THE Post Office Electrical Engineers' Journal

# Modernizing the Telegraph Service

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CONSIDERABLE changes are taking place in the type of apparatus used, the lay-out, and also the general appearance of Telegraph Instrument Rooms as a result of the adoption of the American Report on the British Telegraph Service, (known as the " Simon " report) and also on the success of an initial experiment at Leeds Head Post Office.

There are several causes which account for these changing conditions :—

(*a*) The *spoken* word is in many cases more convenient than the *written* word, and the widespread use of the telephone service has naturally had a serious effect upon the amount of telegraph traffic handled; a progressive reduction in transmissions year by year is undoubtedly attributable to this cause.

(*b*) Phonogram working has greatly extended in recent years, as a result of the facilities provided to subscribers by an expanding telephone service. This feature has also reduced the amount of work done by expert telegraphists.

(*c*) " Telephone - Telegram - Typewriter " circuits, working through a central office fitted with a concentrator switching system, have replaced the Morse concentrator, which was formerly employed on this work.

(*d*) The industrial depression has seriously affected the number of telegrams transmitted;—a boom in trade is usually reflected in an increase in the number of telegraphic transactions.

In view of the throwing spare of a large quantity of telegraph apparatus from the causes referred to above, and also for other very good reasons, the present time has been regarded as an opportune one for a thorough-going re-organization of the telegraph service.

There has been a widespread change in telegraph technique in recent years. The craftmanship of the telegraphists of Morse and Wheatstone days is passing away; indeed, it must be admitted, with a certain degree of sadness, that skilled craftsmen of the old school are no longer necessary. It is a matter of keen regret to those who have a " pride in their calling " to witness the passing away of high-speed Wheatstone and multiplex apparatus.

To-day the Teleprinter holds pride of place. It is an extremely flexible instrument in relation to traffic loads and, during busy periods, considerably more than 100 messages have been dealt with by one operator in an hour. All telegraph offices which deal with traffic amounting to 150 messages a day or over, are being equipped with Teleprinters;—those offices with totals below 150 messages in a day will most probably be associated with a " Telephone-telegram-typewriter " switching system in the near future.

An important feature in the Teleprinter is that touch typing on a standard typewriter key-board produces much less strain or fatigue on the operator than does the older forms of apparatus.

Perhaps the outstanding feature of the re-organization of the Instrument Room is the segregation of line terminal apparatus on to panels, leaving only the Teleprinter with its associated switches on the operating table. Double tables of a new type have replaced the heavy mahogany furniture which has been in use for generations. The operators face each other at these double tables and a recess between the halves of the table gives access to a Vee-conveyor band, which conveys the messages to the sorting tables. Experiments are being made with other forms of conveyors in order to distribute the traffic to the different circuits and further developments in this direction may mature in the near future.

These changes in lay-out have had the effect of reducing the amount of space required. The new model instrument room will be a compact, business-like arrangement and there is little doubt that greater efficiency to the Service will result, whilst in addition both operating and supervising costs will be reduced.

A further important alteration has been authorized in connexion with the day-to-day maintenance of telegraph apparatus at Post Offices; a change in practice which must be regarded as revolutionary. Up to the present it has been the rule to employ both engineering workmen and traffic staff in the larger telegraph instrument rooms, and each group performed certain well-defined aspects of maintenance work. It has recently been decided to terminate this arrangement of dual responsibility for the day-to-day maintenance of working apparatus, also the avoidance of dual control of staff employed in instrument rooms. The principle underlying the new scheme is that the staff concerned with all testing and maintenance work shall be borne on one establishment. The day-to-day maintenance of telegraph apparatus at all large offices is therefore being handed over to a " Testing and Maintenance staff " consisting of Telegraphists, and Sorting Clerks and Telegraphists, who are being specially trained for the work.

In dealing with a change in organization of this magnitude, it has been necessary to have due regard to the staffs concerned, both on the traffic and engineering sides, and to make such arrangements as will obtain the best results, alike to the Administration and to the Staff. As a result of the introduction of the new scheme, a small number of mechanics will be displaced on the engineering side by traffic officers, but redundancy will be avoided because of the introduction of a regular scheme of overhaul of Teleprinters, also the development of Teleprinter private wire and Teleprinter exchange services.

The new testing and maintenance scheme is concerned with the apparatus in instrument rooms functionally associated with the actual transmission or reception of a telegram, including the day-to-day maintenance of Teleprinters, Baudot, Wheatstone, and Morse apparatus, also line testing and telegraph repeater work. The daily cleaning, oiling, adjusting, and balancing of apparatus will be undertaken by the testing and maintenance staff, whilst the replacement of certain simple parts, such as springs in Teleprinter apparatus, is also included in the scheme.

It is the intention to place the traffic staff in full control of the apparatus while it remains in the instrument room, and to ensure that all adjustments, maintenance, and repair work which can be undertaken without removing the faulty instrument to the mechanics shop, shall be so dealt with by the T. and M. Officer. The scheme at present applies to the Central Telegraph Office, (Inland Galleries), also to approximately 70 Provincial Offices. The work is being assigned to a selected staff; before these officers can apply for the new posts they must be in possession of certain technical certificates in Telegraphy, etc. The officers' names are recorded as suitable for the testing and maintenance duties, and their names forwarded to an examiner, who is an engineering officer on the Headquarters staff. The applicants are called up in order of seniority for interview by the examiner, who ascertains by means of an oral and practical test whether the candidate has an up-to-date knowledge of the functions and working of the apparatus and instruments in use at his office; whether he can apply that knowledge under working conditions, and also whether he possesses aptitude for practical testing and maintenance work.

A Training School for testing and maintenance officers has been established on the fourth floor of the G.P.O. (West) in London and the school has been in practically continuous session since February of this year. The school is organized and staffed by the Telegraph Section of the Engineer-in-Chief's Office, and 30 officers are being trained during each course, which lasts for approximately five weeks. A synopsis of the scheme of training is shown below :—

*Section 1.*
- (*a*) Test Boards, Testing operations, Power Supply.
- (*b*) Morse and Wheatstone systems (including Creed Receiver and Printer).
- (*c*) Duplex balancing, Repeaters, Speed trials.
- (*d*) Typewriter adjustments.
- (*e*) Gumming equipment.

*Section 2.*
Teleprinters.
- (*a*) Mechanism.
- (*b*) Connexions.
- (*c*) Adjustments.
- (*d*) Faults.

*Section 3.*
- (*a*) Superposing methods.
- (*b*) Composited circuits.
- (*c*) Voice Frequency circuits.

*Section 4.* (At Offices where multiplex apparatus is still in use).
Baudot Multiplex working.
- (*a*) Cleaning and adjustment.
- (*b*) Morning overhaul.
- (*c*) Tests of Governors, Moderators, Perforators, Transmitters, Receivers, Distributors.
- (*d*) Three-Station Working, Re-Transmitters.

The training scheme has been designed to ensure that each candidate will receive expert tuition by engineering officers in all branches of testing and maintenance work. Provision has also been made in the scheme for the employment of both men and women on these duties.

The candidates who attend the Training Course are given as much practical work as is possible. It is expected of them before they start the course that they are equipped with a certain amount of theoretical knowledge; the possession of technical certificates and subsequent study are indications of this. The course of training is devoted almost entirely to the practical side of the work; to the correct method of using tools, the diagnosis, tracing and removal of faults in apparatus, and the exact localization of faults in lines. Every effort is made to give the candidate opportunities of displaying his powers of initiative and resource, and to encourage the development of a full sense of responsibility.

As may be expected from the way in which the development of present day telegraphy is proceeding, a large proportion of the work of the course is directed to the efficient maintenance of Teleprinter apparatus. In this connexion it may be noted that circuits have been set up to reproduce working conditions in all cases. Panel mounting apparatus is installed, representing the conditions at an important telegraph centre working to offices which are provided with apparatus where the balancing and adjusting sections are fitted on the table.

A view of the Teleprinter room at the Training School is shown in the Figure.

The candidates spend 15 days in the Teleprinter section of the school and then pass to a section fitted with panel-mounted apparatus, power distributing points and switches, test boards and testing appliances, telegraph repeaters, and Baudot apparatus of the manual and automatic type. Two lectures are given each day; these are recorded by the students, who also make a full record of experiments, demonstrations, and inspections carried out during the session. Each student is supplied with a full set of diagrams covering the work done, and technical pamphlets have been drawn up dealing with the newest systems of telegraphy which are now being introduced by the Post Office. This is a departure from earlier methods, where such information had formerly to be obtained from published works. A feature of the school, which it is anticipated will be productive of good results, is the merging of the staffs from the different large telegraph centres. Men from Belfast, Edinburgh, Cardiff, and London meet as members of a comprehensive scheme and obtain a new view-point in regard to the problems outside their own particular zone. The consequence is that when these students return to their own office there will be a generous measure of co-operation and mutual understanding.

Sectional and final examinations are held at the school and Postmasters are advised of the results of the final or passing-out tests. Successful candidates are then placed on probation at their own Office for three months, and during that period they are given full time duty on testing and maintenance work. If a satisfactory report is furnished at the end of the probationary period, the officers are allotted to the position of T. and M. Officer and are subject to a yearly efficiency review.

TRAINING SCHOOL FOR TESTING AND MAINTENANCE OFFICERS: VIEW OF TELEPRINTER ROOM.

Judging by the general high standard of ability, and the practical aptitude of students who have attended the training course up to the present time, there is every reason to believe that the new scheme will prove a conspicuous success.

# The Balancing and Loading of the Northern Underground Telegraph Cable

N. F. SEPHTON, A.M.I.E.E.

*Synopsis.*

DESCRIBES the balancing (by a method not previously used in this country) and the loading of approximately 200 miles of the historic Northern Underground telegraph cable. Discusses the electrical characteristics of the first long-distance telephone circuits to be worked in this cable, which, originally intended as a composite telephone and telegraph cable, has been used for telegraph circuits since it was laid over a quarter of a century ago.

*Descriptive.*

The Preston-Glasgow link in the Northern Underground cable system was laid between 1903 and 1905. The cable is composed of 28—100 lb. multiple twin pairs, 6—150 lb. worming pairs and 29—70 lb. single screened conductors. The multiple twinning has been carried a stage further than is usual in modern multiple twin construction in that two, two-pair M.T. cores are twinned to form a four-pair unit. One such unit forms the centre of the cable, and six similar units are laid up round this centre. The six worming pairs are accommodated in the spaces between the six M.T. units and the cable is completed by an outer layer of 29 single wires each screened with a spirally wound copper tape which is in contact with the lead sheath. The cross-section of the cable is shown in Fig. 1 and the make up of a four-pair unit in Fig. 2.

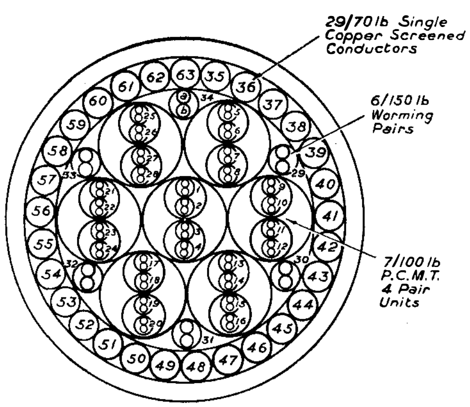


FIG. 1.—CROSS SECTION OF THE NORTHERN UNDERGROUND CABLE.

There seems little doubt that the designer intended the cable to be used for both telegraph and telephone purposes, and the multiple twin formation indicates that some idea of superimposing, as well as the paralleling of pairs to form circuits of higher conductivity, was also in mind. The writer has had access to a manuscript instruction written in 1904, which bears out this suggestion. The cable was unsuitable, however, for commercial telephone service in its existing condition, and, with the exception of a few pairs used for a time as short telephone junctions between Glasgow and Hamilton, the cable was used solely for telegraph circuits.

Within recent years the need for an underground telephone cable up the west coast, as an alternative to the east coast route, became more and more evident. The extension of the London-Liverpool cable northwards to Glasgow would have provided this alternative route, but the postponement of this work rendered necessary the consideration of other means of providing additional circuits. Towards the end of 1931, therefore, the balancing and loading of the 28 M.T. pairs in the old telegraph cable (a scheme which had been discussed at various times) became a matter for practical consideration in order to provide circuits suitable for four-wire working, with repeaters at Preston, Carlisle and Glasgow.

The cable is laid in a $3\frac{3}{4}''$ cast iron pipe and buried split couplings are used generally to protect the joints. For this reason, it was desirable in the interests of economy to adopt a scheme which would involve as little excavation and constructional work as possible. This was effected by—

(i) Balancing by a method which necessitated the opening of only one joint per loading section.
(ii) Installing the loading coils as far apart as possible, and
(iii) Burying the loading coil cases and balancing tail cables directly in the ground.

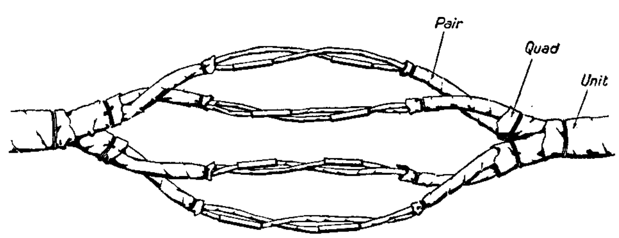


FIG. 2.—MAKE-UP OF FOUR-PAIR UNIT.

It may be pointed out here, that the three points enumerated are the most interesting features of the work, and while it does not necessarily follow that a similar procedure would be desirable in new work, it shows how the problem of modernizing a thirty-year old cable was tackled and solved in an economical manner.

*Loading.*

On account of the heavy gauge of conductor (100 lb. per mile), and the low wire to wire capacity (0.056 microfarads per mile) involved, only very light loading was required. The added inductance is 4.5 millihenries per mile, and it was possible, therefore, to provide circuits which would transmit effectively up to about 3,300 p.p.s. with coils spaced at approximately 5-mile intervals, a very much longer spacing than has been used previously for telephone circuits in this country. In order that the length of the end sections might in all cases be equal to half that of a normal loading section, the actual spacing was adjusted slightly for each repeater section. Thus the Preston-Carlisle repeater section which is 87.39 miles in length is loaded at 18 points with normal spacing of 4.885 miles, and the Carlisle-Glasgow repeater section which is 96.18 miles in length, has 20 loading points with normal spacing of 4.809 miles.

*Capacity Balancing.*

Reference has already been made to the multiple twinning being carried a stage further than in modern practice. For convenience, each two pairs which are twinned together will be referred to as a " quad " and the two " quads " which are twinned will be referred to as a " unit."

Consideration of the make-up of the cable supported by preliminary cross-talk measurements showed that for four-wire working, it would be advantageous to use the two pairs of a quad to form the " Go " and " Return " paths of the same circuit. Under such conditions the side to side cross-talk can be neglected, provided that it is not sufficient to affect the stability of the repeaters. Any resultant side tone is negligible compared with the side tone present in the standard type of subscribers' apparatus. Further, as the capacity couplings between pairs in different quads are small, it was unlikely that there would be any appreciable inter-unit cross-talk. The balancing problem was therefore resolved into that of controlling the cross-talk between pairs in the same unit, but not in the same quad. This is referred to later as the pair to pair, within unit, cross-talk.

Each loading section was balanced in the following manner. A joint (as near the centre of the loading section as possible) was opened. The 28 pairs (after being numbered out for identification purposes later) were cut, and the side to side and pair to pair capacity unbalances of each four-pair unit measured, on both sides. The joint was then selected to give the greatest overall reduction of pair to pair (within unit) capacity unbalance by crossing units, quads, pairs, or wires. That is to say, any complete four-pair unit was chosen to be jointed to the most suitable complete four-pair unit on the other half section, and then within the unit, quads, pair of quads, and wires of pairs, were crossed as desired, care being taken of course to see that no units, quads or pairs were split. By this means it was possible to reduce all four pair to pair (within unit) capacity unbalances considerably, but not generally to within the limits to which it was desired to work. For the final capacity unbalance adjustment small condensers in the form of cable pairs or " tails " were added.

In the original scheme it was not intended to measure the side to side, within quad, capacity unbalances since cross-talk between these two pairs would not prevent satisfactory four-wire working on that quad unless it was of an extremely high order. In practice, however, these values were measured and in the few cases where they were excessive they were reduced by crosses. The result of the little extra care is clearly shown in the overall results, the side to side cross-talk being very much better than was anticipated.

The capacity unbalances between pairs in separate units were measured on a few loading sections, but, as would be expected, these were of a very low order and it was not considered necessary to continue these measurements on the remainder of the sections, although occasional measurements were made during the testing of groups of loading sections.

It was decided that the following limits should be adhered to in respect of the pair to pair (within unit) capacity unbalance :—

(*a*) For the half section and the first three full loading sections from a Repeater Station, 100 micro-micro-farads.

(*b*) For the fifth, sixth, seventh, and eighth loading sections from a Repeater Section, 150 micro-micro-farads.

(*c*) For the ninth loading section from a Repeater Station to the centre loading section of the Repeater Section, 250 micro-micro-farads.

Actually, after a little experience had been gained on the first few loading sections, it was found that a somewhat higher standard of balance could be maintained.

*Balancing and Loading Equipment.*

(i) *Capacity " Tail " Cables.* The capacity tail cables consist of 5-foot lengths of 300 pr. 20 lb. A.S.P.C. Twin, lead-covered cable. Before the commencement of the work on site, these tail cables had been prepared in the following manner: All the wires at one end were insulated by means of paper sleeves, the layers being stepped or tapered in the usual manner. Lead cap-ends were then plumbed on. After the cables had been pressure tested, and tested for insulation resistance, the cable sheath was sprayed with bitumen, bound with 1" linen tape, and again painted with bitumen. A length of steel flexible tubing, with a brass collar at each end, was slipped over the cable sheath, and the space between the sheath and the tubing filled with bitumen. The outside of the tubing was also coated with bitumen. After delivery at the centre joint and prior to commencing jointing operations a cast iron casing was fitted over the cap-end and clamped to the underside of the existing cast iron pipe by means of mild steel straps. See Fig. **3**.

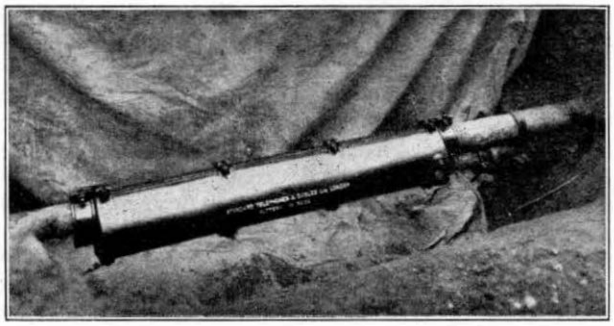

Fig. 3.—Protection Box and Tail Cable in Position at Balancing Joint.

The tail cable was then laid along under the main cable so that the open end was in a position for the pairs to be teed-in at the balancing joint as required. The capacity of each pair is about 45 micro-micro-farads, and pairs were connected in parallel, as required, to give higher values. All the pairs in the tail cable which were not used as balancing capacities were connected to the sheath, and it was arranged to use these earthed pairs as screens between separate sets of pairs used as balancing condensers.

(ii) *Loading Equipment*. Each loading coil case contains twenty-eight side circuit loading coils of 22 millihenries inductance. To effect the necessary segregation for four-wire circuit operation, the coils are mounted on two separate dowels, with fourteen coils on each dowel. All the auxiliary wiring within the coil case is screened. A single stub cable, of 60 pr. 40 lb. P.C. Quad type, is provided, and in order to maintain the group separation, quads 1—14 are used for the "Go" paths, and quads 15—28 for the "Return" paths, the remaining quads 29—30 being left spare. The connexions to the coils are made between quads, that is to say, the two pairs of one quad in the stub cable are connected through two coils to the corresponding pairs of the next quad in the stub cable. Thus, the AB pairs of quads 1, 3, 5, 7, etc., of the stub cable each pass through a coil and thence to the AB pairs of quads 2, 4, 6, 8, etc., respectively. The CD pairs of the quads are dealt with in a similar manner. At the main joint, the pairs of each quad in the main cable on the Preston side are connected to pairs in odd-numbered quads in the stub cable, and the pairs of the corresponding main cable quads on the Glasgow side are connected to pairs in adjacent even-numbered quads in the stub cable. Whereas, however, the AB pairs in the main cable pass in and out of the coil case *via* one of the quads numbered 1—14 in the stub cable, the CD pairs pass in and out *via* one of the quads numbered 15—28 in the stub cable, Fig. **4**.

The loading coil cases are buried in the

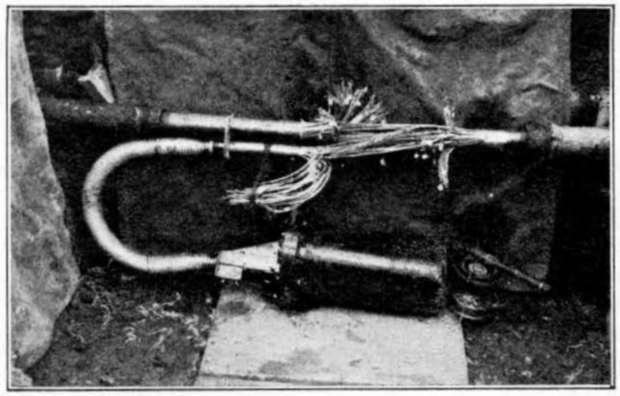

Fig. 4.—Loading Joint Partly Made.

earth directly under the main cable, but in order to prevent them from sinking, a large concrete slab 3 ft. by 2 ft. by 3 inches thick has been placed under each case. Where it appeared necessary to afford still further protection against possible subsidence, the ground below the slab was packed with stones. The stub cables are armoured in a similar manner to the capacity tail cables, one end of the flexible tubing being clamped to the top surface of a specially strengthened supporting bracket on the coil case, by means of bolts which pass through a flange fitted to the tubing. The other end of the tubing was clamped rigidly to the main pipe line by the joint protection box, when the latter was fitted in position, after the stub cable had been jointed into the main cable. (Fig. **5**.) These cast iron protection boxes, which are really very large split couplings of special design, have been used to enclose the completed balancing and loading joints. Fig. **3** will render a further description unnecessary.

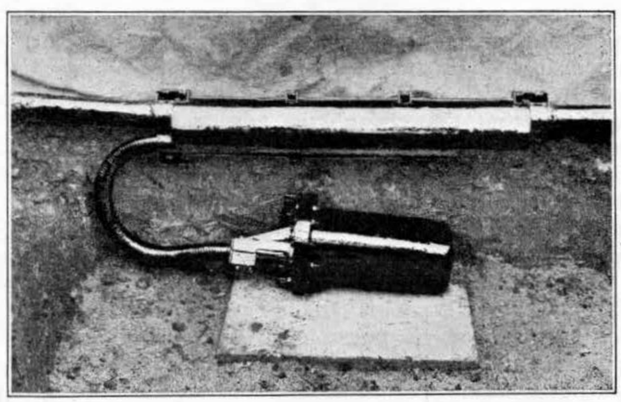

Fig. 5.—Loading Coil Case and Protection Box in Position.

In places where there was a possibility of damage to either a balancing or a loading joint due to future excavations, a 7 ft. by 2 ft. steel boiler plate has been placed over the protection box.

*Electrical Tests carried out during Construction.*

On the loading sections, the capacity unbalance measurements were made by the Contractor's testing staff from the centre joint, each unit being tested for the pair to pair capacity balance as soon as it was jointed, in order that any errors of selecting, or of jointing-in the balancing tails, could be rectified before that unit was insulated and "put away." For this test the leads from the capacity unbalance measuring sets were connected to the bight of the conductors by means of clips resembling those known in the Department as test clips No. 10, but insulated with protective rubber sheaths. During the early stages of the work either check capacity unbalance measurements or open cross-talk measurements were made from one end of the loading section by the P.O. Staff, but later on these tests were discontinued except when required as a check on the terminated cross-talk tests. These latter tests, made with the distant end closed with a resistance approximating to the characteristic impedance of the line, were carried out on all the loading sections and consisted of the following measurements :—All side to side and pair to pair (within unit) cases and, during the very early stages of the work, a few pair to pair (between unit) cases. Conductor Resistance and Insulation Resistance tests were made on each loading section either by P.O. Staff or by the Contractor's Staff, the latter also being responsible for the tap-through tests.

As the loading group of three or four consecutive loading sections was completed, the usual group or "sling" tests were made by the P.O. Staff. These tests consisted of Conductor Resistance, Inductance (D.C.), Capacity (D.C.), Insulation Resistance, and Terminated Cross-talk between all side circuits and between all pairs in the same unit and occasionally between a few pairs in different units. The balancing and loading operations on both repeater sections were commenced at Carlisle and as each group of three or four loading sections was tested it was linked to the previous group. Thus it was possible to make Insulation Resistance, Cross-talk, and Impedance measurements at Carlisle to various points along the Repeater Sections as the work progressed. The insulation resistance tests were useful as an indication of the condition of the cable. The cross-talk tests gave an indication at an early date of the order of the overall near end cross-talk that might be expected. The data obtained from the various impedance measurements proved very useful later when it was necessary to investigate irregularities in both repeater sections by A.C. methods, besides providing values of characteristic impedance and attenuation constant, etc., in advance of the completion of the work.

Before passing on to discuss the results of the overall tests it will be of interest to mention that the cable as a whole appeared to be in a remarkably good state of preservation and that everywhere there were indications of very thorough workmanship on the part of the original jointers. The insulation resistance obtained on the loading sections was generally of the order of 30,000 to 40,000 megohms per mile between Preston and Carlisle, and 12,000-20,000 megohms per mile between Carlisle and Glasgow. This reflects credit on the cable maintenance staff of the N.W. and Sc.W. Districts, for records of 1913 show that the insulation resistance at that time was only of the order of 500 megohms per mile, and the writer himself remembers obtaining values of only about 8,000 megohms per mile between Preston and Carlisle in 1924. The conductor resistance balance was extremely good throughout and showed that the manufacturers and jointers of thirty years ago knew their work.

*Overall Tests on the Completed Repeater Sections.*

(i) *D.C. Tests.* The results of the D.C. tests call for little comment. Table No. 1 bears out the remarks on the conductor resistance made above.

TABLE No. 1.

CONDUCTOR RESISTANCE.

| Repeater Section. | Pairs in. | Loop (ohms.) | | Unbalance (% of Loop). | | Mean Loop Resistance per Mile of Cable. |
|---|---|---|---|---|---|---|
| | | Max. | Min. | Max. | Mean. | |
| Preston-Carlisle | Centre Unit | 1463.0 | 1461.6 | 0.057 | 0.041 | 16.74 |
| ,, ,, | All other Units | 1472.3 | 1469.8 | 0.055 | 0.019 | 16.83 |
| Carlisle-Glasgow | Centre Unit | 1609.6 | 1609.2 | 0.012 | 0.006 | 16.73 |
| ,, ,, | All other Units | 1616.2 | 1613.4 | 0.055 | 0.019 | 16.82 |

The overall insulation results were a little disappointing as the general condition is better than the recorded figures 22,000 and 12,000 megohms per mile for the Preston-Carlisle and Carlisle-Glasgow Sections respectively would indicate. The Preston to Carlisle results in particular are spoiled by the leading-in cable at Preston H.P.O.

(ii) *Cross-talk.* The cross-talk measurements were made with standard P.O. apparatus, and the circuits under test were in all cases correctly terminated at the distant end. A reed hummer was used as the source of disturbance for the majority of the tests. Near end cross-talk tests were made from each end of the repeater sections and all side to side, side to phantom, and pair to pair (within unit and between units) cases were measured. The distant end cross-talk tests were made at Carlisle only, and on each repeater section all the side to side and pair to pair (within unit) cases were measured. The results of these tests, corrected where necessary for differences of impedance between the measuring apparatus and the circuits under test, and in the case of the distant end tests, for the attenuation of the disturbing circuit, are summarized in Table No. 2. The Contractor had made no guarantees for overall cross-talk results, but stated that every effort would be made to keep within the following limits for pair to pair cross-talk between any two quads in the cable :—Near End, 78 decibels, Distant End, 74 decibels. It will be seen that the results obtained are in all cases better than the above values and also that the side to side, and side to phantom cross-talk is not excessive.

(iii) *Transmission Efficiency.* The attenuation of all pairs was measured at frequencies of 800, 2,400 and 3,000 p.p.s. by the Mayer method, with a line input current of 1 mA. The results are summarized in Table No. 3. Fig. **6** shows the variation of the attenuation constant and phase constant with fre-

TABLE NO. 2.

CROSS-TALK EXPRESSED IN DECIBELS.
SOURCE OF DISTURBANCE — REED HUMMER.

| Near End Measurements. | | Within Quad. | | | | Pair to Pair. | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Side/Side. | | Side/Phantom. | | Within Unit. | | Between Units. | |
| Repeater Section. | Measured at | Worst. | Average. | Worst. | Average. | Worst. | Average. | Worst. | Average. |
| Preston-Carlisle | Preston | 72 | 77 | 54 | 61.5 | 88 | 92 | 90 | >94 |
| ,, ,, | Carlisle | 63 | 69 | 54 | 60 | 81 | 85 | 88 | >94 |
| Carlisle-Glasgow | Carlisle | 68 | 72 | 54 | 62 | 81.5 | 85 | 88 | >94 |
| ,, ,, | Glasgow | 68 | 74 | 57.5 | 64.5 | 84.5 | 89 | 88 | >94 |
| **Distant End Measurements.** | | | | | | | | | |
| Repeater Section. | Measured at | | | | | | | | |
| Preston-Carlisle | Carlisle | 74 | 86 | — | — | 90 | >94 | >94 | |
| Carlisle-Glasgow | Carlisle | 74 | 82 | — | — | 90 | >94 | >94 | |

TABLE NO. 3.

