier Telephony, the author explains in a simple manner the principle of the modulation of a carrier wave by speech waves, resulting in the production of frequency side-bands. The suppression of the carrier and one side-band is also described.

Introduction.

DEVELOPMENTS in the design of equipment for providing carrier telephone circuits in the underground cable network have been proceeding at a rapid pace during the last year or two, and the provision of a special cable between London and Birmingham for the transmission of television programmes and a large number of carrier speech channels over four co-axial or concentric pairs might perhaps justify the thought that we are at the beginning of a new era in the science and practice of this branch of telephony. It is true that carrier telephony has been advancing steadily during the last twenty years, but now we may be reaching the point when it will be the exception for new circuits for distances of over, say, 50 miles, to be provided by any other means. These new developments are arousing much interest and it is thought that the present is an opportune time for a series of articles on this subject.

Principle of Carrier Working.

When a conversation takes place over an ordinary telephone connexion, the alternating electric currents which are transmitted over the circuit have the same frequencies as the corresponding sounds in the speaker's voice. An open wire line is capable of transmitting frequencies higher than the highest audible frequencies, but, however wide this range of frequencies which can be transmitted without undue attenuation may be, only the range of normal speech frequencies can be used for speech purposes so long as the ordinary system of transmission is used. The fundamental idea of carrier telephony is to transmit speech by means of currents in a range of frequencies different from that of the speaker's voice and so obtain more than one speech channel from each physical circuit.

The idea of transmitting speech by means of a high frequency current, the strength of which is varied in sympathy with the intensity of the current from a telephone transmitter, and its re-conversion to audio frequencies at the receiving end, had been evolved by experimenters in the field of wire telephony in the decade before 1900. The advent of wireless telegraphy diverted attention from this work, but later, wireless telephony, using these principles, provided equipment which was adapted for high frequency transmission of speech over wires. Dr. Ruhmer (Belgium) and Major Squier (U.S.A.) made experiments on these lines about 1910 and in the following years.

A purely diagrammatic representation of the method used by the early experimenters is given in Fig. 1. The carrier current, having a frequency usually chosen from within the range 20,000 to 100,000 cycles per second, was generated by a high frequency alternator or oscillating arc. When the microphone transmitter was spoken into, its varying resistance caused variations in the strength of the high frequency alternating current in the same way that the direct current is varied in the ordinary subscriber's circuit and the high frequency current was passed to line through the transformer.

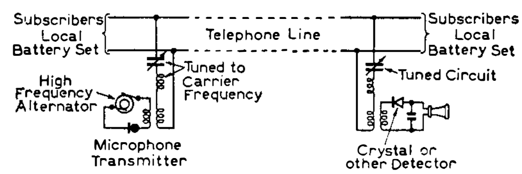


FIG. 1.—PRINCIPLE OF EARLY CARRIER CIRCUITS.

The effect of this varying of the high frequency current by the transmitter is illustrated in Fig. 2. Fig. 2(*a*) represents the varying current in the transmitter circuit of a local battery instrument when speech is being transmitted and Fig. 2(*b*) shows the corresponding alternating current transmitted over the line. The transmitter in the high frequency circuit acted upon by the same sound waves, would vary the amplitude of the high frequency current as indicated in Fig. 2(*c*) The "envelope" of the high frequency wave, which has been sketched in as a broken line, corresponds to the speech current curves of Figs. 2(*a*) and 2(*b*).

In the diagram, the carrier frequency represented (8000 c.p.s.) happens to be within the audible range, but if the current received at the end of the line were passed through a telephone receiver the original speech would not be heard—only scratchy high notes, such as may sometimes be heard on wireless reception due to interference between wireless broadcast programmes. The principles of carrier working are, of course, similar to those of wireless broadcasting and some will remember the early name "wired wireless" for carrier telephony. As in wireless, detection or rectification is necessary for the received signals to be converted back into the original speech. If the rectifier shown in the receiving circuit in Fig. 1 were a perfect rectifier the positive half waves (say) would be passed freely whereas the negative half waves would be unable to pass. Thus instead of an alternating current a direct current of fluctuating value would pass through the rectifier, and the comparatively slowly varying average value of this current would correspond to the original speech wave. The high frequency components have a low impedance path through the condenser and the current through the receiver corresponding to the original speech is indicated by the broken line of joints. If the bearer spacing could be reduced to, say, 2 feet 6 inches, there would be a saving of one foot on the length of the No. 2 type of manholes.

With regard to (3) a concrete extension, into which the sleeve may be slipped while jointing is in progress, may be provided in the smaller manholes. In the No. 2 type of manhole three bearers are provided and the joints should occur on alternate sides of the central bearer. In Fig. 2 the positions of the cables and joints in the manholes concerned are indicated.

Modification of Existing Plant.

In connexion with exchange transfers and provision for future development, the enlargement or reconstruction of existing manholes is frequently necessary and presents an excellent opportunity for modernizing the manholes and cable lay-out therein. Existing cables may be lengthened by insertion where necessary. Such cases require most careful consideration and in cities, where large conduit routes are involved and congestion exists owing to other undertakers' plant, special designs of manholes are usually required.

An interesting case which occurred in connexion with the London Wall automatic exchange transfer is shown in Fig. 4. This manhole was inserted on two conduit routes, 20-way and 9-way, to enable existing cables to be diverted to the new main distribution frame. The manhole was built in proximity to numerous obstructions and concrete piers were provided to keep the weight off the main sewer which was immediately below. A portion of the old Roman wall was disclosed during excavation and had to be broken down to make room for the manhole. Views taken inside the manhole are shown in Figs. 5 and 6. The results are considered pleasing, and access to both cables and joints is facilitated.

Cable Chambers.

The purpose of a cable chamber is to accommodate the external cables between the street conduits and the main distribution frame. Where possible, the frame is situated on the ground floor, immediately above the cable chamber, and the joints between the paper core and enamel, silk and wool terminating cables are made in the cable chamber. If the main distribution frame is accommodated on an upper floor, the cables are usually drawn into steel pipes fixed to, or enclosed within, the walls of the building

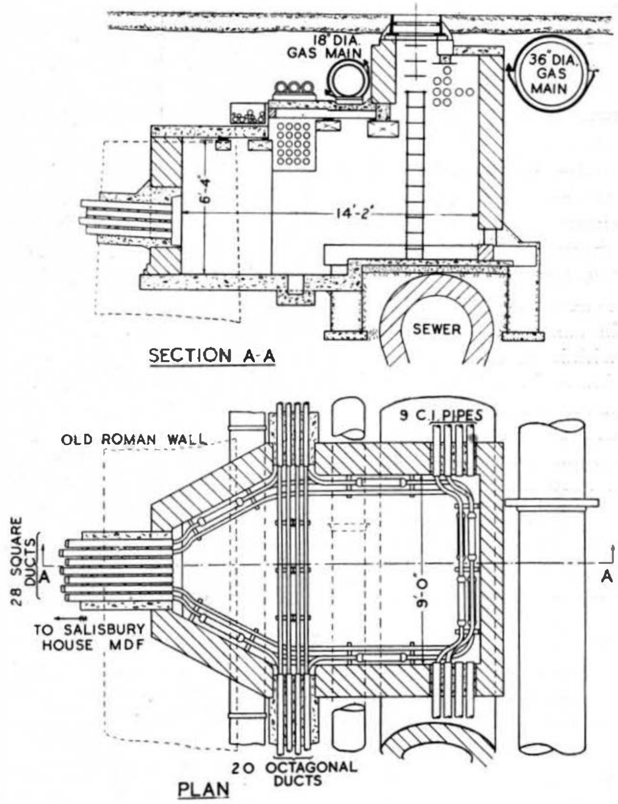


Fig. 4.—Manhole for London Wall Auto. Transfer.

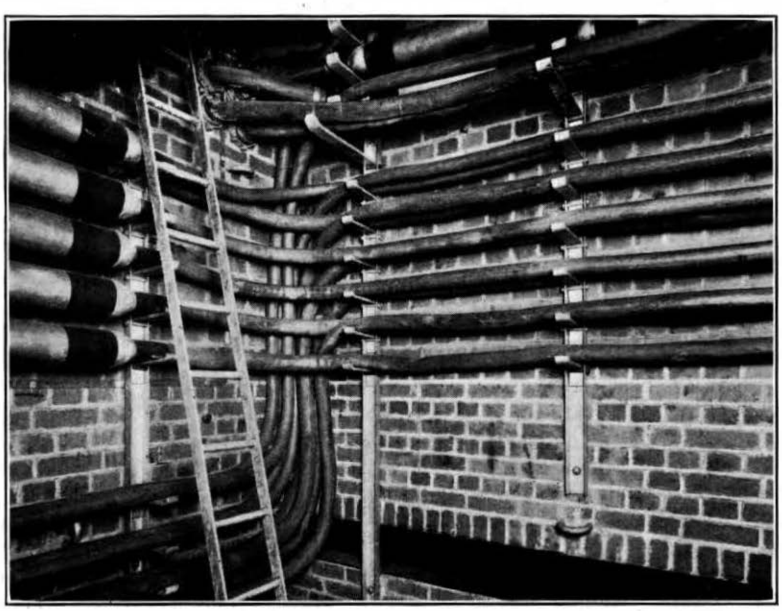


Fig. 5.—West Wall, London Wall Manhole.

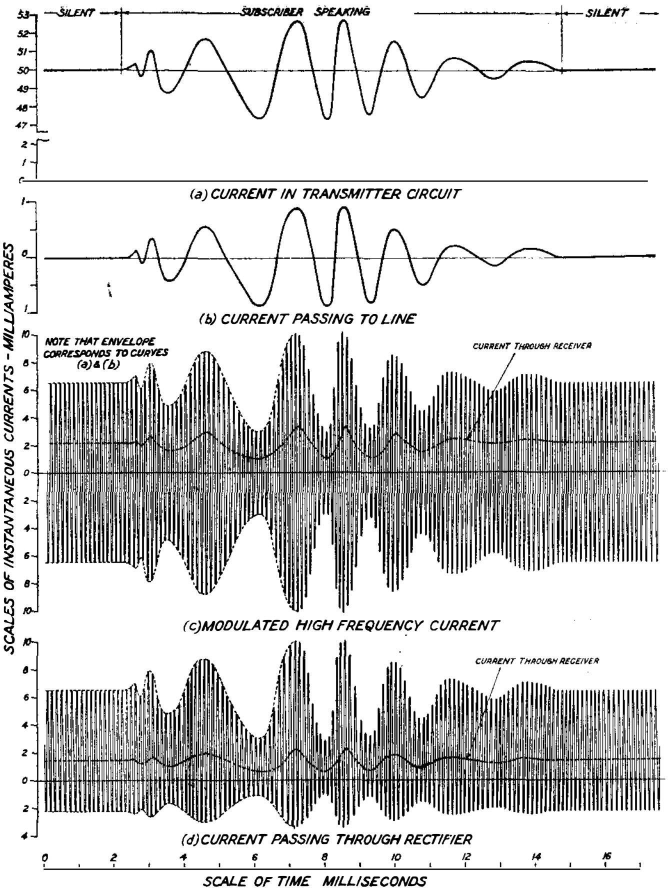


FIG. 2.—SPEECH AND CORRESPONDING CARRIER CURRENTS.

Fig. 2(*c*). The practical case in which the rectifier does not discriminate so completely against currents of one polarity is represented in Fig. 2(*d*). The current passing through the receiver is again shown by the broken line. Although no special significance is to be attached to the actual values of the currents in Fig. 2, an attempt has been made to indicate reasonable values.

The process of varying the amplitude of a high frequency wave in accordance with a speech current is usually spoken of as " modulation " and for the corresponding process of restoring the original speech at the receiving end of the circuit, the term " demodulation " is often used. It is interesting to note that the action of a telephone transmitter can be regarded as " modulation " of a direct current.

Fig. 1 shows a circuit which can transmit speech in the direction A to B and transmission in the opposite direction could be effected in a similar way provided currents of different frequency were used for the two directions. The resonant circuits tuned to the carrier frequencies prevent the generating circuit from shunting the receiving circuit and *vice versa*. The presence of small condensers in the tuning circuits prevent interference between the high frequency circuits and the ordinary telephone circuit on which it is superposed.

The possibility of transmitting more than one additional conversation in this way was early appreciated, but it was not until about 1918 that carrier systems were working on a commercial basis.

The high frequency current sent to line was conceived as carrying the low frequency voice current and the aptness of the term *carrier telephony* will be realized. This term is still universally used in technical literature written in English for systems of high frequency wire telephony although present day systems employ a modification of the principles described to which the term is not so clearly applicable.

Side-Bands.

Major Squier in one of his early experiments used carrier frequencies of 100,000 and 70,000 c.p.s. for the two directions of transmission, and, as only a short length of line was used, the high attenuation of ordinary circuits at such frequencies was no great disadvantage. The wide difference between the carrier frequencies enabled satisfactory discrimination to be attained with tuned circuits as used in wireless at that time. When, however, carrier systems were developed for commercial use the necessity of using frequencies closer to the normal telephonic frequencies, to reduce attenuation, was apparent. In the first commercially operated carrier systems, installed by the Bell System in U.S.A. for operation on open wire lines, the highest frequency used was 30,000 c.p.s.

For a proper understanding of these systems it is necessary to give some account of the " side-band frequencies " which are produced when a carrier current is modulated. This is a matter which cannot be explained satisfactorily in an entirely simple manner, but the importance of an understanding of this part of the subject is too great to permit of its being evaded.

The diagrams in Fig. 2 are intended to represent transmission of the complicated waves which occur in speech, but any such wave can be considered as the sum of a number of simple waves. Thus in Fig. 3 the peaky 500 c.p.s. wave, which is shown at (*d*),

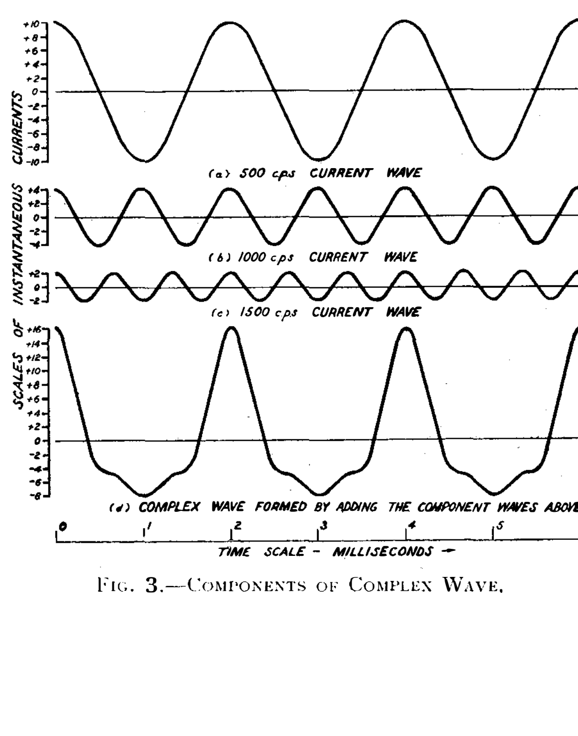


FIG. 3.—COMPONENTS OF COMPLEX WAVE.

can be formed by adding together the instantaneous values of current represented by the simple 500, 1000 and 1500 c.p.s. waves shown above it in the figure. In a similar way the complex wave, which is obtained when a carrier wave is modulated by a speech wave, can be resolved into a number of simple waves. The mathematical analysis of a modulated wave, demonstrating the presence of side-band frequencies is readily accessible,[1] but the following graphical explanation is perhaps less abstract.

Fig. **4**(*a*) illustrates how the curve representing the variation in intensity of a pure alternating current

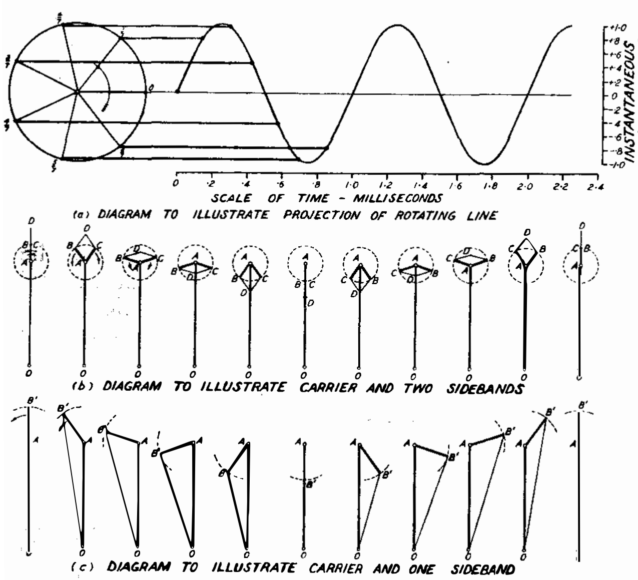


Fig. **4**.—Graphical Constructions.

of 1000 c.p.s. can be derived from the projection of a line rotating at 1000 revolutions per second. An extension of this conception is involved in this explanation.

If a 10,000 c.p.s. carrier current is modulated by a 1000 c.p.s. speech current the resulting modulated current wave in the ideal case, will be as in Fig. **5**(*b*). The 1000 c.p.s. audio wave and the unmodulated 10,000 c.p.s. carrier wave are shown at (*a*) and (*d*). To generate the modulated wave in a manner similar to that indicated in the case of the steady 1000 c.p.s. wave of Fig. **4**(*a*) it is necessary to imagine the rotating line revolving at the constant speed of 10,000 revolutions per second, but at the same time the length of the line must change in accordance with the amplitude of the audio wave.

Fig. **4**(*b*) shows a construction, repeated at intervals of 1/10,000 sec., which makes use of revolving lines of constant length. The line OD represents the amplitude of the carrier. The line OA is fixed and the lines AB and AC, of equal length, are pivoted at A and rotate in opposite directions each at a speed of 1000 revolutions per second, AB and AC always making equal angles with OA. The point D is obtained by completing the parallelogram so that AD is the vector sum of AB and AC. It can be verified that this construction gives the correct variation in amplitude of the modulated wave.

To generate the modulated wave of Fig. **5**(*b*), we must make the line OA of Fig. **4**(*b*) rotate with a speed of 10,000 revolutions per second while the arms AB and AC continue to rotate at 1000 revolutions per second relative to the line OA. The complete modulated wave of Fig. **5**(*b*) will result if the point D is projected across as in Fig. **4**(*a*).

The arm AB which rotates in the same direction as OA is actually rotating 1000 revolutions per second faster than OA, *i.e.*, at 11,000 revolutions per second. Similarly the arm AC rotates an equal amount slower than OA, *i.e.*, at 9000 revolutions per second.

A simpler construction than that of Fig. **4**(*b*) is shown in Fig. **4**(*c*) in which a single arm AB′ rotates relative to OA. The length of the line OB′ varies very nearly in the same manner as the length of OD in Fig. **4**(*b*), but OB′ does not remain in line with OA. This means that when the arm OA is made to rotate at 10,000 r.p.s. the line OB′ will be alternately

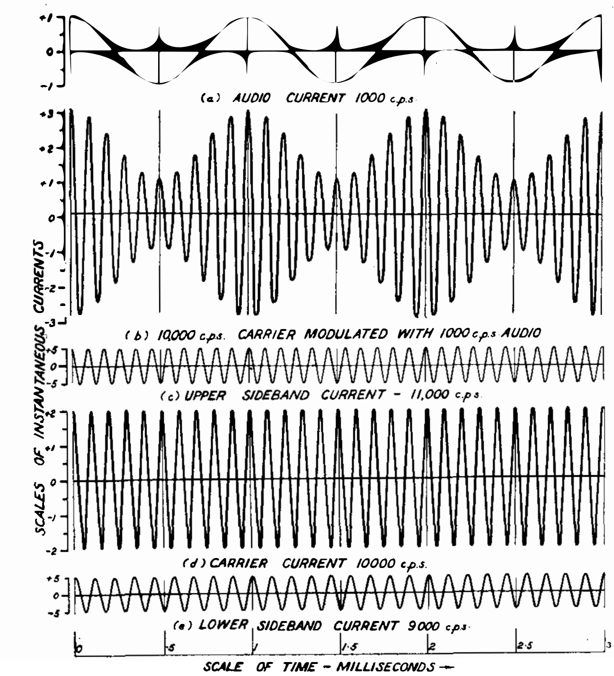


Fig. **5**.—Production of Side Bands.

in front of and behind it. The wave resulting from the horizontal projection from B′ would vary in amplitude in the way required and have the correct average frequency, but, owing to the displacement of OB′ from the line of OA, the moments when the instantaneous current passes through zero would not be the same in the modulated wave as in the unmodulated carrier wave. It will be clear that the modulation of a carrier current by a telephone transmitter as has been described cannot alter the moments when the current passes through zero. This is, in a general way, true of all ordinary methods of modulation and these all produce frequencies above and below the carrier frequency.

[1] Engineering Instruction, Transmission, Carrier, A 1003.

The significance of this is that the 10,000 c.p.s. wave, when it has been modulated, is no longer a pure 10,000 c.p.s. wave, but contains components which have frequencies of 11,000 c.p.s. and 9000 c.p.s. At (*c*) (*d*) and (*e*) in Fig. **5** are shown the components of unvarying amplitude which, when added, give the modulated wave at (*b*).

To sum up, when a carrier current of frequency f_0 c.p.s. is modulated by a lower frequency f c.p.s., the resulting current contains, in addition to current of the original carrier frequency, currents having frequencies $f_0 + f$ and $f_0 - f$. These are referred to as the upper and lower side-band frequencies respectively. The transmission of side-band frequencies is essential to the satisfactory reproduction of the original signal although, as will be seen later, it is not essential that all the components of the modulated wave should be transmitted.

Good quality commercial telephone speech requires the transmission of frequencies from 300 c.p.s. up to about 2400 c.p.s. Thus it will be seen that, in the case of a 10,000 c.p.s. carrier frequency, modulation by telephone speech involves the presence of a lower side-band extending from 7600 c.p.s. to 9700 c.p.s. (*i.e.*, 10,000-2400 to 10,000-300) and an upper side-band extending from 10,300 c.p.s. to 12,400 c.p.s. The frequencies concerned cover a band of 4800 c.p.s., which is twice the highest frequency to be transmitted. The transmission of high quality speech and music (say extending up to 7000 c.p.s.) requires a much wider band, though with broadcast carrier frequencies spaced 9000 c.p.s. (9 kilocycles) apart the side-bands of adjacent stations overlap at a point corresponding to frequencies of 4500 in speech or music.

Single Side-band Transmission.

The band of frequences required for the transmission of speech by carrier telephony can be reduced by using electrical filters to remove either the lower or the upper side-band frequencies. The transmission of carrier and one side-band corresponds to the construction shown in Fig. **4**(*c*) except that to be comparable with Fig. **4**(*b*) the arm AB′ should be the same length as AB. Considering ordinary telephony, the suppression of one side-band does not make any material difference to the received signal except that its strength is reduced to one half. Where it is necessary to transmit the lowest frequencies of speech and music as in broadcasting it is desirable to cut off the unwanted side-bands very sharply and completely without affecting the transmitted side-band. Difficulties associated with this requirement have hitherto prevented the use of single side-band transmission for broadcasting.

It is possible to go a step further and to transmit one side-band without the carrier. In this case it is necessary to add the carrier frequency at the receiving end. The frequency of the added carrier has to match the frequency of the carrier at the sending end very exactly as a discrepancy of more than a few cycles per second will spoil the quality of the received speech.

When the carrier and one side-band are suppressed, the transmitted side-band occupies a band of frequencies equal to that of the speech transmitted. Thus, if speech containing frequencies ranging from 300 to 2400 c.p.s. modulates a 10,000 c.p.s. carrier and the lower side-band only is transmitted, the frequencies will range from 10,000-2400 to 10,000-300, *i.e.*, from 7600 to 9700 c.p.s., a band width of 2100 c.p.s. as in the case of the original speech.

The suppression of the carrier in a single side-band system affords a slight reduction in the band width required for transmission, but its greatest advantage is in the reduction of the power transmitted. As the carrier frequency itself is unchanged by speech its actual transmission is not necessary; it is the side-band which carries the message and the side-band is all useful power.

When a single side-band only is transmitted the frequencies of speech are in effect transposed into a different frequency range, enabling the whole useful frequency range of a transmission system (whether open wire line, underground cable, submarine cable, etc.) to be used.

News Broadcasting System

A system whereby news may be broadcast to 100 subscribers has been installed at the offices of a London newspaper. It consists essentially of a high quality microphone and associated amplifier which feeds speech currents into a very low resistance. The 100 subscribers' lines are each connected as desired across this resistance *via* a suitable network consisting of a resistance and two condensers. The connexions are effected by means of a special cordless switchboard—providing adequate supervisory signals. The lines are grouped in five groups of twenty—each separate group having an exchange number.

The power supply for the microphone amplifiers (a spare is provided) is obtained from the electric light supply and all the apparatus required is mounted in the back of the switchboard.

The International Telephone Conference (C.C.I.F.) in London, February, 1936

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A short account of the history and method of working of the C.C.I.F. is given. The nature and purpose of the recent conference in London is stated, together with the principal matters discussed by the various technical commissions. Mention is also made of the social side of the conference.

OVER one hundred and twenty delegates and technical experts representing twenty different countries assembled in the examination rooms of the Civil Service Commission, Burlington Gardens, on February 18th, to discuss the questions placed before the first five technical commissions of the C.C.I.F.[1] by the Xth Plenary Assembly, which met at Budapest in September, 1934. The agreed replies will be submitted for ratification to the XIth Plenary Assembly at Copenhagen in June this year. Before dealing with the London conference, a brief outline of the history and present constitution of the C.C.I.F. is necessary, since this International Committee is not known to all readers of the Journal.

Brief History of the C.C.I.F.

In 1922 international telephonic communication in Europe was very limited in scope—for instance, Great Britain was connected to the Continent by only twenty-three circuits, many of doubtful efficiency, confined almost entirely to liaison with North France and Belgium. The technical means for long distance service were already well known and exploited, particularly in the U.S.A. All that was lacking in Europe was a controlling or co-ordinating body, and suggestions of forming a single long-lines company to operate through business between the various countries, or of forming an International Commission, of which Governments would be stockholders, were put forward in November, 1922.[2] In order to study the problem, an International Conference met in Paris in 1923, at which Belgium, England, France, Italy, Spain and Switzerland were represented. This Conference drew up a list of questions relating to international long distance telephony, and formulated a provisional expression of view in respect of each question as a basis of discussion. On April 28th, 1924, a meeting in Paris of nineteen Telephone Administrations of Europe decided that the formation of a long-lines company or an International Commission would be inconsistent with the legitimate prejudice of the European States to keep under their own control the working of the telephone service within the limits of their respective frontiers. It was found that plain general recommendations, framed after thorough examination by an International Committee, would be quite sufficient for a satisfactory international telephone system, and it was decided to organize provisionally a " Comité Consultatif International des Communications téléphoniques à grande distance," and this was known as the C.C.I.

The International Telegraph Conference, opened in Paris on September 1st, 1925, officially recognized the C.C.I., but left it free to choose its own " bureau," and to establish its own internal regulations and method of working. A " Comité Consultatif International des Communications télégraphiques " was also constituted, and it was left to the discretion of the next International Wireless Conference in 1927 whether it would be advisable to form a " Comité Consultatif International des Communications radioélectriques." This procedure grouped under the International Telegraph Union (sometimes called the Berne Bureau) all the organizations of telecommunication, and at the International Telecommunications Conference in Madrid in 1932, the International Telegraph Union became the International Telecommunications Union (U.I.T.) with separate advisory committees for telephony (C.C.I.F.), telegraphy (C.C.I.T.) and radio (C.C.I.R.) to study technical and service questions arising in their respective domains. For telephony, C.C.I.F. is used as an abbreviation instead of the old C.C.I. because of the use of C.C.I. by the " Chambre de Commerce Internationale." " T " having been used by the telegraphists, " F " was taken from the German word " Fernsprecher " (Telephone).

From 1924 to 1932 Plenary Assemblies were held annually, the first three at Paris, then at Como, Paris, Berlin, Brussels, Paris, and Madrid successively. The volume of work for study between Assemblies is so great that two years are now found necessary, and the Xth Assembly was held in Budapest in 1934, while the XIth Assembly will be at Copenhagen this year.

The agreed recommendations and typical specifications of the C.C.I.F. are published after each Plenary Assembly, and after the Xth Assembly, the whole of the earlier recommendations were revised and published in one work, the Livre Blanc or White Book of 5 volumes and an Index, which is the standard reference book for International Telephony. Other publications include phrase books, in three languages, for operators and for maintenance personnel, and an International Telephone Vocabulary in seven languages, which is now being revised. The

[1] Comité Consultatif International Téléphonique.

[2] See " European International Telephony," by F. Gill. Elect. Communication, Vol. 3, No. 1, July, 1924.

C.C.I.F. also maintains a laboratory in Paris which houses the European Master Reference System (S.F.E.R.T.)[3] against which national sub-standards are calibrated. The laboratory carries out experiments and tests in accordance with a programme arranged by the 4th Commission de Rapporteurs.

To study questions between Conferences, at first a Permanent Commission was composed of one member of each Administration of the countries most concerned, either because of the importance of their systems or because of their geographical situation as intermediate countries for through traffic. The work soon grew too much for one commission, and after 1926 several " Commissions de Rapporteurs " were set up. There are at present eight of these, dealing with (1) Protection, (2) Corrosion, (3) Transmission—Lines and Maintenance, (4) Transmission—Apparatus and methods of measurement, (5) Radio telephony, (6) Operation, (7) Tariffs, (8) Symbols. The sixth and seventh commissions met together in Lucerne and the eighth commission met in Berne in 1935, but the work of the first five commissions is so interlinked that it was decided that they should all meet at the same time, as they had at Stockholm in 1934, before the Xth Plenary Assembly. Since the C.C.I.F. works in close co-operation with a large number of other international organizations such as the C.C.I.T., the U.I.R.,[4] the U.I.C.,[5] and the C.I.G.R.E.,[6] delegates from these and other organizations also attended portions of the London meeting, which became one of the biggest purely technical telephone conferences ever held.

The Conference in London, February, 1936.

To those whose recollections of Burlington Gardens are confined to Civil Service Examinations, the thought of holding a conference in those depressing halls may not be attractive, but the Office of Works worked marvels with carpets, curtains, publicity pictures, palms and Lloyd Loom furniture, making the premises most attractive. A postal counter was provided, telephone kiosks and a P.B.X. were installed and on Monday, 17th February, receptionists, telephonists, messengers and doorkeeper were ready to assist the first delegates, who arrived on that day for sub-committee meetings. The actual conference was opened by Col. A. G. Lee, Engineer-in-Chief to the Post Office, on February 18th, in the presence of about 100 delegates and 30 ladies. Col. Lee welcomed old friends and new, who had travelled to London at the worst time of the year, and hoped that the warmth of our welcome and clarity of the discussions would compensate for the cold and fog outside. He drew the attention of the conference to the duty of improving international telephony to the utmost that technical developments would permit within the limits imposed by economic considerations. Mr. Holmgren, of Sweden, expressed the thanks of all the delegates to Col. Lee for his welcome, and to the British Post Office for offering London as the meeting place for the technical commissions. The Conference then divided into " Commissions " for separate and joint examination of the replies furnished by the different Administrations and Operating Companies to the questions studied during the past 18 months.

The 5th Commission (Radio-telephony) had the shortest programme, and prepared its replies in three days, under the presidency of M. Le Corbeiller (France). Its work was largely concerned with the development of automatic devices for the correction of the wide variations in the level of speech which radio-telephone links have to handle. The commission studied the requirements of such devices and specified certain of the more important conditions to be fulfilled. The problem of two radio links joined by a long international telephone line was also studied, since it has been found that faulty operation of echo suppressors and other equipment connected with the land line may be caused by atmospherics or other noises emanating from the radio links. This question requires further study.

