THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

Vol. XXVII April, 1934 Part I

Sub-Audio Telegraph Working on a Continuously-Loaded Submarine Telephone Cable

J. G. STRAW, B.Sc.(Eng.), A.M.I.E.E.
and
Capt. A. ARNOLD,

DURING the last five years increasing use has been made of the possibilities of simultaneous transmission of telephone and telegraph signals over lines, aerial, underground and submarine, in all countries with well-developed communication systems.

Such multiple use of a transmission line is made possible by the use of electrical filters enabling the complete range of frequencies transmitted over the line, within the practical limit of attenuation, to be split up into sections each providing either a simplex or duplex communication channel. An arbitrary division may be made between those channels carrying signals at their natural frequency and those carrying signals shifted from their natural frequency to some other range in the frequency spectrum. The method of working under this latter division is known as carrier working. Under the former division comes what is referred to as composited or sub-audio telegraph working.

It will be understood therefore that sub-audio telegraph working involves the transmission of the telegraph signals in their natural frequency range of say 0-100 p.p.s. and the imposition of a lower limit (200-300 p.p.s.) to the frequencies of the adjacent speech channel.

The problem of composited working on underground circuits has been dealt with in a paper read before the I.P.O.E.E. by Messrs. Owen & Martin in 1930. In this article, we are concerned with the novel application of similar principles to transmission over a continuously-loaded submarine telephone cable.

In 1930 a proposal to investigate the possibility of working sub-audio telegraph circuits over the Blackpool-Port Erin (Isle of Man) telephone cable was discussed and agreed to somewhat hesitantly. Fears were expressed as to the possible effect of the telegraph currents upon the loading material, and an upper limit of 6v was suggested for the line voltage. The possible troubles to be guarded against were :—

(1) Permanent disturbance of the magnetic material surrounding the cores concerned, with consequent possible serious affects upon the cable crosstalk.

(2) Intermodulation affects in magnetic material, both of line and terminal equipment, productive of noise on the telephone circuits concerned.

The proposal was not immediately carried into effect and, meanwhile, considerable experience of sub-audio working was obtained on the Jersey—Guernsey—Dartmouth cable on which a circuit was successfully set up for traffic early in 1933.

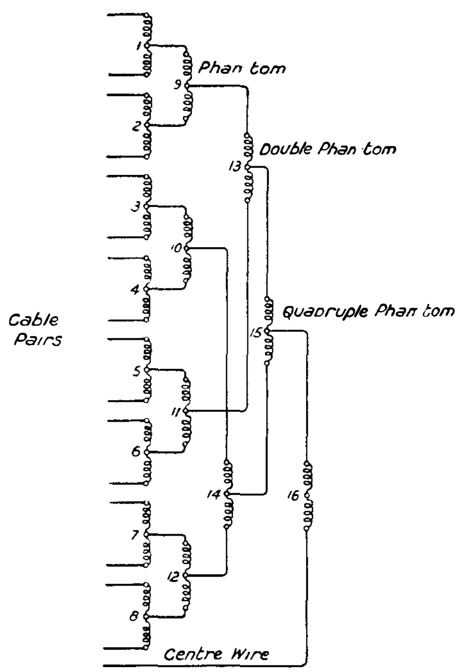


FIG. 1.—BLACKPOOL—PORT-ERIN CABLE CIRCUIT ARRANGEMENTS.

Eventually, in response to a request for two further circuits between Blackpool and the Isle of Man, the matter was again taken up.

The whole of the possible circuits in the cable with the exception of one double and a quadruple phantom circuit, unworkable from crosstalk considerations, were in use. Special considerations had to be given also to the fact that certain circuits were periodically in use for broadcast programme transmission and it was decided to avoid working on the quads carrying them.

Filter Equipment.

Terminal filters for the separation of telephone and telegraph channels on phantom circuits in the cable were designed on the basis of a high-pass cut-off of 250 p.p.s. ($Z_0 = 150\Omega$) and a low-pass cut-off of 100 p.p.s. ($Z_0 = 500\Omega$). Following experience gained on the Dartmouth-Guernsey-Jersey cable, the low-pass filter coils were specified to be on cores of a material known as DU. No other ferromagnetic core material known enables coils having so minute a variation of effective resistance with current to be produced. This type of coil was specified also for the immediately adjacent coils in the high-pass filters, as may be seen by reference to Fig. 2 which gives details of the design. The

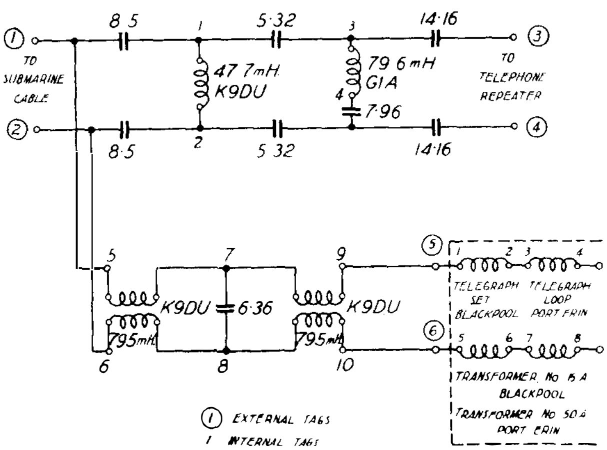


Fig. 2.—H.P. and L.P. Filters Inserted at Blackpool and Port Erin on Cable Termination.

balanced pairs of condensers required for the high-pass filters presented a problem in view of the high capacity involved. Mica dielectric condensers were eventually ruled out on the score of expense, and paper dielectric condensers specified to an absolute accuracy of $\pm 1\%$ and to a maximum difference of capacity between balanced pairs of 0.5% of nominal capacity.

The telephone circuits concerned were working 2-wire, and provision had consequently to be made for the maintenance of the telephone circuit balance. The high-pass filter was reproduced in its entirety in the balance circuit whilst partial simulation sufficed for the low-pass filters (see Fig. 4).

The filters were made up as line and balance units on separate panels, and after completion selections based on impedance measurements on the high-pass filter were made for the four line and balance pairs required.

Opportunity presented itself to repeat those impedance measurements after a period of twelve months and it was found that there was only slight variation in the filter characteristics. It was then felt that there was reasonable hope of the high capacity paper condensers retaining their nominal capacity with sufficient accuracy for satisfactory use and the units were introduced into the two phantom circuits Nos. 10 and 12 formed on pairs 3/4 and 7/8 of the cable during April and May, 1933 (see Fig. 3).

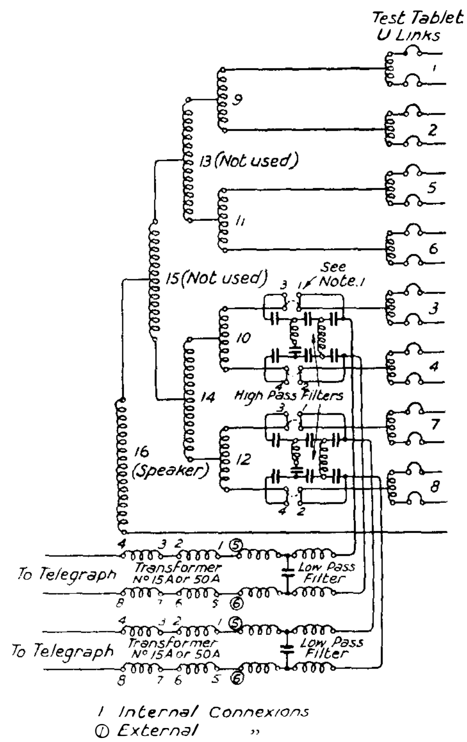


Fig. 3.—Insertion of Filters into Phantom Circuits.

Note. 1. U-links on panel enabling telegraph circuits and associated filters in telephone line and balance circuits to be cut out of circuit. The dotted connexions show U-link position with filters cut out of circuit.

There was no noticeable adverse effect on the stability of the 2-wire circuits.

Telegraph Circuits.

From a telegraph point of view, it was desired to obtain two telegraph circuits in the submarine cable to work duplex if possible. In the event of

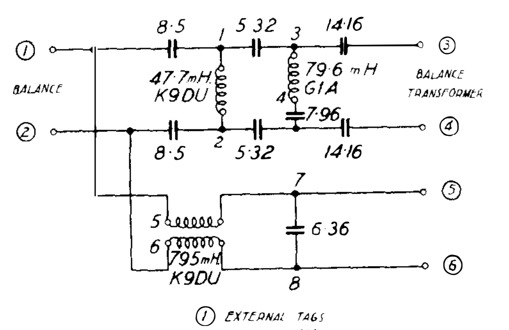


Fig. 4.—Balance Filter Units.

failure to obtain satisfactory duplex, there was the alternative of providing one circuit working two-loop simplex. Whatever the result of the experiments on the submarine length, the circuit or circuits obtained were to be repeatered at Blackpool and extended to Liverpool to form Liverpool-Douglas circuits.

Telegraph Apparatus.

The sub-audio section had to work with low value line currents, thus entailing the use of sensitive receiving relays (Relays 299 AN Special). Tests made for satisfactory telegraph transmission

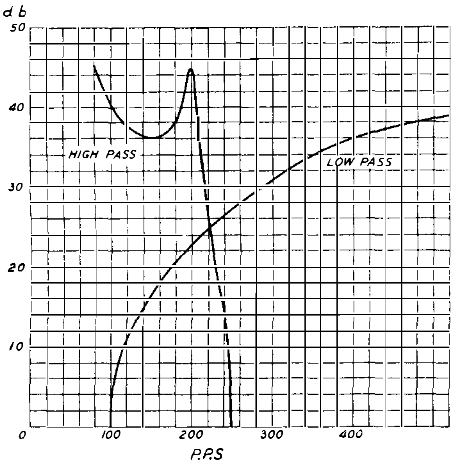


Fig. **5**.—Line Filter Unit Attenuations.

and interference made it desirable to provide a line voltage supply reasonably free from any possibility of bias, since this is a serious matter where sensitive relays are in use. (Further details of this are given in a subsequent paragraph).

For these reasons it was decided to use copper oxide rectifiers, working on the voltage doubling principle with the addition of potentiometers for line voltage supplies. A low-pass telegraph filter in the sending end circuit at each end was inserted as an aid to the suppression of interference.

A further, and very desirable, object was the improvement of the shape of the arrival curve, or, in other words, to overcome line distortion by some device introduced into the circuit. Previous work in another direction had shown that a sending end magnetic shunt device could be applied with beneficial results. A device of this kind, details of which will be given later, was introduced in the sub-audio section of the circuit.

A novel part of the work was the design of the complete networks required for the duplex balances. As far as the authors are aware, no previous opportunity had presented itself for working either simplex or duplex over a continuously-loaded cable. The complete network had to include subsidiary networks to balance the high-pass and low-pass separation filters at Blackpool and Port Erin, the loaded cable between these points, the unloaded cable between Port Erin and Douglas, and various transformers and condensers included in the line circuit for the suppression of interference on the telephone channels.

The apparatus has been designed for rack mounting. None of the standard panels was suitable for this type of circuit and it was therefore necessary to design the various panels required for the sub-audio section of the circuit and the Liverpool side of the repeater at Blackpool.

Fig. **6** is a schematic diagram of the complete telegraph circuit. It shows the two-loop working over phantoms between Liverpool and Blackpool, the conversion to differential duplex, via the cable down transmitting relay to the Douglas side of the repeater, and thence to Douglas. Operating in the reverse direction, the signals actuate the "cable receiving relay" of the repeater at Blackpool,

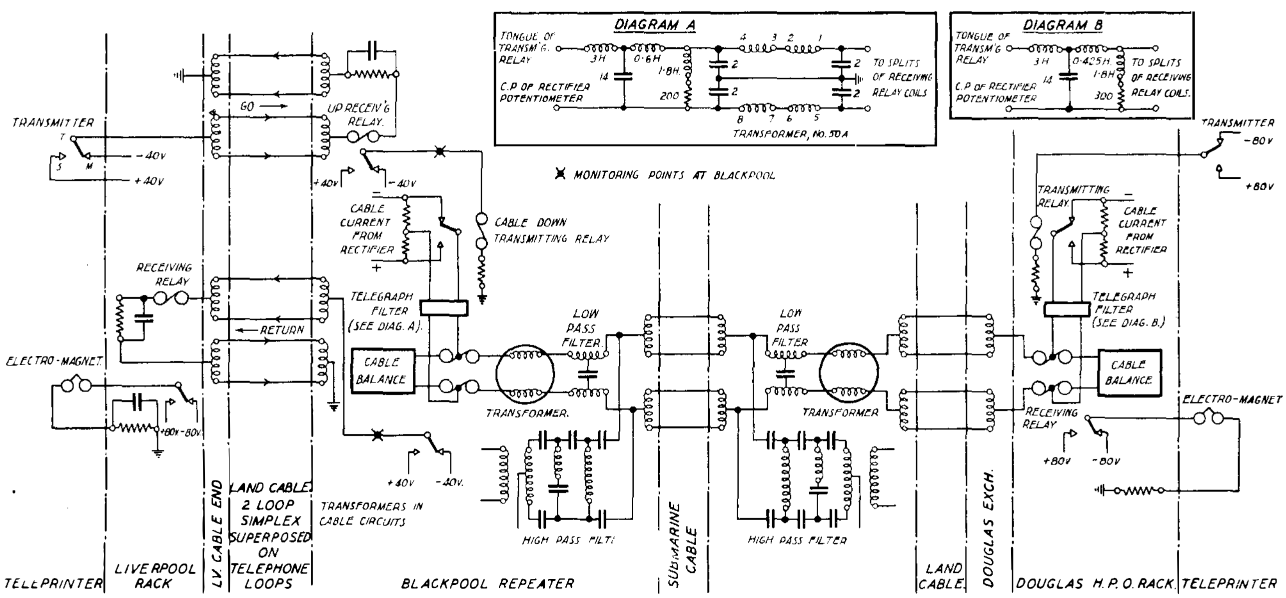


Fig **6**.—Teleprinter Circuits; Schematic Diagram.

the contacts of which in turn transit to Liverpool. The local voltages at Liverpool and Blackpool are 40v and at Douglas 80v. The positions of the separation filters, low-pass and high-pass, are indicated, likewise the telegraph filters. The last-named filters are shown in greater detail in Diagram A and B on Fig. **6**. The apparatus in Diagram A is in the transmitting circuit on the Douglas side at Blackpool. The cable voltage supply (-ve and centre-point of potentiometer to which the rectifier is connected) are shown teed to a 3 H coil and the junction of the connecting wires on Tag No. 8 of the Transformer No. 50 A respectively. The 3 H and 0.6 H coils, together with the 14 μF condenser, constitute the telegraph filter; the 1.8 H coil in series with the 200Ω resistance forms the sending end magnetic shunt. The remainder of the network was necessary for the suppression of interference and will be explained later. The circuit of Diagram B is part of the transmitting circuit at Douglas. The coils of 3 H and 0.425 H with the 14 μF condensers comprise the telegraph filter, whilst the 1.8 H and 300Ω resistance coils make up the magnetic shunt.

Before any work was taken up in the field, the complete apparatus for two circuits was set up in the laboratory and as many tests as possible were carried out over artificial cables closely simulating the complete circuit Liverpool to Douglas, including the separation filters, the repeaters intended for Blackpool, and the apparatus for Port Erin. Many tests were made for distortion by means of the Teleprinter Distortion and Margin Tester, and for interference by listening tests made at the terminals with an amplifier in circuit. The telegraph filter and sending end shunt values were determined by experiment; and the most suitable values of resistance and capacity for the vibrating coils of the receiving relays were found in the same way. When later, the apparatus was installed and the circuits set up, it was found that the preliminary work had been very accurate leaving few additions and changes to be made.

Fig. **7** shows in detail four of the panels on one of the repeaters fitted at Blackpool. The " Up " panel is arranged for two-loop working on the Liverpool side and the " Down " panel for differential duplex on the Douglas side. The arrangement, in principle, is well known and requires little explanation. Many changes and additions have, however, been made in detail and it may be of interest to explain these.

Taking the " Down " panel first, it will be seen that signals from Liverpool operate (via the Relay 299 AN on the " Up " panel) the transmitting relay (Relay BN) the contacts of which re-transmit to Douglas via a telegraph filter, a kick coil (Transformer No. 50A), to the mid-points of the line meter, thence through the coils of the line relay (Relay 299 AN special) to the sea cable *via* the sea cable filters, etc., and the telegraph balance panel. The telegraph filter, which is shown as a separate panel, consists of two inductance coils L1 and L2 in series the junction of the two coils being led to one side of a 14 μF (10 + 4 μF) condenser. The other side of this condenser is connected to the centre point of the cable rectifier potentiometer. The values of this filter were obtained by experiment. The values for the sending end magnetic shunt were determined from distortion tests made over the simulated circuit, and were later adjusted slightly in the field. As far as is known, this device has not been fitted on a working circuit in this country before but it is regretted that owing to consideration of space a detailed technical explanation of its action cannot be included in this article.

The condensers, centre-point earthed, connected between terminals 4 and 8 of the Transformer No. 50A were necessary to aid in the suppression of interference in the telephone circuits; the other condensers were added during the trials over the working circuits to suppress interference in the double-phantom telephone circuit.

Interference with the telephone circuits was caused by the vibrating circuit of the line relay. To smooth the currents in this part of the circuit, an inductance of 1.9 H in series with resistance A and two 1 μF condensers were introduced. The arrangement did not interfere with the proper working of the vibrating circuit, whilst beneficial results to the telephone circuits were obtained by reducing the effect of the vibrating currents working back inductively to the line coils of the relay and thence to the telephone circuits.

A potentiometer of 4,000Ω + 4,000Ω was introduced in the vibrating circuit to eliminate any possible bias from the local batteries.

It was considered advisable to use a potentiometer of 500Ω + 500Ω across the spacing and marking contacts of the transmitting relay to obtain a centre tap from the cable rectifier (used in lieu of a battery). This was done because it was considered that if the centre tap had been obtained from the rectifier or from two rectifiers, ageing, etc., might have introduced bias.

Various tests made on the simulated circuit indicated that with the line coils of the Relay 299 A.N. connected in parallel, a lesser value of distortion was obtained than when the coils were connected in series. It was therefore decided to use a modified form of Relay 299 AN for use on these circuits and relays of this type modified to have half the normal number of turns on the four line windings and the normal number of turns on vibrating windings were provided. To distinguish these relays from the normal 299 AN type, the word " special " has been inscribed on the top of the relay covers.

40 V +ve and −ve tappings from the Universal Battery are available at Blackpool and the various resistances have been based on that voltage value. These voltages are used for all purposes except transmission to the sea cable.

The repeater panel is provided with jacks and keys the main functions of which can be ascertained from Fig. **7**.

The " Up " panel was designed for 2-loop simplex working on the Liverpool side. A Relay 299

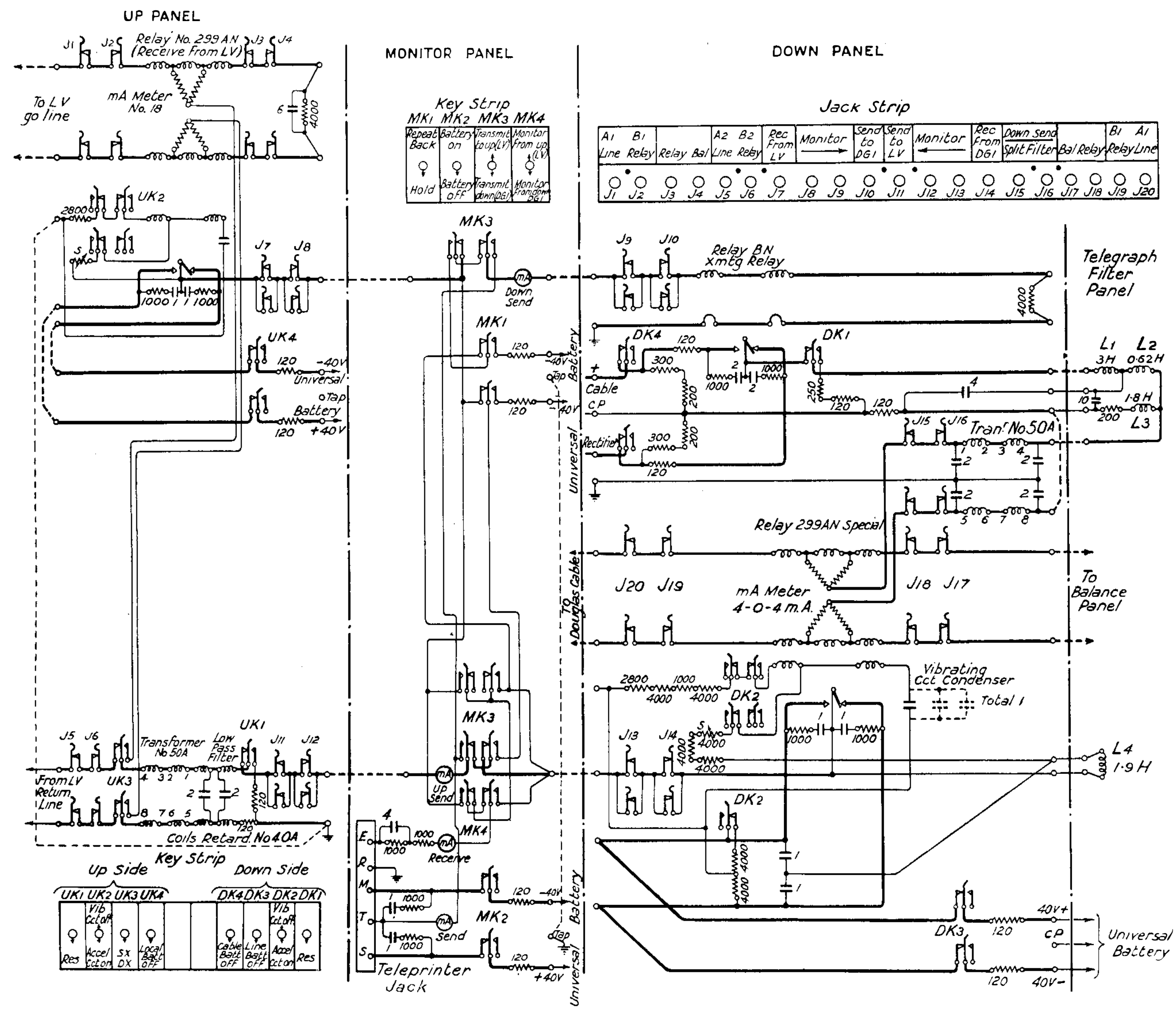


Fig. 7.—Connexions of Repeater at Blackpool.

A.N. with vibrating circuit is used to receive from Liverpool and the tongue of this relay is connected, via the Monitor Panel, to the coils of the transmitting relay (Relay B.N.) on the Down Panel. The contacts of the latter relay transmit to Douglas. For transmission to Liverpool, the line relay (Relay 299 AN Special) on the Down Panel is operated and its tongue transmits via the Monitor Panel over the return line to Liverpool. The telegraph filter on the Liverpool side at Blackpool is made up of four Coils Retardation No. 40 A and two 2 μF condensers connected in parallel.

The shunted condenser closing the Liverpool " go " line at Blackpool is 6 μF, this value being obtained as a result of distortion tests.

The Monitor Panel is a simple arrangement which provides many desirable facilities. Four keys, four milliamperemeters, and the usual apparatus associated with a Teleprinter No. 3 A are used. When the circuit is " through " all keys are in the normal (unoperated) positions and transmission in both directions can be observed on the " Down Send " and " Up Send " meters. By operating Key No. 4, " Monitor," to the required side, signals from either terminal office can be read on the monitoring teleprinter. If it is required to speak to either terminal office, the operation of Key No. 3, " Transmit," to one side provides facilities for simultaneous transmission and reception between the repeater and a terminal office. While this is proceeding, Key No. 1, " Repeat Back—Hold," may be operated to the " hold " side, thus providing the second terminal with normal conditions. If, however, Key No. 1 is left at " Repeat back," the second terminal office will, when transmitting, have its signals repeated back. This informs the second terminal office that the circuit is not through to the distant teleprinter. The two milliamperemeters

" Teleprinter Send " and " Teleprinter Receive " indicate the signals passing " out " and " in," respectively, to the monitoring teleprinter.

One feature of the monitoring circuit is the arrangement of a resistance in series with the shunted condenser. When a signal is sent from one terminal office to the other with the repeater monitoring, there would be a momentary short-circuiting effect due to the shunted condenser and the condenser shunting the teleprinter electromagnet. This would be detrimental to reception at the terminal offices. To obviate this, a resistance of 1000Ω is placed in series with the shunted condenser and the teleprinter electromagnet.

The teleprinter motors are driven from the Universal Battery, 120 V tapping.

Fig. 8 shows the arrangement of three panels at Douglas. The arrangements of the terminal and telegraph filter panels are similar in principle to the vibrating circuit at Douglas made 10,000Ω + 10,000Ω. The other resistances in the vibrating circuit and in parts of the main circuit had to be raised to suit the voltage.

(2) The telegraph filter is exactly the same, except that an 0.425H coil is used in place of the 0.6H.

Again referring to Fig. 8, it will be seen that a common monitor panel is used for both circuits. The panel is equipped with sockets to accommodate both types of plug used for the power connexion to the motors of Teleprinters, a starting switch, and two Jacks Inst. N.T. No. 4. The monitoring keys (one per circuit) are mounted with other keys on the terminal panel. The function of the key in the normal position is to leave the circuit connected to the Teleprinter on the telegraph table, and, when operated, to transfer the local connexions of the circuit to the monitoring teleprinter placed close to the rack. The

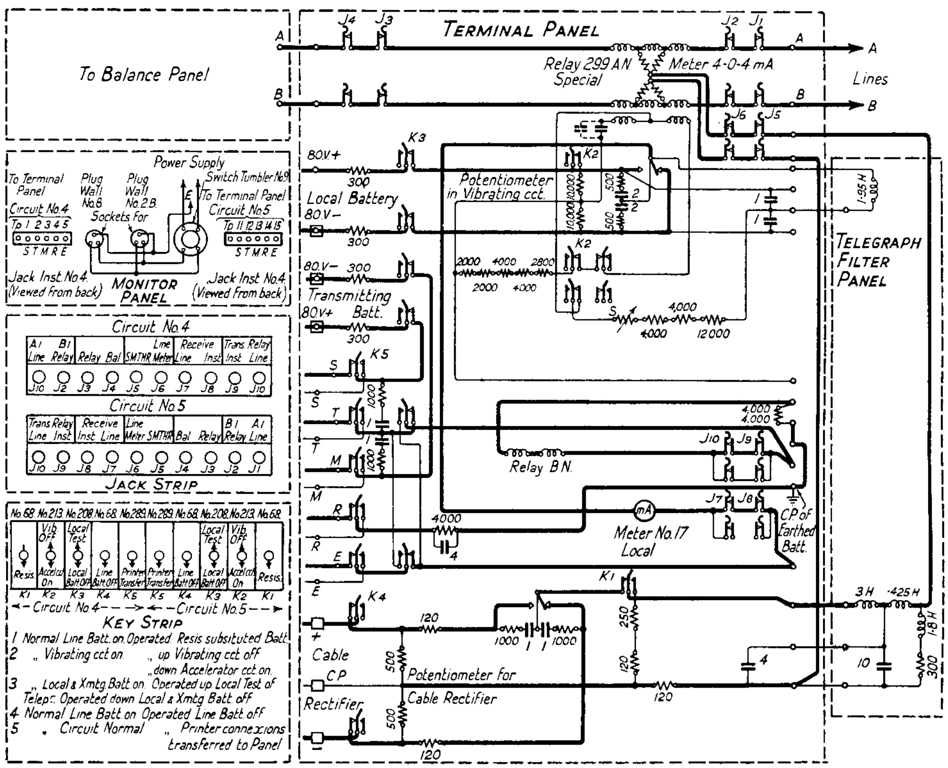


Fig. 8.—Connexions of Panels at Douglas.

Repeater Panel, Down Side, at Blackpool. In this case, the panel is a terminal unit equipped with Relay 299 AN Special and the standard local circuit. The working teleprinter and local meters are fitted on the telegraph table. The transmitting relay is a Relay B.N. With certain exceptions, similar to those on the Blackpool Down Panel, the panel conforms in detail to a normal differential duplex set. It differs from the Blackpool Down Panel in the following respects :—

(1) The battery supply for local voltages is 80V ±. For this reason, the potentiometer in the monitor keys are labelled " transfer " in the operated position.

At Douglas the teleprinter motors are driven by rectified A.C. from Rectifiers No. 22C.

When the investigation was commenced it was known that the voltage applied to the sea cable must be low and that it could not be finally fixed until listening tests had been made on the actual telephone circuits. The voltage applied had also to be consistent with satisfactory telegraph transmission.

With these points in view, it was desirable to have an extremely flexible supply with a wide range of voltages. Recent work has shown that power supply from rectified A.C. is efficient for telegraph purposes and that the necessary range could be obtained if a transformer with suitable tappings were used in the rectifier circuit. It was therefore decided to use a suitable rectifier unit for transmitting over the sea cable. As Fig. **9** shows, the system of volt-

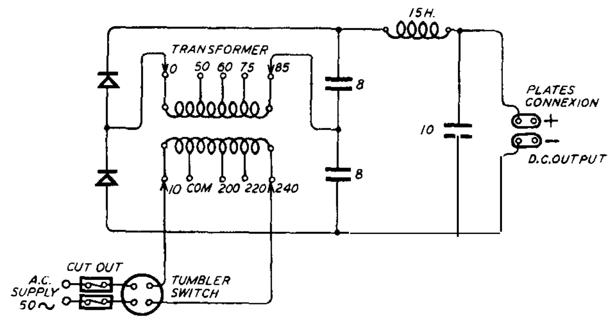


FIG. **9**.—RECTIFIER PANEL.

age doubling was chosen. With this type of circuit connexion, a short circuit of the output will not overload the rectifying elements. The circuit includes simple but effective smoothing apparatus. As previously mentioned, some difference due to ageing or a defect in a rectifier element might occur and to obviate any ill effects from such changes a potentiometer of 500Ω + 500Ω has been provided on the Repeater Down Panel at Blackpool and to the Terminal Panel at Douglas to which the rectifier panel is connected by two wires only. The centre point of the potentiometer is therefore the centre point of the voltage supply to the submarine cable.

Duplex Balances at Blackpool and Douglas.

From the nature of the circuit and various tests made on the simulated circuit, it was obvious that in arranging these panels some degree of simulation would be necessary. The arrangement at Blackpool (Fig. **10**) shows that complete simulation of the low-pass filters was necessary and nearly complete simulation for the high-pass filters. To balance the sea cable in sections, it was possible to fix the inductances, leaving adjustable resistances and condensers for the other factors. Partial simulation of the high-pass and low-pass filters at Port Erin was found to be effective. For the section of the circuit Port Erin-Douglas, an adjustable condenser and rheostat sufficed. The network provided for each circuit at Douglas is similar to those at Blackpool, except that the incidence of the line is reversed. Here R1 and C1 are concerned with the cable Douglas to Port Erin; the high-pass and low-pass filters at Port Erin are simulated: R2, R3, R4, C2 and C3 together with the fixed value inductances balance in sections the sea cable and filters, etc., at Blackpool. It was observed that the balance figures for the two circuits at Blackpool are practically identical; but at Douglas there was a difference of 1.30 μF between the total capacities required for each circuit. By crossing the balance panels and lines this difference was found to be in the circuit. Without making special tests the difference cannot be located, but it is possible that it is due partly to the Douglas-Port Erin section of the circuit and partly to the condensers at Port Erin. This is borne out to some extent by the fact that the balances at Blackpool are alike and, had there been any difference between the circuits as balanced from Blackpool, it would have been observed there.

The R values in the Blackpool balances were inserted to compensate for transformers No. 15A inserted at the telephone balance rack. These transformers are inductive to the double phantom but non-inductive to the phantoms. As far as the telegraph circuit was concerned, it was only required to insert a resistance equal to the resistance of all the transformer coils in series in front of the existing balance networks. Transformers No. 15A were chosen for this purpose because the residual inductance of the coils is negligible when used in this way.

The telegraph apparatus at Blackpool and

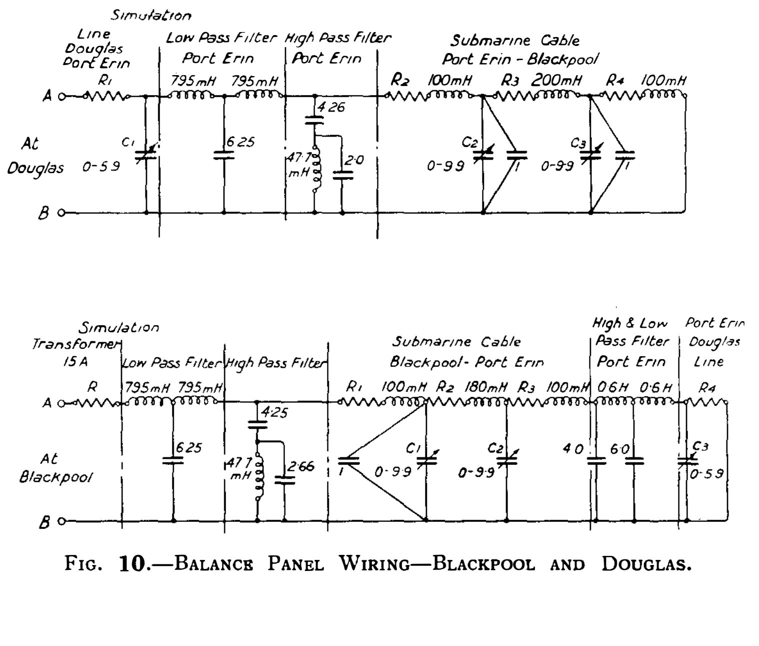


FIG. **10**.—BALANCE PANEL WIRING—BLACKPOOL AND DOUGLAS.

Douglas is mounted on racks of two bays. At Blackpool the apparatus rack is in the telephone repeater station; at Douglas in the telegraph instrument room. Each rack has eight connexion strips mounted on it by means of which the various panels are interconnected. This does not apply to every panel, but to any panels not in the same bay. Those in the same bay are connected directly except where connexion must be made to a line or any other external connexion, in which case connexion is made to the strips.

The various keys, jacks and switches with which the apparatus is equipped provide many desirable facilities. Space does not permit enumeration of these, but one or two of the more important may be mentioned briefly, as examples.

(1) The two offices in conjunction can make the two duplex circuits between Liverpool and Douglas into one circuit working on the two-loop method. Thus, if the circuits should become partially faulty rendering them unable to work duplex, two-loop working could be adopted.

(2) Lines may be interchanged.

(3) Duplex balances may be interchanged.

(4) By adding duplex balances, the lines to Liverpool may be converted to duplex working instead of two-loop simplex working.

(5) The sending loops between Liverpool and Blackpool may be changed over.

During the first trials made on the circuit, the transformer tappings for the cable voltage supply were set to permit a received current of 1.7 mA at Blackpool and Douglas. Satisfactory duplex working was obtained under this condition. When, however, additional condensers had been fitted at Blackpool to suppress interference in the double phantom, the telegraph circuits became unstable, even at simplex. The transformer tappings were then adjusted to give received currents of 4 mA. After refining the duplex balances, satisfactory duplex working was again obtained.

Distortion tests were made between Douglas and Blackpool. The method of making these tests are fully described in an accompanying article. For the purpose of the present article it is only necessary to say that the satisfactory results obtained in traffic were fully confirmed by the figures obtained by the distortion measurements.

Interference experienced on the Telephone Circuits.

During the preliminary laboratory work using artificial cables, it was observed that noise on the telephone circuits was chiefly due to induction *via* the vibrating circuits of the line relays and local battery circuits. Noise directly attributable to line currents was relatively very small. Additional smoothing apparatus associated with the vibrating circuits of the telegraph relays (referred to under Telegraph Apparatus) led to a considerable improvement.

After installation on the submarine cable itself, it was at once apparent as regards the telephone circuits directly concerned no interference trouble was going to be experienced.

Only on the double phantom circuit (No. 14) at Blackpool was there any audible interference from the telegraph circuits, probably due to some unbalance effect on the Blackpool-Liverpool lines.

However, after several trials, it was found that the addition to the telegraph circuits of inductive coil *a* to the superposed circuit together with centre-point-earthed condenser combination shunted across the lines eliminated the interference entirely.

As in the case of the direct interference met with in the laboratory trials, it was found that the double phantom circuit interference came from inductive pick up of harmonics of telegraph local battery and vibrating circuit currents.

Conclusion.

It was the intention to complete the circuits, officially known as Liverpool-Douglas 4 and 5, and have them in readiness for traffic use during the Tourist Trophy Racing week 1933. The circuits were therefore given trials in traffic for two days prior to the first day of the racing week. They worked satisfactorily and were favourably reported upon. The circuits gave satisfactory results during the heavy traffic of the racing week and have continued to do so since that time.

From the point of view of operation of the telephone circuits, experience in service has shown no new difficulties to have been introduced by thus requiring the cable to perform a dual function.

There is therefore reason to hope that the future may see further extension of sub-audio working both on this and other submarine cables.

The authors desire to acknowledge their indebtedness to their various colleagues who were associated with the work both in design and installation.

The Use of the Teleprinter Distortion and Margin Tester

W. F. BEVIS

WITH the installation of the Blackpool-Douglas (Isle of Man) Sub-Audio Telegraph Circuits, the Teleprinter and Distortion Margin Tester, developed in the Post Office Research Section and described in a recent article[1] in this Journal, has had its baptism for general field use, and, in view of the special nature of the case, it is considered that an article dealing with some of the tests carried out and the results obtained will prove of general interest and be of value to those officers who may be called upon to use the set.

The uses to which the Distortion Set was put in this case were :—

(1) Ascertaining the optimum value for the Magnetic Shunts which were used for distortion correction at the transmitting ends of the circuits.

(2) Checking the accuracy of the duplex balances.

(3) Measuring the distortion remaining on the Blackpool-Douglas section of the circuits after the installation adjustments had been made.

(4) Measuring the Excess Margin available for Teleprinter working over the circuits.

It should perhaps be mentioned that the whole of the design of the terminal equipment on the circuits was based on the results of distortion measurements on artificial lines made up to represent the submarine and land cables. The distortion tests made on site were therefore to some extent in the nature of confirmatory tests, but also had the object of enabling adjustment of the terminal equipment to the practical conditions to be made.

Fairly extensive distortion measurements were carried out in order to obtain technical data and also to gain experience in the use of the set in the field.

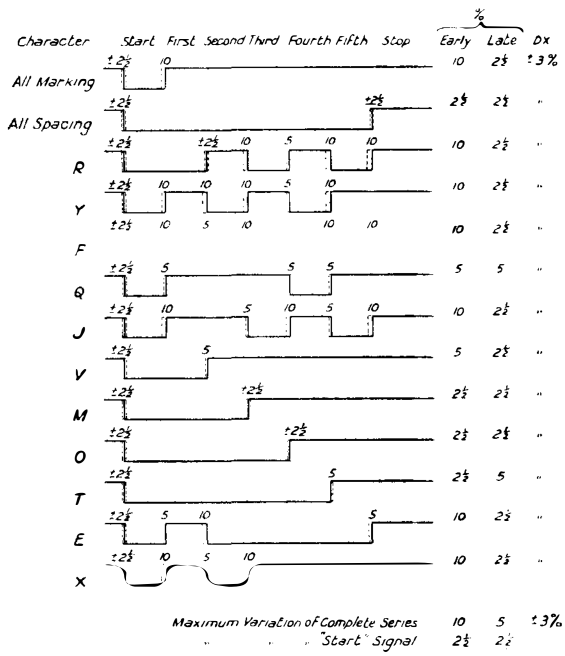
Testing Procedure.

For testing purposes a series of signals, which it was considered would give representative values for the distortion likely to be met with in practice, was chosen from the Teleprinter Code. These signals are shown in diagrammatic form in Fig. 1.

The transmitting speed throughout the tests was 50 bauds, and all distortion figures have been expressed as a percentage of a unit signal element.

Each Teleprinter Character as shown in Fig. 1 was set up on the Distortion Tester Transmitter at the distant (transmitting) end and the amount of distortion received on the Distortion Tester Stroboscope was recorded at the receiving end of the circuit. In this case, a record was taken for each individual changeover from " Marking " to " Spacing " or vice versa throughout the character, in terms of the extent to which it was " Early " or " Late " with reference to the correct position. These values are tabulated beside the character concerned in Fig. 1.

From a practical working point of view, the only value of importance is the greatest of these readings and is the only one which would need to be recorded in the general case.



Estimated Total Distortion		Figures for Calculation of Teleprinter Excess Margin	
Sx	Dx	Sx	Dx
		Early late	Early late
15%	21%	12½%- 7½%	18½%- 13½%

FIG. 1.—SCHEDULE OF CHARACTERS USED, WITH RESULTS FOR OPTIMUM CASE : RECEIVING AT BLACKPOOL.

The sub-audio circuits are worked duplex and, thus, the added distortion due to imperfection of the duplex balances had to be taken into account in assessing the maximum distortion likely to be met with under normal working conditions. This was recorded by first observing a complete signal display on the stroboscope at simplex and then noting the resulting displacement of the units in the display when duplex signals were transmitted against the received signals. In the present case this displacement was recorded as plus or minus three per cent.,[2] *i.e.*, any element in a display was displaced up to a maximum of plus or minus three per cent. at duplex as compared with the distortion received at simplex.

[1] " Determining the Transmission Efficiency of Telegraph Circuits." E. H. Jolley, A.M.I.E.E. P.O.E.E.J., Vol. 26, Part 1, page 1.

[2] NOTE : To simplify the reading of this article the duplex value has been taken as ± 3% to differentiate from the ± 2½% of the " Start " signal. Actually the duplex unbalance was scheduled as ± 2½%.

In general, the object in view when setting up these circuits was the reduction of the distortion to a minimum and since, as already mentioned, the conditions for the sub-audio channels had hitherto been reproduced as nearly as possible in the laboratory by artificial cable, the first step was to check the experimental results with those obtained on the working circuits. The results on the latter agreed with those previously obtained. However, owing to an alteration—which has been discussed in a previous article[3]—in circuit conditions at Blackpool, it was found to be necessary to change the value of the Magnetic Shunt resistance at the Douglas end to restore the original working margin in that direction.

To ascertain the optimum value of the Magnetic Shunt resistance, series of tests were made with different values and these results are summarized, in Table I when receiving at Douglas with different values of resistance at Blackpool, and in Table II when receiving at Blackpool with the corresponding resistance changes at Douglas. Figures for the estimated Total Circuit Distortion, and those for the Calculation of Teleprinter Excess Margin are given. The effect of the value of the Magnetic Shunt resistance on the circuit distortion is clearly demonstrated in these Tables.

The results set out in the analysis in Fig. 1 were obtained when receiving at Blackpool and the optimum value had been fixed (*i.e.*, 300 ohms). It may prove interesting to compare this schedule with another obtained under less favourable conditions. Fig. 2 gives an analysis when receiving at Douglas and when the Magnetic Shunt Resistance at Blackpool was 400 ohms instead of 200 ohms.

Excess Margin for Teleprinter Circuits.

To decide the " Excess Margin " available on a circuit on which Teleprinters will be used, the following method is adopted. The maximum variation " Early " of the " Start " signal is added to the maximum variation " Late " of any of the succeeding elements and is recorded as the percentage " Late "; also the maximum variation " Late " of the " Start " signal is added to the maximum variation " Early " of the succeeding elements and is recorded as the percentage " Early." Thus, two readings in terms of Maximum " Early " and Maximum " Late " are scheduled.

In duplex working, the added distortion due to duplex unbalance must also be taken into account.

The duplex variation is recorded, in the present case, as plus and minus, 3% and accordingly the simplex variation of the " Start " signal of $\pm 2\frac{1}{2}\%$ will be increased a further 3% in either direction under duplex conditions. Similarly, the simplex limits " Early ' and " Late " of any of the succeeding elements will also be subjected to this added distortion and 3% must accordingly be added to each for the duplex assessment. Thus an overall of 6% must be added to the simplex reading.

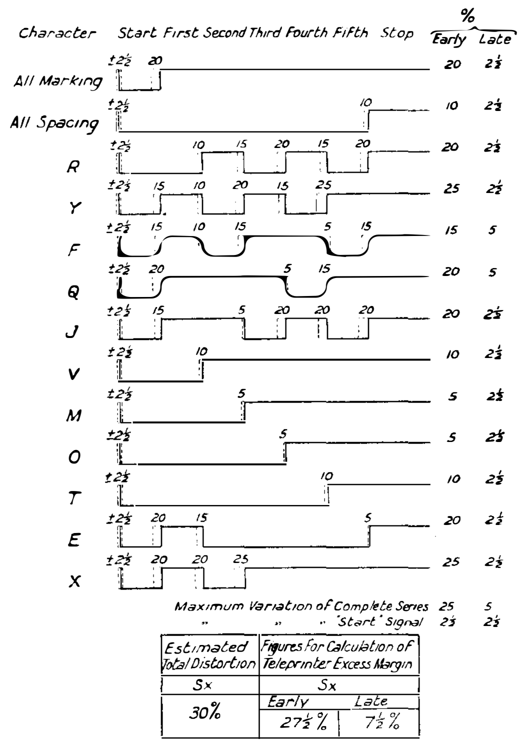


FIG. 2.—SCHEDULE OF CHARACTERS USED, WITH RESULTS WHEN USING MAGNETIC SHUNT RESISTANCE OF 400Ω AT BLACKPOOL : RECEIVING AT DOUGLAS.

This is illustrated in Fig. 3, where the values taken are those set out in Fig. 1 in the column " Figures for the Calculation of Teleprinter Excess Margin." It will be seen that at Simplex, the maximum variation " Late " (A, $2\frac{1}{2}\%$) of the Start Signal is added to the maximum variation " Early " (B, 10%) of the succeeding elements, giving an overall of $12\frac{1}{2}\%$ " Early " (A to B). For the duplex condition, a further 3% " Late " (C) must be added to the Start Signal and 3% " Early " (D) to the succeeding elements, giving an overall of $18\frac{1}{2}\%$ " Early " (C to D).