ATTENUATION CONSTANT AND CHARACTERISTIC IMPEDANCE MEASURED AT FREQUENCIES OF 800, 2400 AND 3000 PERIODS PER SECOND.

| Repeater Section. | Measured at. | $\beta$ (Nepers per mile). | | | $Z_0 \lfloor \phi_0$ (Vector Ohms.) | | |
|---|---|---|---|---|---|---|---|
| | | 800 | 2400 | 3000 | 800 | 2400 | 3000 |
| Preston-Carlisle | Preston | — | — | — | $315 \lfloor 12^{\circ}5'$ | $380 \lfloor 11^{\circ}35'$ | $445 \lfloor 12^{\circ}5'$ |
| ,, ,, | Carlisle | 0.0273<br>0.0278 | 0.0285<br>0.0292 | 0.0305<br>0.0310 | $345 \lfloor 10^{\circ}40'$ | $350 \lfloor 3^{\circ}15'$ | $525 \lfloor 5^{\circ}40'$ |
| Carlisle-Glasgow | Glasgow | — | — | — | $355 \lfloor 13^{\circ}10'$ | $420 \lfloor 5^{\circ}25'$ | $470 \lfloor 5^{\circ}5'$ |
| ,, ,, | Carlisle | 0.0249<br>0.0252 | 0.0258<br>0.0264 | 0.0266<br>0.0271 | $365 \lfloor 14^{\circ}5'$ | $395 \lfloor 6^{\circ}50'$ | $455 \lfloor 12^{\circ}10'$ |

The $Z_0 \lfloor \phi_0$ values are means of all the pairs.
The upper $\beta$ values are means of pairs in the centre unit.
The lower $\beta$ values are means of pairs in all other units.

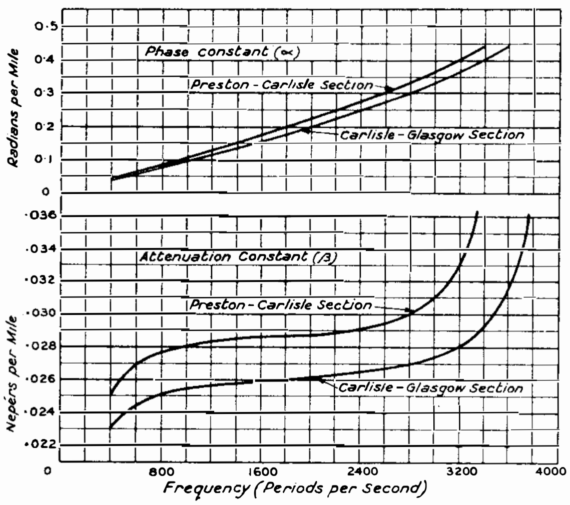


FIG. 6.—ATTENUATION AND WAVE-LENGTH CONSTANT FREQUENCY CHARACTERISTICS.

quency. It will be seen that the change of attenuation constant over a range of 400-3,000 p.p.s. is only 0.006 nepers and 0.0045 nepers for the Preston-Carlisle and Carlisle-Glasgow Repeater Sections respectively. This represents a total change of 0.525 nepers (4.5 decibels) and 0.435 nepers (3.8 decibels) respectively over the Repeater Sections, each of which have the same overall attenuation of 2.42 nepers (21 decibels) at a frequency of 800 p.p.s. Fig. **6** also shows that the phase constant is almost directly proportional to frequency over the range concerned.

The lower cut-off frequency and the higher attenuation constant of the Preston-Carlisle circuits as compared with the Carlisle-Glasgow circuits is only partly due to the closer spacing of the loading coils in the latter section. It is in fact chiefly due to the lower mutual capacity of the pairs in the Carlisle-Glasgow section. The average values are 0.059 microfarads per mile between Preston and Carlisle and 0.052 microfarads per mile between Carlisle and Glasgow. This explains why the phase constant of the Carlisle-Glasgow circuits is lower than that on the Preston-Carlisle circuits.

The velocity of propagation on the Preston-Carlisle circuits is about 56,000 miles per second and on the Carlisle-Glasgow circuits about 60,000 miles per second.

(iv) *Impedance and Uniformity of Electrical Constants.* The impedance of each pair was measured, at frequencies of 800, 2,400 and 3,000 p.p.s., from each end of the repeater sections. For these measurements the pair under test was extended by similar pairs to form an electrically long circuit. The results are summarized in Table No. 3. Impedance-Frequency measurements were made over a range of frequency of from 200 p.p.s. to the cut-off frequency, at intervals of 100 p.p.s. on not less than 20% of the pairs, from both ends of the two repeater sections. Representative curves are illustrated in Figs. **7** and **8**. These tests show that the Carlisle-Glasgow circuits are quite good in respect of uniformity of distribution of electrical constants.

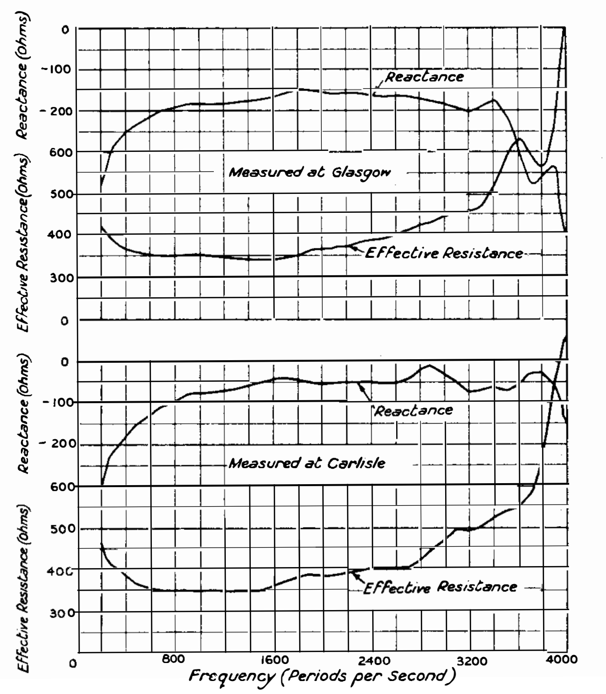


FIG. 7.—TYPICAL $Z_0 - f$ CURVES, CARLISLE-GLASGOW SECTION.

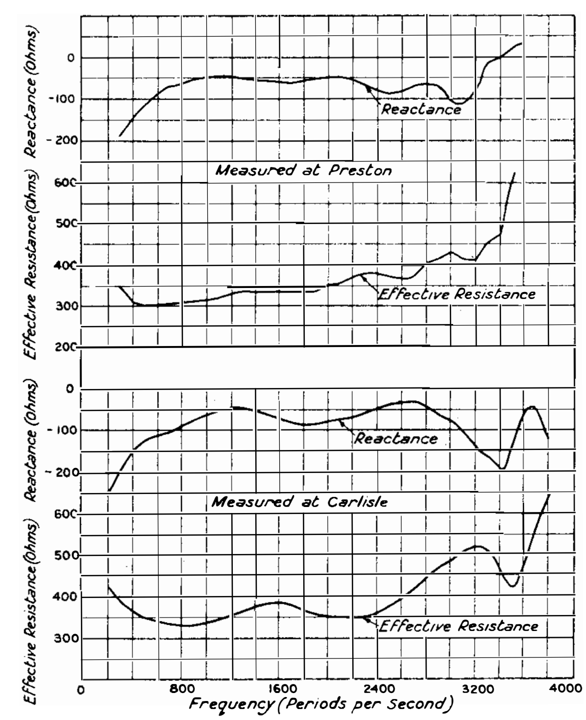


FIG. 8.—TYPICAL $Z_0 - f$ CURVES, PRESTON-CARLISLE SECTION.

In the case of the Preston-Carlisle repeater section, the curves obtained at Carlisle are not nearly so good. It will be seen that there are marked " humps " at frequencies of about 1,600 and 3,200 p.p.s., and " troughs " at about 800 and 2,100 p.p.s. Measurements over a limited range of frequency on one pair from each unit show that this " roll " is a general feature. The matter was investigated and the cable cut at L.P.5 which appeared to be the point from which the reflection occurred. Further investigations showed that L.P.5 was actually about the centre of the irregularity, though it was proved that the loading equipment itself was not faulty. An examination of the schedule of loading section lengths showed that L.C.S. 4-5 and L.C.S. 6-7 are 243 yards and 115 yards, respectively, shorter than a normal loading section, while L.C.S. 5-6 is 298 yards longer than a normal loading section. Hence though all three loading sections conform to the specification tolerance of $\pm 5\%$ deviation from a normal section, the difference in length between L.C.S. 4-5 and L.C.S. 5-6 is 6.3% of a normal section and that between L.C.S. 5-6 and L.C.S. 7-8, 4.8% of a normal section. It is believed that the resultant of these two irregularities causes the " roll " shown in the impedance-frequency characteristic. The effect is not noticeable at the Preston end because the distance to L.P.5 is great enough to reduce the amplitude and to increase the periodicity of the reflected wave sufficiently to nullify its effect on the sending end impedance.

An interesting fault was discovered during the overall tests on a pair which had previously passed all other tests during, and after, the loading satisfactorily. It was actually a high conductor resistance fault, but its existence was at first only apparent when testing with a low value of alternating current. The conductor resistance of the pair had been measured with direct current and the unbalance was only about 0.2 ohms, but the attenuation as measured by the Mayer method showed that the A.C. resistance must be of the order of thousand of ohms. Attempts to locate this fault by D.C. or A.C. methods were at first quite unsuccessful, but later, after leaving the fault for 12 hours, a very satisfactory impedance-frequency location was obtained. The normal impedance-frequency characteristics of the pair, as well as the open circuit characteristics measured during the loading operations, giving the velocity of propagation on this pair accurately, were available, so that it was possible to make a most accurate location using the difference curve method (see Fig. **9**). The fault was not in either a balancing or a loading joint and a further period of waiting was necessary before it was possible to localize further by the usual A.C. short distance methods. The secondary location proved eventually to be only about 20 yards out in 4,000 yards, but, as the fault was not in a primary joint, further localizations on a 50-yard length were necessary. These were of a most exasperating nature because the resistance of

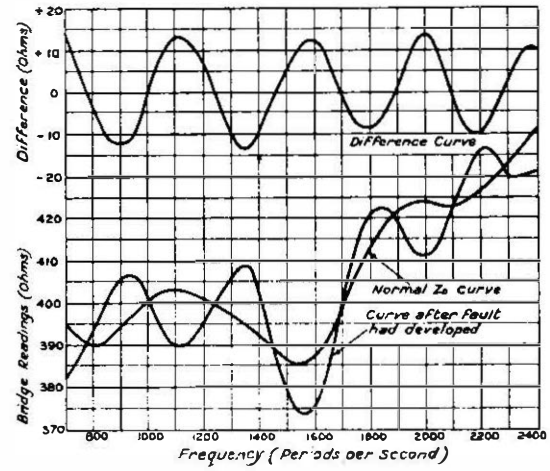


FIG. **9**.—CURVES USED FOR LOCATION OF HIGH CONDUCTOR RESISTANCE FAULT.

the fault was never constant for two consecutive minutes. The site, amid the Scottish border moorlands, in February, was about as quiet and lonely as one could find on any main road in the country, yet the fault resistance, without the slightest apparent cause, varied from a complete disconnexion to less than 0.2 ohms. At one time the searchers abandoned the chase, convinced that the fault had been cleared in a joint, only to find two hours later that it had become a complete disconnexion temporarily. The electrical tests at last indicated that the fault was within 9 yards of a joint and the iron pipe was bared for this distance, an easy matter on the moorlands. The last location, obtained by a combination of electrical and mechanical (cable tapping) methods, led to the cable being opened at a point 18 inches away from the fault and a tug caused the faulty conductor to come right out.

The fault was caused by a complete break in the conductor and the two portions were brought to the metallurgical laboratory at Dollis Hill for examination. It would appear that the conductor had been partially cut through during manufacture and that at a later date the constricted portion had failed. Microscopic photographs are shown in Fig. **10**. The darkened portion in plan shows the extent of the cut. The side elevation shows the ends of the wire

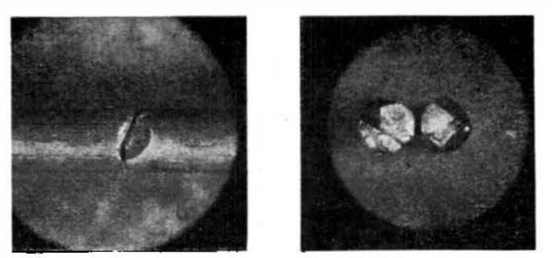

FIG. **10**.—MICRO-PHOTOGRAPH OF FAULTY CONDUCTOR.

in their correct relative positions originally. The records show that the pair concerned has not been in use for over ten years so it is impossible to say how long it had been completely broken. The remarkable point was that the conductor resistance balance of this pair was better than the average of the rest of the pairs over the particular loading section concerned. It might be of interest to add that the A.C. tests over 96 miles gave the position to within 0.3 of a loading section, and the *third out was actually only 22½ ft. from the fault.*

*Conclusion.*

The practical details of the complete scheme were decided in collaboration between the Department and Messrs. Standard Telephones and Cables, Ltd., with whom the balancing and loading contract was placed and who supplied the whole of the equipment. The work was commenced on January 1st, 1932, and the overall tests were completed by February 26th. The scheme proved completely successful and circuits were brought into service early in March. One feels that it would have given much pleasure to the designer, Mr. A. W. Martin, had he lived to see the cable carrying out all the functions which he had in view.

Finally, the writer wishes to thank all those who have helped in the collection of information, and especially acknowledges the courtesy of Messrs. Standard Telephones and Cables, Ltd., to whom the majority of the photographs are due.

# 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 MARCH, 1932.

| 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. |
| 768,868 | 694 | 9,363 | 42,115 | 2,825 | London | 43,177 | 174,064 | 3,327,549 | 138,506 |
| 90,403 | 2,003 | 17,355 | 39,732 | 3,634 | S. Eastern. | 3,955 | 49,303 | 336,175 | 41,556 |
| 105,466 | 4,376 | 36,401 | 59,244 | 3,443 | S. Western. | 23,786 | 27,458 | 259,295 | 61,062 |
| 71,270 | 4,919 | 40,536 | 58,791 | 6,591 | Eastern. | 19,986 | 48,405 | 147,986 | 51,558 |
| 116,860 | 7,238 | 52,078 | 48,889 | 5,329 | N. Mid. | 33,720 | 119,452 | 314,065 | 80,326 |
| 93,042 | 4,059 | 32,446 | 61,836 | 2,513 | S. Mid. | 15,816 | 41,626 | 266,683 | 82,001 |
| 66,406 | 3,358 | 32,089 | 50,315 | 3,849 | S. Wales. | 6,794 | 38,092 | 161,866 | 54,797 |
| 128,171 | 6,762 | 29,874 | 51,897 | 5,131 | N. Wales. | 16,326 | 52,937 | 388,277 | 126,559 |
| 177,662 | 946 | 14,189 | 24,184 | 3,631 | S. Lancs. | 13,073 | 105,548 | 580,233 | 85,619 |
| 108,539 | 5,143 | 31,568 | 36,039 | 5,766 | N. Eastern. | 20,765 | 67,033 | 305,965 | 52,516 |
| 73,245 | 3,368 | 24,591 | 24,737 | 3,862 | N. Western. | 8,855 | 41,973 | 227,931 | 48,512 |
| 56,281 | 2,113 | 17,614 | 20,346 | 3,250 | Northern. | 11,165 | 33,471 | 173,782 | 38,327 |
| 26,701 | 3,618 | 10,828 | 10,832 | 627 | Ireland N. | 213 | 3,994 | 58,067 | 6,496 |
| 78,838 | 4,664 | 32,803 | 37,270 | 1,735 | Scot. E. | 9,313 | 28,820 | 174,825 | 46,636 |
| 101,376 | 4,518 | 25,201 | 28,937 | 1,660 | Scot. W. | 11,064 | 35,778 | 252,660 | 38,442 |
| 2,063,128 | 57,779 | 406,936 | 595,164 | 53,846 | Total | 238,008 | 867,954 | 6,975,359 | 952,913 |
| 2,050,355 | 57,547 | 408,951 | 587,646 | 49,259 | Figures as at 31 Dec., 1931. | 234,157 | 821,531 | 6,804,602 | 980,050 |

Territory transferred to London District from South Eastern, South Midland and Eastern Districts, February, 1932.

# The First Telephone

IN the Science Museum at South Kensington is a pair of instruments, made in 1860 by Philipp Reis, and described as the original telephone.

The question whether these instruments ever really transmitted speech was the subject of fierce controversy in the eighties, when Graham Bell's telephone was being developed commercially; and Prof. Silvanus P. Thompson wrote a book in 1883 advocating the claim of Philipp Reis to the honour of being the inventor of the telephone. Recently it was suggested that the description of Reis's instruments in the Science Museum was hardly fair to Graham Bell, and the question was discussed by the Council of the Institution of Electrical Engineers.

Philipp Reis was born near Frankfort in 1834, became a schoolmaster and an active member of the local scientific society, and in 1860 made and demonstrated apparatus which he named "the telephone." The transmitter consisted of a diaphragm made of some thin membrane carrying a platinum contact which rested against an adjustable platinum point. The receiver consisted of a steel knitting needle wound to form an electromagnet and mounted on a sounding board, or on the body of a violin. The original idea underlying Reis's work was that the opening and closing of the contact by means of the diaphragm, vibrating under the influence of sound waves, could be made to interrupt a current at the frequency of the sound, and so produce audible electromagnetic vibrations of the same frequency. A sustained musical note could be transmitted in this way, and obviously the next step was to try singing and speech. Reis apparently thought that the actual making and breaking of the contact could transmit the complex series of tones necessary for articulate speech. He made numerous variations in the transmitter in the course of his experiments until he hit upon the best conditions of contact pressure, diaphragm size, etc. As a receiver, he also tried an electromagnet with an armature and a reed—thus almost anticipating the Bell receiver—but apparently obtained his best results with the "knitting needle" arrangement. The final form of the transmitter is shown in Fig. 1, reproduced from Prof. S. P. Thompson's book (Philipp Reis: Inventor of the Telephone). The contact was simply joined in series with a battery of 2 or 3 cells (at B) and the receiver, seen on the right of the figure. The electromagnet and key on the side of the box were also joined in series with the other apparatus and used for signalling.

In Fig. **2** is shown an earlier form of transmitter. The conical hole (*a*) in a block of wood served as mouthpiece. At (*b*) was a thin stretched membrane on which rested (or was cemented) a platinum button. The platinum contact (*d*) was adjusted by the screw (*h*).

A transmitter of this type was recently tried, at the same time as the original Reis transmitter according to Fig. **1**, and could be made to transmit speech for a few moments by careful adjustment of the contacts.

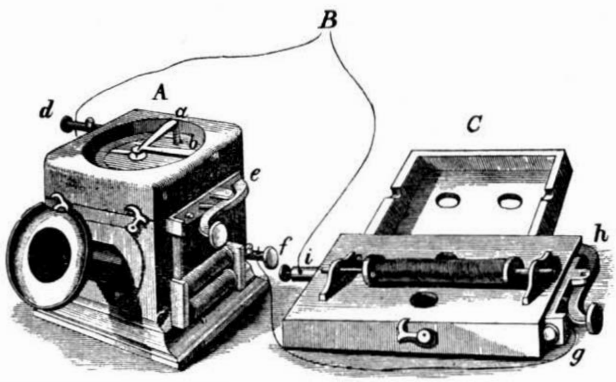


Fig. 1.—Reis's Telephone.

When the platinum contacts were so adjusted as to be microphonic (that is, the contact resistance varying more or less in proportion to the pressure) they would act as a fairly satisfactory microphone provided that the motion of the diaphragm was not great enough to cause actual separation and sparking. This was verified by the P.O. Research Section, using a modern receiver and a step-up transformer. When the adjustment was exactly right, speech was transmitted reasonably well, the volume being 20 db or so below that of a carbon transmitter, but it was impossible to keep the adjustment right for long. Loud speech caused the contacts to separate and scratching noises were heard in the receiver, but quiet speech was transmitted with good quality. The Reis knitting needle receiver was not nearly so efficient, however.

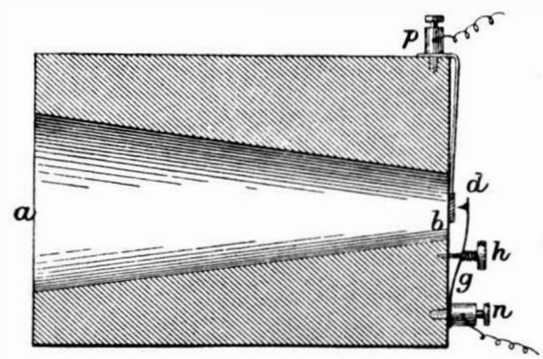


Fig. 2.—Earlier Form of Reis's Transmitter.

The model in the Science Museum showed signs of having carried an excessive current, the cotton insulation being charred in places, and the iron core seemed to lack the right magnetic properties. At any rate, it could only be made to produce audible speech by the use of an amplifier having a gain of about 30 dbs, but the quality of the sneech was very good.

The phenomenon of talking relay cores is not very uncommon in exchanges, and at Marlborough Repeater Station many of the input transformers emitted speech in sufficient volume to perturb the man on night duty. If the state of the core material happens to be favourable for this phenomenon—now known as " magnetostriction," the volume of sound can appear surprisingly great in a perfectly quiet room.

Thus it is fair to assume that some of Reis's knitting needle receivers may have been far more efficient than the specimen tested and capable of translating into audible speech the currents produced by one of his transmitters when this instrument was working under exactly the right conditions.

In Prof. Thompson's book there is evidence from various contemporaries of Reis that speech was transmitted by his telephone, though very unreliably. It would seem that the conditions were not clearly understood, for singing was more frequently transmitted and the right adjustments for speech were obtained rather by accident than design.

There is one record of a statement by Reis, however, which shows that he had at least some inkling of the nature of a microphonic contact. He is reported to have said frequently " You understand it is a molecular action " (molekular bewengung).

There is no mention of the use of carbon for the contacts. Various metals were tried and platinum was no doubt finallv selected because it would stand up to the sparking which must have occurred in such a low resistance circuit.

In weighing the evidence, it must be remembered that the marvellous adaptability of the human ear enables telephone speech to be tolerably well understood even when it is so distorted and weak as to be scarcely detectable by any other means.

If we assume the tension of the diaphragm and the condition of the contact to be just right, and the listener to be in a perfectly quiet room and not too critical—then speech could certainly have been transmitted, though at a level of volume and intelligibility far below what is now rather vaguely known as the " commercial limit." It was probably in such exceptionally favourable conditions that Reis's telephone " talked," and the small amount of contemporary interest which the invention seems to have aroused was no doubt due to the extreme weakness and unreliability of the transmission.

To sum up : Philipp Reis is certainly entitled to the honour of making the first telephone, though credit for the invention of the telephone as we now know it must be shared between Graham Bell and Hughes. A.C.T.

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# A New Total Counter for Telephone Calls

J. W. Dyk.
(Amsterdam Municipal Telephone Administration).

IN every telephone exchange of importance, it is essential for the Administration to have correct and complete statistics of the traffic handled by the equipment. A correct account of the total output of the service is necessary if only to check receipts.

Such records have usually been obtained by the adoption of one or other of the following methods, or by combinations of these methods :—

(1) Totalling the numbers of calls recorded on the subscribers' meters.
(2) Using special meters on selector racks to measure the traffic.
(3) Random testing in different parts of the exchange.

Each of these methods suffers more or less from the disadvantages listed below :—

(*a*) Because of the amount of work involved, the analysis can only be taken at fairly lengthy intervals (*e.g.*, monthly).
(*b*) Reading and calculating errors are highly probable.
(*c*) The taking of the record is costly because of the time occupied.
(*d*) The results are never instantly available.

The fact that a correct recording apparatus—which would combine great rapidity of registration with practically unlimited possibility in number of calls—was not available has led the majority of telephone Administrations to content themselves with periodic control countings in groups of selectors.

It is the purpose of this article to describe a new apparatus in which the disadvantages and difficulties referred to above do not occur.

The apparatus is illustrated in Fig. 1. The horizontal angle iron in the centre of the figure carries a number of relays mounted vertically, one relay being fitted for each unit of 1st selectors. Units can be connected in parallel if desired, but this increases the liability of inaccuracy and it is generally sufficient to arrange for one relay per unit serving from 200 to 300 subscribers.

Each relay, provided with the normal yoke and armature, is mounted with a small vertical tube which, in turn, is connected at the top and bottom with two inclined gutters. Each relay has a steel spring fitted on the yoke, the top end of this spring being bent at right angles. Level with the bend in the spring there are two horizontal incisions in the tube, in which the steel spring can move to and fro, thus alternately opening and shutting the tube.

forced up to the top inclined gutter which acts as a distributor to the various tubes. Any surplus balls drop down a wide vertical tube at the right-hand end of the apparatus into the front portion of the lower gutter and thence to the funnel referred to previously. The lower gutter and funnel are divided longitudinally into two parts to separate balls released by the tubes from surplus balls. The surplus balls are driven up the second tube shown on the left of the figure, and thence pass to the distributing chute, but in this case the recording meter is not affected.

The circuit conditions provide for the operation of a relay in the 1st selector on completion of a conversation. The local contact of this relay energizes the counter relay associated with the particular group, thus recording the call. Similar

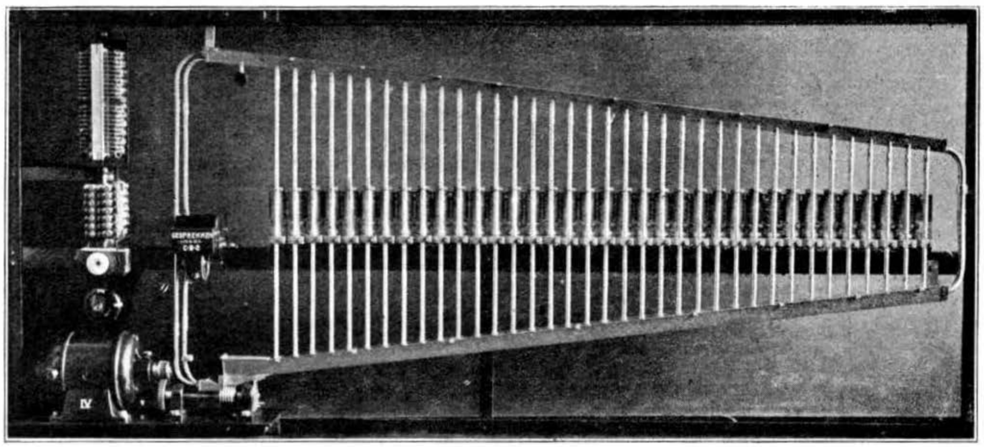

Fig. 1.—Total Calls Counting Apparatus.

The tubes are filled with little balls, of slightly less diameter than the tube. With each attraction of the armature, the spring is moved backwards and a ball drops into the lower gutter. Only one ball can drop at a time, however, in any tube as the lowest ball is not released until the spring has taken hold of the following ball.

The balls falling out of the various tubes travel down the lower inclined gutter to a rectangular-shaped funnel from which they are driven by a continuously moving worm gear, through one of the tubes on the left of the figure. As they pass through this tube, the balls operate a toothed wheel corresponding in width to the diameter of the balls. The toothed wheel is connected by gearing to the totalling meter.

After passing the toothed wheel, the balls are

arrangements are also provided for recording every call passing through the group of selectors, so that records are obtained of both ineffective and effective calls. The liability of two or more calls maturing and being completed at exactly the same instant is very small and the arrangement therefore gives an extremely high standard of accuracy.

The counters have been introduced with great success in all exchanges in Amsterdam. Ten such counters are in constant use and experience has shown that they require little or no repairs, and that lubrication and supervision were superfluous. The apparatus has rendered it possible to obtain much valuable data regarding the service, and its capacity for rapid recording will be appreciated from the fact the 100,000 calls per hour can be handled without difficulty.

# A Method of Approach and Solution to some Fundamental Traffic Problems

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DURING the past few years the British Post Office has been actively engaged upon the replacement of Manual by Automatic systems of Telephone switching. The most important problem introduced by this change is the quantity of equipment required to perform those operations previously performed by the telephonist, since it is this which largely determines the subsequent plant, accommodation and staff charges to be met under the new system. It is necessary, therefore, to make a close study of the incidence of telephone traffic. Certain theories have been advanced, and one closely associated with the work of M. Erlang has been adopted by the British Post Office and the results issued in tabular form. The purpose of these notes is threefold; firstly, to assist those engaged in the practical application of these tables towards a clearer understanding of their precise nature; secondly, to show that all the problems are by no means solved; and thirdly, to suggest lines of investigation.

The first problem simply stated is as follows. If the average number of calls simultaneously in progress is K, it might be expected that individual observations would show that sometimes as few as D, and sometimes as many as R calls were in progress at one time. It is desired to provide equipment for Q simultaneous connexions, so that those calls lost by reason of this restriction in plant might not exceed a predetermined proportion of the whole. This problem can be approached from first principles.