The 1st (Protection) and 2nd (Corrosion) Commissions are largely composed of the same members, and met alternately under the presidencies of Dr. Jäger (Germany) and M. Collet (France). It is well known that the presence of a power distribution system in the vicinity of overhead telephone plant may cause noise interference on the telephone circuits by electrostatic or electromagnetic induction. The limit of psophometric E.M.F. induced by power lines in international telephone circuits has long been under consideration, but pending further study of the noises arising in the telephone system itself and their effect on the subscriber, the limit hitherto provisionally fixed at 5 mV has been retained. Other matters discussed included the calculation of mutual induction between parallel systems, the telephone form factors of various types of D.C. plant, and the cause and prevention of acoustic shock and, in cases of earth faults on power lines, of electric shock. The co-operation of eminent representatives of the power interests increased immensely the value of the conclusions reached, and in view of the inevitable clash of interests, the success in reaching agreement is most gratifying. The 1st Commission continued its sittings until March 4th, in order to proceed with a draft revision of the " Directives " which the C.C.I.F. has issued concerning the measures to be taken to protect telephone lines against disturbance from power lines. The 2nd Commission considered the possibility of using certain organic materials for cable sheaths, but could not recommend any of them for an extensive practical trial. The composition of lead alloys and the influence of certain impurities upon the mechanical properties of lead sheaths were studied and certain useful conclusions were reached, and progress was made in the sifting and recording of the latest information concerning protective coverings for lead cable sheaths. The subjects of electrical

[3] Système fondamental européen de référence pour la transmission téléphonique.

[4] Union Internationale de Radiodiffusion.

[5] Union Internationale des Chemins de fer.

[6] Conférence internationale des grands réseaux électriques à haute tension.

drainage and insulating joints were examined with a view to a revision of the existing recommendations in Vol. II of the " Livre Blanc."

The 3rd and 4th Commissions (*Transmission*) deal with Transmission from different aspects, and many of their meetings were necessarily held jointly. The 3rd Commission, under the presidency of Herr Ministerialdirektor Höpfner (Germany) had to consider not only the improvement of audio-frequency telephony from the point of view of noise, cross-talk, overall efficiency and frequency response, but also the many problems introduced by single and multi-channel carrier working. Agreement was reached on many of the required characteristics and on the new specification requirements for some component parts of transmission systems. The co-ordination of telephony and telegraphy (sub-audio, V.F., super-audio and telex) involved five questions, the replies to which were agreed by the C.C.I.T. representatives. Broadcast transmissions over telephone circuits were studied in co-operation with the U.I.R., and agreement reached on four questions, while the permanent maintenance sub-commission of the 3rd C.R. made certain recommendations concerning the setting-up and handing over of broadcast circuits to broadcasting authorities. The 4th Commission, with Capt. B. S. Cohen (Great Britain) as chairman, is responsible for the S.F.E.R.T. laboratory in Paris, and has laid down a programme of tests to be carried out in that laboratory in the immediate future. The measurement of noise and of speech impairment due to noises of various natures and intensities is under review, and studies of effective transmission are being made and valuable results obtained. The various methods of articulation testing have been re-examined, with the object of correlating the results obtained by various administrations. Progress has also been made in the measurement of the non-linearity of lines and apparatus, particularly commercial transmitters, and the distortion due to non-linearity. The measurement and standardization of the values of room noises met with in practice were discussed in connexion with the requirements for effective transmission.

Concluding Session.

The 3rd and 4th C.R's completed their answers to 44 transmission questions by the evening of Friday, February 28th, and Herr Höpfner expressed the thanks of the delegates for the arrangements made by the British Administration for the conference, and for the hospitality offered to the delegates and their ladies. Capt. Cohen and Capt. Hines in replying paid tribute to the chairmanship of Herr Höpfner, and to the exemplary and devoted services of the General Secretary, M. Valensi, which contributed in no small degree to the success of the conference and to the speed with which the unprecedented volume of work had been covered.

The Social side of the Conference.

Not the least of the benefits obtained from an International Conference are those due to the personal contacts and friendships formed outside the conference room, at lunch, at dinner and at social meetings in the evenings. The personal touch so introduced into the field of international telecommunications is of as great service as the drawing-up of regulations which, of necessity, depend on good-will for their execution. In addition to much private entertaining on the part of the British representatives, the delegates were entertained to a Banquet by His Majesty's Government, at which Major Tryon, the Postmaster-General, paid tribute to the work of the C.C.I.F. in studying the manifold problems of international telephony, and in producing agreed recommendations for the solution of the problems as they occur, and he wished the organization success in coping with the problems of the future, such as television. Herr Höpfner, in reply, emphasized the wonderful co-operation within the Committee, which is indispensable to the solution of the problems mentioned by the Postmaster-General. The telephone cable and equipment manufacturers of Great Britain entertained the delegates and their ladies to a dinner, dance and cabaret, at which Sir Thomas Purves made an inimitable speech in fluent and colloquial French, while M. Le Corbeiller replied with a racy discourse in perfect English. Visits were also paid to the Dollis Hill Research Station, the National Physical Laboratory and the International Trunk Exchange, Faraday Building. On the last mentioned occasion, during tea a remarkable demonstration of radio-telephony to all parts of the world was given, many of the principal delegates speaking over the radio links from a telephone instrument in the room, while the remainder listened by means of watch receivers.

The ladies accompanying delegates had a most elaborate programme of visits arranged by a ladies' committee formed by the Contractors and the Department. They were conducted to all the principal historical places of London, to the Chinese Exhibition and to a theatre, as well as to Windsor and Hampton Court, and many other places. The Contractors most kindly defrayed all the expenses of these excursions.

All who attended the conference were impressed by the spirit of goodwill and co-operation shown the whole time, and will retain very happy memories of the 1936 Conference in London.

Signalling on Trunk Circuits. Introduction of Two-Frequency Working

Part I. Methods of Signalling

H. S. SMITH, A.M.I.E.E.

A review of the present methods of signalling is given, and the desirability stressed for automatic signalling on all types of circuits. It is then shown that this can be accomplished by the use of A.C. signals of frequencies within the voice frequency band.

THERE are two methods at present in general use in this country of signalling on trunk circuits: the first is known as "Generator Signalling" and the second as "Automatic Signalling."

Generator Signalling. Under the generator signalling method an exchange operator, who has plugged into a circuit for the purpose of setting up a trunk connexion, finds it necessary to take further action in order to apply the signalling condition which will call the distant exchange operator. This action is the deliberate operation of the connecting cord ringing key, which connects the exchange generator to the circuit and so transmits an alternating signal current at a frequency of approximately 17 cycles per second. The ringing key must be operated steadily for a period of two seconds (the reason for this period is explained later) to ensure the actuation of the distant calling device; these conditions apply also when it it desired to send a clearing signal.

Automatic Signalling. The automatic signalling method enables the ringing operation to be dispensed with, as the action of seizing or releasing a circuit causes automatically the immediate application of the correct calling or clearing signal; the signalling current is usually drawn from the exchange battery.

Provision is also made for supervisory signals which indicate that the distant operator's speaking key is thrown or restored (speaking-key supervision) and, when the connexion is extended, that the called subscriber is at the telephone or has replaced his receiver (switch-hook supervision).

The provision of facilities for automatic signalling is of great importance, as the use of this method effects a considerable saving of time and effort on the part of the operating staff. The introduction of automatic (machine switching) exchanges gives even greater importance to this method of working, for, by the addition of the dialling facility, controlling operators are enabled to complete and supervise connexions to telephones served by distant automatic exchanges, without assistance by intermediate switching operators.

Usage.

Automatic signalling is used on circuits over which it is practicable to employ direct current signals and is highly developed to provide the main facilities mentioned above, together with a number of subsidiary features which are of utility under a variety of circumstances. This method of signalling is in general use on junction circuits connecting exchanges within local areas and on short trunk routes between exchanges in adjacent areas. It is also in use on a number of longer trunk routes which provide suitable conditions.

Generator signalling is at present used on the remaining circuits which are unsuitable for signalling by means of direct current. In general, trunk circuits connecting long-distance exchanges are of this type, as they include transformers for a number of reasons and signalling has therefore to be carried out by means of alternating current.

Influence of Line Plant Developments.

In the simple case of two-wire physical line circuits the transformers are inserted in order to obtain derived or phantom circuits by superimposing, to preserve good balance, or to effect impedance matching. In these circumstances end-to-end signalling is carried out by means of ringing current from the exchange generator.

A similar condition applies when a two-wire circuit is equipped with a repeater for transmission improvement, but in this case arrangements are necessary for the ringing current to be regenerated at the repeater station. For this purpose an auxiliary "ringing repeater" is used, which comprises apparatus for relaying 17 c.p.s. current from the station generator onward.

The more recent practice of using underground cables, containing light gauge conductors, in conjunction with numerous repeaters, results in very high resistance lines, usually arranged as four-wire circuits having separate "go" and "return" channels. In addition to physical and phantom lines of this type, use is made, to an increasing degree, of carrier and radio channels, which are also arranged to provide, in effect, four-wire repeatered circuits, "go" and "return" being provided by means of the frequency bands transmitted in the two directions.

Such circuits are provided on the basis of transmitting only the essential range of frequencies: for commercial speech circuits this range is, in general, covered by the frequency band extending from 200 to 2600 c.p.s. On circuits of this description the low frequency of 17 c.p.s. cannot be transmitted and it is necessary to convert generator signals to a frequency within the speech band: the frequency most used for this purpose is 500 c.p.s. At the terminal stations circuits of this type are equipped with apparatus which is operated by the signal sent out by the exchange operator (17 c.p.s. ringing) and transmits onward a corresponding signal from the 500 c.p.s. generator: at the distant station the received 500 c.p.s. signal is used to effect the application of local current to the exchange equipment. The circuit overall thus works as a 17 c.p.s. generator signalling circuit. As, however, the intermediate signal is in the voice frequency range, it is necessary to take steps to guard against false signals which may be caused by the 500 c.p.s. components of speech currents during conversation. To this end the 500 c.p.s. generator output is interrupted twenty times per second; hence the expression " 500/20 signalling." The receiving apparatus is arranged to respond only to modulated signals from such a source, when of a certain minimum duration and thus to secure " voice immunity."

Another feature encountered on long underground circuits is " echo." The " go " and " return " directions of transmission are not completely separated on a four-wire circuit as only compromise balances are used at the terminal stations. The circulatory currents which result become noticeable when the time of transmission over the circuit is appreciable and the speaker is liable to hear an echo of his voice in his receiver. The " echo-suppressor " effects a remedy which is satisfactory so far as commercial speech is concerned, but which, when signalling is considered, involves steps being taken to cover the " hang-over " period required by the echo-suppressor to release. This is necessary as the suppressor may already be operated from the distant end of the circuit at the moment at which it is desired to signal. The result is that the applied signal duration has to be extended and it is necessary to ensure that operators will apply the signalling condition long enough to cover the overall period required. In order to include a factor of safety, instructions are given that the ringing key shall be held in the operated position for a period of two seconds; this accounts for the " deliberate " operation previously mentioned.

The use of light gauge cables with repeaters and of carrier and radio channels is not now confined to the main lines, but is extending to short trunk routes. In a number of cases the effect has been to re-introduce generator signalling on groups of trunks which have been enlarged by utilizing additional circuits of such types. These short trunk circuits are used, however, for handling " no-delay " traffic, which places a premium on the automatic signalling method. Moreover, with the introduction of " on-demand " service and the attainment of high grade transmission for long distance calls, a very large proportion of the traffic throughout the trunk system is now handled in much the same way as " no-delay " traffic.

It is evident that the distinctions which have existed between long and short distance trunks, with regard to handling and signalling, are largely disappearing and that there is a need for automatic signalling on all types of circuits. Consequently, means must be found to provide automatic signalling facilities by means of alternating currents.

Automatic Signalling by means of Alternating Current.

A direct current automatic signalling circuit provides, in addition to a two-way speech channel :—

a " call " and " clear " signal channel in the " go " direction,

a " supervisory " channel in the " return " direction and

availability of all channels for use concurrently.

It is possible for one speaker to break through the conversation of the other and signalling can be carried out independently, not only of conversation, but as regards direction. These conditions are illustrated in Fig. 1.

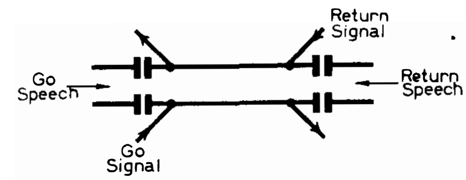

FIG. 1.—D.C. AUTOMATIC SIGNALLING CONDITIONS.

On the repeatered type of circuit the state of affairs is very different; no independent signalling channels are provided and, if the circuit is of the type on which an echo-suppressor is employed, the speech channel can only be used one way at a time. Allowance is also necessary for any hang-over period which has to expire after the channel has been in use one way, before it may be used in the reverse direction. (*Note* : A new type of echo-suppressor, which may be arranged to provide a " break-through " facility, is being developed and has been described in the Journal.)[1]

In order that automatic signalling may be effected, arrangements must be made to use the speech channel for signal currents as well as for conversation. Sub-audio and super-audio frequencies, which might be applied as required without being overheard by subscribers, are unsuitable for use on account of the limitation of transmission to the commercial frequency band. It is necessary, therefore, to employ voice-frequency currents and to apply the signals in such a way that they will not disturb listeners. Although many of the required signals can be applied at times outside the conversation period, there are a number of occasions when subscribers are listening during the signal period; for example, a subscriber awaiting the completion of a trunk call on-demand, listens during the setting up process. In these cases, arrangements must be made, when necessary, to cut off the conversation path to the subscriber while signalling proceeds.

Consideration is also necessary regarding :—

(*a*) interference by signalling currents with Telex (teleprinter) calls set up over trunk circuits,

(*b*) confusion on the part of subscribers between signals overheard and the three-minute tone (chargeable time announcement) and

(*c*) speech interference with the signalling equipment.

The necessary precautions include the avoidance of the use of frequencies in the neighbourhood of 300 and of 1500 c.p.s. (Telex) and of 900 c.p.s. (Time Announcement) : the region of 1200 c.p.s. is that in which subscribers' transmitters provide their greatest power output to the circuit and is also avoided.

[1] *P.O.E.E. Journal,* Vol. 28, Part 1, April, 1935.

Experimental Schemes.

Several experimental schemes have been devised and subjected to practical trial on working trunk circuits. One scheme has already been described in detail in the Journal.[2] This scheme employs the duplex principle and makes use of two frequencies, one for the transmission of signals in the " go " direction and the other in the " return " direction. It is possible to use such a system on circuits equipped with echo-suppressors only by making the suppressors insensitive to the signalling frequencies.

Developments with a view to overcoming the special requirements regarding the echo-suppressor are incorporated in a later scheme, which uses the pulse principle and is so arranged that supervisory signals comprise a series of short pulses of signal frequency current. The object of this arrangement is to ensure that controlling signals can over-ride signals in the return direction, during the silent intervals in which the suppressor releases.

Further developments cater for most of the features of automatic signalling systems, such as :—auto-signalling between operators, dialling by operators into distant machine switching networks and access to the outgoing end of a circuit jointly from a manual switchboard and from automatic selector equipment. The last mentioned facility is intended to be used on circuits of the dialling type for routing calls *via* intermediate exchange selectors to remote exchange subscribers.

Equipment has been designed and orders will shortly be placed for its installation on a number of trunk routes. The considerations which have led to this design and the principles on which the equipment works are discussed in Part II.

[2] *P.O.E.E. Journal,* Vol. 26, Part 4, January, 1934.

Part II. Development and Application of the Two-Frequency Signalling System

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The requirements of an ideal voice frequency receiver are enumerated, together with an account of some of the factors influencing the choice of signals. A previous design is reviewed and a new system, utilizing two frequencies and providing signalling and dialling, is described.

Introduction.

IN the early stages of the development of a V.F. signalling system, two outstanding problems were encountered. These were to design a V.F. receiver which would fulfil all or even most of the requirements of an ideal receiver and to devise a system of signals which would function correctly irrespective of speech, supervisory tones or other sources of A.C. which might occur during the signalling periods. A signal can only be A.C. of frequency within the range transmitted by a speech channel, or a number of such frequencies, the distinction between signals being frequency, duration or sequence. The V.F. receiver is required to detect the presence of signal frequencies by operating a particular relay or series of relays for each signal. This it should do over a large range of signal input levels (*e.g.,* 25 db.); one relay at least should be capable of following dialled A.C. impulses accurately over a large range of input levels (*e.g.,* 15 db.), of impulse speed and ratio of tone to no tone. The receiver relays should not be operated by non-signal currents (speech, clicks and surges, supervisory tones, telex, 17 c.p.s. ringing or anything but the signal frequencies), but should these disturbances occur concurrently with signals the receiver operation should be unaffected. In addition the receiver should be easy to make and maintain, and be capable of working entirely off the exchange battery.

So far as is known, no receiver yet designed fulfils all these requirements; in fact it would appear that to protect the receiver against operation by any but signal currents, of necessity implies that the operation on signal currents may be adversely affected by non-signal currents present at the same time. The adverse effect may be completely to prevent operation of the receiver relays, or to reduce the range of input levels over which the receiver will function, or to prevent, or to interfere with the accuracy of, dialling. Apart from their possible effect on the receiver, speech and other sources of A.C. may, by actuating echo-suppressors or other voice switched devices, completely block the transmission of a signal. If the signal ceases before the disturbing A.C. ceases, it will be completely lost. N.U. tone in particular presents difficulty in that normally it persists until the connexion is broken down, but since it may, by operating an echo-suppressor, prevent a clearing signal from releasing the switches, lock-up conditions are produced. It is clear that, since it has been found impossible to avoid encountering N.U. tone, release can only be obtained by interrupting the N.U. tone for a short period every few seconds, and ensuring that the release signal is given during the break in the tone. The interruption must not be too frequent, firstly because the interruption also mutilates the ringing as well as the N.U. tone, and, secondly, for fear of confusion of the N.U. with the busy tone. An interruption every 10 seconds was originally planned, but every 5 seconds is now tolerated.

The signalling system described in the previous article already referred to, made use of a receiver which partially fulfilled the requirements enumerated above. The range of operation was limited to 17 db., its operation could easily be affected by speech or other disturbances occurring at the same time as signals, and it would not follow dialled impulses. A separate and much more complicated receiver, to be brought on the line only when required, was contemplated for dialling. A continuous tone system of signals was used. With this system, a signal consisted of A.C. continuously transmitted until another signal was given, that is, the length of the signal was not fixed but was determined by the next operation in a sequence of operations. It had the advantage that signals could not easily be lost by speech and other sources of current blocking transmission, because the duration of the signals automatically became greater than that of the disturbance. For example, the release signal would persist until the break in the N.U. tone occurred, and cleared the connexion. The alternative to the continuous tone system is the use of timed pulses of A.C., each pulse or series of pulses representing a particular condition. The main disadvantage of the pulse system is the possibility of disturbing sources of A.C. causing the complete loss of signals. By using answer-back signals, *i.e.*, reverted pulses to indicate that signals have been correctly received, some of the difficulties may be overcome. The N.U. tone difficulty, however, was thought to be insurmountable with pulse signalling as no means of synchronizing the release pulse of tone with the break in the N.U. tone could be successfully devised.

The Pulse Signalling System.

A new signalling system has been designed, incorporating a receiver which will operate over a very large input level range, and will respond to two frequencies separately and impulse on one of them, thus eliminating the necessity for separate dialling receivers. It is affected by speech, clicks and other disturbances, but these are allowed for in the circuit design. A system of pulse signalling has been adopted by which, in conjunction with the circuit design, signals cannot be permanently lost and which guarantees release against N.U. tone, as will be explained later.

V.F. Receiver. (Fig. **2**). The lower level of the received tone on which this receiver must work (approx. 20 db. below 1 mW into 600 ohms) necessitates the use of thermionic valves in order that sufficient power shall be available to operate relays of the P.O. 3000 type. These valves (V2 and V3) have to work with only 50 volts available on the anode, and must therefore be more sensitive than the normal repeater type. Two such valves are needed individually to operate two relays (X and Y) of the impulsing type on the two signalling frequencies, and the circuit in which the valves and relays work should provide operating conditions of the trigger type, in order that rapid impulsing of the relays may be secured. The range of levels over which the receiver must work (25 db.) together with the maintenance of a reasonably low tapping loss on the line, makes essential the use of a further valve (V1) to precede the signal frequency valves. Immunity from operation on speech must be secured primarily by the employment of as good signal frequency filters as is compatible with a reasonable band width, together with electrical devices for overcoming the tendency to respond at the signal frequencies and their submultiples. No time delay of the slugged relay type can be employed in the receiver since the relays must respond to dialling.

The above points give the rough data for the design of the receiver, and the following points are elaborations which are essential if continuous operation under commercial conditions is to be secured.

The valves must be of a robust type, capable of maintenance under automatic exchange conditions, and with characteristics which will enable a large supply to be obtained from the contractors at a reasonable price. For operating the signal relays, pentode valves (V2 and V3) are used of a recently introduced commercial type (V.T. 103), the cathode being indirectly heated with a current of 0.2 ampere, and capable of delivering a current of 10 mA into a 2,000 ohm relay, when working under minimum grid current conditions, from the anode potential of approximately 50 volts. The combination gives an ample margin of safety for impulsing the relay under the standard dial test variation of 7 to 12 i.p.s. Since no special electrode construction is used, and the valves are stated to be capable of working continuously with 250 volts on the anode, a much longer working life than normal should be secured, and it is anticipated that 5,000 hours will be attained.

The circuit in which these valves work is based on the rectified reaction principle,[3] in which application of an alternating potential to the grid, gives an almost instantaneous rise in anode current from zero to 10 mA when the potential rises above a certain level. The conditions are thus appropriate for impulsing the signal relay, while the function of the circuit has been stabilized so that repeated application of the same potential under variable external conditions produces no change in the impulsing. In particular, the effects of changes in battery volts of the normal order (46-52 volts) have been compensated by deriving the initial " cut off " grid bias from a barretter circuit. The grid bias is made to vary by the barretter to a greater extent than the battery voltage variation, so as to nullify the effects of this variation.

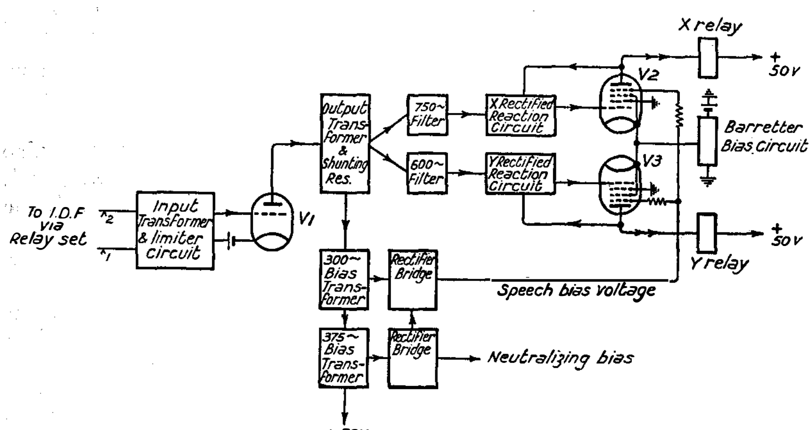


Fig. 2.—Block Diagram of Two-Frequency Signalling Receiver.

[3] *P.O.E.E. Journal*, Vol. 25, Part 3, October, 1932.

The alternating potentials applied to these circuits are derived from the inductances of simple resonant circuits or filters, tuned to the signal frequencies. These resonant circuits are excited from step down windings on a transformer in the anode circuit of the preceding valve. When interrupted signal tone is applied to this valve, the alternating voltage on the resonant circuit inductance does not rise or fall instantaneously, due to the decrement of the circuit, and therefore by adjusting the maximum response of the resonant circuit with a shunting resistance on the transformer, the points on the resulting voltage envelope where the rectified reaction stage strikes and releases, can be varied within a certain limit. This enables the duration of the current per impulse in the signal relay to be easily adjusted, and gives a ready means of obtaining the correct make percentage from the relay contacts.

In order to secure this performance over the desired range of input tone levels, the first valve (V1 in diagram) stage is of the limiter-amplifier type, using a triode valve of the indirectly heated type requiring a current of 0.2 amperes. When an alternating tone potential of a certain magnitude is applied to the control grid of the valve, grid current flows and it is arranged by means of grid resistances and condensers that a further increase in the magnitude shall bias back the grid of the valve proportionately to the applied alternating potential. The signal current in the anode circuit has therefore an increasing percentage of harmonics with increasing input magnitude, but the magnitude of the fundamental (*i.e.,* the signal frequency) remains constant. The signal potential on the resonant circuit remains constant therefore, and in consequence the performance of the relays does not vary. The tone level at which this " limiting action " takes place is determined by the step-up of the input transformer between the line and the grid of the first valve, but in practice, the maintenance of a low tapping loss on the line of the order of 0.25 db. limits the ratio. With the specified ratio of 1 : 10 a lower dialling level of -15 db. is obtainable, whereas the upper limit is dependent on the breakdown of the grid circuit, levels of $+10$ db. being easily attained. Although the limiting action falls off below -15 db., sufficient response exists on the resonant circuits down to -25 db. to enable signalling to be carried out.

Performance with Superposed Non-Signal Currents.

The receiver will not normally signal or dial with superposed currents on the line of non-signal frequency unless they are some 20 db. below the signal level, neither will it function until a time interval has elapsed between the non-signal and signal currents; the time interval depends on the relative magnitudes of the two currents and the time constant of the grid circuit of the limiter valve. The time constant has been made as small as the associated wiring, resistances and capacitances will allow, consistent with the production of a true limiting action. No other simple limiting stage is known which gives a more constant output, without these disadvantages.

Immunity of Operation on Non-Signal Currents.

As mentioned previously, these non-signal currents include 17 c.p.s. ringing, telex on 300 or 1500 c.p.s., supervisory tones such as N.U., D.C. clicks or surges, and speech.

Non-signal frequencies of low periodicity such as D.C. clicks or surges will not operate the receiver, since the resonant circuits are protected from shock excitation by the limiter valve, but will paralyze the receiver for a short period, as explained above.

Non-signal frequencies at levels up to $+30$ db. of higher periodicity than the signal frequencies, cannot operate the receiver provided they are outside a bandwidth of ± 30 c.p.s. about the signal frequency, owing to the combined effect of the limiter valve, the resonant circuit selectivity, and the trigger action of the rectified reaction circuits.

The resonant circuits will respond, however, to submultiples of the signal frequencies down to the 3rd order, *i.e.,* if the signal frequency is 600 c.p.s., the resonant circuits will respond to 300, 200 and 150 c.p.s., due to the production of harmonics by the limiting stage. As a result of research into the operation of these receivers by speech, it has been found that in most classes of speech these submultiple frequencies occur most frequently, in addition to which many automatic tones have large harmonics of this order, and telex is at present working on 300 c.p.s. In order therefore to prevent this operation, transformers tuned to the first submultiple of the two signalling frequencies (300 and 375 c.p.s.) are included in the anode circuit of the limiter valve and by rectification of the voltages developed, are made to supply a heavy negative bias potential to the suppressor grids of the pentode valves in the rectified reaction circuits, when these frequencies occur in the non-signal currents. These tuned circuits will in turn respond to their submultiples and thus the bias output from this portion of the circuit extends with a band-pass effect over all frequencies lower than the signal frequency which would be likely to operate the receiver. The small response of this circuit to the signal frequency is neutralized and therefore the performance is unaffected.

With the above devices it is found that no operation on commercial speech is obtained provided the attenuation of the lower frequencies is not exceptional. In the latter case the relays will operate very occasionally and for very short periods. The design of the associated circuit and the sequence of signals is so arranged, however, that such infrequent operation will not produce a false signal.

Manual Circuit Signals.

The system of signals used for manually operated circuits is shown diagrammatically in Fig. **3**. The calling signal is a short pulse of X (750 c.p.s.) frequency which is automatically transmitted when the plug is inserted in the outgoing multiple jack. The lighting of the cord circuit supervisory lamp at the calling exchange is the normal called subscriber clearing signal and is the one most subject to interference by speech. For this reason, it is made a succession of pulses of tone, the pulses continuing until either the incoming end answers or re-answers, or the circuit is cleared from the calling end. Y frequency (600 c.p.s.) pulses are used with intervals between them long enough for signals in the reverse direction to break through a voice switched device. While the pulses are being transmitted the line is cut

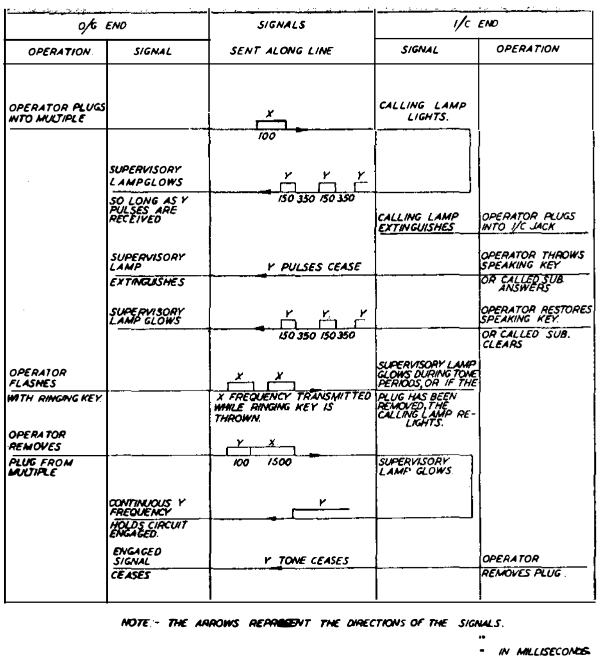


FIG. 3.—OPERATION AND SIGNALS, MANUAL TO MANUAL CIRCUITS.

at each end to prevent subscribers or operators hearing any more than the first two pulses. The answering condition is the cessation of the Y pulses, whereupon the circuit opens for speech transmission and the supervisory lamp extinguishes. The pulses are controlled by the called subscriber's gravity switch and the " B " operator's speaking key for normal supervision. The " B " operator may flash the " A " operator's supervisory lamp by means of the Y pulses, using the ringing key for the purpose. The " A " operator may also flash the incoming end supervisory lamp by operating the ringing key, the throwing of the key sending out X frequency tone which ceases on restoration of the key. The clear from the outgoing end of the circuit, given automatically on withdrawal of the plug, is a long pulse of X frequency followed immediately by a short one of Y. The first part of the signal is made of long duration to enable it to pass echo-suppressors which may have been operated by Y pulses, busy or ringing tone. The terminating Y pulse distinguishes a clearing from a flashing signal, the latter being a transient and the former a permanent lighting of the supervisory lamp. If two lines are connected in tandem the X pulse will be transmitted along both and may light the supervisory lamp at the terminating as well as the intermediate exchange. It is undesirable that a permanent clear be given at the terminating exchange until the plug is removed at the intermediate exchange. The X pulse is therefore arranged to cut the line at the first receiving point, thus confining the Y frequency part of the clearing signal, and therefore the permanent lamp glow, to its own particular link. Should the " A " operator remove the plug from the multiple before the called subscriber has cleared, the forward clearing signal may be blocked by an echo-suppressor and be lost. The circuit therefore provides for the clearing signal to be given again when the called subscriber eventually hangs up his receiver. It is very desirable that both ends of a circuit be held engaged until the connexion has been taken down at both ends. The removal of the plug at the " A " exchange is indicated by the clearing signal which is automatically transmitted. The presence or absence of a clearing signal from the " B " exchange is no indication of whether or not the plug is still in the answering jack. To signal the removal of the plug necessitates a separate signal, and a continuous tone of Y frequency is used for this purpose, the tone persisting from the time the " A " operator clears until the " B " operator clears. A continuous tone is permissible in this case because it is always the last signal in the sequence.

When the speaking condition has been established, the receiver is subject to occasional short duration operations of the two relays. These are prevented from giving false clears by making the supervisory lamp at the " A " end of the circuit dependent upon at least two operations of the Y relay within a short period of one another, and at the " B " end by delaying the response of the supervisory lamp to the operation of the X relay in the receiver.