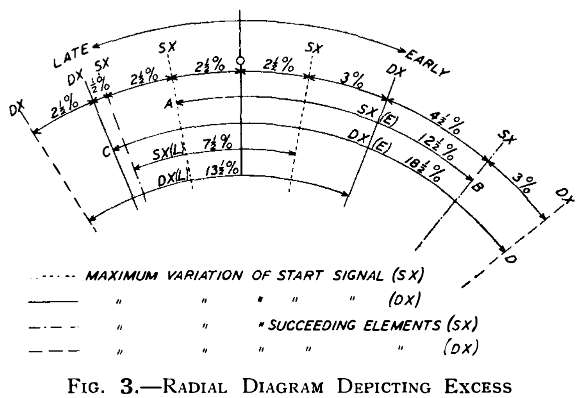


FIG. 3.—RADIAL DIAGRAM DEPICTING EXCESS MARGIN ASSESSMENT.

[3] " Sub-Audio Telegraph Working on a Continuously-Loaded Submarine Telephone Cable." J. G. Straw, B.Sc., A.M.I.E.E., and Capt A. Arnold. P.O.E.E.J., Vol. 27, Part 1, page 1.

TABLE I.

SCHEDULE OF SOME OF THE DISTORTION MEASUREMENTS TAKEN AT DOUGLAS, ISLE OF MAN.

Circuit.	Magnetic Shunt Resistance at Blackpool. Ω	Line Current. mA	Estimated Total Circuit Distortion.		Figures for Calculation of Teleprinter Excess Margin.				Remarks.
			SX %	DX %	SX		DX		
					Early. %	Late. %	Early. %	Late. %	
LV-DGI 4	400	6	30		27.5	7.5			
,,	300	5	27.5		27.5	5			
,,	100	2.7	45		22.5	27.5			
,,	150	3.5	25		17.5	12.5			
,,	250	4.6	22.5		22.5	5			
,,	200	4	17.5	26	17.5	5	26	13.5	Final Conditions.
,,	200	4	40		27.5	17.5			Final Conditions. *Signals repeated back from Blackpool.
LV-DGI 5	200	4	17.5	23.5	17.5	5	23.5	11	
,,	150	3.4	17.5		17.5	5			
,,	250	3.7	35		35	10			
,,	200	4	17.5	26	17.5	5	26	13.5	Final Conditions.
,,	200	4	35		27.5	12.5			Final Conditions. *Signals repeated back from Blackpool.

* A circuit facility is provided whereby the transmitted signal is passed to the distant end, through the panels, and is there repeated back to the transmitting end.

TABLE II.

SCHEDULE OF SOME OF THE DISTORTION MEASUREMENTS TAKEN AT BLACKPOOL.

Circuit.	Magnetic Shunt Resistance at Douglas. Ω	Line Current. mA	Estimated Total Circuit Distortion.		Figures for Calculation of Teleprinter Excess Margin.				Remarks.
			SX %	DX %	SX		DX		
					Early. %	Late. %	Early. %	Late. %	
LV-DGI 4	400	3.7	20		17.5	7.5			
,,	300	3.0	15		12.5	7.5			
,,	250	3.3	20		12.5	12.5			
,,	200	3.6	20		7.5	17.5			
,,	150	3.0	35		12.5	27.5			
,,	350	3.4	20		12.5	12.5			
,,	300	4.0	15	21	12.5	7.5	18.5	13.5	Final Conditions.
,,	300	4.0	35		20	25			Final Conditions. *Signals repeated back from Douglas.
LV-DGI 5	400	3.6	15		12.5	7.5			
,,	450	3.7	25		17.5	12.5			
,,	350	4.0	20		20	10			
,,	300	3.7	15		15	10			
,,	250	3.2	25		17.5	12.5			
,,	300	3.9	20	26	12.5	12.5	18.5	18.5	Final Conditions.
,,	300	3.9	30		25	15			Final Conditions. *Signals repeated back from Douglas.

* A circuit facility is provided whereby the transmitted signal is passed to the distant end, through the panels, and is there repeated back to the transmitting end.

Teleprinter Tests at Douglas.

Table III gives the results of some of the Teleprinter tests at Douglas. These tests were taken in accordance with the method described in the recent article[1] dealing with the Teleprinter Margin and Distortion Set under the sub-title " Measurement of the Margin of a Teleprinter " and therefore the margin of the machines was determined by shortening and lengthening the Start signal. The amount by which the Start signal can be shortened is equivalent to the amount of " Early " distortion on the code elements that the machine will accept without failure. Conversely, lengthening of the Start gives the corresponding value for permissible " Late " distortion. The margin of the machines has therefore been tabulated in terms of permissible " Early " or " Late " distortion. The letter " Y " was the character used throughout.

TABLE III.
MARGIN MEASUREMENTS OF TELEPRINTERS 3A AT DOUGLAS, I.O.M.

Machine.	Machine Failed when permissible distortion was :—	
	Early.	Late.
A	39%	33%
B	30%	40%
C	35%	27%
D	50%	27%
E	41%	27%
F	40%	33%

The letter " Y " was the testing character used for each machine.

Application.

For a typical example, the values given in Table III for machine A may be taken in conjunction with the " Figures for Calculation of Teleprinter Excess Margin " shown in Fig. **1**.

Simplex.	*Duplex.*
12½% Early—7½% Late.	18½% Early—13½% Late.

Machine A failed when the distortion was :—

39% Early or 33% Late.

Teleprinter Excess Margin at Simplex.

	Early.	*Late.*
Teleprinter Margin ...	39%	33%
Line Distortion ...	12½%	7½%
Excess Margin ...	26½%	25½%

Teleprinter Excess Margin at Duplex.

	Early.	*Late.*
Teleprinter Margin ...	39%	33%
Line Distortion ...	18½%	13½%
Excess Margin ...	20½%	19½%

To appreciate fully the value of these tests it will be profitable to take a further example, this time using the " Figures for Calculation of Teleprinter Excess Margin " given in Fig. **2**. The same values have been retained for Teleprinter Margin as were used in the previous example. As the distortion figures were high at simplex, duplex values were not taken in this test, but a comparison of the simplex figures will suffice.

Teleprinter Excess Margin at Simplex.

	Early.	*Late.*
Teleprinter Margin ...	39%	33%
Line Distortion ...	27½%	7½%
Excess Margin ...	11½%	25½%

It will be seen that the machine would work correctly, but since the margin on the " Early " side is reduced from 26½% to 11½% the margin for satisfactory service is also reduced.

Without a distortion measuring device, no really satisfactory indication of this difference could have been obtained by direct Teleprinter reception. It should be pointed out, however, that the figures were obtained when using—from a practical view point—a distortionless transmitter. In practice, the transmission would come from a Teleprinter and an additional allowance of at least 5% is necessary for any imperfection in the Teleprinter transmitter contacts and also a further 5% for a possible speed difference between the sending and receiving machines. These effects will therefore, in practice, tend to reduce the Excess Margin by approximately 10%.

Total Distortion.

Although the foregoing distortion figures are strictly only applicable to Teleprinter operation at 50 bauds, they can also be used for the purpose of assessing the Total Distortion. Total Distortion is defined[4] by the C.C.I.T. as the maximum difference between the intervals of time separating any two operations of the receiving relay from the corresponding operations of the transmitter. An assessment of the Total Distortion can therefore be made by an examination of the complete results for a representative series of characters such as those used in this case, and is given by the sum of the maximum " Early " distortion and maximum " Late " distortion occurring anywhere in a series of signals.

Figures for the Total Distortion assessed in this way have been included in Figs. **1** and **2** and in Tables I and II.

[4] " Signal Distortion in Telegraph Circuits." E. H. Jolley, A.M.I.E.E. P.O.E.E.J., Vol. 25, Part 4.

Communication Engineering in East Africa[1]

C. W. MILLARD, B.Sc.

AT the time of my arrival in Kenya in May, 1930, the Posts and Telegraph Departments of Kenya and Uganda only were united under one administration. The Department in Tanganyika is now being amalgamated with those of the other two colonies so that the whole of the communication system of East Africa (Fig. 1) will come under one control centred in Nairobi. This amalgamation applies only to certain Departments, the government and finance of the three colonies remaining separate.

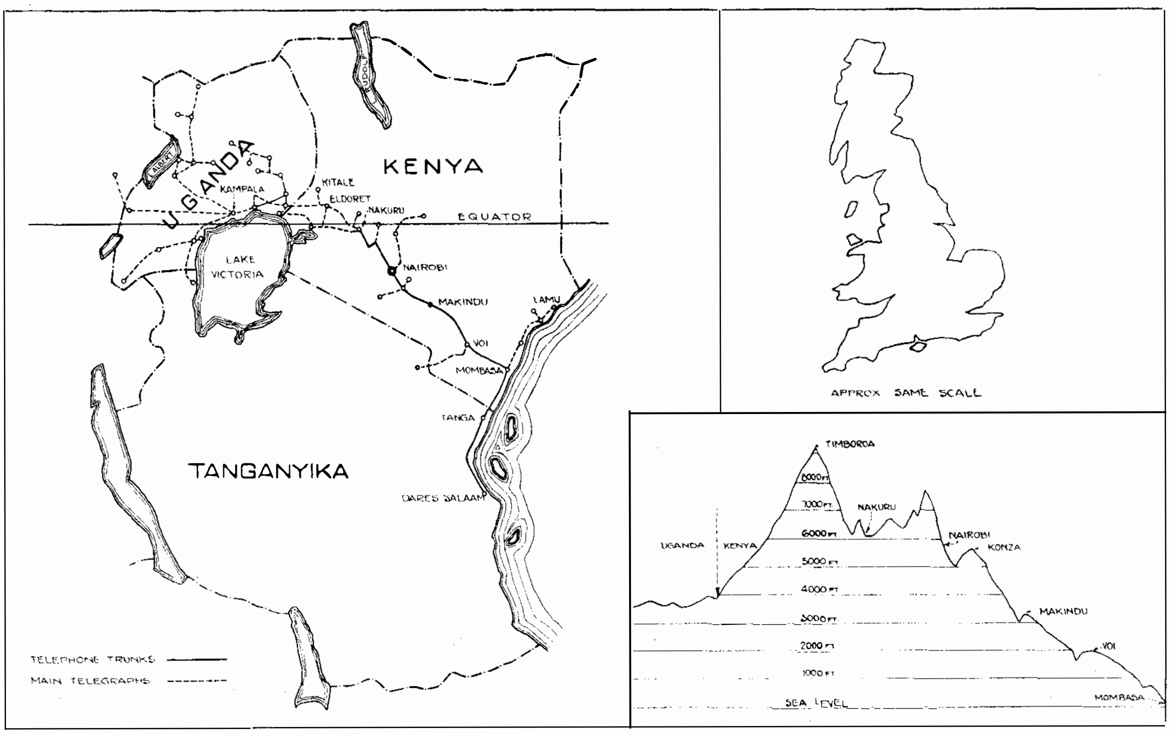


FIG. 1.—EAST AFRICA.

The head of the Department of Posts and Telegraphs is the Postmaster-General in Nairobi. In the Engineering Department the staff tree is as follows :—

The Chief Telegraph Engineer.

2 Telegraph Engineers—one in charge of Kenya and one of Uganda.

3 Assistant Telegraph Engineers.

6 Sub-Telegraph Engineers.

About 22 Inspectors.

Indian and Native Staff.

From a comparison of the number of the staff and the amount of plant it might appear at first sight as if the administration falls intermediate between that of a small Engineering District in this country and that of a large Section. It would be futile, however, to make any such comparison either on the basis of equal areas or of equal amounts of plant, for the following reasons :—

(1) The incomparably lower density of plant per given area in the colony.

(2) The lower standard of training of the Indian and Native staff compared with the workmen in England.

The general effect of these factors upon the duties of the Engineer is to load on to him a great amount of small detail such as in England would be left to very junior staff, with only occasional supervision from senior officers. In this country the intensive training of new entrants into the Department, the long established principles of work, and the example to new and junior staff of a vast amount of plant all installed to set standards, relieves the Engineer of the onus of detailed inspection of all work at all its stages. In any colony employing non-European labour, on the other hand, the economy in cheap labour must be purchased at the price of untiring supervision in great detail. If this is occasionally

[1] Extracts from a paper read before the North Western Centre of the I.P.O.E.E. at Preston on 16th May, 1933.

tedious the Engineer has much to compensate him. A zest is added to his work that is often lacking in larger administrations, in that he sees the work through from its inception to its completion. For example, the work of surveying for a new route, of preparing the estimate, indenting for material, arranging for the transport of the material to the distant work, the construction and final testing of the lines before handing over for service, may fall to the lot of one and the same officer. The fact that he may have to examine every detail of construction that his Indian or Native subordinates are carrying out is perhaps relieved of its tedium by the feeling that it is his job and not, as often in larger organizations, his small part of a job.

There is an obvious danger in such an organization where the number of senior officers is very limited and much time may be necessary in attending to detail, that such functions as general organization, economic planning with a view to the future and all aspects of work involving a wide view of the work as a whole, may receive too little attention. The appointment of one Assistant Engineer as personal assistant to the Chief Telegraph Engineer in some ways safeguards this danger. The duty approximately covers that of Efficiency Engineer in the Home Service but with rather a wider scope.

The other two Assistant Telegraph Engineers are attached to the office of the Telegraph Engineer, Kenya, there being no corresponding posts in the Uganda establishment, which is on a much smaller scale than that of Kenya.

One Assistant Telegraph Engineer has charge of all Construction in Kenya and the other of Maintenance.

Where in England Sections are divided into smaller areas in charge of Chief Inspectors, in Kenya the sub-divisions of the country are supervised by Sub-Telegraph Engineers and Inspectors according to their size and importance.

A feature of the distribution and functions of the Inspectors in Kenya is that the distribution of new works in progress in the country is not so even as in this country, with the result that a fair proportion of the Inspectors form as it were a mass of manœuvre, being attached to any particular district and engaged on construction and reconstruction wherever new routes may be projected or underground schemes laid down.

No clerical assistance is provided outside Headquarters at Nairobi and Kampala, with the exception of an Asiatic Storekeeper at Mombasa, who assists with typing and general office work.

At Nairobi a European Chief Clerk supervises a small staff of Indians including a draughtsman, two typists and filing clerks, two accounts clerks and a registry clerk.

A single Indian draughtsman who serves the whole of the administration of Kenya is helped in preparing prints by a native.

Grades corresponding to all classes of workmen are filled in Kenya by Indians and Natives.

The system of finance is governed by Colonial Financial Regulations. The costing and estimate of works is not in general made to include labour costs as all labour is provided under the Personal Emoluments Vote. The costing of individual works therefore only includes material, which is alone provided for by the Annual Votes.

Works are carried out and stores issued and returned to stock on a system of Works Authorities very similar to that of Works Orders and Advice Notes in use in this country, except that estimates are not prepared for Small Works. Further, there is nothing equivalent to the bulk supply of stores to simplify the handling of stores on numerous small transactions. It is questionable, however, whether this would work very well with the non-European Staff.

Stores.

The main stores is located at Nairobi with subsidiary stores at other centres. The normal stock of Engineering stores held may not exceed £15,000 in the unallocated stores, but material may be purchased in excess of this sum and held on allocated stores in respect of special large works such as have been made the subject of special and non-recurrent votes.

In a stores where the number of transactions is comparatively small the whole procedure of the issue and recovery of stores and its accounting can be made very simple and the system in use is very effective.

Workshops.

The workshops in Nairobi are in charge of a European officer approximately equivalent in rank to a Sub-Telegraph Engineer. He is assisted by two Europeans and a staff of Indian Carpenters, an Indian Blacksmith, Seychellois mechanics and natives.

The machine plant includes a circular saw, various lathes, a machine drill, an engraving machine and an aerograph paint-sprayer which is also used as a blower to clean out exchange units and apparatus.

Local conditions render the functions of the workshops rather wide, and the work very interesting. The difficulty and expense of obtaining plant from England, especially at short notice, gives the workshops a lot of work in making up plant and adapting apparatus and fittings held in stock to the special circumstances of the work.

The difficulties mentioned before also bring in a large proportion of reconditioning jobs on tools and apparatus which have really run their normal life close.

The Indian Carpenters can be very skilled craftsmen and their work is interesting to watch on account of their use of very primitive tools and methods.

Lines—Aerial.

Although wooden poles have been employed very considerably in the past the high cost of maintenance they demand, owing to the ravages of insects and to their liability to rot, is rapidly leading to their being superseded by iron poles. These poles consist primarily of two parts—a base with a flange at the bottom and an Upper which fits into the base and is made secure with a screw ring. Both are manufactured in a range of sizes, the number of types of base being rather less than the number of types of " Uppers," as one size of base will serve a range of " Uppers." The base may be equipped with a large square base plate to give it more purchase on the ground. On the main trunk routes the normal pole used is 24′ or 26′ in length; sizes ranging from 18′ to 36′ are obtainable however.

Tubular steel arms are the normal fitting to these poles, although wooden arms are adapted in emergencies The tubular arm rests against the pole with a curved saddle welded to the arm and secured by bolts to a backstrap on the other side of the pole.

a maximum angle of deviation is established and kept up to as closely as possible with a maximum number of poles in straight runs. This angle is set as 15°. The most economical line will therefore contain only angles of 15° and long straight runs. The box sextant provides a speedy and accurate means of gauging angles and of estimating the minimum number of angles necessary to negotiate a given curve in the line.

Trunk System—Transmission.

The main trunk system of Kenya, already constructed and immediately projected, consists of aerial lines of 200 lb. copper at 12″ spacing.

The system, together with that part of the Tanganyika system to which it is immediately connected, consists of the following lines :—

Trunk.	Number of Trunks.	Length Miles.	Estimated Transmission equivalent db.	Remarks.
(Eldoret-Nakuru) ...	(1)	(125)	(7.5)	(Projected).
Nakuru-Nairobi ...	1	121	7.5	
Nairobi-Mombasa ...	2	331	20.0	
Mombasa-Tanga ...	1	105	6.5	66 mls. in Kenya.
Tanga-Dar-es-Salaam ...	1	160	14.0	

The whole assembly is very neat in appearance and in townships, if painted a suitable green, is quite unobtrusive.

Some difficulty is experienced with the saddle grips on the pole which have to be tightened up thoroughly if slewing of the arm is to be prevented.

All normal pole and arm fittings are obtainable in suitably modified forms for this type of construction. The cost, however, of both poles and fittings is considerably higher than for wooden pole construction.

Main Lines.

All main lines, Telephone and Telegraph, are of overhead open wire construction. Wherever possible they follow the railways and such routes carry the Railway Telegraph Lines, Train Control and Station-to-Station lines, the latter connecting the Tablet Instruments and vibrators at the Stations. Both Iron and Copper Telephone and Telegraph circuits are used.

In East Africa, lines following the railway, unlike those in this country, are erected and maintained entirely by the Post Office, under agreement for repayment with the Railway.

Surveying for main routes, although robbed to a great extent of such difficulties as wayleaves and clearances, is often carried out in very rough and big-game-infested country.

The latitude possible in the routing of the lines, the usual requirement for which is that it keeps within easy sight of the railway for maintenance, allows of considerable economy in the use of stays, provided

The transmission equivalent of the Nairobi Mombasa Trunk, calculated as 20 db., was confirmed by measurement, by comparison with non-reactive artificial cable, made up in the Department's workshop at Nairobi, and designed to the same Characteristic Impedance Modulus, but differing by an angle of about 12° from that of the actual line. This

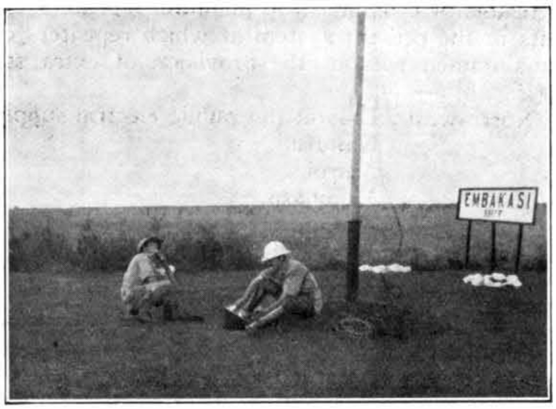


Fig. 2.—Transmission Testing in the Field.

figure was therefore taken as the basis of calculation of the equivalents of the other trunks, with the exception of the Tanga Dar-es-Salaam section. Actual speech from Mombasa to Dar-es-Salaam with the Tanga exchange and all composite apparatus cut out was quite evidently worse than the calculated value of 16 db. and did not compare favourably with speech from Nairobi to Mombasa. Until actual measurements could be made on this line, therefore, a tentative figure of 20.5 db. has been assumed, and divided up as 6.5 db. Mombasa to Tanga, and 14 db. Tanga to Dar-es-Salaam. The calculated figure of 6.5 db. Mombasa to Tanga was taken as being warranted by the speech tests.

This system differs from such systems as those of European States in one important feature. In England, for example, the provision of direct zone centre to zone centre trunk communication is sufficient to limit the number of links connecting zone centres, which will be in use in establishing a call between subscribers connected to remote centres. In such a case, therefore, in allotting the maximum allowable loss to every grade of line, some loss can be allotted to the main trunk itself, although a zero zone centre to zone centre loss would be the ideal and would, amongst other things, simplify the provision of Subscribers' and Junction Lines.

In East Africa, on the other hand, anything from one to five links may be involved in the chain of trunk communication and this number of links will, of course, be increased eventually.

It is therefore essential in this particular case that if the C.C.I. figure of 29 db. between subscribers is not to be exceeded, that the loss in individual trunks should be kept as close to zero as possible. This is also important both by reason of the low efficiency of the large number of old pattern magneto subscribers' instruments and also because of the necessity of connecting extended Rural Schemes working on a party line basis to the trunk system.

To apply the ideal of zero trunk loss to the Kenya Trunk System, and at the same time keep within the other limits recommended by the C.C.I., the principal difficulty is that the ideal spacing of Repeater Stations is impossible owing to the limited number of points on the line at which it would be practicable or economical to maintain repeaters. The points in the present system at which repeaters can be maintained without the provision of extra staff are (Fig. **3**) :—

North-west : Eldoret (no public electric supply).
Nakuru.
Nairobi.
Mombasa.
Tanga.
South-east : Dar-es-Salaam.

The chief factor determining the range of levels is the long section Nairobi-Mombasa. with a transmission equivalent of 20 db., which it would be most desirable to divide into two repeater sections of approximately 10 db. each. The uninhabited nature of the country between the belt round Nairobi and the coastal area precludes the maintaining of a small repeater station at any intermediate point at present. Makindu and Voi are the only points at which European or Asian maintenance officers are stationed and both these officers spend a great part of their time away from their Headquarters on the maintenance of lines and railway tablet instruments.

The gains allowable at the forementioned stations are restricted by the difficulty in maintaining line balances closely enough approximating to the line, over wide ranges of temperature and humidity. Measurements of conductor and insulation resistance taken over twenty-four hours showed that from the maximum values obtained during the early afternoon to the minimum at about 5.45 a.m., there was a range of 10 per cent. variation in conductor resistance and of ten to one in insulation resistance.

With the changes in line characteristics attendant on such variations it was found that the sum of the nett gains in both directions on the two wire repeaters should not be allowed to exceed 18.5 db. or 20 db. at the most.

The overhearing from trunk to trunk on Nairobi-Mombasa route was measured by comparison with artificial cable and found to be generally better than 65 db., which is a very high standard.

The problem of cross-talk and noise level mainly concerns induction from parallel telegraph lines. All trunk routes carry telegraph lines, with the exception of the Mombasa-Dar-es-Salaam trunk, over which two telegraph circuits are composited on the single telephone trunk. On long overhead trunks, such as those in the Kenya system, morse induction is one of the chief causes of trouble. The trunks are transposed on a system based on the British Post Office system except that the crosses are made on double-groove double shed transposition insulators instead of on four ordinary insulators on J. or U. bolts. Transposition sections are limited to approximately eight miles, and every section between railway stations consists of an integral number of half transposition sections. This is necessitated by the presence on the trunk route of " Station-to-

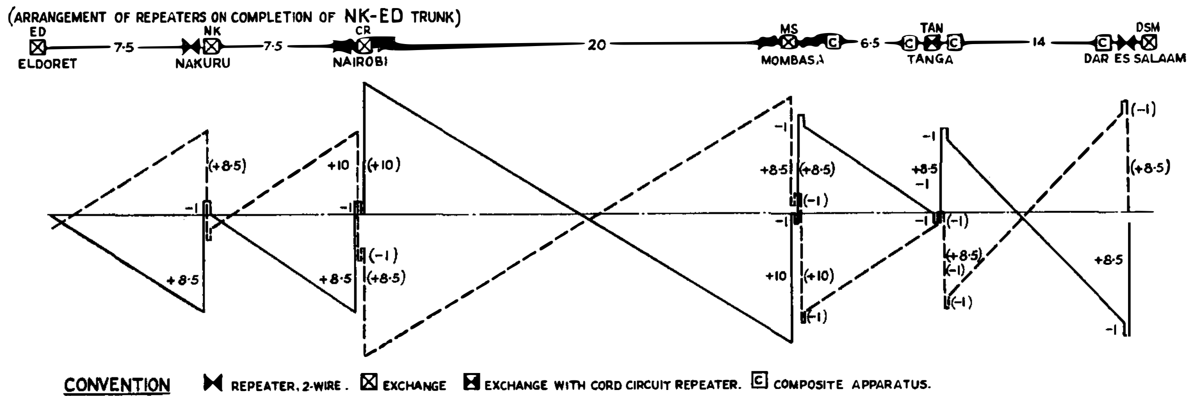


FIG. 3.—TRANSMISSION LEVEL DIAGRAM, ELDORET—DAR ES SALAAM.

Station " wires for the Railway Tablet system, on which are superimposed through condensers the Station-to-Station vibrators. These vibrators work at a high energy level necessitated by the excessive noise level in the single vibrator lines due to morse induction. If this latter level could be reduced it would then be possible to reduce also the vibrator energy level by working the vibrators on smaller battery power through smaller condensers, say 0.5 μF instead of 2 μF.

An attempt was therefore being made to suppress the noise level due to Morse telegraphs by the insertion of L. or T. type low-pass filters in the telegraph circuits. The principal difficulty in the design of these filters was the construction of suitable inductances, as at the time no A.C. Bridge was available. An experimental telegraph circuit was therefore constructed, consisting of Wheatstone apparatus working through reactive artificial line approximately equivalent to one of the Nairobi-Mombasa telegraph lines, in series with an air core transformer, the secondary of which was connected through a variable attenuating network to a telephone receiver. By means of a switch experimental filters could be cut out of circuit at the same time as the variable attenuating network was inserted in the telephone circuit, by which means the improvement in cross-talk due to the insertion of a particular filter could be measured at the same time as the effect on the received signals was observed from the Wheatstone slip, for various speeds of working.

The present provision of single trunks from Nakuru to Nairobi and Mombasa to Dar-es-Salaam, and two trunks from Nairobi to Mombasa is quite sufficient to meet traffic requirements for some time to come. When eventually further channels become necessary, carrier systems can be installed on the single trunks, and the two trunks from Nairobi to Mombasa can be phantomed. To obtain a plus circuit on the Nairobi-Mombasa trunks free from Morse disturbance will mean, however, the re-transposing on a phantom basis of the whole route.

Lines—Local.

In the larger exchange areas cable both underground and aerial and open lines are in use. The underground development of the larger centres is now being pushed forward rapidly. In Nairobi and Mombasa the layout of the towns provides for narrow alleyways running parallel to the main streets behind the shops, which lanes lend themselves to distribution from the underground cables by aerial cables suspended from brackets on the walls. Distribution from the boxes is effected by running Braided and Compounded Copper Cadmium twin wire backwards and forwards through the suspending rings.

Open wire distribution is practically all 40 lb. bronze, no 70 lb. bronze or bare copper cadmium being in use. There would appear to be considerable room for the use of Copper Cadmium, as many of the subscribers' lines in such scattered townships as Nairobi are comparatively long. The difficulties ordinarily experienced regarding the identification of coils of Copper Cadmium would be very great where the wire would be handled largely by non-European staff. The difficulties could be overcome by the purchase of bronze in the 40 lb. gauge and Copper Cadmium in the 70 lb. gauge only. The need for identification of pole routes carrying copper cadmium would then be minimised, although care would still have to be taken.

Rural Telephone Schemes.

A problem which is rather special to colonial systems is that of giving telephone communication to groups of subscribers in scattered areas, in which there is a community of interest such that the proportion of local calls over junction calls would be very high. In some respects similar circumstances arise in this and other districts and are met by the provision of R.A.X. equipment. The chief difference in the problem is, however, that in the colonies the group of subscribers is generally very much more scattered and the provision of individual lines to each subscriber would entail an uneconomical provision of external plant. This is met in Kenya by party line schemes on a large scale. A group of, say, 30 subscribers in an extended district, let us suppose, devoted to the growing of tea or coffee, would be served by three or four lines on a party-line basis, with code ringing, the lines being terminated on a small P.B.X. having access to the general system of communications. The system is magneto and the code a combination of long and short rings. The disadvantages of such a system are only too obvious from the point of view of transmission, traffic and privacy, but they meet a great need in an economical way, and it is difficult to see how they can be replaced at present by any system comparable in cost which does away with their main objections.

Exchanges.

The advent of Automatic switching in highly developed countries such as England, although it has revolutionized the Telephone system, has produced rather less startling changes in principle than it has in small Colonial systems. In this country manual exchanges developed from the most elementary exchanges to manual systems which commenced by centralizing power for signalling and also for speech and proceeded to develop by employing more and more relay operated devices in the cord circuit. The step to completely automatic equipment of the cord circuit was therefore robbed of some of its sharpness. In Kenya, at the time of my arrival, all exchanges were of magneto signalling type; neither C.B.S. nor C.B. exchanges existed. Had full automatic switching never matured the natural development would have followed lines similar to those pursued in this country. As it was, the cutting over of the Nairobi Automatic Exchange from Magneto working, in 1931, shut the door on any manual central battery development.

The Nairobi Automatic Exchange was manufactured and installed by Messrs. General Electric Co., Peel Connor Works, Coventry. The expansion of the Nairobi Exchange area will probably not reach 900 subscribers for some time and the present 700 odd lines are allotted four digit numbers and are all reached *via* the second level of the first selectors. There is full availability at present to second group selectors of which there are an equal number to first group selectors. The ultimate capacity of the exchange is 2000. The exchange does not embody any special features. Forced release in the event of the called party being held longer than 1 minute after the calling party has restored is provided and the transmission bridge is located with the penultimate selectors.

The climate in Nairobi was a factor which had to be considered. In the dry season there is much dust, while during the rains the warm atmosphere is heavily charged with moisture. It was advisable, therefore, to provide some means for drying and scrubbing the air in the exchange and a de-humidifier was installed. The windows of the exchange are therefore not made to open. The de-humidifier cleans the air and controls the humidity by passing it through a shower of water cooled to a temperature of about 40° Fahrenheit, at which temperature the amount of moisture that can be held by the air is very small. The air is warmed after this process and circulated to the exchange. A hygrometer in the apparatus room gives an alarm when the humidity rises above a certain level. It was generally agreed amongst the exchange staff that the dry atmosphere was rather trying, but the effect on the maintenance of the apparatus was good.

At the railway headquarters in Nairobi a 100-line P.A.B.X. is installed, having 10 junctions to Nairobi exchange. Incoming calls only to the P.A.B.X. are handled by the operator, but outgoing calls only require the subscriber's number to be prefixed by the extra digit nine. All other exchanges in Kenya and Uganda are manual, a few only being sufficiently large to require magneto multiple boards. The largest of these are equipped with about three or four hundred lines.

International Links.

At present no telephone links connect East Africa with either the World network or with other African systems. Kenya has, however, direct telegraph communication with London *via* the beam station at Nairobi and a submarine cable outlet from Mombasa to Zanzibar.

Telegraphs.

With the exception of Morkrum Teletype apparatus occasionally employed on the Nairobi Mombasa line the telegraph system is Morse. For local circuits and on long-distance circuits during slack periods of traffic hand speed working is employed, both simplex and duplex, but all long lines are equipped with Wheatstone or Creed automatic apparatus. Quadruplex working is available if traffic demands between Nairobi and Nakuru, the A. side being relayed to Eldoret. A high-speed duplex repeater was at one time installed at Nairobi to connect Kampala in Uganda to the coast—a distance of nearly a thousand route miles—but this has since been withdrawn from active service.

Universal battery has not yet been installed, but is being considered for Nairobi and Mombasa, leclanché batteries being at present employed. A few minor circuits are equipped for central battery omnibus apparatus working with polarised sounders.

The railway employ hand-speed single current working only.

Composite Apparatus manufactured by the S.T. and C. Co. is installed at Mombasa, Tanga and Dar-es-Salaam, enabling sub audio telegraph apparatus to be used on each leg of the trunk. The severe limitation this apparatus imposes on the speed of working of Automatic Telegraphs renders its use with Wheatstone Apparatus of limited advantage and until printing telegraphs are installed on the Mombasa Dar-es-Salaam circuit the principal gain is from the quiet working of the speech channel and from the facility of individual circuits between the terminals and between each terminal and Tanga, thus obviating the repetition of messages at Tanga.

The circuits are operated almost entirely by Indian and Native operators, with European supervision in the major offices. The standard of operation of the circuits is very high and both Indians and natives often take down direct on to typewriters at the highest hand speeds normally employed in this country.

Train Control System.

The railway employs an omnibus speech circuit between Nairobi and Nakuru for traffic control, which eventually will be extended considerably. The scheme is the S.T. & C. system and is very ingenious.

A 300 lb. copper pair of high efficiency runs over the main trunk route from Nairobi to Nakuru and terminates in the Train Control Office at the Railway Headquarters in Nairobi. All principal stations are provided with specially designed telephones in parallel across the line, which terminates at Nairobi on a set comprising a set of ringing keys, a loud speaker and amplifier and the Controller's telephone set.

Selective ringing from Headquarters is effected as follows: The keys are somewhat similar in principle to automatic dials except that each key is capable of sending out automatically a distinctive train of three sets of impulses, totalling seventeen impulses. Thus Key 1 may send out 2-6-9; Key 2, 2-4-11; Key 3, 3-5-9, and so on. (Fig. 4).

At the Station instruments a 23,000-ohm selector mechanism in series with a condenser is connected in parallel with the telephone across the line. The make and break of the impulses is on a double current principle and successive impulses therefore reach the selector relay as condenser kicks of successively opposite polarity. The relay, by means of pawls, propels a light ratchet wheel against the torsion of a spring in such a way that as soon as a continuous train of impulses ceases the wheel would slip back unless at the pause it happens to be equipped with a stud which will engage with a detaining pawl. Thus if the train of impulses—2 pause 4 pause 11—is sent out all wheels equipped with a stud at step 2 will wait for the subsequent impulses. All those with studs at other points will slip back. Similarly, after the second train of impulses, only the wheel set with studs at the 2nd and 6th steps will be ready to receive the final 11

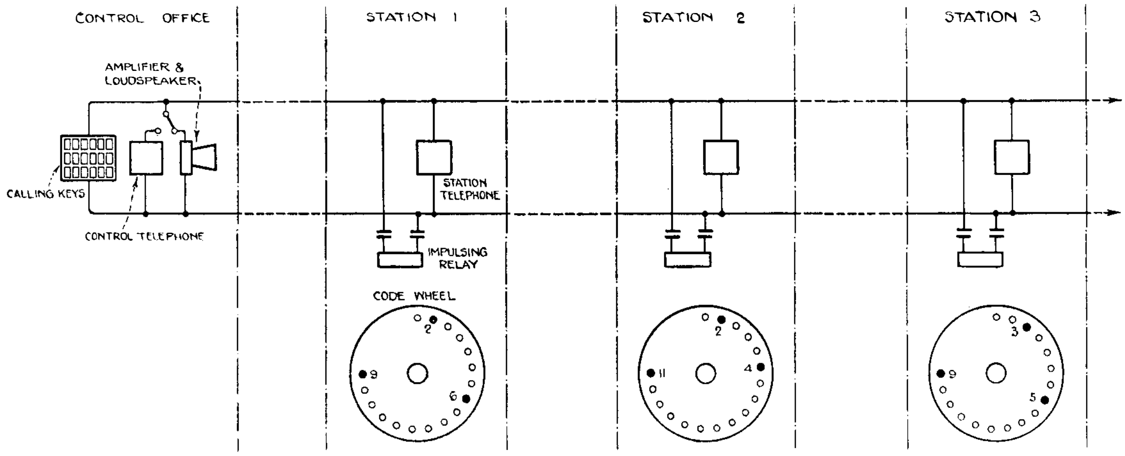


FIG. 4.—TRAIN CONTROL APPARATUS—SCHEMATIC.

impulses to carry it to the 17th step at which it closes a local bell contact and causes ringing. A final impulse after a few seconds kicks the operated selector wheel off stud 17 and causes ringing to cease.

The station staff in lifting the receiver and speaking can attract the attention of Control by means of the loud speaker which is normally in circuit. Control in lifting his receiver changes over from the loud speaker to a desk set. Stations can only intercommunicate by requesting Control to ring for them.

All the speech apparatus is specially designed to match the line and the Anti-Side Tone circuits are therefore very effective: The transmission is excellent. The effect of the 23,000 ohm relays in leak on the line is claimed to improve the transmission.

A Station set is installed beside the Trunk Test Desk at Nairobi to enable Control to get in touch with the Maintenance Staff.

Tablet Instruments.

All railway systems employing single tracks have to adopt some means by which the traffic can be regulated to ensure that trains proceeding in opposite directions do not enter the same section. This can be effected very simply by the elementary expedient of providing a driver with some token such as a ring or disc of metal, or a distinctive wooden staff at each section, without which he cannot proceed and which he hands over either to the driver of the waiting train at the end of the section, or, in the absence of a train, to the Stationmaster, and receives in return the token permitting him to enter the next section.

This is provided on the Kenya railways, which employ single track working throughout, by the use of electrically controlled machines, which issue the tokens or tablets as they are called, automatically, and which are inter-connected to render interference with the strict routine impossible, except by means so irregular as to involve criminal tampering with the apparatus.

The apparatus at the station is arranged so that the instruments controlling the issue of tablets for each section are situated one in each end of the section and connected by a single earth returning circuit. To obtain a tablet from the instrument, certain conditions are necessary. The Stationmaster at the down-station must give permission by depressing a plunger and completing a circuit. Until this is done the releasing mechanism at the up-station is locked. Further, the mere depression of the plunger will not unlock the up-station tablet if a tablet has been issued from the down-station and has not yet been returned by the driver at the up-station, and appropriately inserted at the up-machine.

Actually the apparatus is much more complicated than a very brief sketch would imply and is designed to cover all contingencies.

The apparatus is necessarily very robust, the relays being very large and clumsy, but with the rough usage to which they are subjected, combined with climatic conditions, a considerable amount of maintenance is necessary. If U.M.C. data were obtainable, I think they would appear rather appalling although they would not reflect on the diligence of the tablet maintenance staff.

Tablet Inspectors are recruited from Asiatic staff with one European senior Tablet Inspector. They are provided by the railway with accommodation at Headquarters, and also with a coach in which they live away from Headquarters.

Maintenance.

Many maintenance problems met with in East Africa are peculiar to the tropics.

Big game cause occasional trouble. The effect of of a herd of elephants on an overhead route is such that the gang's first duty is not to set the poles upright but to find the route!

Giraffe not infrequently become entangled in the lines, and it would be quite uneconomical to provide lines high enough to clear them.

The usually leisurely pace of the patrolling lineman is sometimes hastened by a rhinoceros.

Periodically birds cause a large amount of damage. During locust plagues poison is sprayed from trains to form a belt across which the young locusts or "hoppers" cannot cross. The resultant heap of dead locusts attracts vast flocks of small birds which alight on the wires in such numbers that a single span in which the normal loading is about eight pounds may be suddenly loaded over a hundredweight.

Several special circumstances existed which made it inadequate to adopt any system of fault records based closely upon that which exists in the Home country. Firstly, the work of linemen is done principally by natives with a sprinkling of junior Indian staff. Then again, the links between important centres frequently consist of single channels, any disturbance to which may cause complete rupture of the chain of communication. Further, the Inspectors at the terminus of a faulty line are frequently absent from headquarters on work in remote parts of their district, leaving as the senior engineering officer at the terminal of the line an Indian, or even a native lineman. It was therefore necessary that the senior officer at Headquarters should be able to follow the progress of locating and clearing faults at all stages—a procedure which would not generally be necessary in this country. To make this possible a visible index loose-leaf record was employed. All faults were reported to headquarters and entered by the clerk in the record against the relative circuit, and coloured metal clips were used to show the existence of a fault, the occurrence of long duration faults, and the fact that the interruption reports were outstanding.

The book was brought to the senior maintenance officer daily and kept him in touch with the position so that he could take any action necessary to expedite matters. The record was further very useful, as by an analysis of the fault record a survey could be made in either of the Inspectors' districts in which maintenance was not up to the average, or of routes upon which particular types of trouble were common, so that corrective measures could be taken.

At the time of the institution of this system a consignment of Evershed and Vignoles Bridge Megs had just arrived from England. This instrument is very compact, light and robust and combines both the megger and the rheostat in the one box. In its original form, although it was possible to make Conductor and Insulation Resistance measurements, it was not possible to use it for the Varley Loop test, as this test demands that one leg of the generator shall be dissociated from the rheostat and earthed. The internal wiring was therefore rearranged so as to bring the required generator terminal on to a switch which would either make the required rearrangement or restore the normal connexions for ordinary resistance measurements. This instrument has now been modified by the manufacturers on similar lines.

These instruments now released the existing wooden bridge meggers of the old pattern and it was decided to allocate the new instruments to work where a portable instrument was essential and to build the others into permanent test desks at principal exchanges. (Fig. 5).

These desks were made up in the workshops and were designed to make the procedure of precision testing as simple as possible. The desks incorporated a trunk test panel and the protective strips. The lines came straight from the M.D.F. where they were not protected to the protectors on the desk,

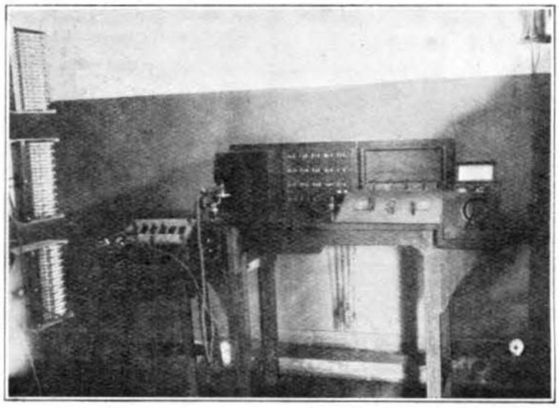


Fig. 5.—Trunk Test Desk.

thence to the test jacks, through the U links to the M.D.F., and so to the exchange. The test cord circuit terminated on three plugs, two of which were inserted in the line jacks and the other of which could either be earthed for earth localization or resistance unbalance tests, or connected to a line for Varley Loop Test for contact. The cord circuit (Fig. 6) contained two switches and jacks giving all the necessary conditions for Insulation Resistance, Conductor Resistance and Varley Loop Tests to be made and also the required terminating conditions for these tests to be made from the distant station. Three jacks were connected to three corresponding jacks on the Telegraph Test panels in the Telegraph room, enabling Telegraph lines to be extended to the test desk.

A magneto phone was built into the desk and could be substituted for the test apparatus by throwing a switch. With two such desks—one at each

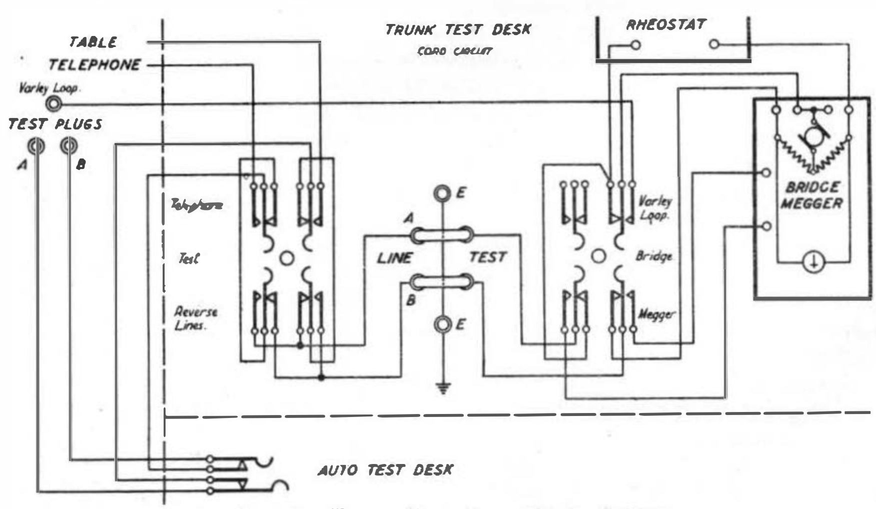


Fig. 6.—Trunk Test Desk, Cord Circuit.

end of the line—the work of fault localization was greatly facilitated.

Apart from ordinary fault conditions one of the principal troubles experienced was from cross-talk, chiefly disturbance from Morse circuits. It was impossible to get down systematically to analysing this trouble without the provision of some type of cross-talk measuring apparatus. I therefore designed and built an adjustable attenuating network having a characteristic impedance of 687 ohms and a zero angle approximating as closely as possible to the characteristic impedance of 200 lb. copper line which is about 687 ohms/12°. The network (Fig. 7) was made adjustable by steps of one

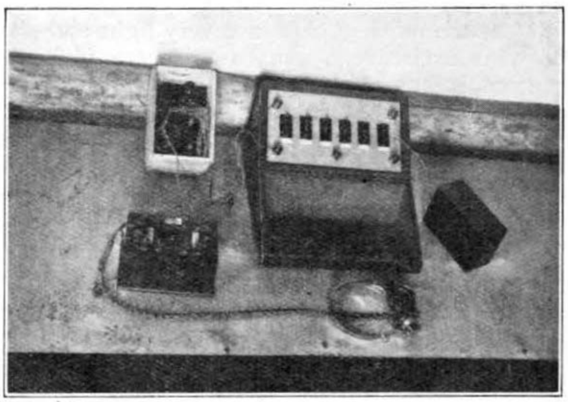


Fig. 7.—Artificial Cable used for Cross-talk Measurements.

decibel from one decibel to 40 decibels and by the addition of two fixed networks in separate boxes of 40 db. and 10 db., respectively, could be extended to 90 db. An old army D, mark III, buzzer was employed as a howler and gave a remarkably pure tone approximating to 800 cycles. Special keys were made up enabling both cross-talk and attenuation measurements to be made. By the aid of this apparatus the most important lines were brought up to a very high standard of immunity from disturbance, 65 db. being aimed at as a minimum standard.