Suppose a bag to contain a large number of black and white balls in equal proportions and suppose balls be drawn out 1 2 3 . . . . . $n$ at a time. The result can be tabled as follows :—

| Number of balls drawn at a time. | Grouping. | Arrangements in each group. | Chance of obtaining such grouping on large number of trials. | |
|---|---|---|---|---|
| 1 | 1 Black | B | 1/2 | ………(1) |
| | 1 White | W | 1/2 | |
| 2 | 2 Blacks | BB | 1/4 | ………(2) |
| | 1 White 1 Black | BW | 1/2 | |
| | ,, ,, | WB | | |
| | 2 Whites | WW | 1/4 | |
| 3 | 3 Blacks | BBB | 1/8 | ………(3) |
| | 2 Blacks 1 White | BBW | 3/8 | |
| | ,, ,, | BWB | | |
| | ,, ,, | WBB | | |
| | 1 Black 2 Whites | BWW | 3/8 | |
| | ,, ,, | WBW | | |
| | ,, ,, | WWB | | |
| | 3 Whites | WWW | 1/8 | |

It will be seen that the chance of obtaining any particular arrangement of balls depends upon the total possible arrangements and the chance of obtaining any particular grouping of balls depends upon the number of arrangements it includes. Further it follows that some groupings or combinations will be more probable than others, since they include more arrangements.

Under the conditions of the foregoing data, if $p$ is the chance that a black ball be drawn and $q$ that of a white ball, in a draw of one ball at a time, $p = q = \frac{1}{2}$ and, as it is a certainty that a ball will be drawn, $p + q = 1$.

The binominal expansion :—

$$(p+q)^n = p^n + \frac{np^{n-1}q}{1\,!} + \frac{n(n-1)p^{n-2}q^2}{2\,!} + \ldots \frac{n(n-1)\ldots(n-r+1)p^{n-r}q^r}{r\,!} \ldots + q^n$$

gives every possible grouping of $p$ and $q$ in a selection of things taken $n$ at a time. The proportion of each group to the whole will be the ratio of the appropriate term in this expansion to its sum. That is

$(p+q)^n$ when $n = 1 = p + q$ identical with (1)

$(p+q)^n$ $n = 2 = p^2 + 2pq + q^2$ identical with (2)

$(p+q)^n$ $n = 3 = p^3 + 3p^2q + 3pq^2 + q^3$ identical with (3)

If, however, the black and white balls are not in equal proportions, let $p = Kq$. Then $p + q = 1$ and the results of a draw may be tabled as before.

| No. of balls drawn at a time. | | Grouping. | | | |
|---|---|---|---|---|---|
| 1 | | B | | W | |
| | chance of each group | $p$ | | $q$ | |
| 2 | | BB | WB | WW | |
| | | | BW | | |
| | chance of each group | $p^2$ | $2qp$ | $q^2$ | |
| 3 | | BBB | BBW | WWB | WWW |
| | | | BWB | WBW | |
| | | | WBB | BWW | |
| | chance of each group | $p^3$ | $3p^2q$ | $3pq^2$ | $q^3$ |

The chances, in N repetitions of the draw of 3, are respectively $Np^3$, $N3p^2q$, $N3pq^2$, $Nq^3$.

In general, therefore, the chance of obtaining

$r$ black balls in a single selection of $n$ balls will be the value of the term containing $p^r$, so that in a draw of $n$ balls, the chance of obtaining $n$B, $(n-1)$ B1W, etc., will be as follows :—

| Group | $n$B | $(n-1)$ B1W | $(n-2)$ B2W | $(n-r)$ B$r$W |
|---|---|---|---|---|
| Chance | $p^n$ | $np^{n-1}q$ | $\frac{n(n-1)}{2!}p^{n-2}q^2$ | $\frac{n(n-1)\ldots(n-r+1)p^{n-r}q^r}{r!}$ |

The sum of all the chances is 1.

Of course, in any single selection of $n$ balls only one value of $r$ black balls will be obtained, but in repeated samples taking N draws of $n$ balls, the number of times all the different values of $r$ from 0 to $n$ might be obtained would tend to the values below, that is, the successive terms in the expansion of N $(p+q)^n$, the sum of all the terms of which will be equal to N times 1.

| Arrangement | $n$B | $(n-1)$ B1W | $(n-r)$ B$r$W | $n$W |
|---|---|---|---|---|
| Number of times | $N(p^n)$ | $\frac{N(np^{n-1}q)}{1!}$ | $\frac{N(n)(n-1)\ldots(n-r+1)p^{n-r}q^r}{r!}$ | $N(q^n)$ |

The meaning of the result might be illustrated by Fig. 1, considering N draws of 4 balls under the

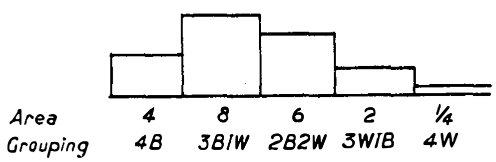


FIG. 1.

conditions already indicated, but where $p=\frac{2}{3}$ and $q=\frac{1}{3}$. With larger numbers, however, a smooth curve might be obtained, as in Fig. 2.

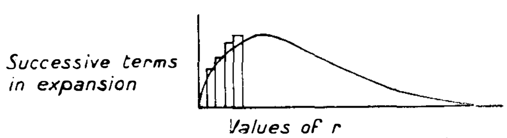


FIG. 2.

The chance of obtaining $r$ black balls is given by the ratio of the area representing the term containing $p^r$ to the whole area of the curve and the chance of obtaining more than $r$ black balls is the ratio of the area up to the term containing $p^r$ to the whole area of the curve.

It is now clearly possible to write down the proportion of balls of one colour which, in the long run, will be obtained from repeated sampling of balls taken $n$ at a time.

Applying the foregoing to Telephone Traffic, let an hour be divided up into N intervals. N may be large, so that more than one call cannot occur during one interval. Let there be $x$ calls originated in this hour. Then the chance of a call occurring is $\frac{x}{N}=p$ and the chance of a call not occurring is $q$. Assuming that a call is as likely to occur during any one interval as during any other, it is easy to see that the results of sampling would be identical with those which might be expected if balls were drawn $n$ at a time from a bag containing N$p$ black balls and N$q$ white balls, where the black balls represent the intervals during which a call arrives and the white balls the intervals during which no call arrives. If the samples were taken over a large number of hours during each of which $x$ calls arrived, it might be expected, in the long run, that the resultant distribution of calls and spaces would approach the binomial distribution :—

$$p^n \quad np^{n-1}q \quad \frac{n(n-1)}{2!}p^{n-2}q^2 \; \ldots\ldots\ldots \; q^n$$

Taking just one hour, however, within the limit of error introduced by the restricted sampling, it might be expected that the same distribution would be obtained. Let this be assumed for the moment so that the next step can be taken.

The binomial expansion may be written :—

$$q^n + nq^{n-1}p + \frac{n(n-1)q^{n-2}p^2}{2!} + \ldots + p^n \ldots (4)$$

or

$$q^n\left\{1 + \frac{np}{q} + n\frac{(n-1)p^2}{2!\,q^2} \ldots + \frac{n(n-1)\ldots(n-r+1)p^r}{r!\,q^r} \ldots + \frac{p^n}{q^n}\right\} \ldots\ldots (5)$$

Suppose $n$ approaches infinity and $p$ approaches zero so that $p=\frac{m}{n}$

Then $q=(1-p)=\left(1-\frac{m}{n}\right)$

$n=\frac{m}{p}$ and $np, =m.$

also as $n \to \infty$, $q \to 1$

and $1 - \frac{m}{n} \to 1$,

$n(n-1) \to n^2$,

$n(n-1)(n-2) \to n^3$, and so on.

Substituting, therefore, in (5)

$$(1-p)^{\frac{m}{p}} \left\{ 1 + m + \frac{m^2}{2!} \cdots + \frac{m^r}{r!} \cdots + \frac{m^n}{n!} \right\} \quad \text{......(6)}$$

Now $(1-x)^{\frac{1}{x}}$ when $x$ approaches 0, becomes equal to $e^{-1}$.

So $(1-p)^{\frac{m}{p}}$ becomes equal to $e^{-m}$.

and (6) can be written as :—

$$e^{-m} \left\{ 1 + m + \frac{m^2}{2!} + \cdots \frac{m^r}{r!} \cdots + \frac{m^n}{n!} \right\}$$

or $$e^{-m} + me^{-m} + \frac{m^2}{2!} e^{-m} \cdots \frac{m^r}{r!} e^{-m} \cdots \frac{m^n}{n!} e^{-m} \quad \text{.....................(7)}$$

This is the well-known Poisson Limit to the Binomial expansion.

The general term is $\frac{m^x e^{-m}}{x!}$.

The assumption made so far can now be tested. It will be easy to compare the manner in which calls actually arrive with this theoretical law.

Suppose a record be taken of the demands received at a position during fifteen intervals, each of half a minute's duration. The actual period might, of course, be for one hour, but the smaller period will indicate the method.

Let the results be as follows :—

| Time in half minutes. | No. of demands received. |
|---|---|
| 1 | 2 |
| 2 | 5 |
| 3 | 1 |
| 4 | 3 |
| 5 | 4 |
| 6 | 1 |
| 7 | 2 |
| 8 | 3 |
| 9 | 2 |
| 10 | 1 |
| 11 | 3 |
| 12 | 2 |
| 13 | 2 |
| 14 | 4 |
| 15 | 2 |

They may be grouped as follows :—

| Demands per ½ min. | No. of occasions. |
|---|---|
| 0 | — |
| 1 | 3 |
| 2 | 6 |
| 3 | 3 |
| 4 | 2 |
| 5 | 1 |

This can be shown graphically as in Fig. **3**.

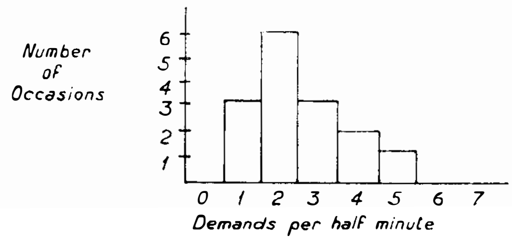


Fig. 3.

If the base elements of this curve are unity, then the area of the curve is equal to the total number of occasions. This curve might be called a Frequency Distribution curve of the rate of arrival of calls.

If the total area of the curve be equated to unity, the area enclosed by the bounding ordinates, representing the particular number of demands per half minute, is the chance of that number being obtained.

The average number of demands per unit of time in this example is $2\frac{7}{15}$ or approximately 2.5. A Poisson Series with an average of 2.5 gives the following values :—

| Demands per ½ min. | No. of occasions. |
|---|---|
| 0 | 1.23128 |
| 1 | 3.07818 |
| 2 | 3.84774 |
| 3 | 3.20645 |
| 4 | 2.00403 |
| 5 | 1.00201 |
| 6 | .41751 |
| 7 | .14912 |
| 8 | .04659 |
| 9 | .01294 |
| 10 | .00324 |
| 11 | .00074 |
| 12 | .00015 |
| 13 | .00003 |
| Total | 15.00001 |

It might be expected that the result of one single experiment of fifteen observations would differ widely from the values given by a Poisson Series, which is rather a condition to be expected only if a large number of samples were taken. This point will be treated again later. It is perhaps sufficient to notice that whether, in the long run, calls arrive in all the possible combinations of successes and failures, or whether, during the busy hour, at least, they tend to arrive in a more regular manner, might be determined from idle plug records or records of that type.

It is now possible to proceed towards the solution of the main problem.

Suppose that we can obtain a frequency distribution of calls simultaneously in progress (or junctions engaged) instead of a distribution of demands per half minutes. The distribution might be represented by Fig. **4**.

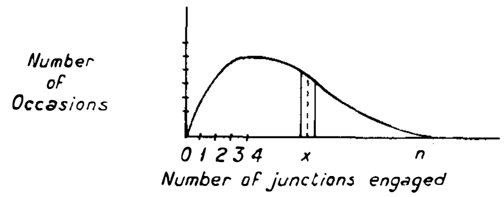


Fig. **4**.

The scale of the picture can be so chosen that the area of the curve is unity. This area is in fact the total speech time. If only $x$ junctions are available, we can say that the calls which would have engaged the $(x+1)$th, $(x+2)$th . . . $(x+n)$th junctions will be lost. The lost traffic might therefore be the tail area beyond the $x$th term, providing that a restriction in outlets does not in some way alter the distribution. We return to this point later, but in the meantime will find what the distribution might be in an unrestricted system.

In principle, the method is to find the chance that a call occurs during an instant T, that second and subsequent calls occur during the instants 2T, 3T . . K T and that these calls continue to be in progress up to time $t$, where $t = \mathrm{K\,T}$. Going back to the conception of the Binomial, the chance of calls occurring and remaining in progress can be represented by $p$ whilst $q$ can represent all the remaining failures, *i.e.,* instants where calls occur and cease before time $t$ or do not occur at all.

Let it be assumed that $m$ is the average number of calls arriving in a unit of time. Dividing up this unit into $n$ intervals of length T so that $n\mathrm{T}=1$, then the chance $p$ of a call occurring in an interval T, is $\frac{m}{n}$. If $n$ is very large and T exceedingly small it may be supposed that only one call can occur in an interval T and that $p$ is exceedingly small. The connexion between these assumptions and the development of the Poisson Series is obvious.

Let $y=\mathrm{F}(t)$ represent the frequency distribution of lengths of call or holding time as in Fig. **5**. The upper limit of length is $b$.

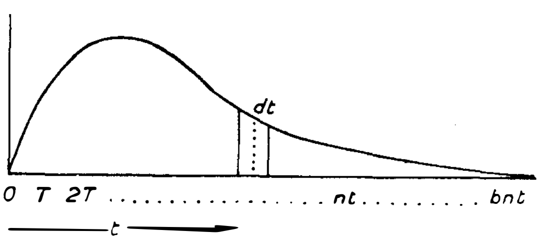


Fig. **5**.

Then $\frac{\mathrm{F}(t)\,dt}{1}$ is the chance that a call will last for a time between $(t-\frac{1}{2}dt)$ and $(t+\frac{1}{2}dt)$, and $\mathrm{P}_t$, the probability of a call exceeding a given time $t$, is the ratio of the area of the curve beyond $t$ to the whole area, *i.e.,*

$$\mathrm{P}_t = \int_t^b \frac{\mathrm{F}(t)\,dt}{\text{unity}} \quad \ldots\ldots (8)$$

Now the chance of a call :—

– occurring in an interval T is $p$.

– not occurring in an interval T is $(1-p)$......$(a)$

– continuing beyond time $t$ is $\mathrm{P}_t$.

– ceasing before $t$ is reached is $(1-\mathrm{P}_t)$.

– occurring in interval T but finishing before time $t$ is reached is $p(1-\mathrm{P}_t)$.........$(b)$

– occurring in an interval T and continuing beyond $t$ is $p\mathrm{P}_t$........................$(c)$

Equations $a$, $b$ and $c$ represent all the possible conditions under which calls can or cannot be in progress at time $t$.

Grouping together the successes or failures, all the chances are given by[1] :—

$$\Pi\ \{p\mathrm{P}_t + p(1-\mathrm{P}_t) + 1 - p\} \quad \ldots\ldots (8a)$$

which is analogous to

$$\{p+q\}\ \{p_1+q_1\}\ \ldots\ \{p_n+q_n\}$$

where $\mathrm{P}_t$ is in turn given all the values obtained from equation (8) by giving $t$ the infinite number of values O, T, 2T, 3T . . . $n$T . . . $bn$T.

Equation (8a) will therefore contain an infinite number of factors.

It has been shown previously that the coefficient of $p^r$ in an analogous series is the chance of obtaining $r$ items of one kind.

Similarly, the chance that K calls are going on at a certain time will be the quantity in the product shown in equation (8a) which is associated with the K$^{\text{th}}$ power of the term which corresponds to $p$ (in this case $p$P). Writing (8a) :—

$$\Pi\ \{p\mathrm{P}_t\mathrm{Z} + p\,(1-\mathrm{P}_t) + 1 - p\} \quad \ldots\ldots (9)$$

The required term is that containing $\mathrm{Z}^k$.

The simplest case—which is taken by most investigators—is when all calls are of equal length, say L.

Thus, at any instant ST, a call for which $t$ is less than L is still continuing, and calls for which $t$ is greater than L have ceased.

That is :—

$\mathrm{P}_t=1$ for $t$ less than L; $\mathrm{P}_t=0$ for $t$ greater than L. Then (9) becomes

[1] If the probabilities of two independent events are respectively $\mathrm{P}_1$ and $\mathrm{P}_2$, the probability of their falling together is the product of their independent probabilities.

$$\Pi\ (pZ + 1 - p) = \Pi \left\{ \frac{m}{n}\ Z + 1 - \frac{m}{n} \right\}$$
$$= \left\{ \frac{m}{n}\ Z + 1 - \frac{m}{n} \right\}^{nL}$$

a product containing $nL$ factors corresponding to the $nL$ instants T in which a case might have occurred.

So that the chance of K calls going on at the moment is the coefficient of $Z^K$ in this product or :—

$$\frac{nL(nL-1)\ .\ .\ .\ (nL-K+1)}{K\,!} \left(\frac{m}{n}\right)^K \left(1 - \frac{m}{n}\right)^{nL-K} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

As $n$ approaches infinity, this expression approaches :—

$$\frac{(nL)^K m^K}{K\,!\ n^K} e^{-\frac{m}{n}(nL-K)} = \frac{(mL)^K}{K\,!}\ e^{-mL} \ldots\ldots\ldots\ldots\ldots (10a)$$

From the foregoing, therefore, if there were an infinite number of selectors or outlets, the number of occasions on which 0, 1, 2, . . . . . K, were in use would be as follows :—

| No. of Selectors in use. | Number of occasions. |
|---|---|
| 0 | $e^{-mL}$ |
| 1 | $mLe^{-mL}$ |
| 2 | $\frac{(mL)^2}{2\,!}\ e^{-mL}$ |
| ........................ | |
| K | $\frac{(mL)^K}{K\,!}\ e^{-mL}$ ....(11) |

Written in a more familiar manner the general term is $\frac{m^x}{x\,!}\ e^{-m}$. The distribution of the frequency with which 0, 1, 2, . . . . . $x$, junctions are engaged is therefore a Poisson Series if the calls each have an equal holding time and the frequency distribution of their rate of arrival is also a Poisson Series, a condition commonly described as chance order. This solution was arrived at by Dr. E. S. Pearson of University College, London, and is a particularly helpful method of approach leading up to the principles adopted in the more general solution, shown in Appendix I. It is there shown, for the first time it is believed, that the frequency distribution of calls in progress (or junctions engaged) can be represented by a Poisson Series regardless of the way in which the call lengths are distributed, but providing only that the calls arrive according to a Poisson distribution. Alternatively, a solution is possible no matter in what way calls actually arrive. This may have some use in grading problems since calls do not arrive according to a Poisson distribution at the commoning points in a grading.

Proceeding from this point, however, it will be assumed that the frequency distribution of the rate of arrival of calls can be represented by a Poisson Series although the method to be adopted is perfectly general. We now require to determine the proportion of calls lost as the outlets are reduced.

Let the frequency distribution of junctions engaged be represented by a Poisson Series :—

$$N \left\{ \frac{1}{S_n},\ \frac{m}{S_n},\ \frac{\frac{m^2}{2\,!}}{S_n}\ \ldots\ \frac{\frac{m^x}{x\,!}}{S_n}\ \ldots\ \frac{\frac{m^n}{n\,!}}{S_n} \right\}$$

where N is the total number of observed intervals, $m$ is the usual " $m$ " of a Poisson Series, and $S_n$ is the sum of all the terms in the Poisson Series, by which each term is divided so that the sum of the Series is unity. The whole expression has the value N and therefore each term now represents the actual number of occasions upon which 0 1 2 . . . . . $n$ junctions would be engaged simultaneously.

As shown in Appendix II., when there is only one junction available it will be engaged for a time $N\left\{\frac{m}{1+m}\right\}$ and disengaged for a time $N\left\{\frac{1}{1+m}\right\}$ so that the distribution of junctions engaged will be

| | | |
|---|---|---|
| 0 | Junctions engaged. | $N\left\{\frac{1}{1+m}\right\}$ |
| 1 | ,, ,, | $N\left\{\frac{m}{1+m}\right\}$ |

If a second junction is available, some of the accepted traffic will be carried by each junction. Some of the number of occasions upon which 1 junction only is engaged will become occasions of two junctions engaged, some of those hitherto of 0 junctions engaged will become occasions of 1 junction engaged. We proceed to examine the effect of curtailing junctions.

Invert the problem. Take the distribution of junctions engaged with two junctions available and examine the conditions when the second junction is withdrawn. Let the distribution be

| | | |
|---|---|---|
| 0 | Junctions engaged. | K |
| 1 | ,, ,, | $K_1$ |
| 2 | ,, ,, | $K_2$ |

Taking away junction 2, then $K_2$ becomes zero; every occasion of 2 junctions engaged becomes an occasion of 1 junction engaged. Some occasions of 1 junction become occasions of 0 junctions engaged.

To fix our ideas, we might refer to the theoretical table in Appendix IV., showing the distribution of junctions engaged when the junctions are reduced one at a time from 12 to 1 and the distribution of the traffic carried by each junction. This table was calculated by starting with a distribution with 12 junctions available and reducing the junctions by one at a time. The table is based on the assumption that observations are carried out at five-second intervals for $11\frac{3}{4}$ hours and the average volume of traffic offered is 4.0028 T.U's. It was, in fact, used to check the results of an artificial traffic record.

The first junction is engaged for $N\left\{\frac{m}{1+m}\right\}$ or 6770 intervals.

The distribution of the traffic carried must be 0 intervals when no junctions are engaged and 6770 intervals when one junction is engaged. The distribution of junctions engaged must be 1690 intervals of 0 junctions and 6770 intervals with one junction engaged, that is, in the proportion $N\left\{\frac{1}{1+m}\right\}$ and $N\left\{\frac{m}{1+m}\right\}$ where the $m$'s are those of the Poisson Series when all the junctions are available. So that whatever operations occur between 12 and 1 junctions *the ratio of the first and second terms of the distributions of junctions engaged is the same.*

The second junction is occupied for

$$N\left\{\frac{m^2}{1+m}-\frac{\frac{m^3}{2}}{1+m+\frac{m^2}{2}}\right\} \text{ intervals}$$

or 6249 intervals.

The distribution must be :—

| | Distribution of junctions engaged 2 junctions. | Traffic carried by 2 junctions. | Distribution of junctions engaged 1 junction. | Traffic carried by 1st junction. |
|---|---|---|---|---|
| 0 = | $\left\{N\frac{1}{1+m+x}\right\}$ | 0 | $N\frac{1}{1+m}$ | 0 |
| 1 = | $\left\{N\frac{m}{1+m+x}\right\}$ | $L-N\frac{x}{1+m+x}$ | $N\frac{m}{1+m}$ | $N\frac{m}{1+m}$ |
| 2 = | $\left\{N\frac{x}{1+m+x}\right\}$ | $N\frac{x}{1+m+x}$ | | |

Where L is the total traffic carried by junction No. 2 and is

$$N\left\{\frac{m^2}{1+m}-\frac{\frac{m^3}{2\,!}}{1+m+\frac{m^2}{2\,!}}\right\}$$

Equating

$$N\frac{1}{1+m+x}+L-N\frac{x}{1+m+x}=N\frac{1}{1+m}$$

$$N\frac{1}{1+m+x}+N\frac{m^2}{1+m}-N\frac{\frac{m^3}{2}}{1+m+\frac{m^2}{2}}$$

$$-N\frac{x}{1+m+x}=N\frac{1}{1+m}$$

whence

$$\frac{1-x}{1+m+x}=\frac{1-\frac{m^2}{2}}{1+m+\frac{m^2}{2}}$$

so that $x=\frac{m^2}{2}$

Proceeding, as each additional junction is brought into use it becomes clear that each series of the distribution of junctions engaged is a truncated Poisson Series of the same " $m$ " as in an unrestricted system.

It is now possible to introduce the " difference " term. Taking the distribution of traffic carried by the third junction, it is clear that when the third junction is withdrawn, the 3816 occasions of three junctions engaged become occasions of 2; 1467 occasions of 2 become occasions of 1; so that the new distribution when only two junctions are available is obtained by increasing each term by these differences.

Writing down these conditions :—

| | Distribution of junctions engaged 2 junctions. | Differences between terms of Distribution of junctions engaged where 2 junctions available and only 1 available. | Distribution of Traffic carried by 2nd Junction. | Distribution of junctions engaged 1 junction. |
|---|---|---|---|---|
| 0 = | $N\frac{1}{1+m+\frac{m^2}{2}}$ | $N\left\{\frac{1}{1+m}-\frac{1}{1+m+\frac{m^2}{2}}\right\}$ | $N\left\{\frac{1}{1+m+\frac{m^2}{2}}+\frac{\frac{m^2}{2}+m}{1+m+\frac{m^2}{2}}-\frac{m}{1+m}-\frac{1}{1+m}\right\}$ | $N\frac{1}{1+m}$ |
| 1 = | $N\frac{m}{1+m+\frac{m^2}{2}}$ | $N\left\{\frac{m}{1+m}-\frac{m}{1+m+\frac{m^2}{2}}\right\}$ | $N\left\{\frac{\frac{m^2}{2}+m}{1+m+\frac{m^2}{2}}-\frac{m}{1+m}\right\}$ | $N\frac{m}{1+m}$ |
| 2 = | $N\frac{\frac{m^2}{2}}{1+m+\frac{m^2}{2}}$ | $N\frac{\frac{m^2}{2}}{1+m+\frac{m^2}{2}}$ | $N\frac{\frac{m^2}{2}}{1+m+\frac{m^2}{2}}$ | |
| Totals = N | | | $N\left\{\frac{\frac{3m^2}{2}+2m+1}{1+m+\frac{m^2}{2}}-\frac{2m+1}{1+m}\right\}$ | N |

The general term of the expression for traffic carried is :—

$$N\left\{\frac{(x+1)\frac{m^x}{x!}+x\frac{m^{x-1}}{(x-1)!}\ \ldots\ldots+1}{1+m+\ldots\ldots+\frac{m^x}{x!}}-\frac{x\frac{m^{x-1}}{(x-1)!}\ \ldots\ldots+1}{1+m\ \ldots\ldots+\frac{m^{x-1}}{(x-1)!}}\right\}$$

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

So that the series is :—

Traffic carried by 1st Junction

$$N\left\{\frac{m}{1}-\frac{m^2}{1+m}\right\}=N\frac{m}{1+m}$$

Traffic carried by 2nd Junction

$$N\left\{\frac{m^2}{1+m}-\frac{\frac{m^3}{2!}}{1+m+\frac{m^2}{2}}\right\}$$

and the total traffic carried by $x$ junctions is :—

$$N\left\{\frac{m}{1}-\frac{\frac{m^{x+1}}{x!}}{1+m\ \ldots\ \frac{m^x}{x!}}\right\}$$

and the loss is : —

$$N\left\{\frac{\frac{m^{x+1}}{x!}}{1+m\ \ldots\ \frac{m^x}{x!}}\right\}\text{ or }Nm\left\{\frac{\frac{m^x}{x!}}{1+m+\ \ldots\ \frac{m^x}{x!}}\right\}$$

or using the better known symbols, the loss per hour in units of speech hours is[2] :—

$$A\left\{\frac{\frac{A^x}{x!}}{1+A\ \ldots\ +\frac{A^x}{x!}}\right\}$$

It will be seen that the " difference " terms equal the discarded terms divided proportionately amongst the terms retained in each series.

The feature of interest is that traffic which has already passed through earlier switching plant is often described as being smoother than so-called pure chance traffic. The condition would appear to be

[2] See Appendix III.

brought about by the shortened tail of the original series so that occasions where the greater number of junctions, which would be engaged in an unrestricted system, do not occur. Clearly, then, it is illogical to assume that outlets from 2nd stages of selection have less capacity than outlets from earlier stages whether graded or ungraded. Incidentally, some switches in the system should be provided not on a lost call basis but on a delay basis.

It is now possible to proceed by easy steps to work out tables showing precisely how many channels would be required for given volumes of traffic so that a predetermined proportion might be lost by reason of insufficiency of equipment.

Let the curve in Fig. **4** represent the terms of a Poisson Series.

Let the scales be reduced so that the total area of the curve is unity. Then with $x$ junctions provided, the proportion of traffic lost is the ratio of the area representing the $x^{th}$ term to the whole area up to and including the $x^{th}$ term. The values of the separate terms in Poisson's Series have been tabled. Two are given below :—

| | Average 1.30 | Average 1.40 |
|---|---|---|
| $x=0$ | .272532 | .246597 |
| 1 | .354291 | .345236 |
| 2 | .230289 | .241665 |
| 3 | .099792 | .112777 |
| 4 | .032432 | .039472 |
| 5 | .008432 | .011052 |
| 6 | .001827 | .002579 |
| 7 | .000339 | .000516 |
| 8 | .000055 | .000090 |
| 9 | .000008 | .000014 |
| 10 | .000001 | .000002 |

It is desired to ascertain the capacity of 6 junctions so that .002000 parts of the total traffic are lost.

Correcting for the tail and interpolating at the point where $x=6$, $\frac{172}{753} \times 0.1 = .022842$.

That is a Poisson Series with an average of 1.323 would have the value .002000 for the term in which $x=6$.

So that six junctions will carry 1.323 units of traffic if the proportion of lost traffic be $\frac{.002000}{1.000000}$ or $\frac{1}{500^{th}}$ part.

So far, the problem dealt with applies only to systems in which every call has access to every junction. Before proceeding further, it would perhaps be advisable to indicate certain difficulties likely to be met by an investigator. They are so instructive that no apology is offered for their inclusion here.