Dialling Circuit Signals.

The system of signals used for dialling circuits is shown diagrammatically in Fig. **4**.

The insertion of a plug in the outgoing multiple jack sends a pulse of X frequency as in the manual case. In non-director areas no signal is necessary to indicate to the operator that the circuit is ready to receive dialled impulses, but in director areas a short pip of 900 c.p.s. tone is used for this purpose. The operation of the dial causes 750 c.p.s. tone to go out whenever the dial contacts open. At the conclusion of dialling the line must be left open for the transmission of ringing, busy or N.U. tone. The

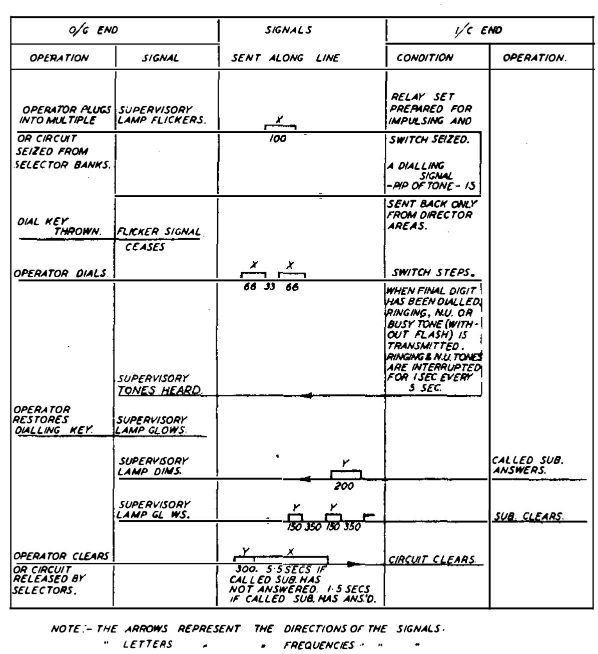


FIG. 4.—OPERATION AND SIGNALS, MANUAL TO AUTO OR AUTO TO AUTO CIRCUITS.

called subscriber answering therefore needs to be indicated by a pulse signal, for which the Y frequency is used. Once the subscriber has answered, signalling proceeds as in the manual case. If the connexion is taken down before the subscriber's answering signal has been received, it is possibly because N.U. tone has been encountered. For this reason the clearing signal, if given before the subscriber has answered, is made long enough to be sure of covering at least one break in the N.U. tone.

The dial is connected *via* the cord circuit and impulses a relay in the terminal relay set, contacts on the relay controlling the A.C. impulses sent out over the line. Connexion between the dial contacts and the impulsing relay is made by the Tip and Ring wires from the multiple jacks and cannot be conveniently made in any other way. The action of impulsing the relay produces surges in the speech path itself. These surges must be prevented from going out with the A.C. dialling as they would seriously interfere with the receiver operation. It is necessary to restore the transmission from the switches back to the cord circuit after each digit, since the operator may have to listen for a signal between digits. This means that after dialling the final digit, speech or noise currents may be present in the cord circuit, and these if allowed to pass to the line itself, might block the Y pulse which indicates that the called subscriber has answered. It is clear that what is wanted up to the time the called subscriber answers is one-way transmission, from the line to the cord circuit (thence to the operator or subscriber), but not from the cord circuit to the line. This is provided by locating in the terminal relay set at the outgoing end of the line a thermionic valve so arranged that it permits the transmission of supervisory tones in one direction but stops all transmission forward except the A.C. dialling impulses. Surges are also produced at the incoming end of the circuit by the impulsing of the selector, but these can be kept off the line by relay contacts which segregate the trunk line from the selector impulsing circuit while impulsing takes place.

Construction.

The equipment is designed in five units each on a jack-in type baseplate. The units are V.F. receiver (TL 1750), outgoing (TL 1751) and incoming (TL 1752) manual relay sets and outgoing (TL 1753) and incoming (TL 1754) dialling relay sets, the numbers in brackets being the circuit diagram numbers. By associating these units in the appropriate manner, unidirectional or bothway circuits can be provided to work either manually or dialling, or to work manual one way and dialling the other. The arrangements are shown in Fig. 5. Fig. 6 shows the equipment required for one end of a bothway dialling circuit.

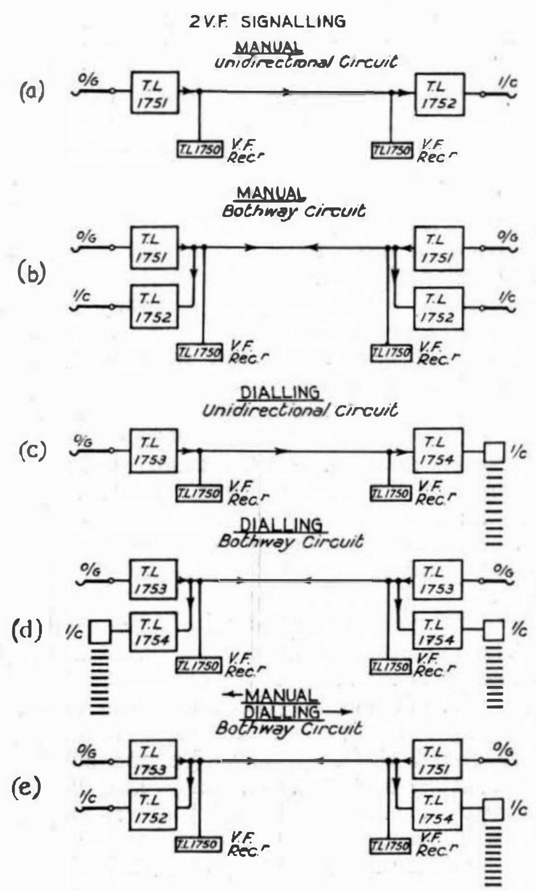


Fig. 5.—Arrangement of Units to give Various Facilities.

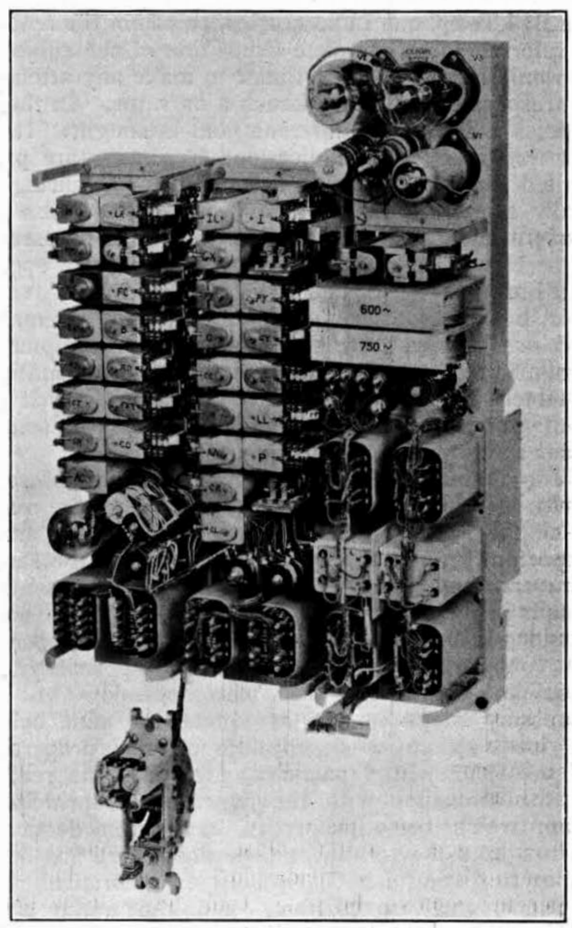


Fig. 6.—Equipment required for Bothway Dialling Circuit.

An Outline of the Principles of Atomic Physics

F. C. MEAD, B.Sc., A.R.C.S.

I. Fundamental Phenomena and Experimental Methods

In this first article of a series, the aim of which is to present in outline the principles and advances of atomic physics, the principles of the measurement of charges and masses of fundamental particles are discussed and illustrated by their application to the electron.

Introduction to Series.

THE amount of literature at present available on the subject of Atomic Physics is very profuse. In presenting a short series of articles on this subject, therefore, it is felt that some explanation is warranted. The literature already available varies from the specialized treatise to the popular narrative and between these two extreme types there is an almost infinite gradation. It might therefore be considered that the whole field has been covered. The present series is addressed particularly to Communications Engineers, but it makes no pretence at being a complete and detailed exposition of the subject. Communications Engineers are fortunate to be already provided for in this way by the extensive and well-known writings of Dr. Karl Darrow, of the Bell Telephone Laboratories, to whom the reader is referred for a complete exposition of the subject. It would indeed be impertinent to make any attempt to trespass on the field of such a narrator. In these articles a somewhat different goal is sought. It is felt that many Communications Engineers are prevented for one reason or another from acquiring a really scientific acquaintance with the progress of modern advance in Physics, because it is necessary to be busy with other things in these days of speed and hurry. The popular article is, it is true, available, but an exposition of this nature does not make full use of the knowledge and mental equipment available in the trained engineer and the information obtained by reading popular literature which is addressed to the absolute layman is necessarily somewhat scrappy and unconvincing.

The author has therefore aimed in the present series at presenting in the briefest outline, the main principles underlying a very fascinating and important branch of Physical Science. At the same time care has been taken to avoid omitting essential details in the argument which might lead to the conclusions being unconvincing. The subject is opened by considering the first principles as briefly as possible, consistent with the inclusion of all necessary steps in the argument, the aim being to lead up to a description of the properties of the fundamental particles, providing the reader in the meantime with the experimental principles from which these properties have been deduced. Throughout the treatment the utmost care has been taken to distinguish clearly between theoretical conceptions and proven facts and the author has deliberately erred on the side of extreme caution in trying to persuade the reader not to be carried away by the picture of the fundamental particles—which has been painted by physicists, and of which so much is made in popular expositions of the subject—and not to believe too strongly in the reality of their existence. It is hoped, however, that the evidence is presented sufficiently clearly to enable the reader to judge for himself, and that the real facts which will emerge from the study of this subject will be all the more convincing on this account.

Atomic Physics is one of a group of subjects which is based on the general idea that all natural phenomena are discontinuous. This idea seems to be in accordance with the facts of nature as determined by experiment. In a previous article[1] an attempt was made to explain how this idea has given rise to a new system of mechanics, Wave or Quantum Mechanics. This new system rests on the theory that radiation is discontinuous and has been found to account for a large number of hitherto anomalous phenomena relating to the ultimate nature of matter. The idea of discontinuity, however, is older than this. The theory that matter is discontinuous and ultimately composed of atoms, was for many years the basis of the science of Chemistry. We have now to deal with a subject which rests on the theory that electricity is discontinuous, and that every charge is a collection of minute charges or atoms of electricity. This theory emerges quite naturally from simple observations on well known electrical phenomena, and in consequence is best approached from the historical point of view. The result of applying this theory to explain other phenomena, leads, as we shall see, to the further elucidation of the ultimate nature of matter, indicates that the atoms of Chemistry are themselves divisible and provides a theory of their structure.

Such is briefly the scope of the subject with which we are dealing.

Historical Origin and Development.

The subject now known as " Atomic Physics " arose out of the study of the conduction of electricity in gases. It had long been observed that the conductivity of air at normal atmospheric pressures was very small, the only discharge phenomena taking place being the brush discharge and the peak discharge. These discharges, however, only occurred between two electrodes reasonably close together and

[1] *P.O.E.E. Journal,* Vol. 27, Part 1.

under special conditions. For instance, the occurrence of the spark and brush discharges between two electrodes in air with a fixed voltage depends on the radius of curvature of the electrode surfaces. The discharge takes place more readily when one of them has a surface of small radius of curvature. In order to facilitate the discharge, one of the electrodes was commonly made in the form of a point for this reason. It was also observed that the discharge passed more easily when the point electrode was the negative pole.

It was later observed that the conductivity increased and the discharge passed more easily as the gas pressure was reduced. If two electrodes are enclosed in a glass tube at such a distance apart that, at the voltage applied, the spark discharge will not pass, the conductivity is negligible. If now the gas pressure is gradually reduced, the spark discharge commences, but is not accompanied by as much noise as is the spark discharge at normal atmospheric pressures. As the pressure is reduced still further, the number of parallel paths in the discharge increases and the character of the discharge changes, passing through various distinct phases with the details of which we are not concerned. However, as the pressure is reduced down to below 0.1 mm. of mercury, the luminous effects disappear almost entirely, but conductivity still takes place. Still further reduction of pressure down to about 10^{-6} mm. of mercury enables a stream of bluish rays to be observed, apparently originating at the cathode. These rays are hence known as " cathode rays." It is noted that if the cathode is a plane, the rays proceed in straight lines normal to the cathode, quite independently of the position of the anode. Simple experiments indicate that the rays have the following properties :—

(1) The fact that an obstacle placed in the path of the rays casts a well defined shadow indicates that the rays travel in straight lines.

(2) The fact that an obstacle placed in the path of the rays becomes heated indicates that the rays carry appreciable energy.

(3) The fact that a magnetic field deflects the rays, just as if they were a flexible electrical conductor carrying a current towards the cathode, leads to the inference that the rays consist of a stream of electric charges.

(4) The fact that in an electrostatic electric field, the rays are deflected towards the positive deflecting electrode shows that the charge carried by the rays is a negative one.

These elementary properties of cathode rays are seen to be consistent with the theory that they consist of negatively charged particles. Further, in such a case the energy dissipated in heating an obstacle placed in their path, may be conveniently associated with kinetic energy due to the particles possessing appreciable mass.

We shall therefore examine the consequences of making this assumption as to the nature of cathode rays, remembering the whole time that it is merely a convenient way of explaining the facts so far observed and not necessarily a complete picture of the mechanism of the rays.

Let m be the mass of a particle in grams.
Let q be the charge carried by such a particle in coulombs.
Let v be the linear velocity of such a particle in cms. per sec.
Let V be the voltage between cathode and anode in the discharge tube.

Assuming that the speed of the rays is due to the accelerating effect of the voltage between the electrodes upon the charge carried by the particle, the energy acquired by the particle in passing from cathode to anode is $Vq \times 10^7$ ergs. Equating this value to the kinetic energy of the particle,

$$\tfrac{1}{2} m v^2 = Vq \times 10^7 \text{ ergs} \qquad (1)$$

Now let us suppose that the rays pass between two plates, parallel to the beam of rays, situated a distance d cms. apart, and across which is maintained a constant voltage E. While passing between the two plates, each particle is subjected to a uniform deflecting force $\frac{qE}{d} \times 10^7$ dynes perpendicular to its direction of motion.

Let us suppose further that the undeflected beam is moving parallel to the axis of X, and the deflecting force is acting along the axis of Y. By Newton's laws of motion, the acceleration f along the Y axis is given by the equation

$$\frac{qE}{d} \times 10^7 = mf$$

or $$f = \frac{q}{m} \cdot \frac{E}{d} \times 10^7 \text{ cms. per sec. per sec.}$$

If now we consider the deflection y sustained by a particle in the direction parallel to the Y axis, during a time t in which the distance travelled parallel to the axis is x, we obtain the following relations :—

$$x = vt$$

or $$t = \frac{x}{v}$$

$$y = \tfrac{1}{2} f t^2$$

$$= \tfrac{1}{2} \cdot \frac{q}{m} \cdot \frac{E}{d} \times 10^7 \times \frac{x^2}{v^2} \qquad (2)$$

and hence,

$$\frac{q}{mv^2} = 2 \cdot \frac{y}{x^2} \cdot \frac{d}{E} \cdot 10^{-7}$$

In commercial forms of cathode ray tubes which are used as oscillographs, a fluorescent screen is placed at the end of the tube remote from the cathode, on which the beam of cathode rays impinges and appears as a bright spot. Such a tube is shown diagramatically in Fig. **1** and an end-on view of the fluorescent screen is shown in Fig. **2**. The deflection of the spot produced by applying a voltage E to the deflecting plates is a measure of the value of y in this experiment. The values of x and d may be obtained directly from the dimensions and position of the deflecting plates.

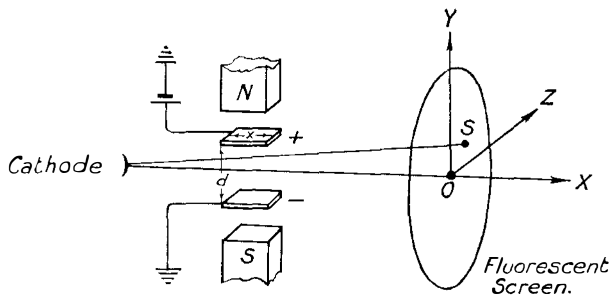


FIG. 1.—DIAGRAMMATIC VIEW OF CATHODE RAY TUBE.

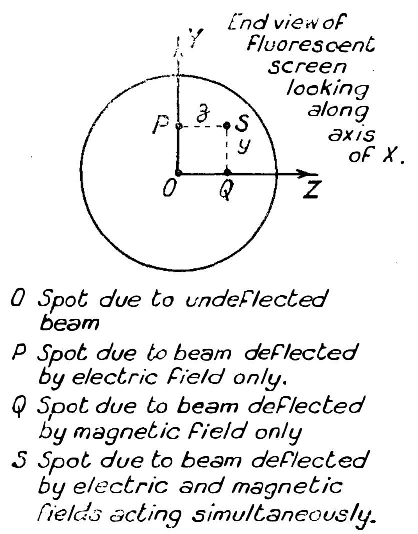


FIG. 2.—END VIEW OF FLUORESCENT SCREEN.

We may thus write $\frac{q}{mv^2} = K_1$

$$\text{or} \qquad \frac{q}{m} = K_1 v^2 \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

where K_1 is determined by the experimental observations.

Now suppose that in addition to the electrostatic field there is a magnetic field of strength H gauss also acting along the axis of Y. Under these conditions it is known that a moving charge is acted upon by a force mutually perpendicular to the direction of motion and to the direction of the magnetic field, that is, the deflecting force is along the axis of **Z**.

Let n be the number of particles per cubic cm. and A sq. cms. the cross section of the rays. Then the charge carried by the rays is $nAqv$ coulombs per second, which is equivalent to a current of $nAqv$ amperes.

A conductor of length l cms., carrying a current of i amperes in a magnetic field of strength H gauss is, by Ampere's law, acted upon by a force $F = Hil \times 10^7$ dynes.

In the case under consideration this is a centrifugal force constraining the particles to move in a circular path of radius r cms., and we have

$$F = \frac{Mv^2}{r} = HnAqvl \times 10^7 \text{ dynes}$$

where M is the total mass of the particles under consideration.

Now, it is clear that $M = nAlm$ grams.

We may thus derive the expression

$$HnAqvl \times 10^7 = \frac{nAlmv^2}{r}$$

$$\text{whence} \qquad Hqv \times 10^7 = \frac{mv^2}{r}$$

$$\text{and } \frac{q}{mv} = \frac{1}{\mathbf{H}r \cdot 10^7}$$

The value of r may be determined by the deflection suffered by the rays in the direction of the Z axis in a given longitudinal travel along the X axis, and the value of the magnetic field strength H may also be determined, hence we may write

$$\frac{q}{mv} = K_2$$

$$\text{or } \frac{q}{m} = K_2 v \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

From equations (3) and (4) corresponding to the electric and magnetic deflections respectively, the values of $\frac{q}{m}$ and v may be calculated.

To sum up, if we have a cathode ray tube provided with a fluorescent screen and the direction of the undeflected beam of cathode rays is along the X axis, the application of an electric field parallel to the Y axis will cause a deflection of the spot on the fluorescent screen parallel to the Y axis. The application of a magnetic field parallel to the Y axis will deflect the spot on the fluorescent screen in a direction parallel to the Z axis. These deflections are shown diagrammatically in Figs. **1** and **2**. The measurement of these two deflections enables the separate values of q/m and v to be calculated.

Experiment shows that the value of q/m remains substantially constant, while the value of v may be changed by varying the value of the discharge voltage V or by using a discharge tube of different dimensions; these variations are in accordance with equation (1).

The value of q/m obtained is found to be

$$1.77 \times 10^8 \text{ coulombs per gram.}$$

This ratio q/m is a constant of first importance as will be seen later.

The Conception of the Electron as a Particle.

The term " electron " originated in electrolysis, and was supposed to represent the quantity of electricity which, when passed through an electrolytic cell, would liberate one atom of a monovalent substance. Faraday's experimental laws of electrolysis lead to the conclusion that equal quantities of electricity will deposit equal numbers of atoms of a substance, and it is an experimental fact that 1 coulomb will deposit 1.045×10^{-5} grams of hydrogen.

If, therefore, the mass of the hydrogen atom is M grams, and q coulombs is the charge which will deposit it electrolytically,

$$\frac{q}{M} = \frac{1}{1.045 \times 10^{-5}} = 95{,}706 \text{ coulombs per gram.}$$

If we now identify the charge q associated with the hydrogen atom in electrolysis, with the charge q associated with the cathode ray particle, we may determine the ratio of m to M.

Taking the ratio of q/M to q/m, we obtain

$$\frac{m}{M} = \frac{1}{1840}\ .$$

On the assumption that their associated charges are equal, the cathode ray particle has a mass $\frac{1}{1840}$ that of the hydrogen atom, and it is this particle which is now identified with the term "electron."

In addition, according to well established principles derived from the kinetic theory of gases, the mass of the hydrogen atom, M, is 1.65×10^{-24} grams. From the measured value of q/M we thus deduce that

$$q = 1.58 \times 10^{-19} \text{ coulombs}$$

$$\text{and} \quad m = 9 \times 10^{-28} \text{ grams.}$$

It is essential to think carefully and clearly about these particles. It may be thought and indeed it appears to be commonly understood, that the measurement of mass, charge and velocity establishes that cathode rays are a stream of material particles. It should be clearly understood that this is not necessarily the case. In a previous article[2] by the author on the subject of Wave Mechanics it was seen how electrons may be diffracted and exhibit in many ways the properties of waves. Had this aspect of the electron been observed before the phenomena of deflection by magnetic and electric fields, the popular conception of the electron as a material particle might not have become so general. The phenomena we have discussed, in which experiments have lead to the determination of values which appear to be physical constants, having the dimensions of mass, electric charge and velocity, lead to the theoretical conception that these values may be properties of a material particle. It must be remembered that this is a theoretical conception and not a proven fact, but it is the way in which the idea of the electron as a particle arose.

The determination of constants which are consistent with the existence of material particles shows that the picture of an electron as a particle is a representation of at least one aspect, but not necessarily the whole story of the electron's properties.

It must also be remembered that in calculating the mass of the electron in terms of the hydrogen atom, one assumption has been made which still remains to be substantiated. It has been assumed that the charge associated with the hydrogen atom in electrolysis and the charge associated with the electron are identical. The justification of this assumption will be apparent from the experiment next to be described.

[2] Loc. cit.

The Direct Measurement of the Electronic Charge.

We now pass to an experiment, which, however great the practical difficulties, is delightfully simple in principle, and by means of which, Millikan measured independently of electrolysis and cathode rays the value of the electronic charge.

Millikan introduced oil spray into an experimental chamber containing two parallel horizontal insulated plates, and observed the motion of single oil droplets by means of a microscope provided with a calibrated eyepiece scale. When produced in a spray, these droplets are electrified by friction and one droplet may be kept under observation in the microscope almost indefinitely by allowing it to fall across the field of view under gravity and then bringing it back by applying an electric field in the appropriate direction between the two insulated plates.

Let m be the mass of the droplet in grams.

This value can be estimated from its size as observed by the microscope together with a knowledge of the density of the oil in bulk.

It can be determined more accurately by observing the rate of fall under gravity, and making use of a known relation, known as Stoke's Law, between the mass, the velocity of fall and the viscosity of the gas. Stoke's Law may be verified experimentally by using particles of known mass.

Let q be the charge carried by the droplet in coulombs,

and E the strength of the applied electric field in volts per cm.

Then the force acting on the particle due to the electric field $= Eq \times 10^{7}$ dynes.

If the value of E is adjusted so that the particle remains stationary, we have

$$Eq = mg \times 10^{-7} \text{ and } q = \frac{mg}{E} \times 10^{-7} \text{ coulombs}$$

where g cms. per sec. per sec. is the acceleration due to gravity.

In these experiments the value of q varied from one droplet to another, but was always an integral multiple of 1.59×10^{-19} coulombs, the smallest value of charge observed being 1.59×10^{-19} coulombs. It is seen that this value agrees very closely with the value obtained from experiments in electrolysis.

No smaller value of electric charge has ever been observed, or appears to be associated with any known phenomenon, and accordingly it is believed to be the fundamental unit of electricity. According to the earlier history of the subject, this fundamental unit was, as we have seen, given the name electron. In the light of modern knowledge, however, it is necessary to distinguish between two ideas which are commonly confused, namely,

(1) the existence of the elementary charge or atom of electricity,

(2) the association of this elementary charge with material particles.

In electrolysis experiments and those with oil drops, the association of the elementary charge is with a relatively large material particle, the atom or the oil drop, and the presence of any mass which is a thousand times or more smaller than these particles is not evident. In cathode ray experiments it is evident that a definite mass of very small value is associated with the elementary charge, and indeed when charges are in motion they always appear to have mechanical inertia and a definite, if small, value of mass is associated with them. It appears, therefore, that the elementary charge is only one aspect of the conception known as the electron, and the association of a definite mass with the charge is a consistent assumption.

The Mass Spectrograph.

The determination of the value of q/m for cathode rays and the independent determination of the electronic charge by Millikan, form the basis of Atomic Physics and the methods used in these experiments may be used to explore the subject still further. In particular many of the phenomena encountered involve the appearance of beams of energy which may or may not be conveniently considered to be a stream of particles of nature similar to cathode rays. In order to investigate the properties of such beams we may make use of an instrument known as the mass spectrograph. This device was used by Aston for the analysis of a particular form of discharge tube phenomenon known as "positive rays." As, however, its principle is applicable to any stream of charged particles it is proposed to discuss it from the general point of view.

As its name implies it is an instrument which distributes the charged particles into a spectrum by giving each particle a dispersion proportional to its mass. When the ordinary spectrograph of optics is utilized to analyse light, the beam under consideration is arranged to be incident to a prism or diffraction grating which disperses the beam. The dispersion in this case depends upon the frequency, and the resulting spectrum observed is a frequency spectrum. In the case of the mass spectrograph the means utilized for dispersing the beam of particles discriminates between particles of different masses in such a way that the resulting spectrum is a mass spectrum. The lightest particles all impinge upon one end of the screen or photographic plate placed to receive them in the path of the dispersed beam. The heaviest particles impinge on the other end, and between these two extremes the particles of intermediate mass fall. This is very convenient in the case of particles consisting of ions or charged atoms, because the particles are arranged in the spectrum according to their atomic weights and the ratio of these atomic weights is immediately obtainable.

Actually the principle of the mass spectrograph has already been applied in the measurement of q/m of cathode rays.

Referring to equation (2), the deflection suffered by a particle in the electric field depends on the value of q/m and v^2. If the stream contains particles carrying equal charges but of varying mass and velocity, instead of a single point on the fluorescent screen of the tube, a number of points will appear corresponding to different values of m and v^2. The beam will have suffered dispersion. By suitable arrangements of electric and magnetic fields acting together, it is possible to arrange that the dispersion of the beam due to difference of velocities is eliminated and a spectrum obtained on the fluorescent screen, each line of the spectrum corresponding to a different value of mass. By means of equations (2) and (3) the actual deflection corresponding to particles of different mass may be calculated and a scale constructed from which the masses corresponding to any observed spectrum line may be observed.

The principle of the mass spectrograph can be applied to determine the nature of any beam of rays which is encountered experimentally. If the mass spectrograph disperses the beam it may be reasonably postulated that it consists of charged particles whose mass may be computed. If the beam is undeflected by the mass spectrograph, it may consist either of (1) charged particles, whose energy is so high that the deflection is inappreciable, (2) particles carrying no charge, or (3) photons. The identification of these particles necessitates the development of additional experimental technique which we shall proceed to consider in the next article.

Copper Wire Manufactured from Fire-Refined Copper

In the past, electrolytically-refined copper has been used exclusively for wire for Post Office purposes. Supplies are now available, however, of copper prepared by a fire-refining process in which the percentage of impurity present has been reduced to the order of that found in electrolytic copper. Samples of wire drawn from fire-refined copper which have recently been tested, indicate that further improvement has been made in the quality of the material during the past year. Fire-refined copper from two sources is now considered to be quite suitable for use as annealed wires, and merits consideration for use in hard-drawn wires.

The Post Office Circuit Laboratory

R. W. PALMER, A.M.I.E.E.

A brief history of the Engineering Department's Circuit Laboratory is given and its functions and organization are described

Introduction.

A DESCRIPTION of the early days of the Post Office Circuit Laboratory, which was at first combined with the Automatic Training School, was given in the *Post Office Electrical Engineers' Journal* in July, 1925, but both of these very young organizations have since grown in size and importance as a result of rapid advances in the telephone art, and recent developments in the Training School have already been described in this Journal in July, 1934. Although the laboratory has remained in King Edward Building it now has better accommodation (Figs. **1** and **2**), an enlarged staff and improved testing facilities as compared with the first years of its existence, and some insight into its present organization and functions may therefore be of interest, not only to those to whom the Post Office Circuit Laboratory is merely a name, but also to those who come into contact with it in one way or another in the course of their official work.

Fig. 1.—The Main Apparatus Room.

The Functions of the Circuit Laboratory.

The need for a Circuit Laboratory was felt as early as 1922 when the Post Office was embarking on an extensive programme of conversion of telephone exchanges to the automatic system, since this involved the making of rapid critical tests of an exceptional number of selectors and relay sets, the circuits of which were being newly designed by the five Telephone Manufacturers as well as by Post Office development engineers. The Engineering Department already possessed the necessary facilities for judging the proposals on paper, but the Circuit Laboratory was introduced in 1924 to cover the practical side of this new problem.

Since the theoretical and practical sides of circuit design and of other development work must be kept in intimate contact on a day-to-day basis, the development engineers must have easy and rapid access to the apparatus under test or under discussion. The Post Office Circuit Laboratory is, therefore, situated adjacent to the Headquarters offices and is so organized that development engineers (and also Headquarters' maintenance engineers in a similar capacity) are free to give direct instructions to the laboratory and to co-operate actively in the tests, and, what is perhaps of greatest importance, the test results are communicated with a minimum of

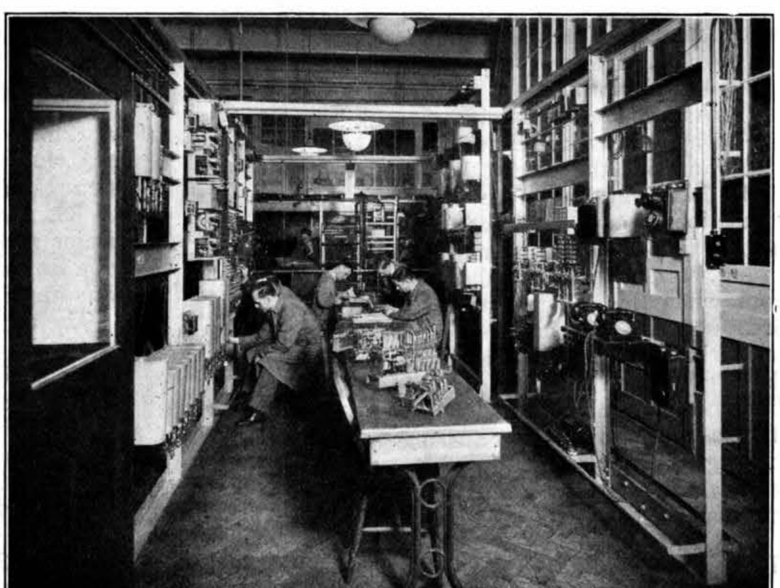


Fig. 2.—The Annexe.

formality and without delay. Another important characteristic of the Post Office Circuit Laboratory is the absence of original development work : that is to say, it does not originate new lines of development, and its function is to provide practical test results and constructive criticism (and occasionally destructive criticism) on apparatus or circuits developed by other organizations. These test results frequently lead to further development by circuit or apparatus engineers or by contractors, either during or after the completion of any series of tests, and sometimes the criticisms point to the need for research on new lines by the separate Post Office organization devoted to this class of work.