A recent acquisition to the precision testing apparatus has been an A.C. Bridge of Resistance Capacity type, together with a variable frequency oscillator, giving a range of frequencies from 60 to 50,000 p.p.s. The bridge and oscillator have been rendered as portable as possible by being built into convenient boxes. The power supply to the oscillator is derived on the H.T. side from a small motor generator, the D.C. input side of which, together with the filament supply, is obtained from either the 24-volt battery of the repeaters or can be run from the 24-volt lighting circuit of the railway coach used for maintenance. (Fig. 8).

The Linemen's staff is almost entirely native. Linemen are recruited originally as Porters who act as firepot boys and generally assist the Linemen. Porters showing promise are usually brought into one of the main centres where they can come directly under the supervision of Europeans and receive some training. The Linemen outside the exchange areas are stationed at stategic points along the main route and make their headquarters at a wayside station where they are responsible for discipline either to a Tablet Inspector—if one is stationed there the local Indian Postmaster, if a rural Postmaster exists, or to the Indian Stationmaster, who interprets written instructions and makes out his reports for him. Their scale of pay varies from 16/- a month plus 3d. a day subsistence as a porter, to about 45/- a month, which is a fair sum to a native.

Although old linemen are not actually entitled to a pension, consideration is given to boys who have given long and satisfactory service to the Department.

With regard to exchange maintenance, the Inspectors are assisted by Indian linemen. Indians show considerable aptitude in the maintenance of automatic exchanges, particularly in routining.

Conclusion.

The advent of world-wide Telephone Communication has found many small colonies with only rudimentary telephone systems and has imposed upon them the task of preparing themselves for ultimate connection to much larger systems. International Telephone links are possibly a long way off in East Africa, but when the time comes it will be of the greatest importance that the whole of the plant is up to a pitch comparable with the highest standards of those systems to which it will be connected.

To establish these conditions is no mean task as a considerable amount of existing plant was laid down at a time when telephone networks on the modern scale were unthought of.

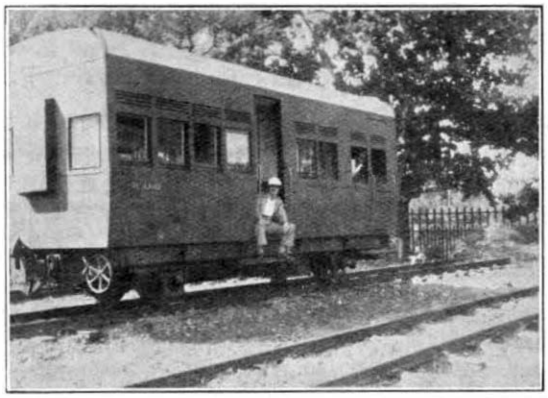


Fig. 8.—Railway Coach allotted for Maintenance.

The extension of a backbone Trunk system which will ultimately connect Uganda with the coast is very necessary, and work in this direction is progressing steadily.

The cleaning-up of the old open wire local line networks is also going forward and cable schemes for the larger exchange areas are under consideration.

The rapid development of the small automatic exchange of Satellite and Rural Automatic types will have to be considered in the solution of the problem of small isolated groups of subscribers.

The future holds many interesting problems for the Communication Engineer in East Africa.

The Macadie Keysender

Lt.-Col. F. REID,
M.C., T.D., B.Sc.,(Hons.), A.R.C.Sc.

WHILST there is ample evidence that the majority of subscribers prefer an automatic telephone system to a manual one, it has to be admitted that the labour of dialling presents an appreciable drag in the operating of a busy P.B.X. With a view to lightening this burden on busy P.B.X. operators the Post Office, some time ago, decided to develop a mechanical keysender which would be easier and faster in operation than the standard dial.

From a preliminary consideration of the subject and after examining earlier attempts to solve the problem, the following principles were laid down as a basis of the design :—

(1) The sender should be manually operated by keys of a typewriter pattern. It should be entirely mechanical in action and not involve any connexion to electric power supply for driving the mechanism.

(2) The sending of impulses to line should commence immediately the first digit is set up. This follows standard dialling practice, and is considered preferable to the alternative scheme of setting up the complete code before pressing a start key to send out the impulses.

(3) The speed and impulse ratio must comply with the specification for the standard dial, *i.e.*, speed 10 $\pm$ 1 impulses per second and impulse ratio (break percentage) 63 – 70%.

(4) The interval between digit trains should be 600 milliseconds.

(5) The size should be sufficiently small to permit of the sender being fitted to existing P.B.X. boards.

There was no dearth of ideas on which to base the design, and models on two alternative schemes were commenced, but at an early stage in the development it was decided to concentrate on a design evolved by Mr. D. Macadie, then a Staff Officer at the Post Office, Holloway Factory. In a few months, Mr. Macadie produced a model, constructed at Holloway Factory, which was considered a sound engineering solution of the problem. To ensure that the detailed construction would permit cheap and reliable mass production, further models were constructed by the General Electric Company, closely following the Post Office model. Improvements to lighten the pressure on the keys and to ensure greater reliability, were introduced during this second stage of the development.

The various models were tested by the Post Office Research Section and one of the final models was given a practical trial on the P.B.X. board at Dollis Hill, when, over a period of 16 months, it dealt with approximately 40,000 outgoing calls, with little or no maintenance attention and without showing any appreciable signs of wear.

The following extract from the Research Report on one of the later models is of interest :—

" It was found that the time required to deal with a call was 3 to 4 seconds. When using a dial and the normal dialling keys, 10 to 12 seconds were required. It will be realized that this leaves the operator free for the extra time, but she cannot use the sender again for about 6 seconds. The amount of wear on the moving parts due to 12,000 seven-digit calls is negligible. The impulse speed remained constant at 10.7 i.p.s. and the make percentage 32 throughout the tests. The tests made indicate that this type of sender is much less fatiguing than a dial and is preferred by the telephonist. The mechanism is necessarily more complicated than a dial, but the moving parts are very light and should not wear excessively. In cases where faults have occurred it has neither been difficult to find the trouble nor to put it right."

The Post Office is arranging to introduce the Macadie Keysender into service on rental terms and the mechanism has been coded as Keysender No. 5.

A general view of the keysender with the cover removed is shown in Fig. 1. The mechanism can be conveniently dissected into the following parts :—

Frame and key lever Assembly.
Code Storage Ring.
Code Storage Mechanism.
Impulse Mechanism.
Internal Ratchet Restraining Pawl.
Off-Normal Springs.
Visual Indication Disc.

Before examining the detailed construction of the keysender it will be helpful to consider the principles on which it operates. In any type of keysender where the code is set up at a faster rate than it is sent out, provision must be made to store the code. In the Macadie Keysender the code storage device consists of a fixed circular ring carrying a series of steel pins held lightly friction-tight in holes drilled in the flange of the ring. A code is stored by pushing forward appropriate pins. The digit " n " is stored by pushing forward a pin spaced at an interval " $n + 6$ " pin spaces from the preceding projecting pin; for example, a series of " ones " is stored by pushing forward every " seventh " pin.

The impulses are sent out by interrupting a pair of impulse springs by the rotation of an impulse wheel, the speed of which is controlled by a governor. The impulse wheel, in addition to rotating about its own axis, rotates by a " sun and planet movement " about the main axis of the code storage ring, the relative angular velocities being such that a main axial rotation of one pin space coincides exactly with one complete impulse period. The main axial rotation causes a cam associated with the impulse springs to sweep over the face of the code storage ring, bearing against each projecting pin in turn. During the period of engagement between this cam and a projecting pin the impulse springs are lifted clear of the impulse wheel for a period of 6 impulses giving the inter-digit pause. As the interval between consecutive projecting pins for the digit " n "

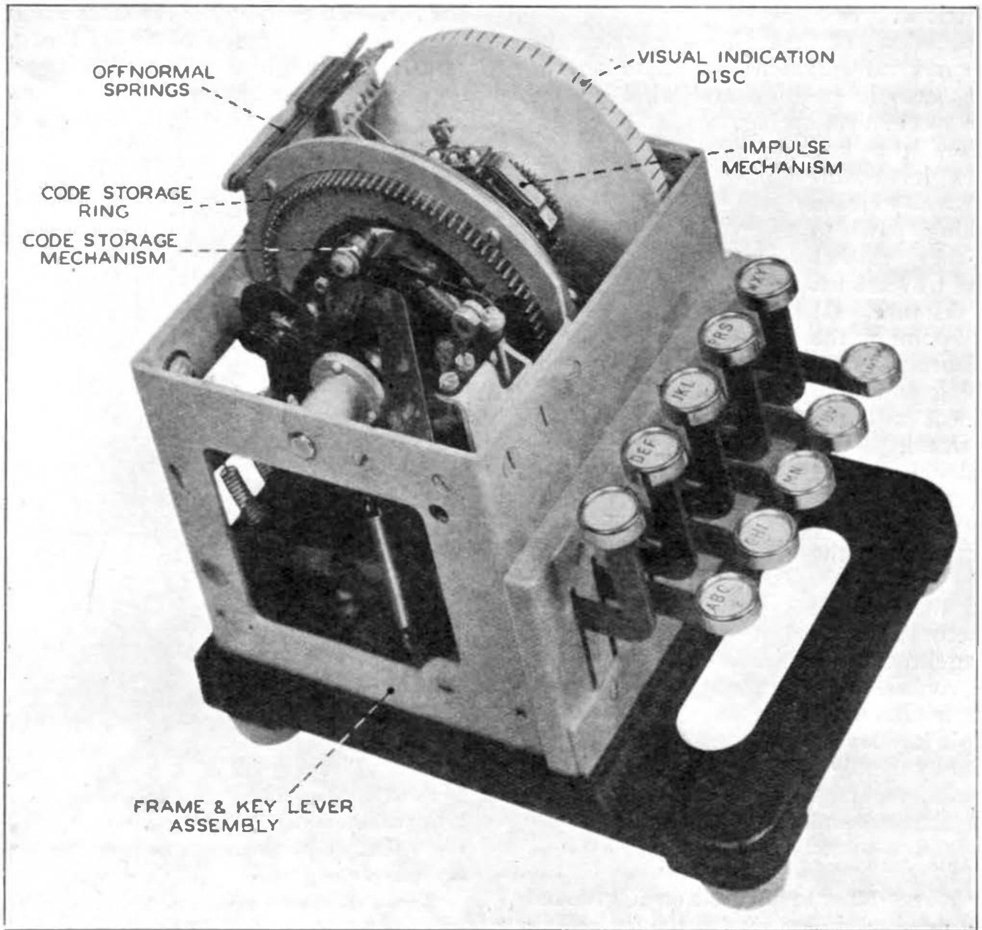


FIG. 1.—THE MACADIE KEYSENDER.

is " $n + 6$ " pin spaces, n impulses are sent out before the impulse springs are lifted. It is of course essential that the lifting of the impulse springs should occur during a " make period."

A novel feature of the impulse mechanism is that it has no zero position. It comes to rest on the completion of any call, in a position determined by the position of the last projecting pin and starts off again from this position to a new position, in accordance with any further code which is set up.

A restraining pawl is provided on the storage mechanism to cause the impulse mechanism to halt should it at any time catch up with the code setting and to bring the impulse mechanism to rest on completion of the code. This restraining pawl has to take up successive positions corresponding to each code pin operated, but must move from one position to the next after the operation of the code pin. This is achieved by attaching the restraining pawl to the storage mechanism by a helical spring. Normally the outer end of the restraining pawl is held in an internal ratchet mounted concentric with the code storage ring, and on the depression of a key the code storage mechanism steps forward, stretching the helical spring. On the release of the key the restraining pawl is kicked clear of the internal ratchet and jumps forward to its new position under the action of the stretched helical spring.

The code pin selection is effected by a marking arm on the storage mechanism, the marking arm being attached to a ratchet wheel which is stepped forward through the appropriate angle by the operation of any digit key. The marking arm, like the impulse mechanism, has no zero position but steps forward on each operation of a digit key. This continuous stepping forward feature enables the sender to be used, without modification, for codes of any number of digits, the only limitation being that the code shall not be so large, and set up so rapidly, that the code setting gets ahead of the impulse sending by more than one complete revolution. The accurate setting of the marking arm is of vital importance, and in the earlier models occasional overshooting occurred if a key was struck too violently. This defect has been overcome by allowing each digit key to travel beyond the angle necessary for correct setting. On the release of the key the ratchet wheel is allowed to return with the key, but at an early and definite stage of the return journey when all moving parts are travelling slowly, a locking pawl is snapped into engagement with the ratchet wheel. After the marking arm has been thus locked in its correct position, a striker pushes the marking arm against the selected code pin. The striker also knocks out the restraining pawl which limits the forward rotation of the impulse mechanism.

The depression of a digit key has thus to perform three main functions.

(1) On depression of the key—operate the storage mechanism ratchet wheel to set the marking arm in position and wind up the impulse mechanism spring.

(2) Just before the key completes its downward travel—release the locking pawl to allow the ratchet wheel to travel back a short distance. At a definite point on the return journey—snap the locking pawl into engagement with the ratchet wheel.

(3) After the ratchet wheel has been locked—operate a tripping lever to actuate the striker.

To perform these three functions, three rocking plates, a storage rocker, a locking pawl rocker, and a striker rocker, are mounted beneath the digit key levers and are operated by the digit key.

It should now be profitable to examine the detailed construction of the keysender.

Digit Key Assembly and Frame (Fig. 2).

The ten key levers KL are pivoted on a grooved bearing rod BR mounted in the rear of the frame and held in position by a plate SP. The key lever restoring springs S1 are attached to the spring grading bar SB. To even up the resistance to finger pressure over the whole range of keys, the grading bar is sloped at an angle so that the springs on the smaller digit keys have a higher initial tension. All the digit keys when operated travel through the same distance. The key pressures are light, being about 1 lb. 12 oz. Each digit key is provided with an adjustable shoe AS (Fig. 3) so that the point of engagement with the storage rocker RP1 can be accurately adjusted.

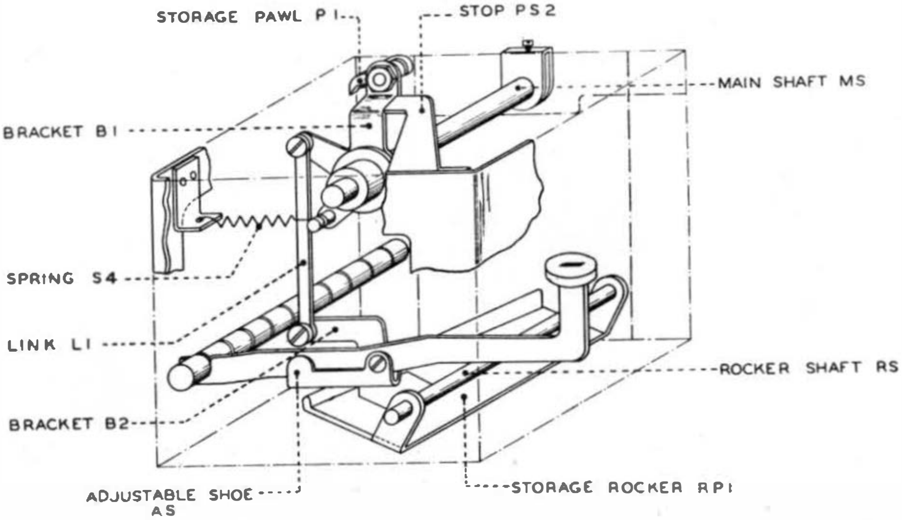


Fig. 3.—Code Storage Mechanism.

The three rockers, storage rocker RP1, locking pawl rocker RP3 and striker rocker RP2 rotate about the spindle RS (Fig. 4).

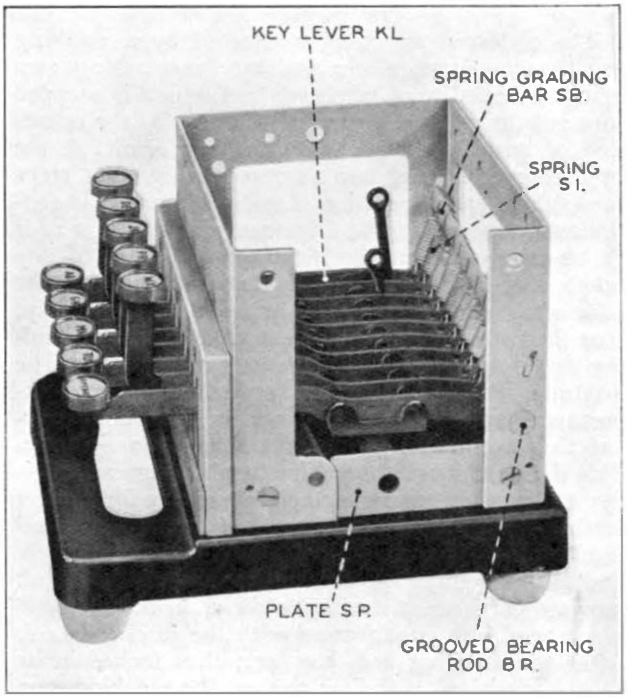


Fig. 2.—Digit Key Assembly and Frame.

Code Storage Mechanism.

Storage rocker (Figs. 3 and 4).

The movement of the storage rocker RP1 on the depression of a digit key is communicated to the storage pawl P1 (Fig. 3) *via* bracket B2, link L1, and bracket B1. The storage rocker is tapered so that for equal downward movements of the key levers the correct angular movement of the storage pawl for each digit is obtained. The storage pawl has an angular movement of 25° 12′ when storing digit " 1 " and of 56° 36′ when storing digit " 0." The storage pawl turns the ratchet wheel RW (Fig. 5) which rotates about the main shaft MS (Fig. 3). On the release of a digit key, the storage pawl P1 returns to stop PS2 (Fig. 3) under the pull of spring S4. The ratchet wheel is carried back for a short distance until the locking pawl is operated by the locking pawl rocker.

Ratchet Wheel (Fig. 5).

Front and back views of the ratchet wheel RW are shown in Fig. 5. The marking arm MA is attached to the ratchet wheel by the flat spring FS1, which allows the outer end of the marking arm to be pushed forward against a code pin when the pins CP are hit by the striker. The impulse mechanism restraining pawl P2 is attached to the ratchet wheel

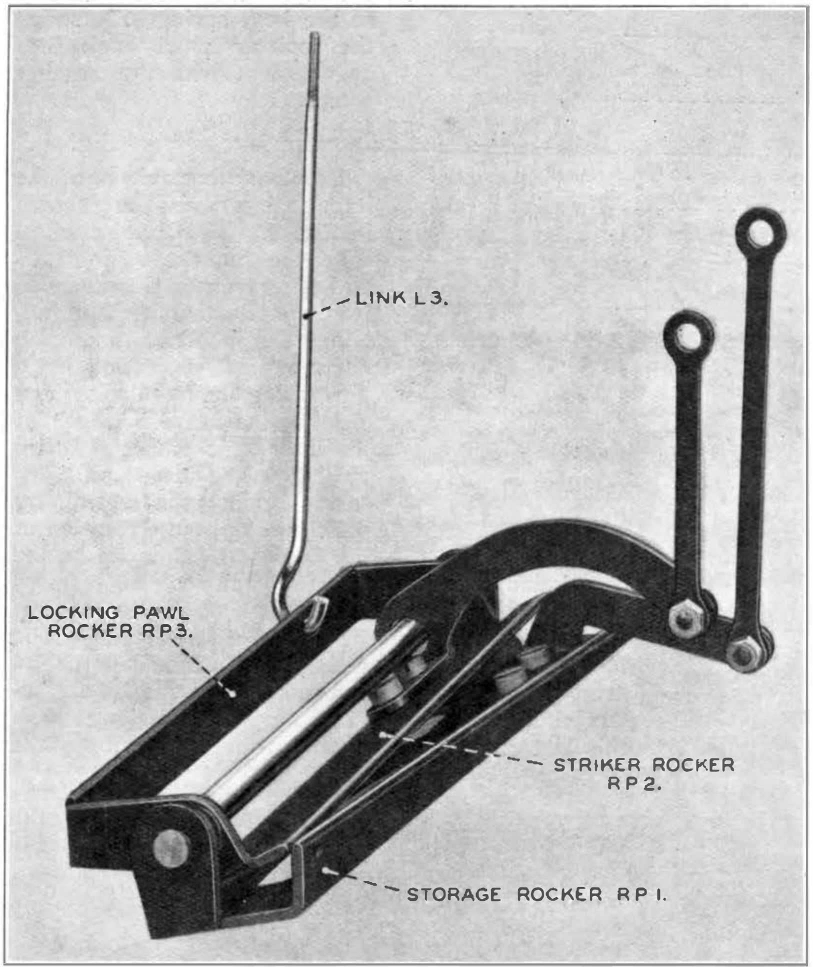


FIG. 4.—CODE STORAGE ROCKER.

by the helical spring S2. On the downward motion of a digit key, the ratchet wheel is stepped forward but the outer end of the restraining pawl being held in an internal ratchet (see Fig. **10**) remains stationary and spring S2 stretches. The restraining pawl P2 is held against the marking arm MA by a flat spring FS2. In consequence, when MA is hit by the striker, the restraining pawl P2 is also pushed forward, is momentarily disengaged from the internal ratchet, and jumps to the new position of the ratchet wheel.

To eliminate bounce on the impact of the restraining pawl P2, stop PS1 is not rigidly fixed but is carried on a pivoted arm held in position against the rib of the ratchet wheel by a spring S6. The cone AP on the ratchet wheel is a forced release for the restraining pawl in the event of repeated partial operation of digit keys which might occur in playing with the keysender. The ratchet wheel steps forward on each depression but as the restraining pawl is only freed by a full operation of a key, spring S2 might be stretched an excessive amount but for the presence of AP which pushes the restraining pawl P2 clear of the internal ratchet should the ratchet wheel be turned through a large angle without releasing P2 in the normal manner.

The squared end of the bearing RB (Fig. **5**), which rotates with the

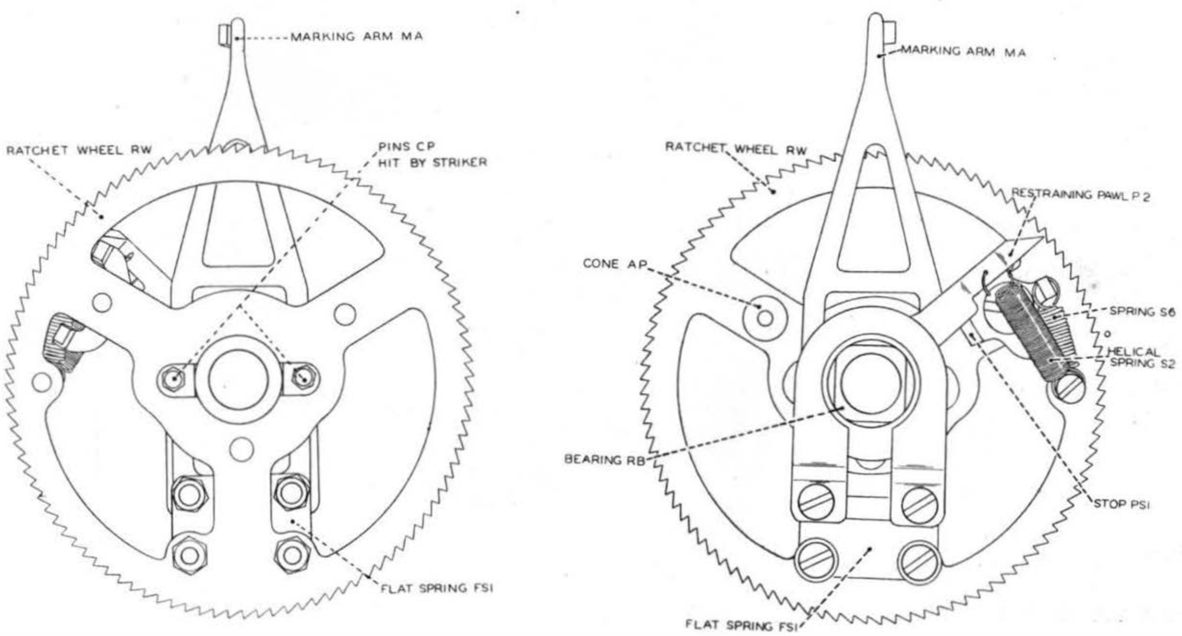


FIG. 5.—RATCHET WHEEL.

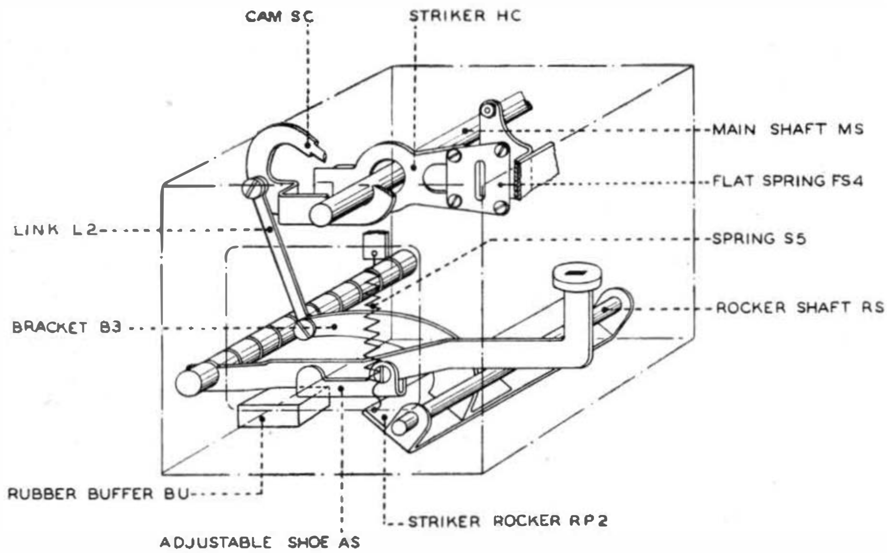


FIG. 6.—STRIKER MECHANISM.

ratchet wheel, engages in a D-bush anchored to the main spring driving the impulse mechanism thus winding up the impulse mechanism through the correct angle on each rotation of the ratchet wheel.

Striker Mechanism (Figs. 6 and 7).

On the depression of a digit key the adjustable shoe AS also operates the striker rocker RP2 (Fig. 6) pulling down cam SC *via* the intermediary of bracket B3 and link L2. The actual striker HC is attached to the frame by a flat spring FS4. The end of striker HC is so shaped that on the downward movement, cam SC passes in front of the striker pulling it away from the marking arm, but on the return journey SC passes behind the end of the striker and pushes it against the marking arm. This action which sets the code pin and releases the restraining pawl must occur after the ratchet wheel locking pawl has been snapped into position. In Fig. 7 the main shaft has been almost completely withdrawn.

Ratchet Wheel Locking Pawl (Fig. 8).

Towards the end of its downward movement, the key lever engages with the locking pawl rocker RP3 (Fig. 8), and, *via* link L3 and flat spring FS3, disengages locking pawl P3 from the ratchet wheel to allow the ratchet wheel to travel back on the release of the key. On the return journey of the key, spring S3 snaps the locking pawl back into engagement with the ratchet wheel.

Impulse Mechanism (Fig. 9).

Front and back views of the impulse mechanism are shown in Fig. 9. The impulse wheel IW, the impulse springs IS and the governor G are copied from the Post Office standard dial. T1 is the cam which bears against projecting code pins lifting the impulse springs clear of the impulse wheel for the inter-digit pause of 6 impulses. The stop pin DP bears against the restraining pawl and stops the rotation of the impulse mechanism on the completion of impulsing. The tailpiece T2 restores the code pins to normal, as the impulse mechanism sweeps round the face of the code storage ring. The last code pin operated at the end of a code is not, however, restored, as the rotation is stopped by the restraining pawl when T1 commences to engage with this last code pin. In consequence, any subsequent

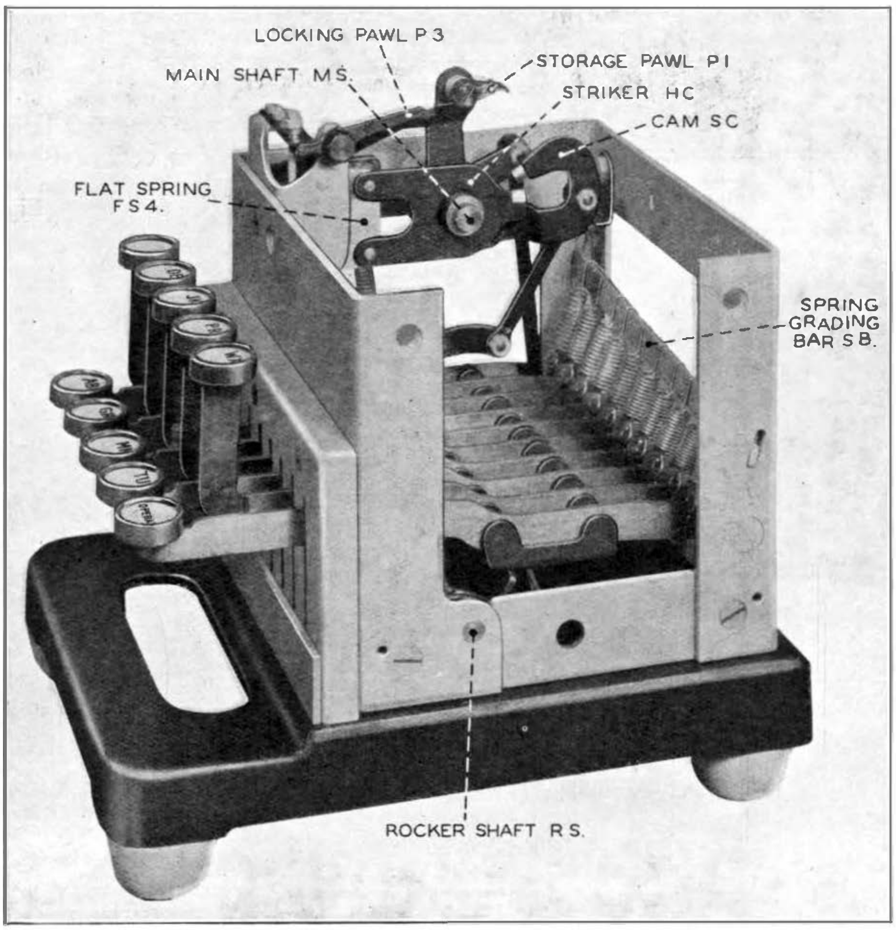


FIG. 7.—STRIKER MECHANISM.

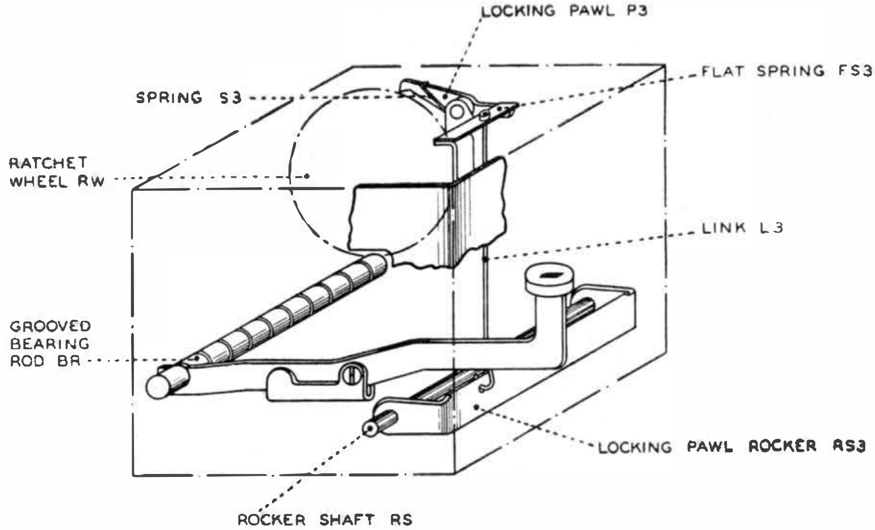


Fig. 8.—Ratchet Wheel Locking Pawl.

code starts with a make interval. The impulse mechanism is carefully balanced about the axis of rotation by a cylindrical weight. The inner end of the main driving spring S is anchored to the D-bush.

Code Ring and General Assembly on Main Shaft (Fig. **10**).

Fig. **10** shows the code storage ring CSR carrying the code pins CP and fixed in the frame by mounting ring MR. The impulse mechanism is mounted on the main shaft. During assembly the stop pin DP is lined up with the restraining pawl on the storage mechanism and the impulse mechanism given a quarter turn in a backward direction before lightly engaging the D-bush on the impulse mechanism with the square on the ratchet wheel hub. The impulse mechanism is then given one and three quarter turns in a backward direction, winding up the drive spring S before pushing the impulse mechanism fully home with the stop pin DP bearing on the restraining pawl P2. The sun and planet movement consisting of the starwheel SW engaging on the internal gear IG is clearly shown. The impulse springs are wired to the collector rings CR and connexion made to fixed tags on the frame *via* wire brushes CB.

Off-Normal Springs (Fig. **11**).

This sketch shows the internal ratchet IR, the tip of the restraining pawl P2, and the stop pin DP on the impulse mechanism bearing against the restraining pawl. The internal ratchet is mounted in a ball bearing concentric with the code storage ring and is free to turn through the small angle determined by the slot and screw pin SL. The pressure of stop pin DP against the restraining pawl, due to the comparative large torque of the impulse mechanism drive spring, turns the internal ratchet in its ball bearing in a counter-clockwise direction holding the off-normal springs OS open *via* the strip link L4 and lever ●SL. Immediately the restraining pawl jumps forward when a code pin has been operated, the pressure on the internal ratchet due to the impulse mechanism spring is relieved and the off-normal springs push the internal ratchet in a clockwise direction until limited by stop SL, and in so doing close the off-normal springs.

On completion of impulsing, the impulse mechanism will again catch up with the restraining pawl and the pressure of stop pin DP on the restraining pawl P2 will again open the off-normal springs before bringing the impulse mechanism to rest.

Visual Indication Disc.

Attached to the impulse mechanism is a light disc with lines on its outer edge, Fig. **1**. This disc can

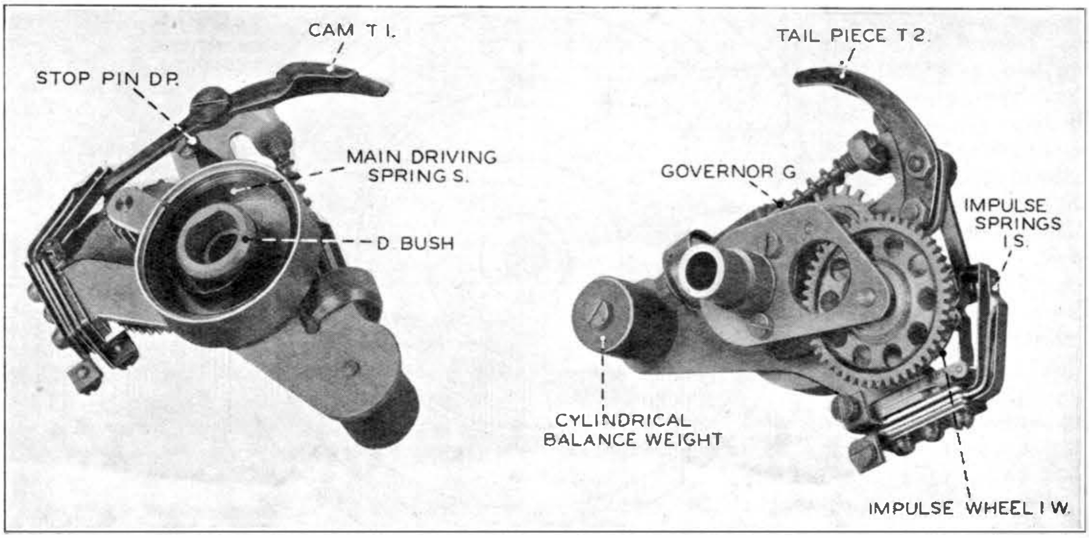


Fig. 9.—Impulse Mechanism.

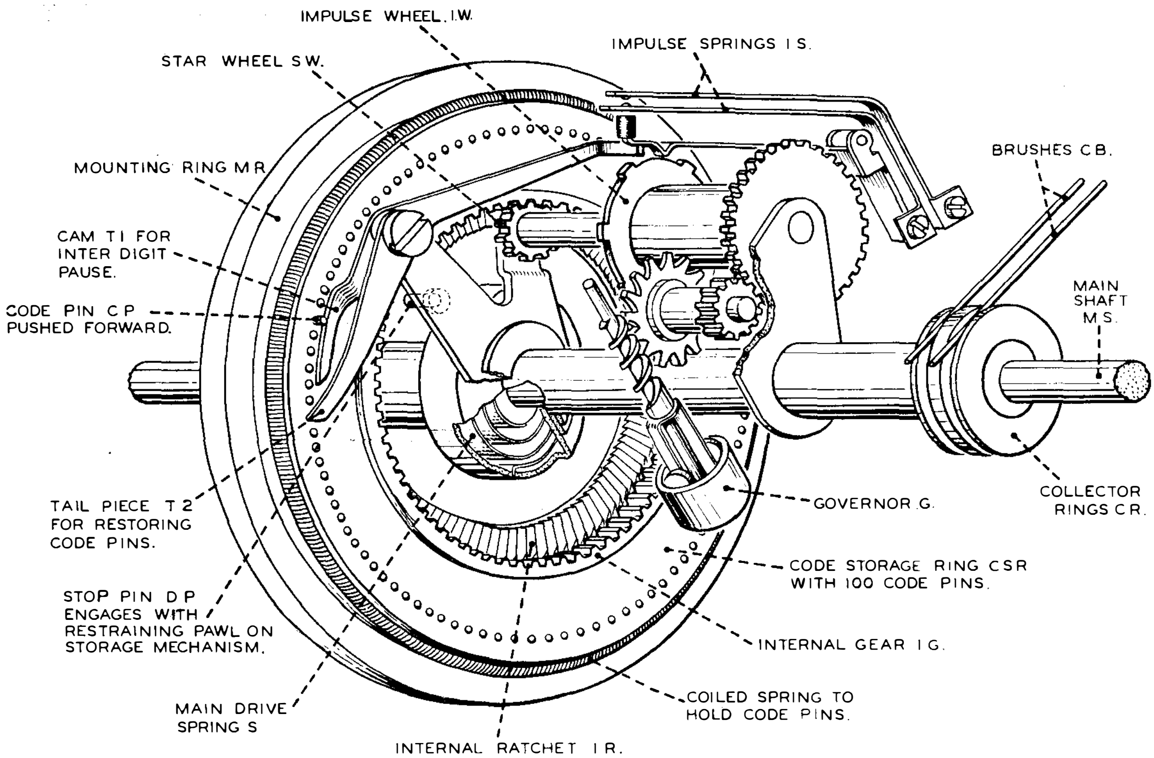


FIG. 10.—MAIN SHAFT ASSEMBLY.

be seen through a window in the cover and serves as a visual indication that the sender is engaged, and cannot be used for another call until the disc comes to rest.

Adjustments

The code storage ring in Keysender No. 5 has 100 code pins and as each depression of digit key 4 causes the marking arm to step $4 + 6 = 10$ code pin spaces, 10 depressions of digit key 4 will cause the marking arm to make exactly one complete revolution. This enables accurate adjustment of the adjustable shoe on key 4 to be made. Next key 3 is adjusted so that 10 depressions of key 3 ($10 \times 3 + 6$

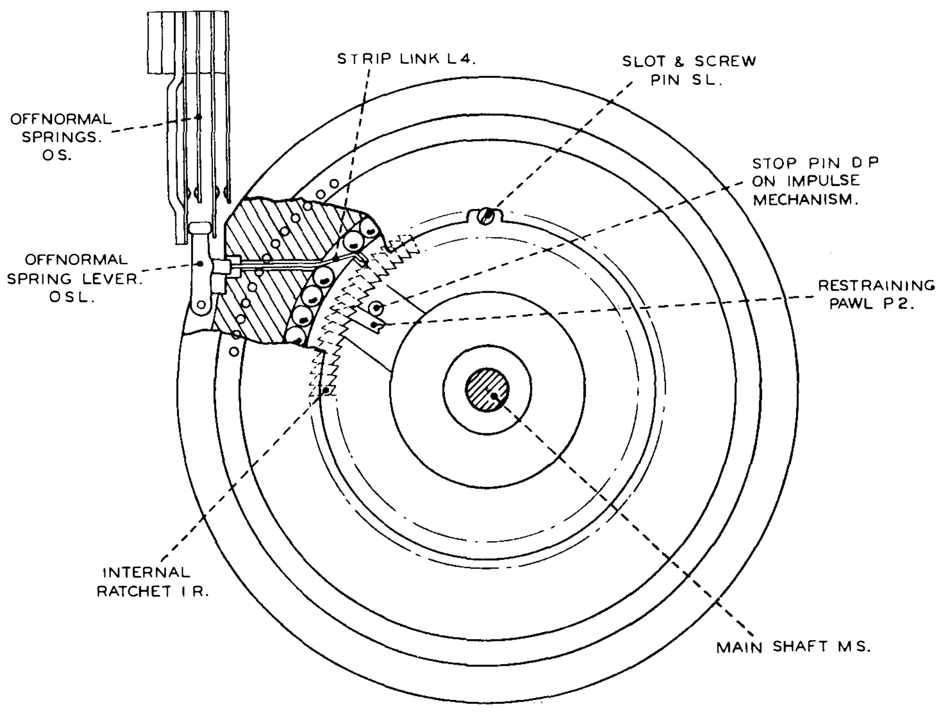


FIG. 11.—OFF-NORMAL SPRINGS.

steps) and 1 depression of key 4 give exactly one complete revolution of the marking arm.

By following this procedure for keys in the successive order 4, 3, 9, 10, 1, 7, 6, 8, 5, and 2, all ten keys can be quickly adjusted. The adjustment of keys can be checked by verifying that the marking arm makes one complete revolution by depressing the following keys, 1, 2, 3, 4, 5, 6, 7, 8, and 10, also by 1, 2, 3, 4, 5, 6, 7, 9, and 9.

A nut and screw adjustment is provided for accurately setting the time at which the locking pawl is operated.

Arrangements for fitting keysenders to P.B.X. boards.

It is quite probable that ultimately large P.B.X. boards will be designed to take mechanical keysenders, but this is not contemplated at present as keysenders will only be fitted in cases where the subscriber is willing to pay the extra rental.

For the practical trial on the Research Section P.B.X. at Dollis Hill a switchboard AT 1810 $\frac{10 + 50}{60}$ was modified by removing one cord circuit so that the keysender could be neatly housed at one end of the keyshelf. The exchange dialling keys were replaced by a strip of interlocked keys with make-before-break contacts and the board was wired to Fig. **12** and operated in the following manner. The

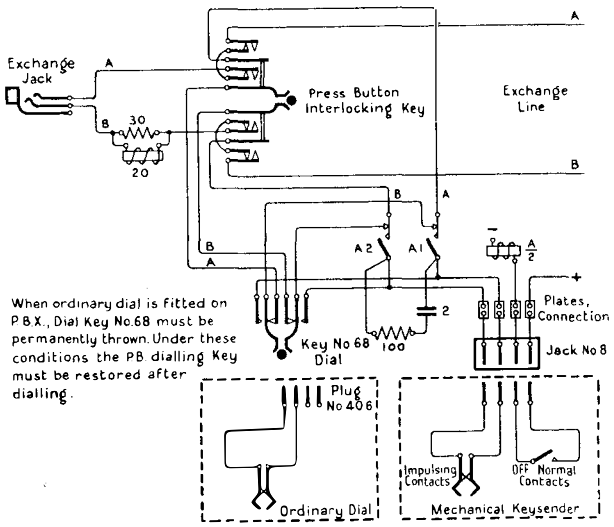


FIG. 12.—MODIFICATIONS TO CORD CIRCUIT OF SWITCHBOARD A.T. 1810 $\frac{10 + 50}{60}$

operator plugs in to an exchange jack; on receipt of dialling tone, she presses the corresponding exchange line dial key and sets up the code on the keysender. The closing of the keysender off-normal dial springs operates relay A and connects the keysender to the exchange line. Immediately the code has been sent out, relay A restores and connects the exchange line through to the calling extension *via* the cord and conversation can commence immediately the connexion has been established.

To make a subsequent exchange call, the press button dial key of another exchange line is depressed (after verifying that the keysender has completed the first call) thus connecting the A relay contacts and keysender to the new exchange line. Due to the mechanical interlocking of the keys, the dial key on the exchange line used for the earlier call restores and the connexion is maintained *via* the key contacts which, being make-before-break, do not cause any interruption to the conversation when operated. A dial key can be reset at any time if desired by operating a common reset key fitted to the dial key strip.

An alternative method of connecting the keysender to a Switchboard B.E.C.B. multiple No. 9 is shown in Fig. **13**. In this arrangement, the ring-back key on each cord circuit is replaced by a combined ring-back and dial key. The operation is much the same as that previously described, but, as the dial keys are not mechanically interlocked, the operator has to restore the dialling key first brought into use before throwing a second dial key. In both schemes, the use of an auxiliary relay could be obviated by fitting make-before-break contacts on the keysender off-normal springs.

Development of the Design.