In general, telephone traffic is, at many stages in the plant, divided and sub-divided until it constitutes as it were small portions of traffic directed to separate parts of the apparatus. It cannot be established for a moment that these small portions are constant in size. On the contrary, it is common knowledge that the total Exchange traffic varies not only from day to day but both from hour to hour and season to season. Much more so, for instance, will the traffic between any two particular exchanges vary. The following table represents the hourly traffic units obtained from artificial records which are, of course, free from the effects of the seasonal or daily variation met with in actual telephone traffic.

TRAFFIC UNITS PER HOUR.

| | |
|---|---|
| 3.197222 | 4.140278 |
| 3.473611 | 4.312500 |
| 3.700000 | 4.365278 |
| 3.808333 | 4.487500 |
| 3.975000 | 4.884722 |
| 3.986112 | |

It might perhaps be mentioned that the holding times in this artificial record were based on some 10,000 Busy Hour observations taken on actual traffic and varied in length from 5 seconds to nearly 20 minutes. The British Post Office now bases its equipment provision on traffic volumes observed during the busiest two consecutive half hours of two consecutive hourly periods in the busiest part of the day. It will often occur that one consecutive hourly period chosen in some other way will show a larger volume of traffic. The whole theory so far discussed assumes however that the traffic is neither rising nor falling during the hourly period chosen. Any attempt for instance to discard a few minutes of an hour at one end of the hourly period and accept another part at the beginning of the hour does not necessarily mean that one of those comparatively less busy periods occurring in its turn with the other parts of the hour has been replaced by a more busy period which has occurred in its turn to be associated with the period outside the true busy hour. It is much more likely that the busiest hour does not commence precisely at 10 a.m. or 10.30 a.m. as the case may be.

The following readings taken from artificial records at intervals of 5 seconds for 15 minutes, show this condition, if instead of an hour, a 5 minute period only be considered :—

| Time 0—5 mins. | Time 5—10 mins. | Time 10—15 mins. | Time 0—5 mins. | Time 5—10 mins. | Time 10—15 mins. |
|---|---|---|---|---|---|
| 1 | 4 | 8 | 2 | 4 | 4 |
| 1 | 4 | 8 | 2 | 5 | 4 |
| 1 | 4 | 8 | 1 | 5 | 4 |
| 1 | 4 | 8 | 1 | 5 | 4 |
| 1 | 3 | 8 | 1 | 6 | 4 |
| 1 | 3 | 9 | 1 | 6 | 4 |
| 0 | 3 | 10 | 1 | 6 | 4 |
| 0 | 3 | 10 | 1 | 7 | 4 |

| Time 0—5 mins. | Time 5—10 mins. | Time 10—15 mins. | Time 0—5 mins. | Time 5—10 mins. | Time 10—15 mins. |
|---|---|---|---|---|---|
| 0 | 2 | 8 | 1 | 8 | 4 |
| 1 | 3 | 8 | 2 | 7 | 5 |
| 1 | 3 | 8 | 2 | 6 | 5 |
| 1 | 3 | 7 | 3 | 7 | 5 |
| 1 | 3 | 7 | 4 | 7 | 6 |
| 1 | 3 | 6 | 4 | 7 | 6 |
| 1 | 3 | 6 | 4 | 7 | 5 |
| 1 | 3 | 6 | 4 | 7 | 5 |
| 1 | 2 | 6 | 4 | 7 | 5 |
| 1 | 3 | 6 | 5 | 7 | 4 |
| 1 | 3 | 6 | 5 | 8 | 4 |
| 1 | 3 | 6 | 5 | 9 | 4 |
| 1 | 3 | 5 | 5 | 8 | 5 |
| 1 | 3 | 5 | 5 | 7 | 5 |
| 0 | 3 | 5 | 5 | 7 | 5 |
| 1 | 3 | 5 | 5 | 6 | 5 |
| 1 | 3 | 4 | 5 | 6 | 6 |
| 1 | 3 | 5 | 5 | 6 | 6 |
| 2 | 4 | 5 | 4 | 6 | 7 |
| 2 | 4 | 5 | 5 | 7 | 7 |
| 2 | 4 | 5 | 5 | 7 | 7 |
| 2 | 4 | 5 | 5 | 8 | 6 |

The busiest five-minute period is clearly from about 8 minutes to 13 minutes.

We now recapitulate the various assumptions that have been made. Firstly it has been assumed that calls arrive according to the law $\phi(n) = e^{-m} \frac{m^n}{n!}$ given in equation (7). It has also been shown that this assumption can be tested. In comparing records taken at B-positions, it must be remembered that when all multiple order-wire junctions between two exchanges are engaged, the distant A-telephonist will often go from one to another order wire a number of times in quick succession. This may result in the receipt of a far larger number of demands within a unit period than would ever occur if the subscriber were to meet the engaged signal and make repeat attempts himself. Even on a single order wire group, the A-telephonist not infrequently keeps the call in hand for a few seconds with the same effect on the record. Considering the conditions likely to be met in practice in an automatic system, it has been assumed that within the interval " $a$ " representing the maximum time for which a call is held, a second call from the same subscriber will occur so rarely that its effect can be ignored. If calls do occur in these circumstances, the second call will have the time of its arrival influenced by the first call, so that the general effect will be to shorten the tail of the series representing the mode of arrival. It is common knowledge that subscribers frequently make calls one after another. At subscribers' P.B.Xs. calls are not infrequently delayed for want of free exchange lines before being passed to the exchange. In actual practice the theoretical results may therefore give the maximum loss possible, but a loss which may never in fact be reached.

An examination of observational results would appear to be a method by which this problem may be solved.

It is relatively unimportant whether or no the theoretical curve of a distribution of junctions engaged fits in the main fairly well with observed conditions. It is of cardinal importance that the theoretical and observed conditions should closely fit within the region of the tails. This is by far the most difficult aspect of all problems of this nature, since it concerns essentially small quantities.

There is another feature of interest. Let it be assumed that 1.82 traffic units are offered to a group of trunks. As 1.80 traffic units require by the present tables seven trunks, eight trunks will be provided. Clearly the grade of service will be superior to a loss of one call in every five hundred. So that, in general, such an interpretation of the tables will ensure not that there is an average loss of one in five hundred, but that this loss shall be the maximum on any one group of trunks.

The reader should perhaps be warned that in attempting artificially to simulate actual traffic conditions, it is difficult to obtain a truly random distribution of points from which calls start and he will be well advised to test his distribution before proceeding further.

Up to now the problem has been one of the quantity of equipment required to obtain a specified grade of service. It often happens however that it is required to determine the probable grade of service with a fixed quantity of equipment and a known volume of traffic. Referring to the Poisson Series already discussed, let it be assumed that 1.30 traffic units are offered to 3 outlets. The proportion of lost traffic is the ratio of the term for which $x = 3$ to the area up to that term, that is in the long run $\frac{.099792}{.956904}$ or 1 in 13.12 calls would be lost.

## APPENDIX I.

Let the distribution of lengths of call be

$$y = f(L) \quad \text{as in Fig. 6}$$

where a call may vary from $L = 0$ to $L = a$, and $\int_0^a f(L)\, dL = 1$

$$\dots\dots\dots\dots (12)$$

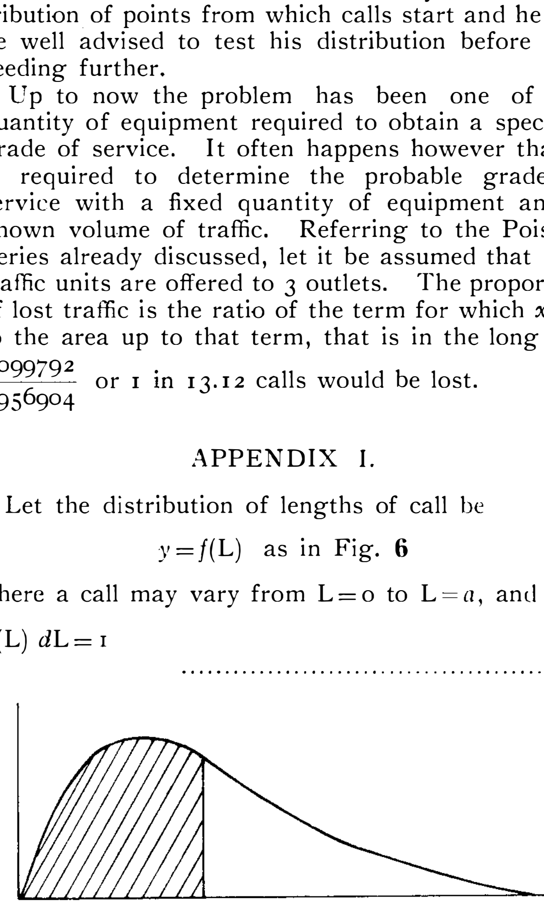


FIG. 6.

The chance of a very short call may be practically zero, but this means that the curve runs along the axis for some way before rising.

Let

$$F(L) = \int_0^L f(L)dL \text{ and } F(a) = 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots(13)$$

or F(L) is chance of a call of duration less than L. Consider the calls $x$, likely to be in progress at a given instant of time T. Suppose this instant T be taken as the origin, and co-ordinate $t$ measured backwards as in Fig. **7**.

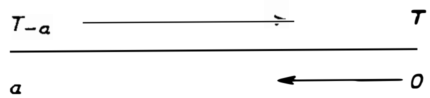


FIG. **7**.

Then we need only consider the calls which commenced during the interval $(T-a)$ to T, or on the new scale, from $t=0$ to $t=a$. Any calls originating before that time will have ceased, if $a$ is maximum length.

Suppose in a given case there are $n$ calls starting in the interval $t=0$ to $(t-a)$. Afterwards it will be necessary to sum for all possible values of $n$, but it is easy to start with a given $n$ and find the chance of the various $x$'s.

Let $n$ calls occur in the intervals

$$\left.\begin{array}{l} \{t_1 \pm \tfrac{1}{2}dt_1\},\ \{t_2 \pm \tfrac{1}{2}dt_2\} \ldots \{t_n \pm \tfrac{1}{2}dt_n\} \\ \text{and let the corresponding associated lengths of call be} \\ L_1, \quad L_2 \quad\quad L_n \end{array}\right\} \quad (A)$$

$t_s$ and $L_s$ $(s = 1, 2, \ldots n)$ are supposed quite independent. These $n$ values of $t$ are not to be considered as in any order in time, if it is desired to give them identities it might be supposed that they are in order of the subscriber's telephone numbers. This being so, $t_s$ is equally likely to have any value between 0 and $a$ or the chance of call occurring in any one given interval $dt$ is $\frac{dt}{a}$. Here an assumption comes in which may or may not be important; it is assumed that second calls by a subscriber in the interval $a$ are very rare. If they were frequent and $t_s$ and $t_p$, say, represented calls of the same subscriber, it is clear that there will be restriction on the range of $t_s$ and $t_p$. It would be necessary then to go into the problem of how many of the $n$ calls were likely to be repeat calls. Assuming however that $t$ may vary freely, the chance of the system (A) given above is

$$= \frac{1}{a^n} f(L_1)f(L_2) \ldots f(L_n)\, dL_1\, dL_2 \ldots dL_n\, dt_1 \ldots dt_n \quad \ldots\ldots\ldots\ldots\ldots(14)$$

$x$ calls will be in progress when $t=0$, if $x$ of the quantities $L_s - t_s$ are $> 0$, $n-x$ are $< 0$ (as $L_p - t_p$ in Fig. **8**).

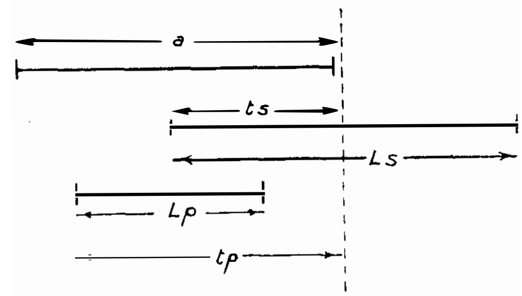


FIG. **8**.

Out of the $n$ calls each considered as having separate identities, *e.g.*, as if identified with different subscribers, there will be $\frac{n!}{x!(n-x)!}$ ways of picking out $x$ to be in progress at $t=0$, and $n-x$ to have ceased.

Hence the chance of $x$ calls being in progress

$$= \frac{n!}{x!(n-x)!}\,\frac{1}{a^n}\underbrace{\int_0^{t_h} f(L)dL \ldots \int_0^{t_k} f(L)dL}_{n-x \text{ integrals}}$$

$$\underbrace{\int_{t_j}^{a} f(L)dL \ldots \int_{t_i}^{a} f(L)dL}_{x \text{ integrals}}\, dt_1 \ldots dt_n \quad \ldots\ldots(15)$$

Where $t_h \ldots t_k$ represent the $n-x$ calls which have ceased at $t=0$

$t_j \ldots t_i$ represent the $x$ calls which continue at $t=0$

All values of $t$ between 0 and $a$ have now to be integrated.

Consider

$$\int_0^a dt_k \int_0^{t_k} f(L)dL = \int_0^a F(t)dt = \int_0^a F(L)dL$$

$$\int_0^a dt_j \int_t^a f(L)dL = \int_0^a dt_j \left\{ 1 - \int_0^{t_j} f(L)dL \right\}$$

$$= \int_0^a \{1 - F(t)\}dt = a - \int_0^a F(L)dL$$

Hence the chance of $x$ calls being in progress becomes :—

$$\frac{n!}{x!(n-x)!}\,\frac{1}{a^n}\left\{\int_0^a F(L)dL\right\}^{n-x}\left\{a - \int_0^a F(L)dL\right\}^x$$

$$= \frac{n!}{x!(n-x)!}\, p^x(1-p)^{n-x} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(16)$$

Where $p = 1 - \frac{1}{a}\int_0^a F(L)dL$ and

$$1 - p = q = \frac{1}{a}\int_0^a F(L)dL \quad \ldots\ldots(17)$$

$q = 1 - p = \frac{1}{a}$ {integral of integral curve of $f(L)$}.

This is the ratio of the shaded area to the rectangle A B C D which is of area $1 \times a = a$ shown in Fig. **9**.

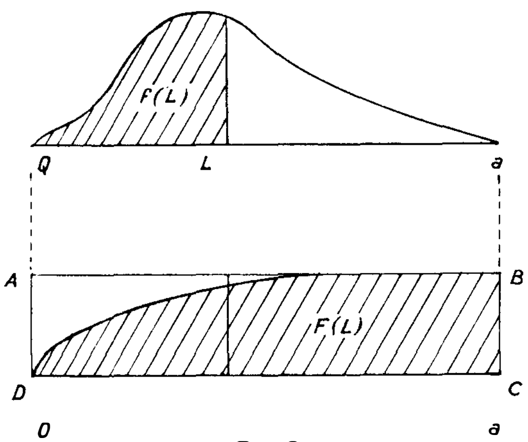


Fig. **9**.

Expression (16) gives the chance of $x$ calls being in progress at $t=0$, if $n$ occurred during previous time $a$. We have now to sum for all possible values of $n$. Suppose $\phi(n)$ is the chance of $n$ calls in time $a$. If the random law of arrival of calls holds,

$$\phi(n) = e^{-m}\frac{m^n}{n!} \quad \ldots\ldots(18)$$

where $m$ = average number of calls in time $a$.

Hence the chance of having $x$ calls in progress at one time is :—

$$\sum_{n=0}^{\infty}\left\{C_{nx}\right\} = \sum_{n=0}^{\infty}\left\{\phi(n)\frac{n!}{x!(n-x)!}p^x(1-p)^{n-x}\right\} \ldots(19)$$

in general, and in particular if (18) be true

$$= \sum_{n=0}^{\infty}\left\{\frac{n!}{x!(n-x)!}e^{-m}\frac{m^n}{n!}p^x(1-p)^{n-x}\right\} \ldots(20)$$

$$= \frac{m^x p^x}{x!}e^{-m}\sum_{n=0}^{\infty}\left\{\frac{\{m(1-p)\}^{n-x}}{(n-x)!}\right\}$$

$$= \frac{(mp)^x}{x!}e^{-m}e^{m(1-p)}$$

$$= \frac{(mp)^x}{x!}e^{-(mp)} \quad \ldots\ldots(21)$$

or the distribution of $x$, calls in progress is a Poisson series where $m$ = average number of calls in time "$a$" multiplied by

$$\frac{1}{a}\left\{a\int_0^a F(L)dL\right\}$$

= average number of calls in unit time multiplied by

$$\left\{a - \int_0^a F(L)dL\right\} \quad \ldots\ldots(22)$$

Considering the integral, let $y = f(L)$ be represented by the curve shewn in Fig. **10**.

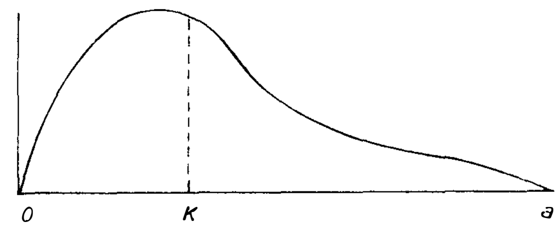


Fig. **10**.

$\int_0^a F(L)dL$ is the moment of the curve about its tail. The moment about K, the mean, is zero. The total area is unity. Therefore the moment about the tail is $1 \times$ distance K to $a = a - K$.

Hence (22) equals $\{a - (a - K)\} = K$, the mean or average holding time and (21) equals $\frac{m^x}{x!}e^{-m}$ where $m$ is now the average number of calls arriving during the average holding time, a brilliant solution arrived at by Mr. Sadler of the Nautical Almanac Office. For the first time therefore it becomes possible to obtain a solution no matter in what way calls arrive. The solutions will, of course, vary according to the manner in which it is assumed calls arrive.

## APPENDIX II.

Let the frequency distribution of the number of junctions engaged at each observation be proportional to the terms of the Poisson Series :—

$$1, \frac{m}{1}, \frac{m^2}{2!}, \frac{m^3}{3!}, \ldots \frac{m^x}{x!}, \ldots \frac{m^n}{n!}.$$

so that the proportions of times during which 0, 1, 2, . . . $x$, junctions are engaged are :—

$$1, m, \frac{m^2}{2!}, \ldots \frac{m^x}{x!}.$$

Examine first what might happen if only one junction is available. Let N be the number of calls offered per hour and $n$ be those accepted by the 1st switch. Let B be the average holding time of each call in hours.

Then as the first junction will lose all calls occurring during the time for which it is engaged, the proportion of lost calls will be $\frac{nB}{1}$ which equals $\frac{N-n}{N}$.

$$\text{So } n = \frac{N}{1+NB} \text{ or } nB = \frac{NB}{1+NB} \qquad 3.$$

NB is the total speech time per hour in hours. It is also the average number of calls in progress at any time, and is, therefore, the " $m$ " of a Poisson Series. This shows, as it should, that the traffic carried by the first junction is independent of the number of junctions available provided that the restriction in outlets is not sufficiently severe to alter the manner in which calls arrive. It also shows that, if only one junction is available under the same conditions, the ratio of the 1st and 2nd terms in the distribution of junctions engaged is always 1 and $m$. If there are two junctions available, the distribution will be proportional to 1, $m$, $\frac{m^2}{2}$, and so on. This is the key to the situation.

Then if $x=1$, one junction is engaged for a time $\frac{m}{1+m}$ and the speech time lost is

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

If $x=2$ then one junction is engaged for a time $\frac{m}{1+m+\frac{m^2}{2!}}$ and two junctions for a time $\frac{\frac{m^2}{2}}{1+m+\frac{m^2}{2!}}$

The speech time accepted is $\frac{m+2\frac{m^2}{2!}}{1+m+\frac{m^2}{2!}}$

And the speech time lost is :—

$$m - \frac{m+m^2}{1+m+\frac{m^2}{2!}} = m\left\{\frac{\frac{m^2}{2!}}{1+m+\frac{m^2}{2!}}\right\}$$

In general when $m$ units are offered to $x$ junctions the loss is

$$m\left\{\frac{\frac{m^x}{x!}}{1+m\ldots+\frac{m^x}{x!}}\right\}$$

That is the proportion of traffic lost when $x$ junctions only, are provided for $m$ traffic units is

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

## APPENDIX III.

It might have been postulated that equation (21) represents the frequency with which $x$ calls are simultaneously in progress and also the frequency with which $x$ calls are made in time periods equal to the average call length. Also the required value is the frequency with which $(x+1)$, and $(x+2)$, . . . $n$ calls are made, and as upon each of these occasions one call will be lost, the proportion of lost traffic might be represented by the ratio of the area of the tail beyond $x$ to the whole area or unity providing always that the lost calls are not large enough to introduce material error in the assumption that the manner of arrival of calls accepted is $e^{-m}\frac{m^n}{n!}$. This is incorrect. We say equation (21) represents the number of occasions upon which $x$ calls are in progress, what is the chance of another call arriving during this condition? If the call arrives it will be lost.

The distribution in an unrestricted system is 1, M, $\frac{M^2}{2}$, . . . . $\frac{M^x}{x!}$. In a restricted system as now shown it will be $1+K_0$, $M+K_1$, $\frac{M^2}{2}+K_2$, . . . . . $\frac{M^x}{x!}+K_x$.

The proportion of time during which $x$ calls are in progress is $\frac{M^x}{x!}+K_x$ so that of M calls arriving within the unit time period the number lost will be—

$$M\left\{\frac{\frac{M^x}{x!}+K_x}{(1+K_0)+(M+K_1)+\ldots\frac{M^x}{x!}+K_x}\right\}$$

$$= M\left\{\frac{\frac{M^x}{x!}}{1+M+\frac{M^2}{2!}\ldots+\frac{M^x}{x!}}\right\}$$

since $K_0$, $K_1$, . . . . . $K_x$ are separately proportional to 1, M, $\frac{M^2}{2}$, . . . . $\frac{M^x}{x!}$.

[3] See "Automatic Trunking in Theory and Practice," by G. F. O'dell and W. W. Gibson, Institute of Post Office Electrical Engineers. Paper No. 107.

# APPENDIX IV.

## CALCULATED DISTRIBUTION OF JUNCTIONS ENGAGED.

| | Junctions Engaged. | Traffic carried by 12th junction. | Junctions engaged when 11 available. | Traffic carried by 11th junction. | Junctions engaged when 10 available. | Traffic carried by 10th junction. | Junctions engaged when 9 available. | Traffic carried by 9th junction. | Junctions engaged when 8 available. | Traffic carried by 8th junction. | Junctions engaged when 7 available. | Traffic carried by 7th junction. | Junctions engaged when 6 available. | Traffic carried by 6th junction. | Junctions engaged when 5 available. | Traffic carried by 5th junction. | Junctions engaged when 4 available | Traffic carried by 4th junction. | Junctions engaged when 3 available. | Traffic carried by 3rd junction. | Junctions engaged when 2 available. | Traffic carried by 2nd junction. | Junctions engaged when 1 available. | Traffic carried by 1st junction. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 154 | — | 154 | — | 154 | — | 155 | — | 157 | — | 162 | — | 173 | — | 196 | — | 245 | — | 356 | — | 649 | — | 1690 | — |
| | | (1) | | (1) | | (3) | | (8) | | (20) | | (44) | | (93) | | (196) | | (444) | | (1174) | | (4167) | | |
| 1 | 619 | — | 620 | 1 | 621 | 1 | 624 | 2 | 632 | 5 | 652 | 11 | 696 | 23 | 789 | 49 | 985 | 111 | 1429 | 293 | 2603 | 1041 | 6770 | 6770 |
| | | (1) | | (2) | | (7) | | (17) | | (40) | | (88) | | (185) | | (392) | | (889) | | (2349) | | | | |
| 2 | 1238 | 1 | 1239 | 1 | 1241 | 4 | 1248 | 10 | 1265 | 25 | 1305 | 55 | 1393 | 116 | 1578 | 245 | 1970 | 555 | 2859 | 1467 | 5208 | 5208 | | |
| | | (2) | | (3) | | (9) | | (22) | | (53) | | (117) | | (247) | | (524) | | (1187) | | | | | | |
| 3 | 1652 | 2 | 1654 | 3 | 1657 | 11 | 1666 | 26 | 1688 | 65 | 1741 | 143 | 1858 | 301 | 2105 | 637 | 2629 | 1444 | 3816 | 3816 | | | | |
| | | (2) | | (3) | | (9) | | (23) | | (53) | | (117) | | (247) | | (524) | | | | | | | | |
| 4 | 1653 | 4 | 1655 | 6 | 1658 | 20 | 1667 | 49 | 1670 | 118 | 1743 | 260 | 1860 | 548 | 2107 | 1161 | 2631 | 2631 | — | | | | | |
| | | (1) | | (3) | | (7) | | (18) | | (42) | | (93) | | (198) | | | | | | | | | | |
| 5 | 1323 | 6 | 1324 | 9 | 1327 | 29 | 1334 | 72 | 1352 | 171 | 1394 | 377 | 1487 | 795 | 1685 | 1685 | | | | | | | | |
| | | (1) | | (2) | | (5) | | (12) | | (28) | | (62) | | | | | | | | | | | | |
| 6 | 883 | 7 | 884 | 12 | 886 | 36 | 891 | 91 | 903 | 213 | 931 | 470 | 993 | 993 | | | | | | | | | | |
| | | | | (1) | | (3) | | (7) | | (16) | | | | | | | | | | | | | | |
| 7 | 505 | 8 | 505 | 14 | 506 | 41 | 509 | 103 | 516 | 241 | 532 | 532 | — | | | | | | | | | | | |
| | | | | (1) | | (1) | | (3) | | | | | | | | | | | | | | | | |
| 8 | 252 | 8 | 252 | 15 | 253 | 44 | 254 | 110 | 257 | 257 | | | | | | | | | | | | | | |
| 9 | 112 | 8 | 112 | 16 | 112 | 45 | 112 | 112 | | | | | | | | | | | | | | | | |
| 10 | 45 | 8 | 45 | 16 | 45 | 45 | | | | | | | | | | | | | | | | | | |
| 11 | 16 | 8 | 16 | 16 | | | | | | | | | | | | | | | | | | | | |
| Tail | 8 | 8 | | | | | | | | | | | | | | | | | | | | | | |
| Carried Tfc. | 68 | | | 109 | | 276 | | 576 | | 1095 | | 1848 | | 2776 | | 3777 | | 4741 | | 5576 | | 6249 | | 6770 |

# Recent Developments in Pneumatic Ticket Tube Design

J. E. M. McGregor, A.C.G.I.

Very considerable improvements have been made in pneumatic ticket systems since the original installation many years ago at the London Trunk Exchange, G.P.O. South. As large systems of these tubes are now being installed at a considerable number of towns in connexion with the introduction of Trunk Demand working, it is thought that the following notes may be of general interest. These tubes differ from the usual docket tubes used by the Department in that no carrier is necessary for the transmission of the record ticket. These tickets are made of a stout paper and are about $5\frac{1}{4}''$ long by $2\frac{3}{8}''$ wide, provided with a sail by turning up one end. The tubes are rectangular in section of $2\frac{3}{4}'' \times \frac{3}{8}''$ bore, and the tickets are propelled through the tubes by means of a current of slightly rarefied or compressed air.

The tickets were originally provided with a sail by bending the head as shown in Fig. **1**(*a*), this being modified later by folding into an arrow head as shown in Fig. **1**(*b*), which was a considerable improvement as the friction of the ticket against the tube was greatly reduced, the rubbing surface being confined to the edges of the arrow fold. It will be noted that with both these folds, the head of the ticket was expanded by the current of air, thus forming a close-fitting piston.

The latest practice is to fold up the tail of the ticket, making a sail at 90° or 60° about $\frac{1}{4}''$ long. The ticket now no longer acts as a close-fitting piston, but is carried freely with a minimum of friction by the current of air, which thus requires less pressure for its purpose. This shape of ticket has another very considerable advantage in that several tickets may pack up without blocking the

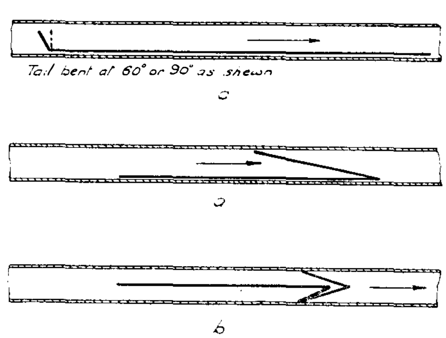


Fig. 1.—Methods of Folding Tickets.

tube, as there is only an effective thickness of one layer of paper per ticket, whereas with the first form of ticket there are two layers and with the arrow head, four. This of course makes for much greater reliability of working with the tubes.

The tubing used was originally of plain section, Fig. **2**(*a*), but is now slightly corrugated as shown in Fig. **2**(*b*). This further reduces the frictional loss and the risk of interference with the passage of the ticket by blisters or flakiness of the interior surface.

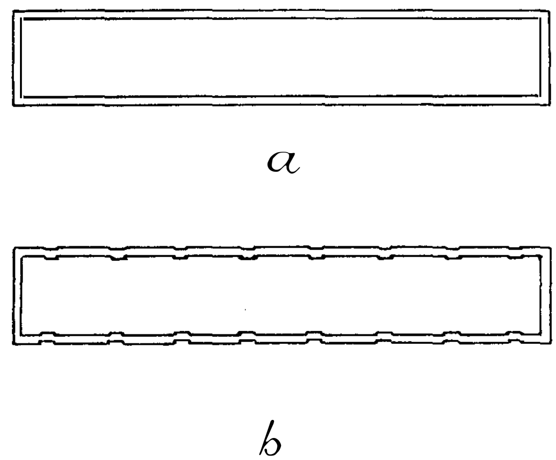


Fig. 2.—Sections of Tubing.