The work that is being carried out by the Post Office Circuit Laboratory relates not only to automatic telephone exchange equipment, but also to other apparatus which is either similar to or is required to work in conjunction with telephone switching equipment, such as, for example, subscribers' apparatus, trunk signalling, telegraph switching, and miscellaneous circuits using telephone type relays. The nature of the work falls under the following broad headings :—

(1) Testing of circuits developed by the Post Office.
(2) Assembly of models of circuits for such tests.
(3) Testing of circuit models submitted by contractors.
(4) Brief testing of circuit elements as required by circuit designers.
(5) Demonstrations of facilities, lay-out, accessibility, etc.
(6) Test and criticism of new developments from the "practical" point of view.
(7) Measurement of time lags and similar operating characteristics.
(8) Tests of proposed maintenance adjustments of various apparatus.
(9) Investigation of special maintenance troubles in telephone exchanges.
(10) Assembly, test, or overhaul of special routine testers, acceptance testers, and other exchange testing equipment of a unique or novel character.
(11) Assembly or modification of experimental apparatus for field trials or other experiments outside the Circuit Laboratory.

The tests are therefore mainly concerned with "functions" or "performance" and they naturally include simple measurements of current, impedance, timing, etc., and also the checking of physical dimensions when this affects performance or adjustment. Great stress is laid on the tests being of a practical nature in all cases and this is reflected in the use of skilled workmen for the actual tests and in the conditions under which tests are made, (Figs. **2** and **3**). It also accounts for the absence of equipment for making chemical, metallurgical, acoustic or other tests which are more proper to research laboratories and staff.

History and Development.

The introduction of the Post Office Circuit Laboratory was due to the foresight of Mr. B. O. Anson in 1922, and excellent pioneer work was carried out by Mr. F. I. Ray. It started on the 1st October, 1924, with a staff of three (one Assistant Engineer, and two Inspectors), and it shared an Executive Engineer with the Training School. To this nucleus was added a Skilled Workman Class II in the following month, and the type of work carried out by this small band of workers immediately created its own demand, so that at the end of the first year the number of minor staff had grown to 11, and the number of Assistant Engineers had increased to three. At the end of the second year the total staff had grown to 31, including nine officers on the major staff, and after this the advantages of using skilled workmen, suitably trained for the practical testing work, were fully realized, and there began a steady increase of total staff to the present figure of 85, accompanied by a much smaller increase of major staff to the present figure of 15. An Executive Engineer, exclusively for the Circuit Laboratory, was appointed in 1935.

FIG. 3.—TESTING AUTOMATIC EQUIPMENT ON THE RACKS.

The accommodation available for laboratory work was originally part of the Training School Demonstration Room, and in the days when models of automatic apparatus were scarce and were being developed with great rapidity, there were outstanding advantages, both economic and technical, in sharing the standard selector trains with the Training School. The growth of laboratory investigations soon necessitated a separate corner for the experimental work, and in 1929 an additional 3,500 sq. ft. of floor space was equipped specially for experimental work. The life testing of automatic apparatus which had been introduced in 1927 was at this time accommodated in a separate laboratory in the basement, but this was transferred to the Research Branch in 1931, as it had grown to such proportions as to be outside the normal scope of circuit laboratory work. It was at this time (1931) that the Training School and Circuit Laboratory parted company, the former being transferred to Dollis Hill to co-ordinate the various Post Office technical training courses in telephone and telegraph subjects, but by this time the laboratory was already self-contained to a very large extent and the additional plant required as a result of the withdrawal of the Training School equipment was not serious. This factor, however, together with the steady growth of work, necessitated a further increase to the present total floor space of approximately 7,400 sq. ft.

Circuit Laboratory tests have always been conducted on standard rack mountings and under conditions simulating those of a working telephone exchange as far as possible, and to this end an assembly and wiring shop was gradually developed for the purpose of making " commercial " models of circuits, properly mounted and wired, ready for jacking on standard racks. One result of this policy has been the utilization of laboratory models of special routiners, etc., for subsequent installation on site, and this has produced savings in installation time and in the nett costs of the experimental work. Speed in setting up models was found to be essential, and therefore, a comprehensive stock of Strowger relay parts was held for the assembly of almost any relay design within a few hours. This assembly organization also covered selectors and uniselectors to a lesser extent, and as early as 1928 it was so efficient that for three years the laboratory carried out all of the repair and replacement work on relays and switches for the London automatic exchanges until similar organizations under the Central Normal Stock Scheme could be introduced. The Relay Assembly Group is still actively engaged on experimental work, since it now deals with 3000 type relays as well as Strowger relays, and its services are frequently engaged in connexion with investigations and field trials conducted by other branches of the Engineer-in-Chief's office. The calls for assistance in connexion with experimental work outside the Circuit Laboratory have increased considerably during recent years, and this has necessitated the introduction of an office recording procedure whereby such cases of assembly and wiring are given a C.L.W. number (" Circuit Laboratory Works ") and are kept quite separate from the local work of making circuit models for subsequent test in the laboratory. One special department of this C.L.W. work is the maintenance and periodic overhaul of the Acceptance Testers used by the Equipment Branch before the opening of new exchanges. These testers are of a unique character and the centralized overhaul in the Circuit Laboratory is considered to be essential in view of the important decisions which have to be made as a result of their use.

Present Organization.

Under normal circumstances tests on about 90 circuits are in various stages of completion at any one time and this load is divided among 18 testing groups who carry out the practical testing work. Each testing group consists of a Skilled Workman Class I and an assistant, and the work of the groups is directed by seven Testing Inspectors. Specialization in various classes of apparatus is arranged among the Inspectors, but the wide fluctuation in the demand for C.L. tests and the variety of equipment to be tested is so great as to prohibit any rigid classification of duties either among the Inspectors or among the testing groups. Although the Inspectors are all specialists on some particular subject, reliance is placed on team work among the staff and on the pooling of the knowledge and experience of individuals, and a further aid to flexibility is the frequent movement of the minor staff from one Inspector to another to cope with sudden demands of work. As a result of this the number of testing groups controlled by one Inspector varies from two to three (and occasionally beyond this range) according to the circumstances prevailing. A total of 15 Youths in Training is normally maintained and they are attached to the various testing groups in turn, except when they are away on Training Courses at Dollis Hill or attached to the London District for exchange experience. The movements of staff to the various duties are so numerous that the Staff Trees used locally are constructed with label holders and engraved labels so that the prevailing distribution of staff can always be shown.

The day to day organization of the work and personnel and the checking of test results is in the hands of an Assistant Engineer and a Chief Inspector who are responsible to the Executive Engineer in charge. The number of investigations completed is approximately 30 per month, varying from the timing of sample relays to the complete test of a Line Finder assembly, and it is exceptional for any case to be delayed more than two or three weeks before commencement of tests. In fact, an important phase of the laboratory work is the urgent treatment of small investigations often concerned with the maintenance of apparatus already in service, or with Advice Note cases, and these tests are carried out as far as possible on a " same day " service. These and other tests are commonly carried out on site, for which purpose particular attention is paid to the portability of testing equipment. Another speciality is assistance in times of emergency, both in fault finding and in the provision of apparatus for the restoration of public service and rarely does a week pass without a request by telephone for an urgent job of some kind or another, often at a few hours' notice. It is of no concern to the caller how it is that the necessary staff appears like magic, and no questions are asked as to how apparatus that is normally unobtainable at short notice is produced without delay. That is just part of the Circuit Laboratory service, but that service is dependent not only on flexible organization, but also on the adaptability and resourcefulness of every member of the staff.

The type of information required on any sample apparatus is indicated by the officer originating a C.L. case, but the method of making the actual tests is usually arranged by the Inspector detailed for the work and then the responsibility for observing irregularities during the tests is with the Testing Group staff. The experimental data so obtained is entered by the Skilled Workman Class 1 in a record book, and from this information the reports are normally prepared by the Inspector. The publication and circulation of a comprehensive C.L. Report on the completion of each case has been largely superseded by the issue of one or more Test Reports during the progress of the work. Only one copy of each Test Report is normally sent out, this being addressed to the orginator of the case, and it is therefore possible to omit all descriptive matter and to express the essential information briefly and concisely. By this means the amount of editorial work in the laboratory is cut down to a minimum and the originator of the case is able to have a succession of typed reports of test results within a few days of the completion of each test. Each report bears a serial number following the C.L. case number, this suffix indicating the number of Test Reports issued on the particular subject concerned, *e.g.*, " C.L. 1697/3." The progress of all current cases is reviewed at a conference of the major staff at the beginning of each month and a decision is then taken as to which case numbers may be closed without the publication of a comprehensive C.L. Report.

FIG. 4.—THE GENERAL OFFICE.

The " Common Services " in the Laboratory, including Stores, Wiring, Relay Assembly and Acceptance Testers groups are under a separate Inspector who controls a staff of approximately 20 skilled workmen and labourers. The size of this staff is frequently varied by interchanges with the testing staff in order to cover fluctuation of loads. Approximately 80 items of work (C.L.W. cases) for outside organizations and an equivalent number of experimental jobs for the laboratory itself are completed each month, this work varying from the assembly and adjustment of a single relay to the overhaul or construction of a large tester, and an additional function of this organization is the maintenance of the racks, power plant, and other common services for the Laboratory. The maintenance of testing instruments is separate from the " Common Services " organization and is covered by one of the testing Inspectors who is a specialist in the use of the oscillographs and other instruments of a special nature. Testing instruments are normally held in the common Stores, and the Stores organization also controls the movements of all " plant " items and samples, as well as the issue of day to day materials and small stores for use on the experimental work.

The work of the office (Fig. 4) covers mainly the planning of tests, the study of experimental results and the preparation of reports. There is also the accounting work for stores transactions for which purpose the laboratory holds the equivalent of Section status, the work being carried out by a Clerical Officer. There are also two Clerical Officers and a Writing Assistant who deal with a considerable volume of staff work which is rendered more complicated by the constant movements of the personnel to meet the fluctuations of load, and these officers also deal with the general office procedure and the maintenance of records.

Equipment and Facilities.

The present value of permanent plant held for the use of the Circuit Laboratory is approximately £15,000 and this covers racks, telephone equipment and testing instruments, but excludes a large quantity of samples held on loan. The racks are arranged round the Apparatus Room in a single line approximately 200 ft. in length and facing inwards, as seen in Fig. 1. Semi-indirect lighting is used for general illumination, but this is supplemented where necessary by local lighting mounted on long brackets with universal joints. The racks are equipped with selector and relay set shelves, which are quickly and easily detachable so that they can be varied to meet the requirements of any experimental assembly. It is a standard principle that not only selectors and relay sets, but also telephone instruments, models of manual cord circuits, lamps, keys, etc., should be mounted as far as possible on the standard jacked-in base plates to facilitate mounting on the racks and to enable assembly or subsequent modifications to be carried out on a " unit " principle with neat shelf wiring.

Apart from the racks for the accommodation of samples of individual selectors or relay sets, space must always be held ready for larger items such as P.A.B.X. units and switchboards, U.A.X. units, and, in some cases, special racks assembled by a contractor complete with experimental equipment already wired up. Round the outer walls, and also in the centre of the apparatus room, are benches or tables for general work on equipment which has been temporarily jacked out from the racks (Fig. 5), and these tables are also used by the testing staff for writing up notes. The benches are also used for experiments such as on U.A.X. power plant, subscribers' extension circuits, and other apparatus which is not suitable for rack mounting.

Fig. 5.—Adjustments and Writing-up Notes.

The common power plant is immediately adjacent to the laboratory racks in order to reduce the voltage drop on the leads, and consists of two 52 V. 300 Ah. main batteries and a small booster battery for special work, together with the usual charging facilities. A number of tappings from the main batteries is brought out to a jack field on the main power board for the purpose of adjusting voltages on the power cables to the laboratory racks, the normal connexions being completed by U-links, and special connexions being effected by means of heavy gauge flexible conductors. For purposes of power distribution, the apparatus room is divided into four equal parts, and separate power cables are normally fed from the battery tappings at 22, 40, 46, 48, 50 and 52 volts to each of the four parts. These cables are terminated on 23 local distribution panels mounted on the laboratory racks, as seen in Figs. 3 and 5, and each local panel has rotary switches, enabling any of the power cables to be picked up as required. The rotary switches are in triplicate to enable three different voltages to be in use simultaneously on any one rack, and local fuses are provided at this point in addition to the main fuses in the power cables at the main power board. It has been remarked that facilities exist on the main board for varying the voltage on any of the power cables, but in addition to this it is often convenient to use portable counter E.M.F. or booster cells at the racks. An important addition to every local power panel is a permanent voltmeter which enables a constant watch on the supply voltage to be maintained during any critical tests, and there are also standard supervisory lamp circuits on every rack to simulate exchange conditions of operation. Supplies of ringing current, voice frequency current, tones, and standard time pulses of various kinds are fed to the racks with adequate facilities for rapid localization of faults, and a system of inter-rack junctions is also provided for general use, together with a separate series of junctions direct to the oscillograph table.

An electromagnetic oscillograph (3 elements) manufactured by the Cambridge Instrument Company, is permanently situated in the centre of the laboratory and is equipped with both drum and continuous film cameras. The instrument has been adapted in several respects to meet the special requirements of the laboratory, and has an electrically controlled tuning fork which gives a transverse line across the oscillogram every 10 milliseconds. There is also a cathode ray oscillograph (S.T. & C.), the auxiliary equipment for which is made up in small portable units, making it particularly suitable for field work. Direct visual observation is assisted by a " time base " unit which automatically holds stationary the wave form of impulses at frequencies as low as 10 i.p.s., and a cathode ray tube having an " after glow " of several seconds is employed for direct observation of transient operations. For permanent records a separate continuous film camera can be coupled up with the oscillograph in a few seconds, and this camera has recently been adapted by the Circuit Laboratory for automatic exposure of a series of oscillograms such as for the investigation of irregularities in time pulses, etc. A dark room equipped with the usual facilities is of course a necessity, and this is in one corner of the laboratory in order to be easily accessible. It contains an automatic print drier and other equipment to meet the special requirements of oscillograph work, and, because of the large number of oscillograms taken, a simple system of numbering the oscillograms is employed in conjunction with a record of the electrical conditions under which each picture is taken. In addition to the oscillographs, which are normally operated jointly by an officer in the " Oscillograph Group " and an officer directly concerned with the technical investigation, there is a selection of testing instruments available for the common use of the Testing Staff, and this includes high grade measuring instruments, bridge networks and a range of timing instruments, such as millisecond meters, impulse ratio testers and impulse frequency measuring devices. Three pulse machines generating impulses of any frequency or ratio, and in trains of any number of digits, are mounted on trolleys for use in any part of the laboratory, and these are separate from the standard 10 i.p.s. impulses which are provided as part of the common services fed to all racks.

The Relay Assembly Shop is equipped with stocks of relay and switch parts, assembly jigs, adjusting stands with a universal mounting, current testers and a comprehensive file of relay adjustment and piece-parts data. The wiring shop (Fig. 6) covers a wide range of work for which it is supplied with all facilities for assembly and wiring of single items of equipment of any size from small relay groups to complete rack assemblies, and the special experience and facilities of this organization have been utilized on occasion for such divergent requirements as exhibition " stunts " and remote control equipment for Portishead Radio Station. An auxiliary of the wiring shop is an iron-workers' bench, used by tradesmen-fitters loaned by the London Engineering District as and when required in connexion with small experimental construction work such as testing stands or rack equipment.

Not the least important of the laboratory equipment is the Mess Room, which, though small, is at least able to provide the essential cup of tea; but of all the facilities and equipment of the Circuit Laboratory the greatest is the enthusiasm and the team spirit which exists among the staff. The policy of " The Lab " (as it is affectionately known) is just " Personal Service," and the greatest pleasure of the staff is in getting a job done well, and on time.

FIG. 6.—PART OF THE ASSEMBLY AND WIRING SHOP.

Lead Alloys, Suitable for Cable Sheaths

Among the more recently developed lead alloys which are suitable for extrusion as cable sheaths, is one containing 0.06% tellurium. This small addition causes the material to be definitely stronger and more resistant to mechanical fatigue than pure lead. It is not so good in this respect as some of the other alloys, notably the 0.85% antimony alloy and 0.5% antimony, 0.25% cadmium alloy which have been used for submarine cables. It has, however, the advantage over these that it is less likely to develop local weaknesses at points where the sheath is held up in the lead press during extrusion.

Standards of Length

GEO. F. TANNER, M.I.E.E.

The article briefly describes the fundamental apparatus necessary for the establishment of effective size control in a modern engineering works producing a multiplicity of similar parts, such as are employed in the equipment of telephone exchanges.

General.

NO measurement is absolutely correct. The question that arises is :—To what degree of accuracy, or how inaccurate can a component be made, to function properly? The answer is that the limit of error permissible in each case must be stated; this is known as the " tolerance."

To the engineer there is no more important factor than accuracy in length, for in one way or another it directly controls all the other physical agents that are harnessed to do his will. It may, indeed, be said with truth that the degree of success or perfection of all constructive effort largely depends upon the accuracy with which length is measured.

In any large engineering concern there must be some system of size control, for if the measuring system is faulty then it is not possible to give to the workshop the full advantage of the tolerance which might otherwise be allowed. Fundamentally this control consists in the provision and maintenance of a comprehensive system of gauges and length standards. With these gauges and standards all the tools used in the workshops are checked at regular intervals.

Slip Gauges.

The " Slip Gauge " may be regarded as the starting point of control. Slip gauges are rectangular steel blocks, each block having two opposite faces ground and lapped to the highest order of accuracy, both as regards flatness and parallelism. Owing to the perfect flatness of the lapped faces, a number of slips can be made to adhere by the simple process of sliding the cleaned faces of the blocks against one another. This is known as " wringing action."

Slip gauges are made by specialists who employ precision tools for the purpose. They are made in definite serial sizes, as for example

0.1001″	to 0.1009″	in	steps	of 0.0001″	9	Blocks
0.101″	,, 0.109″	,,	,,	,, 0.001″	9	,,
0.11″	,, 0.19″	,,	,,	,, 0.01″	9	,,
0.1″	,, 0.9″	,,	,,	,, 0.1″	9	,,
1″, 2″, 3″, and 4″		,,	,,	,, 1″	4	,,

Any size can be built up, *e.g.*, if 3.2795 inches is required, it is produced as follows :—

0.1005″
0.109″
0.17″
0.9″
2.0″
———
3.2795″
———

Wring the first two 0.1005″ and 0.109″ together, then in turn the 0.17″, 0.9″, and the 2″ slips. By this means the size has been built up to a very high degree of accuracy and can be used for checking a length or gap gauge, or for any other purpose desired.

An example of wringing action and proof of the extreme accuracy of slip gauges is shown in Fig. 1

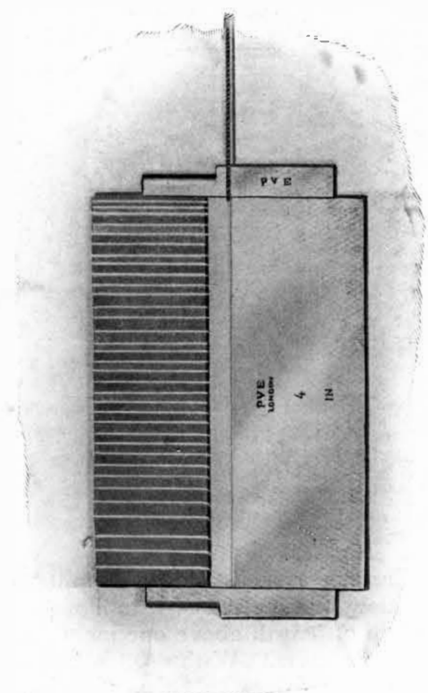


FIG. 1.—PILE OF SLIP GAUGES SUSPENDED BY CORD, DEMONSTRATING " WRINGING ACTION."

where 35 gauges, whose total length equals 4″, are wrung together and are bridged across to a 4″ standard by means of two blocks having flat faces. The suspension is achieved merely by wringing action. A difference of 10 millionths of an inch between the 4″ standard and the 35 gauges would have made the test impossible.

Slip gauges expand or contract with an increase or decrease of temperature. It would not be practicable to have such measuring appliances made of a material which had a negligible coefficient of expansion, as it is necessary when making measurements (at other than 68°F. or 20°C.) that the slip gauges and the article being measured both expand at practically the same rate.

Slip gauges are made from high grade carbon steel of special manufacture. They are hardened throughout and put through a process to relieve all hardening strains.

They are usually made to one of three degrees of accuracy as follows :—

Type 1. *Reference.*
- In English units. Within 2½ millionths inch below one inch and 2½ millionths inch per inch above one inch. Standard temperature 68°F.
- In metric units. Within 0.00006 mm. below 25 mm., and within 2½ parts in a million for a length over 25 mm. Standard temperature 20°C.

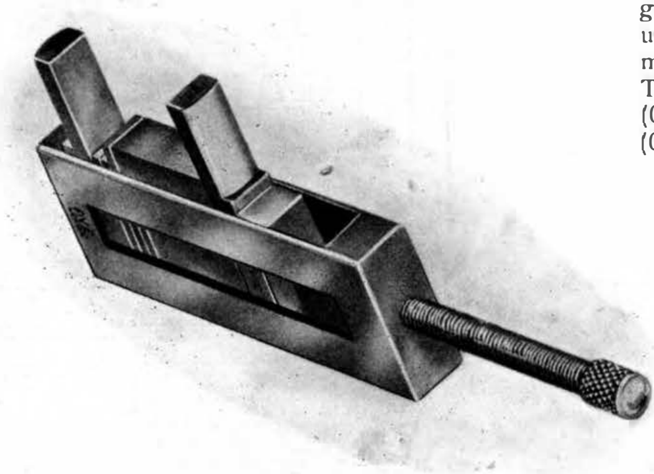


FIG. 2.—SLIPS AND JAWS ASSEMBLED IN HOLDER FOR INTERNAL OR EXTERNAL MEASUREMENT.

Type 2. *Inspection.*
- In English units. Within 5 millionths inch below one inch, and 5 millionths inch per inch of length above one inch.
- In metric units. Within 0.00012 mm. below 25 mm., and within five parts in a million for length over 25 mm. Standard temperature 20°C.

Type 3. *Workshop.*
- In English units. Within one hundred thousandth inch below one inch and one hundred thousandth inch per inch of length above one inch.
- In metric units. Within 0.00024 mm. below 25 mm., and within one part in a hundred thousand for length over 25 mm. Standard temperature 20°C.

Type 3 is adopted by the Post Office as the standard for checking of the sub-standards, gauges, and instruments used in the inspection and examination of apparatus and tools.

Many measurements are made with slip gauges alone; it is, however, convenient to have other accessories for use with them. For example, Jaws may be used to convert slip gauges into Gap, Ring, or Plug gauges. The jaws may be wrung on to the slips, but frequently holders are used as shown in Figs. **2**, **3** and **4**.

Limit Gauges.

For checking the product of the workshop, " Limit Gauges " are in common use. They are known as " go " or " not go " gauges and are designed to give the maximum and minimum sizes for a given component. It is sometimes convenient to have them adjustable so that they may be set to slip gauges. Fig. **5** depicts a typical gauge.

Standard Bars. (Fig. **6**).

These are used for reference purposes only. Workshop bars are slightly less accurate, but greater liberty may be taken in their use without undue hazard to their accuracy. Standard bars are made to an accuracy of at least 2½ parts in a million. Their end faces are flat to within 0.000005" (0.0001 mm.) and parallel to within 0.00001" (0.0003 mm.).

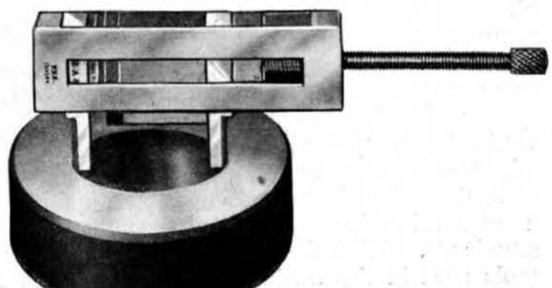


FIG. 3.—TESTING SIZE OF RING GAUGE WITH SLIPS AND JAWS.

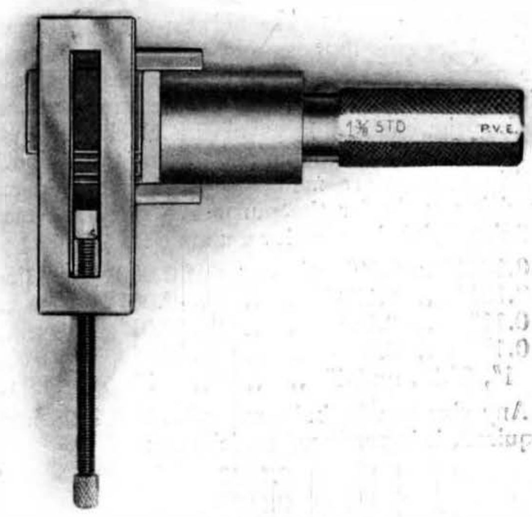


FIG. 4.—TESTING SIZE OF PLUG GAUGE WITH SLIPS AND JAWS.

The bars usually have two raised portions, termed nodal bands. These bands give the correct support for each bar when used in a horizontal position,

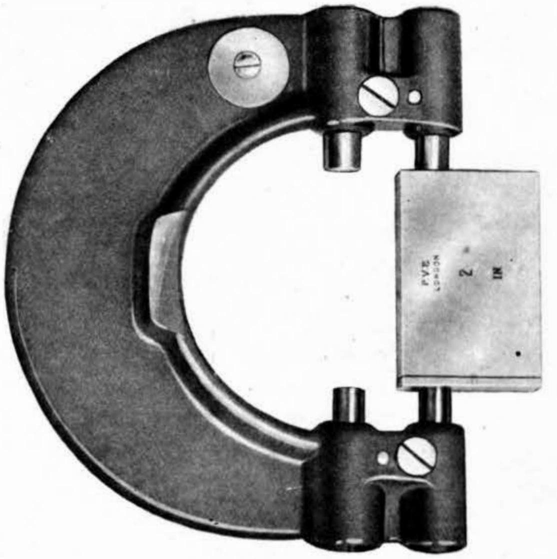


Fig. 5.—Setting adjustable Limit Gauge with Slips.

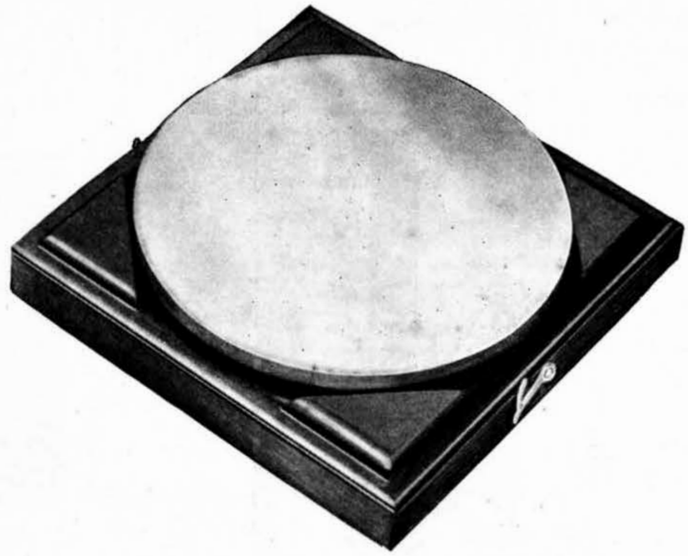


Fig. 7.—Toolmaker's Flat in Steel, hardened, ground and lapped.

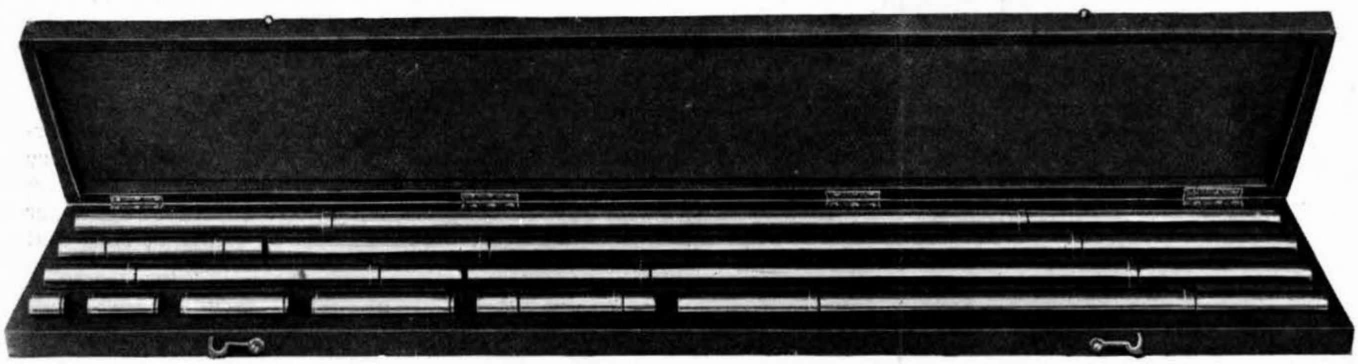


Fig. 6.—Standard Reference Length Bars.

e.g., in a measuring machine, and are of equal size to within 0.0001″ (0.003 mm.). When supported at these points, the end faces are parallel with one another. Any other points of support would cause the faces to be inclined to one another due to natural flexure.

Standard bars are used only for the highest grade work, as first standards, and for testing combination workshop bars or secondary standards. In the case of dispute, such standards with a N.P.L. certificate of accuracy would be accepted as final.

High Precision Surface Plates.

For the purposes of the highest accuracy in tool and gauge measurement, particularly for comparison work, it is essential to have a truly flat surface. A 5″ or 8″ diameter plate will be found to meet most requirements. These plates are of steel, hardened, ground and lapped and should be accurate to ±0.00001″. Larger sizes are usually of close-grained cast iron and require to be of more rigid design. The steel plates have both faces lapped and are parallel to ±0.00001″. They should be finished so that slip gauges will " wring " on to the surfaces. Fig. 7 shows a typical toolmaker's flat in steel.

Wall and Bench Type Generator Comparators.

These are precision machines for comparing vertical heights. They are useful for comparing work against standards or for checking standards against each other. They combine in one apparatus an accurate surface plate, and a precision level and scale, which allows any differences of length within the capacity of the machine to be read direct in units of one hundred thousandth of an inch, and by estimation to a millionth of an inch. A typical machine is shown in Fig. 8.

Optical Flats.

A simple means of ascertaining the flatness of slip gauges, micrometer anvils and other lapped surfaces is by means of " Optical Flats." (See Fig. 9). These are cylinders made from a very fine grade of glass. They are approximately 2″ in diameter and ⅝″ thick. Both surfaces are truly plane to the order of 0.000005″. Uneven wear or scratches or burrs, of slip gauges, length bars or other gauges, may be detected by bringing the face of the flat in contact with the surface to be tested and observing the interference bands or fringes through the glass. If the surface is truly flat, the interference lines will be

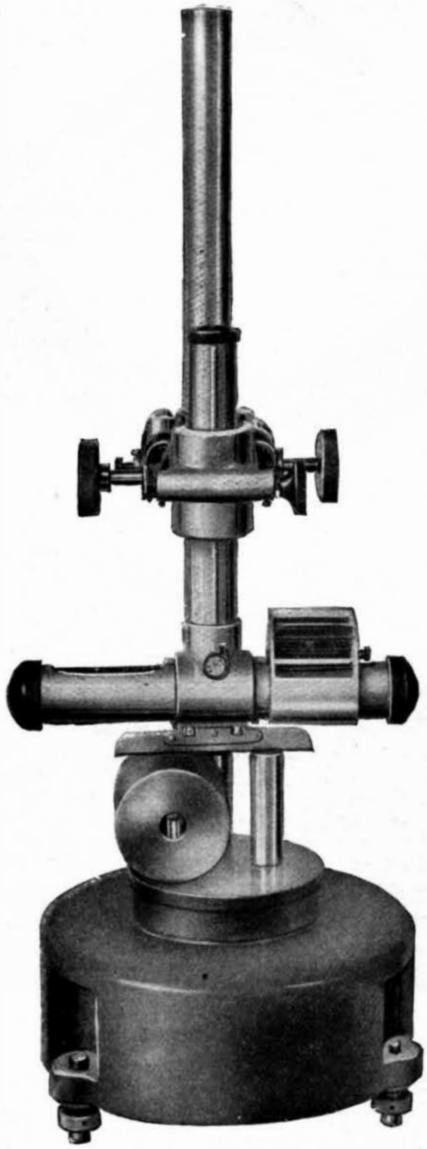


Fig. 8.—Bench Type Generator Comparator comparing Cylinder against Length Standard.