It is interesting and instructive to follow the development of any design from its inception to the final production stage, and a brief reference to the earlier Macadie models will illustrate the evolution of the design. In the first Macadie Model (Fig. **14**) the code storage device consists of a wheel the face of which is divided into compartments each capable of housing a steel ball 1/16 inch in diameter. Attached to this storage wheel is a ratchet stepped through " $n + 6$ " teeth on the operation of the " n " digit key. A supply of steel balls is stored in tube T, and one of these balls falls by gravity into the storage wheel compartment immediately opposite the lower end of this tube. A gate lever closing the end of this tube is held open in the unoperated position of all digit keys, by a radial arm which carries the ratchet stepping pawl. Immediately any digit key is depressed this arm is moved away from the gate lever which closes the gate and prevents a further fall of steel balls into compartments, until the return of the digit key to its normal unoperated position when the gate is again opened by the radial arm. The storage wheel being attached to the ratchet wheel is also turned through an angle " $n + 6$ " compartments on the operation of the " n " digit key but a steel ball is only fed into the last compartment on the return of the key to rest. Successive operation of digit keys in any order thus stores steel balls at the required digit spacing round the code wheel. The code wheel always rotates in a counter-clockwise direction viewed from the impulse mechanism side. The gear wheel GW is attached to the ratchet and storage wheel, and turns the frame of the impulse mechanism also in a counter-clockwise direction through an angle " $n + 6$ " impulses. The impulse mechanism carries a pair of impulse springs operated by teeth on the edge of the storage wheel and also a pair of shorting springs operated for a period of 6 impulses

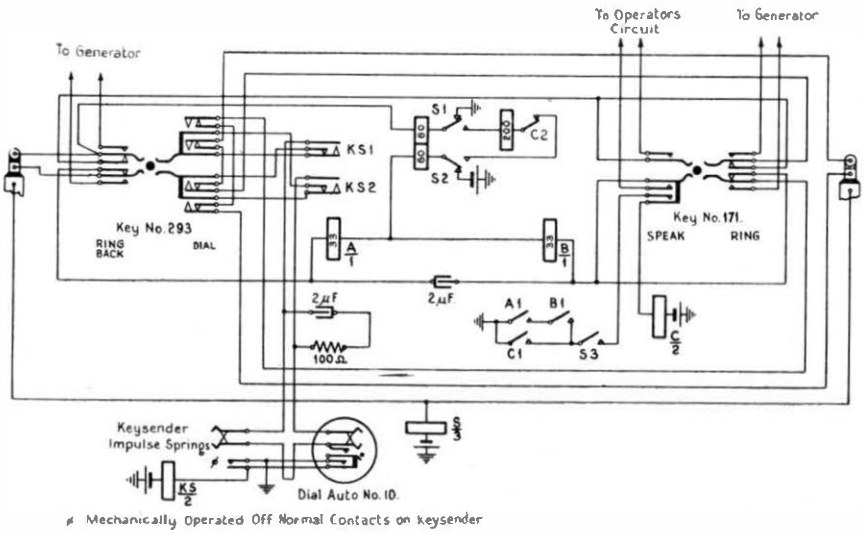


FIG. 13.—MODIFICATION TO CORD CIRCUIT OF SWITCHBOARD, B.E.C.B. MULTIPLE, NO. 9.

on passing any ball. The forward rotation of the impulse mechanism winds up the impulse mechanism spring which causes the impulse mechanism to rotate backwards generating continuous impulses except during the inter-digit pause when the shorting springs are operated. The motion of the impulse springs is thus an oscillating one. They are carried forward with the storage wheel on each depression of a key and run back to the zero position when impulsing. The actual motion is a combination of

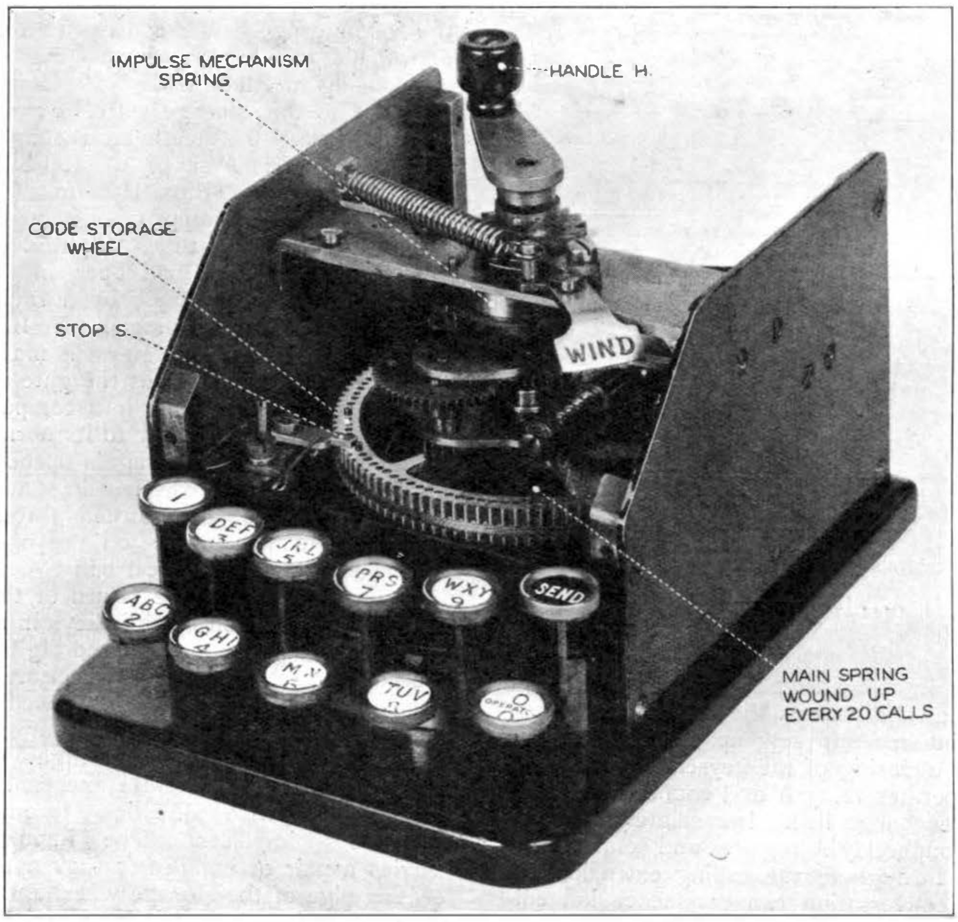


FIG. 14.—FIRST MODEL KEYSENDER.

the two angular movements, a steady backward rotation relative to the storage wheel of 10 impulses per second and a forward movement with the storage wheel of " $n + 6$ " impulses on the depression of a digit key. The radial arm carrying the ratchet stepping pawl also acts as a restraining pawl to halt the impulse mechanism until the key is released on the first digit of any code and at any other time should the impulsing catch up with the keying. A steel ball is retained in its compartment until the storage wheel has made almost one complete revolution and is returned home to the tube T when brought opposite its upper end, being guided into the tube by the guide spring G.S.

The most serious defect of this first design is that due to the inertia of the moving parts fast operation of the digit keys results in errors in storage. To reduce the rate of keying to a safe speed, about 3 per second, a dashpot was added, but this increased the pressure necessary to operate the keys. In addition, the use of a large impulse wheel with sufficient teeth for the complete code was felt to be a weakness in the design if correct impulsing was to be obtained.

In the second Macadie Model, shown in Fig. 15, the code storage device consists of a horizontal wheel, but the balls have been replaced by steel pins as in the final model. A main drive spring at the foot of the main spindle is wound up every 20 calls by a few turns of the handle H. A warning notice " Wind " is displayed when rewinding is necessary. The main spring tends to rotate the storage wheel in a clockwise direction—viewed from above—but is prevented by a stop S, which bears against the pin last projected by the operation of a digit key. The digit key levers are so shaped that digit key " one " is immediately under a pin $1 + 6$ spaces away from the pin held by the stop S, and similarly for the other digit keys. The depression of digit key " n " thus pushes up a pin at an interval " $n + 6$ " spaces away from the stop. The depression of the key also withdraws the stop S from engagement with the pin previously projected, but the storage drum is prevented from rotating by the end of the digit key engaging with a tooth of a circular rack attached to the storage wheel. On release of the key, the end of the digit key is withdrawn from the rack before stop S returns and the storage wheel jumps forward " $n + 6$ " pin spaces when it is again held by the stop S. The rotation of the storage wheel also turns the impulse mechanism, winding up the impulse mechanism spring. The impulse teeth are cut on the edge of the storage wheel and on the backward rotation of the impulse mechanism impulses are sent out except when a cam attached to the impulse springs passes a projecting pin. This cam lifts the impulse springs away from the impulse teeth for an interval of six impulses. It was intended

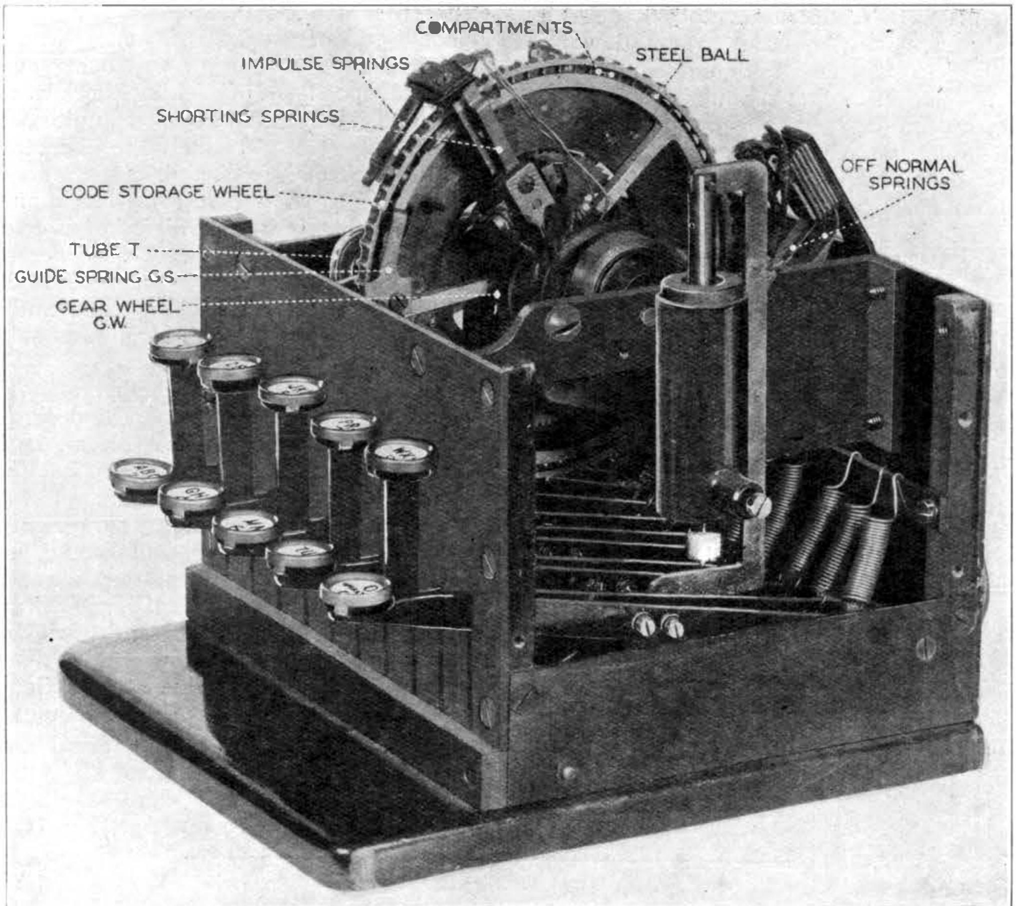


Fig. 15.—Second Model Keysender.

in this design to commence sending out impulses on the release of the first digit key just as in Model 1, but the impact of the storage wheel against the stop so distorted impulses that a start key was added as an afterthought. The impulse mechanism is now locked to the storage wheel until the depression of the start key, when it is released and runs back sending out the code stored. In use, therefore, the whole code is set up before depressing the start key. The model was designed on the basis that it would be operated in the same manner as Model 1 and in consequence the number of pins in the code wheel are insufficient and a slight enlargement of the model would be necessary to deal with the longest codes.

Future Developments.

There has been considerable diversity of opinion as to the need for a mechanical keysender, some authorities contending that it was better to lighten the P.B.X. operator's load by providing through dialling from extensions. The development of a mechanical keysender by the Post Office was started in August, 1929, and the final Macadie Model was completed at Holloway Factory in March, 1930, but the effect of trade depression on calling rates had reduced the complaints from P.B.X. operators and the view that through dialling from extensions was an adequate remedy gained ground. It has recently been decided, however, to provide mechanical keysenders both for P.B.X. operators and, if desired, for individual telephones, in cases where the subscriber is willing to pay the additional rental. The first supplies, which are being manufactured by the General Electric Company, should be available in August. The question, therefore, whether such a device is wanted by the public will shortly be no longer one for theoretical discussion, but one to be determined by the acid test of experience. If the view that there is a public demand for a device simpler and faster to operate than a dial is borne out by experience, further developments and improvements in design and in particular a considerable reduction in size will no doubt follow.

It may be advisable to mention one or two suggestions which have already been considered but not incorporated in the present design.

Key Interlocking. It would have been comparatively easy to fit an interlocking device to prevent the simultaneous depression of two keys, but the expense was considered unwarranted. If two keys are operated simultaneously in the present design, only the larger digit is stored.

Cancel Key. It has been considered unnecessary to provide a cancel key. To cancel a call the plug must be withdrawn for a short period and the keysender allowed to run down until it has discharged any code stored. As a rule this will require about two seconds and should in practice not represent any appreciable loss in time.

Inter-digit pause. When the keysender was designed, an inter-digit pause of 600 milliseconds was the accepted standard for the relay senders fitted in connexion with Keysender B-position working. There has been a tendency recently to propose a longer interval and 800 milliseconds has been suggested, although it is possible using a standard dial to have inter-digit pauses of the order of 450 milliseconds. Judged from practical trials of the Macadie Keysender, lost calls due to an insufficient inter-digit pause are a very rare occurrence. Whilst the basic design of the keysender can be adapted to provide any required inter-digit pause, an increase in this interval would necessitate an increase in size and slower operation, and is therefore to be deprecated. The main object of providing a keysender is quickness of operation and to slow down all calls to secure a very slight reduction in the number of times an engaged condition is encountered is surely unwise, particularly as the standard dial is likely to suffer equally from this alleged defect. The Post Office has at present under consideration a new design of two-motion selector which, amongst other advantages, has a faster hunting speed and this appears to be the correct line of development if the number of calls lost due to insufficient hunting time is appreciable.

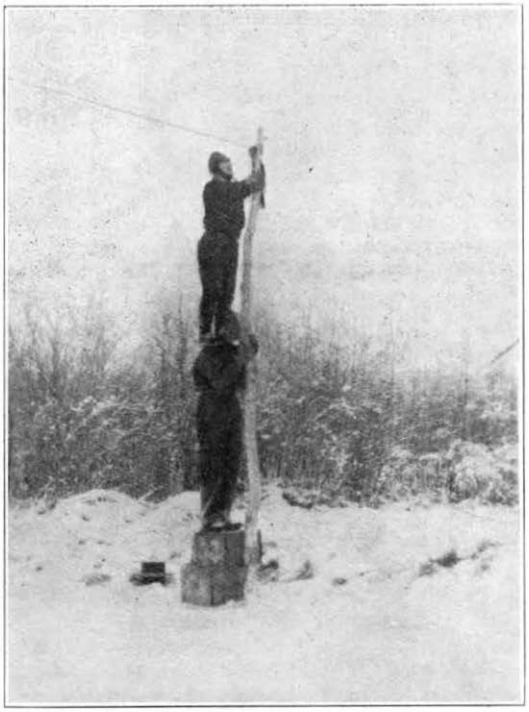
Number of Code Pins. It has been suggested that the number of code pins in the storage ring should be increased. This matter was carefully considered when the design was being evolved in view of the importance of making the keysender small in size and it was decided that 100 pins were sufficient. The longest code likely to be encountered is WOOlwich 0009 which involves a total of 110 pin spaces ($5 \times 16 + 2 \times 15$). As impulses are sent out immediately the 1st digit key is released, keying will have to be at the rate of 5 per second before overlapping occurs. It was considered that the combination of such a long code and such a high speed of keying is a highly improbable coincidence which may be ignored.

The future will show whether or not the Macadie Keysender is the forerunner of designs which may eventually replace the dial on an extensive scale. Those who are apprehensive because the mechanical keysender is somewhat more complicated than the standard dial should take courage in the thought that it is not nearly so complicated as an ordinary watch which is carried in the pocket and has to work twenty-four hours each day, much more onerous requirements than the keysender will be required to meet.

Acknowledgment is due to the General Electric Company for the loan of several negatives used to illustrate this article.

The British Polar Year Expedition, 1932-33

An article describing the telephone equipment of the British Polar Year Expedition was published in Vol. 25, Part 2, July, 1932. The expedition, under the leadership of Mr. J. M. Stagg, spent rather more than a year in the North of Canada and returned last October. It is satisfactory to know that the telephone line worked very well and enabled the expedition to take many more auroral photographs than would have been possible with any other means of communication.



Fixing one of the Insulators of the Main Telephone Line to the Old Fort Rae.

The following account has been kindly supplied, together with the photographs, by Mr. Stagg.

" The Expedition left England for North-West Canada in the spring of 1932. A substantial part of our programme of investigation at Fort Rae consisted in photographing aurora by special cameras from two ends of a base line, the observers manipulating the cameras being in communication by telephone to enable them to photograph the same parts of the aurora at exactly the same instant. In this way, the apparent displacement of the aurora relative to its stellar background could be measured on the pairs of photographs so taken, and, by a suitable technique of measurement and computation, the position in space of the aurora could be determined.

" Our two stations were chosen along the western shore of the north arm of the Great Slave Lake, some sixteen miles apart. Finding it an almost insuperable job to erect the telephone wire (a very light Silmalec wire supplied by the kindness of the British Aluminium Company and insulated with double cotton and wax by Messrs. Henley's, Ltd., the whole weighing about 23 lb. per mile) during the summer months, we waited till the Lake had frozen sufficiently to be safe to work on. Then, cutting poles from the stunted birch and spruce trees along the lake-side, we inserted them through the ice covering, and within a very short time they were frozen rigidly into position. ' Shell ' insulators were tied to the tops of the poles (usually 8 or 9 feet above the lake surface), and the wire threaded through. The poles were erected every 100 yards, approximately, down the lake. Then, after putting a tension not less than 100 lb. weight on the wire, it was bound at every alternate insulator to prevent the whole wire sagging in case of breakage. Most of this work was done at temperatures between −5°C and −15°C; it was then that those of our party who were engaged on the work had their first little experience of frost-bite.

" The ' earth ' return was by water. For, con-

Part of the Telephone Equipment used in the Auroral Photographic Work. The Headgear Receiver is worn under the Burberry Windproof Helmet and over the Woollen Balaclava.

OPERATING THE AURORAL CAMERA INSIDE THE SHELTER. THE SLIDE CARRYING THE LENS CAN BE MOVED INTO SIX DIFFERENT POSITIONS RELATIVE TO THE PLATE, SO ALLOWING SIX EXPOSURES ON EACH PLATE TO SAVE TIME ON OCCASIONS OF QUICKLY CHANGING AURORA.

trary to our earlier expectations, although the ice thickens steadily throughout the winter to six feet, there is a residual water flow below. At first, we put the earth spikes, supplied by the P.O. Engineering Research Station, near to the Lake shore, but very soon the ice there had formed to the bottom, and signal strength fell off badly as the spikes became totally embedded in ice. Fresh spikes were let down into the central channel of the lake through five feet of ice, and, with a water return reassured, the telephone worked very well thereafter.

" In addition to the main length of line down the open Lake, smaller parts had to be taken through the ' bush ' in the immediate neighbourhood of each of the terminal stations. The tallest spruce trees were selected, bared sufficiently far up to keep the cable above the shrubs in the vicinity, and the wire tied through insulators in the same way as described for the poles on the Lake.

" At the two stations, the observers operating the auroral cameras were equipped with breast-plate microphones and headgear receivers kindly supplied by Messrs. Siemens Bros. and Co., Ltd., the microphones having a special auxiliary diaphragm of celophane fitted over the working diaphragm to prevent accumulation of hoarfrost and ice crystals from obstructing its movement. These celophane diaphragms were exceedingly useful. Frequently after several hours outdoor work at temperatures at or below $-30°C$, the intensity of the speech would begin to decrease. We then knew that the deposition of frost on the celophane was obstructing communication with the main diaphragm. All that was needed then was to unlock the mouthpiece with the celophane, shake it or tap it, and replace it with a new lease of life to the microphone. Throughout the whole of its term of use, the whole telephone system worked admirably; speech was generally exceedingly good. Breakages of the wire occurred, it is true, during high wind and low temperature, where a kink had got into the wire during erection; at the insulators where the wire was probably too

A TYPICAL AURORAL DISPLAY PHOTOGRAPHED WITH THE SPECIAL CAMERA.

sharply bent by the binding at alternate poles; and at places where the wire had sagged sufficiently to be caught by Indian dog-sleighs : but through none of these did we lose much of value in auroral photography.

"During vigorous auroral displays, with their accompanying magnetic storms, the associated earth currents at times seemed to cause a marked waxing and waning of signal strength and clearness, but never enough to damp out speech completely. At other times, when the sky was so completely blanketed by cloud that we were unable to see aurora, and when, therefore, the plugs for the headgear receiver and microphone were out, so that the bells only were in the telephone circuit, the bell at one or other end of the line would give momentary tinkles as if short period surges of current were being generated in the telephone wire. On developing the photographic records from the magnetic circuits next day, we invariably found that a large magnetic disturbance had been in progress at the time of the tinkles, so that the presumption is strong that vigorous aurora was also present had we been able to see it. We had no special earth current measuring apparatus in our equipment, but, being interested in any of the concomitant phenomena of aurora and its effects on the earth's magnetic field, we made some rough measurements of the elements in the circuit at the time when these surges were produced; these are :—

1. Total resistance of the circuit comprising line, ' earth ' (*i.e.,* water) return, and two telephone bells, all in series, 3,700Ω.
2. Resistance of each bell separately, about 950Ω.
3. By impressing a momentary e.m.f. of approximately 48 volts on the bell terminals, a ' tinkle ' was obtained : 36 volts produced a click, but not a ring.

" Assuming from this last item that the critical voltage for a ' tinkle ' is approximately 45 volts, and letting the bell resistance be 900Ω, the current in an e.m.f. surge is of the order of 50 mA.

" Altogether we took over 4,500 pairs of auroral photographs using the telephone line, and although we know that not all of these are suitable for measurement, we hope that a large percentage will furnish the data necessary for the computation of the auroral positions. At the same time and throughout the whole of our stay at Fort Rae, we have continuous registrations of the variations in the three components of the earth's magnetic field, so that when these are measured and the auroral heights computed, we hope to get valuable insight into the correspondence between the various phases of the auroral displays and the synchronous changes in the magnetic field."

The earth currents which coincided with strong auroral displays and caused the bell almost to act as a summons to duty for the photographers, represented a difference of potential of about 150 volts between the ends of the line.

A.C.T.

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., 1933.

No. 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.
811,613	559	8,622	44,738	3,204	London	39,140	197,054	3,631,608	162,955
98,146	2,144	18,655	45,312	5.404	S. Eastern	4,820	53,436	366,089	49,595
113,753	3,910	36,482	70,487	5,377	S. Western	26,127	41,741	285,025	64,966
78,130	4,572	41,155	67,924	8,636	Eastern	16,015	59,621	163,842	56,165
124 594	7,323	49,757	55,236	8,438	N. Midland	15,067	153,652	332,118	131,536
99,784	4,052	31,367	63,790	4,116	S. Midland	17,172	59,394	307,810	70,189
68,491	3.023	30,758	56.008	6,252	S. Wales	6,730	50,604	165.494	41,372
135,842	5,996	30,907	57,563	5,711	N. Wales	11,330	75,600	446,785	115,462
179,905	969	10,951	26,206	6,850	S. Lancs.	11,373	115,511	651,285	84,464
114.642	5,115	27,908	38,415	8,112	N. Eastern	11,048	88,377	340,397	60,432
75,699	3,165	21,947	26,754	6,761	N. Western	4,722	45,244	250,121	57,849
58,335	1,917	15,458	21,997	5,547	Northern	4,112	47,578	190,234	36,210
28,635	3,204	11,116	11,911	1,026	Ireland N.	221	5,420	70.619	5,488
83,730	4,591	32,522	40,370	3,389	Scotland E.	4,837	44,747	178,975	51,020
105,224	4,857	22,512	32,248	4,400	Scotland W	8,546	50,570	270,392	41,249
2,176,523	55,397	390,117	658,959	83,223	Totals.	181,260	1,088,549	7,650,794	1,028,952
2,146,626	56,650	393,041	649,188	79,767	Figures as at 30 Sept., 1933	193,425	1,060,086	7,531,122	998,052

+ Includes low gauge spares (*i.e.,* wires of 20 lb. or less in cables and 40 lb. bronze on overhead routes.

Some Elementary Considerations of the Significance of Wave Mechanics

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

Introduction.

DURING the past ten years there has arisen a new method of dealing with problems relating to the ultimate structure of matter. It arose from the failure of Newtonian mechanics to explain the radiations emitted by atoms, just as relativity arose from the failure of the same Newtonian mechanics to explain the motions of astronomical bodies.

Newtonian mechanics fails not because it is inherently unsound, but because it is only an approximation. The errors involved are vanishingly small when considering the motions involved in ordinary engineering problems. It fails when dealing with motions involving velocities which are an appreciable fraction of the velocity of light or with dimensions so large that they are comparable with the actual dimensions of universal space or so small that they are comparable with the wave-length of light. It may be thought that such considerations do not normally come within the scope of engineering. It must be remembered, however, that present-day engineers, and particularly communications engineers, are making use of thermionic valves, metal rectifiers, and similar devices, the mechanism of which involves these unusual dimensions and velocities. Indeed, the methods of wave mechanics are necessary in order to elucidate their action more fully. It is considered, therefore, that a few notes on the significance of this newly-developed system of mechanics would be of general interest.

Brief survey of the Historical development.

The strict historical development of wave mechanics happens to be one of the most difficult and confusing ways of approaching the subject, so that, although it is felt that it is essential to approach from an historical point of view, the strict order of events will not be followed in the main discussion. It is, however, profitable to consider briefly a survey of the true historical development.

Heisenberg attacked the problem of developing a quantitative theory of the intensity and frequency of the lines in the spectrum of the radiation emitted by elements in an original manner. Bohr had previously tackled the problem on the basis of Newtonian mechanics making use of Planck's quantum theory and had developed a theory which accounted for the frequency of emitted spectra.[1] This theory, however, completely failed to explain certain anomalies and in particular the wide variation in the intensity of different lines, in spite of considerable elaboration. Indeed the theory became so complex and full of comparatively wild assumptions as to the structure of the atom that further development had to be abandoned.

Heisenberg made a fresh start and decided to make no fundamental assumptions as to atomic structure, merely studying the limitations imposed on the possible types of atomic structure, by virtue of the observed facts of the relations between the frequencies and intensities of spectral lines. This method of attack was based on an analysis of the frequencies and intensities by means of Fourier's Theorem.

Space will not permit of our tracing the details of his work here, but it resulted in the properties of atoms being shown to follow a new system of mechanics. Heisenberg himself did not at first recognize the mathematical significance of the laws which he found the atomic radiations obeyed. Mathematicians, however, at once recognized that they followed the properties of " matrices." The theory of matrices was a branch of pure mathematics which had been developed many years previously, but which had so far no known physical significance. Heisenberg's quantum mechanics thus became to be known as matrix mechanics. We shall content ourselves by mentioning in passing that a matrix is an array of terms, of which the well-known determinant is a special case. It may thus be seen that all Heisenberg had done was to arrange the spectral terms in a regular array, and discovered the properties of this array without any further assumptions.

Largely inspired by Heisenberg's work, de Broglie had been working on the development of the quantum theory and in 1924 introduced the first system of wave mechanics which gave results in agreement with those of Heisenberg. This was further developed and modified by Schrödinger from the mathematical point of view and led to extremely interesting explanations of experimental results which so far had baffled physicists, but, in addition, it completely revolutionized the conception of matter and indicated in advance of experiment the possibility of the diffraction of matter, which has since been discovered by Davisson and Germer[2] and confirmed by Professor G. P. Thomson.

The Physical conceptions underlying Wave Mechanics.

The whole business of wave mechanics really started when it was suspected that all natural phenomena were discontinuous. It had long been postulated that some phenomena were discontinuous, for example the theory that matter was composed of indivisible particles called atoms is really a theory of the discontinuity of matter. Newton's idea that light consisted of tiny corpuscles emitted by luminous bodies was evidence of his belief in the discontinuity of light. Many such examples can be found among earlier ideas of natural phenomena. It is really a question of point of view. What appears to our

[1] " New Discoveries, New Tools, New Problems." W. G. Radley, B.Sc. (Hons.), A.M.I.E.E. P.O.E.E. Journal, Vol. XXI., p. 75, April, 1928.

[2] C. J. Davisson. Bell System Technical Journal. Vol. VII., p. 90, January, 1928.

eyes to be a smoothly-polished, uniform, metallic surface, we know from other considerations to be granular in structure, a highly complex system of minute very dense particles with relatively vast volumes of empty space separating them. The limitation is not so much in our eyes as in the discontinuous nature of the means we use for seeing, that is light itself. When we use radiation of higher frequency, such as X-rays, to examine the metal surface we are at once able to see the discontinuities in that surface.

We have already mentioned that classical mechanics fails when dealing with speeds in the neighbourhood of the velocity of light and with dimensions comparable with the wave-length of light. We have also noticed that it was from a study of the frequency and intensity of spectral lines that Heisenberg was led towards a new atomic mechanics. It appears, then, that the failure is most probably intimately connected with the nature of light itself.

There have been two theories as to the nature of light, both of which have been prominent from time to time. These are the corpuscular theory of Newton and the wave theory of Huygens. There have always been difficulties in the way of adopting one or the other as the best way of explaining all the known facts relating to the properties of light. One of the difficulties associated with the wave theory was the fact that light travels in straight lines. A narrow beam of light behaves in so many ways just as a stream of weightless particles would. When it passes through a slit, the greater proportion passes on in a straight line, a small proportion being scattered in a regular manner. The phenomenon of diffraction at a single slit, in fact, might easily be imagined to be due to a few of the light corpuscles being deflected by collision with the edges of the slit. If, however, the beam of light is incident upon two parallel slits not too far apart, the scattering is more pronounced, and the distribution of illumination upon a screen placed behind the slits differs distinctly from that due to a single slit. Some parts of the screen which are illuminated by scattered light in the case of the single slit are dark when a double slit is used and *vice versa*. This fact, which is explained at once by the wave theory, leads to great difficulties from the point of view of the corpuscular theory. It would appear that a corpuscle passing through one slit and reaching a given point on the screen, will reach a different point if there is an adjacent slit through which other corpuscles are passing. The presence of an adjacent slit appears to have an effect upon the corpuscles which do not pass through it.

It was for reasons such as this that the corpuscular theory was abandoned about the middle of the nineteenth century and at that time the possibility of its ever being revived again seemed very remote.

Within the last ten years, however, phenomena have been discovered which have swept away these reasons for abandoning the corpuscular theory, although, strange as it may appear, they have at the same time strengthened the position of the wave theory. In fact, they have indicated that both theories must be tenable at the same time; they are really two aspects of the same set of ideas.

The electron has been discovered and recognized as a concrete particle for many years. Its mass had been determined and established as a physical constant for an electron at rest, varying with velocity in accordance with the theory of relativity. A stream of such particles when impinging upon a photographic plate leaves a permanent record just as light does and hence we are enabled to study the effect of a beam of electrons passing through slits. We can study the optical properties of electron beams. The remarkable fact is that these electrons are diffracted and give rise to interference effects just like light waves, as shown by the classical experiments of Davisson and Germer in the Bell Telephone Laboratories and by Professor G. P. Thomson at Aberdeen. The same difficulty arises in attempting to explain the phenomena on a corpuscular theory as was the case with light. In this case, however, we have other evidence that we are dealing with discrete particles.

We are faced with one of two alternatives :

Either (1) we must concede that light and electron beams are at the same time wave motions and motions of particles in a straight line;

Or (2) we must conclude that our accustomed method of calculating the motion of particles, that is our classical system of Newtonian mechanics, is not universally applicable.

It seems clear that the second alternative is inevitable, and we must seek to modify our system of mechanics to cover these anomalies. It would appear that the problem is intimately associated with the properties of waves, and this proves to be the case and for this reason the name " Wave Mechanics " has been applied to the new system. At the same time the dependence of the new mechanics upon the Quantum Theory has caused it sometimes to be called " Quantum Mechanics."

Experiments on the diffraction of electrons, lead, according to the simple wave theory of the phenomena, to the determination of the length of the waves apparently associated with the beam of electrons. The wave length varies with the speed of the electrons and it is found experimentally that

$$\lambda = \frac{h}{mv} \quad \text{...(1)}$$

where λ is the wave length associated with the beam,
m is the mass of each electron,
v is the speed of the electrons,
h is a constant.

It turns out that h is Planck's constant $= 6.55 \times 10^{-27}$ erg. secs.

According to Planck the energy E of a quantum of radiation of frequency n is given by

$$E = hn \quad \text{...(2)}$$

According to the theory of relativity the intrinsic energy possessed by a particle of matter of mass m is mc^2 where c is the velocity of light.

$$\text{Thus } E = mc^2 \quad \text{..................................(3)}$$

In addition we have the well-known wave property connecting the wave velocity V with the frequency n and wave-length λ

$$V = n\lambda \qquad \text{.....(4)}$$

From these four equations we have associating an electron with a quantum of energy

$$E = hn = \lambda mv\, n$$
$$= Vmv$$
$$\text{Thus } mc^2 = Vmv$$
$$\text{or } V = \frac{c^2}{v}$$

This equation leads to the explanation of the fundamental idea underlying wave mechanics. The wave associated with the electron moving with a velocity v, is a wave with a velocity greater than that of light. The theory of relativity leads to the conclusion that velocities greater than that of light are not physical possibilities. We must conclude, therefore, that such waves have no real existence. This may seem a strange conclusion and at first sight we might be led to ignore them altogether for this reason. According to the theory of wave mechanics, however, although the waves associated with the moving electron have no real existence, they merely determine its motion. As they move faster than the electron we can imagine that they go on ahead and the electron is constrained to follow along their path. When the waves encounter an obstacle they are diffracted and the electrons suffer diffraction in their turn when they reach the obstacle. It must be understood that this conception is only approximately true, but it does give a mental picture of the ideas involved.

In the case of light waves, Einstein postulated that they consisted of weightless particles, which he called photons. In the case of photons $V = v = c$, and the waves and particles travel at the same speed. All this means is that the imaginary waves are themselves the system of mechanics. The motion of real particles is determined by some sort of imaginary wave. The whole conception is a mathematical device for performing the calculation of the motion. It can be seen that the determination of the motion of particles by means of wave mechanics becomes an optical problem which may be solved mathematically. The equation of motion is a wave equation and the method has been applied to the atom by Schrödinger with very successful results in explaining the intensities of spectral lines and the anomalies which could not be explained by Bohr's theory.

We cannot concern ourselves here with the somewhat intricate details of the mathematical development but we will indicate in conclusion some of the far reaching results of considering physical phenomena from the new point of view.

The Results of Wave Mechanics.

One of the most useful practical results of Wave Mechanics is that problems relating to the electrical conductivity of crystals, etc., may be considered more like problems in optics. Instead of regarding the electrons as a system of particles moving through the body in question and obeying the laws of classical mechanics, we consider them as a beam of energy whose motion is determined by the associated waves.

The treatment of the problem then becomes a matter of optical interference, diffraction, and polarization. The equation of motion is a wave equation, and the development of wave mechanics mathematically becomes the discovery of means of solving this equation in its various forms. These solutions are seldom straightforward and a number of approximations have been developed for the solution of problems of particular types. One of these problems is that of the metal rectifier which has recently been studied by A. H. Wilson[3] and others with very illuminating results.

A second conclusion from Wave Mechanics which has a philosophical bearing, relates to the question of causality in physical phenomena. According to the causal principle which has hitherto been accepted as a general hypothesis in scientific thought, an exact knowledge of the present renders possible an exact calculation of the future. In other words, we can predict the behaviour of a mechanical system under certain postulated conditions, provided we can observe its behaviour completely and accurately under a similar set of conditions. According to the conclusions of Wave Mechanics, an exact knowledge of the present is not possible and there must always be errors of observation owing to the discontinuous nature of energy and matter. It can be calculated that the product of the errors involved in any observation cannot be less than the elementary quantum of action, or Planck's constant, the symbol h in equation (2) above.

The most that we can do is to assess the behaviour of a system within certain narrow limits and calculate the probability of its behaviour under a given set of conditions in the future. When we are dealing with a small number of discrete particles or small quantities of energy, the discontinuities are prominent and the probability assessable is low. With larger quantities of particles or energy such as we are accustomed to deal with in engineering problems, the probability approaches closely, though never actually reaches, unity. Determinism, or the principle of causality, therefore breaks down, according to this theory, on account of the fundamental impossibility of exactly knowing the present.

[3] A. H. Wilson. Prov. Roy. Soc. A., Vol. 136, p. 487, 1932.

The Manufacture of Porcelain Insulators

W. H. BRENT,
B.Sc., A.M.I.E.E.

IT is exceedingy doubtful if the users of porcelain insulators realize in full the variety and number of processes which the finished article will and must have gone through before being pronounced satisfactory for delivery from the factory. Many items of telephone use, such as instruments, automatic equipment, including dials, and other apparatus, have obviously, from their multiplicity of small parts and intricate character, called for the application of much ingenuity in their assembly. There are more than a dozen different operations involved in the manufacture of one of the porcelain insulators used by the Post Office, whilst a steel insulator spindle, to take another example from external construction work, when made under modern mass production methods, has some sixteen different stages to go through.

Electrical porcelain is made from the four ingredients, Ball clay, China clay (Kaolin), Silica and Felspar (chiefly aluminous silicate). The first material is obtained from Dorset, the second from Cornwall, whilst the silica and felspar normally come from Norway. The steps taken to convert these into a homogenous vitreous material of the required shape at the works of Messrs. Bullers, Ltd., of Milton (North Staffordshire) will be described. Telephone and Wireless relay insulators are made by a " Throwing " process, whilst larger articles, including H.T. insulators, as used by the Grid System, are made in the " Jolly " Shop.

What are colloquially termed the " Slops " are the primary substances each thoroughly puddled with water until a definite weight per pint of fluid is secured. Naturally the silica and felspar, being rock-like in character, have to be ground down very finely before this is done. A certain number of gallons of each slop, according to the type of porcelain, is run into large revolving cylinders. Heavy balls inside the cylinders grind and mix these up together. The " slip " is then passed to a rotating cage with 120-mesh sides to retain any particles of appreciable size; any iron particles are extracted from the slip as it runs down over a series of magnets on its way to the filter presses. These contain flat canvas bags about 2 ft. square with an opening in the centre of each for the slip to enter. The presses are about 20 ft. long and pressure from the ends forces out the surplus moisture so that a flat pinkish-buff pancake of moist clay is taken from each bag.

To complete the conditioning of the material, it passes in succession through two large sausage machines, from the second of which it is extruded practically free from air bubbles and with the moisture evenly distributed.

In the manufacture of the telephone insulator, the Throwing house is the scene of the next stage, and here one of the oldest mechanical aids to industry, the potter's wheel, is used—the only difference being that the wheels are now driven by electrical machinery in place of the treadle arrangement. In this shop, lumps of clay are cut off and weighed roughly on scales in order to check their size and are given to the " thrower " who turns each piece on his wheel to a cylindrical form approximating to the insulator being made. The clay at this stage is still quite soft and a short period of drying off at a low heat has to be given to the cylinders of clay before the next operation can be carried out. Fig. 1 shows a view of the throwing house.

In the turning shop (Fig. 2) each cylinder receives its final form, although all dimensions are somewhat greater to allow for shrinkage. First of all, the inner sheds are formed by means of correctly shaped cutters; then at the next lathe, the spindle thread is formed as the insulator is placed on the chuck and, guided by the profile edge of a jig, the cutting tool removes the surplus clay, trimming the outer sur-

FIG. 1.—THE THROWING HOUSE.

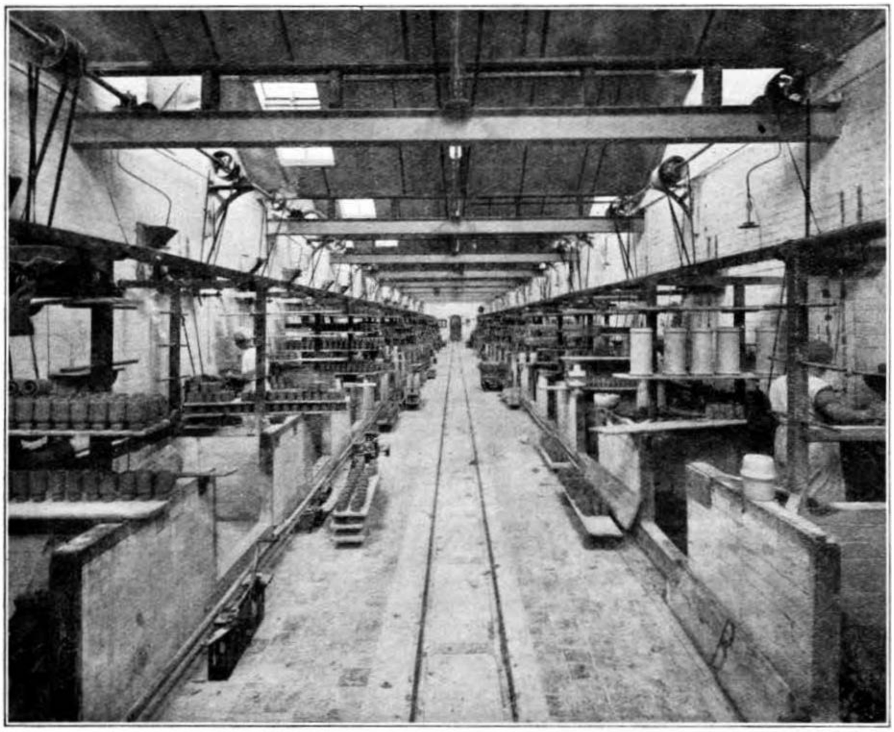


Fig. 2.—The Turning Shop.

face as required. If leading-in insulators are being turned out, these have several extra operations including the cutting of the cavity and the threads for the cap and the drilling of the holes which will take the cable leads and wires in service.

The stages which follow lead up to the firing of the material, and for this it must be as thoroughly free from moisture as possible. The insulators or other articles are transported on boards some 6 ft. long to the drying room, where they remain exposed to the dry hot air for several days, until only combined water is left. These long boards are used throughout the factory for the conveyance of the insulators and the rather top heaviness of the No. I Insulators when stood on the extending inner shed has led to the familiar name of "Tumbledown" being given to this by the workers.

High Tension insulators with sheds 10 or 12 inches in diameter are made in the Jolly shop (Fig. 3). Each shed is worked up separately by roughly shaping the lump of clay and dropping it into a mould conforming to the outer surface. It is then well pummelled into contact with the sides of the mould and when this has been done the whole is rotated after the manner of the potter's wheel whilst the shape of the inner surface is produced. These insulators, too, must be dried out completely, but where a pin-type insulator has two sheds, each part is jollyed separately and carefully welded together with some of the same material, which later fuses as one complete mass.

In yet another shop, die pressing machines turn out small articles in repetition for uses not essentially electrical. These may be resistor blocks for fires, door knobs, accumulator stoppers, electric light switches or the small egg insulators, sold by wireless retailers for aerials. The wet clay mixture used for electrical porcelain is not suitable for this work although much the same ingredients are of course required, but in the form of a powder with a little lubricant for die working. This powder is granular in appearance and brick red or grey in colour, but the finished product generally is an entirely different colour. The interesting feature of these machines is the ingenuity which has been used to obtain holes

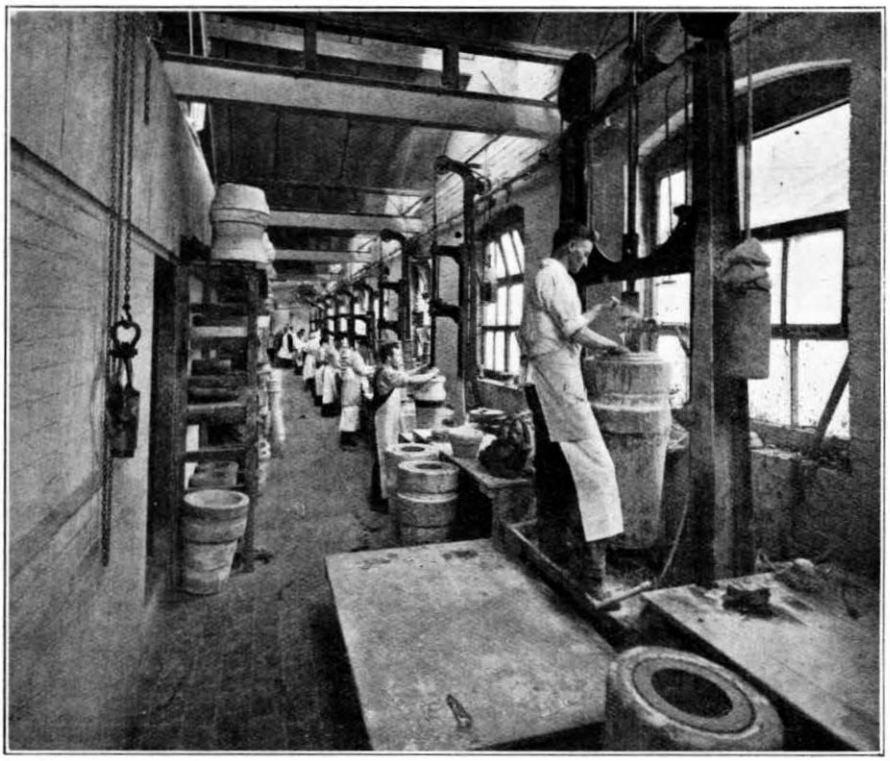


Fig. 3.—The Jolly Shop.

FIG. 4.—EXIT END OF TRUCK OVEN.

dipped into a mauve-coloured fluid.

The large champagne-bottle-shaped brick ovens, some 30 or 40 feet high, are a familiar sight in the pottery district. The internal space, 12 to 15 feet in diameter, is packed with the fire clay containers which carry the articles to be fired. When the oven is full, the fires around the circumference are lit and the heat very gradually raised to the correct temperature and then almost as carefully cooled down. It is interesting to note that actual temperatures are not recorded, but in order to judge the state of the oven a number of clay rings are put in initially at certain points and withdrawn one by one as firing progresses. The shrinkage of the ring, measured on the diameter by a special form of caliper, indicates to those in charge whether the required firing point has been reached. The same shrinkage, too, takes place in the insulators which are being fired and the dimensions change by approximately one-seventh in height and one-tenth in diameter during the process. This naturally has to be allowed for in forming the clay shapes.

In addition to three or four such ovens, Messrs.

at right angles to the movement of the dies and to form screw threads by pressure. The tool makers shop where the intricate little steel dies are being prepared is of no less interest than the machines themselves.

Whatever process the article has been through it must be absolutely dry and free of moisture. At the end of the drying period, each article is examined and should there be the slightest hair line crack, the trained eye of the examiner will observe this, remove the piece and return it with other waste material to the starting point. For, once fired, a defective article is only fit for the scrap heap, but waste from the lathes or drying shops, being unfired, is valuable and easily worked up again.