It will, of course, be appreciated that the erection of the tubing has to be very carefully carried out, the joints being perfectly butted and smooth, and the edges facing the travel of the ticket being chamferred away so that the ticket meets no obstruction.

The tubes are usually assembled as far as possible in banks, either in the floor or overhead and are run generally on edge, this forming the best grouping both for convenience and accessibility.

The ticket tubes are used as

(*a*) *Collecting tubes* for transmitting the tickets from the operators' positions and delivering them to a central point which, in the case of completed calls, is known as the Ticket Filing Position (T.F.P.) and, in the case of tickets which have to be sent on for the calls to be completed, is called the Pneumatic Distribution Position (P.D.P.). Each collecting tube may serve any number up to 10 positions.

(*b*) *Distributing tubes* which run from the P.D.P. to individual positions.

The apparatus employed depends on the systems installed, these being the Mix and Genest system and the McGregor system, which has been developed especially for the Department. Some buildings are being equipped with both systems in part, owing to installations having to be put in hand during the development of the new system.

The Mix and Genest system is shown in Fig. **3**. It will be seen that a rarefied air or vacuum system

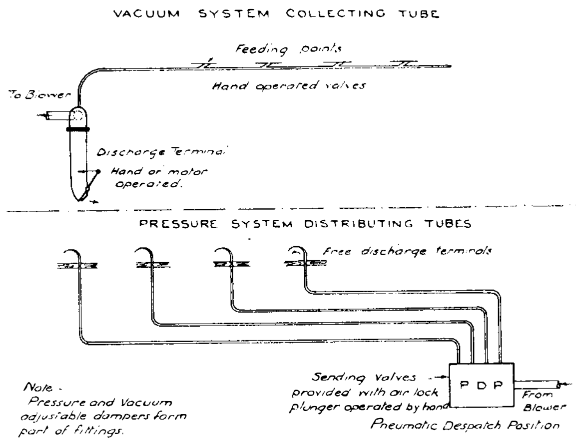


FIG. **3**.—DIAGRAM OF MIX AND GENEST SYSTEM.

is used for the collecting tubes whilst a pressure system is used for the distributing tubes. In the vacuum system, tickets are inserted in the tube through a simple valve (see Fig. **4**) and this is

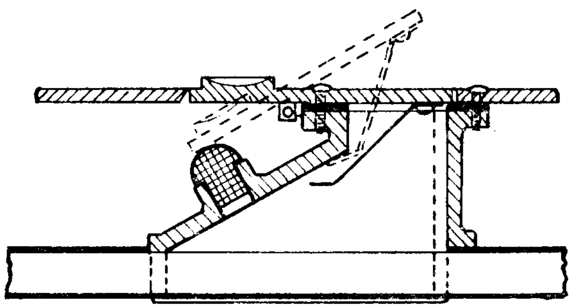

FIG. **4**.—MIX AND GENEST VACUUM DESPATCHING VALVE.

operated by pressing the button which opens a cover so that the ticket may be admitted. The ticket then travels through the tube under the influence of a current of rarefied air, being finally discharged through a rather complicated terminal embodying an air lock (Fig. **5**). The terminal consists of two compartments A and B separated by a flap door C, the outer compartment being closed by another door D. The air is led away at the point E. The doors are controlled by levers so arranged that C is closed before D is opened and D is closed before C re-opens. Normally C is open and the tickets fall through into the chamber B. The door D is opened to let the tickets fall out, during which period any following tickets collect in the upper chamber A. The by-pass between the chambers is introduced to provide an air leak to reduce the noise caused by opening the inner door against the vacuum, the outer door being made slightly flexible for the same reason. This terminal has to be operated by hand, or, if the terminals are mounted in a bank, they are opened and closed in turn by a cam shaft driven through

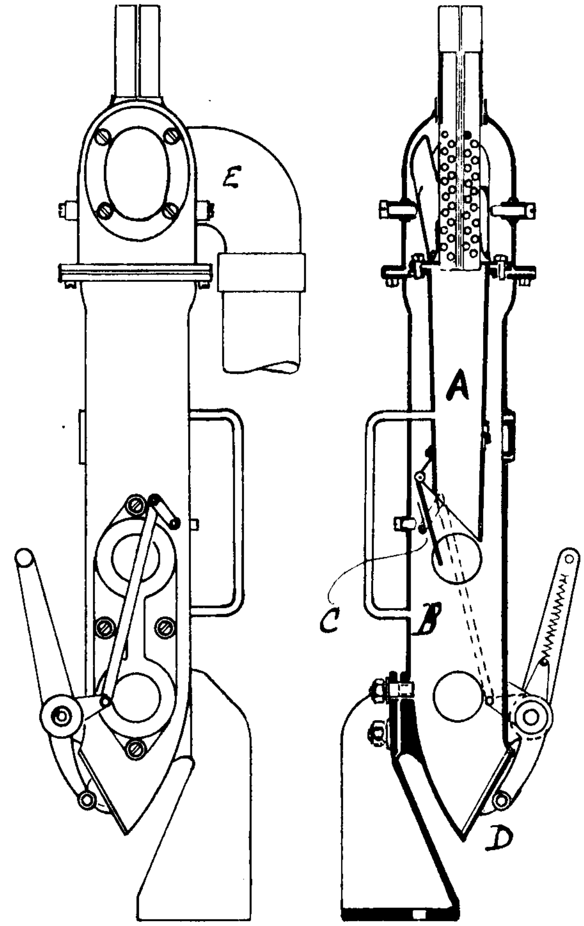


FIG. **5**.—MIX AND GENEST VACUUM DISCHARGE TERMINAL.

reduction gear by an electric motor, the operation of opening being timed to take place at about 5 second intervals. Where a large number of terminals is installed, they are generally opened in sequence by a series of cams set at different angles.

Another terminal used on Mix and Genest systems is operated by the ticket striking a contact lever in the tube which sets a chain of relays in action, cutting off the vacuum and permitting the ejection of a ticket.

In the McGregor system a different principle is employed and the ejection of the ticket is purely automatic, no auxiliary motor, relay or hand operation is required and there is no delay.

Before dealing with this in detail, it may be advisable to complete the description of the Mix and Genest system as regards the distributing tubes which are operated by compressed air. In this case, the sending ends of the valves are grouped conveniently in a panel at the P.D.P. The delivery terminals of the collecting tubes discharge their tickets at the back or sides of this panel on to conveyors and/or chutes which bring the tickets on to the sorting space provided in front of the despatch position. When conveyors are installed, owing to a large number of terminals discharging at the

P.D.P., they are usually driven by the motor operating the discharge terminals.

Owing to the distributing tubes being operated by compressed air, it is necessary to insert the tickets through a valve embodying an air lock, Fig. **6**. As will be seen, this valve has two chambers, one

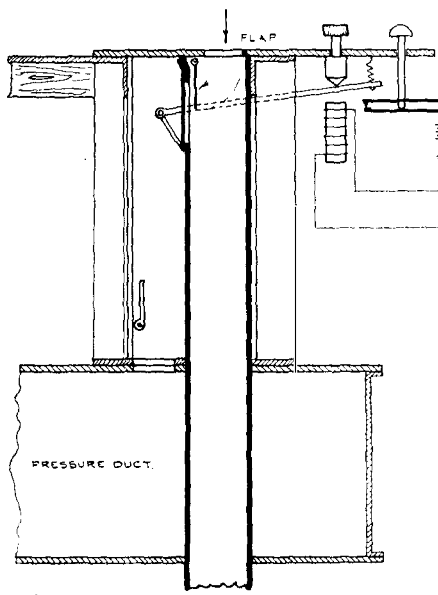


Fig. **6**.—Mix and Genest Pressure Despatch Valve.

directly connected to the air supply, the dividing wall having a slot covered by a flap door, normally closed, whilst the chamber connected to the tube is open. When a ticket has been inserted, the plunger is depressed, thus opening the flap to admit air behind the ticket and causing the ticket slot to be closed by another flap. The plunger is retained by an electromagnet, the circuit of which is interrupted when the ticket is ejected through the discharge terminal. An auxiliary press button switch is placed on, or adjacent to, the terminal to open the circuit for testing purposes. A lamp is placed in circuit to show that the tube is in operation.

The discharge terminal is shown in Fig. **7** and consists of the open end of the tube provided with a guide for the ejected ticket which strikes a contact lever for the purpose of interrupting the control circuit described above.

Both the vacuum discharge terminal and the pressure despatch terminal are provided with a means of adjusting the vacuum and pressure to the length of the tube.

The McGregor system is shown in Fig. **8** and is operated by rarefied air both for collecting and distributing tubes. (This system is covered by Provisional Patent No. 28306/31, J. E. M. McGregor).

The sending valve on the collecting tube (Fig. **9**) is a simple fitting to provide a guide for the ticket into the tube and is normally closed by a cover which is lifted to insert the ticket. The cover is held by a spring in either the open or closed position and the valve is thus suitable for one hand operation.

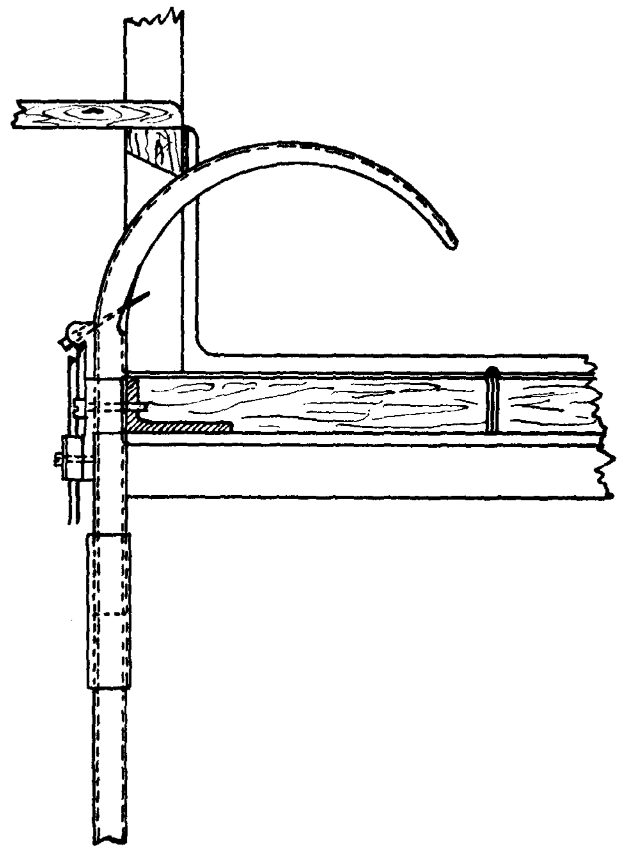

Fig. **7**.—Mix and Genest Pressure Discharge Terminal.

The essential part of the system is the discharge terminal which is shown in Fig. **10**.

Whereas in all known systems it is necessary to provide auxiliary means to cause the ejection of the ticket, this necessitating in many cases quite a complicated design, the McGregor terminal is perfectly simple and absolutely automatic, the ticket being ejected by its own impact on the door.

The principle employed is that of hinging the door of the terminal on the centre line and practically balancing it both statically and dynamically as regards the two halves for the various forces acting, namely, the working vacuum of the tube, atmospheric pressure, and gravity, and the inrush of air when the door is opened. No difficulty was experienced in developing the system for use on short tubes, but on the longer tubes the last consideration was found to give very great trouble as, owing to the length of the tube causing a drag on the column of air in the tube, the inrush of free air assumed a much greater value and caused the ejected ticket to be driven back into the terminal. A great deal of experimental work had to be carried out as regards the method of bypassing the air to the service pipes, although the general design was unaffected. In the early stages, too, though individual tickets could be discharged, it was found difficult to deal with a series of tickets overlapping or travelling at various spacings. All these difficulties were overcome in time, and the final model was found to eject

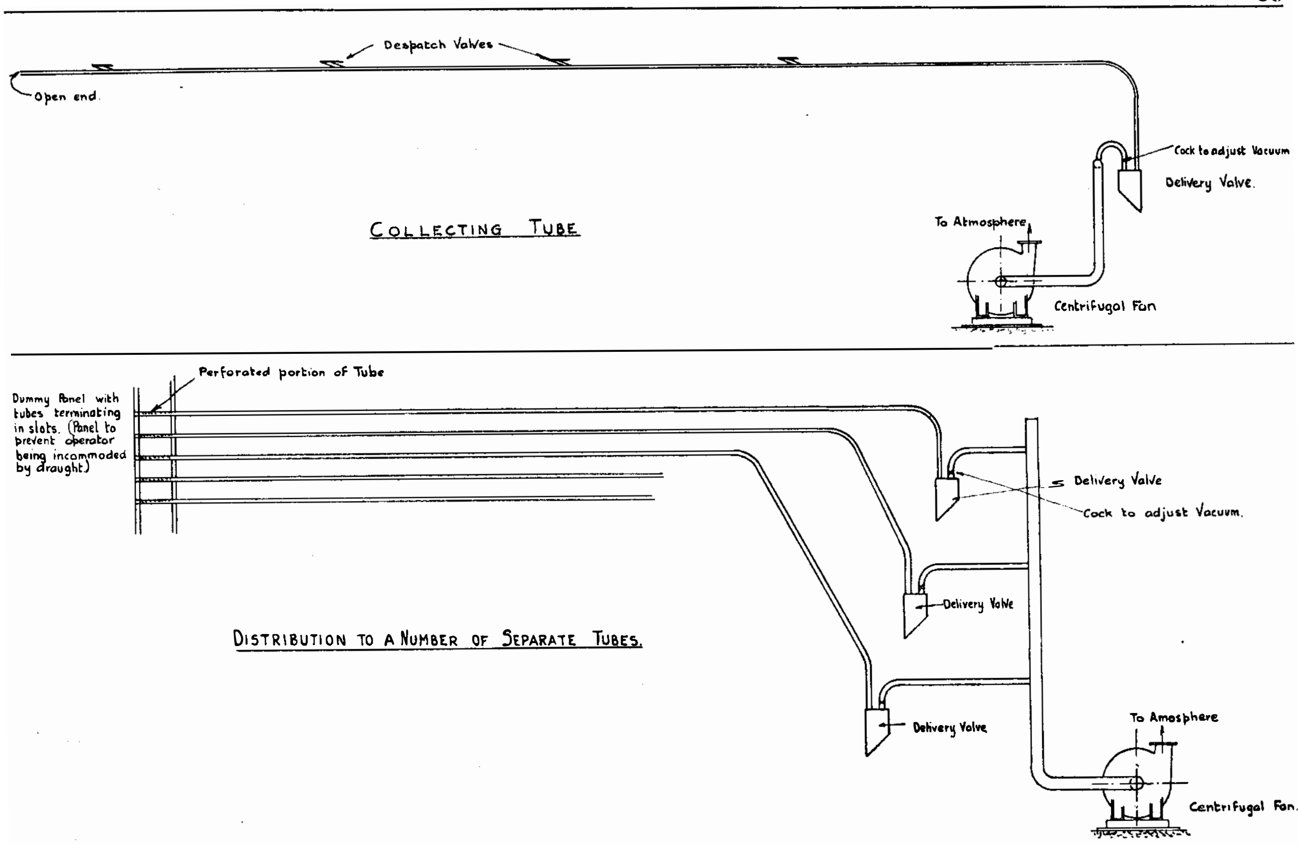


FIG. 8.—DIAGRAM OF McGREGOR SYSTEM.

any and all tickets automatically, however, and from whatever number of points, they were fed into the tube. The illustration is self-explanatory, the terminal consisting of an internal casing connected to a surrounding air chamber by means of the perforations shown. The service pipe is connected to this air chamber at A. The tube is connected at B and the ticket travels through the terminal along the guide formed by the tube till it strikes the door

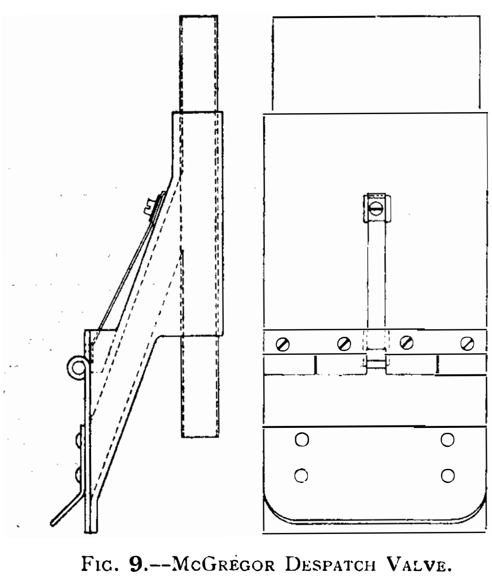

FIG. 9.—McGREGOR DESPATCH VALVE.

which opens under the impact and allows the ticket to fall out. The closing of the door is assisted by the rubber buffer D and the door is so adjusted that it is sufficiently out of balance to remain closed normally.

The adjustment of the door is controlled by the sluice E controlling the active area of the top half of the door and the slide F controlling the open portion of the guide. This adjustment is perfectly easy. It is essential for the proper working of the apparatus that close contact is made by the sluice F with the surface of the door and the casing.

Inspection covers are provided at G to enable the bypass holes to be cleared if necessary, it being important that the balance of air flow at the ends of the door should be maintained. The hinging and movement of the door also must be perfectly free.

For distributing tubes at the sending end, the open ends of the tubes are collected in a panel, part of the inrush of air being bypassed by perforations in the tubes behind the panel as shown in Fig. 8. The tickets are discharged by the same terminal used for the collecting tubes.

On all collecting tubes, whichever system is employed, it is considered advisable to instal a device to give an alarm if the tube becomes blocked and the Float Contactor, which has been designed for the Department, is now standard. This is shown in Fig. 11 and consists essentially of a spring-biassed strip of aluminium which is lifted by the current of air as long as air is passing freely in the tube, but

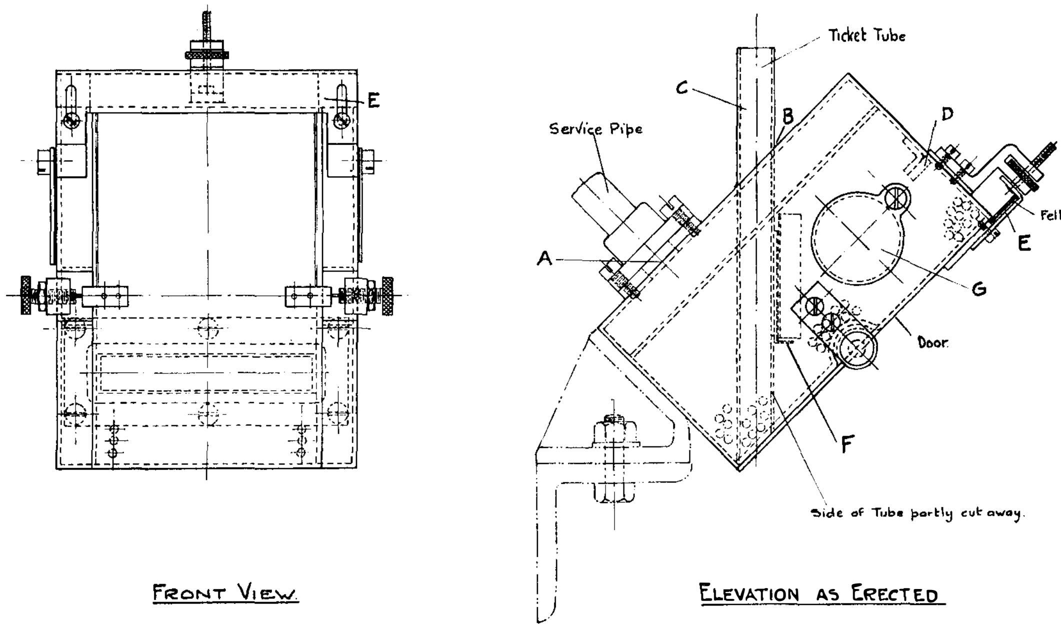


FIG. 10.—McGREGOR DISCHARGE TERMINAL.

drops in case of a blockage, causing an external contact to close and light an alarm lamp. This fitting is a great improvement on the old cylinder and piston device formerly used.

In the original system, the air supply for the vacuum and pressure tubes was obtained by means of a rotary blower drawing from a vacuum container and discharging into a pressure container from which ducts were led to headers connecting with the tubes. This system necessitates make up and relief valves to balance the varying pressure and vacuum loads, and owing to the time lag in their operation, it is impossible to maintain the correct pressures on the tubes. Separate blowers of the centrifugal fan type, which have a more suitable characteristic, are now used, these being constructed in combined sets consisting of a vacuum blower and a pressure blower driven by a common motor. This system has been adopted as, while the vacuum load is constant, the pressure load varies from nothing to any amount depending on the number of tubes in use, and the combination ensures that the motor is working between half and full load and not at low efficiency.

Each tube has its own time and pressure characteristic depending on its length and the number and

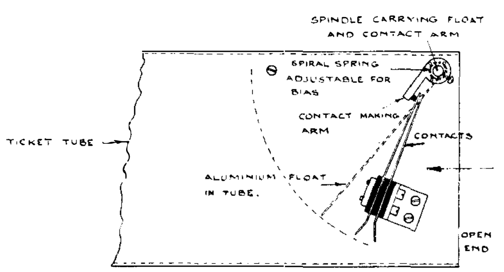


FIG. 11.—FLOAT CONTACTOR FOR ALARM CIRCUIT.

type of bends installed, and no general formula is strictly applicable. On the shorter tubes there is no advantage in increasing the speed of travel above 30 feet per second as damage to the tickets will probably result, whilst on the longer tubes (200—250 feet) it is found that the practical limit of velocity is about 20 feet per second, this being obtained with a vacuum of about 13 inches water gauge. Increasing the vacuum above this results in very slight gain and it appears that the slip of the ticket is a minimum on such tubes with vacua of about 8 to 13 inches, increasing rapidly outside these limits.

This vacuum is measured with the air flowing freely through the tube and no tickets travelling. The actual vacuum available from the blowers is about 24″ water gauge. While the ticket is travelling freely it is under the lower vacuum, but directly the ticket drags at the bends or a stoppage is being caused by tickets piling up, the air flow is reduced and the air bypass resistance automatically falls, allowing the effective vacuum on the tube to rise to the full water gauge available from the blowers. The vacuum is thus self-regulating and the bypass, or bypass and regulating cock, acts as a governor owing to its resistance to air flow varying with the quantity of air passing. Owing to this useful property, and to the fact that from the point of view of speed there is no advantage in using a normal vacuum higher than about 13″, it is possible to use a comparatively high resistance bypass; this is made use of in the McGregor system, a high resistance bypass being necessary to control the inflow of air from atmosphere when a ticket is being discharged.

In conclusion, the author would like to express his thanks to Mr. Baines, Mr. Cross and Mr. Webber for their assistance in the experimental work and the construction of the fittings for the new system.

# Telephone Efficiency Demonstration Rooms at Post Office Engineering Research Station, Dollis Hill

THE problem of correlating the various line and apparatus transmission values, obtained in the laboratories and by measurements on actual lines and circuits, with the actual telephone conversation efficiency has become one of considerable importance. The difficulties of the problem can perhaps best be indicated by enumerating the various transmission impairments which, in combination, result in giving a certain effective transmission to a typical connexion.

Consider the case of a typical trunk connexion. The transmission impairment due to the trunk line will consist of the volume loss, the articulation loss due to the cut-off, that due to cross-talk, to noise level, and any other impairment such as that due to echo effects, etc. The local line and exchange losses will be primarily volume losses, but there will be further impairments due to cut-off of the lower frequencies caused by the cord circuit, etc., and to line noises and cross-talk.

The instrument losses will be a combination of volume losses associated with the local lines, and, in addition, the losses due to the manner in which the subscriber talks, including the distance from his mouth to the transmitter, etc. The articulation loss will be due to a combination of the frequency characteristics of the transmitter, receiver, and subscriber's set, to the side-tone effect, and the amount of extraneous noise (room and street noise), and also the internal noise due to the transmitter. The enunciation of the speaker and the acuity of hearing of the listener will also obviously enter into the picture. The combination of all these diverse elements, many of which cannot be directly added together, will form the only true measure of the real telephone conversation efficiency. It is not surprising, therefore, that volume and articulation measurements give only a partial indication of the real efficiency.

Various methods of measuring effective transmission are under consideration, including the American proposal to express it in terms of repetition rate, taking as a basis the number of repetitions due to unintelligibility demanded per 100 seconds of conversation. This method has given such definite results in America, that it is now being used as a practical basis for transmission standardization. The method is being investigated here. Apart from this general investigation, a convenient method of studying effective transmission has been designed, and is described in this article.

Two offices situated at a convenient distance apart in the Central Block at Dollis Hill have been allocated for this purpose. A certain amount of wall draping has been introduced into these rooms in order to produce representative acoustical conditions, and each room is equipped with a key control device by which all the various factors which enter into a telephone conversation can be controlled.

Fig. 1 shows one of these sets of key controls. The row of keys on the right hand vertical strip enables tie lines of varying types to be introduced into the circuit between one room and the other.

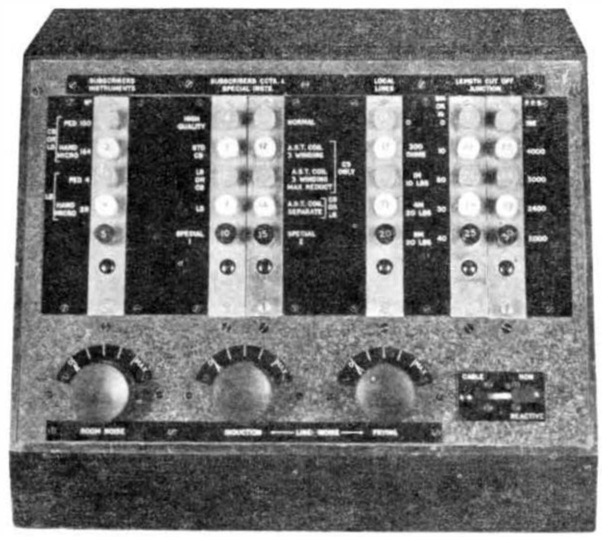

FIG. 1.—KEY CONTROL BOARD.

The tie line can either be non-reactive with no cut-off or with high frequency cut-off varying in steps from 2000 to 4000 p.p.s. Alternatively, a reactive tie line can be introduced equivalent to 20 lb. cable. The second row of keys varies the length of the tie line in convenient steps from zero to 40 decibels. The third row of keys enables local lines of various lengths and types to be introduced from zero to about 700 ohms and made up of various cable gauges. The fourth row of keys controls the amount of side tone coupling of the particular telephone instrument under trial and gives a number of graduations from full coupling to the maximum anti side-tone condition which can at present be obtained in practice. The fifth row of keys introduces various types of instrument circuits, whilst the last row introduces particular telephone instruments.

Below the vertical strips of keys, three rotary keys will be noted. The one on the left introduces definite values of room noise. A gramophone record has been obtained of what is regarded to be representative office noise, combining the effects of typewriters, conversation in undertone, rustling of papers and street traffic noises. The noises are introduced into the demonstration rooms by means of a gramophone with an electrical pick-up connected to a suitable moving coil loud-speaker, the latter being carefully adjusted as regards its location and position in the room, in order to give the most realistic results. There are four (on) points for room noise which give successively 40 loudness units, equivalent to a very quiet office, 55 loudness units representing a typical office of the type in which a number of people are working. The third point represents 65 loudness units which can be regarded as that of an extremely noisy office, whilst the last point (75 units) represents an exceptional degree of noise only likely to be met with in telephones in busy workshops and similar locations. A sound is said to have a loudness of a certain number of loudness units when it appears to be equally loud as a tone of 1,000 p.p.s. the same number of decibels above its threshold loudness. It is, of course, realised, that room noise frequency characteristics will vary very considerably in practice. It is thought, however, that the particular room noise record in use can be taken as reasonably representative.

The central dial introduces line noise of the type produced by power line disturbance and the graduations on this dial are so arranged as to introduce line noises producing voltages varying from 0.15 to 2.7 millivolts across the terminals of a 60-ohm bell receiver associated with a standard C.B. termination.

The dial on the right introduces frying noise, also varying from an intensity of 0.15 millivolts to 2.7 millivolts across the receiver terminals. This noise, which is very characteristic and representative of the type of disturbance frequently met with on commercial circuits, is produced by the rubbing of stiff wires against a roughened metal surface. A series of stiff wires are mounted on a spindle maintained in slow rotation, and the device can be seen in the top left hand panel of Fig. **2.**

The above voltages are measured on a valve voltmeter indicating the R.M.S. value of the voltage and with a frequency response characteristic weighted to take into account the variation in disturbance produced by tones of different frequencies.