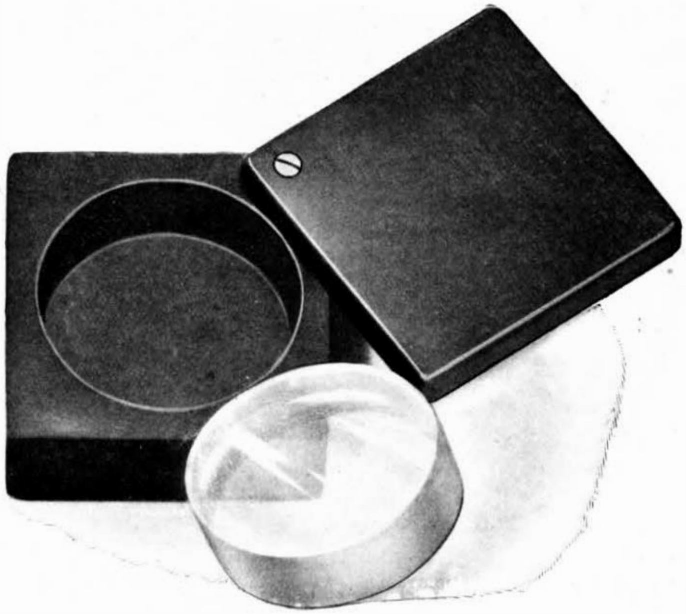


Fig. 9.—Optical Flat for Testing Surfaces of Slip Gauges, etc.

straight and parallel, but if it is round or hollow, the bands will be curved and irregular, thus forming a map of the contour of the surface under inspection.

Scratches on the surface of an optical flat will not impair the accuracy as they do not raise a ragged edge, but they tend to make observation more difficult.

Flats may be obtained singly, but a set of three is often purchased together as they may be tested among themselves for flatness.

Diameter Measuring Machines.

These machines are designed to measure the diameters of screw or plain cylindrical plug gauges or other work. They are probably more often used as comparators, and in such cases it is necessary to calibrate by means of slip gauges of approximately the size of the work to be tested. By this method it is possible to estimate readings on the micrometer to $\pm 0.000025''$.

The machine consists essentially of a base, intermediate slide and a top slide or carriage. The base is a casting with brackets for the work-holding centres and two vee grooves are ground in the upper part of the base. From Fig. 10 it will be seen that

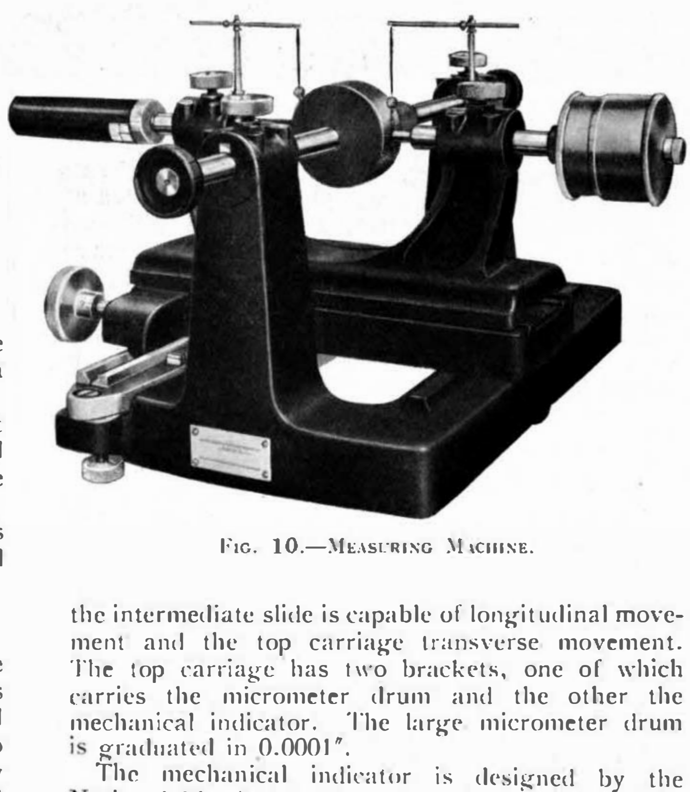


Fig. 10.—Measuring Machine.

the intermediate slide is capable of longitudinal movement and the top carriage transverse movement. The top carriage has two brackets, one of which carries the micrometer drum and the other the mechanical indicator. The large micrometer drum is graduated in 0.0001″.

The mechanical indicator is designed by the National Physical Laboratory. The purpose of the indicator is to provide a moveable anvil, the displacements of which are magnified with reference to a fiducial line and also to enable operators to obtain repetitive results. The magnification of the displacement of the anvil is obtained by a two stage system of levers giving a ratio of approximately 250 : 1 which gives 0.025″ movement of the point of the needle for a movement of 0.0001″ of the anvil. On some machines the magnification is obtained by means of a fluid gauge.

These machines are much used in the inspection department of engineering works. Adaptions of this machine are used for measuring odd fluted taps.

Screw Pitch Measuring Machines.

A machine for measuring the pitch of screws, principally screw gauges, has been designed by the National Physical Laboratory. In operation the screw being measured is held stationary between the centres (see Fig. 11). The indicator, carrying a stylus which bears on the flanks of each thread successively, is carried on a slide mounted on balls. This slide is actuated by means of the special micrometer shown on the right hand side of the illustration.

The act of rotating the micrometer spindle causes the slide to move in relation to the gauge. The stylus which is mounted on a leaf spring, falls in and out of each thread; the point of the indicator reads zero when this stylus is in a central position in each successive thread. The micrometer reading is taken each time the indicator reads zero. The micrometer readings then show the pitch error of each thread of the screw which is being measured.

Special discs are provided to fit the micrometer to suit all common pitches. Any other pitch can be measured by means of a fully graduated disc and special tables supplied with the machine.

The small hand wheel shown below the micrometer actuates a screw for the purpose of moving the indicator in relation to the slide so as to bring the stylus opposite to the screw to be tested in any position between the centres. The micrometer has a travel of one inch.

For the purpose of measuring the pitch of screw ring gauges, an internal attachment is provided to fit on the front of the indicator. A chuck and faceplate are included in the equipment.

These machines are made by Messrs. Pitter Gauge and Precision Tool Co., by special permission of the N.P.L. and each machine is inspected and certified by the laboratory and a curve furnished showing the pitch of the micrometer screw and the pitch errors of a test screw supplied with each machine.

Measurement by Optical Projection.

The use of some form of projection apparatus is becoming more widely adopted in engineering workshops, and inspection departments. The forms of screw thread gauges, taps, chasers, hobs, form cutters, profile gauges and the teeth of gearing may be determined immediately by optical projection. It will show up at once faults in workmanship that would otherwise take considerable time to trace and remedy. It will indicate departures from a pattern immediately they occur in production, thus preventing the wastage of good material.

Apparatus and tools supplied by contractors may be inspected and the grade of finish, as well as the extent of any departures from pattern or specification, at once determined.

A typical machine made to the design of the National Physical Laboratory, has been found to give

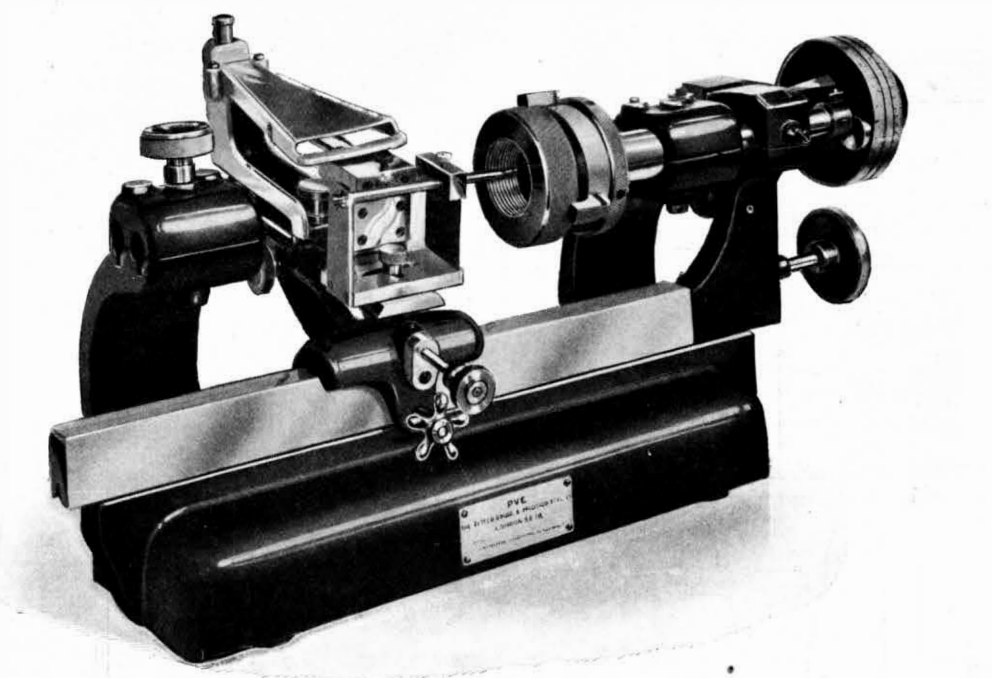


Fig. 11.—Testing Pitch of Screw Ring Gauge.

excellent service and will be described briefly. A general view of the machine is shown in Fig. 12 and a close-up view of the projector in Fig. 13.

The apparatus may either be set up for a fixed magnification (usually 50 times full size) or it may be mounted upon machined rails so that the magnification may be varied by moving the apparatus with reference to the screen. A suitable projection lens is

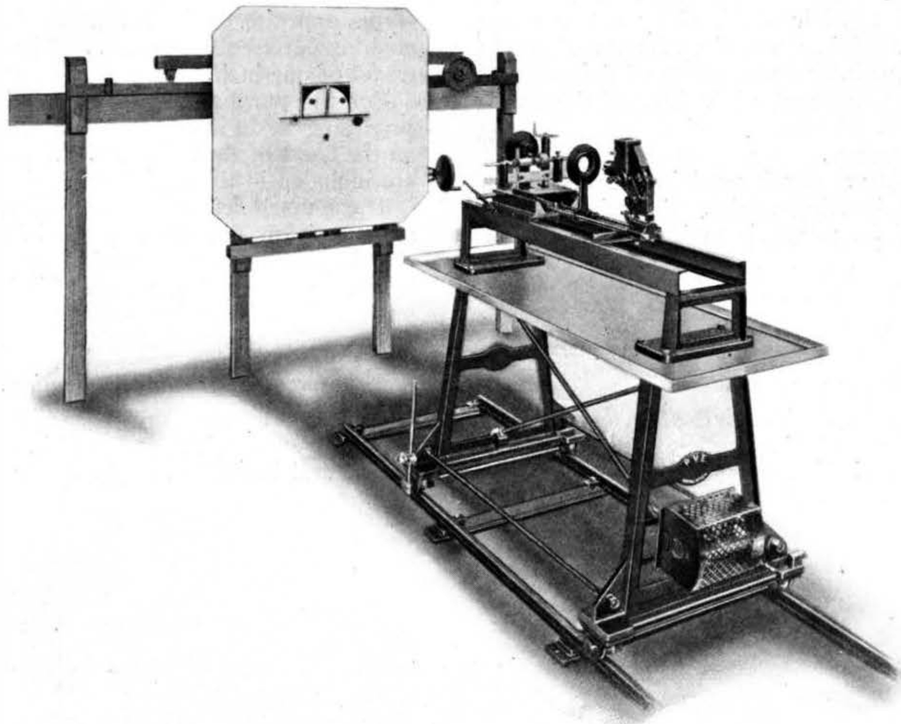


FIG. 12.—OPTICAL PROJECTION APPARATUS FOR VARIABLE MAGNIFICATION.

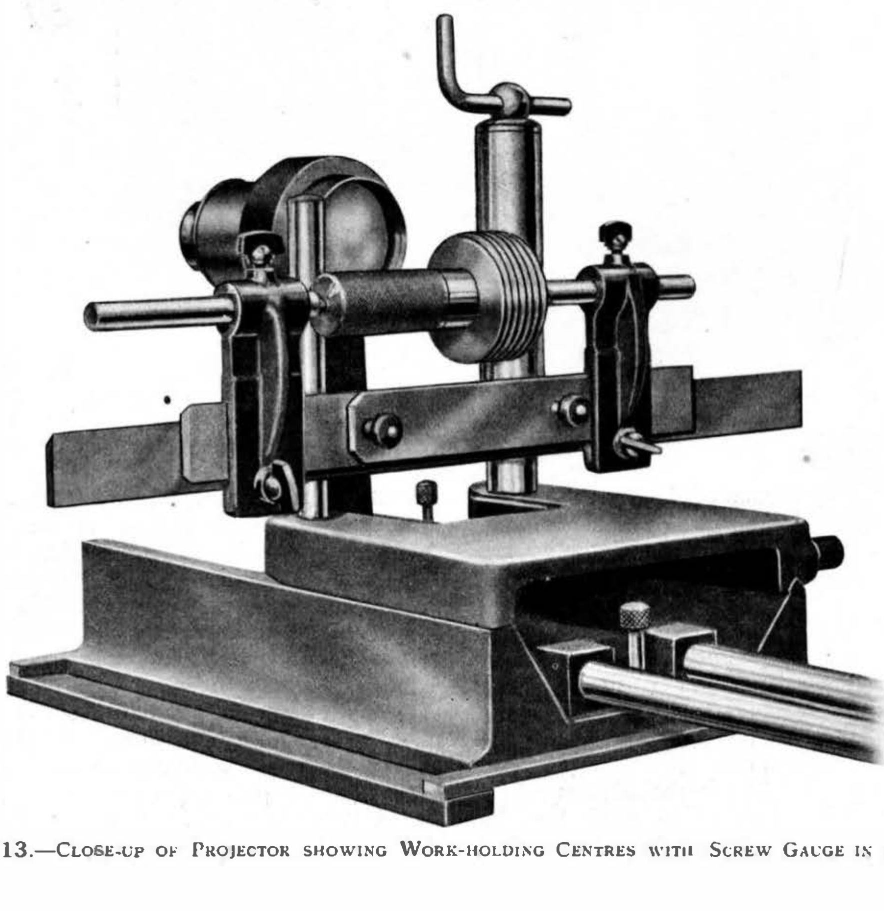


FIG. 13.—CLOSE-UP OF PROJECTOR SHOWING WORK-HOLDING CENTRES WITH SCREW GAUGE IN POSITION.

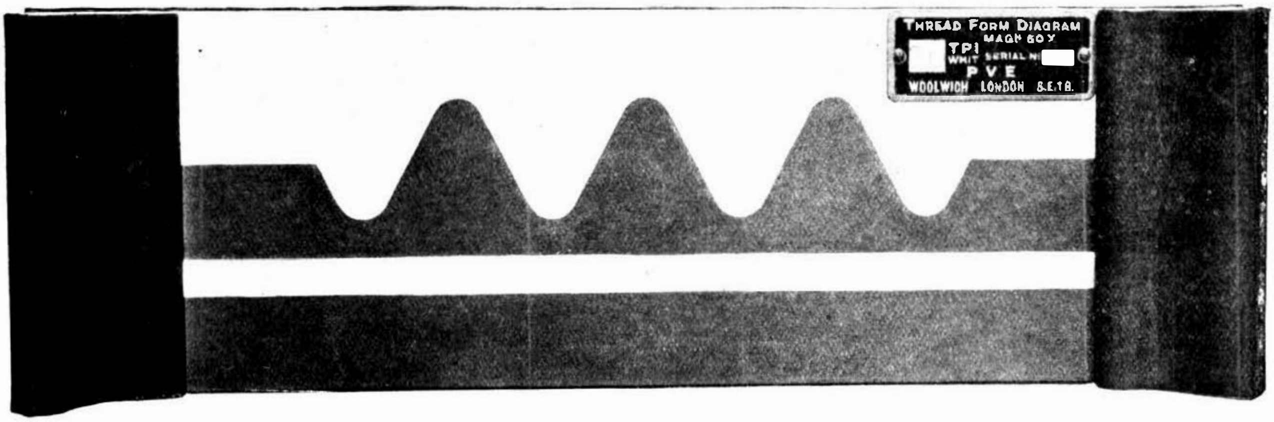


FIG. 14.—THREAD FORM DIAGRAM.

provided and centres for holding the work. Where small work, or work of one type, is to be inspected, the fixed projector will provide all that is necessary, but where the work is varied or bulky in form, a travelling projector is essential.

Briefly the projector consists of :—

(a) A special arc lamp taking about 5 amps. with accessories for regulation.

(b) A suitable condenser.

(c) Centres suitable for holding various classes of work.

(d) A combination projection lens which will project work up to 2¼″ diameter and give a field 5 feet in diameter free from distortion, also a 5″ focus projection lens to project work up to 6″ diameter and produce a field 3 feet in diameter free from distortion.

(e) A suitable rigid stand which may also act as a work-table. A metal stand has obvious advantages, especially where rails supported upon sleepers laid upon a cement floor may be fitted.

(f) A suitable screen. A simple screen 5′ 6″ square, mounted upon an easel-type support, is much used. Sometimes a more elaborate adjustable screen is mounted upon a central pivot, permitting rotation and adjustment vertically or laterally. This may be fixed to a wall for support.

The apparatus requires a dark space of about 26′ by 9′ to give magnifications up to 50 times full size.

Standard thread form diagrams are available at most large works. These diagrams produce the accurate form and pitch of various standard threads. Fig. 14 shows a diagram for a standard Whitworth thread of 20 T.P.I. Fig. 15 shows how these thread diagrams are systematically racked at a large works. Such diagrams are of particular value for comparison with the actual forms obtained from work projected upon the screen.

It is hoped that, in this necessarily brief review of modern methods of dealing with length measurements, it has been possible to convey an impression of the meticulous care that is taken in all large engineering concerns to ensure the uniformity and accuracy that is so essential in the production of the multitudinous piece parts that go to make up a modern automatic telephone exchange.

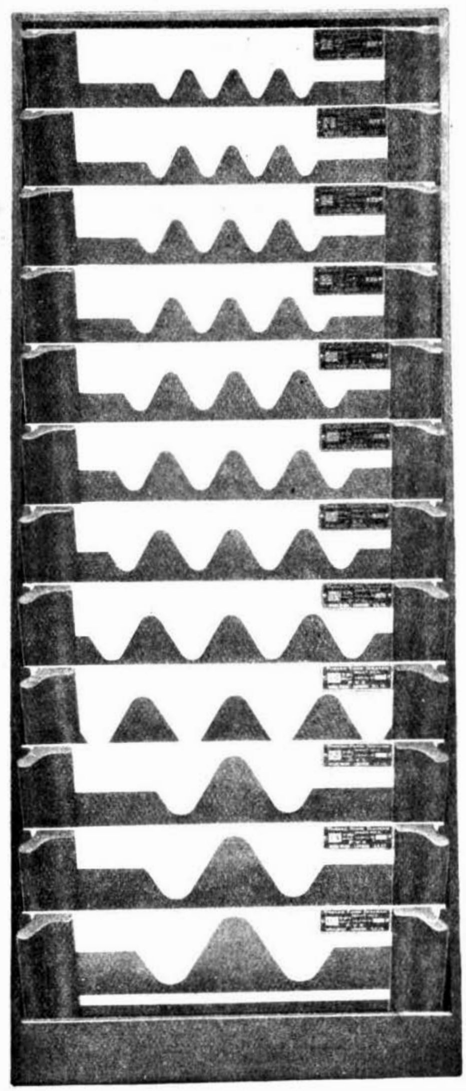


FIG. 15.—RACK FOR THREAD FORM DIAGRAMS.

Acknowledgment.

The author's thanks are due, for the courtesy and assistance in the loan of blocks, to Messrs. Pitter Gauge and Precision Tool Co. who are specialists in the production of length standards in both English and metric units.

Storm Damage 1935-36

J. STRATTON, A.C.G.F.C., A.M.I.E.E.

The author gives a brief survey of the damage caused to the Department's plant by the exceptionally severe gales experienced throughout the country during the past few months.

Introduction.

THE winter of 1935-36 will be remembered by telephone engineers as one of the worst on record. Although the very wet weather has given trouble in the underground system by reason of floods and land subsidences, the worst damage has been caused by gales of wind and snow to the overhead system.

Line plant must be designed to give, on the one hand, maximum immunity from damage, and on the other, service at the cheapest possible rental to the subscriber. Eighty-two per cent. of the trunk circuit wire mileage and ninety-two per cent. of the subscribers' circuit wire mileage are at present underground. The remainder, the overhead portion, is mainly in rural areas where there are insufficient circuits to justify the provision of underground cables. In spite of this, the total interruptions to the service from last August up to the end of February, 1936, were approximately 10,000 trunks and junctions out of order, 100,000 subscribers' circuits interrupted and 1,100 exchanges isolated.

The gales this winter have been notable not only for their violence, but for the very widespread damage done, affecting every district in the country. In general the temporary repairs have been effected within one week, but owing to the widespread nature of the damage it has not been possible to transfer gangs from one District to another to any large extent and additional unskilled labour has been recruited in order to effect a speedy clearance of faults.

Spares in underground cables were used in all possible cases to the fullest extent in effecting a temporary restoration in service. Wherever practicable this was made permanent and a minimum amount of overhead reconstruction done. It will be appreciated that permanent restoration of the overhead plant takes several months.

The first serious gale occurred in September, 1935, and others followed in October and December, 1935, and January and February, 1936.

The Gale of September, 1935.

The first gale occurred in the southern part of the country on the 16th and 17th September, roughly south of the line through Chester and York. On the 19th the high winds and storm conditions spread to the North Wales and North Eastern Districts, while the storm had not yet abated in the southern part of the country. By the 22nd the gale had extended, but with lessened force, to the Northern and Scotland East Districts. The damage was mainly due to the up-rooting and breaking of trees, causing either these to fall across the overhead wires or large branches to be blown against the wires. The damage was considerably aggravated by the fact that the storm was early enough to find the trees in full leaf. It is also highly probable that many trees that were not blown down or broken were weakened to such an extent that the later gales had far more effect than would be normally expected. The District that was probably most affected was the South Eastern where a storm raged for several days. In the South Wales District, in addition to the wind, there were severe hail storms which did considerable damage, and in the Newport area, mud to the extent of 9″ in depth in some places had to be removed from the roads and considerable damage was done by rushing water.

The Storm of October, 1935.

This again was mostly wind and rain and the greater part of the damage was due to falling trees and broken branches. This time it was the northern half of the country in which the severest damage was done, particularly in Northern Ireland and Scotland. In Northern Ireland the whole of the District was affected and some idea of the damage can be gathered from the fact that hundreds of trees were blown down and on the Belfast-Dublin route falling trees broke the wires in at least ten different places. In Scotland the main centres of extensive breakdown were :—

(1) South-east Scotland—border area, Peebleshire and Berwickshire.
(2) Central Highlands—Perthshire—Crieff, Perth and Pitlochry.
(3) East Coast—Angus and Kincardineshire.
(4) Western Highlands—Ross and Cromarty and the Isle of Skye.

The most serious damage occurred in the south-east of Scotland and was mostly due to trees crashing. The routes concerned were damaged in a number of places and the work of clearing was made more difficult by additional breakdowns caused by heavy branches of trees, weakened by the storm, continuing to fall for some time afterwards, thereby cutting off exchanges and subscribers which had either been restored or not previously affected by the gale. In the West Highlands, communication between Glasgow and some 50 exchanges, including Oban, Fort William, Inveraray, Lochgilphead and Campbeltown was severed. There was considerable difficulty in ascertaining immediately the full extent of the damage owing to the fact that contact with the distant offices had been broken.

Expedients were taken to effect temporary communication; for instance, Port Ellen on the Isle of Islay where telephone service to the main-land had recently been opened *via* Campbeltown, was still in communication with Campbeltown by means of a submarine cable route. Campbeltown was cut off from the rest of the main-land. A telegraph service was, however, possible for both places *via* the Port

Ellen-Port Patrick radio link and thence *via* Stranraer-Glasgow underground cables.

The Storms in January, 1936.

A further wind and rain storm affecting practically every District occurred on the 9th and 10th January. Flooding occurred in several districts, particularly in and around Glasgow where damage to cables was caused. One of the most spectacular effects of this storm was the damage to the Menai Bridge which links the main-land to the Isle of Anglesey. All the telephone and telegraph communication passes over this historic suspension bridge, which was erected by Telford to carry the Irish mail by road to Holyhead. The users of this bridge will be familiar with the wave like motion which is set up in the floating span in very high winds, but the gale of the 9th January added a new terror in the form of an extensive lateral swing that finally broke away the stop blocks which were fitted some years ago to limit lateral movement and the span finally settled down two feet out of normal alignment. As a consequence, the bridge had to be closed to vehicular traffic for the first time in its history. The Department's plant had been designed to allow for extensive movement of the floating span, but this abnormal swing caused a rupture of some of the cables. The local staff made a splendid effort and restored all circuits within 24 hours. The arrangements for providing a flexible connexion between the floating span and the fixed portions of the bridge may be of some interest. The lead covered cables are terminated in cable distribution heads at the ends of the fixed and floating spans and high grade V.I.R. wire forms a flexible link.

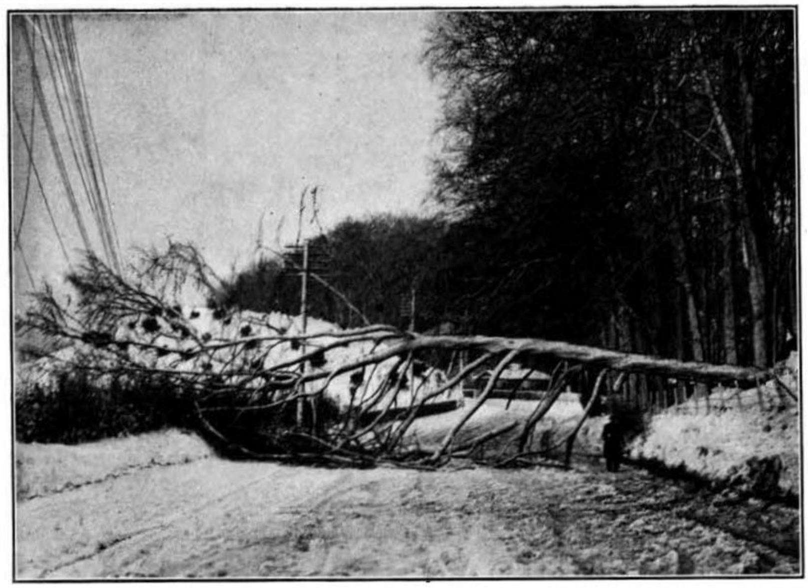


Photo *Belfast Telegraph*

FIG. 2.—TYPICAL BREAKDOWN IN NORTHERN IRELAND.

This wire is protected by flexible metallic tubing connected to the cable heads by means of steam tight glands, the tubing serving as mechanical protection and also as a safeguard against dampness due to salt spray. Fig. 1 gives a sketch showing the location of the flexible joints and V.I.R. cable.

The gale in this district also caused the atmosphere for many miles inland to be highly charged with salt and there was considerable trouble for some days afterwards due to the accumulation of salt on insulators. In the absence of a heavy shower of rain

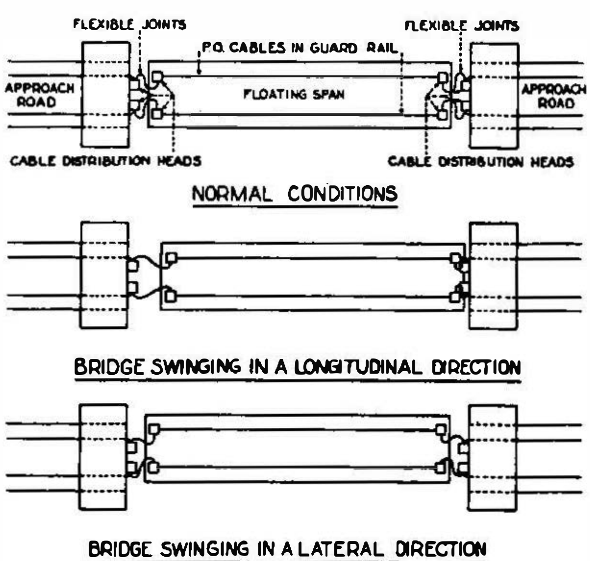


FIG. 1.—MENAI BRIDGE CABLING ARRANGEMENTS.

Photo *Newcastle Chronicle*

FIG. 3.—BROKEN H POLE AT KENTON, NEWCASTLE-ON-TYNE

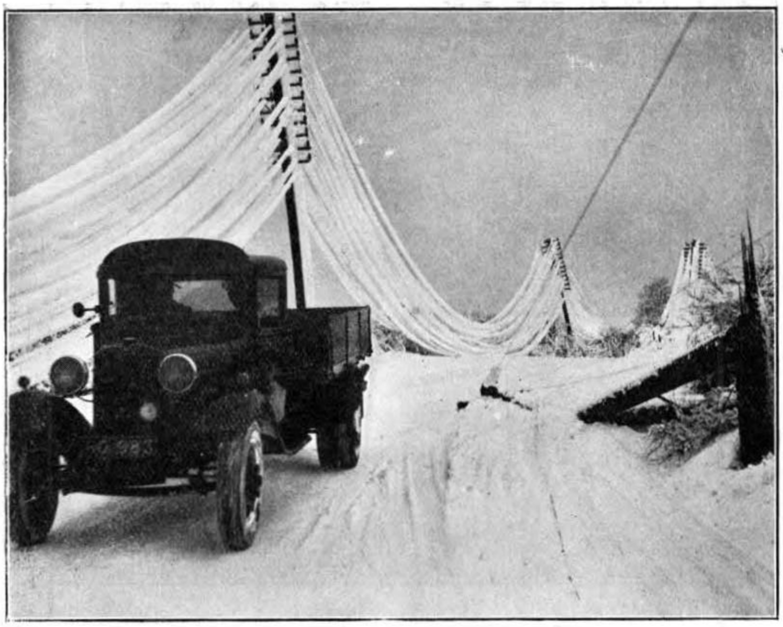


Photo *Staffordshire Evening Sentinel*

FIG. 4.—TYPICAL DAMAGE IN THE STOKE AREA.

casual unskilled labour from the Labour Exchanges was of great use in clearing the roads and railways. Fig. 2 gives some idea of the damage done.

In the South Lancs. District, the Isle of Man suffered the worst damage. The snow storm there was considered to have been one of the most severe in living memory, the damage to the Department's plant occurring as the result of a combination of circumstances. On the 19th, after the rainfall, there was a rapid fall of temperature followed by a heavy snow fall which clung to the ice-coated wires, building them up to a diameter of more than 2". In the following night the wind reached gale force and, with the weight of the snow carried by the wires, literally razed the routes to the ground. In all, 11 poles were broken, more than 200 displaced and about 150 miles of new wire had to be erected. Difficulties were considerably accentuated by the failure of all communication between Douglas and other parts of the island except by railway and even this was temporarily suspended. It might be mentioned that the Air Service between the main land and the island was of considerable use in speeding up the transfer of additional staff to the island in order to clear the damage.

to wash off the salt it was necessary on the longer distance circuits to send men out to wash the insulators.