The glazing fluid is similar in composition to the material of the body, but the proportions of fusible elements are much higher so that a smooth surface of the character of glass will be obtained. The colour again is no guide to that of the fired article for whilst white insulators are dipped into a cream or buff solution, those which are to be brown are

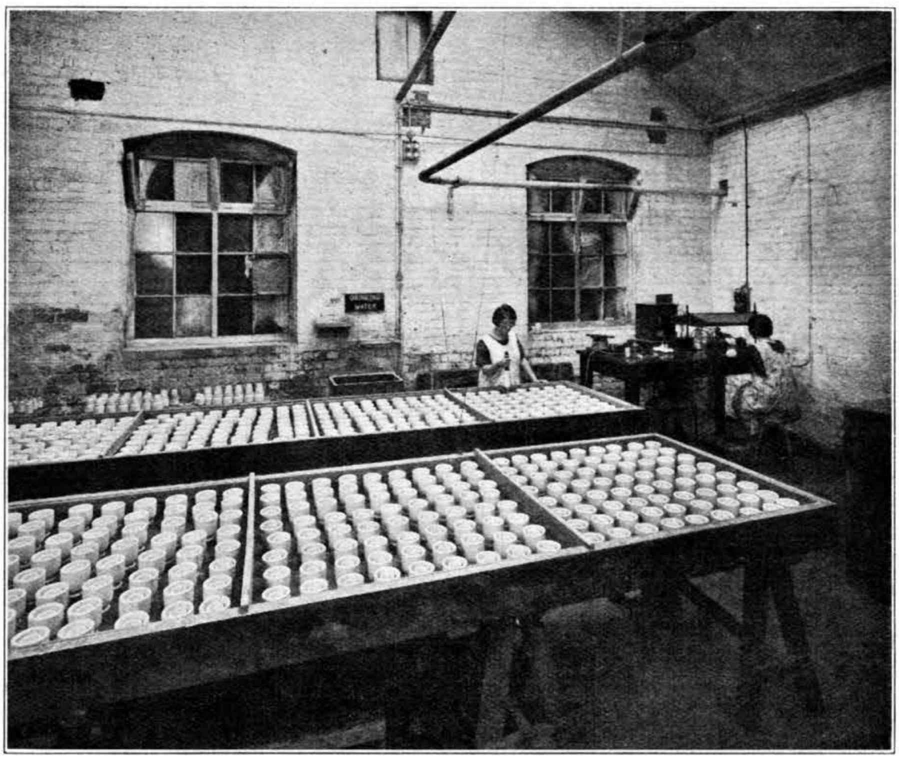


FIG. 5.—ELECTRICAL TESTING OF INSULATORS.

Bullers work a truck oven over 100 yards long. Along the length of this the trucks carrying the fire clay containers pass at slow speed, taking four days to arrive at the far end. The greatest heat is at the centre and is maintained constant day in and day out by gas burners fed from a producer gas plant. As the trucks travel up towards the furnace, their loads are being gradually warmed up by heated air and waste gases coming down the tunnel from the centre. Similarly, after the trucks have passed through the furnace, the air coming in at the exit cools down the fired truck loads and the same becomes preheated for the burners; seemingly, a very convenient and ingenuous arrangement. Fig. 4 shows a truck load being withdrawn from the oven.

Once the material has been fired, no further work can be done on it and the remainder of the passage through the factory is concerned with the examination and testing prior to despatch. The Post Office requires that every single insulator shall be electrically tested to ensure that it is sound, for in service each will represent a separate parallel path to earth and the overall insulation resistance will be largely affected by the inclusion of any inherently bad insulator points. For the electrical tests—carried out in the majority of contracts by the manufacturer with occasional check tests by the Department's Inspectors—the insulators are inverted in a large shallow trough and water run in until the surface is ½ inch below the lips of the outer sheds. The interior of each cup, including the space between the two sheds, is then filled with water to ½ inch from the lip and the whole left to soak for 12 hours. The tests are made between the trough and the water in the spindle hole and the water in the space between the two sheds and with a 500 volt D.C. battery and galvanometer the deflection must indicate more than 10,000 megohms to be satisfactory. Generally, if the insulator is good it is well above this figure and, if poor, well below, but rejections are surprisingly few. Fig. 5 shows insulators under test.

The insulation test is thus mainly through the material from the spindle hole, which is unglazed, to the head of the insulator, which is also unglazed. This is also the case with leading-in insulators but, in view of the connecting holes between, the insulator is only immersed so that the water is ½ inch below the top of these holes, the spindle hole being filled to ½ inch from the top.

The glaze is not put on to render the insulator waterproof as is shown by porosity tests which are occasionally made. For this test, the insulator is broken to give a fresh surface and the pieces immersed in a 0.5% alcoholic solution of fuchsin for 24 hours under a pressure of 2,000 lbs. per sq. inch. When taken out and wiped with a cloth there must be absolutely no signs of impregnation by the alcohol.

The chief function of the glaze is to give a surface from which rain will readily clean off any soot and dirt. As the surface leakage may exceed by several times the leakage through the material from the spindle to the groove, this aspect is naturally an important one. It also speaks well for porcelain insulators that when they are recovered after many years and the surface well cleaned with a solution of caustic soda and " Quebracho " extract, they are found to give results practically equal to new. Experiments have been made, however, with unglazed insulators and extended field trials which are being carried out in a variety of atmospheric conditions show a somewhat unexpectedly good performance.

To ensure interchangeability of insulators and good fit on the spindles—on which they are to be screwed with the interposition of a 5/32nds inch rubber washer—the Cordeaux thread of each spindle hole is tested by screw gauges. These are a " Go " screw gauge to check that the insulator will screw on any spindle, a " Not go " screw gauge and a " Not go " plug gauge to see that it will not be too loose on the spindle, and a " Tell-tale " plunger gauge, which measures both the depth of the screwed cavity and the length of the shed. Certain limits must be observed on these, and those insulators which pass are ready to be packed and despatched to the Depot of the Post Office Stores Department, from which they will in due course be issued for the erection of circuits throughout the country.

A Loudspeaker Telephone

A loudspeaker telephone has recently been developed in the P.O. Engineering Research Laboratories which is capable of operating over all circuits, so that it can replace the usual form of telephone. A high-quality moving-coil microphone is used in conjunction with a moving-coil speaker mounted in one small cabinet occupying not much more space than a telephone. The output of high-quality speech to line from a talker speaking two or three feet from the instrument is equal to that obtained from similar speech spoken directly into a modern telephone transmitter, whilst the level of the incoming speech at a similar distance from the moving-coil speaker can be adjusted to be up to 10 decibels above that obtained when listening on the normal telephone. Voice-operated switches, operating in a few milliseconds, are used to prevent acoustic " howling."

The successful development of this instrument has only been made possible by the application of a new device in voice-operated switching systems, which enables either listening party to " break in " at will when the switches are operated against him either by the other subscriber or by extraneous line and room noises. The resultant telephone conversation is quite normal and no switching operations can be detected by the parties using the instrument.

The small table model can be replaced by a larger form of speaker to be suspended together with the microphone in a conference room, so that two or more groups of people at different centres can conduct a conference without the necessity of all meeting together at one place.

A full description of these systems will appear in the Journal at a later date.

Mechanical Ramming

J. J. EDWARDS,
B.Sc.(Eng.), A.C.G.I., A.M.I.E.E.

THE search for new methods and appliances to cut down the heavy cost of laying plant underground, has until comparatively recent times stopped short of a method which will cheapen one very important part of the work—namely, punning, ramming, or backfilling, as our American friends like to call it. With the ordinary trench for single and multiple ducts, the efficiency of the reinstatement and punning plays an important part in securing the stability of the route, and even with the newer ploughing and trench excavation methods for single armoured cables described in this Journal in recent times, punning the refilling materials is still a necessary and important part of the work. Again, even the moledrainer has to give way to trenching or thrustboring methods when crossings of public or private roads and entrances are reached, and it was, in fact, on the scheme where moledraining was first used by the Post Office that a mechanical rammer was tried on the trenching sections for the first time on the Department's work.

The mechanical rammer or punner driven by compressed air from a portable compressor driven by a petrol or diesel engine has, of course, been known and employed on suitable works for a number of years, but this punner is of small diameter which receives and transmits very rapid blows. So far as Post Office work is concerned, the pneumatic rammer has been found mainly useful for ramming the refilling material in pole holes which have necessitated the use of the compressed air drills, driven from the same plant, for their excavation. A certain amount of trenching work has also been carried out with these compressed air plants, but the number of such works necessitating the use of compressed air equipment is small.

There is a definite field, however, for the employment of mechanical appliances on the short road crossings and numerous trenching sections which occur on almost every cabling scheme undertaken by direct labour. In the majority of these cases, the cost of transport of a compressor plant to site and of the standing charges involved in keeping it idle between the sections where it is required, render the use of such a plant out of the question. In the past this has meant resort to manual methods because there has not been available any self-contained portable mechanical concrete breaker or drill or mechanical rammer with a sufficiently low first cost and therefore standing charges to permit of it being taken on to the job and used as required. The former requirement, *i.e.,* of a self-contained, portable, mechanical drill or breaker, has even yet not been met adequately, although there are hopes that such a machine shortly to be tried out will be found to meet it, but there are now on the market mechanical rammers which fill the second requirement mentioned above.

In principle, the portable power rammer is an internal combustion engine utilizing the explosion to give the rammer the required lift. Figs. **1** and **2** show sections, through planes at right angles, of a rammer, made by Messrs. C. H. Johnson & Sons, Ltd., of Manchester.

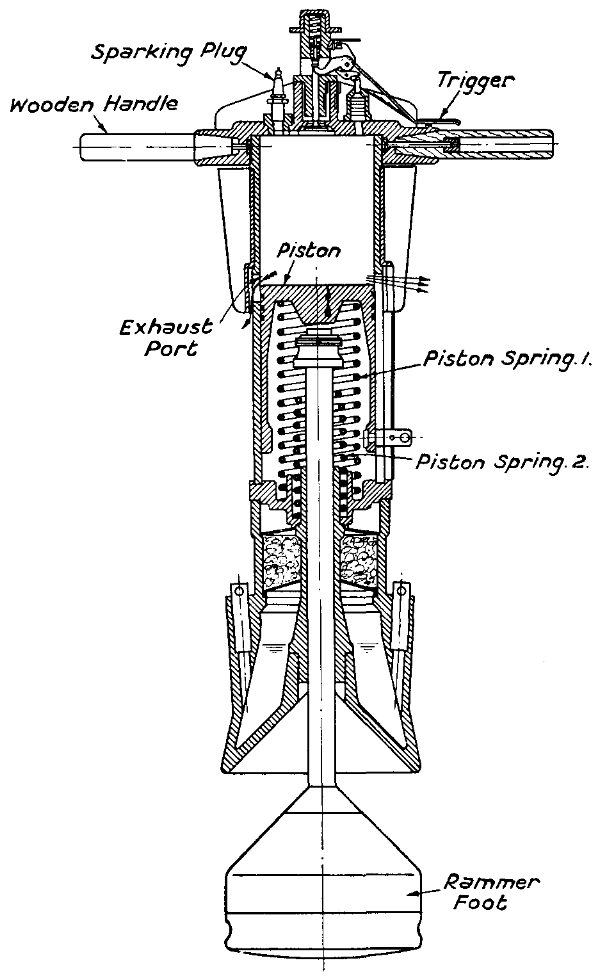


FIG. 1.—PORTABLE POWER RAMMER ; END OF EXPLOSION.

The cylinder is of cast steel and contains the fuel and surface vapouriser in its base. The fuel is pure benzole and the vapouriser consists of a number of wire sponges through which the fuel is drawn. The mixture enters the cylinder by means of tubes at the side and ignition is effected by means of a sparking plug, fed from a battery and ignition coil which the operator carries in a case on his back. The rammer foot consists of a round wood body built up of several vertical piles of wood glued together, and retained by a sheet iron casing which also covers the bottom.

The operation of the machine is briefly as follows : The space between the top of the piston and cylinder head being filled with benzole vapour, the trigger just above the handle on the right is depressed thus throwing a spark across the sparking plug. As a

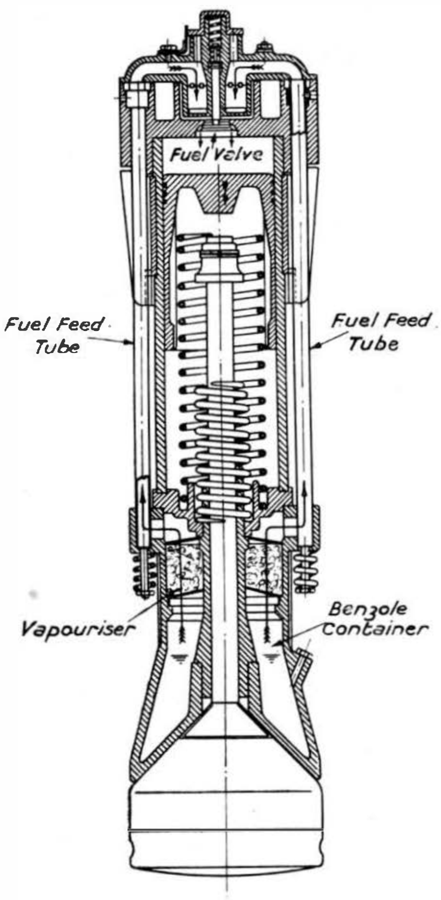


Fig. 2.—Fall of the Rammer.

result of the explosion the rammer cylinder is forced upwards and the exhaust gases start to escape through the ports, which are then uncovered. The piston moves upward under the influence of spring 1 and in consequence of this lifting motion the rammer jumps to a further height. The quick upstroke of piston and piston rod spring 2 lift up the piston rod which carries the ramming foot. The rammer then having reached its highest point begins to fall, the piston at that point lying close to the top of the cylinder head. The wooden foot and machine come down together, so giving the blow, and then the piston falls under gravity and draws a new charge from the container to the top of the cylinder.

Thus the operator has only to hold the handles and keep the machine vertical, in addition to pressing the ignition trigger—and keeping his chin out of harms way when the machine jumps. By moving in the required direction as the machine jumps, the operator can direct the blow of the machine as he wishes.

In this particular make of machine, the quantity of fuel drawn into the cylinder is fixed, but, in another make, it is possible to vary the charge by the extent to which the handles which the operator holds are depressed. Also machines have been built with ignition by means of a magneto mounted on the cylinder head instead of by coil and battery. This has the advantage of relieving the operator of the weight of the coil and battery, but no information is so far available as to the success of the magneto arrangement.

In the Department's service, a 140-lb. machine of this type has given good results on trenching works, being found equal to at least three men with hand punners, and it is of interest to note that the agreement recently concluded between the various Associations of Municipal and County Authorities and the G.P.O. recognizes the use of such machines on contract reinstatement works.

By utilizing a chisel instead of the punner foot, the machine can be used as a concrete breaker and trenches can be cut across roads far more quickly than a gang with wedges and sledge hammers can cut them.

The shape of the chisel is shown in Fig. 3 and from this it will be seen that a collar is formed on the rod just above the chisel blade. The body of the machine when used for concrete breaking is fitted with a different bottom section tapering towards the lower end and this moves up and down over the chisel rod. Thus when the explosion takes place as before, the cylinder or body rises, and, as it falls, it slides down

Fig. 3.—Concrete Breaking Attachment on "Johnson" Rammer.

the rod and imparts the blow by impact on the collar above the chisel which remains stationary on the material to be broken, and is driven in when the breaker falls. This process is repeated until the chisel has been driven in sufficiently far for the material to break away.

To move the position of the chisel to start a new cut, a wire rope connected to a chain link inserted under the chisel collar is coupled to the handle of the tool by means of rubber bands, so that chisel and cylinder are lifted at the next explosion and can be diverted to the new position. The wire rope is then uncoupled from the handles again and hooked on to the operator's belt so as to be within easy reach.

The height of drop of the breaker is about 16-20 inches and the chisel generally receives some 50-60 blows per minute. Various chisels are available for use on different ground surfaces and materials and include diamond points, chisel, and spade ends. Shifting the machine on site is facilitated by a small trolley which is easily wheeled by one man. It is included as part of the equipment.

With this machine it is only possible to work vertically or approximately vertically. Even with this disadvantage, which renders the machine less flexible than the pneumatic breaker, it is still more economical than manual labour. It is found to be approximately equal to four men with hammers and wedges, on straight trenching works and road crossings. The running cost of the machine is of the order of 1½d. per working hour and, as has already been indicated, the standing charges are sufficiently low to make the machine a practical proposition. The maintenance cost, from present experience, does not seem to be unduly high and there should therefore be a considerable saving from the employment of machines of this type.

There is nevertheless room for a similar internal combustion engine machine which shall have the same flexibility on concrete breaking work as has the pneumatic type of tool, but it seems likely that such a machine will be a single-purpose machine and will not combine ramming with rock or road breaking. The number of explosions per minute of a machine designed for rock drilling or concrete breaking will probably be so large that the time per explosion cycle will be insufficient to permit of the raising and lowering of a comparatively heavy punner foot by a machine of practicable size.

Measurement of Side-tone

The efficiency of any telephone anti-side-tone device is usually determined by comparing the volume heard in the local receiver with that received at the exchange end of the line.

All anti-side-tone arrangements involve a balance impedance which is made to match an assumed average line impedance. If this impedance is used in the test a very favourable result will be obtained. If, however, another device is tested with the same impedance it may give a bad result, although in actual service the two devices may be equally efficient on the average. In order to secure a fair test comparable with working conditions, a rhythmically-varying impedance is being tried in the Research Section. It has been found that 90% of the line impedances met with in practice will, if plotted vectorially, lie within a rectangle whose corners are 300, 1100, 1100-800*j*, 300-800*j*. This rectangle can be approximately covered or "scanned" by using a variable resistance R_1 in series with a condenser which is shunted by another variable resistance R_2. By means of two continuously-rotating uniselectors, R_1 and R_2 are varied at different rates, such as four and seven times per second. The varying impedance of the network is used as the line impedance against which the anti-side-tone telephone is tested and a comparison of side-tone volume with received speech volume is made by any convenient method. The result should give a fair measure of the average efficiency of the anti-side-tone device in practice, and the rhythmically-varying network can, of course, be used to measure the effect of side-tone on reception in noisy situations.

The arrangement is in course of construction, but preliminary tests indicate that no trouble need be feared from noisy contacts on the variable resistances.

The Introduction of the Standard Telephone Relay

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

WITH the development of automatic telephone systems the telephone relay has acquired an importance far greater than it previously possessed under manual exchange conditions. A certain relay fault liability may be satisfactory when the fault can be found and cleared as soon as it occurs, but in the common network of an automatic exchange, particularly in the director system, there are many heavily worked relays on which a fault is very difficult to locate quickly and yet can have a serious effect on the service. Until recently the responsibility of relay design has been with the manufacturers, each contractor supplying his own type and designing models with varying factors of safety. Although this practice has enabled development to proceed unhampered, and has produced a fund of experience both in manufacture and maintenance, it was inevitable that difficulties would be encountered with regard to interworking and interchangeability.

The Post Office therefore decided to standardize one type of relay, the best that could be designed in the light of past experience, and to require all contractors to supply this one type, models of which would be designed for particular circuits in close co-operation with the Department. A proposed standard telephone relay was designed by Messrs. Ray and Biddlecombe, of the Post Office Engineering Department, in co-operation with the contractors, and was described in this Journal in October, 1931. This type of relay, now known as the 3000 type, was adopted as standard in 1932 (Fig. 1). The general design having been decided upon, it was then necessary to deal with a large number of details, and one of the minor points which arose during the early discussions was the varying nomenclature of spring sets, spring piles, contact assemblies, actions, contacts, etc. In obtaining agreement on certain difficult points some unfamiliar terms such as " contact unit " were introduced. The new terminology has been used in this article and the meaning of any new terms will be apparent from the context. The first important work was the study of the details of construction to ensure that all requirements of manufacture, circuit application and maintenance would be met economically, and as a result a number of small changes in dimensions and shapes of piece parts were found necessary.

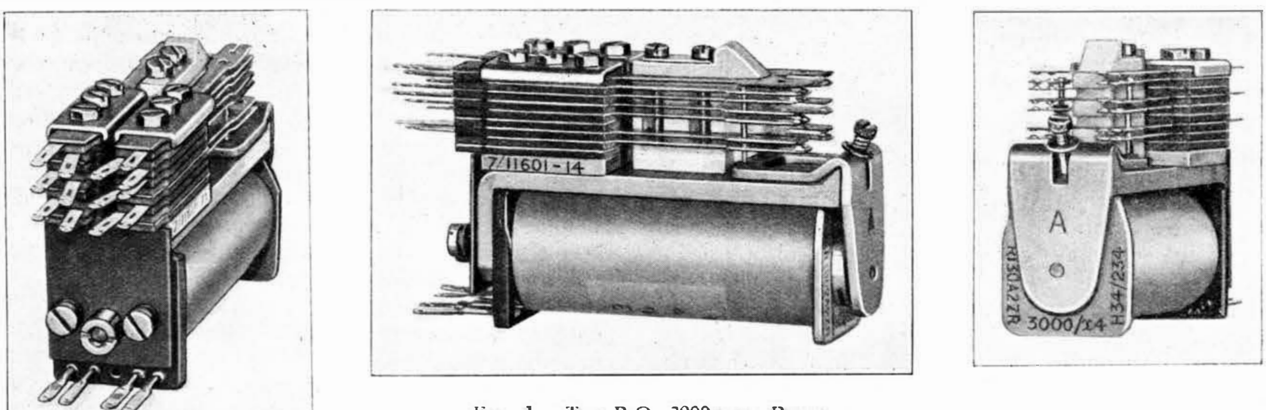


FIG. 1.—THE P.O. 3000-TYPE RELAY.

Buffer Blocks.

In the original design of relay the number of contact units (*e.g.*, make, break, change-over, etc.) was limited to six, *i.e.*, three units per spring set, but this limitation has been extended to allow 4 contact units per spring set provided that the total number of individual springs in any one spring set does not exceed the original limit of 9. Thus a complete set of 9 springs may consist of 3 change-over units with 3 springs per unit, or it may consist of one change-over (3 springs) plus 3 makes (2 springs each). Additional buffer blocks have been provided to accommodate this arrangement of 4 contact units and the 5 standard blocks are shown in Fig. 2. When 4 steps are provided, the buffer block has a web between left and right hand sides to give added strength to the shallow steps. The large step on the 4 step blocks is in the second position in order to leave the first position free for an X make or X break contact unit.

X and Y Contact Units.

In previous types of relay, early or late operation of any contact unit (*i.e.*, X or Y operation) was obtained by special adjustment of the springs. This had disadvantages in maintenance because reference to an adjustment card was usually necessary if these special adjustments were to be carried out correctly, and a contact sequence dependent on the bending of springs is not definite enough to ensure the reliability required in automatic exchange circuits. X or Y contact units on a 3000 type relay are provided as part of the mechanical

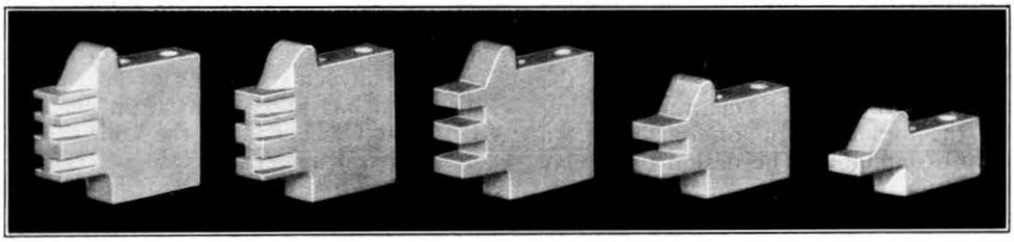


Fig. 2.—Buffer Blocks.

construction of the relay so that when adjusted in the standard manner the correct sequence of contact operation is assured. The essential details that determine the order of operation of the contact units are the lengths of the lifting pins, so an X contact unit has a special lifting pin which causes that unit to operate earlier than the remainder. It is also necessary to ensure that the contact units in the spring set opposite to that containing the X unit do not operate until late in the travel of the armature, so the buffer block and spring sets are raised on a metal packing piece, causing the normal spring set to be clear of the armature lifting stud until the X unit has operated. This is visible in Fig. 3, which is a schematic sketch of a normal

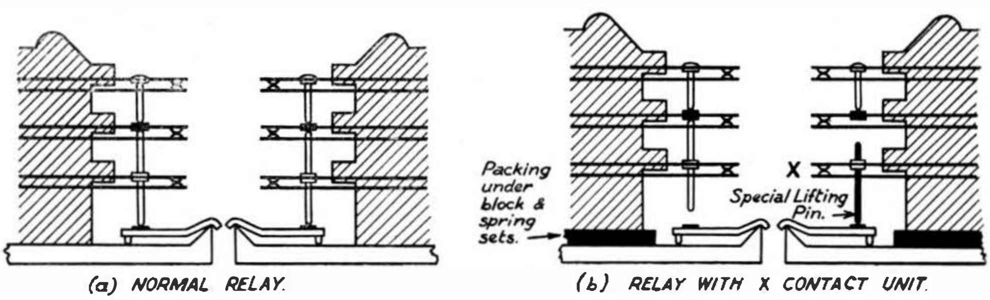


Fig. 3.—Provision of X Operation (Break Contact Units).

relay compared with an X unit relay. The clearances between lifting pins and studs in this example show clearly how all contact units other than the X unit are delayed in operation.

When a Y contact is required, all that is necessary is to provide a short lifting pin for the Y lever spring to delay its operation. No packing piece is required in this case.

Other Modifications.

Residual studs, in the form of large headed rivets, have taken the place of residual strips, largely on the score of ease of manufacture and assembly, and also because studs are less liable to accidental damage during maintenance operations. The standard sizes of fixed residual, namely 4, 12, and 20 mils, have not been altered, and these sizes are so different that they are easily identified without having the studs made of different materials as was originally proposed.

On the coil fixing nut it has been decided to remove the flange which was arranged to eject the coil when the nut was unscrewed, because the cost of providing this flange and its associated constructional details was not thought to be justified by the maintenance facility provided.

Contact pressure on the 3000 type relay is controlled by the pressure of the buffered springs on the block steps, and the standard " readjust " block pressures are 16-20 gms. for relays with 14-mil springs, and 11-15 gms. for relays with 12-mil springs. The use of 18-mil springs on standard relays has been abandoned because there are few automatic circuits in which sufficient operating current is available to lift such a heavy spring load.

The main requirement of lever spring tension is that it shall be sufficient to deflect the break springs clear of the block steps when the relay is unoperated. It is now specified also that each lever spring shall be adjusted to press on the one below it with 5-8 gms. in order to keep the load on the armature between known limits and therefore to control the operate current, etc. This lever spring pressure also helps to damp out any oscillation of the springs during the operation or release of the relay.

Manufacturing Developments.

It has been no small upheaval for the manufacturers to introduce a new design of so fundamental an item as the telephone relay. In the early stages the contractors had to modify their organization for designing models of the new type to suit particular circuit conditions, and this reorganization was unfortunately accompanied by an abnormal load of work resulting from the review of every relay in every existing circuit; it also involved the scrapping of much of the old designing experience and the old design data which normally would have been used for new work. The problem was eased somewhat by division of the work of relay design among the five contractors concerned, each contractor being responsible for the initial design of relays for a particular group of circuits. The design of a relay with so many variables and often conflicting circuit requirements is a complicated process as is shown by the article on this subject in the Journal of April, 1933, so each manufacturer in turn takes a fortnightly duty as "checking contractor" to whom all new designs are submitted. Any questions arising from this check are then discussed at a meeting of all contractors. The "designing contractor" then submits to the Post Office a model of each of the principal circuits. At this stage the relay designs are scrutinized and the relays tested to ensure,

(1) That the relays agree with the standards already laid down.
(2) That they meet all circuit requirements, and
(3) That they will be the most economical in maintenance.

The contractor was affected to an even greater extent by problems of manufacturing methods, manufacturing tolerances, and the provision of new tools, and these matters were complicated by the necessity for all piece parts to be interchangeable when made by different contractors. Moreover, any relay made by one manufacturer must have the same operating characteristics as a similar relay made by any other. This meant narrow manufacturing and adjustment tolerances that had to be discussed in committee and agreed by all parties as being economical and effective in their aim. Some idea of the magnitude of this committee work can be gained from the fact that hundreds of working drawings of piece parts and assemblies were prepared, involving over a thousand different dimensions. Machine tools for all piece parts had then to be built to these dimensions and tolerances, and the factory organization was modified, where necessary, to deal with the manufacture, assembly, and adjustment of the new relay.

Brief mention must also be made of the development and manufacture of special relays, such as the 3000 type shunt-field relay and the mercury contact relay, because each of these had its own problems of design. Then there were the many indirect effects of the introduction of a new relay; for example, mounting plates and covers for relays mounted in ones and twos, or in strips of 10-20, or on selector and relay-set base-plates. All of these details have received careful consideration in the light of past experience and the requirements of the new relay.

Circuit Design.

The designing of 3000 type relays for application to particular circuits has already been referred to, but while every circuit was being examined in detail it was obvious that the opportunity should be taken to review the efficiency of these circuits from the relay point of view. The relay and circuit designers have aimed at producing relays that shall have no special piece parts and shall be so reliable and with such large factors of safety that a mass-produced relay adjusted to reasonable mechanical tolerances will be guaranteed to function correctly in the circuit without any current tests or special "tuning up." This aim has imposed a strain on the ingenuity of the Post Office and of the contractors, but it has been agreed universally that such an ideal is the essence of good service and in all but the most difficult circuits the ideal has been achieved. Of the relay codes so far approved, over 90% relate to "general purpose" relays that are standard in construction and adjustment and have the standard factors of safety. Most of the "special purpose" relays are in common equipments of which there are but a few in any exchange, so that in a complete exchange installation the percentage of "general purpose" relays should be much higher than that quoted above.

It will be realized from the foregoing that the designing or even selection of relays for a particular circuit is not a case of finding a relay with the proper number of make and break contact units plus, perhaps, a little simple arithmetic to decide on the resistance of the relay coil: this is not because the new relay is any more critical than the older types, but because the new selectors and relay-sets must do more than their predecessors and must function with a greater reliability and at less maintenance cost. In some cases small modifications of the circuits have been found to give a better relay performance and, subject to the requirements of urgency, such modifications have been adopted. Relay resistances as shown on existing circuits have, of course, been modified in many instances, and in this connexion the sensitivity of the 3000 type relay has been utilized to allow of reduced battery consumption as far as possible. Impulsing relays, ringing trip relays, and fast-switching relays have received special attention, and in some cases an improved performance has been obtained even with the greater factors of safety now specified. The fact that these two improvements have been possible simultaneously is a tribute not only to the 3000 type relay, but also to the new designing organization which has accompanied its introduction.

Maintenance Facilities.

One of the new maintenance facilities made possible by the adoption of the 3000 type relay is the almost complete abolition of Adjustment Cards which previously had to be referred to before any relay could be adjusted or checked. This has been achieved mainly by the inherent design of the relay whereby the adjustments on the majority of relays are to standard figures laid down in a common Maintenance Adjustment Instruction. These figures are easily memorized. Current tests are not required except on some "special purpose" relays, and this not only reduces the cost of specifying such tests but also reduces the time required to recondition a faulty relay. Any adjustment particulars which are individual to particular relays, and which therefore cannot be covered in the common adjustment instruction, are shown as far as possible on the relay itself, or alternatively, a reference to a special adjustment card is given on the relay. The scheme of showing this information is described briefly below :

(*a*) There are alternative standard pressure adjustments according to the thickness of the contact springs. The information concerning which of these pressures is to be applied is conveyed by the colour of the P.O. code label on the relay. A white background to the label indicates 16-20 gms. pressure (14-mil springs), and a green background indicates 11-15 gms. pressure (12-mil springs).

(*b*) The adjustment of a screw residual is peculiar to each individual relay code, but this is specified on the label in the space following the P.O. Code number. The figure printed there is the nominal value of the residual gap, in mils (see Fig. 4).

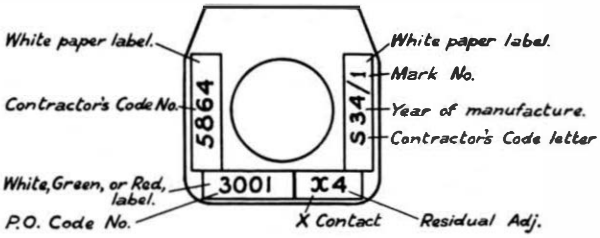


FIG. 4.—TYPICAL LABELS.

(*c*) The presence of X or Y contact units is apparent from close inspection of the relay or from the circuit diagram, but as a reminder to the maintenance staff, the letter x or y is shown on the P.O. Code label in such cases. The adjustment of these X or Y contact units is then carried out in accordance with the common adjustment instruction.

(*d*) The policy of placing the simpler adjustment information on the relay itself has confined the provision of adjustment cards to those few " special purpose " relays which have non-standard adjustments or require current or timing tests. In these cases the P.O. Code label has a red background indicating that reference to a special adjustment card is essential. These adjustment cards bear the same code number as the relay.

A further maintenance facility introduced concurrently with the 3000 type relay is easy identification of spare parts for replacement purposes. The parts common to all relays, *e.g.*, yoke, armature, buffer block, coil fixing nut, etc., can be identified by inspection and reference to a common table of code numbers. The code number of a relay coil is shown on a printed label visible through the transparent coil covering (Fig. 5), and the code number of a spring set is stamped on the side of the bottom clamping plate (Fig. 1). Spring sets will not be dismantled by the exchange staff (the complete spring set being changed when required), so that it is not necessary to provide particulars of individual springs and insulators. Individual piece parts schedules for each relay are thereby avoided.

Conclusions.

Although the new standard 3000 type relay is not yet working in any telephone exchange, the work of introduction is now well under way and its first application will be for Group Service installations. Experimental relays of this type, however, have been working for a year in a director automatic exchange, and the results have been particularly good. At the time of writing, only three dirty contact faults have been experienced during the history of the exchange.

It will have been apparent from the foregoing description of the work of introducing the new relay, and more particularly the magnitude of that work, that the wholesale change from old types of relay to one new type has been made possible only by co-operation between the Post Office and the contractors and especially among the contractors themselves. This co-operation and pooling of experience has been of immense value. It might even be said that telephone equipment would have benefitted by the mere standardization of any type of relay, however bad, but sufficient has already been said to indicate that the type of relay actually adopted is inherently capable of giving a much more reliable performance than has been obtained previously, and this will be a considerable factor in improving the quality of telephone service.

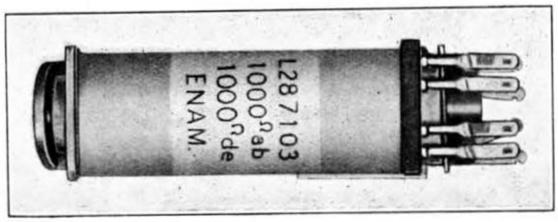


FIG. 5.—TYPICAL COIL MARKING.

The introduction of the 3000 type relay is not the end of telephone relay standardization, because there is still a need for a smaller and cheaper relay for use in simple telephone circuits which require only a few contact units and few special circuit requirements. To meet this need, a second standard type known as the 600 type (or " minor " relay) is being developed as a miniature of the 3000 type although incorporating all or most of the maintenance advantages of its larger brother. It is intended that this standard minor relay shall be used for Manual exchanges and P.B.X.'s and also as subscribers' line and cut-off relays in automatic exchanges, while the 3000 type will be confined to the main equipment in automatic exchanges and to any other equipment having special circuit requirements.

The photographs which accompany this article have been supplied by the courtesy of the Automatic Electric Co., Ltd.

Routed Schematic Diagrams

J. READING, B.Sc.(Eng.), A.M.I.E.E.

PRIOR to the introduction of a standard relay, the five contractors (Messrs. Automatic Electric Co., Ltd., Ericsson Telephones, Ltd., General Electric Co., Ltd., Siemens Bros., Ltd., and Standard Telephones & Cables, Ltd.) concerned in the supply of equipment and installation of telephone exchanges, have supplied schematic and wiring diagrams of all the circuits installed.

The Department's A.T. and other circuit diagrams have been followed precisely as regards circuit function but in other respects each contractor has adopted the practice best suited to his own purpose. Contractors' diagrams have therefore shown certain differences which, although not of great moment to men employed continuously in one exchange, are very troublesome when men are called on to attend to equipment installed by different contractors. The very fact that the differences are so minor probably makes them more difficult to remember.

The variations in practice have been summarized for convenience in the following paragraphs :—

(1) *Relay and other resistances.* The resistances of the relays shown on the Department's diagrams have been regarded as a guide only, and the contractors, in designing the most suitable relay to give the desired circuit function, have often departed from the resistance value shown on the Department's diagrams. Other resistances in the same circuit as the relay have had to be of a correct value for the relay used, and hence were also different from the value shown on the Department's diagrams.

(2) *Circuits.* In recent years, differences have been of a minor character only, *e.g.,* the substitution of separate make and break contacts in place of a change-over.

(3) *Coil Tag Designation.* Relay coil tags were lettered a, b, c, d, and e, on the schematic and wiring diagrams, but different letters were used for corresponding tags by different contractors, while one contractor numbered tags.

(4) *Spring or Contact Unit Designation.* Some contractors numbered individual springs on the schematic and wiring diagrams, using different systems of numbering. Other contractors showed contact unit numbers on the schematic, and spring numbers on the wiring diagrams. The contact unit numbers were sometimes empirical, that is, they did not indicate where the springs could be found on the relay.

(5) *Lay-out of the circuit.* Each contractor produced drawings differing widely in the layout of the circuit schematic, rendering it difficult to recognize circuits as identical when prepared by different contractors.

(6) *Form of wiring diagrams.* Contractors' wiring diagrams being generally evolved for the purposes of shop wiring were not always in the most convenient form for maintenance purposes.

(7) *Filing space.* For each of the Department's diagrams, there were at least two equivalent diagrams (schematic and wiring) from each of five contractors. The filing space required thus became a serious matter. An elaborate recording system was also necessary so that the contractors' equivalent of the Department's drawings could be found readily.

(8) *Replacement of worn-out copies.* Drawings worn-out through constant use on maintenance, could only be replaced by purchase from the particular contractor.

Introduction of the Standard Telephone Relay.

Some advantage would have resulted from the coordination of the various practices, but so long as different relays were being used by each contractor, any change would have entailed high cost for the preparation of new drawings and would have had a serious disorganizing effect in the contractors' works. The latter effect is a very great obstacle, as staff who have used particular conventions for many years do not take kindly to changes employing other conventions for similar items, and additional supervision is necessary for some time to ensure that mistakes do not occur. Standardization would have been attained only in the appearance of the circuit diagrams but not on the Relay-sets. Concurrently, therefore, with the negotiations for the introduction of the standard telephone relay (3,000 type) the contractors were asked to investigate the possibility of unifying their practices as regards conventions and nomenclature. Symbols were also being dealt with at the same time by a Committee in the Engineer-in-Chief's Office which submitted proposals to the British Standards Institution.

Routed Schematic Diagrams.

Given a Standard relay, there is no reason why relay-sets supplied by all the contractors should not be identical as regards circuit design, but there remains the need for wiring the relay-sets in an identical manner. Several hundred diagrams are involved and the preparation of wiring diagrams by the Department is not an undertaking to be entered upon lightly. There is also the difficulty in ensuring that the diagrams are interpreted in an exactly similar manner at each contractor's works. A new type of diagram which shows schematically the routing of the wiring, has therefore been evolved with the co-operation of the contractors. On this " routed schematic diagram " :—

(*a*) The routing of a wire from a spring on one relay to a spring on another relay is defined by showing the numbering of the relay springs.

(*b*) Where three springs are concerned, *i.e.*, the wire is run from one spring to a second, where it is looped, and thence to a third where it is terminated, there are three possible routes, and the routing is defined by the symbol " L " to show the spring upon which the wire is looped.

(c) Where more than three springs are concerned, there will be several loops and the routing of the wire is defined by stating, in the correct order, the springs, tags, etc., on which the wire is looped.

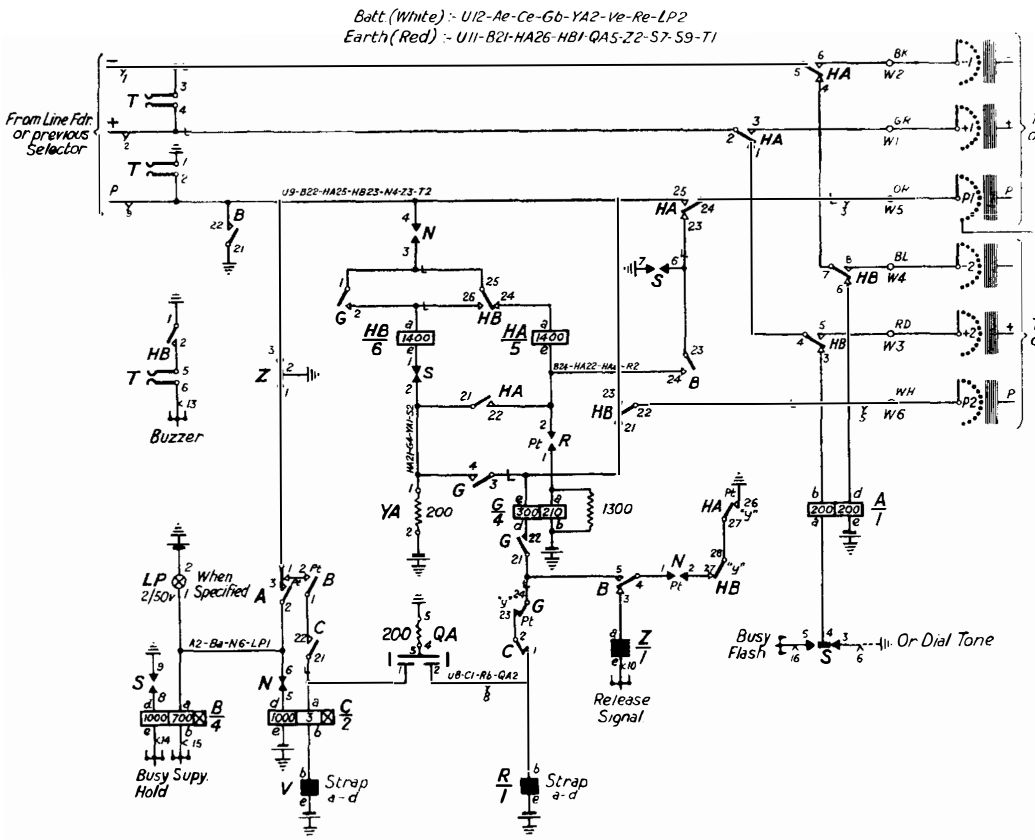
Thus a diagram results similar to the schematic in form, but carrying, in addition, wiring information. The diagram will be numbered in accordance with the Department's diagram with the addition of " W," *e.g.*, the routed schematic diagram corresponding to A.T. 1569 will be numbered ATW 1569. An example of such a diagram is shown.

(c) On receipt of a letter of approval, the contractor makes five true-to-scale photo tracings and forwards them, together with the original tracing, to the Engineer-in-Chief.

(d) The tracings are signed " Approved as standard," and the Department retains the original tracing and distributes a photo tracing to each contractor.

Thus each contractor has identical information for the wiring of any particular relay-set or selector, and from the Department's copy of the tracing, prints will be supplied to exchanges for maintenance purposes.

Consideration is being given to the application of the scheme to wiring diagrams of strip-mounted apparatus, shelf-jack wiring, and similar equipment,



ROUTED SCHEMATIC DIAGRAM FOR 200-OUTLET GROUP SELECTOR.

The contractors have arranged to modify their practices where necessary, and an agreed list of rules, conventions, nomenclature and symbols, incorporating B.S.I. Standards, has been drawn up and published as A.T.W. 2200.

The procedure adopted for the preparation of routed schematic diagrams is as follows :—

(a) The Contractors' Committee allot a particular circuit to one contractor, who

(b) Prepares the A.T.W. (T.L.W., or C.B.W., etc.) and sends a blue print for approval to the Engineer-in-Chief.

but for the time being, contractors will continue their individual practice.

The scheme represents a further step towards standardization, and has been made possible by the very complete co-operation of the contractors. Ultimately it will reduce the cost of contractors' drawings supplied to the Department. Maintenance conditions will also be rendered easier in that reference to involved wiring diagrams will not be necessary as complete wiring information is given without spoiling the simplicity of the schematic diagram.

Some Acoustical Aspects of Telephony[1]

E. G. RICHARDSON,
B.A., Ph.D., D.Sc.(Armstrong College, Newcastle-on-Tyne)

THE transmission of speech over a distance involves a number of problems both acoustical and electrical. Normally, there is but one medium (the air) between sender (the voice) and receiver (the ear), but in order to carry the energy to a distant receiver the engineer interposes a system consisting of a second transmission medium (the line) with transformers (microphones) at each end. Of the characteristics of the line in relation to its transmission of wave forms my readers are more competent to speak than I am, but it is with the acoustical characteristics of the two ends of the system that I wish to deal more particularly in this paper.

Dealing first with the receiving end, we may regard the ear as made up of two essential parts; a mechanical transformer and a series of tuned (mechanical) circuits. The ear drum, with its connexion of ossicles to the oval window debouching on the inner ear, is a step-up transformer by which the R.M.S. force on the ear drum is increased by sixty times at the entrance to the cochlea. The latter contains a series of tendons immeshed in a flexible membrane, which is itself surrounded by a liquid (*lymph*) so that the resonators thus formed are heavily loaded and damped. They are further graded in length and tension like the strings of a piano. This part of the ear, then, is the mechanical analogue of a series of tuned circuits of high resistance, connected in parallel across a pair of bus bars, each circuit having a bundle of nerves which, like an ammeter, registers the current in each circuit at the central switch-board or brain, the whole acting as a Fourier analyser of the complex wave-form which reaches the inner ear. One writes " inner ear " and not simply " ear " since the transformer in question is not distortionless, and the wave-form reaching the inner ear is not necessarily an exact copy of that in the air. The so-called " subjective combination tones " heard when two simple tones are loudly sounded are examples of such " iron-cored " characteristics; they are heard in the cochlea (" secondary ") even when their existence cannot be proved on the ear drum (" primary ") side.