A control board of the type just described is fitted in only one of the two offices (designated "Room A"). The board fitted in the other office ("Room B") is shown in Fig. **3**, and does not include keys to vary the tie line or line and frying noise, but only

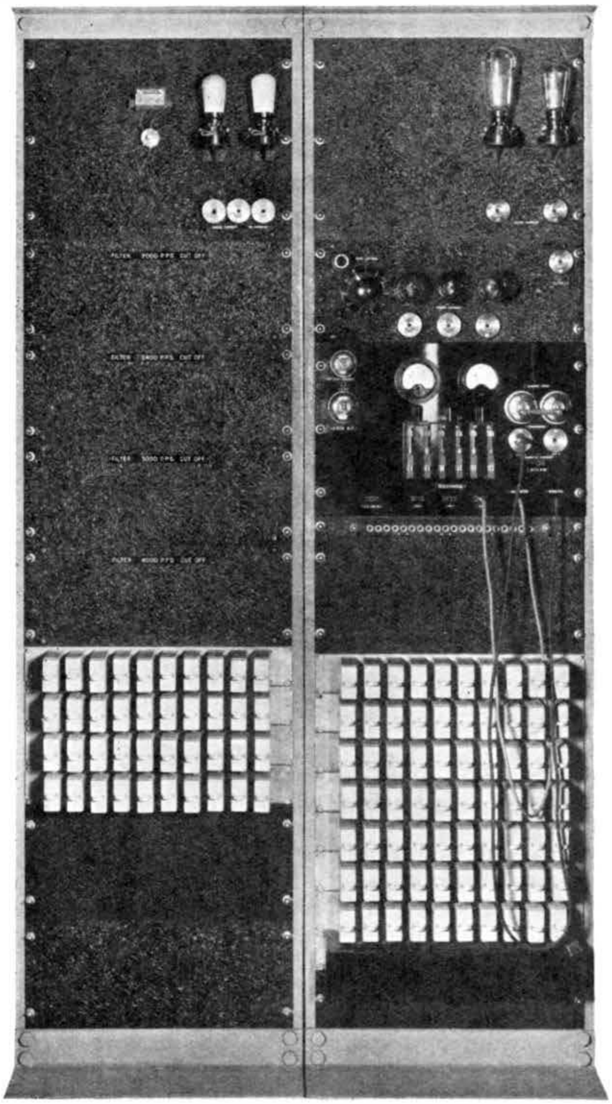

Fig. **2**.—Apparatus Racks, "Room A."

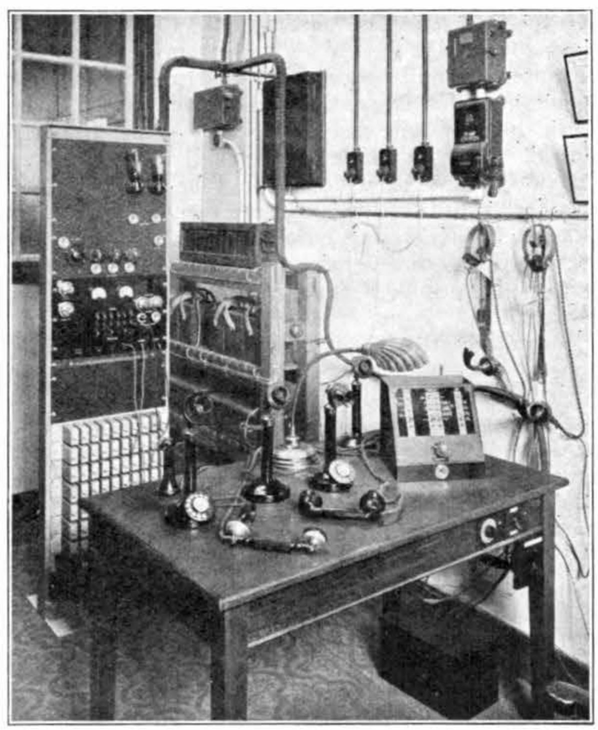

Fig. **3**.—"Room B" Equipment.

keys to vary the telephone instruments, local lines and room noise.

Fig. **4** shows the test table in " room A." It may be of interest to indicate the particular types of telephone instruments shown in this illustration and upon which a considerable number of transmission tests have recently been made. Reading from left to right, these are a pedestal instrument with No. 1 C.B. transmitter; a pedestal instrument equipped with Inset Transmitter No. 10, which is of the type fitted in the hand microtelephone, and which is designed for use on both C.B. and L.B. circuits; and a pedestal instrument fitted with Inset Transmitter No. 3, which is only used for local battery purposes. In front is the old microtelephone No. 28, followed by a Telephone No. 162, the new pattern hand microtelephone, and lastly a condenser microphone on pedestal, an instrument giving extremely high quality transmission. The controls, jacks and keys shown on the right below the table top are for the introduction of operators' telephone instruments for similar comparative trials.

The remaining apparatus is mounted on three racks; two of these are similar and carry the subscribers and local apparatus whilst the third carries the tie line and common apparatus. Two of the racks, shown in Fig. **2**, are fitted in " room A," the other local rack being in " room B," shown in Fig. **3**.

Dealing with the common apparatus first, the left-hand rack in " room A," Fig. **2**, has at the top a panel carrying the arrangements for supplying line noise. The two valves seen on the right of this panel are to enable the noises to be applied to the two ends of the circuit without providing a circuit for stray currents from one end to the other. The noises are supplied to the grids of the valves in parallel, the anodes being connected through high impedance transformers across the two ends of the line.

Below this panel are four panels, carrying the filters which may be inserted in the tie line to represent different types of loaded lines.

Below these are the relays to effect the necessary switching; some of the relay covers contain the resistances making up the sections of non-reactive line. At the back of the lower blank panels is space for an artificial cable also controlled by some of the relays.

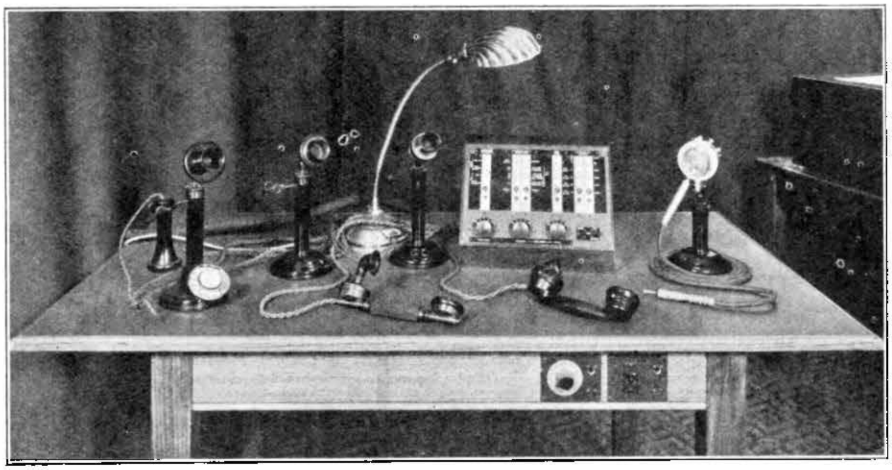

Fig. **4**.—Test Table, " Room A."

Coming to the local apparatus racks, Figs. **2** and **3**, the top panel is the amplifier for room noise. The second panel is an amplifier for high quality transmission. At End A the condenser microphone shown in Fig. **4** may be connected, while at End B a high quality moving coil receiver may be connected to the corresponding amplifier, thus providing very high quality transmission in the direction A to B. (In the opposite direction ordinary instruments are used.) The microphone and receiver are similar to those used on the Primary Reference System.

The next panel is for controlling the power supply. As far as possible, power is taken from the lighting mains, *e.g.*, for the line and room noises and gramophone motor. The station 50-volt battery is used for relay operation, but independent 22-volt batteries are used for speaking purposes so that really quiet conditions can be obtained. A 4-volt battery is provided for supply to a potentiometer enabling local battery transmitter current to be used under conditions representing two or three, new or average dry cells. A 6-volt battery is provided for the high quality amplifier filaments with a 200-volt battery for the anode supply.

The 22-volt, 4-volt and 6-volt batteries are charged in series from the 50-volt supply.

A milliammeter and a voltmeter are fitted with cords and plugs by which they may be connected to the various battery, valve anode and transmitter circuits as required.

Below the power panel is a strip of jacks connected in the speaking circuit at various points as indicated in Fig. 5. These are very useful for "patching" special apparatus and lines into circuit.

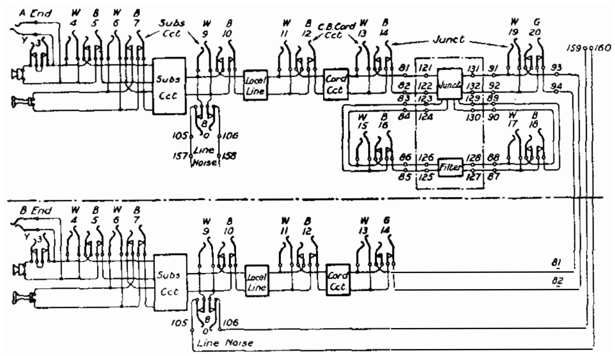


FIG. 5.—CONNEXIONS OF "PATCHING" JACKS.

The next panel has mounted on it, and on a small shelf at the rear, the various coils, condensers, etc., required for the various subscribers' circuits. Space and spare connexions are provided so that alterations and additions can easily be made.

The lower parts of these racks are occupied by the relays required for switching, with, right at the bottom, the resistances and condensers making up the various local lines. The apparently large number of relays is necessary in order to prevent unpleasant bangs in the receiver when changing over circuits carrying battery current. The receiver and line are short circuited automatically during the transient periods.

It will be seen that with the above arrangement it is possible to set up almost any circuit and local condition desired, and to compare it with any other condition. A large number of tests have been made by various members of the Engineer-in-Chief's Office, and valuable information has been obtained, in particular, as to the relative advantages of different side tone arrangements under various conditions.

The arrangement of apparatus is on somewhat similar lines to that set up in the headquarters offices of the American Telephone and Telegraph Company.

B.S.C.
E.J.B.

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# Standard Grading Frame for Automatic Exchanges

G. BROWN, A.M.I.E.E.

A NEW grading frame for use in automatic exchanges equipped with Open Type Racks will shortly be specified as standard for new work, and a description of its main features may therefore be of interest to Engineers concerned with exchange equipment.

The new frame, which is officially described as a Trunk Distribution Frame or T.D.F., has been designed with a visible grading field on the front and all cabling and wiring at the rear, on the same principle as the Open Type racks with which it will be associated in practice. It will be constructed so that it will line up on the same floor angle with standard racks and may be installed either as a sectional or a centralized T.D.F. as required.

Provision has been made for grading outlets from the following types of selectors :—

| | | |
|---|---|---|
| Group Selectors | 100 outlets | 3-wire links |
| Group do. | 200 do. | 3-wire do. |
| 1st Code do. | 200 do. | 3-wire do. |
| 1st Code. do. (Levels to Multi metering 2nd Codes) | 100 do. | 4-wire do. |
| A-digit Selectors | 100 do. | 5-wire do. |
| Coder Hunters | 24 do. | 5-wire do. |
| Subs. Uniselectors (Booster metering) | 24 do. | 3-wire do. |
| Subs. Uniselectors (4th wire metering) | 24 do. | 4-wire do. |

The grading will be effected on connexion strip designed for the purpose and equipped horizontall in panels on the frame. Fig. 1 shows a portion o three grading connexion strips assembled one abov the other as they would be when equipped on th frame. The soldering terminals are made wit separate slots for incoming cable terminations an jumper wires, and have their tips forked and splaye to receive the bare cadmium copper grading wire.

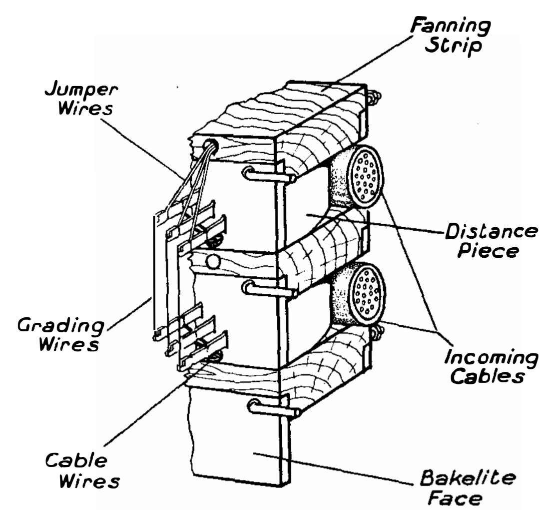


FIG. 1.—PART OF GRADING CONNEXION STRIPS.

It is intended to use three types of grading connexion strips—one with 22 sets of terminals arranged in triples whilst the other two have 25 sets of four and five terminals respectively. The connexion strips with 22 triples will take gradings of 200 outlet selectors, leaving two sets of terminals on the right of each strip. Gradings of 100 outlet selectors require only half a strip. In this case, a white dividing line will separate the 11th and 12th sets of terminals, thus leaving one set at the right-hand end of each 10 sets of terminals for connexions from 11th contacts on levels, if required.

The outgoing connexion strips are the regular Post Office standard type as used on Intermediate Distribution Frames.

Each bay of the T.D.F. has capacity for sixty-four incoming and sixteen outgoing connexion strips with four miscellaneous connexion strips equipped on the top, rear, for connexions such as:—Spare outlet earth connexions, Congestion Meters and Routine Access Relays.

Cabling is arranged so that the incoming cables will be served down the right-hand side and the out-

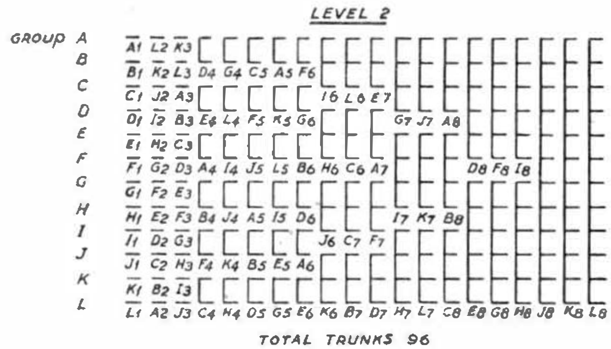


Fig. 3.—Typical 20-contact 12-group Grading.

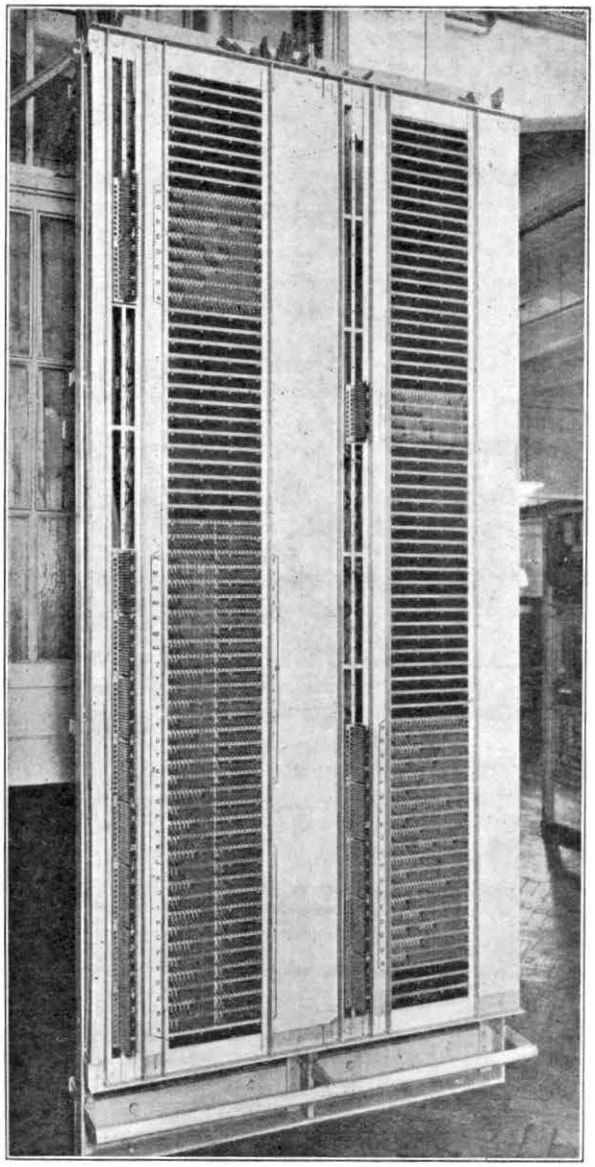

Fig. 2.—Model Trunk Distribution Frame.

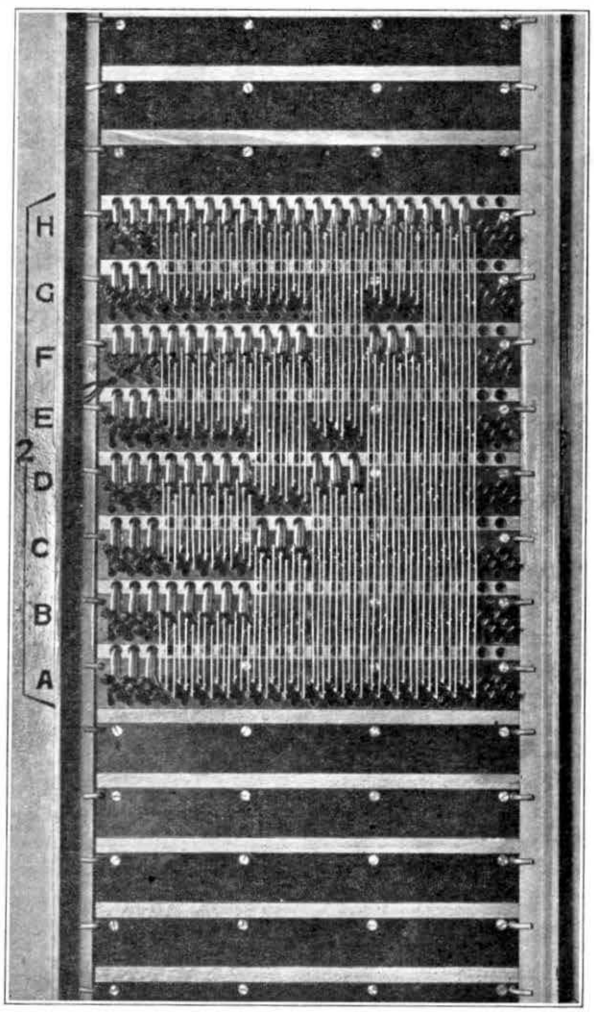


Fig. 4.—Typical Grading.

going cables down the left-hand side, looking at the front of the frame. The sheet steel covers, which serve as designation plates, are removable for cabling purposes.

Fig. 2 shows a front view of an experimental model of two bays manufactured for the Post Office by Messrs. Siemens Bros., Woolwich. On the left of each bay there is a column of ordinary connexion strips on which the outgoing cables are connected. To the right of these, separated by vertical designation plates, are the rows of horizontal connexion strips terminating the incoming cables.

Incoming groups from selector levels are cabled to the horizontal strips and formed into graded groups with 26 lb. bare cadmium copper wire. Each graded group is cross-connected with jumper wire to its

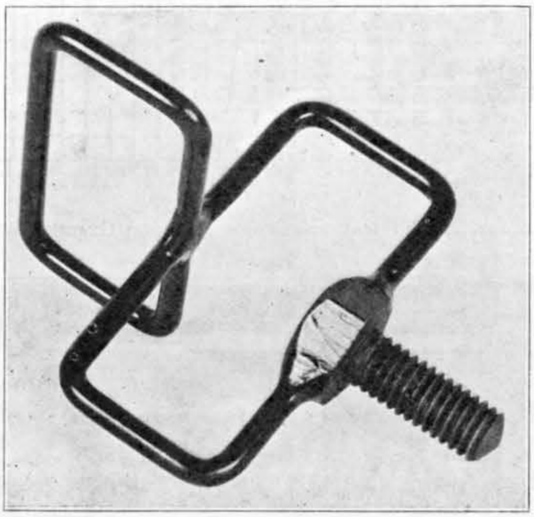

Fig. 5.—Jumper Ring.

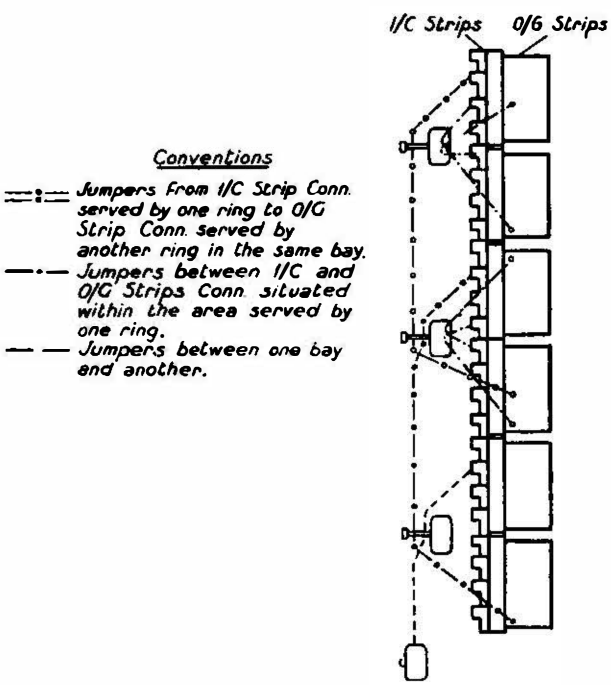


Fig. 6.—Arrangement of Jumper Wires.

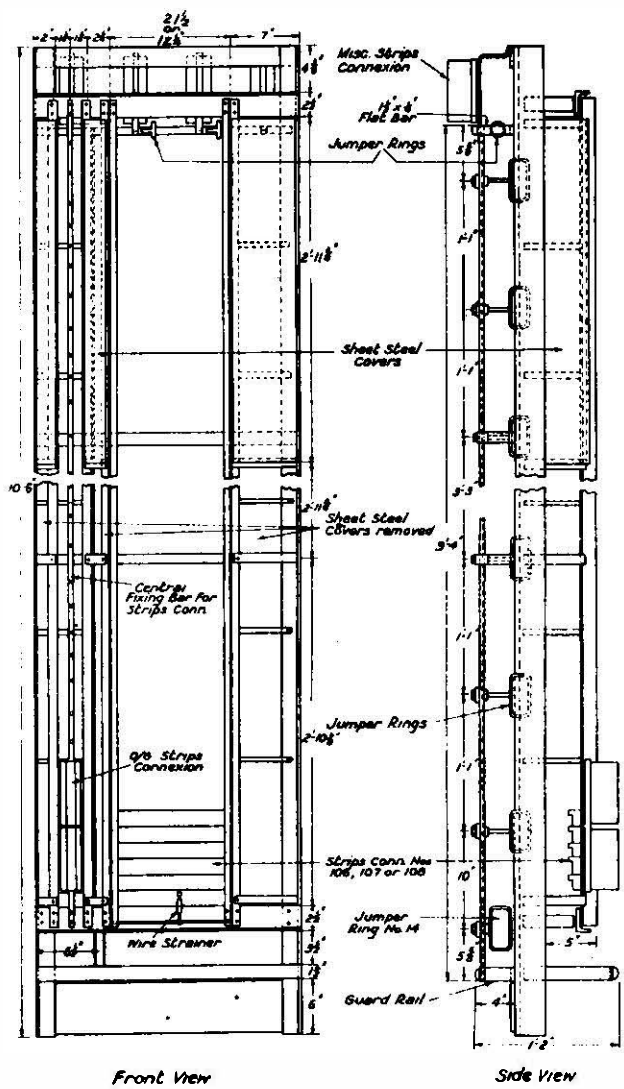


Fig. 7.—Unit Grading Frame.

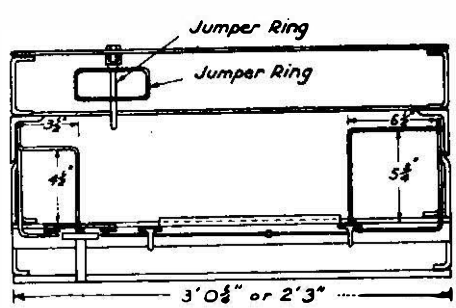


Fig. 8.—Section of Unit Grading Frame.

allotted position on the outgoing terminal strips and from there cabled to the next piece of apparatus in the chain of connexions.

A typical grading diagram showing a 20-contact 12-group grading is seen in Fig. **3**. This grading was one used in trying out the model frame in the Department's circuit laboratory. A closer view of eight of the groups (A to H) is seen in Fig. **4**. The remaining four groups (I.J.K.L.) appear on the upper portion of the right-hand bay in Fig. **2**. This was arranged to prove the utility of the frame for dealing with conditions which may arise where, due to space limitations in the grading field, it becomes necessary to split a grading into two portions and float one of them over to the second bay. In these circumstances, the split portions of the grading should be cross-connected with jumper wire between the incoming terminal strips concerned. A single jumper ring is fitted at the bottom of each bay for this purpose. It will be observed that the growth of the wired panel is upwards, and the markings shown in the illustrations are typical only.

A jumper ring (suggested by Mr. E. F. H. King, of the Engineer-in-Chief's Office) which separates vertical cross-connexions from those run in a horizontal direction is illustrated in Fig. **5**. This new type of ring prevents wiring congestion in the jumper field and facilitates rearrangements resulting from changes in traffic density.

Fig. **6** indicates typical jumpering arrangements and various framework constructional details are shown in Figs. **7** and **8**.

It will be seen that the width of the unit frame, which is 2 feet 3 inches for selector gradings, *i.e.*, when connexion strips with 22 sets of three terminals are used, increases to 3 feet 0¼ inch when the longer grading strips with 25 sets of four or five terminals are required.

Provision has also been made for small exchanges where, as a rule, floor space for auxiliary frames is limited. In these cases it will usually be possible to combine the selector gradings on one panel with subscribers' uniselector and hunter gradings, as illustrated in Fig. **9**. This composite panel is

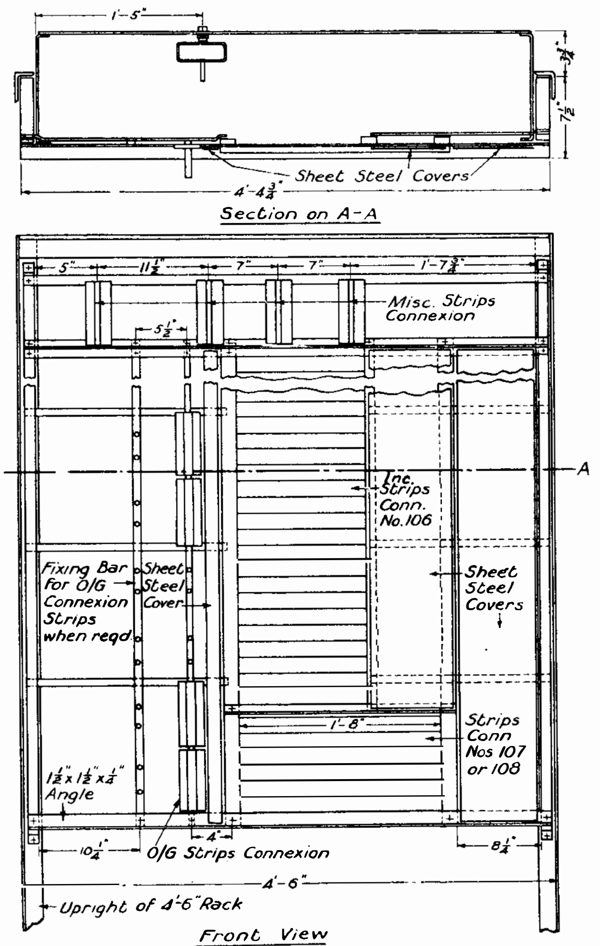


FIG. **9**.—COMPOSITE GRADING PANEL.

designed to be equipped on any standard 4 feet 6 inches open-type rack and should be arranged at the outset for the ultimate capacity required.

The author is indebted to Messrs. Siemens Bros., Ltd., for the illustration of the grading terminal strips shown in Fig. **1**.

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# The Quantitative Spectrographic Analysis of Lead Cable-Sheath Alloys

G. H. METSON, B.Sc.(Eng.), Grad.I.E.E.

*Introduction.*

A MATERIAL which is to be mass-produced according to specification must be constantly examined during manufacture to ensure that its composition lies within limits prescribed by its purchaser. Accordingly, the producer is continually applying tests, chemical and physical, which must be sufficiently accurate to maintain his standard of quality and yet rapid enough to keep pace with his speed of production. A case illustrative of this production-control lies in the Telephone industry in the manufacture of lead cable-sheath alloys.

In recent years it has been found that certain alloys of lead with antimony, cadmium and tin show a marked superiority over pure lead in resisting vibrational fatigue failure. These alloys are now being extensively employed and it has become desirable to introduce new and faster methods of alloy-analysis for control and test purposes. In the past all alloy-analysis has been done by chemical methods which, although excellent from the point of view of accuracy, have the disadvantage of being slow and highly technical.

It is the object of this article to describe a system of lead alloy-analysis which has recently been developed in the Post Office Research Section to overcome the disadvantages of the chemical method. This system, which employs the principles of quantitative spectrum analysis, is sufficiently accurate for its purpose and is many times faster than the corresponding chemical analysis.

*Quantitative Spectrum Analysis.*

Although many attempts have been made during the last fifty years to develop a system of quantitative spectrum analysis, it was not until quite recently that a really practical system was introduced. In 1928, Shiebe and Neühausser[1] adapted the logarithmic sector photometer to the problem and evolved a system of analysis of tin in lead-tin alloys which gave excellent results. Their technique has recently been perfected and their theoretical assumptions given a mathematical significance by Twyman, Simeon and Fitch.[2]. These investigators have made quantitative determinations of silicon, nickel and chromium in iron alloys with an accuracy compatible in many cases with that obtainable by chemical methods.

The theory of the method is simple and is explained in a few words. The optical spectrum of an alloy containing, for example, 99 per cent. lead and 1 per cent. antimony consists of numerous spectral lines due to the lead and a smaller number of lines due to the antimony. Shiebe and Neühausser discovered that, given a standard method for exciting the spectrum, the *intensity* of a line due to a minor constituent—in this case, antimony—increases in a regular manner as the percentage of antimony in the alloy increases. Consequently, if we devise a photometer for comparing the intensities of the antimony lines in the various alloys, we have a means for ascertaining the antimony content of the alloys. The type of photometer adopted by Shiebe and Neühausser for this purpose is known as the Rotating Logarithmic Sector Photometer,[3] and is shown in Fig. 1. It will be seen that the instrument consists essentially of a disc whose outer edge is cut in a logarithmic spiral. This disc is placed in front of the spectrograph slit and rotated by a small electric motor.