On the 16th January snow fell in the Eastern District and caused a fair amount of damage, widespread but not of a serious nature. On the 19th a snow storm, causing far more serious damage, affected the northern half of the country. Scotland reported extensive damage particularly in the Edinburgh and Dundee Sections and in the area south of the Clyde and Stirlingshire. The West Highland area that was affected by the previous wind storm did not suffer to any great extent. For a day or so after the storm many of the roads in the southern area of Scotland were still impassable owing to the snow and it was difficult to obtain full information as to the state of the affected telephone lines.

In Northern Ireland the breakdown was general, the gale being one of the most severe that has occurred in that District for the past 20 years, the wind at times reaching a velocity of 90 m.p.h. When the wind dropped the snow had accumulated to a diameter of 2" on the 100 lb. copper wires and 6" on some of the electric power transmission lines. Breakdown gangs were working day and night to clear the debris from the roads and railways and to sling up interruption cables wherever possible. Owing to the shortage of the larger type interruption cable approximately 300 miles of 1 pair drop wire were used in the temporary restoration. This was a case where

The Northern District reported considerable damage. Again it was not only severe, but very widespread and practically every part of the area embracing the north east coast of Yorkshire, Durham and Northumberland suffered to varying degrees. As previously, the damage was due to the accumulation of wet snow on the wires, many of which reached an accumulated thickness of 3". There was not much

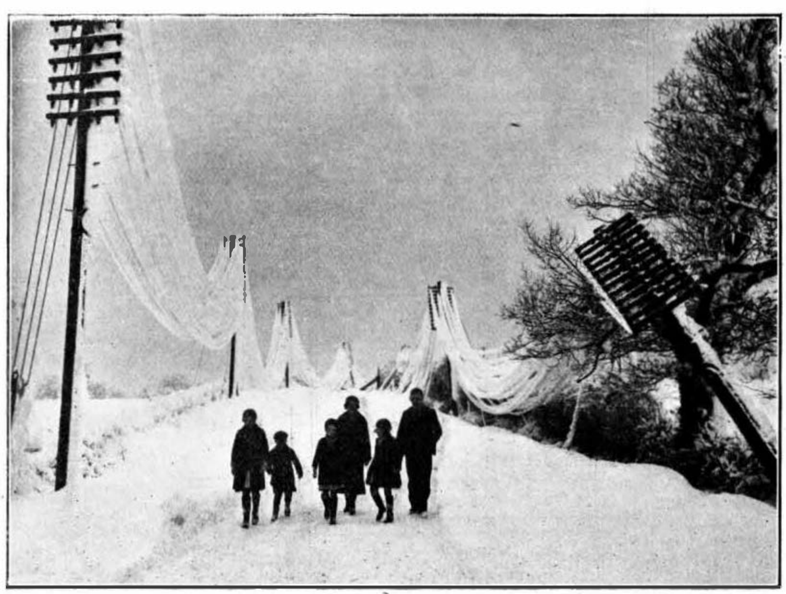


Photo *Staffordshire Evening Sentinel*

FIG. 5.—TYPICAL DAMAGE IN THE STOKE AREA.

wind, but the extra weight of the snow was so much that some heavy H poles were snapped in two, many were displaced at dangerous angles, and one route collapsed for a distance of five miles. Fig. **3** shows one of the broken H poles.

The North Western and North Eastern Districts reported severe damage, but not to the same extent as the others. In the North Western District the breakdown was especially in the Cumberland and Westmorland areas. Here, the snow had gathered on the wires and before the thaw took place the wind reached gale force, in many areas from an unusual angle. The routes affected were those which had previously escaped much damage in the former gales.

On the 21st a further snow storm occurred, this time affecting the North Wales and North Midland Districts in the Stoke, Burton-on-Trent and Uttoxeter areas. Figs. **4** and **5** give a very good idea of the amount of snow accumulation on the wires in the Stoke area, this accumulation sometimes reaching a diameter of 4½ inches. The exceptionally heavy preliminary clearance work which was necessary delayed the work of restoring communications.

The Storms in February, 1936.

On 9th and 10th of February further storms affected the south west of England and Ireland. Most of the damage was due to rain and gales, and was followed by snow, the work of restoration being thus considerably hampered. Floods also occurred in several places. The river Avon overflowed in Bath and near Warminster, and burst its banks at a point near the Bristol-Salisbury cable where Post Office jointers were just completing a repair. In a few minutes a night's work was lost.

At the time of writing (end of February) one can only hope that March will not live up to its reputation for gales. It will, no doubt, be realized that the storms this winter have followed so closely on one another that, generally, temporary repairs only have been possible. It will probably be early summer before all the permanent repairs are completed.

This article is, necessarily, a summary of the information and a selection of the photographs supplied by the local staff in all Districts, to whom the author wishes to express his indebtedness and thanks.

Joints in Overhead Wires

One of the drawbacks to the use of the lightest-gauge overhead wires is the difficulty of making, quickly and easily, a joint which shall have a strength comparable with that of the wire. This difficulty has been experienced to some extent in the case of the Department's 40-lb. bronze and cadmium-copper wires. The standard joint is made by means of a copper sleeve 2½ in. long, into the opposite ends of which the wires to be jointed are passed. The ends of the sleeve are then gripped in clamps, and one clamp is rotated so as to give the sleeve, and the wires within, 3½ complete twists.

Such a joint, made on sound wire, and with due care, is satisfactory. Its weakness lies in the fact that certain precautions are necessary. If, for instance, the clamps are not spaced at the extreme ends of the sleeve, the twists are concentrated into a shorter space and the sleeve and wires are over-stressed. Again, if the clamps are not rotated exactly in a plane perpendicular to the wire, the latter suffers alternating bending stresses; while if the joint is to be made near an insulator, and of the two clamps the one nearer the insulator is rotated, the twists are communicated to a short length of wire, whose physical characteristics may suffer in consequence. These objections may seem trivial in themselves, but it should be remembered that the measure of the life of an overhead wire is its resistance to fatigue, and resistance to fatigue is influenced by the treatment the wire receives.

A new jointing tool has therefore been designed which it is hoped will largely overcome the difficulties. Shaped roughly like the letter U, it carries between the tips a slotted tube which can be rotated about its own axis by a projecting tongue which normally lies within the arms of the U. In operation, the sleeve, with the wires enclosed, is placed in the slot of the tube, where it is gripped by a pair of flats at its mid-point. Other pairs of flats at the tips of the arms of the U engage the ends of the tube and hold it rigid. If now the tube is rotated by the central tongue, the two halves of the sleeve receive simultaneous twists in opposite directions. With a 3-in. sleeve, two complete revolutions of the tongue give a joint superior in strength to the older pattern. No twist is communicated to the line, the spacing of the points at which the sleeve is gripped are fixed, and even if the tool is carelessly used, no alternating bending stresses are communicated to the line-wire.

Preliminary supplies of the tool have been obtained and distributed to certain Districts where its performance under field conditions will be watched with interest.

A further modification of jointing practice is on trial.

Corrosion at joints is an important factor in the life of overhead wires. Recent experimental work has revealed the profound effect of corrosive forces on the resistance of metals to fatigue. It is the Department's usual practice to paint line wire joints with black varnish to prevent the entry of water; but unless done carefully, such painting is not very effective. Moreover, its complete omission by a careless workman cannot be detected by inspection from the ground.

Accordingly the possibility of issuing jointing sleeves packed with some preservative has been considered; and as a first experiment it has been decided to try ordinary petroleum jelly. Preliminary trials have shown no adverse effect on the conductivity of the joint, while the coating of jelly is permanent to a remarkable degree. Arrangements have therefore been made for all sleeves for use with the new tool to be issued ready packed with petroleum jelly, and a close watch will be kept on the results.

R.M.

Colourdex Visual System of Works Control

T. W. BATEY

FOR some time the method employed at Headquarters to control, by means of loose leaf Control Sheets, the progress of building and equipping new telephone exchanges was not regarded as being entirely satisfactory in-as-much as it did not adequately convey the picture that was required. It was felt that some means of obtaining quickly a survey of the situation existing throughout the country was desirable.

The recent supplementing of the Control Sheets by the introduction of a system of visual survey has now made it possible for Controlling Officers to see at a glance the position of all works in progress. This ready survey is provided by an installation known as the "Colourdex" which, by means of coloured cards, flags and discs, presents a comprehensive pictograph containing details of every projected telephone exchange scheme controlled from Headquarters.

The apparatus comprising the "Colourdex" system is pivoted on a vertical pillar fixed to the floor and ceiling. Sliding over this pillar is a tube or sleeve to which horizontal arms 3 ft. long are attached. These arms are fitted with pins or rods about 7 in length and notched at ½" intervals. The apparatus is light and flexible and is balanced by a weight suspended over a pulley. It can thus be easily moved up or down to bring to eye level the arm and rod carrying the particular case it is desired to examine (See Fig. 1).

Each pin carries all desired particulars of a given exchange from a control point of view. It shows as "fixed" information the name of the exchange, type, number of lines and the date required, together with the names of the Contractor and the equipment engineer dealing with the case. To this is added, after the event has actually happened, the date on which the main specification was issued, the date on which the Engineer's Order was placed, and the date when the Contractor commenced installation.

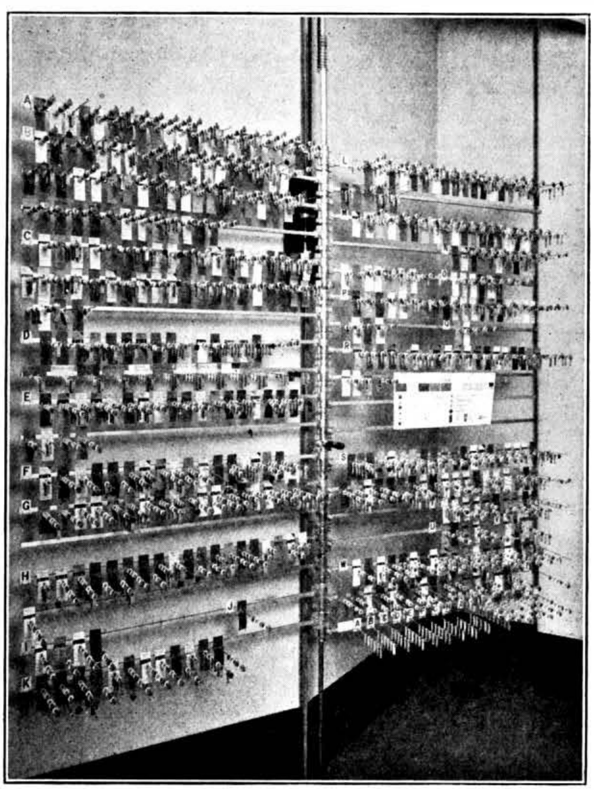


Fig. 1.—Colourdex Installation.

All this detail is displayed on a coloured card fixed at the head of the pin, the colour of the card being decided by the year in which the exchange is required, *e.g.*, an exchange that is required in 1936 is given a green card, in 1937 a grey card and so on. The pins are arranged in alphabetical order according to the name of the exchange.

For Control Sheet purposes the progress of the work of providing an exchange is marked by certain definite points or stages, and for use on the "Colourdex" the nine most vital points from an engineering standpoint have been selected. The titles of these stages have been reduced to a simple alphabetical code and are shown on the "Colourdex" by means of lettered discs clipped to the pin and placed in order, reading from the point of the pin (Fig. 2). A pale green strip inscribed with a numeral

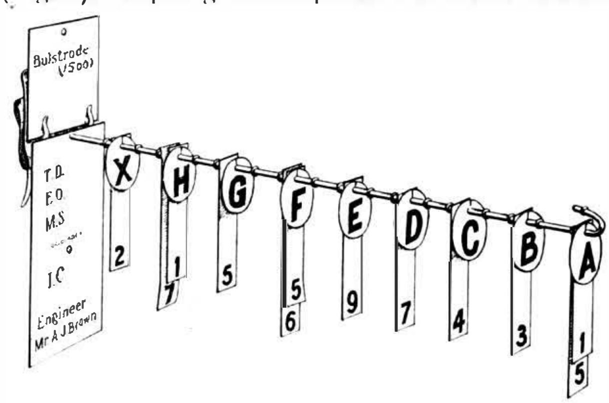


Fig. 2.—Pin and Date Discs.

A. Traffic Data due.
B. Building Dates due.
C. Engineer's Order due.
D. Main Specification due.
E. Building to be commenced.
F. Building to be ready.
G. Installation to commence.
H. Equipment to be tested out.
X. Exchange Transfer.

to represent the month forecasted for the completion of each stage is then clipped on behind the disc, the year being indicated on a longer strip showing the last numeral of the year, *e.g.*, 6 for 1936.

As these dates become due and the stage is completed the disc and date are removed and the next stage is ready for observation. It is frequently necessary, however, to revise the dates of the different stages and this is done by the addition of a red strip which indicates the new date. Should the date be passed and the particular work involved not carried out a black signal disc is immediately hoisted on to the point of the pin, and thus vividly calls attention to the fact that delay is being incurred. A red disc is also hung against the stage concerned.

At present the up-to-date position of over 500 cases of new exchanges and exchange extensions situated throughout the country is exhibited and it is thus possible to maintain with ease efficient control over every one.

The Negative Feed-back Amplifier
A Mechanical Analogy

A. C. TIMMIS, B.Sc., A.M.I.E.E.

The properties of the negative feed-back amplifier are enumerated and a qualitative explanation of these properties given by comparison with the mechanical analogy of a steam turbine and governor.

Introduction.

THE principle of negative feed-back has been known under the names of "reversed reaction," or "negative reaction," for many years; but the introduction of a negative feed-back amplifier for the simultaneous amplification of a large number of carrier channels, by H. S. Black, of the American Telephone and Telegraph Co.,[1] has aroused much interest among telephone engineers. A simple type of negative feed-back amplifier used in Holland was recently described in this Journal.[2]

The mathematical explanation of the operation of this amplifier is brief, but not satisfying to the engineering mind. The author has therefore sought to obtain a physical conception of it, by developing a mechanical analogy which will appeal to the engineer, if not to the mathematician.

Principle and Properties of the Negative Feed-Back Amplifier.

A negative feed-back amplifier consists essentially of a high gain amplifier from whose output terminals a fraction of the current is led back to the input terminals in opposite phase to the input current. In a typical case, the gain (expressed as a current ratio) of the high gain amplifier by itself may be 300, and the feed-back 1/20th of the output. As will be shown later on, the *net* gain of the arrangement will be roughly 20 and the amplifier will, in general, have the following properties :—

(1) Any change of gain due to such causes as variation in valves or supply voltages is reduced (to approx. 1/15 = 20/300) by the stabilizing effect of the feed-back.

(2) Noise currents arising inside the amplifier are reduced in the same ratio.

(3) Harmonics due to non-linearity in the amplifier are reduced, and its "linearity" improved in the same ratio.

(4) Phase shift, which is practically the same thing as transit time, through the device, is also reduced.

(5) If the feed-back becomes positive at any frequency within the transmitting range of the amplifier, it will of course be unstable. The main practical difficulty in constructing a wide-range feed-back amplifier is to avoid such instability.

Of all the advantages (3) is the most valuable, since it means that a large number of carrier channels may be worked through the amplifier without intermodulation, or non-linearity interference, and the output for a very small harmonic content is practically the full output as limited by grid current.

Perhaps (1) is the most striking property, for a valve may be taken out and replaced by one having a very different amplification without changing the net gain appreciably.

Qualitative Mechanical Analogy.

All these extremely valuable properties of the negative feed-back amplifier can be explained at least qualitatively with the aid of the following analogy :—

The electrical circuit is shown schematically in Fig. **1**, and the analogous mechanical arrangement in Fig. **2**. Steam is supplied to a turbine T *via* a throttle A, which we assume varies the flow (I_2) of steam proportionally to its movement, and is controlled through the differential link L, so that the movement of A is proportional to $I_1 - I_B$. The movement I_B is determined as in the usual centrifugal governor, by the speed of the turbine which is proportional to I_2.

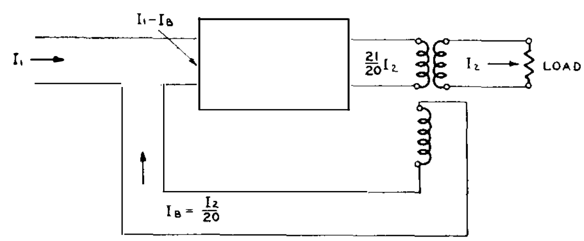


FIG. 1.—ELECTRICAL CIRCUIT.

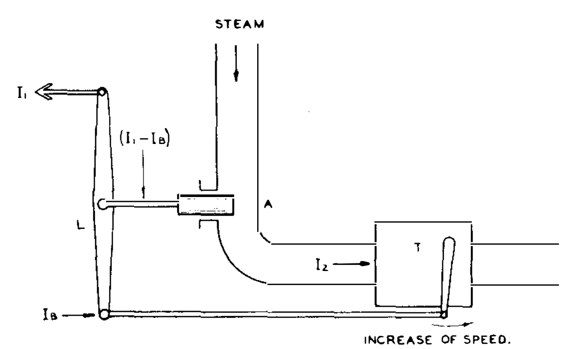


FIG. 2.—MECHANICAL ANALOGY.

[1] Bell Tech. Journal, January, 1934.

[2] *P.O.E.E. Journal,* Vol. 28, Part 3, p. 225.

The corresponding parts of the two arrangements are :—

Fig. 1.	Fig. 2.
H.T. Battery.	Boiler.
Output current (I_2).	Rate of flow of steam (I_2).
Load.	Turbine.
Feed-back current (I_B).	Movement I_B.
Input current (I_1).	,, I_1.
Feed-back coupling.	Governor mechanism.
Grid, controlling I_2.	Throttle, controlling I_2.

Consider now the effect of an increase in the flow of steam, due to change of boiler pressure or any cause whatever arising *before* the turbine. A change in the turbine would correspond to some change outside the amplifier, and does not concern the present argument. The turbine, in fact, may be regarded merely as an indicator of I_2, and part of the governing mechanism. As soon as the flow increases, the governor closes the throttle until the turbine speed (and therefore I_2) settles down to a value slightly higher than before. It is convenient to assume that this operation takes place very rapidly. In the electrical circuit it is practically instantaneous, as the feed-back path contains no delay network. But the change of I_2 may be due to a slow ageing effect in a valve (analogous to dropping steam pressure) or a ripple caused by A.C. filament supply, which is analogous to a periodic fluctuation superimposed on the steam flow. It is evidently immaterial whether the change in I_2 is due to something additional or to a change of gain, and whether it is fast or slow. Therefore the governing effect will reduce non-linearity, which is merely a change of gain with (instantaneous) amplitude.

Hence, by analogy, we see why the amplifier has the valuable properties (1), (2) and (3), mentioned above. As regards (5), positive feed-back would correspond to the throttle opening wider, instead of closing, with increase of speed. Under these conditions the turbine would " race " and I_2 would increase until some limiting factor, such as pressure drop in the pipe line (resistance in the electrical case), intervened.

The reduction of phase shift (4) is, at first sight, a rather surprising effect. Phase shift, or transit time of a current wave through the amplifier from input to output, depends on the amplification available to build up the output current. This equals 300 in the example being considered. But, if the amplification were only the net amplification of (approximately) 20 times, the rate of building up would be correspondingly slower.

In the case of the steam turbine we may say, choosing suitable units :—

$$\text{amplification} = \frac{\text{steam flow}}{\text{throttle movement}} = \frac{I_2}{I_1 - I_B}$$

This ratio may be made large either by using a throttle valve having a large change of aperture for a small movement, or high steam pressure. It is obvious that, with higher amplification, the turbine speed will respond more quickly to a certain movement of the throttle. This corresponds to rapid building up of a current I_2 in the output circuit, or load of the amplifier. The analogy must not be pushed too far, but in both the electrical and the mechanical case, we may say that the full amplification (300 times) is available to build up the output current, although the net amplification of the arrangement is only 20 times. An ordinary amplifier, with an amplification of 20 times, would have a correspondingly slower building up rate, and therefore greater phase shift.

The time of transit through the amplifier is analogous to the time taken for steam to flow from the throttle to the exhaust end of the turbine.

Magnitude of Stabilizing Effect.

Having obtained a qualitative explanation of the properties of the feed-back amplifier we may calculate the magnitude of the stabilizing effect very simply, using either Fig. **1** or Fig. **2**.

$$\text{Gain} = \frac{I_2 \,*}{I_1 - I_B} = 300 \text{ and } I_2 = 20\, I_B$$

$$I_2 = 300\, I_1 - 300\, I_B = 300\, I_1 - \frac{300\, I_2}{20}$$

$$\therefore\ 16\, I_2 = 300\, I_1$$

$$\text{net gain} = \frac{I_2}{I_1} = \frac{300}{16} = \text{approx. } 20, \text{ the feed-back ratio.}$$

Now let gain be increased by a small amount, x

$$I_2 = (300 + x)\, I_1 - \frac{300 + x}{20}\, I_2$$

$$\therefore \left(16 + \frac{x}{20}\right) I_2 = (300 + x)\, I_1$$

$$\text{net gain } \frac{I_2}{I_1} = \frac{300 + x}{16 + \frac{x}{20}} = \frac{300}{16} + \frac{x}{16} \text{ approximately.}$$

Thus the change of gain is reduced to $\frac{1}{16}$, which is the ratio $\frac{\text{net gain}}{\text{gain without feed-back}}$. Expressing this in dbs.; change of gain is reduced by the same number of dbs. as the reduction in gain caused by the feed-back.

Note. * Strictly, $\frac{\frac{21}{20} I_2}{I_1 - I_B} = 300$, but, as may easily be verified, this makes a negligible difference to the net gain.

Notes and Comments

New Features

VOL. 29 of the *P.O.E.E. Journal* contains a number of new features which, it is thought, will add to the Journal's usefulness.

Firstly, in accordance with recent practice, the colour of the cover has been changed, this time to green. The reason for the change is to enable those of our readers who do not have their copies bound to distinguish readily the parts belonging to the different volumes.

Secondly, a brief summary of each article has been added immediately following the title to serve as a guide both when reading the article initially and also when tracing information at a later date.

A further new feature is the increased size of the Supplement which contains not only answers to the City and Guild's examinations in telecommunication subjects, but also answers to the limited competitive examination for Probationary Inspectorships in the Engineering Department. It is hoped that this feature will greatly add to the attractiveness of the Journal to the junior staff.

For the student and engineer alike two new series of articles are commenced in this issue, one dealing with Carrier Telephony and the other with Atomic Physics. The former deals with a branch of telecommunication engineering which is developing at a very rapid rate and the latter with the modern conception of the electron. Both series, it is felt, will have a general appeal.

New Year Honours

We offer our congratulations to those members of the Post Office staff who received awards in the New Year's Honours List. Chief among the recipients was Mr. T. R. Gardiner, the Deputy Director General, whose distinguished services were fittingly marked by the accolade of Knighthood.

Among the engineering staff Mr. C. J. Mercer received the O.B.E. on his retirement from the service, Capt. L. P. Gill was awarded the M.B.E. and Mr. V. G. Pendry the Medal of the Order.

The Assistant Postmaster General

We welcome to the Post Office Sir Walter James Womersley, who was previously a Junior Lord of the Treasury and succeeds Sir Ernest Bennett as Assistant Postmaster-General. Sir Walter is M.P. for Grimsby, of which town he was Mayor in 1922 and is one of its most distinguished business men.

Erratum

The formula on page 303 of the January issue, relating to Traffic Control Signals, is incorrect. It should read

$$E_c = E\left(1 - e^{-\frac{t}{RC}}\right)$$

Revised Trunk Charges

We are glad to note that the policy of attracting fresh telephone and telegraph traffic by reducing charges is still being actively pursued. From the 1st May next a maximum charge of 2/6 for a three minute long distance telephone call will be introduced throughout the inland network. We have no doubt that the success which followed similar recent reductions will attend this latest effort to popularize the telephone service.

Book Review

" Electrical Measurements and Measuring Instruments." E. W. Golding, M.Sc. Tech., A.M.I.E.E., M.A.I.E.E. 812 pp. 447 ill. Pitman. 20/-.

This valuable work on the subject of electrical measurements and measuring instruments was first published in 1933 and was intended to cover the syllabus of the B.Sc. (Eng.), City and Guilds Final and A.M.I.E.E. examinations in this subject. That it has fulfilled its purpose is evidenced by the appearance of the present second edition so soon after the first.

Nearly one-third of the book is devoted to electrostatic and electromagnetic theory, units, capacitance and inductance so that the reader has a clear conception of the theory and nature of the electrical properties of a circuit before the problems of their measurement are broached. The remainder of the book deals with the measurement of inductance, capacitance, resistance, flux, voltage, candle-power, temperature, power, energy, frequency, phase difference, etc., and of the instruments used in these measurements. Special chapters deal with high voltage measurements, wave form, eddy currents, transients and the localization of cable faults.

The second edition has Sections added on Symmetrical Components, Rectifier Instruments, Photo Electric Cells and Linear Time Base currents for Cathode-ray oscillographs while other Sections have been expanded and revised.

Although the book is written primarily for power engineers there is much of value to the telephone engineer and, above all, students studying for examinations of degree standard in this subject will find the work extremely useful. H.L.

Col. H. Carter, T.D., B.Sc., A.R.C.Sc., M.I.E.E.

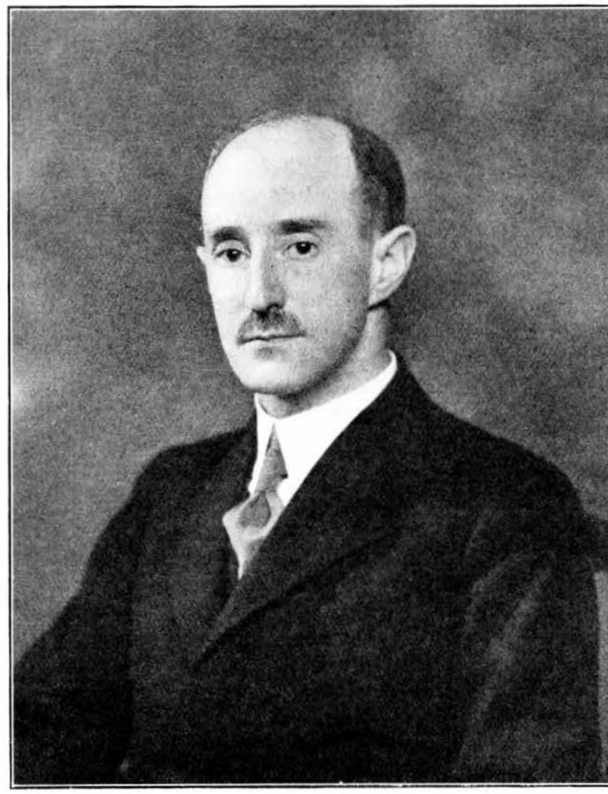


Photo *Lafayette*

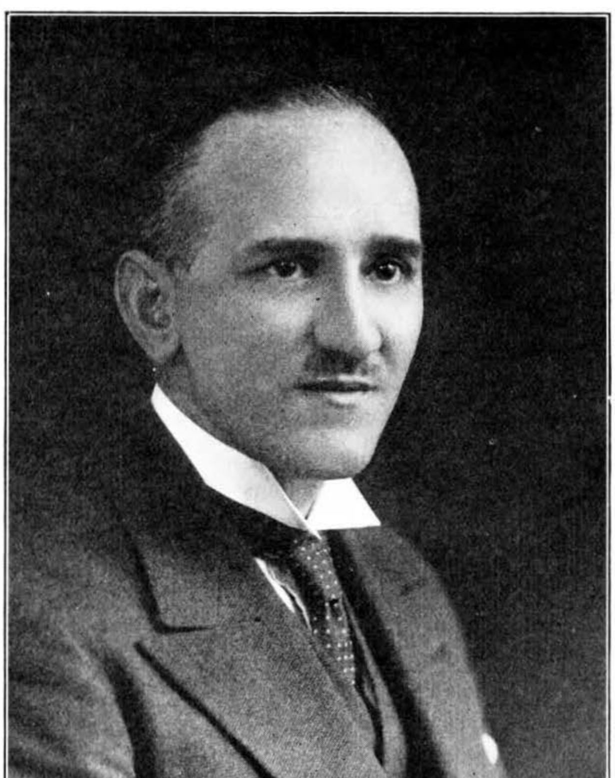
Colonel H. Carter, after becoming an Associate of the Royal College of Science, extended his training at the City and Guilds Engineering College and took his degree B.Sc. (Physics) at London University in 1911. He was a successful candidate in the Open Competition (1911) for appointment in the Post Office as Engineer (Second Class) and took up duty under Mr. J. Sinnott in the Construction Section where, after a wide experience in all fields of construction activity, he specialized in the development and application of protective measures against the manifold dangers of electric power distribution and cable sheath corrosion.

Colonel Carter, as a delegate of the British Post Office, attended a number of important International Conferences of the C.C.I. and C.M.I. held at Paris, Prague, and in Sweden and Germany. He has served also on committees of the British Standards Institution and was Chairman of the " Interference " Committee of the British Electrical Association. His responsibilities were increased and his experience widened by promotions to Executive Engineer in 1928 and Assistant Superintending Engineer in 1933. His appointment as Staff Engineer, External Plant and Protection Branch, dates from 1st January last.

Not content with the responsibilities of his important office duties, Colonel Carter has for many years rendered valuable services of a military character. He served from 1909 in the London University O.T.C. (Artillery), and East Kent Yeomanry and joined the Royal Engineer Signals from 1914 to 1921. He was attached to G.H.Q. (Signals) in France and served also in Heavy Artillery, and Divisional Artillery Units. He was Officer-in-Charge of Telegraph Construction Company and was honoured by being mentioned in Despatches. After the completion of his Royal Engineer Signals Service Colonel Carter became keenly interested in matters of Air Defence and commanded the London Air Defences Signals Company as Lieut.-Colonel and Colonel T.A. from 1929 to 1934.

W.V.

F. E. Nancarrow, A.R.C.Sc., M.I.E.E., M.I.R.E.



It is idle to claim that Dame Chance takes no part in moulding a man's career, but she usually chooses her favoured ones from among those deserving of her smiles. Mr. Nancarrow has indeed carried her approbation. Early in life he applied himself so assiduously to study that at the end of his period of engineering training in a Naval Dockyard he proceeded to the Imperial College of Science as a Whitworth Exhibitioner and a Royal Scholar. He entered the Service in 1914 by open competitive examination, as Assistant Engineer, and after a brief period in the Equipment Section joined the Radio Section, remaining there for 19 years. He took a leading part in the development of radio measurements, laid the basis of frequency measurement and was prominently associated with the development of tuning fork control and radio reception. Mr. Nancarrow was transferred to Bodmin during the later part of the erection period and subsequently, as Executive Engineer, had charge of the Bodmin and Bridgewater Beam Stations. Here he was brought into close contact with both Marconi and Frankin. In September, 1928, Mr. Nancarrow was recalled to Headquarters where he was given charge of the construction and development of the plant for transatlantic short wave telephony services and the Leafield Short Wave telegraphy circuits.

Early in 1930, he returned to Dollis Hill where he was responsible for the development of the standard frequency equipment and the crystal cutting, grinding and testing plant. The high standard attained in this work is to a very large extent due to Mr. Nancarrow's personal interest. Promoted to Assistant Staff Engineer in January, 1933, a few months later he was transferred to the Telegraph Branch where recently he succeeded Mr. C. J. Mercer, O.B.E., as Staff Engineer.

Apart from his Departmental activities, Mr. Nancarrow has taken an active part in the work of several external organizations. For many years he has been a member of various committees of the Radio Research Board, the E.R.A. and the I.E.E. As a contributor to this Journal and as a member of the Board of Editors his name is familiar to a large circle of readers.