The tuned circuits in the cochlea are not uniformly graded as to damping, with the further result that the sensitivity of the ear varies with pitch. It is at a maximum in the middle of the audible gamut, decreasing towards the bass and treble to a minimum at the audible pitch limits (about 16 and 40,000 vibrations per sec. respectively)—a fact of great importance to the telephone engineer. There is, however, an important psychological difference in the distortion of the bass or treble region of transmitted sound. If the apparatus is such as to reduce the relative intensity of the lower notes, it has been shown that, within limits, the effect on music is relatively unimportant; a trumpet sounding C still sounds like a trumpet sounding C even when this particular fundamental note has been removed, *e.g.*, by a filter. Incidentally this fact has been used to whitewash the consciences of gramophone companies who were not able, until recently, to record the bass adequately. In speech, however, it is usually found that the upper partials are less important from the point of view of intelligibility. Further, as we shall see later, the pitch range of ordinary speech is less than that in song or in instrumental music. There is one further limitation which the ear imposes; if the intensity becomes too great there is a loss of intelligibility, and at very great intensities temporary deafness may result.

Turning now to the sending end, we find in the organs of speech a system which can be imitated by electrical components in a simpler fashion than the aural organ. The cavities of the mouth, throat, nose, etc., form a series of resonators which can be tuned by the movement of the muscles controlling the lips, tongue and throat through a moderate range of frequency. They are excited by the vocal cords, which are themselves set in vibration by the expired breath passing through the narrow aperture formed when they are brought close together. These cords may themselves be tuned over a range of about two octaves (in singing) by alterations in their tension and in the width of the aperture, but the unmodulated note so produced is rough and raucous; it requires the mollifying modification of the air cavities through which the sound must pass before leaving the mouth. These facts we know from observation of dissected larynxes of baboons and other mammals, or by looking into the throat through a laryngoscope in combination with a stroboscope which exhibits the vocal cords in slow motion. In normal speech each person produces a preferred vocal-cord note which is nearly constant in pitch, except in declamation or in moments of emotional stress. In its general behaviour, the voice may be likened to the modern French horn in which the player's lips take the place of the vocal cords, and the tube of variable length may be likened to the mouth cavity.

The electrical analogue of the voice is shown in Fig. 1. The buzzer actuates two tuned circuits corresponding roughly to the back and front vocal cavities and the resultant wave-form is passed on to the telephone. In this way Stewart was able to imitate the action of the mouth-setting in producing a vowel. Phoneticians have discovered the existence of these two principal resonances, which characterize the various vowel sounds of speech. In the coupled system—vocal cords plus air cavities—the latter will emphasize those component tones in the buzzer note proper to themselves. Hence arise the characteristic features of the vowels. These pairs of resonances are shown in Fig. 2. The vowel a (as in father) in the centre is one of the simplest types, being formed by holding the mouth wide open, so that the two resonances are almost merged into one.

[1] A lecture delivered before the Northern Centre of the I.P.O.E.E. on January 17th, 1934.

At the extremes we have the characteristic " back vowel " u : (= *oo* in tool) with low-pitched resonances, and the front vowel i : (= *ee* in seen) with one high- and one low-pitched resonance. Naturally, these resonances cannot be regarded as invariable;

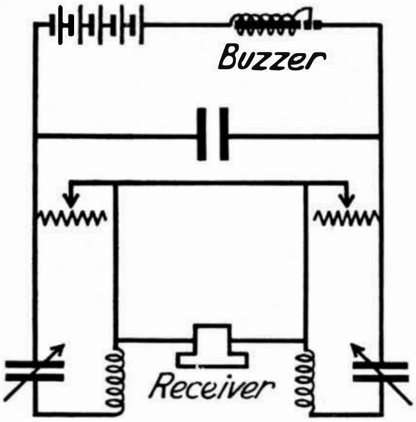


FIG. 1.—ELECTRICAL ANALOGUE OF VOICE.

they will vary as between individual speakers, particularly as between persons of different counties, hence the distinctive dialect sounds. Some of the consonants are mere starting and stopping noises, like the initial scraping of an unskilled performer on the violin, while others, the so-called voiced consonants, partake of the nature of vowels, usually with multiple resonances. Of these, the *s* probably causes most trouble in telephony, as it is likely to find out one of the high-pitched natural resonances of the transmitter diaphragm.

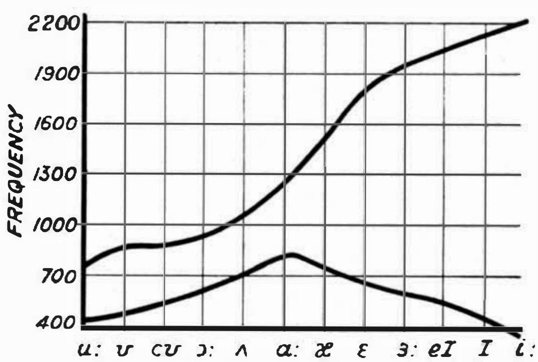


FIG. 2.—VOWEL RESONANCES.

As all these features must be transmitted with as little distortion as possible, a study of the waveforms of the vowels and consonants, before and after transmission, is of great importance to the telephone engineer. In the early days of telephony gramophone records were made and magnified for the purpose of this study. Not everyone knows that the original " phonautograph " of Scott was used to record sound traces merely. It was Edison who discovered that the sound could be reproduced from the trace in the wax, and realized the commercial possibilities of his discovery.

The apparatus which is being used at Armstrong College by two colleagues from the English department—Messrs. Orton and Curry—and myself for the above purpose is shown assembled in Fig. 3. It consists essentially of a distortion-free microphone, a condenser microphone, and a cathode-ray oscillo-

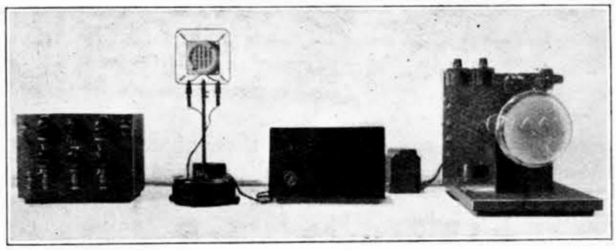


FIG. 3.—OSCILLOGRAPH RECORDER.

graph. The electron beam in the latter normally appears as a spot on a fluorescent screen. But if the e.m.f. from the microphone after amplification is put across the beam, the spot is drawn out to a vertical line whose oscillatory nature is manifest if it is photographed in a camera having a film moving at right angles to the line in question. This, in fact, gives a wave trace of the sound reaching the microphone. For visual demonstration or for showing the characteristics of a continued vowel, a " sweep circuit " can be set up to cause the electron beam to pass slowly from left to right and jump rapidly back again. This is effected by the periodic charge and discharge of a condenser connected to a pair of electrodes at right angles to the pair connected to the microphone. In this way, records of the vowels such as those shown in Fig. 4 can be obtained. We see the two back vowels at the top of the figure with their low-pitched resonances. The middle vowels at the bottom show a faster vibration having less regularity of amplitude, while the front vowels in the centre exhibit still higher fundamentals. Owing to irregularities in the vocal cords, there are imposed on the

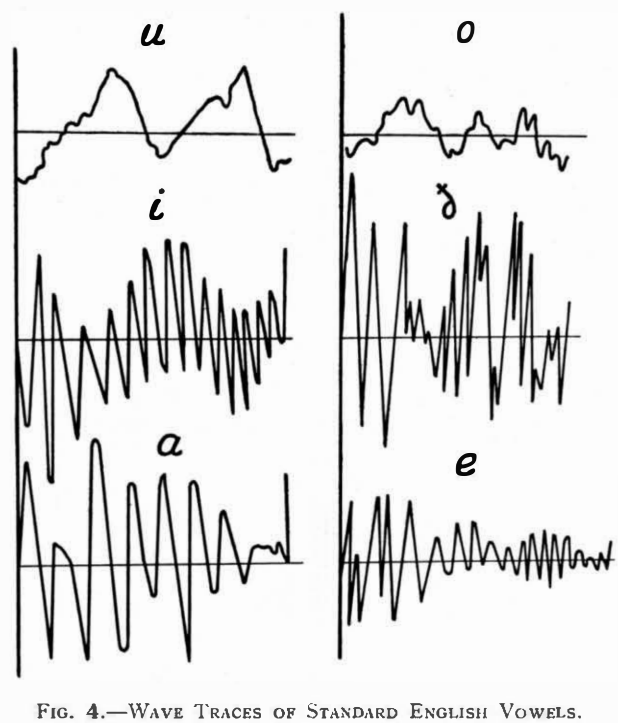


FIG. 4.—WAVE TRACES OF STANDARD ENGLISH VOWELS.

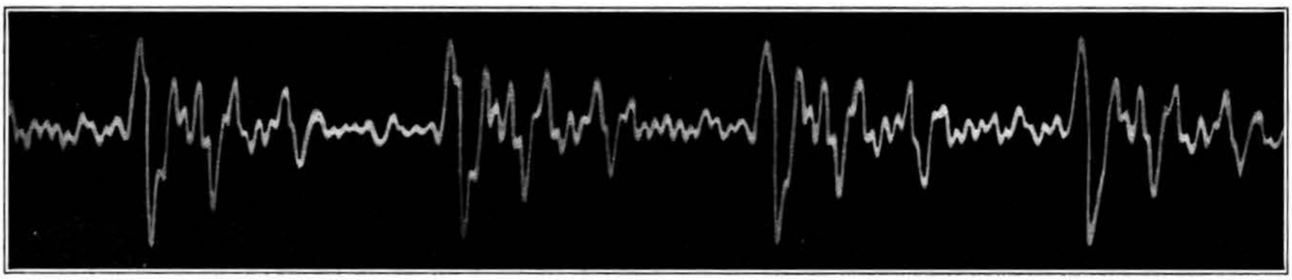
wave-form proper to a vowel, highly damped vibrations which, however, are not exactly periodic. The buzzer in the electric circuit of Fig. 1 produces a similar effect on the wave-form of the current through the telephone. The waverings produced by these damped components can be seen on the tracings, particularly the upper pair in Fig. **4**. The persistent and considerable amplitude of these inharmonic overtones are the most likely cause of hoarseness or a raucous voice; their absence or rapid attenuation characterize a pleasant voice.

It should be noted, then, that the wave-form of a vowel is not constant like that of the tuning fork. As Scripture has pointed out, there are small variations from period to period, ascribed to the damping down by the mouth of " unwanted " high-pitch components from the vocal cords. These will be characteristic of the speaker's larynx, and are of less importance in recognizing the vowel as such, though they probably assist in enabling us to recognize the voice of an individual. The fact that on many telephone systems these components are lost in transmission explains why the speaker's voice appears to be disguised, though we can often hear plainly what is said over the 'phone.

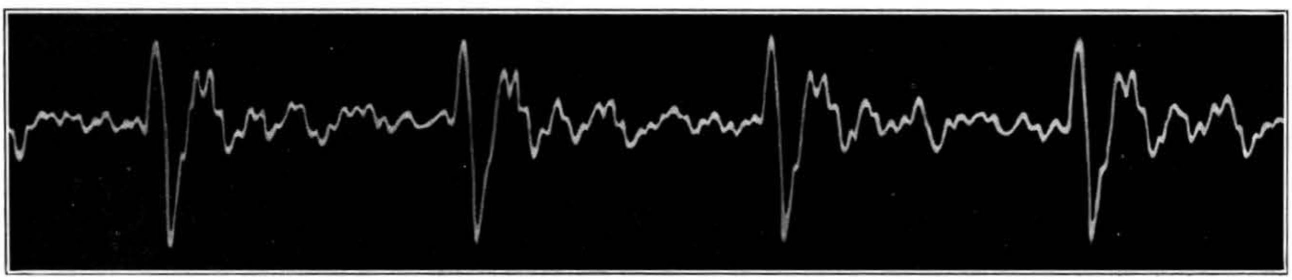
Besides a knowledge of the pitch of the components in speech, it is also useful to have an idea of the intensities involved. We have not actually measured these up to the present in our research work, but data are available from the work of L. J. Sivian of the Bell Telephone Co. of America. He has found that the average pressure on a diaphragm 2 in. from the lips is 5 dynes per sq. cm.

The energy of the voice decreases rapidly above 1000 cycles per sec. It is fortunate that the average energy of disturbing noises which may leak into a telephone cabinet falls off with rising pitch in the same fashion. The output of a person speaking at a normal rate in conversational tone was found to be equivalent to 10 microwatts. This is small compared to some musical instruments, *e.g.*, a bass drum struck *ff* 8 times a second is equivalent to an output of 25 watts.

Apart from distortion, which may be introduced by the microphones and line, there is a possibility of the wave-form being altered between the speaker and the transmitter or between receiver and listener owing to the addition of echoes and external noise. This is, of course, the reason for the provision of telephone kiosks or cabinets, which can obviate both kinds of distortion if suitably built. The distortion due to echoes is that which arises when the speaker is in an empty room with hard walls. The reverberation which results causes copies of the wave-form to be imposed on it, but with a time lag behind the original. It is essentially a phase distortion. This would not matter as far as single vowels are concerned, for it has been proved by many experiments that the ear is cognisant of the number only and relative magnitude of the components of a complex tone which falls upon it. Though capable of doing this Fourier analysis, it apparently has no apparatus which can measure phase differences. When dealing with a succession of syllables, however, the case is altered, for the echoes cause serious overlap in the wave traces of successive syllables, making hearing difficult. This question, then, is essentially one of intelligibility, and can be solved by enclosing the transmitting instrument in a booth, the walls of which are covered with sound-absorbing material, thus reducing the echo to a minimum. To show what a large change in the wave trace may result from such effects, I reproduce two records of the same spoken syllable, one taken with a microphone enclosed in walls absorbing 70% of the sound incident upon them (our usual practice) and the other with the same person speaking into a large tin trumpet with the microphone at the distant end (Fig. 5). Besides showing echo distortion, this shows also the type of distortion we have already discussed,



Vowel a: before transmission.



Vowel a: after transmission.

FIG. 5.—TRANSMISSION SYSTEM PRODUCING DISTORTION.

i.e., that in certain conditions components are over-emphasized owing to resonances in the surroundings. The damping introduced by the horn has rounded off the tops of the peaks, as well as exaggerated certain components in the wave-trace. As one would imagine from comparing these wave-forms, the sound which after transmission had acquired the characteristics of the second form would be difficult to recognize as the spoken vowel of the first record.

It is, of course, of prime importance in telephony that extraneous noises should not be allowed to filter into the transmitter. It is a fact of everyday knowledge that in a noisy office or works one has to shout into the telephone to make oneself heard, thus adding the confusion of an overloaded diaphragm to the surrounding cacophony. In such a case the speech is said to be masked by the extraneous noise, and the extent of this masking at different (average) frequencies is an effect which needs to be determined by experiment. It is often referred to as the "signal/noise ratio." It is the intensity relative to the minimum audible intensity at that pitch which is of importance. The logarithm to base 10 of this ratio gives the loudness reckoned in *bels*; the *decibel* (db) is a unit more often used and is one tenth of a *bel*. The following table (after Fletcher) shows by how much the intensity of speech must be raised above its normal minimum audibility to be just audible above the surrounding noise :—

Locality.	*Masking effect.*
Soundproof cabinet	0 db.
Country estate	10 ,,
Average office	30 ,,
Noisy shop	40 ,,
Railway train or city street ...	50 ,,
Underground railway	60 ,,
Boiler factory	80 ,,

It is evident from this table that a soundproof telephone cabinet is worth while at all sites except a country lane, and during the past few years many proprietary materials have been put on the market for absorbing and insulating sound, which can be used in such constructions.

A simple test of an absorbent specimen may be made by putting a movable plug of the material in a brass tube and bringing a tuning fork near one end (Fig. 6). As the length of the tube to the stop is altered a region will be found for which a certain amount of resonance is obtained. With a hard rigid stop, the resonance will be sharp—(cf. continuous line in diagram)—but with a stop which absorbs and/or transmits some of the sound, the resonance will be less and broader, in the sense that nearly equal response will be experienced for frequencies on either side of resonance (cf. dotted line in diagram). The absorbent properties of the substance can be calculated from such data. Apart from this, the experiment has important applications in connexion with the "smothered" resonances which are a feature of absorbent-lined cabinets, or, what comes to the same thing on a smaller scale, the mouth. It is because the mouth is lined with soft flesh that it is more flexible than the French horn to which we likened it. In the latter instrument the resonances are more marked and much sharper.

The characteristics of a specimen of absorbent stuff may be examined on a large scale by making a partition of it between two rooms as shown in the photograph of the interior of the acoustic laboratory attached to the Washington Chemical Co.'s works, Co. Durham (Fig. 7). The sound from the loudspeaker falling on the panel is partly reflected on to the microphone seen in the photograph, and is partly transmitted on to a similar one in the room behind.

Much can be done in sound insulating by the use of a discontinuous structure, by which is meant the provision of a number of strata of different materials between the outside and inside of a building, or in the partition wall. On every occasion that a sound wave reaches a boundary where there is a sudden change of physical properties, some of it is reflected.

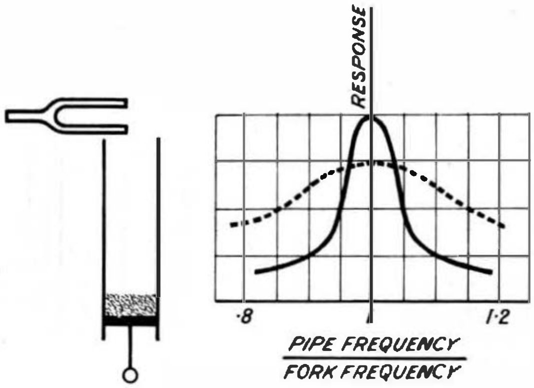


Fig. 6.—Effect of Absorbent Material on Resonance.

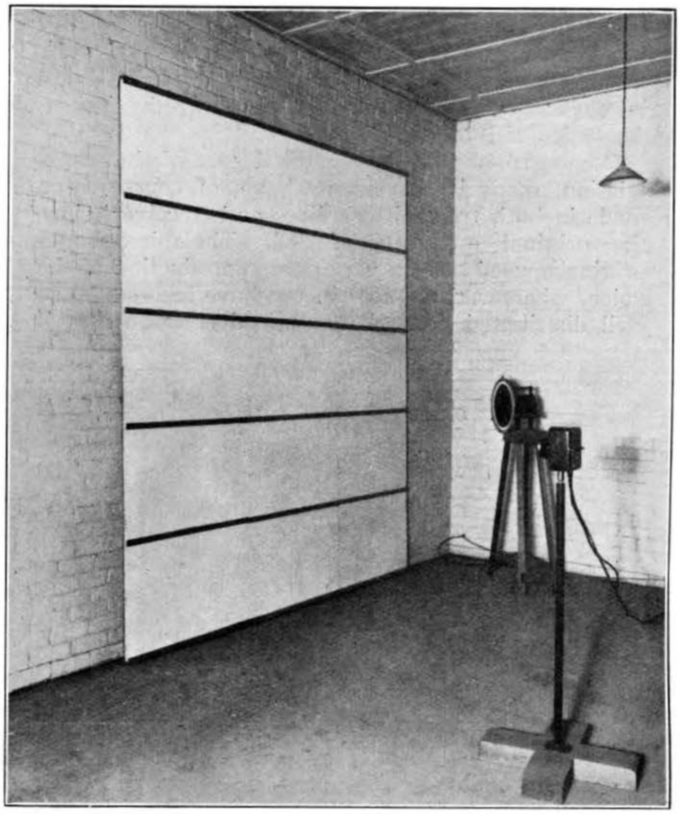


Fig. 7.—Acoustical Laboratory.

The greater is this change, the more is reflected. That is why hard substances are such good reflectors of air-borne sound, and why sound is so readily reflected by the surface of a lake. The efficiency of double walls and double windows in insulating sound is due to the double change from air to wood and back again to air, which the sound has to experience in passing through them. Care should be taken that the solid sections are not bolted together by many bolts passing completely through them from side to side, as this will tend to destroy the discontinuity of the structure. It is better to bolt slab A to slab B, slab B to slab C, etc.

Every elaborate sound-proofing system requires hermetically sealed windows to make it a success. Everyone must have noticed that the slight opening of a window over a busy city street lets in a great deal of noise. This is where the designer of an adequately ventilated sound-proof cabinet finds himself in a quandary. Practicable double windows may however be erected, in which the air enters the interspace at the bottom, through a sieve of sound absorbing material. It comes into the room through a similar arrangement at the top of the inner window.

A sealed air space is an excellent insulator to sound. Care has to be taken, however, to prevent " drumming " due to resonance of the air cavity to notes of a definite, but usually low, pitch. To prevent this, straw-like materials should be packed loosely into the space, *e.g.*, between double-panelled doors, or between a brick wall and its wood panelling, not for the sake of improving its insulation, which it does not, but to break up the large air spaces into smaller ones. Sometimes an air space between the ground floor and the main foundation below may cause resonance to each foot-fall. Stuffing the air space with sawdust will remedy this. Further information on these questions will be found in the author's text-book, " An Introduction to Acoustics of Buildings."

Coming finally to the electrical part of the transmission, many improvements have, of course, been made in both transmitter, line and receiver since the original apparatus of Bell. The microphones originally used gave a very poor reproduction of the voice, whereas those now in use have resonances so well distributed through the effective range that it is only in the extreme bass and treble that the response falls away, or is exaggerated. As a matter of interest, I reproduce a photograph of some early instruments now in the possession of the Physics Department, Armstrong College, which were left by Mr. A. W. Heaviside (brother of the more famous Oliver) who was engineer to the old telegraph and telephone company in this district (Newcastle). The two instruments on the left (Fig. 8) bridge the era between the discovery of the electric telegraph and the telephone. They were attempts to make possible the direct sending of letters (one at a time) by the telegraph in place of the Morse signals and were invented by Wheatstone about 1840. On the right is an old carbon rod type of transmitter with cover open.

In the early days of submarine cables it was found that the capacity to earth attenuated the higher pitched components, a defect which was overcome by loading the line with inductance. If the loading is overdone the line tends, on the contrary, to be on the average high in pitch. An aerial cable is less liable to such distortion, although as the impedance per unit length is proportional to the frequency, the attenuation of the signal tends to be greater as the frequency goes up. This may be offset by a transmitter or receiver whose mechanical impedance is less to the upper range of notes, *i.e.*, one which has more resonance in the treble than in the bass. In measuring the impedance of the receiver we must remember that it is coupled through a short air column to the ear, and the measurement should be made with the instrument attached to a real or artificial ear.

Finally the whole system must be tested to see that it is sufficiently free from distortion and has a sufficiently high signal/noise ratio to make transmission intelligible. Either series of meaningless syllables may be used (articulation test) or a series of simple phrases (intelligibility test). The former is, of course, the more arduous test for a telephone system to fulfill.

And there I must leave this fascinating subject, with the hope that I may have succeeded in showing that there is something more in telephony than mere application of electrical principles and that telephone engineers will find the science of applied acoustics a profitable study.

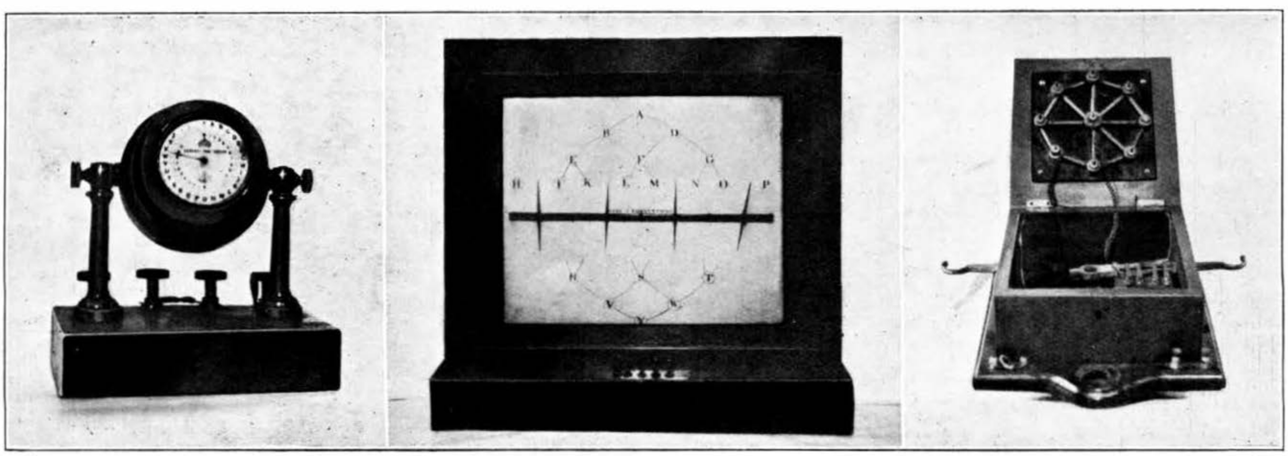


Fig. 8.—Some Early Instruments.

Telephone Transmission Problems

II.—Elementary Theory of Transmission

R. M. CHAMNEY,
B.Sc., A.K.C., Assoc. M.I.C.E.

THERE is one great danger which should be avoided by those who wish to make a complete study of the subject. The use of elementary higher mathematics is in this case essential. Any attempt to do without this valuable aid increases the difficulty of comprehending the subject, and decreases the clarity. Trigonometry is not merely an additional subject to be learned by the student, but a shorthand for expressing geometrical facts and analysing their results. The differential and integral calculus is a shorthand to avoid enormously lengthy and complicated operations in algebra. A sufficient knowledge of these two subjects could be obtained without much difficulty, and this knowledge is vital for the whole subject of transmission if it is to be fully understood.

Most readers are somewhat overawed by the mathematical treatment given in standard works on transmission, but it is, however, unnecessary to go into the subject in mathematical detail in order to understand the broad principles involved.

The most difficult physical conception in telephone transmission would appear to be the fact that the power transmitted along a line decreases logarithmically as the length of line increases. Firstly, let us consider an ordinary circuit which may be set up in a laboratory, such as a Wheatstone Bridge. Simple calculations enable the student to ascertain the value of current passing in each portion of the circuit. The wires used to connect the pieces of apparatus are assumed to have no influence either in diminution of the current values due to resistance, or leakage of the current into an undesired part of the circuit or to earth. Let us now assume that a test is being made of the current from a battery through a resistance and a telephone relay. In the laboratory, it is still quite safe to assume that the resistance of the connecting wires and their insulation do not influence the amount of current passing through the relay. Next, assume that the leads connecting the apparatus are extended by a line of a length relatively great to the original connecting leads. The resistance of the connecting lines now begins to have an effect on the current passing through the relay. Suppose further that these leads are replaced by a line several miles in length and formed of conductors on a pole route. The resistance of this line can be calculated readily from a knowledge of the gauge of the conductors. It will be found if tests are made from time to time that, although allowances may be made for the effect of temperature, small variations of current through the relay will be noticeable. These variations are due to the fact that under certain conditions there is sufficient leakage of current to reduce the amount available for the operation of the relay. We have thus established the fact that a line used for the transmission of direct current energy has two attributes which must be taken into account—the resistance and the leakage. These two factors are termed the Primary constants of the transmission line for the direct current or, as it is sometimes called, the steady current state.

A line may always be considered as being made up of a number of small unit sections provided the length of the section is not too great. In practice a 20 lb. cable could be considered in one mile units without introducing errors of any magnitude.

Fig. 1 shows a network of resistances to imitate sections of an actual transmission line. The line resistance is split into four parts, the leakage resistance being thus disposed symetrically. The total

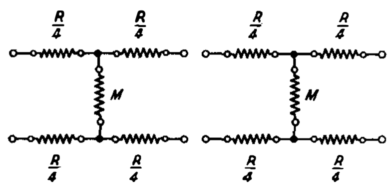


FIG. 1.

line resistance per section is R, therefore each arm is $\frac{R}{4}$. The leakage resistance is M and the leakance, which is the reciprocal, is thus $\frac{1}{M}$.

Consider the case where R = 100 ohms and M = 10,000 ohms. This is not representative closely of any exact line, but these figures are taken so that conclusions may be drawn without too much laborious calculation. The leakance is

$$\frac{1}{M} = 10^{-4} \text{ mhos.} = G.$$

Resistance of lines.

If the single section be " open " at its far or " receiving " end, it will have a resistance of 25 + 10,000 + 25 = 10,050 ohms.

If the far end be " closed " (short-circuited), the resistance will then be 50 ohms in series with two resistances, 10,000 and 50 ohms, in parallel. To the nearest three significant figures, the answer is 100 ohms.

Now consider two sections with the end of the second section open. We have firstly 50 ohms in series with 10,000 ohms which is paralleled with 50 ohms and which is in turn in series with a single section open at the end. If the open resistance be denoted by R_f and an additional suffix be used to identify the number of sections involved, we have

$$R_{f_2} = \frac{R}{2} + \frac{M \times \left(R_{f_1} + \frac{R}{2}\right)}{M + R_{f_1} + \frac{R}{2}}$$

$$= 5100$$

Reasoning on exactly the same method produces a similar formula for the conditions for two sections with the far end closed.

$$\text{or} \qquad R_{c_2} = \frac{R}{2} + \frac{M \times \left(R_{c_1} + \frac{R}{2}\right)}{M + R_{c_1} + \frac{R}{2}}$$

$= 198$ ohms.

The student can thus proceed to evaluate the open and closed resistances for any desired number of sections. Table 1 has been drawn up showing the resistances calculated for sixteen sections.

TABLE I.

Section.	Resistance with far end closed.	Resistance with far end open.
1	100 ohms	10050 ohms
2	198 ,,	5100 ,,
3	292 ,,	3450 ,,
4	380 ,,	2640 ,,
5	462 ,,	2170 ,,
6	537 ,,	1870 ,,
7	605 ,,	1660 ,,
8	665 ,,	1500 ,,
9	717 ,,	1400 ,,
10	762 ,,	1310 ,,
11	800 ,,	1250 ,,
12	833 ,,	1200 ,,
13	862 ,,	1160 ,,
14	885 ,,	1130 ,,
15	905 ,,	1105 ,,
16	920 ,,	1085 ,,

The figures given are only accurate to the first three significant figures in order to increase the clarity of the results.

It will be noticed that columns two and three are apparently approaching the same figure. In Fig. **2** the figures have been plotted in graphical form which shows the results more clearly. If a sufficient number of sections be taken the difference between the open and closed resistances can be reduced to a very small value, whilst at infinity the answer will be 1000 ohms for this line, whatever the terminal condition.

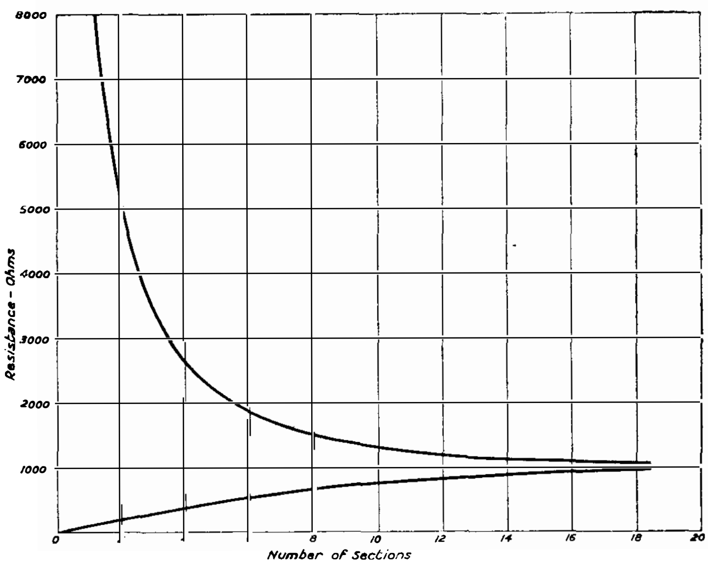


FIG. 2.

There is therefore a resistance for every infinite homogeneous line which will be the same whatever the condition of the far end of the line, *i.e.,* open or closed in any manner, and this resistance depends on the two factors, resistance and leakance. This resistance is called the " characteristic resistance " (R_0).

From the graph (Fig. **2**) it appears possible to find some sort of mean between open and closed resistances which would give the characteristic resistance by a simple calculation. An arithmetic mean might serve at the 16th section, but would clearly be far from true at the 1st section. A geometric mean will be a more probable answer.

The geometric mean will be $\sqrt{R_c R_f} = R_0$, and this will also be found to be equal to $\sqrt{\frac{R}{G}}$

for $R_0 = \sqrt{\frac{100}{10^{-4}}} = \sqrt{100} \times 10^4 = 1000.$

Calculations made from the figures given in Table I for the open and closed resistances will show that the geometric mean gives in every case the answer of 1000 ohms.

The statements made above show a method of proving the resistance formulæ experimentally. The theoretical proof can be found in J. G. Hill's " Telephone Transmission."

The results just obtained can be explained physically as follows. When the far end of a transmission line is open there exists at that end a pressure, but no flow of current. The pressure down the line being relatively high the effect of leakage is relatively great.

When the far end is closed there is no pressure at that end, but a considerable current. The line resistance losses are greater and the pressure down the line smaller than in the open case and the leakage loss correspondingly smaller.

In the case of a line of very great length these two effects balance to the extent that the apparent resistance as viewed from the sending end is the same under all conditions of the far end. If the line be considered as extended to infinity this condition is absolutely true.

Attenuation along lines.

In order to get a correct picture of the amount by which voltage, current and power are attenuated in their course down a transmission line it is essential to consider a homogeneous line of very great length so that no extraneous effects, such as a discontinuity or change of primary constants give rise to abnormal pressures or currents. It is desired only to know the behaviour of the line under consideration.

Take the same line as before and consider the first section. The remainder of the line can be replaced by a resistance of 1000 ohms which gives the equivalent of an infinite line.

Assume a battery to be applied to the line and this battery to have a pressure of 10 volts.

The line, being in effect infinite by assumption, has an apparent resistance of 1000 ohms and thus 10 mA flow through the first 25 ohms in either leg.

The resistance omitting the two 25 ohms on the left of the leakage path is 950 ohms (1000 − 50) and the pressure is $10 - 50 \times .01 = 9.5$ volts.

This current splits between the leakage path and the rest of the line in the ratio.

$$\frac{1050}{11050} \times 9.5 \text{ mA through the leakage path.}$$

and $$\frac{10000}{11050} \times 9.5 \text{ mA}$$

$$= 9.05 \text{ mA into the second section.}$$

Now consider the second section in the same way. The current through the first half line resistances is now 9.05 mA, thus dropping the voltage across the second section leakage path to 8.6 volts.

The current into the third section is thus

$$\frac{10000}{11050} \times 8.6 \text{ mA} = 8.2 \text{ mA}.$$

The same reasoning can be followed to evaluate the current in the remaining sections and Table II shows the results which will be obtained.

TABLE II.

Section.	Volts across following section.	Current into following section.
1	9.05 volts	9.05 mA
2	8.2 ,,	8.2 ,,
3	7.4 ,,	7.4 ,,
4	6.7 ,,	6.7 ,,
5	6.1 ,,	6.1 ,,
6	5.5 ,,	5.5 ,,
7	5.0 ,,	5.0 ,,
8	4.5 ,,	4.5 ,,
9	4.0 ,,	4.0 ,,
10	3.7 ,,	3.7 ,,
11	3.3 ,,	3.3 ,,
12	3.0 ,,	3.0 ,,
13	2.7 ,,	2.7 ,,
14	2.4 ,,	2.4 ,,
15	2.2 ,,	2.2 ,,
16	2.0 ,,	2.0 ,,

The similarity between the voltage and current figures is due to the characteristic resistance of the line being 1000 ohms.

The figures have been plotted in Fig. **3** and show that the attenuation is not a straight-line law. The curve is gradually getting flatter and flatter and will eventually become almost merged in the zero line. The current will not become actually zero until infinity is reached.

The physical effect may be shown in this way. In the first section the line resistance loss is relatively large and a small loss is brought about by the leakage. In the second section, owing to the leakage in the first section, a smaller amount of current loss in line resistance takes place and a smaller pressure is available to dissipate energy in leakage.

In the reverse direction, as we approach the sending end from the far end, the energy absorbed in each section must be added to the amount passed by the section in front. This is the familiar law of Compound Interest where, by adding the interest to the capital, a greater amount of interest is paid during the next period.

By taking a case such as £100 at, say, 5% Compound Interest per annum and finding the amount of principal for each year, a graph can be drawn which shows the same type of curve as that in Fig. **3**.

This type of curve is known as a logarithmic curve and can be obtained also by plotting slide rule readings against a linear scale.

It should be noticed that the amount of attenuation is equal for each section of line, that is to say, the ratio of current into and current out of each section is a constant. The current does not drop by the same amount arithmetically in each section.

This may be expressed in another way.

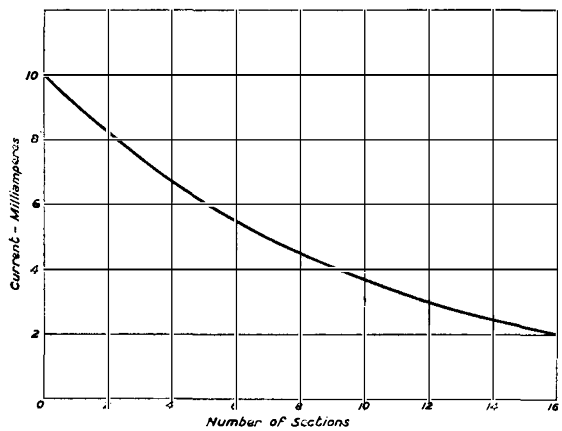


FIG. 3.

Take a length of line such that the current has dropped to half its original amount. This will occur approximately after seven sections. After 14 sections, the current will be half that at the seventh section. In Table II, owing to the omission of the second decimal place, the exact value of current is not disclosed, and thus exact comparison cannot be made. After 21 sections, the current will be half that at the 14th section and so on.

This can also be expressed algebraically. The current at a certain distance from the sending end has been attenuated to half its original value. At equal distances the current will be as follows :—

1	$\frac{1}{2}$
2	$\frac{1}{4} = \frac{1}{2 \times 2}$
3	$\frac{1}{8} = \frac{1}{2 \times 2 \times 2}$
4	$\frac{1}{16} = \frac{1}{2 \times 2 \times 2 \times 2}$
n	$\frac{1}{2^n}$

There must clearly be a relation between the degree of attenuation of current and the values of the primary constants of the line.

If now we take the value of $\sqrt{\frac{R_c}{R_f}}$ for any number of sections of the line and call the result h. It can be proved that $\frac{1+h}{1-h}$ is equal to the natural logarithm of $2\beta l$ where l is the length of the line (or number of unit sections) and β is a constant known as the "attenuation constant." The natural logarithm is found by multiplying the logarithm to base 10 by 2.3025.

This formula is usually written $\frac{1+h}{1-h} = e^{-2\beta l}$

e being the base of natural logarithms and the negative sign indicating a decrease of power as the length of line increases. Table III gives the results worked out from Table I. The results are necessarily approximate.

TABLE III.

Section.	R_c	R_f	$\sqrt{\frac{R_c}{R_f}}$	$\frac{1+h}{1-h}$	$2\beta l$	β	$I_S e^{-\beta l}$
1	100	10050	0.1	1.22	0.2	0.1	9.05
2	198	5100	0.197	1.49	0.4	0.1	8.2
3	292	3450	0.292	1.82	0.6	0.1	7.4
4	380	2640	0.38	2.22	0.8	0.1	6.7
5	462	2170	0.46	2.71	1.0	0.1	6.1
6	537	1870	0.538	3.33	1.2	0.1	5.5
7	605	1660	0.602	4.02	1.4	0.1	5.0
8	665	1500	0.662	4.92	1.6	0.1	4.5
9	717	1400	0.714	6.00	1.8	0.1	4.1
10	762	1310	0.763	7.44	2.0	0.1	3.7
11	800	1250	0.800	9.0	2.2	0.1	3.3
12	833	1200	0.835	11.12	2.4	0.1	3.0
13	862	1160	0.862	13.5	2.6	0.1	2.7
14	885	1130	0.876	15.12	2.8	0.1	2.4
15	905	1105	0.900	19.0	3.0	0.1	2.2
16	935	1085	0.935	23.4	3.2	0.1	2.0

In this table since the primary constants have been taken per section, l is the number of sections involved.

Now, $\sqrt{R \times G} = \sqrt{100 \times 10^{-4}} = 0.1$

or given any line constants the direct current attenuation constant is $\sqrt{RG}$.

The attenuation constant is used, when multiplied by the length of the circuit, to describe its transmission efficiency and the unit is called a "néper."

Ten sections of the line have $\beta l = 10 \times 0.1 = 1$ néper

The relation between the current sent into the line (I_S) and the current received (I_R) is

$$I_R = I_S e^{-\beta l}$$

In Table III these figures have been calculated and will be found to agree with the figures worked out in Table II.

The néper is the International unit of attenuation and is in practical every day use all over Europe as well as in this country for International work.

There is, however, another unit used for internal work in this country—the decibel. This unit is based on the common instead of the natural logarithm, and is thus empirical rather than fundamental. The decibel is the logarithm to base 10 of the ratio of voltages, currents or powers at different points of the line multiplied by a constant.

$$\text{One decibel} = 20 \log \frac{V_1}{V_2} \text{ or } 20 \log \frac{I_1}{I_2}$$

$$\text{or } 10 \log \frac{P_1}{P_2}$$

To obtain the number of decibels for a line multiply népers by 8.686.

This figure can be verified approximately from the results given in Tables II and III. The current entering the line is 10 mA. After sixteen sections this has dropped to 2.0 mA approximately.

The loss over this length in decibels is thus

$$20 \log \frac{10}{2} = 20 \log 5$$

$$= 13.9 \text{ db.}$$

Hence 1.6 népers = 13.9 db.

or 1 néper = 8.7 to the first place of decimals.

We have now established two derived constants for a D.C. transmission line—the Characteristic Resistance and the Attenuation constant. These are called the Secondary Constants of the line.

It has been demonstrated above, experimentally, that the secondary constants can be found at once when the primary constants are known, *i.e.*,

$$R_0 = \sqrt{\frac{R}{G}} \text{ and } \beta = \sqrt{RG}$$

It now remains to show how the primary constants can be obtained from line measurements.

Tests were made on an overhead 100-lb. copper line 50 miles long and the following results were obtained.

With the far end closed, that is to say a "conductivity" test, the resistance was found to be 815 ohms. An " insulation " test taken with the same Wheatstone bridge gave a resistance between the A and B wires of 4280 ohms.

At first sight the line resistance would appear to be 16.3 ohms per mile and the insulation 214,000 ohms per mile. The resistance of a line of 100 lb. copper is known to be 17.6 ohms per mile and hence it is necessary to ascertain the reason for the error.

From the formulæ already developed it is known that

$$R_0 = \sqrt{R_f R_c} \text{ and } h = \sqrt{\frac{R_c}{R_f}}$$

$$R_0 = \sqrt{4280 \times 815} = 1872 \text{ ohms.}$$

$$h = \sqrt{\frac{815}{4280}} = 0.436$$

$$\therefore \frac{1+h}{1-h} = 2.55 = e^{-2\beta l}$$

$$\text{Now} \quad 2\beta l = \log_e 2.55$$

$$= 2.3025 \times \log_{10} 2.55$$

$$= 0.938$$

$$\text{since} \quad l = 50 \text{ miles.}$$

$$\beta = 0.00938$$

$$R_0 = \frac{\sqrt{R}}{\sqrt{G}} \text{ and } \beta = \sqrt{R} \times \sqrt{G}.$$

$$\therefore R_0 \times \beta = R = 1872 \times 0.00938 = 17.6 \text{ ohms.}$$

$$\text{also } \frac{\beta}{R_0} = \sqrt{R} \times \sqrt{G} \times \frac{\sqrt{G}}{\sqrt{R}}$$

$$= G$$

$$\therefore \quad G = \frac{0.00938}{1872} = 0.000005$$

$$= 5 \times 10^{-5}$$

Therefore the insulation resistance = 200,000 ohms.

The effect of leakage on a line is thus to give an apparent diminution of line resistance and a gain in insulation resistance unless the true values are calculated as shown. In general the greater the leakage the further are the test results from the true values of conductivity and insulation.

In concluding this section, the author wishes to emphasize again that the formulæ given have been demonstrated experimentally as true in the cases considered, but not proved by rigid mathematical methods. The student is referred to standard test books for further knowlege.

The effect of capacity has been omitted purposely since this effect only concerns the period before a steady D.C. condition obtains. Rapid variations of direct currents as in telegraphy are truly a special section of the A.C. case.

Note on the Mutual Impedance between Power and Telephone Lines

H. J. JOSEPHS

RECENT work on the interference problem has shown that most cases of interference between power and telephone lines can apparently be traced either to earth fault currents, or to harmonics produced in the power line: the former may induce dangerous voltages, and the latter may cause noise in the telephone circuit. Both effects are closely connected with earth currents; and they may be approximately determined from the Carson-Pollaczek formulæ, if the so-called " mutual impedance " between the two lines is known. Thus the calculation of the mutual impedance under a given set of conditions is therefore of considerable importance.

The Carson-Pollaczek problem may be stated as follows:—Consider a system of two parallel wires, and assume that they are of negligible diameter and insulated from the earth except at the ends where there are point contacts. Assume that both wires are electrically long so that end effects may be neglected. Let wire No. 1 carry an alternating current given by the real part of I exp $(j\omega t)$, where I is some constant and ω is 2π times the frequency. Let the frequency be low enough to allow displacement currents to be neglected. The earth is assumed to be a semi-infinite homogeneous solid of uniform electrical conductivity. In the earth the permeability and dielectric constant are taken to be unity. The problem involved is the determination of the ratio of the mean axial electric intensity on wire No. 2, to the earth return current in wire No. 1.

It is the object of this note to give an extension of the Carson-Pollaczek formulæ to include the case of a stratified earth. Thus we assume that the earth consists of an upper stratum of depth d and of uniform conductivity σ_1. Below this stratum the earth is supposed to have a uniform conductivity σ_2. Extending the Carson-Pollaczek analysis of the problem to include this case, we find that Z, the mutual impedance between the two lines, is given by—

$$Z = 2j\omega \left\{ \log \frac{r_1}{r_2} - 2 \int_0^\infty \frac{e^{-g(h_1+h_2)\sqrt{\beta}} \cos gx\sqrt{\beta}}{g + \alpha(1+N)(1-N)^{-1}} dg \right\} \qquad \text{...........(1)}$$

where,

h_1 = height of wire No. 1 above ground level in cms.

h_2 = height of wire No. 2 above ground level in cms.

x = normal separation between the two wires in cms.

d = depth of upper stratum in cms.

σ_1 = conductivity of upper stratum in c.g.s., elm. units.