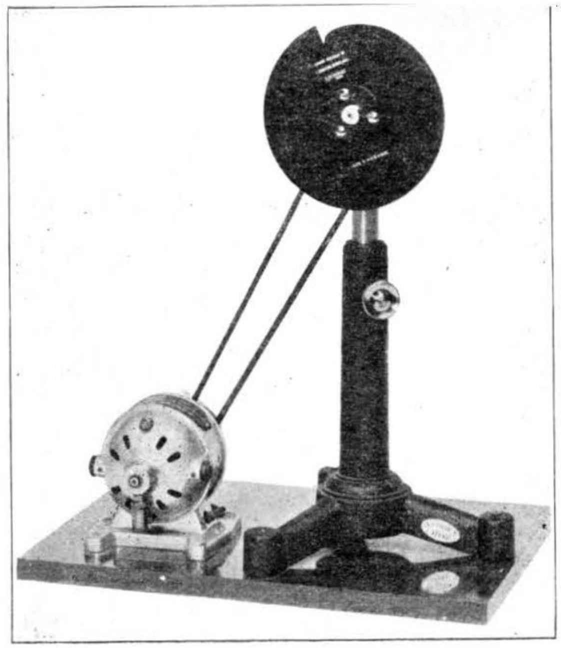


FIG. 1.—LOGARITHMIC SECTOR PHOTOMETER.

The effect of rotating the disc in front of the spectrograph slit is to expose each spectral line logarithmically along its length. This results in the spectral lines photographed on the plate being narrow wedges instead of parallel-sided bars; this effect will be clearly seen in Fig. 2, which is a spectrogram of lead-antimony obtained with the

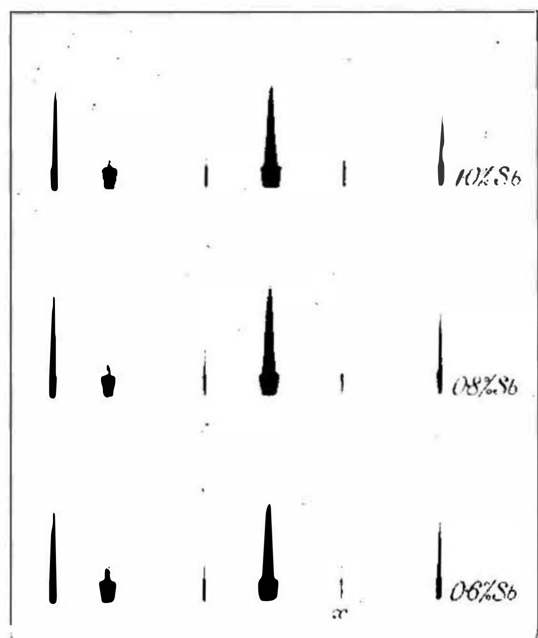



FIG. 2.—SPECTROGRAM OF LEAD-ANTIMONY.

[1] G. Shiebe and A. Neühausser. Zeitschrift für angewandte Chemie. 1928. Vol. 41.

[2] F. Twyman and A. A. Fitch. Quantitative Spectrographic Analysis of Steels. Paper read before the Iron and Steel Institute.

[3] F. Twyman and F. Simeon. The Logarithmic Sector Photometer and its use in Quantitative Spectrum Analysis. Paper read before the Optical Society.

logarithmic photometer. Since the law of photographic blackening is also logarithmic, the lengths of these " wedges " are related to the intensities of the lines producing them. Hence, if we determine the length of a particular antimony line-wedge, we have a measure of the intensity of this line and also a measure of the antimony concentration in the alloy exciting the spectrum.

The method for determining a minor constituent in an alloy will now be apparent. A series of lead-antimony alloys is prepared and their composition determined by chemical analysis. The spectra of these alloys are now photographed under precisely similar conditions using the logarithmic photometer. For each alloy, the length of a particular antimony line-wedge is measured and a curve prepared showing the length of the antimony wedge plotted against the known composition of the alloy. Hence, if we require to know the quantity of antimony in an alloy of unknown composition, we photograph its spectrum using the logarithmic photometer, measure the length of the antimony line-wedge, and compute the composition of the alloy from the reference curve. Fig. 2 shows the manner in which the antimony wedges decrease in length as the percentage of antimony in the alloy decreases.

In actual practice the above procedure is slightly elaborated. It is impossible to standardize the sparking and photographic details so accurately that there is no variation in the length of the lines due to these causes. If a small variation be made from standard procedure, it can be shown both theoretically and experimentally that the lengths of the lines from both major and minor constituent vary equally. Thus the *difference* in length of a particular lead and a particular antimony line is constant and unaffected by slight variations in experimental procedure. It is this difference $\Delta l$

$$\Delta l = l_{Pb} - l_{Sb}$$

that is plotted against " composition " to give the required curve.

*Experimental Procedure.*

The set-up of the apparatus for the routine operation of the analysis is shown in Fig. 3. The position of the logarithmic photometer relative to the spectrograph will be clearly seen. The outer edge of the photometer disc is cut away in a logarithmic spiral such that

$$-\log \theta = 0.3 + 0.2l$$

where $\theta$ is the circumferential aperture, expressed as a fraction of a complete revolution, at a distance $l$ *mm* measured radially inwards from the outermost part of the curve. The disc is carefully centered on an adjustable stand and driven at about 300 revs. per minute.

The alloy under test is clamped in the sparking stand and submitted to a condensed spark discharge from the secondary of a 5000-volt transformer. An inductance of 0.005 henry is included in series with the spark circuit and a condenser of 0.03 $\mu$F connected in parallel with the electrodes. The light from the alloy is condensed on to the slit of the spectrograph by a quartz condensing lens. After passing into the spectrograph through the slit, the light is dispersed into its spectrum by a prism or

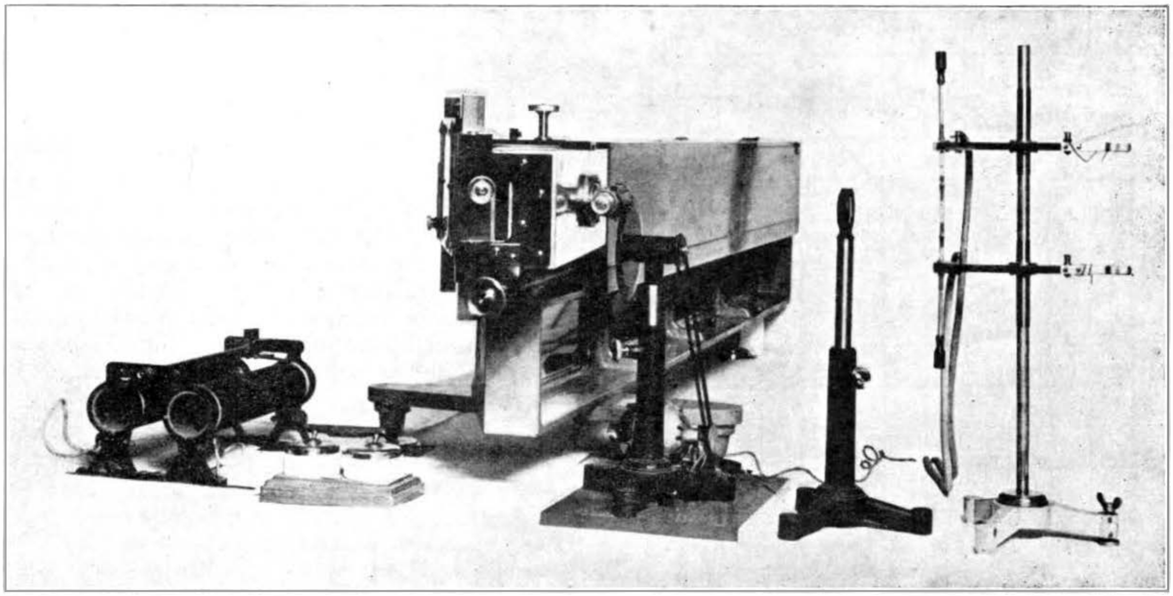


FIG. 3.—VIEW OF APPARATUS FOR SPECTROGRAPHIC ANALYSIS.

grating and recorded on a photographic plate which is developed in the usual manner. As the photographic procedure is important, details are given in an appendix.

The lengths of the antimony and lead wedges are measured by a micrometer-microscope and their difference gives the value of $\Delta l$. Curves relating $\Delta l$ and "percentage composition" for lead-antimony, lead-cadmium and lead-tin are shown in Figs. **4**, **5** and **6** respectively.

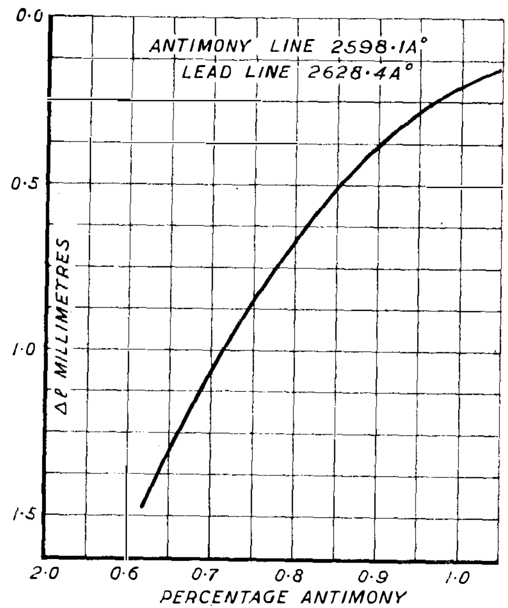



FIG. **4**.—$\Delta l$—PERCENTAGE COMPOSITION FOR LEAD-ANTIMONY.

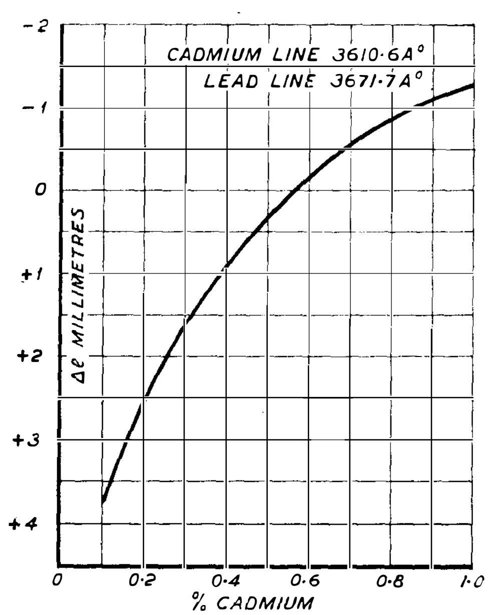



FIG. **5**.—$\Delta l$—PERCENTAGE COMPOSITION FOR LEAD-CADMIUM.

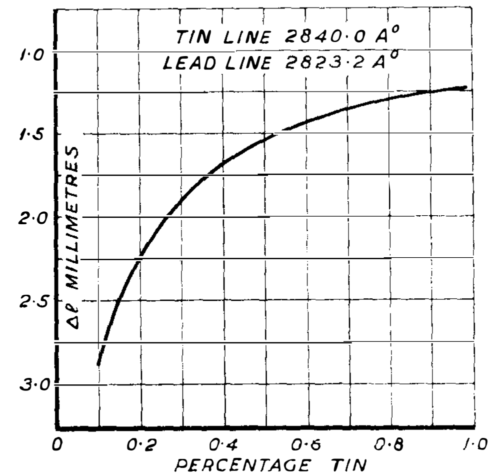



FIG. **6**.—$\Delta l$—PERCENTAGE COMPOSITION FOR LEAD-TIN.

*Discussion of Results.*

A particularly interesting feature of the three curves for the three alloys of lead is that all are of the same mathematical type. In the case of lead-cadmium, for example, if $\Delta l$ be plotted against (log per cent. cadmium) as shown in Fig. **7**, the resulting graph is linear and so may be expressed in the general form

$$y = mx + c$$

where $y = \Delta l$, $x =$ log per cent. cadmium and $m$ and $c$ are constants.

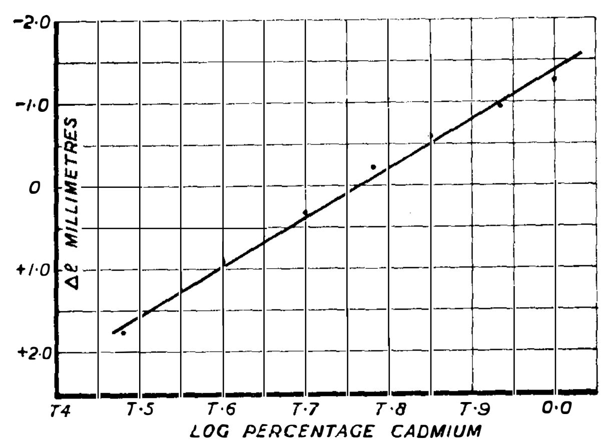



FIG. **7**.—$\Delta l$—LOG % CADMIUM FOR LEAD-CADMIUM.

The curves for lead-antimony and lead-tin are found to obey the same type of law. Twyman and Hitchin[4] have recently discovered that this relationship holds for numerous alloys and there is reason to believe that it is the generalized law of these curves. This result is of considerable value as it

[4] F. Twyman and C. S. Hitchin. Examination of Metals in Solution by means of their Spark Spectra. Proceedings of the Royal Society. Series A. Vol. 133.

will enable future investigators to draw up reference curves from two points only.

In order to form an estimate as to the degree of accuracy obtainable, two alloys were analysed by an investigator having no previous experience of the method. Three separate photographic exposures for each alloy were measured and the mean value of $\Delta l$ obtained for each alloy. The results are appended.

| Actual antimony content. | Mean $\Delta l$ | Estimated antimony content. | % Error. |
|---|---|---|---|
| 0.70% | 0.81 | 0.76% | + 8% |
| 0.94% | 0.35 | 0.89% | − 6% |

With a little experience an accuracy of ± 8% is attainable.

The time actually occupied by a complete analysis was found to be about 15 minutes. The time for the corresponding chemical analysis would be about four hours.

## APPENDIX.

Details of the photographic procedure are given below.

Plates.—Ilford Rapid Process Panchromatic

Developer.—Equal parts of solutions A and B.

A.

| | |
|---|---|
| Hydroquinone ... ... ... | 25 gms. |
| Pot. metabisulphite ... ... | 25 gms. |
| Pot. bromide ... ... ... | 25 gms. |
| Water ... ... ... ... | 1000 cc. |

B.

| | |
|---|---|
| Pot. hydroxide ... ... ... | 50 gms. |
| Water ... ... ... ... | 1000 cc |

| | |
|---|---|
| Temperature of developer ... | 65°F. |
| Time of exposure ... ... | 1 minute. |
| Time of development ... ... | 2½ minutes. |

# Laying Cables by Means of a Moledrainer

L. G. Semple, B.Sc. (Eng.) and R. O. Boocock.

THE decision to provide the Cambridge-Kings Lynn cable by underground construction was largely due to the opportunities which the grass margin afforded for the employment of mechanical methods of excavation. Messrs. Ransomes, Sims and Jefferies, of Ipswich, were approached with reference to the possible use of a moledrainer and they kindly agreed to co-operate in carrying out preliminary trials on their testing ground.

The moledrainer is designed for draining land and consists of a solid steel cylindrical "mole," wedge shaped at the leading end and supported from a chassis by means of a knife edge "coulter."

The Ipswich trials demonstrated that both lead-covered cables, and protected and armoured cables could be drawn into the ground behind the "mole" at a depth of twenty inches without suffering any material damage to the sheath, despite the inclusion in the track of a semi-circular bend of 30 feet radius.

Theoretical calculations, based on dynamometer readings taken at these trials to determine the maximum lengths which could be safely drawn in, were considered sufficiently promising to justify a recommendation to Headquarters for more extensive trials on the proposed cable route.

Authority was given to carry out further tests using a 520-yard length of 122-pair 10 lb. quad type armoured cable. The armouring consists of two spirally-wound steel tapes protected by an outer layer of compound jute yarn, the overall diameter being slightly under two inches.

The second series of trials were witnessed by Headquarters and District officers and by representatives of Messrs. Ransomes, Sims and Jefferies. The general arrangement of the tractor, moledrainer and cable can be seen from the accompanying photographs which show the moledrainer both in and out of action and also a typical section of the cut made by the implement together with a view of the cable in the "drain."

The cable end was dressed, passed through a thimble and looped back on itself, and a split grip secured in such a manner that the conductors, sheath and armouring each took a share of the pull. Connexion to the mole was made through mechanical fuses designed to break at a predetermined load, particulars being supplied by the Birmingham Testing Branch who tested to destruction a sample of the cable. By this means, the pull on the cable could be determined for the corresponding length drawn in, and a safeguard was provided against excessive strain. The moledrainer itself was coupled to the tractor *via* a dynamometer.

Pilot holes were dug at intervals of 50 yards to reveal any obstacles and to permit observation of the cable during its passage through the "drain."

At intervals during the trials the drawing-in was stopped, the cable end dug out and coupled direct to the dynamometer on the tractor, and the tractive

*Messrs. Ransomes, Sims and Jefferies.*

FIG. 1.—MOLEDRAINER WITH CABLE ATTACHED.

*Photo. by R.O.B.*

FIG. 2.—MOLEDRAINER IN ACTION.

effort necessary to pull in the known length of cable determined.

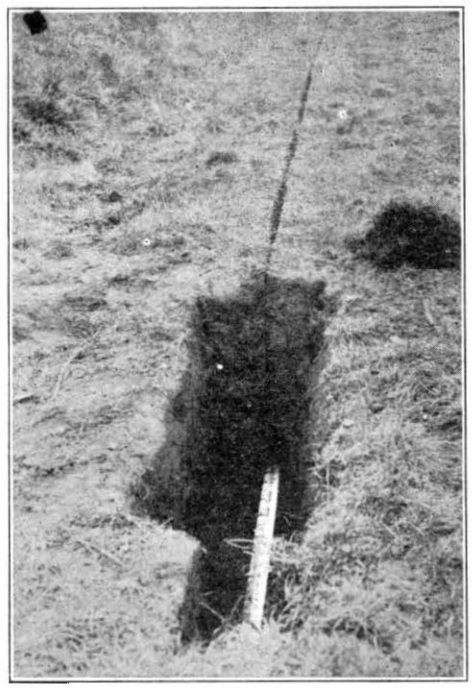
A length of 312 yards was drawn in without difficulty at an average depth of 24 inches and at a speed of about 1 mile per hour in virgin ground having a subsoil of a moist sandy nature. The maximum pull on the cable alone was 21 cwt., and the total tractive effort inclusive of that required to haul the moledrainer varied between 2½ and 3½ tons according to the resistance of soil encountered.

Insulation, conductor resistance, capacity unbalance and resistance unbalance tests were made both before and after the drawing-in operation and they showed that the electrical characteristics had not been materially affected. A comparison of the conductor resistance tests indicated that the cable had not been permanently strained and no sign of mechanical damage was evident.

The success of the trials was such as to justify the adoption of the method where practicable along the route of the proposed Cambridge-Kings Lynn cable and authority was given to hire the moledrainer and a tractor for that purpose.

Efforts to secure a "Caterpillar" type tractor on hire were unsuccessful and attention was therefore directed to a Fordson Tractor which, although of insufficient power to exert the required direct pull, is capable of exerting approximately 4½ tons draft when equipped with a low geared winch and self-anchoring device.

In using this equipment the winch-hawser is hitched to the moledrainer (which had been modified by the addition of wheels at the leading end) *via* a stranded 7/8 wire mechanical fuse which has a breaking load of approximately 4½ tons and which safeguards the moledrainer against liability to excessive damage by buried obstacles. A subsidiary fuse of 7/14 wire is fixed in parallel with the main fuse and with considerable play in it, with the object of absorbing the inertia of the hawser should the main fuse break, thereby preventing any dangerous



*Messrs. Ransomes, Sims and Jefferies.*

FIG. 3.—SECTION OF CUT, SHOWING CABLE IN "DRAIN."

"jumping" of the hawser. The cable is attached to the mole in the manner already described and the tractor driven forward with the winch running free and paying out steel hawser until suitable anchorage is found. The power unit is then disengaged from the tractor wheel drive and engaged with the winch; the hawser takes up the load and being held at the distant end by the resistance of the earth to the moledrainer causes the tractor to move backwards and bury its anchors in the ground. When the anchorage of the tractor becomes greater than that of the moledrainer, the latter is pulled forward, drawing the cable immediately behind it until all the hawser is taken up on the winch. The winch is then disengaged, the power unit engaged with the wheel drive and the anchor automatically withdrawn as the tractor moves forward to repeat the operations.

The tractor-winch combination has advantages over the "Caterpillar" tractor in that it can be used in the more difficult places such as sloping banks, close to existing pole lines or other obstructions which the "Caterpillar" tractor could not negotiate. Provided suitable anchorage for the tractor-winch can be found at approximately 70-80 yard spacing, and there is sufficient width for the passage of the moledrainer, (4 feet, 4 inches) it is possible to negotiate difficult ground by guiding the hawser through snatch blocks or around crow-bars. In this connexion it may be noted that experiments are being conducted with another type of moledrainer which has a maximum width of only 15 inches and which might prove very useful in narrow grass margins.

The crew required for the operation comprises :—

- One Working Foreman, who watches the progress of the moledrainer and controls operations.
- One driver of the tractor-winch.
- One driver of the Rushton tractor and cable bogie.
- One jointer, who is responsible for sealing, dressing and attaching cable ends.
- One—or occasionally two—labourers.

Provided that the route has been accurately surveyed and the work carefully organized to ensure that pilot holes and metalled crossings are excavated and abrupt changes of contour levelled in advance by a supplementary gang, the crew can lay four lengths of 260 yards each in an 8½-hour day—inclusive of loading and unloading cable drums, all subsidiary operations and ineffective time.

With the exception of a few roadway crossings, in which ducts were laid, and approximately two miles of steeply sloping bank, the whole of the 122 pr/10 armoured and protected cable between Cambridge and Waterbeach and the 104 pr/10 armoured and protected cable between Waterbeach and Ely have been laid in the manner described. In a few cases, in particularly difficult soil, it was necessary to reduce the working depth to 14 inches due to the inability of the tractor to exert a pull sufficient to draw the moledrainer and cable through the ground at greater depth. In one or two cases in which reduced depth was not permissible, shorter lengths were pulled in, involving an additional joint. Attention was therefore directed to the "Figure of Eight" method in which cabling operations are commenced at the centre of a predetermined cabling section, one half of the cable length pulled in one direction, the remainder coiled in "figure of eight" formation and pulled in the reverse direction. This method is very useful when laying the smaller sizes of cable which cannot safely withstand the pull required for long lengths. In the case described, 60 pr/10 cable had been supplied in drums of 666 yards and each drum was treated as two cabling sections so that the maximum length pulled in one direction was 166 yards. The method takes very little longer than that already described and has the advantage of saving a joint in the 332 yard length. It is being adopted for the remainder of the work on the Cambridge-Kings Lynn route.

Fig. 4 indicates clearly the manhours savings which have been effected. The full line shows the

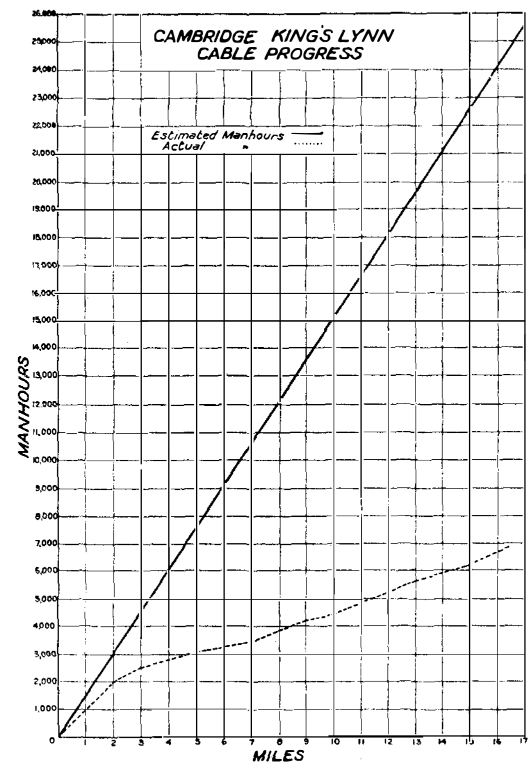



Fig. 4.—Comparative Costs.

estimated manhours expenditure (inclusive of ineffective time) which would have been incurred by manual methods alone and is based on observed rates for the work involved, *i.e.*, trenching at depths varying from 12 inches to 24 inches in the various classes of soil to be encountered on the route and in carriageway crossings, etc. The dotted line shows the actual manhours cost (inclusive of ineffective time) of the work to date and includes the manhours incurred by the supplementary gangs in laying cables by manual methods in places which could not be negotiated by the moledrainer. It should be mentioned, however, that some assistance was afforded the supplementary gangs in their trenching operations by the use of ploughs which cut away the top six inches of the trench.

For the purpose of direct comparison between the manual and the moledraining methods under identical conditions and favourable to the moledrainer, the following figures may be of interest.

*Direct Labour cost per yard.*

| | | |
|---|---|---|
| Manual methods | ... ... | 7·5 pence |
| Moledrainer methods | ... | 1·9 pence |
| Saving | ... ... | 5·6 pence |

The moledrainer cost is inclusive of the cost of trenching in carriageways, etc., which cross the cable track.

Authority has been given for the purchase of the moledrainer and the tractor-winch for use on future works and the following additional notes may prove of interest and value.

The route should be very carefully surveyed and a decision reached at an early stage as to the method to be employed on each section of route. Jointing points should be staked in advance, and the survey book should state clearly the method to be employed between jointing points. When ordering cable, an allowance of one yard should be made for each length to be pulled in by the moledrainer, as the method of attachment involves scrapping the end of the cable. Under no circumstances should the cable be attached direct to the mole. To leave out the mechanical fuse is to court disaster. It is advisable to attach a loose wire between the leading end of the cable and the chassis of the moledrainer. This runs in the slot cut by the coulter and if for any reason the fuse should break and not be noticed immediately, the loose end of the wire will indicate the position of the cable end and save much unnecessary digging.

Abrupt changes of contour should be levelled out. The mole, and therefore the cable, necessarily follows the contour of the ground level and the inclusion of sharp bends unnecessarily increases the stresses imposed on the cable. The moledrainer will ride on moderately sloping banks and any tendency to overturn can be counteracted by one or two men.

In conclusion, the writers wish to take the opportunity of expressing to the directors of Messrs. Ransomes, Sims and Jefferies the appreciation of the Department for the loan of the moledrainer in the early stages of the work and personal thanks for the enthusiastic co-operation afforded in the original experiments.

# Buried Loading Coil Pots

W. H. Brent, B.Sc. (Hons.).

The introduction of armoured cable for minor trunk cable circuits has led to the consideration of the application of direct burial in the ground to the installation of loading coil pots also, in much the same way that the fitting of aerial loading coil pots to poles was developed in connexion with the London-Brighton Aerial Trunk cable erected last year. There is, however, no reason why, in aerial or armoured cable work, the cables should not be brought into a manhole built for the purpose of housing the loading coils, but if the expense of providing this manhole can be avoided, without involving any reduction in the reliability of the circuits to be loaded, it is desirable to do so. The opinion has been formed that a manhole is not justified for the loading of circuits carried in armoured cables and the co-operation of manufacturers has been sought in order to develop a suitable type of pot for the Department's work. At the present time, orders have been placed for buried type loading coil pots for the Canterbury-Ashford, and Ashford-St. Margarets Bay Cables with Messrs. Standard Telephones and Cables, Ltd., and for the Cambridge-King's Lynn Cable with Messrs. Salford Electrical Instruments, Ltd. (Branch of the General Electric Company, Ltd.). As a result of experience with these two types of buried loading pots it is hoped to develop a standardized method.

For the benefit of those readers who may at some time be concerned in the installation of these loading pots, it is proposed to describe in some detail the types supplied by the manufacturers mentioned. Both are typical of Continental practice and are claimed to have given satisfactory service there.

The principal feature to be observed in the majority of the designs intended for use with armoured cable is the absence of the stub cables which one is accustomed to find led out from the coil case for jointing purposes; the non-appearance of these is so marked that it has given rise to the use of an alternative designation, that of "Stubless" Loading Coil Units. Instead of the ordinary design of pot, there is virtually a small and compact joint box built directly on top of the iron case containing the loading coils. This arrangement is common to both of the designs under review. It is in the disposal of the joint and the precautions taken to prevent loss of insulation that the designs differ in detail.