With this record of achievement before them, few will hesitate to agree that if Chance has had any voice in the selection of the Head of the Telegraph Branch her choice has been judiciously made.

T.W.

A. Speight, M.I.E.E.

Mr. Alfred Speight, who from January 1st of this year has taken over the control of the Engineer-in-Chief's Organization and Efficiency Branch, is a Yorkshireman who received his early training in telecommunication engineering with the National Telephone Company whose service he entered as an apprentice in 1900 at Bradford.

On attaining " man's estate " he resigned from the Company and took a nine months' " Busman's holiday " in Canada and the U.S.A. where he was employed on C.B. Exchange Construction and Maintenance with the Bell Company, and incidentally made his first acquaintance with the early system of automatic exchange working at Chicago. Returning to this country in 1905, he rejoined the N.T. Company's service at Bradford and in 1910 became District Electrician for the East Yorks District, with headquarters at Hull. In 1911, he was promoted to the Engineer-in-Chief's office of the Company and, after 12 months retention by the Company for work in connexion with the Arbitration case, joined the Engineer-in-Chief's Office of the G.P.O. in January, 1913. From 1916 to 1919 Mr. Speight served in the Royal Engineers, attaining the rank of Acting Captain.

On his return to civil life he resumed duties in the Telephone Section of the Engineer-in-Chief's Office where his wide experience of matters telephonic very quickly brought him into prominence as an authority on maintenance problems and procedure. In October, 1933, Mr. Speight made his second visit to the U.S.A. and Canada, this time as a member of a G.P.O. Commission to study methods and interchange ideas with the operating Companies on that side of the world. The valuable report of this Commission has exercised a bracing influence on our attitude towards the many problems of telephone maintenance.

Mr. Speight's outstanding personal characteristic is a methodical thoroughness and he realizes that facts are seldom to be found on the surface and have to be sought by persistent and often laborious investigation. His well-known enthusiasm in such quests can no doubt be traced back to the Yorkshireman's early realization of the utter futility of expecting " owt for nowt."

Photo *Lafayette*

With the utmost of confidence his many friends throughout the Service will wish him every success in undertaking the increased responsibilites of his new post.

H.S.T.

Book Review

" Communication Networks." Volume 2. Ernst A. Guillemin, Ph.D. 587 pp. 233 ill. Chapman & Hall. 37/6.

This book differs from previous text-books on transmission in the attention given to the problem of designing transmission and impedance networks to meet specified conditions to a given degree of approximation. The new synthetic methods are no doubt more logical than the older " cut and try " methods, but none the less these have given excellent results in practice. It may be that the new generation of engineers will be armed with sufficient mathematics to apply these methods of attack. Cauer's extension of Foster's reactance theorem and a presentation of the methods of filter design of Cauer and Bode are given for the first time, so far as is known, in a text-book in English. The traditional art of filter design as developed by Zobel is also given. The short section on coil loaded lines is disappointing, the approximations made leading to results which are hardly in accordance with experience, but the book will provide the mathematically minded with many tools for the solution of transmission problems.

G.J.S.L.

District Notes

Scottish Region

AREA ORGANIZATION.

An article in the January edition of the Journal recorded the appointments of the principal officers of the experimental regions and since that date the major portion of the staffs required for the initial setting up of the Scottish Region have been appointed and taken up duty. The Glasgow City Area was opened on the 24th February, the Scotland West Area on the 25th February, Aberdeen on the 26th February, Edinburgh on the 23rd March and Dundee on the 24th March. In each case a local ceremonial meeting was held, when the opportunity was taken for the new officers to meet the supervising and manipulative staffs and for the introduction of the Chief Regional Officers to the members of the Area organizations. Accommodation for the Glasgow City and Scotland West Area staffs has been provided by rearranging the office accommodation available in various Post Office and Telephone buildings in the City of Glasgow. In Aberdeen the accommodation at the Post Office and Telephone Exchange buildings has been rearranged to afford suitable office accommodation for the Telephone Manager's principal officers and staff in the H.P.O. In Edinburgh it has been necessary to transfer the Sectional Engineer's staff from premises in George Street to the District Manager's offices in Queen Street. The last named were secured two years ago with sufficient space for future extensions which had been occupied meanwhile by the Scottish Education Department. At Dundee the Department have acquired the Central Hotel premises and these have been adapted for the accommodation of the whole of the Telephone Manager's staff.

The Engineering staffs at former District Headquarters, Edinburgh and Glasgow, have necessarily taken part in a sort of " general post " consequent on the devolution of work from the Superintending Engineer's to the Telephone Managers' offices. There is evidence of a fine spirit of *esprit de corps* on the part of the new Area staffs and it is confidently expected that matters will go forward with the smoothness characteristic of the Department.

STORM DAMAGE.

Considerable interruption occurred during January in consequence of severe storm conditions. On the 9th and 10th January, the damage resulting from heavy wind and snow isolated 42 exchanges and stopped 26 trunks and junctions and 1750 subscribers were affected, conditions being restored to normal on the 13th January.

On the 19th, 20th and 21st January, a very severe snowstorm occurred which affected practically the whole of Scotland south of the Caledonian Canal. It resulted in the isolation of 150 exchanges, 717 trunk and junction circuits, 15 telegraph circuits and 5820 subscribers. The last of the isolated exchanges was restored on the 27th January and normal conditions were reached by the 30th January.

The repair work was very considerably hampered by the extraordinarily heavy fall of snow which occurred. In some cases gangs were marooned by floods and some days' delay occurred before they could be brought into effective work. The resultant frost and floods rendered many main roads impassable to traffic and this was particularly noticeable in the Spey Valley. In addition to the damage to overhead plant there were several cases in the Glasgow neighbourhood where main subscribers' cables were damaged by floods. Owing to the heavy damage which occurred at the same time south of the Border it was not practicable to obtain any assistance from other Districts and the repair work was effected by the Regional staff.

London District

DEATH OF H.M. KING GEORGE V.

The illness and subsequent death of His Majesty King George V. caused great activity in telecommunications, and the London Engineering District, in common with other districts, was called upon for special measures to deal with the emergency.

On Saturday, January 18th, it was apparent that the normal seven lines between London Trunk Exchange and King's Lynn were not sufficient to carry the traffic between these points, having regard to the world wide interest in news from Sandringham. In co-operation with Officers from Headquarters and the Eastern District additional outlets were provided.

Commencing on the Saturday afternoon and working throughout the week-end six additional King's Lynn lines were completed by Monday, the 20th, and eight further circuits by the 22nd. The lines were routed *via* spares in the London-Cambridge cable and extended to King's Lynn *via* Amplifier Stations at Cambridge, Ely and King's Lynn.

The announcement of the death on the 20th necessitated additional circuits between London and provincial centres, and the following lines were provided :—

6 to Manchester
6 ,, Birmingham
3 ,, Leeds
3 ,, Nottingham
1 ,, Leicester.

The lines were provided partly by spare plant on the direct routes, and partly by the diversion of existing circuits to the new London-Oxford-Liverpool cable and picking up the pairs thrown spare for the new circuits. As the lining up of each circuit was completed it was immediately brought into service and all lines were completed by the 22nd.

Special circuits were also provided between Buckingham Palace and Trunk Exchange and between Buckingham Palace and Fort Belvedere, Sunningdale.

The funeral arrangements at Windsor and the broadcasting of the funeral service called for additional circuits from London. Ten additional Toll A-Windsor circuits and 4 additional Trunk-Windsor circuits were provided, the latter being reserved for Telephoto transmission. These lines were provided by using spare pairs in the London-Slough cable and extended to Windsor on various local lines which had been released by the Traffic Department.

The broadcast of the funeral service from Windsor necessitated the provision of 10 music and 3 control lines between TSX and Windsor. Five music lines were used for transmission and five kept as stand-bys in case of faults.

The music circuits were provided by using two London-Windsor lines as an unloaded phantom for each channel. Circuits withdrawn from service for this purpose were replaced by spare plant and local lines as above. Control circuits were provided by means of spare pairs in the London-Ascot cable and extended to Windsor on spares in a local cable.

In addition to the normal B.B.C. Stations the programme was transmitted on five separate channels to the Continent and to overseas stations *via* the Radio Terminal. Fourteen additional lines were provided between TSX and Broadcasting House in order to supply this network. Normally only two music circuits are available between London and the Continent and considerable work was necessary in co-operation with foreign administrations in setting up the three additional circuits. These were provided by completing one circuit *via* the London-St. Margaret's Bay cable which was in the course of preparation and by the use of two London-Brussels circuits withdrawn from service. Control lines were provided by normal traffic circuits.

During the broadcast, Officers at TSX were in attendance on all Continental control lines and at the switching panel trunk test.

In addition to the five Continental towns served direct, the programme was extended to 13 other stations on the Continent and in each case good reception was reported, both for the London and Windsor ceremony.

Telephoto transmission service was in great demand during the whole of the period and reached the peak on the day of the funeral when 53 " Picture calls " were set up at Trunk Test, 35 being to Continental stations.

Arrangements were made for all circuits temporarily withdrawn from service to be restored to normal by 9 a.m. on the day following the funeral and this was completed to time.

The special arrangements necessary for the sad event involved special effort on the part of the staff who responded splendidly, and the satisfactory results obtained were only made possible by good team work by all concerned. As most of the work had to be carried out in advance of written authority, the co-operation afforded by other Sections and Districts was a fine tribute to the organization and efficiency of the Engineering Department.

South Western District

OPENING OF TAUNTON NEW AUTOMATIC EXCHANGE.

On the 12th December, 1935, the Mayor of Taunton, accompanied by Col. Wickham, M.P., and numerous influential citizens, officially opened the new exchange. The building was declared open and the visitors were conducted in several groups over the exchange premises. Great interest was shown in the apparatus.

After an interval for light refreshments, Mr. G. R. Parsons, on behalf of the Surveyor, expressed appreciation of the presence and interest of so many prominent visitors. Reference was made to the advantages secured by automatic working and of the extensive work involved in the change-over from manual working. It was recalled that Messrs. Ericssons, who installed the new exchange, had also provided the original magneto switchboard in Taunton 44 years ago.

A vote of thanks to the Mayor was proposed by Col. Wickham, who felt some regret in losing touch with the operators who had performed their duties with such tact, discretion and patience. Alderman Penny seconded the vote of thanks and stated that his father was one of the original telephone subscribers in the town.

The Mayor, who is a retired postal official, stated that he thought the staff recognized it was their duty to do the utmost they possibly can to encourage the trade and industry of this country and to be what we are termed—Civil Servants.

FIRE AT TORCROSS (DEVON) TELEPHONE EXCHANGE.

A fire broke out at this small exchange at about 12.15 p.m. on Saturday, the 8th February, and, fanned by a strong easterly gale, spread rapidly and involved the whole of the upper part of the building. The engineering staff stationed at Kingsbridge received early advice and arrived on the scene at various times between 1 p.m. and 1.30 p.m. By this time the building was well alight, but, at some personal risk, two members of the engineering staff entered the switchroom and covered the switchboard with a tarpaulin. Nothing further could be done until about 2.45 p.m. when, the fire having been got under control, the switchroom was again entered and some emergency circuits including important Coastguard circuits were put through to Kingsbridge exchange. The switchboard had been saved from actual fire damage by the prompt use of the tarpaulin and steps were at once taken to dry it out, with the result that it was found possible to restore service generally by 9 p.m. on the same day.

Work in the switchroom was carried out under very difficult, uncomfortable and even dangerous conditions. The upper floor of the house was flooded and portions of the ceiling of the switchroom fell at intervals.

Meantime other premises near at hand had been obtained for the temporary accommodation of the exchange and arrangements had been made for the supply of a new switchboard from Birmingham and other materials needed. Everything necessary was obtained promptly, and the work of transferring the exchange continued without interruption. A new pole and a span of aerial cable were erected during the evening of the 8th instant and the morning of the 9th and the exchange was transferred at 11 p.m. on the 9th.

The easterly gale blew with increasing violence during the whole of the time and in the latter stages of the work was accompanied by torrential rain which caused a sudden flooding of the old switchroom and delayed the transfer of the last 10 subscribers to be dealt with until 3.30 a.m. on the 10th February.

Torcross exchange is situated on the sea front with an easterly exposure and the weather conditions which obtained during the whole of the operations were bad in the extreme. The prompt restoration of communication in these extremely adverse circumstances has been the subject of complimentary observations by the Western District Surveyor.

Eastern District

KING'S LYNN.

King's Lynn area, the northerly extremity of the Cambridge Engineering Section, has been the centre of much activity as regards telecommunication development during the last three months.

Until the end of November, 1935, King's Lynn was served by a magneto multiple exchange with a capacity of 700 lines. On November 30th, 1935, the system was successfully changed over to automatic working. The automatic equipment is housed in a new building, which will eventually form part of the new Post Office. The old Post Office is to be removed to temporary accommodation in an adjoining hall, originally used as a concert hall. The work of equipping the temporary premises is well in hand, and the old building will be evacuated in March. The work of demolishing the old office will then be commenced, and a fine buiding to replace it is due for completion in 1937.

Within a fortnight of the transfer of the King's Lynn exchange to automatic working, a start was made on the arrangements for the Royal broadcast from Sandringham on Christmas Day. King's Lynn is, of course, the switching centre for Sandringham, and much work was involved in setting up the alternative routes allocated for the transmission from Sandringham to the B.B.C. control in London.

Soon after Christmas, a complete overhaul of the King's Lynn-London Trunks was put in hand, including the conversion of amplifiers at Cambridge, Ely and Lynn, associated with the King's Lynn-Cambridge cable, to floating battery working. When this work was well in hand, the emergency arose in connexion with the late King's illness and death at Sandringham. The provision of the large number of additional circuits called for is dealt with in Mr. Riley's article on page 1.

J.E.P.

South Wales District

RETIREMENT OF MR. E. OGDEN, A.M.I.E.E.

The retirement of Mr. Ogden from the position of Sectional Engineer of Cardiff on the 31st December last marks the severance of one who has rendered faithful service to the State for a period of nearly forty-five years, thirty-six of which were spent in the Engineering Department. He commenced his official career in 1890 as a Telegraphist at Manchester where he was contemporary with Mr. T. E. Herbert. In 1899 he entered the Engineering Department and passed through the various grades to the position he has lately vacated. He is, therefore, one of that diminishing band of officers who rendered yeoman service to the Department in its pioneer days. Present day engineers owe a deep debt of gratitude to these officers as it is in a great measure due to their zeal and energy that Post Office Engineering stands so high in public opinion to-day.

During Mr. Ogden's career at Cardiff where he has spent the last twenty-four years he has gained the confidence and respect of his colleagues and a wide circle of friends among officials of Public Authorities.

Notwithstanding a busy official career he took an active part in the formation of the South Wales Wireless Society and in the activities of the Institution of P.O. Electrical Engineers since its inception.

His extensive experience has, above all, enabled him to obtain a wide outlook and in his contacts with his staff he endeavoured always to temper the wind to the shorn lamb.

To mark the occasion of his retirement about 200 colleagues and friends assembled at a complimentary dinner in his honour at Cardiff in January where the Superintending Engineer, H. S. Thompson, Esq., M.I.E.E., on behalf of his colleagues in the South Wales District, presented him with a Superhet wireless set and Mrs. Ogden with a handbag.

Expressions of goodwill were contributed by representatives of the various grades of his staff, the Postmaster of Cardiff and the District Manager, all of whom joined in wishing Mr. Ogden every happiness in his retirement.

H.W.G.

The Institution of Post Office Electrical Engineers

RETIRED MEMBERS.

The following members, who have retired from the Service, have elected to retain their membership of the Institution :—

C. J. Mercer, 23, Stanhope Gardens, Ilford, Essex.
F. Blick, Cornerways, Comptons Lane, Horsham, Sussex.
R. A. Weaver, Sundaken, Cansford Cliffs Avenue, Parkstone, Dorset.
T. E. Herbert, 30, Mouldeth Road, Withington, Manchester, 14.
C. Leigh, 24, Queens Road, Beckenham, Kent.

CORRESPONDING MEMBERS.

The following have been elected corresponding members :—

Mr. E. G. Fry, P.O. Box 810, Bulawayo, Southern Rhodesia.
Mr. F. D. Smith, Sociedad anonima de telefonos, Caracas, Venezuala, S. America.
Mr. M. Shoukr. H. Abaza, State Telephones Dept., Rue Malaka, Nazli, Cairo, Egypt.
M.L. T. Snidvongs, Telephone Dept., Posts and Telegraphs, Bangkok, Siam.
Mr. Snid Tungamani, Telephone Dept., Posts and Telegraphs, Bangkok, Siam.

ESSAY COMPETITION, 1935-36.

The Judges have reported to the Council that the Prize Winners in the recent Essay Competition, arranged in order of merit, are as follows :—

C. Wood, Manchester.
"Displayed at East."
G. A. Manning, Blackburn.
"Broadcast Rediffusion by the Relay System."
L. Trafford, Nottingham.
"Rectifiers and Rectification."
J. H. Robinson, Preston.
"Subscriber's Apparatus, Fitting and Maintenance."
W. E. Hawkins, Chelmsford.
"The Cathode Ray Oscillograph."

The Council has decided to award Certificates of Merit to the following five competitors who were next in order of merit :—

A. F. G. Allan, London.
"The Progress of Voice Frequency Alternating Current Circuits used in Telephonic and Telegraphic Communications."
M. C. Long, Torquay.
"A brief Exposition on the Theory of Alternating Currents."
J. E. Sargent, London.
"The Training of Youths."
F. R. Moody, London.
"The Distribution of Power and Common Services in Automatic Telephone Exchanges."
J. A. Garnett, London.
"Heating and Ventilation."

JUNIOR SECTION.

The Institution is pleased to announce that authority has been obtained for the re-imbursement from official funds of the expenses of members of the Junior Section in travelling to their centre meetings up to a limit of one shilling per meeting. Particulars of the conditions have been forwarded to each Centre Secretary, and are contained in Engineering Instruction Staff General E.0501.

Junior Section Notes

Aberdeen Centre

" Multi-Channel Telegraph Working," A. D. Farquhar. The paper opened with a description of the lay-out of V.F. apparatus in Repeater Stations, followed by a description of the V.F. Generator and its control and testing equipment. The lecture closed with a description of the " Distortion Measuring Set " used for testing purposes. In the discussion, which was opened by Mr. W. J. Eves, our Sectional Engineer, some interesting facts were revealed about the Cathode Ray Tube.

A number of interesting slides, which enhanced the value of the paper, were shown.

Birmingham Centre

The membership has now reached a figure of 88, which is a record so far as the centre is concerned. From enquiries received during the last week or two there are signs that next session should see the century passed.

Since the last issue of the Journal the main items of interest have been the reading of a Paper on " The Spectrum, Visible and Invisible " by Mr. K. R. Honeck, of the E.-in-C's Testing Branch, and an exposition of the more obscure type of faults encountered in C.C.I. working by Mr. L. H. C. Grafton, entitled " Sidelights on C.C.I." Both papers were most capably presented and extremely well received. It is pleasing to record the attendance of both the External and Internal Sectional Engineers at the reading of Mr. Grafton's paper.

Attendances at meetings have recently been much more encouraging and it is hoped that the improvement in this direction will be maintained during the remainder of the session.

The second Annual Dinner and Smoking Concert was held on 22nd February at the White Horse Restaurant. Among those present were: Mr. H. Faulkner, Superintending Engineer; Messrs. J. H. Watkins and H. G. S. Peck, Assistant Superintending Engineers; Mr. J. T. Wells, Local Secretary, North Wales Centre, I.P.O.E.E.; Messrs. Hill and Hudson, Sectional Engineers; Messrs. E. H. Williams and J. Lowe, Assistant Engineers; Mr. M. H. Hemming, C.I., whilst about half a dozen of our more intimate friends, the Inspectors, were also with us. Toasts to " The Birmingham Centre " by Mr. J. T. Wells," " The District " by Mr. C. N. Cartwright and " The Birmingham Section " by Mr. J. H. Watkins were responded to by Mr. D. M. Laing, Mr. H. Faulkner (S.E.) and Messrs. Hill and Hudson (Sec. Engrs.). Mr. R. P. Collins filled the Chair in his usual good style and we are the more appreciative of this honour since Mr. Collins is due to retire on 29th February. Mr. Peck, in proposing a toast to the Chairman, conveyed our hearty good wishes for continued good health and happiness in retirement. Our thanks are due to Messrs. C. A. Lockley (Musical Entertainer), S. Woods (Card Manipulator and Conjuror), and T. J. Jones (Baritone) all of the Engineering Department, and to Carare and Ivan (Comedy Duo) and W. Bonas (Pianist) for their entertainment, which was greatly appreciated. The measure of success attained by gatherings of this nature, where all ranks meet on a more or less common footing is governed by the amount of good feeling which exists between Supervisors and Supervised. We are happy to record that the function was an unqualified success and we are looking forward to a repeat performance next year.

D.M.L.

Blackpool Centre

The February meeting, held in the Dining Club, H.P.O., was well attended when Messrs. L. Pilkington and C. M. Clement gave papers on " Advice Note " and " Fault Control Procedure," the latter paper being illustrated with slides. Both papers were greatly appreciated and a large number of points were raised by members. Mr. G. D. Hulett, Sales Dept., was present, and his notes on the circulation of Advice Notes were very interesting. Both Mr. Clement and Mr. Pilkington answered the questions put to them very fully and some very interesting discussions followed.

Our Chairman, Mr. E. Thompson, has been promoted to Inspector, so the Branch will lose a staunch supporter and very able Chairman. We wish him every success in his new sphere.

The date of the next meeting is Tuesday, March 10th, when a joint paper will be given by Messrs. G. Redfern and J. Wheatley, entitled " Overhead Construction and Faults."

H.H.

Cardiff Centre

The " Guest night " meeting of the Cardiff centre was held at the Central Hotel, Cardiff, on Thursday, February 6th, with an excellent attendance.

Our guest speaker was Andrew P. Yates, Esq. (" Stroller " of the " South Wales Echo and Express "), a well known journalist in South Wales, who gave a talk on " Newsgathering."

The chair for this occasion was occupied by the Superintending Engineer (H. S. Thompson, Esq., M.I.E.E.). Mr. Thompson, who enjoys a reputation for his ready wit, was in good form when he introduced our guest.

In a period occupying the better part of an hour the story of " Newsgathering " was unfolded—pathos, and humour in abundance, playing their part.

Mr. Yates, in his opening remarks, referred to the relationship existing between the Post Office and the Press and said he was happy that the official barriers which once existed had now been broken down for the common good.

There was, he said, in this modern age an evergrowing tendency to create in journalism, as in other spheres of life, specialists, and he was not sure in his mind that it was good. He himself belonged to the old school of journalists, who, in the early days, had recourse to pigeons as a method of conveying news to his paper. He impressed upon his audience that the essence of good journalism to-day lay in its sincerity—that it was not faked news—and that journalistic " scoops " were, in the main, largely the result of accident plus acumen on the part of the " Newsgatherer."

In conclusion, on behalf of the press, he thanked Post Office Engineers for their valuable co-operation with the " Newsgatherers " in the successful carrying out of their duties.

The Chairman said he had occupied the position he did that evening on countless occasions, but he could not recollect an instance when an audience had been so wrapped in attention. A truly striking tribute to the speaker.

Mr. A. V. Games proposed the vote of thanks which was seconded by Mr. A. D. R. Roberts, to which Mr. Yates suitably replied.

Mr. J. S. Rafferty thanked Mr. Thompson for taking the chair that evening and a meeting which will have lasting memories closed.

Dundee Centre

The December meeting was well attended and great interest was taken in a paper by Mr. R. J. Dye on " Digging Tools and their Uses " and " Overhead Construction." Two films entitled " Telephone Workers " and " Manufacture of Porcelain Insulators " were also shown. There was a keen debate.

A paper on " Wireless Interference and Suppression " was held on the last day of January. The lecture covered a wide field and some excellent sketches and illustrations were exhibited.

A request was made for Mr. Wright to give a further lecture on the same subject, at some future date.

Edinburgh Centre

At our December meeting, Mr. D. G. Buchanan read a paper on " Petrol from Coal," and illustrated it by a number of lantern slides. Mr. Buchanan gave us an instructive and interesting insight into the manufacture of this useful commodity. An interesting discussion followed. A suitable acknowledgment was made to Mr. Kenneth Gordon, representative of Imperial Chemical Industries, Ltd., for collaboration and for the loan of slides.

A severe snowstorm which occurred on the day before our January meeting, which was to be " Any Questions " night, caused such havoc to overhead plant that the meeting had to be cancelled.

Mr. A. Alexander gave a paper on " Some Modern Chemical Processes " at our February meeting. It dealt with the manufacture of aluminium and synthetic rubber. The subject was well treated and created a most interesting discussion.

Ipswich Centre

The Ipswich centre, which owing to various causes ceased activities during the 1934-5 session, was revived this session and has had a very successful season. The meetings have been well attended, and papers on " Light and Optics," " Transmission," and " Unit Costs " have been well presented. Further papers promised are " Broadcast Receivers," and " An Elementary Consideration of A.C."

An interesting visit was made by members to the Ipswich Beet Sugar Factory on 4th January.

King's Lynn Centre

The inaugural meeting at this centre was held on the 5th December in the new telephone exchange. There was an attendance of 42 including visitors, which augurs well for the future of this new centre.

The opening paper was read by Mr. R. N. Hamilton on " The Telephone Service." The paper was illustrated by lantern slides and there were numerous exhibits of apparatus. Before the reading of the paper the meeting was addressed by the Assistant Superintending Engineer, Mr. W. M. Osborn, from Cambridge, whose address was relayed and reproduced by a loud-speaker in the lecture room.

The programme for this session includes papers on
" Submarine Cables,"
" Underground Construction,"
" Wireless Interference,"
" Amplifiers and their Application," and
" The Mole Drainer Method of Cable Laying."

Manchester Centre

Yet another Local Secretary has been taken from us, Mr. C. Wood, who took over from our " foundation " Secretary, Mr. W. H. Fox, having received a call to Dollis Hill. As a centre we regret their departure, though we hasten to recognize the Department's perspicacity in rewarding their merit. Mr. R. S. I. Ogden is acting as Local Secretary until the Annual General Meeting.

We would also like to take this opportunity to express our appreciation of the Department's act of grace in allowing travelling expenses to members in outlying stations.

The programme for the second half of the session is as follows :—

Jan. 6. " A General Outline of the Multi-Voice Frequency Carrier Telegraph System." J. Bickerton.
,, 18. Visit to the B.B.C. Studios, Manchester.
Feb. 3. " P.B.X. Schemes from a Traffic View." F. Williams (MR. Traffic Staff).
,, 11. Joint meeting with the I.E.E., by invitation, at the Engineers Club, Manchester.
Mar. 9. " The New Manchester Repeater Station." R. S. Peach.
,, 28. Visit to Barton Power Station.
April 20. Annual General Meeting.
Paper by W. A. Satchwell, Assoc.I.E.E., and S. G. Pearson, A.M.I.E.E., " Auto. Exchange Transfers."

R.S.I.O.

Peterborough Centre

The 1935-6 session has, so far, proved a success, and it is hoped that the centre will continue to receive the support of the staff. The papers given have covered a wide range of subjects, and the attendances have been satisfactory, but we should like to see the external staff represented at the meetings.

Our congratulations are offered to Messrs. J. M. Owen, V. P. List, H. W. Peddle, C. Welch and J. E. Daniels on their lectures, and we now look forward to the last paper on " Sleeve Control " to be given by Mr. R. Porter.

The Annual General Meeting will be held on Wednesday, April 8th, 1936, when the Committee for 1936-7 session will be elected. A large attendance is desired on this occasion.

The committee will be pleased to receive offers of papers for the next session, and would be pleased to see some of the younger generation in the lecturer's position. This session has shown just what can be done and the type of lecture required.

A word to our Boston friends. We hope to arrange a few lectures at Boston during the next session. Suitable accommodation will be available after the exchange transfer to automatic working.

Finally, a programme of summer outings is being prepared, and the venue will be notified in due course.

Book Reviews

" Phenomena in High-Frequency Systems." August Hund. McGraw Hill. 642 pp. 359 ill. 36/-.

The present volume as its title implies is not a comprehensive text-book on wireless communication, but deals with selected branches of the subject.

The first chapter deals with actions and effects in space discharge devices. The phenomena present in ordinary thermionic multi electrode tubes are examined and the chapter is concluded with a brief description of photo-electric effects.

The second chapter deals with high frequency generators, the earlier portion being devoted to the theoretical analyses of the circuits of a number of commonly used thermionic tube generators while the latter portion describes special circuits such as those of magnetion and electron oscillators. The three following chapters are very short and deal with current and voltage changers, phase changers and frequency changers.

Then follows a chapter of 24 pages on the rectification and inversion of currents. There are descriptions of various types of power supply rectifiers and brief mathematical analyses of their behaviour. There is, however, little or nothing about inverters and the title of the chapter seems to be rather misleading in this respect.

The author explains in the preface that he has omitted any reference to modulation, as this has been covered in another work by him in the same series on High Frequency Measurements.

Chapter 7 of 100 pages, deals with voltage, current and power amplifiers and their behaviour is explained with the help of mathematical analyses. The principles of super heterodyne and super regenerative receivers are described and the subject of positive regeneration in amplifiers usefully discussed. The case of negative regeneration or the reversed feed-back amplifier is not mentioned.

Chapter 8 is on the theory of electrostriction and deals with the piezo electric effect and its application to quartz crystals. The chapter contains much useful information about quartz crystals. An important subject on which reference is omitted, however, is that of crystals of low frequency/temperature coefficient.

Chapter 9 deals with electromagnetic theory and in it are derived the electromagnetic field equations relating to the propagation of waves in space. The radiation from commercial antennæ is also investigated.

The following chapter is on the theory of the ionized layer. The phenomena of long and short wave propagation in relation to the physics of the upper atmosphere is discussed very thoroughly, and herein is to be found much information which is not given in text-books on radio communication, but which will help the reader to understand the work of investigators on this subject during recent years.

Chapter 11 is on lines of long and short electrical lengths with special reference to antenna problems. After developing the classic formulæ for line transmission, the author discusses standing waves and then passes to simple form of antennæ for which the effective constants are derived. The chapter concludes with a useful section on Lecher Wires.

The following chapter deals with directive systems. The theory of the wave antenna is developed and the Sommerfeld, Lorentz and Carson reciprocity theorems discussed. The author then deals with frame aerials and proceeds to discuss very fully the various direction finding systems including frame, spaced aerial and systems with modulation. Sources of error due to downcoming and polarized waves are thoroughly explored.

The final chapter of 64 pages, is devoted to the theory of recurrent networks. Among the subjects dealt with are artificial lines, filters, including coupled-circuit, elementary and derived types.

One of the important features of the book is the bibliography of references to papers published in various countries dealing with the subjects under discussion.

As will have been gathered from the foregoing description, this book is not suited to the student with only elementary knowledge of the subject and in many cases a fair knowledge of mathematics is essential to understand the text. On the other hand it is a most valuable work for the radio engineer, radio physicist and teacher, and contains much information not elsewhere available or accessible only by tedious search through the proceedings of learned societies or technical journals. The fact that the work deals only with the more important aspects of high frequency technique, obviates the inclusion of redundant and unnecessary material which so frequently mars literature of this class.

The author has had a distinguished career as a high frequency research technician with the General Electric Company of America and with the Bureau of Standards, and his book can be confidently recommended.

A.J.G.

" Outline Notes on Telephone Transmission Theory." W. T. Palmer, B.Sc., Wh.Ex., A.M.I.E.E. 165 pp. 70 ill. Pitman. 4/-.

This book is a reprint of the earlier edition, and is based on lecture notes originally published in this Journal. The work is very largely mathematical, and extensive use is made of hyperbolic functions, the application of which is made clear in an admirable opening chapter on mathematical requirements. This chapter contains sufficient information for the student to work out for himself the intermediate steps in the development of the fundamental formulæ, and the unusually wide page margins are of much use also in this respect.