σ_2 = conductivity of lower stratum in c.g.s., elm. units.

$$r_1 = \sqrt{(h_1 - h_2)^2 + x^2}$$
$$r_2 = \sqrt{(h_1 + h_2)^2 + x^2}$$
$$\sqrt{\beta} = \sqrt{4\pi\omega\sigma_1}$$
$$\alpha = \sqrt{g^2 + j}$$
$$\phi = \sqrt{g^2 + jK}$$
$$j = \sqrt{-1}$$
$$K = \sigma_2/\sigma_1$$
$$N = \left\{ \frac{(\phi - \alpha)^2}{j(K - 1)} \right\} e^{-2\sqrt{\beta}\, d\alpha}$$

Now assume that,

$$h_1 = h_2 < x,$$

then (1) may be written,

$$Z = -4j\omega \int_0^\infty \left\{ \frac{1}{g + \alpha} + \sum_{n=1}^{\infty} \frac{\alpha^n}{(g+\alpha)^{n+1}} \left(\frac{2N}{N-1} \right)^n \right\} e^{-g\sqrt{\beta}} \cos gx\sqrt{\beta}\, dg \ldots\ldots\ldots\ldots\ldots (2)$$

The infinite series of integrals converges and we obtain an approximate solution by putting $n = 1$, and transforming (2) into the form,

$$Z = \frac{4\omega}{\lambda} \left\{ \frac{1}{\lambda} - \sqrt{j}K_1(\lambda\sqrt{j}) \right\} - 4j\omega \int_0^{2\pi} (M_s + jN_s) e^{-g\sqrt{\beta}} \cos g\lambda\, dg \ldots\ldots\ldots\ldots\ldots (3)$$

where λ is $x\sqrt{\beta}$, and $K_1(\lambda\sqrt{j})$ is the Bessel function of the second kind with imaginary argument. Writing (3) in the usual Carson-Pollaczek form, we have,

$$Z = 4\omega\{(P + P_s) + j(Q + Q_s)\} \ldots\ldots\ldots (4)$$

where,

$$P = \frac{1}{\lambda} \left[\mathrm{Ker}'(\lambda) + \frac{1}{\lambda} \right]$$
$$Q = \frac{1}{\lambda} \mathrm{Kei}'(\lambda)$$
$$P_s = \int_0^{2\pi} N_s e^{-g\sqrt{\beta}} \cos g\lambda\, dg$$
$$Q_s = -\int_0^{2\pi} M_s e^{-g\sqrt{\beta}} \cos g\lambda\, dg$$

and,

$$N_s = I_m \left[\frac{\alpha}{(g + \alpha)^2} \cdot \frac{2N}{N - 1} \right]$$
$$M_s = R_e \left[\frac{\alpha}{(g + \alpha)^2} \cdot \frac{2N}{N - 1} \right]$$
$$\mathrm{Ker}'(\lambda) = R_e \left[e^{i\frac{5\pi}{4}} K_1(\lambda\sqrt{j}) \right]$$
$$\mathrm{Kei}'(\lambda) = I_m \left[e^{i\frac{5\pi}{4}} K_1(\lambda\sqrt{j}) \right]$$

where R_e and I_m denote real and imaginary parts respectively.

In practical applications λ is usually small, and for this case we may use the approximate formulæ,

$$\mathrm{Ker}'(\lambda) = -\frac{1}{\lambda} + \frac{\pi\lambda}{8} - (1.3659315 - \log\lambda)\frac{\lambda^3}{16} - \frac{\pi\lambda^5}{1536}$$

and,

$$\mathrm{Kei}'(\lambda) = (0.6159315 - \log\lambda)\frac{\lambda}{2} + \frac{\pi\lambda^3}{64} - (1.7825981 - \log\lambda)\frac{\lambda^5}{384}$$

When λ is not small, we may use the asymptotic expansions,

$$\mathrm{Ker}'(\lambda) = -x_1 \mathrm{Ker}\,\lambda + x_2 \mathrm{Kei}\,\lambda$$

and,

$$\mathrm{Kei}'(\lambda) = -x_2 \mathrm{Ker}\,\lambda - x_1 \mathrm{Kei}\,\lambda$$

where,

$$\left\{ \begin{matrix} \mathrm{Ker}(\lambda) \\ \mathrm{Kei}(\lambda) \end{matrix} \right. = \frac{\exp x_3}{\sqrt{2\lambda/\pi}} \begin{matrix} \cos \\ \sin \end{matrix} x_4$$

and,

$$x_1 = \frac{1}{\sqrt{2}} + \frac{1}{2\lambda} - \frac{1}{8\lambda^2\sqrt{2}}$$
$$x_2 = \frac{1}{\sqrt{2}} + \frac{1}{8\lambda^2\sqrt{2}} - \frac{1}{8\lambda^3}$$
$$x_3 = -\frac{\lambda}{\sqrt{2}} - \frac{1}{8\lambda\sqrt{2}} + \frac{25}{384\lambda^3\sqrt{2}} - \frac{13}{128\lambda^4}$$
$$x_4 = -\frac{\lambda}{\sqrt{2}} - \frac{\pi}{8} + \frac{1}{8\lambda\sqrt{2}} - \frac{1}{16\lambda^2} + \frac{25}{384\lambda^3\sqrt{2}}$$

$\mathrm{Ker}'(\lambda)$ and $\mathrm{Kei}'(\lambda)$ are oscillatory Bessel functions and behave ultimately (when λ becomes very great) as,

$$\left\{ \begin{matrix} \mathrm{Ker}'(\lambda) \\ \mathrm{Kei}'(\lambda) \end{matrix} \right. = \mp \frac{\exp\left(-\frac{\lambda}{\sqrt{2}}\right)}{\sqrt{2\lambda/\pi}} \begin{matrix} \cos \\ \sin \end{matrix} \left(\frac{\lambda}{\sqrt{2}} - \frac{\pi}{8} \right)$$

The above equations are in a form suitable for numerical evaluation; they do not require the use of special integraphs, tables or curves.

References :

J. R. Carson : Bell System Technical Journal, 1926, Vol. 5, p. 539.

F. Pollaczek : Elektrische Nachrichten-Technik, 1926, Vol. 3, No. 9, p. 339 (from the Telegraphentechnik Reichsamt).

G. N. Watson : " Theory of Bessel Functions." Cambridge University Press. 1922.

Omnibus and Conference Circuits

A. T. J. BEARD, A.M.I.E.E.

AN " omnibus " circuit is the name given to a communication system in which three or more terminal offices are permanently connected together, while a " conference " circuit is the name given to an arrangement of trunk and/or junction circuits connected together to give temporary omnibus circuit conditions. Where the number of terminal offices is less than, say, six, and the offices are situated in the same or nearby towns, it is usually possible to meet the requirements by connecting the various links together at some suitable point or points. Many private wire users, *e.g.*, bankers, brokers, etc., however, require omnibus circuits between towns widely separated from each other, and it is to this type of circuit that the first part of this article refers.

Omnibus circuits.

If it be assumed that the component circuits in an omnibus system are connected together at one point and have similar characteristic impedances, the loss in decibels due to shunting and reflection is given by

$$\text{shunting loss} = 10 \log_{10} (N - 1) \text{ decibels}$$

$$\text{and reflection loss} = 10 \log_{10} \frac{N^2}{4(N-1)} \text{ decibels}$$

where N is the number of circuits joined together.

Columns (2) and (3) of Table I indicate the losses due to shunting and reflection for values of N from three to eight.

TABLE I.

(1) N	(2) Shunting loss in dbs.	(3) Reflection loss in dbs.	(4) Combined loss for any two circuits for loss of 17 dbs.
3	3.0 dbs.	0.5 dbs.	13.5 dbs.
4	4.8 ,,	1.2 ,,	11.0 ,,
5	6.0 ,,	1.9 ,,	9.1 ,,
6	7.0 ,,	2.6 ,,	7.4 ,,
7	7.8 ,,	3.1 ,,	6.1 ,,
8	8.5 ,,	3.6 ,,	4.9 ,,

From the table it will be seen that when only a few circuits are joined together, the shunting and reflection losses are sufficient to restrict definitely the permissible lengths of circuits so joined. Column (4) indicates the values of the combined transmission loss for any two circuits in an omnibus system assuming the loss between any two terminals is not to exceed 17 dbs.

Another factor which limits the number and lengths of circuits which may be connected together is the current available for calling and clearing. With the types of indicator which are normally fitted at private branch exchanges, and the most efficient type of hand generator the maximum resistance of cable circuit over which reliable signalling can be obtained is of the order of 2,500 to 3,000 ohms, or, if the conditions be particularly favourable, perhaps 4,000 ohms. When similar circuits are connected in parallel the current available at the calling indicators, etc., is inversely proportional to the number of circuits so connected and the length of circuit over which reliable signalling can be obtained is reduced accordingly.

Table II indicates the maximum cable lengths of any individual circuit in an omnibus system over which reliable signalling may be expected, on the assumption that 2,500 ohms is the limiting resistance of a two-station cable circuit.

It will be observed that the limiting length of circuit for reliable signalling is very much shorter than the length permissible for satisfactory transmission.

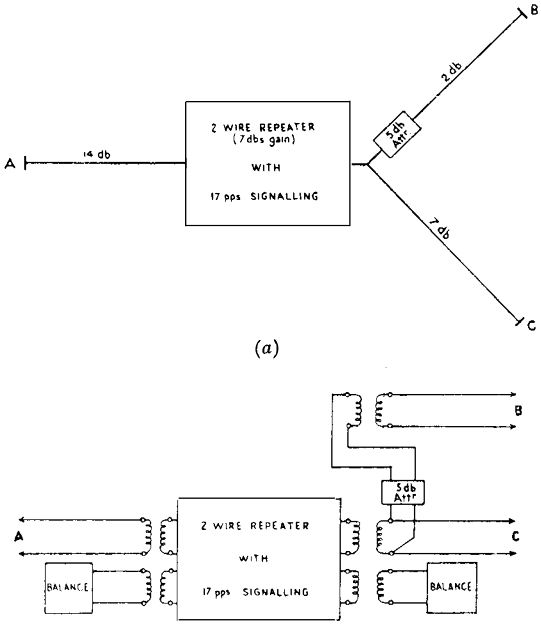
It is usual to describe the component circuits in an omnibus system as " ways." If some of the ways are very short and the stations thereon do not remove their receivers, the conditions for speech over the remainder of the system are improved owing to the fact that the impedances of the bells or indicators on the shorter ways increase the impedances of those ways to values higher than are obtained when the receivers are removed. This small advantage during speech, however, is transformed into a disadvantage during calling by the shunting effect of the bells or indicators on short ways seriously reducing the amount of ringing current received at the more distant stations.

The modern telephone repeater offers a ready means of overcoming the aforementioned limitations. In the case of a three-way system, if the transmission equivalent of one of the ways is of the order of 14 dbs. and the transmission equivalent of each of the other ways is better than 7 dbs., a two-wire repeater

TABLE II.

N.	Resistance.	40 lb. Cable. Loaded 120/1.136. Mileage	40 lb. Cable. Loaded 120/1.136. T.E.	40 lb. Cable. Unloaded. Mileage	40 lb. Cable. Unloaded. T.E.	20 lb. Cable. Loaded 120/1.136 Mileage	20 lb. Cable. Loaded 120/1.136 T.E.	20 lb. Cable. Unloaded. Mileage	20 lb. Cable. Unloaded. T.E.
3	833 ohms.	16.7	2.9 dbs.	18.9	13.2	8.9	3.0 dbs.	9.5	9.6 dbs
4	626 ,,	12.5	2.2 ,,	14.2	10.0	6.7	2.2 ,,	7.1	7.2 ,,
5	500 ,,	10.0	1.8 ,,	11.4	8.0	5.3	1.8 ,,	5.7	5.8 ,,
6	417 ,,	8.3	1.5 ,,	9.5	6.6	4.4	1.5 ,,	4.7	4.8 ,,
7	358 ,,	7.1	1.2 ,,	8.1	5.7	3.8	1.3 ,,	4.1	4.1 ,,
8	313 ,,	6.3	1.1 ,,	7.1	5.0	3.3	1.1 ,,	3.6	3.6 ,,

complete with 17 p.p.s. ringing facilities is inserted in the former way, and if it is possible, the other ways are brought into the repeater station and connected as indicated in Fig. 1(*a*). If these ways differ by more than 2 dbs., an attenuator is inserted in the shorter way to make its transmission equivalent equal to that of the other short way. Should both the short ways be less than 3 db., attenuators are inserted in each to increase their transmission equivalent to 7 dbs.; these cases, however, are very rare.



(*a*)

(*b*)

FIG. 1.—SIMPLE OMNIBUS OR FORKED REPEATER.

The reason for building out the short ways is fourfold :—

(*a*) To facilitate the balancing of the repeater.
(*b*) To stabilize the omnibus system.
(*c*) To prevent the bell or indicators on a short way shunting the remainder of the system.
(*d*) To prevent complaints due to the comparison of the level of the received speech at the different terminals.

If in Fig. 1(*a*), way " A " were 14 dbs, way " B " 2 dbs, and way " C " 7 dbs, the gain of the repeater would be adjusted to 7 dbs and a 5 db attenuator would be inserted in way " B," so that the loss " A " to " B," " A " to " C," and " B " to " C " would each be 17 db, including the shunting loss of 3 db at 0. In Fig. 1(*b*) is shown the manner in which the attenuator should be inserted in way " B " if all the ways are led into the repeater station.

When a two-wire repeater is connected as indicated in Fig. 1(*b*) it is known as a simple omnibus or more frequently as a " forked " repeater.

If the transmission equivalents of two or more of the ways on an omnibus system are greater than 7 dbs and an overall loss of not worse than 17 dbs is desired, it becomes necessary to provide an omnibus repeater. If two-wire circuits, only, are concerned, an " omnibus " repeater is obtained by connecting the halves of two or more two-wire repeaters together through special differential transformers known as Transformers No. 34A, one half repeater and one transformer being required for each way. The upper part of Fig. 2 indicates the manner in which the ways are joined together.

The method of operation is as follows :—If, say, the office on way " A " originates the call, 17 p.p.s. ringing current is sent into the omnibus repeater and operates the line relay L. The operation of relay L breaks the current through relay M, whose armature falls back and places an earth on the ringing relays, R, in all the other ways causing those relays to operate and to send ringing current out to line. The windings of the ringing relays are in series with windings of guard relays, G, which operate at the same time, and put short circuits across the inputs of the amplifying units to prevent them from becoming unstable when the lines are unbalanced during the operation of the ringing relays. During conversation, the speech currents pass to the centre-point of the differential winding of the repeater differential transformer. A small part of the energy is transformed and dissipated in the anode winding and the remainder passes direct to the line winding of the relative Transformer No. 34A. From the latter transformer the energy passes along the omnibus link to the centre-point of the differential windings of the Transformers No. 34A in the other ways. There is a further small power loss in these transformers, but the majority of the energy passes into

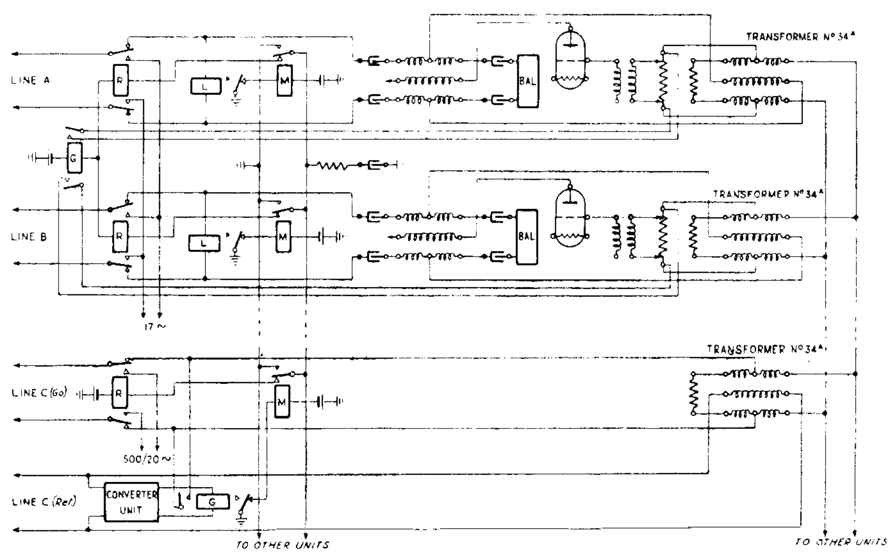


FIG. 2.—OMNIBUS REPEATER.

the valve input transformers, through the valves, where it is amplified, and thence to the repeater differential transformers and out to the various offices. The clearing signals operate similarly to the calling signals.

If one or more of the ways are four-wire, they are connected as indicated in the lower part of Fig. **2**. It will be seen that, although the normal four-wire voice frequency signalling arrangements are retained, a Transformer No. 34A takes the place of the ordinary four-wire termination.

The signalling operations in an omnibus repeater are unaffected by the introduction of a four-wire way and, except for the fact that the signalling on the latter is voice frequency and the GO circuit is short circuited when the line relay is operated, the signalling conditions are identical with those which would obtain if all the ways were two-wire. As no amplifier unit is provided for the four-wire way, the amplification necessary to overcome interconnexion losses is obtained by adjusting the gains of the repeaters on the GO and RETURN circuits.

The number of ways that can be connected to an omnibus repeater is governed by the amount of amplification that can be given by the valves and the quality of the components. With standard valves and apparatus, the maximum number of two-wire ways which can be connected together is usually eight; if some of the ways are four-wire perhaps nine or ten, whilst if any of the ways are forked, the number may be reduced.

The foregoing has assumed that repeaters are necessary to ensure good speech conditions. If, however, the transmission equivalents of some or all of the ways are fairly low, and the only factor affecting their inter-connexion is difficulty in signalling, the difficulty is overcome by fitting signalling units as indicated in Fig. **3**. The arrangements are very

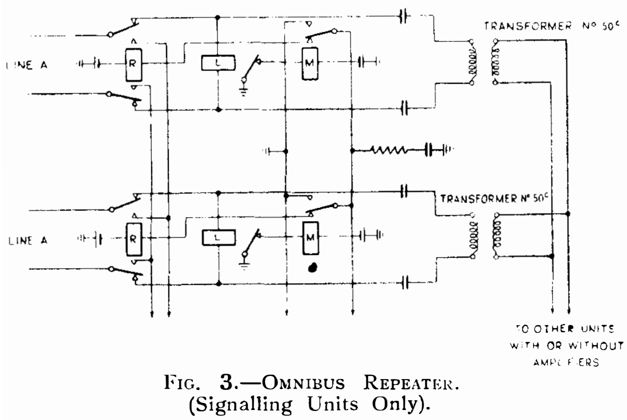


FIG. **3**.—OMNIBUS REPEATER.
(Signalling Units Only).

similar to those for a complete omnibus repeater, except that there are no amplifying units and the guard relays are omitted.

When a renter has an office approximately midway between two repeater stations so that the electrical losses from the repeater stations are nearly equal, it is often possible to obtain satisfactory omnibus facilities by simply connecting the office to the main circuit through transformers as indicated in Fig. **4**. If the transformers are not used and the office instru-

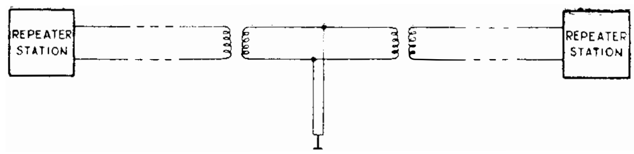


FIG. **4**.—METHOD OF CONNECTING INSTRUMENT AT CENTRE OF REPEATER SECTION.

ment is teed across the main circuit, there would probably be inefficient signalling, and if the local circuit were aerial, serious risk of instability.

A diagram of an omnibus circuit which has been provided for one renter is shown in Fig. **5**.

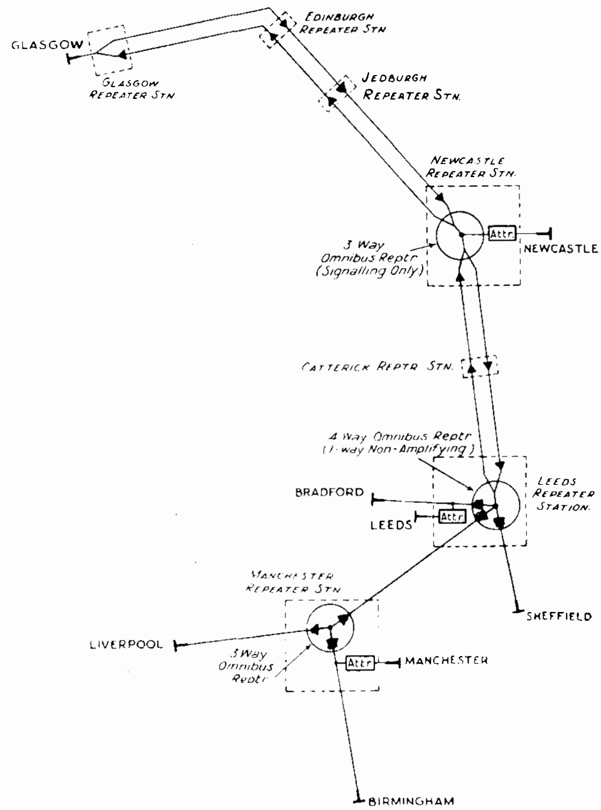


FIG. **5**.—TYPICAL OMNIBUS CIRCUIT.

CONFERENCE CIRCUITS.

Formerly, conference circuits were restricted generally to offices in the same local area, where the electrical losses were low and it was possible to provide the conference facilities by simply connecting circuits together on some convenient switchboard. More recently, however, there have been requests for conference circuits between different towns, and in a few cases between different countries and continents. The first successful demonstration of inter-town conference facilities on a large scale was in 1929, at a joint meeting of the local branches and headquarters of the Institution of Electrical Engineers, when the speeches at each of the various centres were reproduced at all the other centres. The conference facilities for this demonstration were provided by means of a network of trunk circuits and amplifiers which were switched in or out or altered in direction of operation by special operators stationed at the amplifier points. Full particulars of the arrangements are contained in the *P.O.E.E. Journal* of January, 1930.

Since 1929 there has been a general improvement in the transmission equivalents of main trunk circuits and conference facilities can now be provided over most trunk circuits by suitably connecting the circuits together, and, where a large number of circuits are concerned, fitting apparatus to neutralize the shunting losses. Until recently the apparatus consisted of an omnibus repeater. This necessitated the modification of half as many standard two-wire repeaters as there were circuits, and the preparation of balancing networks for each circuit. The length of time required for the modification of the repeaters and the preparation of the balancing networks meant that conference facilities could not be provided at short notice and that a large amount of time and material had to be expended to provide a service which was required at the most for a relatively short duration.

An omnibus or conference repeater which eliminates the majority of the aforementioned difficulties has recently been suggested by Mr. Pyrah, of the Lines Section, Engineer-in-Chief's Office. The suggestion was to take advantage of the feature of the now obsolete 2.1 type repeater in which the amplified currents are not only transmitted to the listener but are also transmitted to the speaker, and to overcome the balancing difficulty by arranging combinations of circuits on either side of the repeater so that the combinations more or less balanced each other.

Fig. **6** shows the connexions of the obsolete 2.1 type of repeater and Fig. **7** shows a modern two-wire repeater modified to the 2.1 type, but with two stages of amplification and wired for use on an eight-way conference system. The modification is carried out by short circuiting the balance winding and disconnecting the line windings of the Up differential transformer so that it is converted into an interstage transformer.

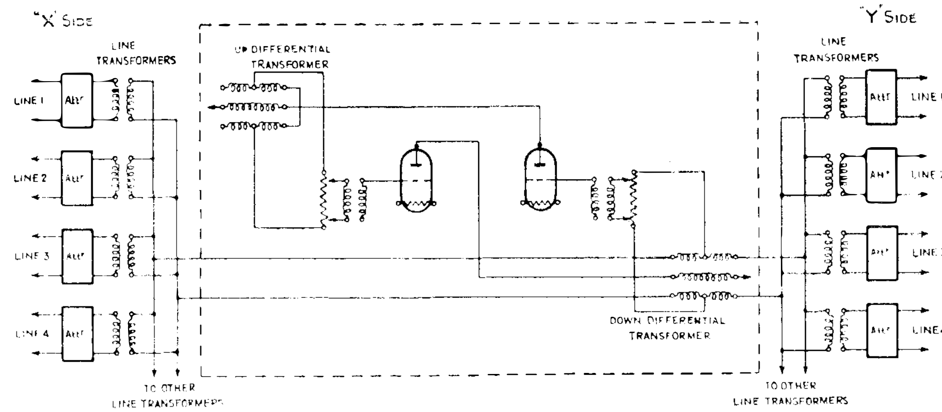


Fig. **7**.—Conference Repeater.

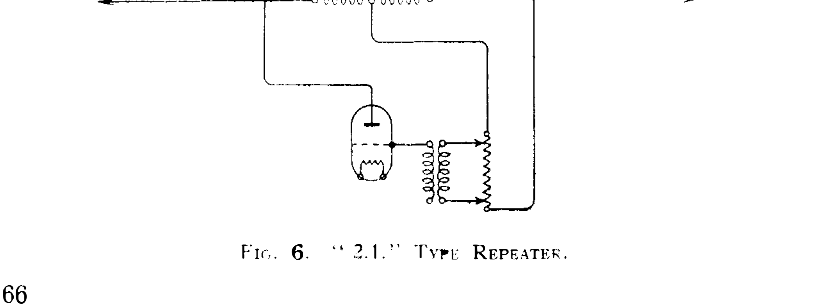


Fig. **6**. "2.1." Type Repeater.

The method of operation is as follows: Speech from, say, line 1 on the X side passes through the attenuator and line transformer to the office side, where the energy divides, part passing direct to the other X side lines and part passing to the centre-point of the line and balance windings of the Down differential transformer where the energy again divides, a small part passing to the Y side lines and the remainder passing through the Down potentiometer to the valves. The latter energy is amplified and is returned to the anode winding of the Down differential transformer and thence *via* both sets of line transformers to the various lines. The energy passed direct to the other lines on the same side of the system is known as the "direct transmission," while that passing through the Down differential transformer and amplifier is known as the "amplified transmission." Owing to the action of filter units (not shown in the diagrams) provided to prevent instability at high frequencies, the amplified transmission is not in phase with the direct transmission at all frequencies, the phase difference varying from 0° to 180°. If the direct transmission is commensurate with the gain of the repeater this difference in phase at different frequencies will give rise to serious distortion. This effect is shown in Fig. **8**, curve B. By fitting attenuators in each line to ensure that the energy available for direct transmission is small, that is to say, not greater than 20 dbs, the distortion can be reduced to a negligible quantity. Curve C, Fig. **8**, shows the gain-frequency characteristics of an eight-way conference repeater in which the direct transmission has been reduced to a negligible quantity by the fitting of 5 db. attenuators in each line and where low frequency correction has been effected. The latter correction is provided owing to the poor characteristics of the repeater at low frequencies. Owing to there being two stages of amplification, the relative losses at low frequencies are approximately twice those of a single-stage repeater.

The advantages and disadvantages of the conference repeater may be summarized as under :—

Advantages :

(1) Fourteen circuits may be in-

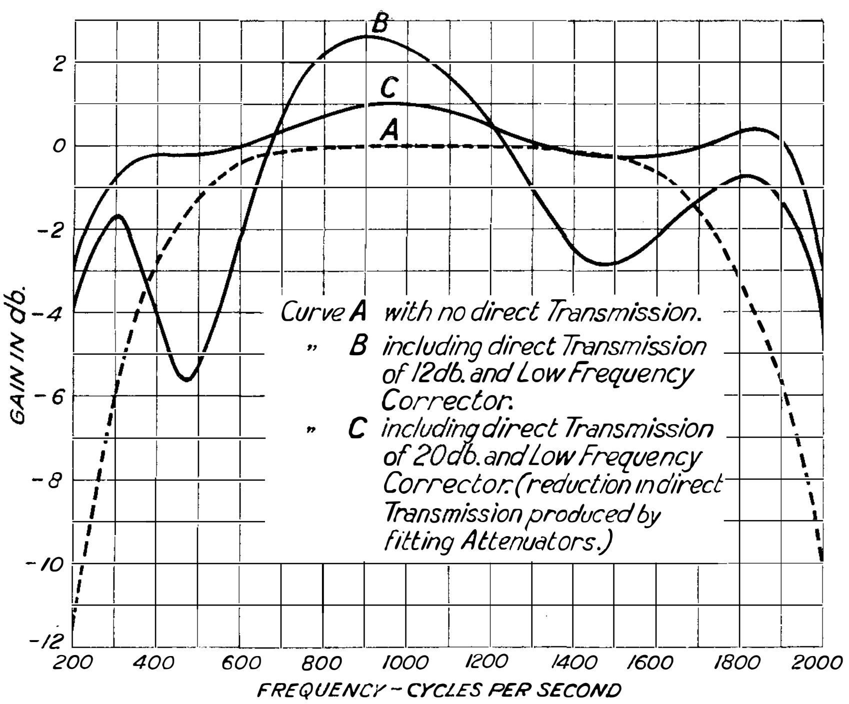


FIG. 8.—GAIN-FREQUENCY CHARACTERISTICS.

terconnected for conference facilities by the use of one modified two-wire repeater.

(2) Balancing networks are not required.

(3) The conference repeater can be provided at short notice.

Disadvantages:

(1) Owing to stability requirements the gain of the repeater cannot be safely increased beyond that required to overcome the shunting losses, but this is not of great importance as the repeater is normally required to overcome shunting losses only.

(2) Low frequency correction is necessary if it is desired to offset the poor characteristics of the repeater at low frequencies.

Book Reviews

" Symmetrical Components." By C. F. Wagner and R. D. Evans. McGraw-Hill Publishing Co., Ltd., Aldwych House, London, W.C.2. Price 30/- net.

In the year 1918, C. L. Fortescue introduced to power engineers engaged in the study of polyphase networks, the method of analysis by means of symmetrical components. The method is analogous in some respects to the resolution of a periodic function into its fundamental and higher harmonics by means of a Fourier series. By means of it a set of unbalanced currents in a three-phase system may be resolved into three systems of balanced currents. The three systems differ from one another in the sequence in which the current attains its maximum value in the three phases. The simplification which arises from this resolution is due to the fact that each set of balanced currents can be treated separately, and in a symmetrical circuit currents and voltages of the different phase sequences do not react on one another.

Probably the most important application of the method of symmetrical components is to the calculation of the reaction of an extensive power system to an unbalanced fault at one point on it. This is a problem of interest to the telephone engineer by reason of the interference resulting from the fault.

The impedance of the system to currents having the different phase sequences is important, and one is pleased to see the prominence given in this book to Carson's fundamental work on the impedance of overhead lines and cables to currents having a zero phase sequence (that is to currents which attain their maximum simultaneously in all three phases and return by means of the earth or an earth wire).

To the power engineer interested in the protection of a large transmission system by means of discriminating relays and circuit breakers, this book would be extremely valuable. Indeed, as Dr. Fortescue points out in an interesting introduction, it is the first text-book to be entirely devoted to the subject. The fundamental principles of the method are lucidly explained; and, provided that the reader is familiar with the handling of complex numbers, one who has not been intimately connected with power circuit problems will have no difficulty in following the application of these principles to the various types of problem which arise.

One slight criticism; at the end of each chapter a number of problems have been added as a means by which the reader might test the information which he has gathered. These would have fulfilled their purpose better had their answers also been given.

W.G.R.

" Handbook of Technical Instruction for Wireless Telegraphists." Fifth Edition. By H. M. Dowsett. Pp. 566; 525 illustrations. Iliffe & Sons, Ltd., Dorset House, Stamford Street, London, S.E.1. Price 15/- net (15/9 post free).

The aim of this book is to provide simple instructions for sea-going operators and others, in the general principles and practice of Wireless Telegraphy and is intended to provide a complete theoretical course for the P.M.G.'s certificate.

Among the important additions to the fifth edition are chapters on Echo Sounding Apparatus, Short-Wave Marine Transmission and Reception, and Marine Telephony and Band Repeaters. The book which, in the earlier editions, described only Marconi apparatus, now covers practically the whole range of apparatus likely to be found in British ships and includes very complete descriptions of apparatus manufactured by Messrs. Siemens Bros., and by the Radio Communication Company. In addition to dealing with the normal types of transmitting and receiving apparatus, chapters are devoted to auto-alarm apparatus and direction-findnig gear.

The work is of a most comprehensive character and completely fulfils the object for which it is written. It can be recommended to all seeking information on marine wireless equipment.

W.S.P.

Notes and Comments

Post Office Board

The Postmaster-General has constituted a Post Office Board which will commence its duties in April. The Board will be composed as follows :—

CHAIRMAN.	
The Rt. Hon. Sir Kingsley Wood, M.P.	H.M. Postmaster-General.
DEPUTY CHAIRMEN.	
Sir Ernest Bennett, M.P.	Assistant Postmaster-General.
Colonel Donald Banks, C.B., D.S.O., M.C.	Director General.
MEMBERS.	
Mr. T. R. Gardiner	Deputy Director General.
Sir Henry N. Bunbury, K.C.B.	Comptroller and Accountant General.
Lt.-Col. A. G. Lee, O.B.E., M.C.	Engineer-in-Chief.
Mr. H. F. Sambrook	Director of Establishments and Personnel.
Mr. L. Simon, C.B.	Director of Telegraphs and Telephones.
Sir Stephen Tallents, K.C.M.G., C.B., C.B.E. ...	Public Relations Officer.
Lt.-Col. F. N. Westbury, O.B.E.	Postmaster-Surveyor of Glasgow.
Sir Frederic Williamson, C.B., C.B.E.	Director of Postal Services.
Mr. H. Napier	Secretary to the Board.

Journal Changes

A NEW front cover design makes its appearance with this issue of the Journal. In introducing the new design, the Board of Editors has had in mind the convenient form of reference resulting from printing the list of Contents on the front cover page, and the design has been produced with this object. Many of our readers do not take advantage of the binding facilities, which are offered at cost price, and the printing of the Contents on the cover will assist those readers in locating articles. In submitting the new design to the verdict of our 9,000 readers, the Board has every reason to hope that it will meet with general approval. The colour of the cover has been chosen with a view to obtaining a clearer reproduction of the photographic illustrations published on these pages. The opportunity has also been taken to modernize the pagination, more particularly with regard to the lay-out of the titles of articles and the use of modern figures in the text and tables.

Some Statistics Concerning Danish Telephone Companies

Through the courtesy of one of our correspondents, we are able to publish the following information extracted from " Svensk Trafiktidning " relating to Danish Telephone Companies having concessions from the State :—

The telephones per 100 inhabitants are 10, as compared with 4.8 U.S.A. and 4.5 England.

There are six companies with concessions; the two main ones are the Copenhagen Company and the Jydsk Company, the latter operating in Jylland. They will be denoted by C and J respectively. A krona may be taken as worth 1/- for general comparison purposes; par was 18 kronor per £1; November, 1933, it was 22 kronor per £1.

	C	J
Inhabitants in area... ...	1,421,700	1,441,700
Subscribers	167,350	81,793
Stations	201,810	96,082
Exchanges with metallic loop	168	131
Exchanges with single wires	205	1,010
Financial figures.	C kronor	J kronor
Income per sub.	174	148
Expenses per sub.	140	127
Income from rentals per sub.	129.78	94.87
Income from calls per sub.	23.87	48.06
Other income per sub. ...	20.02	5.52
Expenses per sub.		
Salaries to administration...	9.09	7.90
Salaries to operators ...	37.86	44.71
To pensions	—	1.18
Directory	0.18	1.14
Mtce., wages and salaries...	12.59	14.57
Mtce. stores	14.18	9.26
Depreciation	39.41	32.85
Interest and commission ...	16.10	9.03
Rents, Rates	10.25	5.94
	C	J
Capital value (kronor) of installations and lines ..	107,951,778	45,425,142
Depreciation (kronor) ...	55,593,886	24,956,704
Buildings and lands (kronor)	11,627,353	2,545,209
Depreciation (kronor) ...	3,011,473	454,834
Subs. Double wire km. ...	(52,040)	15,341
Subs. Single wire km. ...	(—)	90,846
Subs. Cable wire km. ...	748,669	205,296
Poles erected	153,809	505,077
Mtce. cost (kronor), aerial, per mile of wire	22.00	7.43
Mtce. cost (kronor), cable, per mile of wire	0.93	0.30

The telephone annual rentals vary considerably with the size of exchange and allow various numbers of free calls. The following cases are typical.

Copenhagen Telephone Company. A business phone on the Central Exchange including 5500 calls costs 240 kronor. In country districts, allowing unlimited calls to one's own exchange and 100 junction fee calls, costs 80 kr. in Exchanges over 300 subs. and 72 kr. in Exchanges under 200 subs., and either 80 or 72 as determined by the Company for Exchanges with 200-299 subscribers.

Jydsk Telephone Company. The cost is 66, 72, or 76 kronor for Exchanges with less than 50, 51-120, or 121-200 subscribers; this includes unlimited calls to one's own Exchange and 600 calls to Exchanges within 5 km. or to the nearest Exchange.

The cost is 86 kronor for Exchanges with over 200 subs. and this includes 1500 calls to one's own Exchange.

Anti-Sidetone Circuit Locus Diagrams

The Editor,

The Post Office Electrical Engineers' Journal.

11th January, 1934.

Dear Sir,

In an article upon anti-sidetone telephone instrument circuits which was published in your issue of October, 1932, I gave a description of a locus diagram (Fig. 3 of the article) which illustrated in a novel way the performance of an anti-sidetone circuit when connected to any line impedance whatever. Experience has since then proved the value of this method of illustration. I would like therefore to draw attention to a simple geometrical construction by which this locus-diagram can be rapidly drawn for any existing circuit.

In the accompanying diagram the axes and the points O, P and Q have the significance given them in the article. The line AB bisects PQ at right angles, and is the locus of all impedances which give x milliamps in the receiver per volt generated in the transmitter.

As explained in the article x is measured on the telephone instrument circuit itself by applying one volt in the microphone circuit and measuring the corresponding receiver current when the line terminals of the instrument are open-circuited. The geometrical construction shown here provides the locus for any other value of receiver current (y).

The construction depends upon the requirement that points in the impedance field give equal sidetone if the ratio of their distances from the foci P and Q remains constant. The relation between the construction and this requirement is obvious from the diagram.

The construction is made as follows :—

To draw the locus of y mA/V (where $y < x$) ÷ –

Arcs DQFB and PF^1B are drawn with radius PQ and centres P and Q.

Mark off QF and QD at a radius equal to $\frac{y}{x} \cdot QB$.

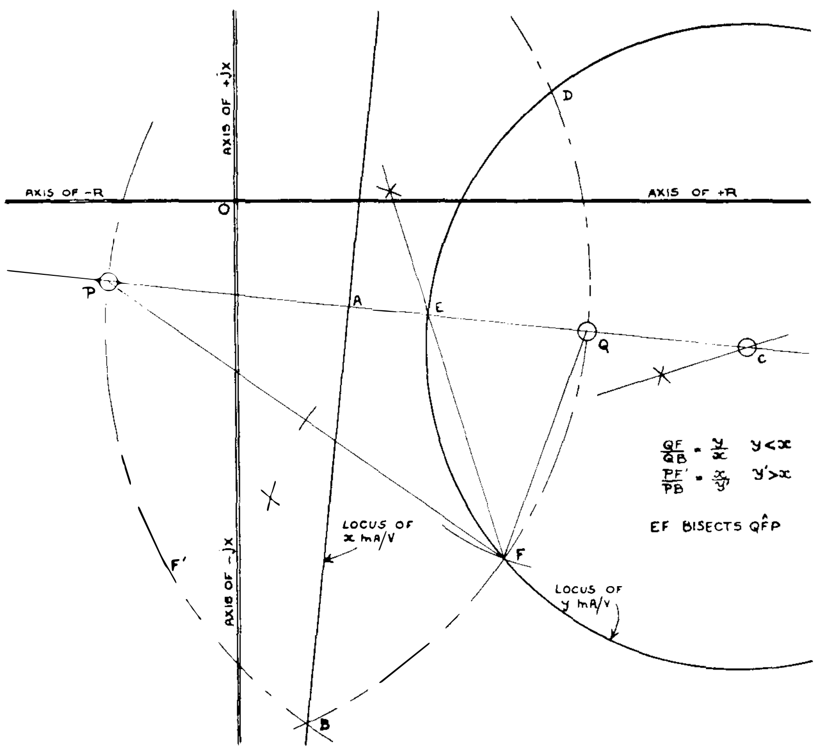
Draw the bisector of $P\hat{F}Q$ to cut PQ at E. Then the locus of y mA/V is a circle passing through F, E and D and having its centre (C) on an extension of PQ.

For values of y considerably greater than x the arc PF^1B is drawn and the inverse formula in the diagram is used. In a rapid estimation of the loci the locus-circle DEF can be drawn by trial without serious inaccuracy.

I beg to remain,

Yours faithfully,

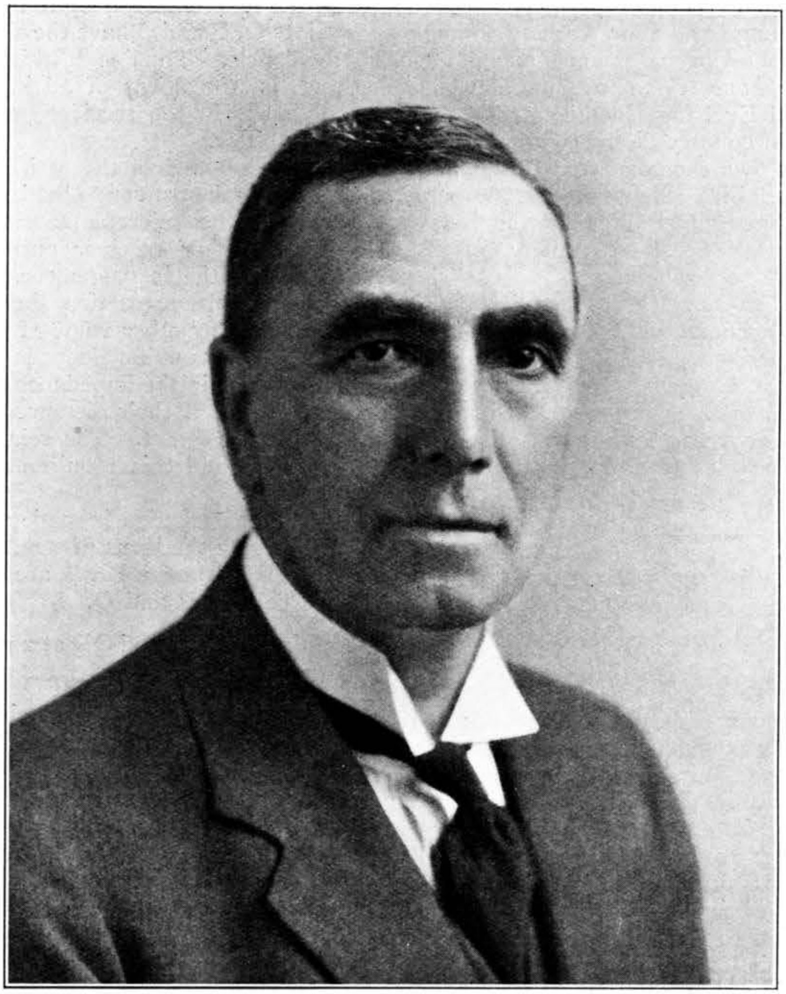
E. R. Wigan.



First International Congress of Electro-Radio-Biology

For the purpose of instituting among physicists, chemists, biologists, naturalists, and doctors a close and profitable collaboration indispensable for the advance of radio-biology considered not as a branch or radiology or biology but as a separate science in itself, the International Society of Radio-Biology is now organizing the First International Congress of Electro-Radio-Biology, which is to take place in Venice, in the Ducal Palace, in September, 1934, under the Presidency of H. E. Count Volpi di Misurata, Minister of State.

Those who desire more detailed information are invited to apply to the International Society of Radio-Biology, addressing their correspondence to : Dr. Giocondo Protti, Venice (Italy), Canal Grande—S. Gregorio, 173.



Major H. Brown, O.B.E., M.I.E.E.

Readers of the Journal will be interested to learn of Major Brown's appointment to the new post of Deputy Engineer-in-Chief to the Post Office. The growth and complexity of the work of the Engineering Department in recent years have made such an appointment inevitable, and all our readers will join us in extending our good wishes to our new Deputy Chief, particularly as he is also Chairman of our Institution. Major Brown is so well known to our readers that accounts of his career, which have been published previously in the Journal, need not be repeated.

A. Wright, M.I.E.E.

Mr. A. Wright, after training at Finsbury Technical College and as an Engineering Apprentice with the London Brighton & South Coast Railway, entered the service of the National Telephone Company in 1897 in the Western District of London and during the next few years occupied the positions of Exchange Inspector, Exchange Manager and District Electrician. At the commencement of this period all exchanges were operated on the magneto system, but in 1901 the first C.B. exchange in London was opened in Kensington with Mr. Wright as Exchange Manager in charge of both Engineering and Traffic staffs.

On the re-organization of the London District on a functional basis in 1905 Mr. Wright was appointed Divisional Maintenance Electrician and subsequently, on Mr. P. H. Cole's departure for Hong Kong in 1907, he was appointed Metropolitan Maintenance Electrician, being responsible for the whole of the Company's internal plant in London from that date until the transfer of the Gerrard Exchange with 6,500 subscribers' lines and 20,000 stations to the Common Battery System in 1907, a very large undertaking in those days.

He was transferred to the Post Office Engineering Department as an Executive Engineer and was stationed in the Superintending Engineer's office, being engaged in the co-ordination of the Post Office and National Telephone Company's methods of maintenance and the issue of an extensive series of numbered District Instructions. Following this Mr. Wright was appointed to the South Internal Section where he spent the whole of the War-time period, during which he entered enthusiastically into the activities of the Volunteer training movement and Special Constabulary. In 1926 he was promoted to Assistant Superintending Engineer in the London Engineering District and on the 1st March, 1934, took up the duties of Superintending Engineer in the North Midland District.

The intervening years saw great changes in the exchange system in the superintendence of which Mr. Wright played a prominent part. Tandem Exchange with Coded Call Indicator equipment and 75 Common Battery exchanges was opened in 1927 as a preliminary to the cut-over of the first London Automatic Exchange at Holborn, followed in rapid succession by the opening of some 60 other large director exchanges and the conversion of 190,000 exchange lines and one-third of a million telephones to automatic working.

Mr. Wright's activities as an Engineer in London have thus covered the whole period from the prime of the Magneto system to that of the Director system and embrace the introduction and virtual demise of the Common Battery exchanges, his principal spare-time occupations mean while being fishing and philately.

Mr. S. C. Bartholomew, M.B.E., M.I.E.E.

Mr. S. C. Bartholomew retired on the 31st December, 1933, after completing more than 43 years' service with the Post Office. With his departure the Department is deprived of the services of a well known expert on power circuit interference, corrosion, and electrolysis.

It seems strange to think that Bartholomew was intended for the Mercantile Marine Service and to this end was educated at the Naval School at Greenwich. This course was interfered with because of eye trouble and he entered the Central Telegraph Office as a Telegraph Learner in May, 1890. In the C.T.O. he came under the influence of the future Engineer-in-Chief, Sir W. Slingo, then in charge of the technical education of the staff. Always an eager student, Bartholomew won the Controller's Grand Aggregate Prize for educational successes in 1897 and continued his studies at the Northampton Institute, and later at University College. In 1900 he joined the Engineering Department as a Clerk in the old Metropolitan Central District, whence he passed as a 2nd Class Engineer to the Construction Section of the Engineer-in-Chief's Office, there to remain until the end of his official career. During this period Bartholomew had among his Chiefs the following Staff Engineers, Messrs. Moir, Sheridan, Eldridge, Groves, McIlroy, A. W. Martin, Pollock, Sinnott, Turner and Ridd. He had to wait long for promotion, not becoming Executive Engineer until 1920 and Assistant Staff Engineer in 1927. During practically the whole of his engineering career Bartholomew has been associated with problems concerning electrical interference, protection against power circuits and electrolytic damage. In connexion with this work he gained an international reputation, being almost as well known abroad as he is in England. On the formation of the Comité Consultatif International des Téléphoniques a Grande Distance (C.C.I.F.) in 1924, Bartholomew from the beginning took a leading part and he served as Rapporteur on several special committees set up by that organization. There followed the institution of the Commission Mixte International (C.M.I.) to investigate technical problems of mutual interest to communication and power engineers. In 1927 Bartholomew was authorized to draw up the constitution and programme of the research work of this Commission. Besides being a member of several C.M.I. committees, Bartholomew was appointed President Rapporteur of the committee dealing with the fixing of the amount of noise interference tolerable on international telephone circuits and the standardization of methods of measurement. Later the ambit of the Commission was enlarged to include damage to cables; also to gas and water pipes by electrolysis and chemical action.

In 1920 Bartholomew became the Post Office representative on a committee set up by the Institution of Electrical Engineers to advise the Electricity Commissioners on the regulations for overhead power lines. The work of this committee was extended subsequently to cover all the regulations of the Commissioners for securing the safety of the public. In 1925 he became a member of another I.E.E. committee dealing with the International Extra High Tension Conference. He was also a member of the British Standards Institution committee dealing with Overhead Power Lines. Important proposals were put forward on behalf of Great Britain for the international standardization of factors of safety, etc., for overhead power transmission lines and, as the British representative, Bartholomew attended a conference in New York in 1926. At this conference he also had

charge of the British standardization recommendations for telegraph, telephone and radio symbols. During his visit to America Bartholomew was presented to President Coolidge, he talked with Mr. Hoover, visited and conversed with Edison at his laboratories and got him to pose for a photograph. On the occasion of the plenary meeting of the I.E.E. at Bellagio in 1927, he had the opportunity of meeting Mussolini. In 1933 Bartholomew was appointed a member of a further I.E.E. Committee set up at the request of the Electricity Commissioners to advise that body on practical problems connected with overhead power lines.

Bartholomew holds the rare distinction of having been awarded three medals by the Institution of Post Office Electrical Engineers for papers read before the London Centre. He was also awarded the Webber Premium by the Institution of Electrical Engineers in 1924 for a paper on " Power Circuit Interference with Telegraphs and Telephones."

An interesting incident in Bartholomew's career was an invitation in 1929 by the Soviet Government (U.S.S.R.) to advise them on the electrolytic dangers associated with electric railways near Moscow and also in the Caucasus, but although the terms offered were attractive the matter was not proceeded with for medical reasons .

Bartholomew has been active in I.P.O.E.E. affairs, having served on its Council during the rather difficult war years. He was Vice-Chairman of the London Centre in 1932-33 and Chairman of the informal meetings of the London Centre during the same period.

During the war he acted as Assistant Company Commander of the Special Constabulary in the City of London set up for duty at Telephone Exchanges, the C.T.O. and the King Edward Building. The duties were concerned with air raid precautions and were not free from difficulty or danger.

As he is familiarly known, " Bart " has always been closely associated with sport. Nurtured on the Rugby game at the Rectory Field, Blackheath, he became Secretary of the C.T.O. Rugby Club and later Vice-Captain. He was a sprinter, winning prizes both in open events and at office sports and notably the Civil Service 120 yards championship in 1895. As a Badminton player he will agree that he is nowadays more artful than vigorous. Bart played chess regularly for the Engineer-in-Chief's Club and managed to secure a draw against Lasker when the latter, as World Champion, played 24 simultaneous games with members of the G.P.O. North and Engineer-in-Chief's Chess Clubs. He has now taken up bowls and is capable of quite good performances on the " Green."

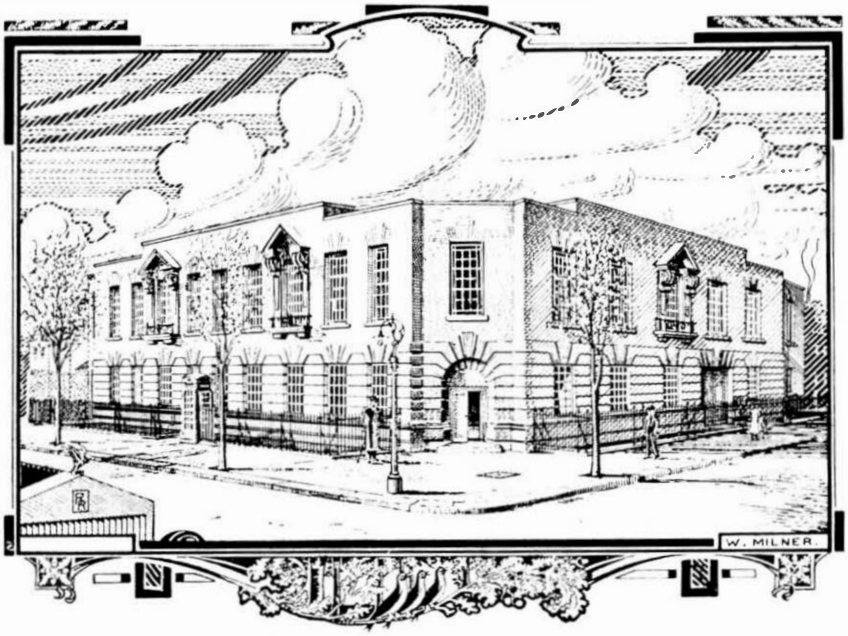
He was awarded the M.B.E. in the Birthday Honours 1932.

It is almost needless to write of Bart's wit and humour, of his abilities as a raconteur; how he adds spice and sparkle to convivial and also to serious occasions. Those who were present at the crowded gathering in the Deputation Room, G.P.O. North, on the 5th January, 1934, when a presentation was made to him by Colonel Lee had abundant evidence of these qualities. Because of his genial sympathy and helpfulness he secured many friends who will always hold him in affectionate regard.

A.O.G.

District Notes

London Engineering District



Larkswood Automatic Exchange.

LARKSWOOD AUTOMATIC EXCHANGE.

This exchange was brought into service at 2.0 p.m. on 11-1-34, when 751 lines were transferred from Walthamstow, Silverthorn, and Buckhurst. Larkswood is the 61st automatic exchange to be opened within 10 miles of Oxford Circus, and is the 72nd in the London Engineering District.

The exchange, situated in Brookscroft Road, was installed by Messrs. Ericsson and is of the director type, the manual switchboard and associated equipment, being located at Leytonstone. Initial equipment for 1700 lines has been provided, the ultimate capacity being 10,000 lines.

The manual switchboard comprises 6 Assistance and 3 Toll Control positions in common with Leytonstone. Incoming direct traffic from manual exchanges is operated on a 4-digit A.C. keysending basis, whilst a 7-digit A.C. keysending route from Silverthorn was brought into use on 30-1-34.

MILEAGE STATISTICS.

During the three months ended December 31st, 1933, the following changes occurred :—

Telephone Exchange.—Nett increase in overhead and underground respectively of 546 and 56,284 miles.

Telephone Trunks.—Nett decrease in overhead, 81 miles. Nett increase in underground, 3,385 miles.

Telegraphs.—Nett decrease in overhead, 153 miles. Nett increase in underground, 347 miles.

The total single wire mileage at the end of the period under review was :—

	Overhead.	*Underground.*	*Total.*
Telephone Exchange ...	45,522	3,631,608	3,677,130
Trunks	9,683	197,054	206,737
Telegraphs	1,166	39,141	40,307
Spare Wires	3,324	162,955	166,279
Total	59,695	4,030,758	4,090,453

FARADAY BUILDING NOTES.

The past three months have been exceptionally busy ones in the City Internal Section. Following the recovery of the old Trunk Exchange on the third floor main Faraday Building, North Block, a new installation is being installed to provide for further extension of Demand Trunk Working, the equipment being, in common with the remaining Trunk Institutions, of the latest sleeve control type. The recovered equipment was that which had served for the whole of the Trunk Services terminating in London for 30 years previously to the inception of Demand Working, and it was in this exchange that the Continental and Radio Services were originally terminated.

A new 32 position Inland Trunk Information Desk has recently been installed in the third floor main.

The installation of Central Automatic Exchange has commenced in Faraday Building, South Block. This exchange is due to open in April, 1935. City Exchange, which is also due for opening in July, 1935, will also be installed in Faraday Building, South Block, and the two exchanges will be served by common groups of code selectors, directors and A-digit selectors. The 200 point line finders, numerical and final selectors will, of course, be individual to each exchange. Two main frames are being erected parallel to each other, each consisting of 15 verticals of standard height, one for City and Central subscribers and the others for junction and through circuits. Since some of the junction cables will contain a certain number of Trunk and Toll circuits, three 1100-pair and four 800-pair tie cables are being provided between the junction frame and the Trunk and Toll Main Frame in Faraday Building, North Block.

In connexion with the opening of the large new wing to the Postal Stores and Letter Offices at Mount Pleasant, a considerable amount of work is in hand for the provision of watchmen's tell tale clocks, electrical clock system, telephones and fire alarms in the new block.

It is of interest to note that the amount of subscribers' fitting work at present being dealt with in this Section is much heavier than for several years previously. It is hoped that this is a forerunner of more prosperous conditions generally.

LONDON PNEUMATIC TUBE SYSTEM.

On Sunday, the 11th February, a memorable day in the history of the London Pneumatic Street Tube System, the first step in the conversion of the C.T.O. network to automatic working was completed. On this occasion five tubes were transferred to the new automatic rotary switch installation in the C.T.O., which, after nearly eighteen months' work, is nearing completion.

The main function of the plant is to transfer carriers automatically from the street tubes working with air at high pressure and high vacuum to the house tube extensions which lead to the instrument galleries, and *vice versa*. Among the many striking features of the Switch Room are motor-driven continuously-running shafting, banks of rotary switches controlled by magnetic clutches, rows of electro-pneumatic valves, and a veritable maze of tubes, pipes, ducts and headers.

The installation includes an improved signal and control system, evolved by the staff of the London District, which is reducing certain delays to traffic while simplifying the operating procedure for the tube attendants. A feature of the change is the replacement of the old block instruments in the C.T.O. by coloured lamp signals controlled by apparatus of automatic telephone type.

The Switch Room has been designed to accommodate a total of 72 rotary switches, of which 53 will be in service on completion of the initial stage of the conversion, expected early in May.

North Midland District

RETIREMENT OF A. B. GILBERT, Esq., M.I.E.E., SUPERINTENDING ENGINEER.

A large gathering of the members of the North Midland District Engineering Staff met at the Welbeck Hotel, Nottingham, on February 28th, to pay their farewell tribute to Mr. Gilbert, who retired that day under the age limit regulation. A number of visitors were present from other Post Office Departments.

Mr. D. S. Arundel, Assistant Superintending Engineer, presided, and referred to the progress which had been made in the District during Mr. Gilbert's period of office as Superintending Engineer and to the way in which he had won the loyal co-operation of all grades of the Staff. Appreciative speeches were made by representative members of all grades, the speakers stressing the consideration and courtesy which Mr. Gilbert had invariably shown to the staff.

Major Darby, District Manager, Nottingham, testified to the good relations with the Engineering Department and to the respect held for Mr. Gilbert by the District Manager's staff.

Mr. Gilbert was presented with a gold watch, and a cheque was handed to Mrs. Gilbert for the purchase of an antique bookcase for her own use. A most enjoyable evening was spent and the function provided a unique opportunity for a closer acquaintance among all grades from every part of the District.

Mr. Gilbert was born and educated in Birmingham, where he entered the service of the National Telephone Co. in 1890. Keen on education and very thorough in his work, he gained rapid promotion and held appointments at Coventry, Birmingham, Derby and Nottingham. In 1902 he was appointed District Manager at Exeter, and in 1906 became Chief Engineer at Glasgow. At the transfer of the National Telephone Company he was appointed to the post of Executive Engineer and was promoted to Assistant Superintending Engineer in Edinburgh in 1913. He came from Edinburgh to take up the post of Superintending Engineer in Nottingham in 1929.

We understand that, notwithstanding his admiration and love of Edinburgh, he will make his home in Nottingham. Full of energy and good spirits he carries with him into his retirement the good wishes of his many friends for many happy years of service to the causes he has at heart.

D.S.A.

South Western District

EXETER H.P.O.

The installation of the Double Tier Phonogram Equipment and the Telegraph Panel-Mounted Scheme, has completely changed the appearance and lay-out of the Exeter Head Post Office Instrument Room. The general cessation of morse working leaves only the Telegraph Repeater Boards which serve the Channel Islands circuits. Arrangements are also in hand for the modification of this apparatus to modern conditions.

COOMBE DOWN AUTO EXCHANGE.

A new satellite on Bath Auto Area has recently been opened. Coombe Down Exchange is of the "S" 100/800 Bypath Type and is believed to be the first of its kind in the country. The initial equipment consists of 3 Line, 3 Selector and 3 Miscellaneous Bays and will accommodate 300 lines. Each Line Bay is equipped with 12 Line and Final Finders which can be used either as a Line Finder or as a Final Finder. Each Selector Bay is equipped with 10 paths and 2 Bypaths. All switches are of the "uniselector" or single motion type. "O" Service is provided on normal lines, but access to the existing exchanges in Bath is obtained by dialling an additional digit "9" as a prefix.

A somewhat similar installation is in progress at Brixham in the Torquay Auto Area.

PLYMOUTH TRUNK EXCHANGE.

Trunk Demand Working was introduced at Plymouth, which now becomes a Zone Centre, on the 27th ultimo. The new service has necessitated the provision of three 3-position sections in the Plymouth Main Exchange. Seven of the positions are used as combined "demand and delay" positions, the other two being used for incoming and through traffic.

The equipment provides 60 Visual Idle Indicators, Generator Signalling for 30 circuits, Auto Signalling for 180 circuits and 10 Record circuits. Transfer circuits are provided between the local switchboard and the Demand suite.

At the opening date the following circuits were connected which include several new Trunks :—

17 Generator Signalling Trunks.
96 Auto Signalling Circuits.
7 Transfer Circuits.

The installation which was provided by the General Electric Co. has proved entirely satisfactory.

The Auto Manual Switchboard at Torquay has been replaced by Sleeve Control Equipment and the Trunk Demand Working introduced at this Group Centre on 10-2-34.

Eleven Amplifying Stations are at present in various stages of completion. These are for use on circuits in the Bristol-Minehead, Bristol-Yeovil-Dorchester-Weymouth, and Bristol-Warminster-Salisbury-Upavon-Tidworth cable routes. The amplifying units are gradually being brought into use as new circuits and transferred circuits are being set up in these cables.

Junior Section Notes

Edinburgh Centre

Mr. W. Davidson gave a paper on " Fault location on Main and Local Cables " at the December meeting. During this month a visit was made to the Chancelot Flour Mills.

In January, Mr. P. S. S. Biggers delivered a paper on " Group Control and its Associated Trunking in small Satellite Exchanges," and the paper already given to the parent section on " Police Telephone and Signal System " was contributed by Mr. McIntosh.

At the February meeting, a paper on " Trunk Demand Working " was given by Mr. J. White.

All the papers were illustrated by lantern slides and very interesting discussions ensued.

Dundee Centre

An instructive paper on the " Slide Rule " was given by Mr. W. Duncan, before a good attendance, at the December meeting.

In January and February, a " Model Railway " at the house of Mr. R. Meredith, " Craigard," West Ferry, said to be one of the most novel of its kind in the Country, was inspected by the members.

Mr. J. McIntosh delivered his paper on " Police Telephone Signal System " in February. It proved of particular interest in view of the proposed adoption of a signal system by the Dundee Police Authorities.

Aberdeen Centre

During December, two papers entitled " Underground Development " and " Relay Automatic " were given by Messrs. A. Birss and J. P. Davidson.

Mr. J. McLeod delivered a paper on " Trunk Demand Working " in January, and at our February meeting a paper on " Unit, Auto., No. 4 " was given by Mr. J. A. Yeats. The attendances were good and the discussions well maintained.

Swansea Centre

The January meeting of the newly-formed branch at Swansea was well attended, when Mr. A. Richards read a very interesting and instructive paper on the maintenance of Messrs. Siemens' No. 16 System of Automatic Telephony.

The paper was greatly appreciated and a large number of points were raised by the members, also the Superintending Engineer, Mr. H. S. Thompson, and the Sectional Engineer, Mr. E. L. Preston.

The lecturer very aptly replied to the questions, and after the meeting a visit was made to the Swansea Automatic Exchange, when a more detailed description of the plant in operation was given for the benefit of the members whose daily work does not bring them into close contact with Automatic Exchange working.

Shrewsbury Centre

A Branch meeting was held in the lineman's room at Shrewsbury, on February 22nd, there being a moderate attendance. Mr. Green, Assistant Engineer, gave a lecture on the subject of " Power Crossings." The lecture was very instructive and all present showed great interest in the details that were given. It became apparent that considerable work lay behind the erection of the power pylons and guards, and great care and foresight was required to protect the interests of the Department.

Interesting discussion followed the lecture, and many amusing anecdotes were related, dealing with incidents which had taken place in various parts of the section during the alteration of plant to give way for power crossings.

Towards the termination of the meeting, the Secretary announced the cancellation of the proposed visit to the works of the " Goodyear Tyre " Company, and further suggestions were requested so that visits could be made in the near future, it being eventually decided that a visit shall be made, if possible, to the Automatic Electric Company's works at Liverpool. The Secretary will notify the members of the date immediately satisfactory arrangements have been made.

Manchester Centre

The current sessional syllabus has, up to the present, proved of exceptional interest, and each of the papers has been received by enthusiastic and appreciative audiences. We have indeed been fortunate in being privileged to hear contributions on the following topical subjects :—

" The Service Aspect of Automatic Telephony."—R. W. Palmer.

" The Post Office International Exchange."—S. Birch and C. H. Hartwell.

" Party Lines—History and Development."—H. O. Ellis and B. Winch.

In every case the authors have been impressed by the discussion evoked and have expressed pleasure at the interest displayed.

Not the least useful side of the Centre's activities has been the visits arranged to places of interest, and the recent tour of the Manchester B.B.C. Studios was thoroughly enjoyed by the participants.

As an innovation, it is proposed that the last meeting of the Session shall take the form of a debate in which the motion will be " that the ' ENG ' service in Manchester will not be a success." After hearing the appointed contestants, the subject will be thrown open for discussion.

Blackburn Centre

The Centre has had another successful Session and the following programme was carried through as arranged :—

" The Blackburn Police Telephone and Signal System."—Mr. W. Butcher.

" Modern Paper Core Cables & Jointers' Tests thereon."—Mr. A. Jackson.

" Reproduction of Sound."—Mr. O. N. Barlow.

" Clerical Procedure in an Engineer's Office."—Capt. T. G. Halsall.

" Some Practical Measurement Tests of Faults."—Mr. G. R. Houldsworth.

" Local Line Transmission."—Mr. W. C. Ward, B.Sc.

The papers were noteworthy for their variety and interest and the excellent discussions which they aroused.

The membership is now 28 and shows an increase of 50% on last year.

The Local Committee will endeavour to arrange an equally attractive programme for next Session and hope that the support and enthusiasm which has been shown this Session will continue. Offers of papers for the 1934-35 Session will be welcomed.

Reading Centre

On Saturday afternoon, March 10th, the Aldershot Centre of the Junior Section were invited by their Reading colleagues to join them in inspecting the equipment in the new Automatic Exchange at Reading. The way towards a profitable inspection had been paved by a paper read by a Reading member, Mr. C. F. Barnes, at the meeting held at Aldershot on March 6th. The attendance reached the splendid figure of 70, and the presence of the Sectional Engineer and his assistants was much appreciated by the members and visitors. Later the Reading staff entertained their visitors to high tea, and everyone was agreed that the afternoon had been spent in a most pleasant and instructive manner.

Book Reviews

" Electrons at Work." By Charles R. Underhill. 354 pps.; 217 illustrations. Price 18/- net. McGraw-Hill Publishing Co., Ltd. ,Aldwych House, London, W.C.2.

Electronic devices are coming into such rapidly increasing use and are fulfilling such a diversity of purposes that a book which gives a complete picture of their fundamentals and practical applications is to be welcomed by the electrical engineer, for it is not only in the realm of Communication Engineering that these devices find practical use, but also in other branches of the industry for such purposes as vehicle detection, smoke detection, examination of materials by X-rays, and many other purposes. To those who desire a general knowledge of the subject of electronics, this book can be recommended.

Fundamental quantities, beginning with the known components of matter and energy; electric potential or voltage; ions and electrolysis; charging bodies; dielectrics; condensers; magnetic and electromagnetic phenomena; oscillation; thermionic valves; gaseous-discharge lamps and tubes, and photoelectric cells, their circuits and uses; cathode-ray apparatus, invisible light, X-rays; alpha, beta, and gamma rays, cosmic rays, neutrons, positrons, deutons, and the artificial disintegration and synthesis of matter—all are treated, and their various applications to industry and biology are discussed.

The book gives a clear insight into the fundamentals of electronics as well as presenting its practical applications in a lucid manner. The text is written in a semi popular style so that it may be easily read and understood, mathematics and complex circuits being for the most part avoided. Throughout the text, principles and applications are emphasized rather than descriptions of apparatus which will inevitably be improved upon and so become obsolescent.

The book contains an excellent index which betrays evidence of great care in its preparation; the nature of the book makes this an important feature by providing easy and rapid reference to the many cognate subjects treated in the pages. W.S.P.

" The Cape Peninsula Automatic Telephone System and Trunk Exchange," by Messrs. Siemens Bros. & Co., Ltd. 274 pages + 171 diagrams and illustrations.

Under the modest title of Pamphlet No. 536A Messrs. Siemens Bros. have produced a most comprehensive and well illustrated description of the equipment they have designed and constructed for the Union of South Africa, to serve the Cape Peninsular telephone area. Commencing with general details concerning the network and conditions to be met, the pamphlet continues with particulars of the main items of apparatus supplied both at the subscribers' premises and in the exchanges, followed by sections on Trunking and Cabling; Circuit Elements; Main Circuits; Traffic Considerations; Power Plant; the Trunk Exchange, etc.

The equipment described represents in general the most modern British Post Office practice including Line Finders with partial secondary trunking, multi metering, early 3000 type relay and T.F.A. type meter, but B.P.O. practice has not been completely followed and innovations have been made in the use of a trunk train with ballast resistance feeds, automatic collection of call office fees and a fully automatic trunk board. The power plant also represents a departure from present B.P.O. standards in that a full float scheme is adopted and that Transrectors are used to charge the booster batteries.

Of these departures from British practice the most revolutionary is the use of the automatic trunk board. This is of the cordless variety and works on a principle basically similar to the sleeve control system, but with the whole of the junction and trunks terminated on the banks of switches. Special features include an improved ancillary of calling signals, call storage should all trunk lines in a group be engaged, and a facility for " camping " on a particular trunk line for cord circuit repeater purposes.

This book can be thoroughly recommended to all who wish to keep abreast of modern developments in telephone exchange design. Apart from one or two minor inaccuracies the only cause for criticism is the index, which, for a book primarily intended as a reference work, could with advantage have been made more complete.

H.L.

" Traffic and Trunking Principles in Automatic Telephony." By G. S. Berkeley, A.M.I.E.E. Ernest Benn, Ltd., 154, Fleet Street, London, E.C.4. Price 10/6 net.

Most text-books on automatic telephony are definitely devoted to apparatus and circuit descriptions, and whilst one or two have included a chapter on trunking, it can truly be said that the information given has been very meagre. Mr. Berkeley is, therefore, to be congratulated in producing a most useful and readable book, dealing solely with this important subject, which is generally supposed to be uninteresting except to those with a liking for higher mathematics.

The book has been so arranged that each of the nine chapters deals with a specific phase of the subject and is complete in itself, whilst the eleven appendices contain, amongst other things, a list of trunking terms, traffic capacity tables for different switching conditions, and notes on their use. This arrangement is a good one, and at once makes the book acceptable to the student and to the general reader who wishes to learn something of the methods adopted in designing and maintaining a service, both satisfactory to the subscriber and economic to the Administration.

The curves, and tables of the traffic capacity of trunks, used by the British Post Office have been based on the theories of Dr. Erlang, and chapters 3 and 4 of the book deal comprehensively with the full availability formula, for which a proof is given, and with the interconnecting formulæ from which the curves, relating traffic and trunks required, for Smooth and Pure Chance traffic, when the trunks are graded, have been derived. The difference between smooth and pure chance traffic is shown, and a clear explanation of the cause of smoothing given.

In Chapter 5, a typical non-director exchange is designed from assumed traffic data. In the course of the design, frequent references are made to the tables given in the appendices, thus familiarising the reader with the application of the tables.

The routing of junction traffic, especially that in director areas, is dealt with at length, and details are given of the latest phases of alternative routing, together wtih a method of making financial comparisons of the economics of the various schemes.

A chapter on traffic recording explains the use of the different traffic meters installed to maintain a continuous watch on the service, and shows how the " critical figures," with which the meter readings are compared, are obtained. The methods of taking and analysing the full and partial switch counts—which, in addition to their value in checking the grade of service, are required for statistical purposes—are given, and a reference is

(*Continued on page* 80.)

Staff Changes

POST OFFICE ENGINEERING DEPARTMENT.

PROMOTIONS.

Name.	From.	To.	Date.
Wright, A.	Assistant Superintending Engineer, London District.	Superintending Engineer, N. Midland District.	1-3-34
Partridge, T. T.	Assistant Superintending Engineer, N. Ireland District.	Superintending Engineer, N. Ireland District.	16-1-34
Hammond, G. W.	Executive Engineer, London District.	Asst. Superintending Engineer, London District.	1-3-34
Frost, P. B.	Executive Engineer, E.-in-C.O.	Asst. Staff Engineer, E.-in-C.O.	20-1-34
Gregory, H. J.	Executive Engineer, E.-in-C.O.	Asst. Staff Engineer, E.-in-C.O.	20-1-34
Marr, H. R.	Assistant Engineer, London District.	Executive Engineer, London District.	13-4-34
Rhodes, T. C.	Assistant Engineer, E. District.	Executive Engineer, E. District.	1-3-34
Carter, F. C.	Assistant Engineer, E.-in-C.O.	Executive Engineer, E.-in-C.O.	1-3-34
Prescott, J.	Assistant Engineer, London District.	Executive Engineer, London District.	1-3-34
Wallcroft, F. E.	Assistant Engineer, E.-in-C.O.	Executive Engineer, E.-in-C.O.	27-1-34
Chapman, F. B.	Assistant Engineer, E.-in-C.O.	Executive Engineer, E.-in-C.O.	27-1-34
Procter, W. S.	Assistant Engineer, E.-in-C.O.	Executive Engineer, E.-in-C.O.	27-1-34
Williams, H.	Assistant Engineer, E.-in-C.O.	Executive Engineer, E.-in-C.O.	27-1-34
Reading, J.	Assistant Engineer, E.-in-C.O.	Executive Engineer, E.-in-C.O.	27-1-34
Speight, E. A.	Inspector, E.-in-C.O.	Assistant Engineer, E.-in-C.O.	23-1-34
Stewart, J. F.	Repeater Officer, Class II., Scot. E. District.	Repeater Officer, Class I., N. Wales District.	To be fixed later.
Partington, H. J.	Inspector, S. Lancs. District.	Chief Inspector, S. Lancs. District.	1-2-34
Roe, W. D. A.	Inspector, London District.	Chief Inspector, London District.	1-3-34
Tomkin, J.	Inspector, N. Wales District.	Chief Inspector, N. Mid. District.	27-1-34
Standing, F.	Inspector, Testing Branch.	Chief Inpector, Testing Branch.	26-10-33
Morris, G.	Inspector, S. Lancs. District.	Chief Inspector, S. Lancs. District.	13-2-34
Beaumont, H. R.	Inspector, N.E. District.	Chief Inspector, N. Mid. District.	8-2-34
Cook, A.	Inspector, N. District.	Chief Inspector, N. District.	5-2-34
Tregilgas, A. St. C.	Inspector, S.E. District.	Chief Inspector, London District.	1-3-34
Levens, T. F.	Inspector, Scot. E. District.	Chief Inspector, Scot. E. District.	28-1-34
Tiley, A. E.	Inspector, N. Wales District.	Chief Inspector, S. Wales District.	11-2-34
Barnard, A. G. E.	Inspector, S.E. District.	Chief Inspector, S.E. District.	27-1-34
Hubbard, W. J.	Inspector, London District.	Chief Inspector, London District.	16-3-34
Jones, C. J.	Inspector, E. District.	Chief Inspector, N.E. District.	14-1-34
Riley, C.	Inspector, E.-in-C.O.	Chief Inspector, E.-in-C.O.	4-10-33
Woodhead, H. C.	Inspector, Rugby Radio.	Chief Inpector, Leafield Radio.	5-2-34
Tonkinson, G.	Inspector, N. Wales District.	Chief Inspector, S. Lancs. District.	1-3-34
Young, J. E.	Inspector, London District.	Chief Inspector, London District.	6-9-32
Drysdale, T. W.	S.W.I., Scot. West District.	Inspector, Scot. West District.	25-12-33
Corkill, G. H.	S.W.I., S. Lancs. District.	Inspector, S. Lancs. District.	1-9-32
Blower, G. A.	S.W.I., E.-in-C.O.	Inspector, E.-in-C.O.	1-10-33
Shipley, F. H.	S.W.I., E.-in-C.O.	Inspector, E.-in-C.O.	22-4-33
Harbord, E. G.	S.W.I., E.-in-C.O.	Inspector, E.-in-C.O.	8-8-33
Padgham, F. V.	S.W.I., E.-in-C.O.	Inspector, E.-in-C.O.	4-11-33
Emery, E. A.	S.W.II., E.-in-C.O.	Inspector, E.-in-C.O.	1-5-32
Stovold, A. T.	S.W.II., E.-in-C.O.	Inspector, E.-in-C.O.	7-3-32
Brown, J.	S.W.I., Scot. West District.	Inspector, Scot. West District.	29-11-33
Jones, R. A.	S.W.I., N. Wales District.	Inspector, N. Wales District.	6-1-34
Muir, W. W.	S.W.I., Scot. West District.	Inspector, Scot. West District.	24-12-33
Everson, W. E.	S.W.I., Eastern District.	Inspector, Eastern District.	15-1-34
Bennett, G. M.	S.W.I., Scot. East District.	Inspector, Scot. East District.	28-1-34
Forrester, D. S.	S.W.I., Scot. East District.	Inspector, Scot. East District.	28-1-34
Davidson, W. B.	S.W.I., Scot. East District.	Inspector, Scot. East District.	17-3-33
Levy, B. J.	S.W.I., N. Ireland District.	Inspector, N. Ireland District.	11-10-33
Jenkins, J. D.	S.W.I., N. Ireland District.	Inspector, N. Ireland District.	23-10-33
Bevan, J.	S.W.I., London District.	Inspector, London District.	27-1-34
Orman, F. H.	S.W.I., London District.	Inspector, London District.	21-10-33
James, G. E. C.	S.W.I., S. Mid. District.	Inspector, S. Mid. District.	30-11-33
Grogan, A.	S.W.I., Scot. West District.	Inspector, Scot. West District.	3-12-33
Peverett, E. A.	S.W.I., Eastern District.	Inspector, Eastern District.	To be fixed later.
Butters, W.	S.W.I., Eastern District.	Inspector, Eastern District.	14-1-34
Macdonald, A.	S.W.I., Eastern District.	Inspector, Eastern District.	16-2-34
Townsend, F. T. G.	S.W.I., Eastern District.	Inspector, Eastern District.	8-1-34
Drew, L. C.	S.W.I., Eastern District.	Inspector, Eastern District.	9-8-33
Body, G. E. H.	S.W.I., S. West District.	Inspector, S. West District.	18-2-34
Walker, E. V.	S.W.I., E.-in-C.O.	Inspector, E.-in-C.O.	7-11-33
Mackenzie, T. G.	S.W.II., N. Ireland District.	Inspector, N. Ireland District.	12-11-33

Promotions.

Name.	From	To	Date.
Stevens, H. F.	S.W.I., N. Wales District.	Inspector, N. Wales District.	4-10-33
Draper, T. G.	S.W.I., N. Wales District.	Inspector, N. Wales District.	1-9-33
Taylor, H. G.	S.W.I., E.-in-C.O.	Inspector, E.-in-C.O.	24-1-34
Abel, G. P.	S.W.I., E.-in-C.O.	Inspector, E.-in-C.O.	To be fixed later.
Blewitt, E.	S.W.I., S. Wales District.	Inspector, S. Wales District.	To be fixed later.
Marshall, E. H.	S.W.I., N. Mid. District.	Inspector, N. Mid. District.	To be fixed later.
Vigar, W. H.	Draughtsman, Cl. II., E.-in-C.O.	Draughtsman, Cl. I., E.-in-C.O.	1-1-34
Parsons, C. W.	Draughtsman, S. Mid. District.	Draughtsman, S. Midland District.	1-1-34

Appointments.

Name.	From	To	Date.
Chapman, R. H.	Probationary Assistant Engineer.	Assistant Engineer, E.-in-C.O.	1-1-34
Duff, J.	Probationary Assistant Engineer.	Assistant Engineer, Northern Dist.	1-1-34
Greening, F. C. G.	Probationary Assistant Engineer.	Assistant Engineer, London District.	1-1-34
Ward, W. C.	Probationary Assistant Engineer.	Assistant Engineer, N. West Dist.	1-1-34
Porter, J. E.	Probationary Assistant Engineer.	Assistant Engineer, S. Mid. Dist.	1-1-34
Gill, C. J.	Probationary Assistant Engineer.	Assistant Engineer, S. Wales Dist.	1-1-34
Gill, F. W.	Probationary Assistant Engineer.	Assistant Engineer, S. Wales Dist.	1-1-34
Hall, L. L.	Probationary Assistant Engineer.	Assistant Engineer, E.-in-C.O.	1-1-34
Thorn, D. A.	Probationary Assistant Engineer.	Assistant Engineer, E.-in-C.O.	1-1-34
Lemmey, C. W.	Probationary Assistant Engineer.	Assistant Engineer, N. East Dist.	1-1-34
Summers, F.	Probationary Assistant Engineer.	Assistant Engineer, S. Wales Dist.	1-1-34
Leckenby, A. J.	Probationary Assistant Engineer.	Assistant Engineer, Testing Branch.	1-1-34
Hayes, H. C. S.	Probationary Assistant Engineer.	Assistant Engineer, S. Lancs. Dist.	1-1-34
Hough, F. A.	Probationary Assistant Engineer.	Assistant Engineer, Scot. East Dist.	1-1-34
Beastall, J. G.	Probationary Assistant Engineer.	Assistant Engineer, S. Lancs. Dist.	1-1-34
Stanton, E. P.	Probationary Assistant Engineer.	Assistant Engineer, E.-in-C.O.	1-1-34
Hadfield, B. M.	Probationary Assistant Engineer.	Assistant Engineer, E.-in-C.O.	1-1-34
Angus, J. L.	Probationary Assistant Engineer.	Assistant Engineer, Scot. West Dist.	1-1-34
Hamilton, R. N.	Probationary Assistant Engineer.	Assistant Engineer, Eastern District.	1-1-34
Swindlehurst, R. J. K.	Probationary Assistant Engineer.	Assistant Engineer, E.-in-C.O.	1-1-34
Salt, R. S.	Probationary Assistant Engineer.	Assistant Engineer, London District.	1-1-34
Collings, E. R.	Unestablished Draughtsman.	Draughtsman, Cl. II., E.-in-C.O.	27-12-33
Bagust, F. C. T.	Unestablished Draughtsman.	Draughtsman, Cl. II., E.-in-C.O.	10-1-34
Eakin, G. W. A.	Unestablished Draughtsman.	Draughtsman, Cl. II., E.-in-C.O.	15-1-34
Dowding, G. W.	Unestablished Draughtsman.	Draughtsman, Cl. II., E.-in-C.O.	7-2-34
Stagg, G. A.	Unestablished Draughtsman.	Draughtsman, Cl. II., E.-in-C.O.	19-2-34
Ealey, S. J.	Unestablished Draughtsman.	Draughtsman, Cl. II., London Dist.	21-12-33
Lee, E.	Unestablished Draughtsman.	Draughtsman, Cl. II., S.W. Dist.	4-2-34
Evans, S. A.	Unestablished Draughtsman.	Draughtsman, Cl. II., London Dist.	5-2-34
Blackwell, C. F.	Unestablished Draughtsman.	Draughtsman, Cl. II., London Dist.	1-3-34
Galloway, F.	Unestablished Draughtsman.	Draughtsman, Cl. II., London Dist.	3-3-34

Retirements.

Name.	Rank.	District.	Date.
Gilbert, A. B.	Superintending Engineer.	N. Midland.	28-2-34
Bartholomew, S. C.	Assistant Staff Engineer.	E.-in-C.O.	31-12-33
Harris, E. C.	Executive Engineer.	S. Midland.	31-12-33
Jarrett, E. J.	Executive Engineer.	Northern.	31-12-33
Peacock, C. T.	Executive Engineer.	E.-in-C.O.	28-2-34
Smith, D. McE.	Executive Engineer.	Eastern.	28-2-34
Hodgetts, W. J.	Assistant Engineer.	S. Wales.	31-1-34
Dalgity, W. J.	Chief Inspector.	Eastern.	31-12-33
Campbell, W. L.	Chief Inspector.	Scot. East.	31-12-33
Etherington, C.	Chief Inspector.	Eastern.	31-12-33
Hutchings, W. G.	Chief Inspector.	S. Lancs.	31-12-33
Weightman, W.	Chief Inspector.	S. Lancs.	4-2-34
Humphriss, P. W.	Chief Inspector.	S. West.	9-12-33
Whittle, J. G.	Chief Inspector.	S. Lancs.	31-1-34
Johnson, J. H.	Chief Inspector.	London.	28-2-34
Donovan, P. W.	Chief Inspector.	London.	28-2-34
Sutton, J.	Chief Inspector.	London.	15-3-34
Pittman, G. S.	Repeater Officer, Class I.	N. Wales.	28-2-34
Stevens, W. H.	Inspector.	S. Wales.	18-2-34
Stacey, W. H.	Inspector.	Eastern.	15-2-34
Evans, T. W.	Inspector.	London.	31-1-34

Retirements.

Name.	Rank.	District.	Date.
Waters, B.	Inspector.	Eastern.	3-1-34
Hacker, W.	Inspector.	S. Lancs.	31-12-33
Jones, W.	Inspector.	S. Lancs.	31-12-33
Crispin, W. J.	Inspector.	London.	31-12-33
Wilson, J.	Inspector.	S. Lancs.	31-12-33
Copland, J. L.	Inspector.	Scot. West.	23-12-33
Wenman, G. A.	Inspector.	London.	31-12-33
Wood, J.	Inspector.	Scot. East.	31-12-33
Bridle, A. W.	Inspector.	S. East.	11-12-33
Trezise, W. H.	Inspector.	N. Eastern.	31-12-33
Wood, C.	Inspector.	N. Eastern.	31-12-33
Wood, S.	Inspector.	N. Wales.	31-12-33
Lucena, H. J.	Inspector.	N. Wales.	31-12-33
Denham, P. R.	Draughtsman, Cl. I.	S. Mid.	31-12-33
Fisher, T.	Draughtsman, Cl. I.	E.-in-C.O.	31-12-33

Transfers.

Name.	Rank.	From	To	Date.
Owen, J. Mc A.	Assistant Engineer.	E.-in-C.O.	N. Midland Dist.	18-2-34
Bryant, G. H.	Assistant Engineer.	N. Midland Dist.	S. Eastern Dist.	1-3-34
Markey, J. M.	Assistant Engineer.	E.-in-C.O.	Northern Dist.	4-3-34

Deaths.

Name.	Rank.	District.	Date.
Wilkie, E. D.	Assistant Engineer.	Northern.	4-2-34
Byrne, W. G.	Inspector.	London.	23-2-34
Viersen, F.	Inspector.	S. East.	17-1-34
Crome, F. T.	Inspector.	E.-in-C.O.	23-1-34
Blyth, F. J. P.	Inspector.	N. Midland.	14-2-34
Strange, A.	Inspector.	S. Eastern.	21-2-34
Mac Farlane, A. E.	Inspector.	London.	25-12-33

CLERICAL GRADES.

Promotions.

Name.	From.	To.	Date.
Evans, G. A. G.	Clerical Officer, S. West. Dist.	Higher Clerical Officer, N. West Dist.	1-1-34
Waller, G. J.	Clerical Officer, Eastern Dist.	Higher Clerical Officer, Eastern Dist.	1-2-34
Ellison, R. F.	Clerical Officer, N. Mid. Dist.	Higher Clerical Officer, Ire. N. Dist.	27-2-34
Pine, T. F.	Clerical Officer, S. Mid. Dist.	Acting Higher Clerical Offier, Eastern District.	4-3-34
Strawson, H.	Clerical Officer, Lnd. Eng. Dist.	Higher Clerical Officer, London District.	9-2-34
Martin, H. E.	Actg. Staff Officer, E.-in-C.O.	Staff Officer, E.-in-C.O.	2-2-34
Bishop, H. G.	Executive Officer, E.-in-C.O.	Acting Staff Officer, E.-in-C.O.	2-2-34
Harrison, A. E.	Actg. Executive Officer, E.-in-C.O.	Executive Officer, E.-in-C.O.	2-2-34
Hughes, J.	Actg. Executive Officer, E.-in-C.O.	Executive Officer, E.-in-C.O.	2-2-34
Glover, G.	Clerical Officer, E.-in-C.O.	Actg. Executive Officer, E.-in-C.O.	2-2-34
Smith, G. S.	Clerical Officer, E.-in-C.O.	Actg. Executive Officer, E.-in-C.O.	2-2-34

Retirement.

Eginton, A. F. ... ... Higher Clerical Officer, Ldn. Eng. Dist.—Retired 8-2-34.

Transfer.

Fryer, G. Y. ... ... Higher Clerical Office, Eastern to N. Eastern Dist.—8-2-34.

Decease.

Knapman, W. C. ... ... Higher Clerical Officer, Ldn. Eng. Dist.—Deceased, 10-2-34.

Reversion.

Kimber, E. J. ... ... Higher Clerical Officer, Eastern Dist.—Reverted to Clerical Officer, Eastern Dist. 1-2-34.

Copyright

The Board of Editors is not responsible for the statements made nor the opinions expressed in any of the articles in this Journal, unless such statement is made specifically by the Board.

Communications

All Communications should be addressed to the Managing Editor, *P.O.E.E. Journal,* Engineer-in Chief's Office, Alder House, Aldersgate Street, London, E.C.1. Telephone: NATional 3440. Remittances should be made payable to "*The P.O.E.E. Journal*" and should be crossed "& Co."

Binding Cases

Binding cases and copies of the Contents for Vols. 3 to 26 are available, and may be obtained from the Local Agents for 1s. 9d. Subscribers can have their copies of Volumes bound, with index included, at a cost of 3s., by sending the complete sets of parts to the Local Agents or to the Publishers. Orders for binding for Vols. 1-19 should indicate whether the original binding case with black lettering, or the later pattern with gold, is required. Cases with gold lettering will be the only type stocked from Vol. 20 onwards.

Back Numbers

The price of the Journal, which is published quarterly, is 1s. (1s. 3d. post free) per copy, or 5s. per annum post free. Back numbers can be supplied, subject to availability of stocks, at 1s. each (1s. 3d. post free). Orders for back numbers may be sent to the Local Agents or to the Publishers.

Advertisements

All communications relating to space reservations should be addressed to the Advertisement Editor, *P.O.E.E. Journal,* Alder House, Aldersgate Street, London, E.C.1. Communications regarding advertisement copy, proofs, etc., should be addressed to the Publishers, Messrs. BIRCH & WHITTINGTON, 10, Station Road, Epsom, Surrey.

BOOK REVIEWS—(*Continued from page* 76).

made to the automatic traffic recorder which is shortly to be installed.

The recent developments in line finding schemes, both with partial secondary and full secondary working, and the new common control Strowger 30-C, and 30-CD, Siemens No. 17, and Bypath systems are described; the effect of the artificial traffic produced by the controls and bypaths on the selectors being treated mathematically.

The final chapter describes a method of checking traffic capacity tables which are obtained theoretically, by clerical means using imaginary calls with pure chance starting times. It also discusses the problem of delays, and quotes formulæ used for estimating the proportion of calls likely to be delayed under certain conditions.

A special feature of the work is the references made at the end of each chapter to articles on the subject matter, thus giving readers who wish to pursue the particular subject, further sources of information.

The book covers the trunking portion of the syllabus of the City and Guilds Final examination in automatic telephony, and students proposing to take this examination will find the questions set after each chapter of great assistance. Many of these have been taken from past papers, answers being appended to those questions involving calculations.

A foreword by Mr. G. F. O'dell—well known for his articles and papers on trunking work—" commends the book to all who wish to study an important subject."

The book is well produced, the diagrams and illustrations being particularly clear, and it can be thoroughly recommended to all those concerned with automatic telephony.

W.W.G.