The theoretical portions of the syllabuses for the City and Guilds, B.Sc. (Eng.), Civil Service, and I.E.E. examinations are adequately covered, except that no mention is made of the optimum load angle for receipt of maximum power, and the simplified expression for the attenuation constant of loaded lines is not developed. An explanation of the physical phenomena of reflection is given in Mr. Cruickshank's foreword, but the connexion between this and the mathematical interpretation is not made clear in the text.

As the book is a reprint, it is not quite up-to-date with regard to amplifiers and carrier working, and one or two symbols need revising.

Several useful examples, in the form of past examination questions, are worked out for the benefit of students, but the example on page 82 is marred by the erroneous duplication of a line of explanation. Apart from this, and a misprint for $\frac{d^2i}{dx \cdot dt}$. on page 159, the text is clear and accurate.

The treatment of the telegraph cable is condensed into six pages, and is the only portion of the work likely to present any difficulty to the student. The Sections on Transmission Units and Line Measurements are most useful, but the necessarily concise statements with regard to the principles governing loading are possibly open to some misinterpretation.

Altogether, considering the subjects treated in the small space of 165 pages, the book is remarkable for its thoroughness and accuracy, and should be regarded as an essential feature of any Telephone Engineer's library.

N.V.K.

Staff Changes

Promotions.

Name.	From.	To.	Date.
Morris, A.	Asst. Suptg. Engr. S. Western	Regional Engr., N.E. Region	11-12-35
Hill, Capt. H.	Asst. Staff Engr., E.-in-C.O.	Regional Engr., Scot. Region	26-1-36
Morgan, J.	Asst. Suptg., Engr., Scot. West	Regional Engr., Scot. Region	23-2-36
Nancarrow, F. E.	Asst. Staff Engr., E.-in-C.O.	Staff. Engr., E.-in-C.O.	1-1-36
Speight, A.	Asst. Staff Engr., E.-in-C.O.	Staff Engr., E.-in-C.O.	1-1-36
Carter, H.	Asst. Suptg. Engr., S. Eastern	Staff Engr., E.-in-C.O.	1-1-36
Hay, P. G.	Exec. Engr., N. Wales	Asst. Staff Engr., E.-in-C.O.	26-1-36
Eason, A. B.	Exec. Engr., Scot. West	Area Engr., Scot. Region	23-2-36
Ireland, W.	Exec. Engr., Scot. East	Effcy. Engr., Scot. Region	To be fixed later.
Warnock, J. W.	Exec. Engr., Scot. West	Area Engr., Scot. Region	25-2-36
Crompton, W. W. B.	Exec. Engr., N. Eastern	Effcy. Engr., N.E. Region	1-2-36
Curling, R.	Exec. Engr., Scot. West	Area Engr., Scot. Region	23-2-36
Linsell, F. A.	Exec. Engr., N. Eastern	Area Engr., N.E. Region	15-12-35
Eves, W. J.	Exec. Engr., Scot. East	Area Engr., Scot. Region	26-2-36
Davis, H. G.	Exec. Engr., Scot. West	Power Engr., Scot. Region	To be fixed later.
Richardson, T.	Exec. Engr., Scot. West	Area Engr., Scot. Region	25-2-36
Graham, R. B.	Exec. Engr., N. Eastern	Area Engr., N.E. Region	To be fixed later.
Smith, W. F.	Exec. Engr., Northern	Area Engr., N.E. Region	,,
Procter, W. S.	Exec. Engr., Scot. East	Area Engr., Scot. Region	,,
Parker, T.	Exec. Engr., N. Eastern	Area Engr., N.E. Region	,,
McDonald, A. G.	Exec. Engr., Northern	Area Engr., N.E. Region	23-2-36
Millar, H. T. W.	Exec. Engr., Scot. East	Area Engr., Scot. Region	To be fixed later.
Britton, F. T.	Exec. Engr., N. Midland	Area Engr., N.E. Region	16-2-36
Baines, J.	Exec. Engr., N. Eastern	Area Engr., N.E. Region	To be fixed later.
Harding, R. W.	Exec. Engr., E.-in-C.O.	Asst. Staff Engr., E.-in-C.O.	1-1-36
Bastow, F.	Exec. Engr., E.-in-C.O.	Asst. Staff Engr., E.-in-C.O.	1-1-36
Morgan, C. E.	Exec. Engr., N. Eastern	Asst. Suptg. Engr. N.E. Region	16-12-35
Jeary, J. G.	Exec. Engr., S. Lancs.	Asst. Suptg. Engr., S. Lancs.	11-12-35
Warren, A. C.	Exec. Engr., Rugby R/Stn.	Asst. Suptg. Engr., S. Western	12-1-36
Little, G. J. S.	Exec. Engr., E.-in-C.O.	Asst. Staff Engr., E.-in-C.O.	1-1-36
Harris, L. H.	Exec. Engr., E.-in-C.O.	Asst. Staff Engr., E.-in-C.O.	1-1-36
Brown, C. W.	Exec. Engr., E.-in-C.O.	Asst. Suptg. Engr., London	1-6-36
Beattie, W.	Exec. Engr., N. Wales	Asst. Suptg. Engr., N. Midland	1-1-36
Hudson, W. E.	Exec. Engr., E.-in-C.O.	Actg. Asst. Staff Engr., E.-in-C.O.	1-1-36
Mumford, A. H.	Exec. Engr., E.-in-C.O.	Actg. Asst. Staff Engr., E.-in-C.O.	11-12-35
Hobson, J. W.	Asst. Engr., Northern	Area Engr., N.E. Region	12-1-36
Bryden, J. E. Z.	Asst. Engr., N. Eastern	Area Engr., N.E. Region	15-12-35
Barlow, T. F.	Asst. Engr., N. Eastern	Area Engr., N.E. Region	12-1-36
Tufnail, M. E.	Asst. Engr., E.-in-C.O.	Exec. Engr., N. Wales	1-1-36
Hollinghurst, F.	Asst. Engr., E.-in-C.O.	Exec. Engr., Rugby R/Stn.	12-1-36
Morrill, A. E.	Asst. Engr., E.-in-C.O.	Exec. Engr., Eastern	1-4-36
Swift, R. E.	Asst. Engr., E.-in-C.O.	Exec. Engr., S. Eastern	1-5-36
Richards, E. M	Asst. Engr., E.-in-C.O.	Exec. Engr., E.-in-C.O.	1-1-36
Doust, J. F.	Asst. Engr., E.-in-C.O.	Exec. Engr., E.-in-C.O.	1-4-36
Halsey, R. J.	Asst. Engr., E.-in-C.O.	Exec. Engr., E.-in-C.O.	1-1-36
Ramsay, M. W.	Asst. Engr., Scot. East	Area Engr., Scot. Region	To be fixed later.
Salter, L. F.	Asst. Engr., S. Wales	Exec. Engr., S. Wales	1-5-36
Blake, D. E.	Asst. Engr., E.-in-C.O.	Exec. Engr., S. Wales	To be fixed later.
Phillips, R. S.	Asst. Engr., S. Lancs.	Power Engr., N.E. Region	,,
Sephton, N. F.	Asst. Engr., E.-in-C.O.	Exec. Engr., N. Midland	1-6-36
Carr, A. S.	Asst. Engr., N. Western	Exec. Engr., N. Western	To be fixed later.
Ackerman, H. M. W.	Asst. Engr., E.-in-C.O.	Exec. Engr., E.-in-C.O.	1-1-36
Potts, E.	Asst. Engr., E.-in-C.O.	Exec. Engr., E.-in-C.O.	11-12-35
Hibberd, W. A.	Asst. Engr., E.-in-C.O.	Exec. Engr., E.-in-C.O.	1-1-36
Luxton, W. G.	Asst. Engr., Scot. East	Exec. Engr., Eastern	16-12-35
Milton, G. P.	Asst. Engr., E.-in-C.O.	Exec. Engr., E.-in-C.O.	1-6-36
Tite, W. G.	Asst. Engr., E.-in-C.O.	Exec. Engr., E.-in-C.O.	1-1-36
Barron, D. A.	Asst. Engr., S. Western	Exec. Engr., S. Lancs.	1-1-36
Holmes, M. G.	Asst. Engr., London	Actg. Exec. Engr., London	To be fixed later.
Martin, J. A. S.	Asst. Engr., E.-in-C.O.	Actg. Exec. Engr., E.-in-C.O.	11-12-35
Deakin, R. E.	Chief Insp., S. Eastern	Asst. Engr., S. Eastern	1-1-36
Maddocks, D. C.	Chief Insp., London	Asst. Engr., London	31-12-35
Carr, G. E.	Chief Insp., E.-in-C.O.	Asst. Engr., E.-in-C.O.	31-12-35
Gosney, G.	Chief Insp., E.-in-C.O.	Asst. Engr., E.-in-C.O.	1-1-36
Thwaites, J. E.	Chief Insp., E.-in-C.O.	Asst. Engr., E.-in-C.O.	31-12-35
McLean, H.	Chief Insp., N. Eastern	Asst. Engr., N.E. Region	31-12-35
Richardson, A. E.	Chief Insp., E.-in-C.O.	Asst. Engr., E.-in-C.O.	12-1-36
Paul, E. M.	Chief Insp., E.-in-C.O.	Asst. Engr., E.-in-C.O.	1-1-36
Davies, B.	Chief Insp., N. Wales	Asst. Engr., Scot. Region	29-1-36
Huntington, F.	Chief Insp., N. Western	Asst. Engr., N. Western	To be fixed later.
Coote, F.	Chief Insp., Scot. East	Asst. Engr., Scot. Region	,,
Worthington, C. E.	Chief Insp., N. Ireland	Asst. Engr., N. Ireland	31-12-35
Critchlow, V. G.	Chief Insp., S. Western	Asst. Engr., S. Western	9-1-36

Name.	From.	To.	Date.
Lyddall, A. G.	Chief Insp., E.-in-C.O.	Asst. Engr., E.-in-C.O.	15-1-36
Huff, W. C.	Chief Insp., London	Asst. Engr., S. Lancs.	12-1-36
Magnusson, L. E.	Chief Insp., E.-in-C.O.	Asst. Engr., E.-in-C.O.	1-1-36
Francis, H. E.	Chief Insp., E.-in-C.O.	Asst. Engr., Scot. Region	9-2-36
Bourdeaux, N.	Chief Insp., E.-in-C.O.	Asst. Engr., E.-in-C.O.	31-12-35
Thomson, E. B.	Insp., Scot. East	Chief Insp., Scot. Region	1-2-36
Reid, W. A.	Insp., Scot. East	Chief Insp., Scot. Region	26-2-36
Middlemiss, W. A.	Insp., Scot. East	Chief Insp., Scot. Region	To be fixed later.
Gaunt, G. L.	Insp., Scot. East	Chief Insp., Scot. Region	2-2-36
Henderson, R. M.	Insp., Scot. East	Chief Insp., Scot. Region	2-5-35
Shipperbottom, F.	Insp., N. Western	Chief Insp., N. Western	To be fixed later.
Smith, H. G.	Insp., London	Chief Insp., S. Midland	8-12-35
Foxcroft, J. R. M.	Insp., London	Chief Insp., London	15-11-35
Devereux, R. C.	Insp., London	Chief Insp., London	6-12-35
Partridge, F. V.	Insp., London	Chief Insp., London	9-2-36
Balcombe, F. G.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	31-12-35
Crank, F. G.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	12-1-36
Symonds, A. E. J.	Insp., Rugby R/Stn.	Chief Insp., E.-in-C.O.	9-2-36
Arman, L. T....	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	11-12-35
Reed, T. F.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	11-9-35
Inscoe, E. S.	Insp., N. Wales	Chief Insp., N. Wales	1-3-36
Hemming, M. H.	Insp., N. Wales	Chief Insp., N. Wales	9-10-35
Tuppen, C. W.	Insp., S. Eastern	Chief Insp., S. Eastern	9-2-36
Wright, C. T....	Insp., S. Eastern	Chief Insp., S. Eastern	9-2-36
Walton, W. R.	Insp., S. Eastern	Chief Insp., N.E. Region	To be fixed later.
Grainger, C. H.	Insp., S. Eastern	Chief Insp., Scot. Region	,,
Johnson, E. W.	Insp., S. Eastern	Chief Insp., S. Eastern	16-1-36
Smithers, F. A.	Insp., S. Eastern	Chief Insp., N. Eastern	15-12-35
Heighton, C. G.	Insp., S. Wales	Chief Insp., S. Wales	12-1-36
Linck, H. C. A.	Insp., S. Wales	Chief Insp., S. Wales	5-11-35
Jacobs, G. E. J.	Insp., S. Wales	Chief Insp., S.. Wales	15-7-35
Murgatroyd, A.	Insp., N. Eastern	Chief Insp., N.E. Region	15-12-35
Thompson, J. G.	Insp., Northern	Chief Insp., N.E. Region	To be fixed later.
Richards, T.	Insp., Northern	Chief Insp., N.E. Region	19-1-36
Reed, E. C.	Insp., Northern	Chief Insp., N.E. Region	2-2-36
Alderton, A. G.	Insp., S. Midland	Chief Insp., N.E. Region	To be fixed later.
Luckham, F. R.	Insp., S. Midland	Chief Insp., N.E. Region	,,
Knight, E. W.	Insp., S. Midland	Chief Insp., S. Midland	,,
Branson, J. W.	Insp., S. Midland	Chief Insp., Scot. Region	,,
Gay, S. G.	Insp., S. Western	Chief Insp., S. Western	16-2-36
Blott, T. G.	Insp., S. Western	Chief Insp., S. Western	9-1-36
Smith, R. C.	Insp., S. Western	Chief Insp., N.E. Region	23-2-36
Hayward, A. E.	Insp., S. Western	Chief Insp., S. Western	7-12-35
Tansley, L. W.	Insp., Eastern	Chief Insp., Eastern	24-10-35
Hett, J. E. W.	Insp., Eastern	Chief Insp., Eastern	27-1-36
Guest, F.	Insp., Eastern	Chief Insp., Eastern	11-11-35
Topham, C. L.	R.O. Cl. II., N. Wales	Chief Insp., N. Wales	To be fixed later.
Prattent, H. J.	R.O. Cl. II., N. Wales	R.O. Cl. I., Northern	,,
Leek, T. W.	S.C. & T., Liverpool	R.O. Cl. II., N. Wales	,,
Garfath, A. J. A.	S.W.I., S. Midland	Inspr., S. Midland	11-4-35
Gibbs, H. F.	S.W.I., S. Midland	Inspr., S. Midland	12-1-36
Bett, H.	S.W.I., S. Midland	Inspr., S. Midland	1-10-35
Moxon, T.	S.W.I., N. Wales	Inspr., N. Wales	1-10-35
Abbott, F. E.	S.W.I., Testing Branch	Inspr., Testing Branch	2-6-35
Cullen, W. E.	S.W.I., Testing Branch	Inspr., Testing Branch	11-4-35
Greasley, E. G.	S.W.I., Testing Branch	Inspr., Testing Branch	11-4-35
Hughes, J. W.	S.W.I., Testing Branch	Inspr., Testing Branch	11-4-35
Knight, H.	S.W.I., Testing Branch	Inspr., Testing Branch	29-5-35
James, P. A.	S.W.I., S. Western	Inspr., S. Western	18-1-36
Balfour, A.	S.W.I., London	Inspr., London	7-9-35
Burgess, H. P.	S.W.I., London	Inspr., London	21-9-35
Dootson, G. W.	S.W.I., London	Inspr., London	19-10-35
Eagar, H. E. J.	S.W.I., London	Inspr., London	16-3-35
Easthill, C. F.	S.W.I., London	Inspr., London	20-6-35
Hambrook, P. R. W.	S.W.I., London	Inspr., London	14-7-35
Harris, G.	S.W.I., London	Inspr., London	7-7-35
Hobbs, F.	S.W.I., London	Inspr., London	5-6-35
Lawson, G. W. G.	S.W.I., London	Inspr., London	27-4-35
Moore, H. J.	S.W.I., London	Inspr., London	21-8-35
Parker, A. A. E.	S.W.I., London	Inspr., London	30-6-35
Pascall, E.	S.W.I., London	Inspr., London	17-9-35
Rothwell, L. J.	S.W.I., London	Inspr., London	27-8-35
Weaire, G. S.	S.W.I., London	Inspr., London	8-8-35
Williamson, F. J.	S.W.I., London	Inspr., London	14-9-35
Wright, H. C.	S.W.I., London	Inspr., London	18-8-35

Name.	From.	To.	Date.
Patterson, R.	S.W.I., N. Ireland	Inspr., N. Ireland	11-4-35
Fox, J.	S.W.I., N. Midland	Inspr., N. Midland	1-10-35
Mason, A.	S.W.I., N. Western	Inspr., N. Western	8-10-35
Thompson, E.	S.W.I., N. Western	Inspr., N. Western	11-4-35
Clements, J. V.	S.W.I., N. Midland	Inspr., N. Midland	8-10-35
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Whitehill, J. C.	S.W.I., N. Midland	Inspr., N. Midland	2-2-36
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Bishop, H. A.	S.W.I., N. Wales	Inspr., N. Wales	To be fixed later.
Bishop, J. E.	S.W.I., N. Wales	Inspr., N. Wales	,,
Cooper, H.	S.W.I., N. Wales	Inspr., N. Wales	,,
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Lord, T. N.	S.W.I., N. Eastern	Inspr., N. Eastern	To be fixed later.
Maynard, R. R. J.	S.W.I., S. Western...	Inspr., S. Western	,,
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Bush, G. F.	S.W.I., S. Midland	Inspr., S. Midland	To be fixed later.
Hale, C. S.	S.W.I., S. Midland	Inspr, S. Midland	,,
Rice, A. W.	S.W.I., S. Midland	Inspr., S. Midland	,,
Cumming, W.	S.W.I., Scot. West	Inspr., Scot. West	,,
Connelly, A. E.	S.W.I., N. Ireland	Inspr., N. Ireland	,,
Waite, D.	S.W.I., N. Ireland	Inspr., N. Ireland	,,
Hargrave, L. R.	S.W.I., S. Western...	Inspr., S. Western...	,,
Mockridge, W. C.	S.W.I., S. Western...	Inspr., S. Western...	,,
Pepperell, A. J.	S.W.I., S. Western...	Inspr., S. Western...	,,
Strange, W. J.	S.W.I., S. Midland	Inspr., S. Midland	,,
Baker, W. J.	S.W.I., S. Eastern	Inspr., S. Eastern	,,
Knowlden, W. A. S....	S.W.I., S. Eastern	Inspr., S. Eastern	,,
Richardson, D. B.	S.W.I., S. Eastern	Inspr., S. Eastern	,,
Smethurst, J.	S.W.I., S. Eastern	Inspr., S. Eastern	,,
Dyson, L. V.	S.W.I., Eastern	Inspr., Eastern	,,
England, R.	S.W.I., Eastern	Inspr., Eastern	,,
Feneley, F. S....	S.W.I., Eastern	Inspr., Eastern	,,
Foulsham, R.	S.W.I., Eastern	Inspr., Eastern	,,
Fryatt, M. E....	S.W.I., Eastern	Inspr., Eastern	,,
Hard, A. A.	S.W.I., Eastern	Inspr., Eastern	,,
Heason, H. G.	S.W.I., Eastern	Inspr.. Eastern	,,
Ibbett, R. E.	S.W.I., Eastern	Inspr., Eastern	,,
Smith, W.	S.W.I., Eastern	Inspr., Eastern	,,
Smith, W. R....	S.W.I., Eastern	Inspr., Eastern	,,
Hunter, W. J.	S.W.I., N. Eastern...	Inspr., N. Eastern	,,
Mann, W. H. L.	Draughtsman Cl. II., E.-in-C.O....	Inspr., E.-in-C.O.	1-8-35
Baker, E. C....	Draughtsman Cl. II., E.-in-C.O....	Inspr., E.-in-C.O.	21-8-35
Bell, D.	S.W.II., London	Inspr., London	21-7-35
Fisk, W. A.	S.W.II., London	Inspr., London	22-9-35
Jago, R. T.	S.W.II., London	Inspr., London	1-10-35
Anderson, J. R.	S.W.II., Northern	Inspr., Northern	19-1-36
Formosa, A. C.	Draughtsman Cl. II., E.-in-C.O....	Draughtsman Cl. I., E.-in-C.O....	25-1-36
Porter, F. V.	Draughtsman Cl. II., E.-in-C.O....	Draughtsman Cl. I., E.-in-C.O....	16-2-36

Transfers.

Name.	Rank.	From.	To.	Date.
de Wardt, R. G.	Suptg. Engr.	S. Eastern	S. Lancs.	1-1-36
Smith, H. A.	Suptg. Engr.	Scot. West	S. Eastern	1-1-36
Ridd, P. J.	Staff Engr.	E.-in-C.O.	London	1-1-36
Johnson, A. S. A.	Asst. Staff Engr.	E.-in-C.O.	London	1-1-36
Morice, A. B.	Asst. Staff Engr.	E.-in-C.O.	S. Eastern	1-1-36
Atkins, W.	Exec. Engr.	Northern	N. Wales	20-2-36
Kilburn, G. A. N.	Asst. Engr.	Scot. East	S. Lancs.	1-2-36
Straw, J. G.	Asst. Engr.	E.-in-C.O.	L.E.D.	13-1-36
Beard, A. T. J.	Asst. Engr.	E.-in-C.O.	S. Wales	1-2-36
Barker, P. L.	Asst. Engr.	E.-in-C.O.	Eastern	1-12-35
Baxter, F. J.	Chief Insp.	Eastern	N. Wales	1-2-36
Bealby, G.	Insp.	E.-in-C.O.	Scot. East	26-1-36
Tyler, H. H.	Insp.	E.-in-C.O.	S. Eastern	8-3-36

Retirements.

Name.	Rank.	District.	Date.
Mercer, C. J.	Staff Engr.	E.-in-C.O.	31-12-35
Wilby, E. J.	Staff Engr.	E.-in-C.O.	31-12-35
Herbert, T. E.	Suptg. Engr.	S. Lancs.	31-12-35
Blick, F.	Asst. Suptg. Engr.	London	31-12-35
Leigh, C.	Asst. Staff Engr.	E.-in-C.O.	31-12-35
Arundel, D. S.	Asst. Suptg. Engr.	N. Midland	31-12-35
Crocker, J. C.	Exec. Engr.	S. Eastern	31-12-35
Pratt, A. J.	Exec. Engr.	S. Lancs.	31-12-35
Ogden, E.	Exec. Engr.	S. Wales	31-12-35
Laidlaw, J. B.	Asst. Engr.	E.-in-C.O.	23-12-35
Hopper, E.	Asst. Engr.	N. Western	31-12-35
Bruce, R.	Asst. Engr.	N. Ireland	7-2-36
Nicholson, W. A.	Chief Insp.	Northern	31-12-35
Powell, E.	Chief Insp.	London	10-2-36
Robertson, A.	Chief Insp.	Scot. Region	31-1-36
Collins, R. P.	Chief Insp.	N. Wales	29-2-36
Bunn, A. G.	Insp.	S. Western	31-12-35
Snelling, F. W.	Insp.	S. Midland	31-12-35
Juson, H. G.	Insp.	London	16-12-35
Ashford, F. W.	Insp.	S. Western	17-1-36
Crear, J.	Insp.	Scot. East	31-12-35
Thorp, H. E.	Insp.	London	31-1-36
Nice, E. J.	Insp.	London	31-1-36
Campbell, A. B.	Insp.	S. Eastern	21-1-36
Hosie, J.	Insp.	S. Lancs.	14-1-36
Halkett, G. J.	Insp.	London	31-1-36
Dowman, G. P.	Insp.	S. Eastern	31-1-36
Rutherglen, C. R.	Insp.	London	31-1-36
Grant, H. A.	Insp.	London	31-1-36
Moody, A. G.	Insp.	London	31-1-36
Nock, W. S.	Insp.	N. Wales	31-1-36
Anderson, J.	Insp.	Scot. East	28-1-36
Rogers, W. J.	Insp.	London	29-2-36
Simpson, A. F.	Draughtsman Cl. I.	E.-in-C.O.	15-2-36
Hockly, S.	Draughtsman Cl. I.	E.-in-C.O.	24-1-36

Deaths.

Name.	Rank.	District.	Date.
Munro, W. E.	Insp.	London	25-12-35

CLERICAL GRADES.

Retirements.

Name.	Rank.	District.	Date.
Hart, W. L.	Principal Clerk	London	31-3-36
Adams, H. G.	H.C.O.	N. Wales	31-1-36
Gouldthorp, A. W.	H.C.O.	N. Western	31-1-36
Lay, J. W.	H.C.O.	Eastern	31-1-36
Ellis, R. H.	H.C.O.	N. Western	31-3-36

Promotions.

Name.	From.	To.	Date.
Buzzing, W. F.	Exec. Officer, E.-in-C.O.	Actg. Staff Officer, E.-in-C.O.	11-2-36
Wager, H.	Exec. Officer, E.-in-C.O.	Actg. Staff Officer, E.-in-C.O.	17-2-36
Hunsworth, C.	C.O., N. Eastern	Actg. H.C.O., N.E. Region	15-12-35
Brook, L.	C.O., S. Eastern	Actg. H.C.O., N.E. Region	15-12-35
Balley, H.	C.O., S. Eastern	Actg. H.C.O., N.E. Region	16-2-36
Whalley, F.	C.O., N. Midland	Actg. H.C.O., N.E. Region	16-2-36
Shadforth, F. J.	Staff Officer, N. Eastern	Staff Officer (with £50 allowance) N.E. Region	8-3-36
Hall, G. W.	Staff Officer, Eastern	Staff Officer (with £50 allowance) N.E. Region	16-12-35
Maclachlan, D.	Actg. Staff Officer, Scot. West	Staff Officer (with £50 allowance) N.E. Region	To be fixed later.
Clements, G. T.	H.C.O., N. Midland	Staff Officer, N.E. Region	23-2-36
Ardis, J.	H.C.O., S. Western	Staff Officer, Scot. Region	23-2-36
Swan, R. K.	H.C.O., Scot. East	Actg. Staff Officer, Eastern	31-12-35
Harding, C. S.	C.O., S. Western	Actg. H.C.O., S. Western	23-2-36
Eadie, J. L.	C.O., Scot. East	Actg. H.C.O., Scot. Region	To be fixed later.
Howarth, H.	C.O., N. Western	Actg. H.C.O., N. Western	15-2-36
Macfarlane, R.	C.O., Scot. West	Actg. H.C.O., Scot. Region	1-3-36
Woodyatt, T. M.	C.O., N. Wales	Actg. H.C.O., Eastern	To be fixed later.
Holloway, B.	C.O., S. Eastern	Actg. H.C.O., N.E. Region	16-2-36
Babb, F. A.	C.O., N. Wales	Actg. H.C.O., N. Wales	15-2-36
Moon, W. J. E.	C.O., Testing B'ch, Birmingham	Actg. H.C.O., Eastern	To be fixed later.
Cumming, A.	C.O., Scot. East	Actg. H.C.O., Scot. Region	To be fixed later.
Roberts, J.	C.O., N. Eastern	Actg. H.C.O., N.E. Region	To be fixed later.
Hammond, A. M.	C.O., Eastern	Actg. H.C.O., Eastern	15-2-36
Kernaghan, D. H.	C.O., N. Ireland	Actg. H.C.O., Scot. Region	26-2-36
Blakey, J. C.	C.O., N. Eastern	Actg. H.C.O., N.E. Region	To be fixed later.
Clubley, G. R.	C.O., N. Western	Actg. H.C.O., Scot. Region	26-2-36
Thomson, A. C.	C.O., Scot. West	Actg. H.C.O., Scot. Region	27-2-36
Cobby, G. H.	C.O., Northern	Actg. H.C.O., N.E. Region	To be fixed later.
Carr, W. C.	C.O., N. Eastern	Exec. Officer, N.E. Region	To be fixed later.
Kimber, J. W.	Staff Officer, London	Principal Clerk, London	1-4-36
Gamgee, A.	Exec. Officer, London	Staff Officer, London	1-4-36
Gould, V. R.	C.O., London	H.C.O., London	25-2-36
Trim, E. G.	C.O., London	Exec. Officer, N.E. Region	To be fixed later.

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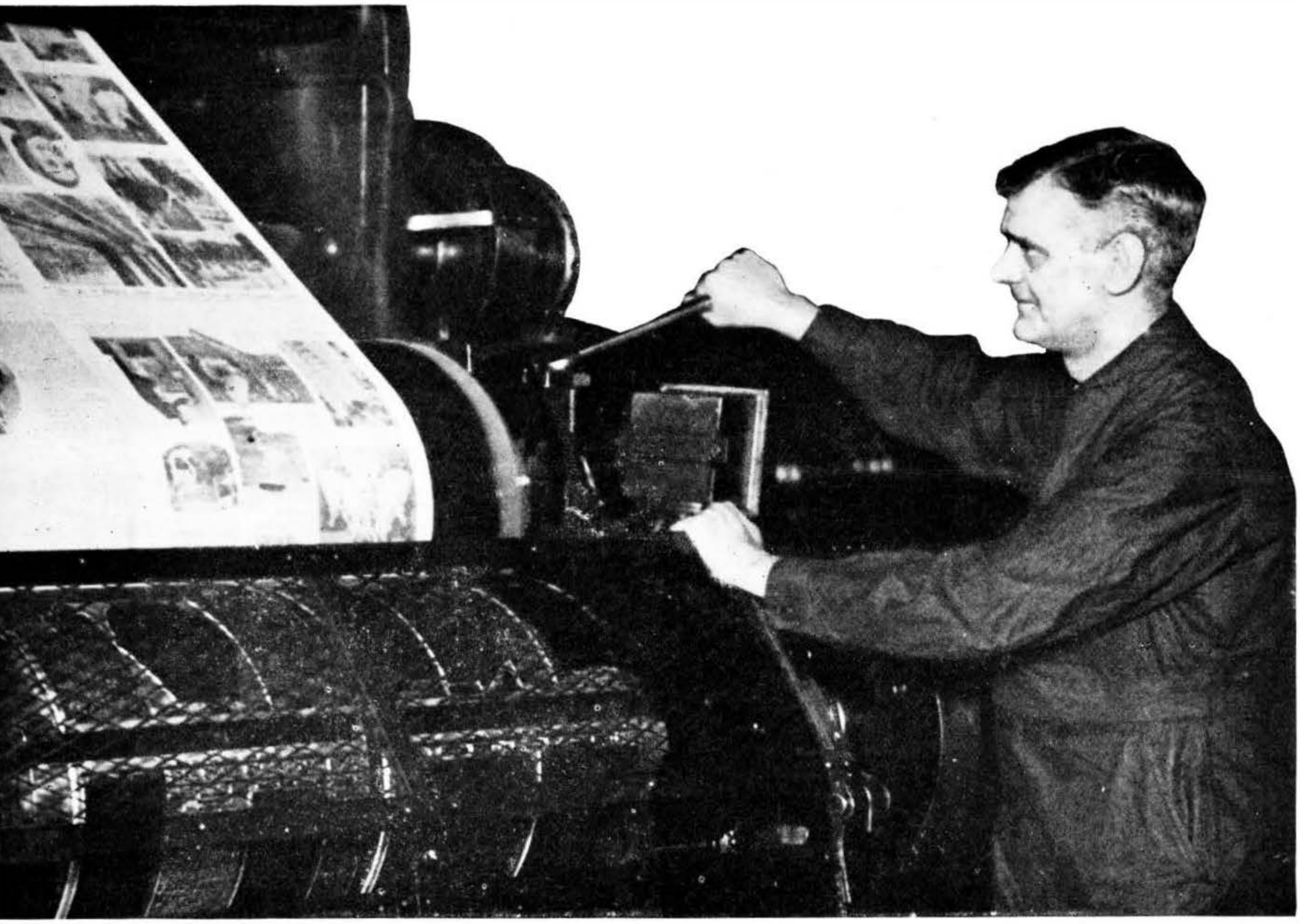

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