A loading coil unit accepted by the Post Office is shown diagrammatically in Fig. 1 and is manufactured by Messrs. Standard Telephones and Cables,

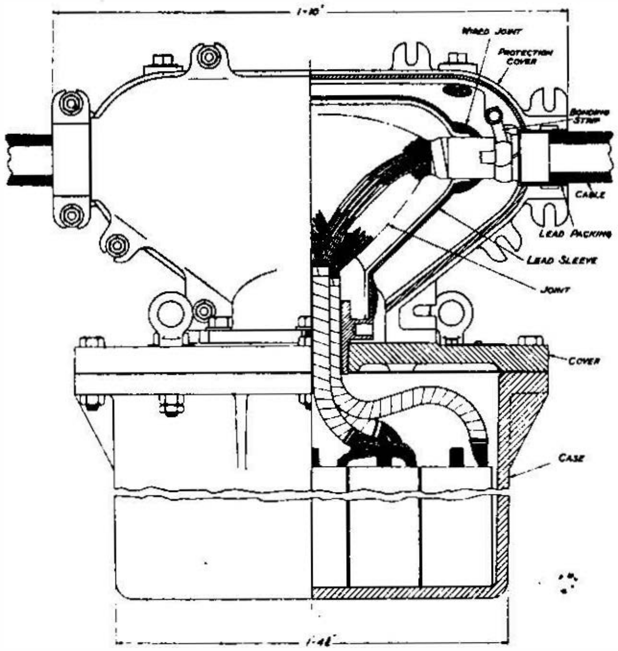



FIG. 1.—BURIED LOADING COIL UNIT (STANDARD TELEPHONES & CABLES, LTD.).

Ltd., at Woolwich. The lower case contains the loading coils, which are accommodated on wooden dowels in groups of 4 to 10 coils each. The rectangular section of the case takes five of these coil assemblies in the length and three in the breadth; the proportions in the diagram are those of a 60-coil pot, the depth being greater for the larger sizes. The cover closes the case with a specially strong flange joint, and the coils and connecting cable forms are completely sealed with a special compound. The cable forms rise through a centre brass nipple to the upper compartment.

To construct the joint, the main cable ends are prepared and supported as accurately as possible in their correct position. The centre cable form is then brought up almost to the top of the intended joint, and the incoming and outgoing quads jointed to the main cable, the quads being distinguished by an appropriate colour scheme. As the joint proceeds, subsequent cable forms are terminated at a lower level for connecting up so that an open joint, which is easy of access, results. It is a distinct advantage of this joint that there is little to obstruct the jointer whilst connecting up.

The triangular-shaped joint having been constructed, it is then protected by an airtight lead sleeve. This sleeve is cast in two halves and is provided with collars to embrace the main cable sheaths and to engage with the brass nipple below. Wiped joints are made at each of these collars and a seamed wipe seals the two sides together. At this stage, the plumbing should be pressure tested to ensure that the joint is hermetically enclosed. A cast-iron protection cover, which is divided in half longitudinally, is placed over the whole and bolted down securely. A means of clamping the armoured cable where it enters the cover is provided.

The photograph shown in Fig. 2, for which I am indebted to Messrs. Standard Telephones and Cables, Ltd., is of a larger pot of this character, being 2 ft. 6 ins. square and 2 ft. 10 ins. in height overall, and capable of accommodating 216 main trunk coils. Still larger sizes are manufactured up to a capacity of 432 coils. The robust construction is evident.

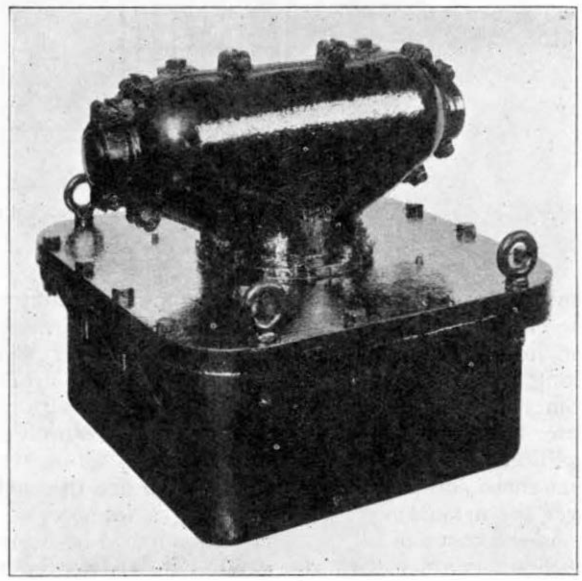


FIG. 2.—216-COIL BURIED LOADING UNIT.

Fig. 3 illustrates in part section the 108-coil unit which is to be supplied by Messrs. General Electric Company, Ltd., for the loading of the Cambridge-King's Lynn armoured cable. The lower cast-iron case contains the coils, each in its metal container for screening, and these are grouped in columns, six along the case and three across. The height of the case varies for the different numbers of coils required and dimension A is $9\frac{1}{8}''$, $11\frac{3}{8}''$ and $13\frac{5}{8}''$ respectively for the 72-, 108-, and 144-coil sizes of pot.

The cover of the lower case is specially cast in brass to include a rectangular-shaped joint box as part of the fitting. In the centre, the connecting wires from the coils rise through two perforated ebonite plates, and the intermediate chamber between, as well as the coil case, is filled with compound as a seal against the entry of moisture. One ebonite plate carries the incoming quads, another the outgoing quads; each quad has a separate numbered hole for reference, thus facilitating the work of the jointer who can thereby make a straight number to number joint. The lid of the box meets the sides on

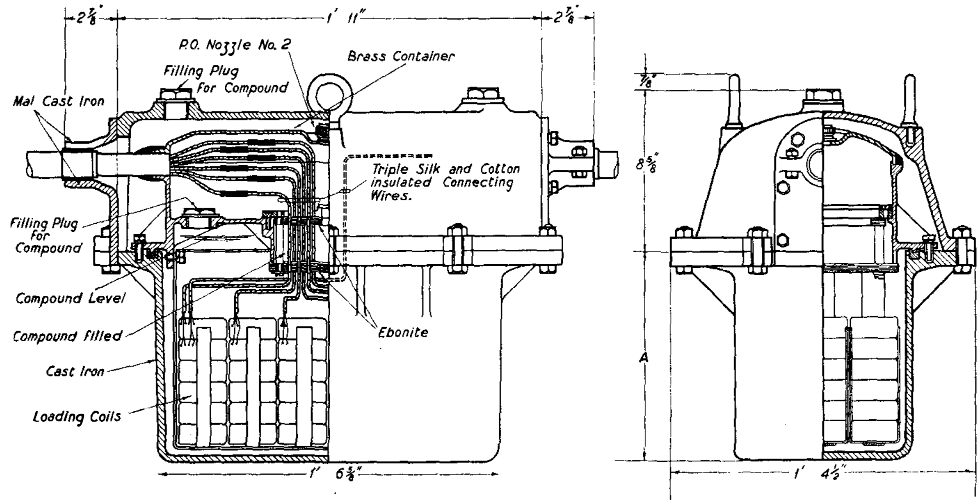



FIG. 3.—BURIED LOADING COIL UNIT (GENERAL ELECTRIC CO., LTD.).

the level of the main cables at the point of entry of the cables, and, after the joints have all been made, the lid is sealed down by means of a solder wipe along the seam and over the cable sheath at the points of entry. After testing the plumbing, the outer cast iron protection cover is bolted securely in position and the end plates fixed. It will be observed that these end plates are split and embrace the cable over the armouring with a clamping action.

As the cases of all types are intended to be buried in direct contact with the ground it is essential to secure that they are as resistant to corrosion as possible. With this object the external surfaces are of cast iron treated during manufacture with special compounds and the joints are well rubbed in with red lead and linseed oil before the final painting.

In order to install a loading coil unit of the buried type, a pit at the site requires to be excavated and a concrete raft six inches thick, on which the pot will stand, made at the bottom of the pit. This arrangement is made in order to ensure that there will be no appreciable sinkage or settlement after the completion of the work and, in most soils, if the raft extends 9 inches beyond the pot on all sides, this method of construction will be satisfactory. The depth should be such that there is two feet between the surface of the ground and the top of the pot when in position.

The two loading coil units described are strikingly illustrative of developments which have taken place in this department of telephone engineering during recent years. First, there is the reduction in size of the coils themselves made possible by the use of Gecallpy and Stanelec (or Permalloy) dust cores. A glance at Figs. **1** and **3** at once shows the small space taken up by the coils, as compared with that required for bringing out the connexions to the main cable. It is therefore probable that developments will take place by modifications in the disposal of the cable joints, although these must not be at the expense of the jointers' convenience, for accuracy and speed in jointing are important. Secondly, it is a reminder that on many cases these units provide for the loading of 10 lb. conductor 4-wire repeatered circuits for minor trunk working, a development in cabling work which is of recent introduction. Further, the pots are essentially designed for use with armoured type cable, and the first scheme in England in which this is included is only now being completed between Cambridge and King's Lynn with interesting results. Truly, therefore, is telephone line construction progressing.

# An Aerial Loading Pot

W. H. Brent, B.Sc. (Hons.).

An interesting use of aerial cable is that adopted for part of the Belfast-Donaghadee section of the Belfast-Glasgow 38 pair/40 Trunk cable. At this part of the route, appropriately named Deadman's Island in County Down, the road runs over a bog for about half a mile with a narrow grass margin between the road and a deep water-filled ditch. On account of this, it was anticipated that any attempt to cut a trench for pipes or ducts would result in the parting of the road longitudinally and the incurring of serious liabilities. The solution was found in aerial cable which not only overcame this difficulty, but also obviated any likelihood of corrosion of the lead cable sheath due to soft peaty water. In order to ensure stability, the poles, which are of the 26 ft. medium class, are set five feet in the ground and each pole is fitted with two medium stay blocks. The cable has an external diameter of 1.25 inches and is carried in 2-inch steel cable rings attached to a 7/12 steel strand messenger.

A further problem which arose was the accommodation of a loading coil pot at a point about midway along the section where it was necessary to bring out light carrier circuits for loading with 18 mH coils (499 yards spacing). The pot was considered too heavy for mounting on a single pole as the total weight was 380 lb. and yet a box, either in the ground or on the surface, was considered undesirable. Finally, it was decided that the best construction was an H-pole structure arranged in line with the route with cross-connecting channel irons on which to carry the iron loading coil pot. Fig. 1 shows the arrangement of the upper portion of this structure in more detail. The poles are spaced sufficiently far apart to take the loading coil case between them; three tie rods are fitted, one two feet from the top, one five feet from the ground, and the third halfway between. Two longitudinal stays are fitted in the manner illustrated and the structure is supported against transverse stresses by providing a sound foundation which consists of two 6 ft. pole braces, one fitted in front of the poles 12 inches from the bottom and one on the back of the poles 2 feet below the ground level. These brace blocks are again braced together near the ends with medium stay blocks.

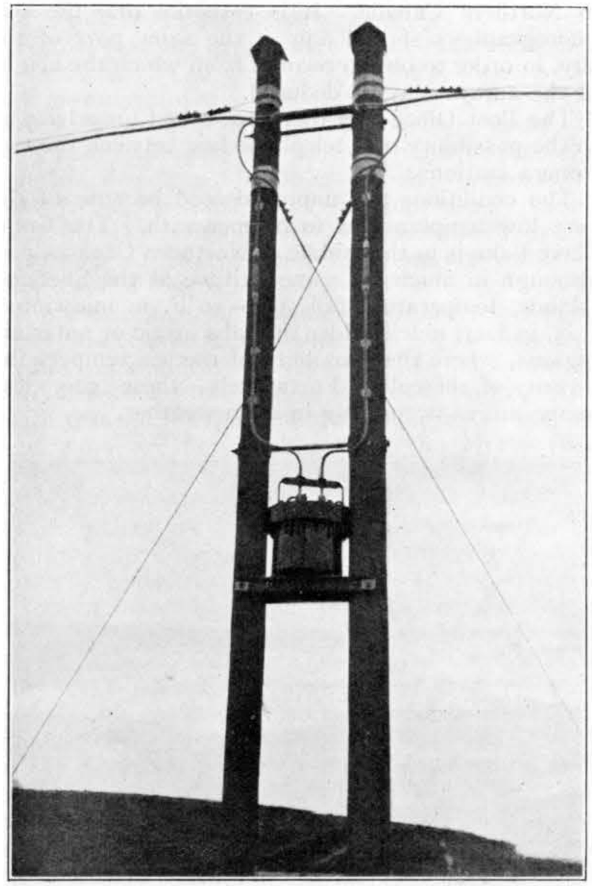


Fig. 1.—Aerial Cable Loading Coil Pot.

The pole work, the erection of the strand wire, and the placing of the steel cable rings was carried out by the staff of the Northern Ireland District; the cabling and the installation of the pot were the work of the Pirelli General Cable Works, Ltd., of Southampton.

# The British Polar Year Expedition, 1932-33

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

ONE of the activities of the British Meteorologists taking part in the Polar Year Expedition will be the simultaneous photographing of the Aurora Borealis from two stations about 17 miles apart on the shore of the Great Slave Lake in Northern Canada. It is essential that the two photographers should aim at the same part of the sky, in order to obtain records from which the height of the aurora may be deduced.

The Post Office was therefore asked for advice as to the possibility of a telephone line between the two camera stations.

The conditions are unprecedented because of the very low temperatures to be met with. The Great Slave Lake is in the middle of Northern Canada, and although in much the same latitude as the Shetland Islands, temperature falls to $-50°$F. in midwinter. It is, in fact, much colder than the arctic or antarctic regions, where the proximity of the sea tempers the severity of the cold. Fortunately, these very low temperatures occur only in calm weather.

*Royal Canadian Air Force.*

The Great Slave Lake.

The lake is only a few feet deep and is frozen solid in winter and covered with deep snow. As will be seen from the aerial photograph (reproduced by kind permission of the Royal Canadian Air Force) there are forests of small trees, mostly birch, all round the shores of the lake.

It was at first proposed to lay a bare aluminium wire on the snow or ice, as was done in Scott's Antarctic Expedition. There are two objections to this course, however. First, the insulating effect of the snow is a doubtful quantity. It proved to be fairly high in the Antarctic, but conditions were very different. Frequent blizzards sweep across the Antarctic snow fields, whilst in the vicinity of the Great Slave Lake the weather is generally calm. Secondly, a wire laid on ice will tend to embed itself completely (even at temperatures below freezing) and as the specific inductive capacity of ice is very high (about 90) the loss of telephone current through capacity would be serious.

Some tests were made at Dollis Hill on short lengths of wire frozen into ice, and it appeared that a capacity to earth of about 1 $\mu$F. per mile was to be expected. Telephony under these conditions would be impossible without specially compensated amplifiers. The difficulty is to some extent confirmed by an article in the Geographical Magazine of some years ago in which it is mentioned that telephone wires laid on the ice were tried at Archangel, and the experiment was a failure.

It was finally decided to run the wire round the edge of the lake, attaching it to insulators wired on to the trees and keeping it clear of the snow as far as possible. The wire is made of an aluminium alloy known as "Silmalec" and was presented to the Expedition by the British Aluminium Co.

The tensile strength, etc., are shown in the Table and compared with cadmium copper.

| | Gauge. | Wt./mile. | Breaking Strength. | Ohms/mile. |
|---|---|---|---|---|
| Silmalec | 16 S.W.G. | 20 lbs. | 145 lbs. | 24.8 |
| Cadmium-Copper | 18 S.W.G. | 40 lbs. | 200 lbs. | 26 |

Weight is one of the foremost considerations, for the cost of transport from London to Fort Rae is nearly £100 per ton, and the size of package must be limited, in view of the trans-shipment necessary during the long journey by river and lake from the railhead to Fort Rae. The Silmalec wire was therefore chosen, and covered (by Messrs. W. T. Henley's) with a layer of waxed cotton. This insulation is expected to last for the period of the observations, which can only be made in the winter months.

The circuit will consist of a single wire and earth return. For the earth connexions, tubular steel spikes about 4 feet long have been made, and three or four of these will be driven deep into the ground at intermediate points, to enable earth connexions to be made for testing purposes. The ground will be frozen for about 2 feet down, and presumably it will be necessary to get into unfrozen ground to make a satisfactory earth connexion.

This circuit, if the insulation remains good, will have very moderate attenuation at speech frequencies, but the best possible telephones are being used in case the leakage or capacity should prove to be excessive. These telephones consist of breast plate transmitters, of a new type just developed by Messrs. Siemens Bros., with head gear receivers. Telephones, batteries, and induction coils have been presented by the firm. Magneto generators and bell sets, which will be used in a tent or hut and connected to the telephones by long cords have been supplied by the Post Office.

It will be the unenviable duty of the observers who are to photograph the aurora simultaneously from the two ends of the base line to manipulate the special cameras in the open, at a temperature of perhaps $-50°$F., while keeping in touch by telephone so that the two cameras may be trained on the same part of the sky. Though the human body may adapt itself to such extreme conditions, it was not safe to assume that microphones and batteries would behave normally.

The battery question has been disposed of by arranging for the observers, who will be clad in special clothing, to carry the batteries in their pockets. The head gear receivers will be worn under some kind of helmet, but the transmitters may have to stand almost the full rigour of the cold. They were accordingly tested at $-50°$F. in the following way :—

A bell jar was arranged to hold the transmitter at the large end, leaving the mouthpiece to project, and a thermo-couple, consisting of two wires wrapped round the microphone case, was arranged to serve as a thermometer. Several pieces of solid $CO_2$ were put in the bell jar and air was blown through. This proved a very convenient way of producing the low temperatures required. It was found that the transmitter efficiency was 3 or 4 db worse at $-50°$F. than at ordinary temperatures, which was rather surprising, seeing that the granules are appreciably warmed by the current. There is a protecting piece of special flexible material in front of the transmitter diaphragm, but removing this material seemed to make no difference. These transmitters are unusually efficient, however, and the loss of a few dbs will not matter.

The articulation, as well as the volume efficiency, is very good. This has been obtained partly by the use of a special mouthpiece, somewhat similar in shape to that of the ordinary breast plate transmitter. The mouthpiece is fixed to the transmitter box by means of a bayonet grip, so that it can easily be detached and cleared of the hoar frost which forms from the moisture of the breath at temperatures below freezing.

If, for any reason, the line should become impossible for speech between the telephones provided, the observers will have to fall back on the Morse code. Wireless transmitting equipment had to be ruled out for various reasons, and two fullerphones, lent by the Royal Corps of Signals, will be used. The fullerphone is an instrument which employs a telephone receiver in series with an interrupting contact (driven by separate buzzer) to receive D.C. telegraph signals of very small magnitude. It was largely used during the Great War because the D.C. signals, which were smoothed at the sending end, could not be picked up by the enemy, as speech and " buzzer " signals were.

In this case the great value of the fullerphone lies in its sensitivity to weak D.C. signals, such as can be transmitted over a very leaky line. Thus, if the waxed cotton covering fails, and the snow proves to be a poor insulator, the fullerphones will probably save the situation. If the insulation remains satisfactory, but the capacity of the lines proves excessive, the D.C. signals will be transmitted easily, even though speech is hopelessly drummy, owing to the excess of low frequencies.

For the sake of the observers, however, it is to be hoped that the fullerphones will not be required. Instant communication is particularly important in their case, and though experienced telegraphists might transmit the information as quickly as speech, those who are not familiar with the Morse code would certainly be more successful with the telephone.

It is interesting to compare the telephone line of the Polar Year Expedition with that used by Scott's Antarctic Expedition in 1911-1912. It was arranged to lay a bare aluminium wire on the snow from Scott's base camp to an advance post in a tent. To avoid any trouble through freezing of dry batteries the " Central Battery " system was used, accumulators being installed at the base camp. The actual telephones (made by the National Telephone Co.) are now in the museum at the Institute of Electrical Engineers. Dr. Simpson, now Director of the Meteorological Office, who was a member of the Scott Expedition, and often used the line, remembers that it worked quite well, except that when the sun was shining, even though the air temperature was below freezing, the insulation would fail for a time. It was partly on account of this rather mysterious effect that it was decided to use insulated, instead of bare, wire for the Polar Year Expedition. Apparently, the capacity to earth of the wire laid on the snow was not excessive, and this may have been due to the dry and powdery nature of the Antarctic snow.

The Polar Year Expedition will be out of touch with civilization, except for the special news bulletins they may receive from a Canadian broadcasting station, until next spring, when it will be interesting to know whether the telephone line proved a success.

# Research

IN the following brief review a number of typical investigations that have been in hand during the past six months have been selected for comment. Some of the major investigations have already been described in articles in the Journal and these are not referred to in this review; fuller information on some of the cases mentioned below, however, will probably appear in later issues of the Journal. It is proposed to include a similar brief review of the Research Section's activities for the previous quarter in each future issue of the Journal.

### Telegraph Services.

As might be expected, the activity in connexion with the provision of Teleprinter services has given rise to a number of investigations bearing on this service. Some of these investigations are briefly referred to below.

*Teleprinter or Wheatstone on long distance Private Wires.* A system has been developed using voice frequency signalling at the renter's premises. This set, which is mains-operated, works duplex with a frequency in one direction of 800 cycles and 1,300 cycles in the other. A standard P.O. relay is used and double current circuit conditions are obtained without the use of a push-pull valve arrangement; a satisfactory working speed of 220 words per minute, Wheatstone, in both directions simultaneously has been obtained.

*Telegraph Distortion Measuring Set.* The line conditions required for Telegraph transmission with Teleprinters are much more exacting than those required for Wheatstone working owing to the effects of signal distortion. It has been necessary to develop methods of measuring the characteristic distortion of line signals. Two methods have been investigated. In the first of these the percentage distortion is measured by an integrating voltmeter, and with inexpensive and simply operated apparatus the amount of regular distortion can be measured to within $\pm 1\%$. In the second method a Baudot distributor is used to set up a group of signals in which the time relationship of the start signal to the operating signal can be varied,—the time relationship corresponding to various degrees of distortion. The method gives a ready means of discriminating between the performance of individual teleprinters with various amounts of distortion.

*Teleprinters on Telephone circuits. (Telex system).* Tests have been carried out on the apparatus using "impulse working" which, after extended trials, has been adopted. Specification data, and testing and maintenance instructions dealing with components and V.F. converter units have been prepared. This system uses a frequency of 300 p.p.s., is mains-operated, and can be connected to any telephone.

*Filters for Teleprinter circuits to render speech impossible.* In connexion with certain private wire Teleprinter circuits, it is desired to use ordinary telephone circuits for D.C. telegraphy, but at the same time speech must be made impracticable on such circuits. To attain this object, experiments have been carried out with filters having slightly different characteristics and it has been found that a low pass filter which freely permits frequencies up to 600 p.p.s. is superior to one cutting off at 450 p.p.s., as the volume of the 300-600 p.p.s. band in the received speech swamps the higher frequencies which normally render speech intelligible.

### Carrier Investigations.

The field for carrier current telephony is extending and the following notes on a few cases are of interest:—

*Carrier working on Anglo-Dutch Cables.* Carrier frequency tests have been completed on these cables and the results indicated that it is possible to work one four-wire carrier circuit on each of the four quads of the No. 3 cable and similar circuits on two diagonally opposite quads of the No. 2 cable. All circuits will operate on a carrier frequency of 5.8 kc. and will transmit the lower side-band only. Tests were also made on the double phantom circuits, but cross-talk conditions make it impossible to work carrier channels on these circuits in addition to the side circuits. Equipment to provide a second experimental carrier circuit between Aldeburgh and Domburg has been installed, and the design and specification data for carrier equipment, modified to work with $\frac{1}{4}$ amp. valves, completed. The equipment for the six channels will shortly be manufactured by Messrs. Standard Telephones and Cables, Ltd.

*Portable Mains-driven Carrier Apparatus.* Successful experimental trials have been carried out in the laboratory of a single-channel carrier system operated from supply mains. This is capable of establishing a zero circuit over an aerial line the attenuation of which is less than 30 db at 9 kilocycles (the highest side-band frequency transmitted). The system employs a common carrier frequency for the two directions of transmission, and transmits the upper side band in one direction and the lower in the other direction. The whole of the apparatus is very compact and will occupy less than four feet of rack space or, alternatively, can be made available in metal boxes for use in exchanges where the traffic is seasonal, as, for example, in seaside resorts.

In this connexion new types of modulator and demodulator, using metal rectifiers in place of certain valves, have been devised and preliminary tests have been very satisfactory. The new design should enable one modulator and one demodulator, employing three valves altogether, to be mounted on a 7-inch plate.

REPEATERS AND TRANSMISSION TESTING APPARATUS.

*Toll Repeaters on the London-Brighton Aerial Cable.* After handing over the cable for maintenance, one circuit was retained for continuous observation as to the influence of temperature variations on A.C. transmission and D.C. resistance values. As an example, during the month of January an effective temperature variation of 16°F. occurred corresponding to a transmission variation of $\pm\frac{3}{4}$ db. only.

*Regeneration in Telephone Repeaters.* An investigation has been in progress on the application of regeneration to Telephone Repeaters with the object of obtaining from one valve a gain, hitherto requiring a 2-stage amplifier. The experimental work so far carried out indicates that an additional gain of 6—10 dbs. can be obtained, without loss of quality, in this way giving a total gain with one valve of 36—40 dbs., a result that is likely to have an important bearing on repeater design.

*Portable Transmission Testing Set.* A set of very compact design has been evolved for measuring "level of transmission" and a demonstration model made up having a range of 0—30 dbs. in steps of 1 db. It is suitable for general use on lines or exchanges, and provision is also made for testing higher levels up to + 10 db. for the case of terminal toll repeater stations. For intermediate toll stations, a simpler type of instrument having a range of + 10 to − 20 db. on a direct reading scale has been provided.

*A Continuously-Variable Audio-Frequency Oscillator.* A very satisfactory oscillator, continuously variable over a considerable range, has been designed in which the principle of a condenser resistance discharge working in conjunction with a valve and a neon tube is used. The oscillator has several advantages over the heterodyne type oscillator and, having a simple dial control and uniform output, will be of considerable use for transmission tests. The apparatus was exhibited recently at the Physical and Optical Societies' Exhibition and at the Royal Institution.

*Acoustical Measurements and Room Noise.* In connexion with various complaints arising from noisy rooms, it has become necessary to have available a portable and simple means of estimating the loudness of room noises. The method that has been adopted is to balance the room noise against a 1,000 p.p.s. tone in a receiver. The tone is supplied by a small oscillator and adjusted by an attenuator calibrated in sensation units (dbs. above the threshold of normal hearing). The results obtained on the average by a number of observers or by a single average observer are sufficiently accurate for the purpose and are in units that have been fairly commonly accepted.

*Acoustic Treatment of Rooms.* A method of reducing reverberation in rooms was suggested by the Research Section and used successfully at Dudley Exchange some time ago. The method consists of the application to the ceiling of narrow strips of Celotex or similar absorbent material. It has now been suggested that this treatment should be standardized and applied in ready-made slabs about 6′ × 4′ which could be fixed readily to the ceilings of rooms requiring such treatment. Sample slabs have been made up for inspection by those interested in the question.

*Design of an Instrument for Measurement of Speech Volume.* An instrument has been designed and constructed for measurement of speech volume used in transmission testing and could also be used for an objective measurement of "noise." The instrument is based on the recommendations of the C.C.I. for meters of this description. The speech is picked up on a condenser microphone and by means of a volume amplifier and rectifier operates a meter through a tuning circuit. The frequency characteristic is practically flat above 150 p.p.s. and the deflection is almost linear with changes of acoustic input pressure. The device is self-contained and operates entirely from A.C. mains.

SIGNALLING EQUIPMENT.

Investigations are continually in progress on questions arising in connexion with the operation of relays and signalling equipment generally and the following are perhaps of general interest :—

*Tests of proposed Standard Relay for Automatic Exchanges.* Extensive tests on this relay indicate that it is approximately equal to the existing Siemens relay as regards stability, magnetic efficiency and stability, and interference. As regards liability to dust faults, however, the contacts of the proposed relay are definitely superior and it has the further advantage that the design is such that it is capable of dealing with a larger number of moving springs than the Siemens relay.

*Comparative fault liability of faults on single and twin contacts and dust faults on relay contacts.* An extensive series of tests on various types of relays have been concluded and the results conclusively indicate that twin contacts have a much smaller fault liability than single contacts.

The general question of dust faults has also been the subject of lengthy investigation in which such factors as the effect of relay covers, the disturbance of dust, varying conditions of pressure, travel (rub), spring thickness, and plane of spring have been taken into consideration. In the course of the investigation it became evident that tests of the effect of contact shape and contact material were necessary and in these tests the inherent tendency of pure silver to a smaller fault liability than other materials was discovered. As a result of the investigation it has been possible to make recommendations as to methods of contact cleaning and periodic cleaning of relay groups.

*Key-sending from P.B.X's by means of 4-frequency signalling.* An interesting scheme has been devised for 4-frequency key-sending from a P.B.X. in which damped oscillations are used instead of a 4-frequency A.C. generator and requires only simple tuned circuits at the P.B.X. The signalling is effected over the exchange lines used for speaking and does not require an earthed phantom as in an alternative method which has also been considered.

*Mechanical Keysenders for P.B.X's.* Trials have been made of a number of models of mechanical Keysenders and one designed by Mr. Macadie and made by the General Electric Company has been under observation on the Research Section P.B.X. and has given satisfactory service for some months.

### Interference.

Owing to the general extension of the grid system in this country questions as to the effect of these lines on communications circuits have arisen and important series of field tests have been carried out.

*The Mutual Induction between Earthed Overhead Lines.* Measurements of the mutual induction between specially constructed parallel overhead lines have been carried out in Germany and Skillingaryd (Sweden). To extend the knowledge of the subject and to obtain further data as to the effect of earth resistivity on the induction, tests have been carried out on Shap Fells, Westmoreland. The experimental work was done in co-operation with the British Electrical and Allied Research Association at the request of the C.M.I. and two specially equipped testing vans which had been used in the previous European investigations were kindly lent by the German Administration. The primary object of the experiments was the determination of the coefficient of mutual induction between an earthed power circuit and a telephone line; measurements of the earth resistivity were made and, using the value obtained, satisfactory agreement was found between the alternating current induction calculated from theoretical formulæ and observed results.

*Noise measurements on Post Office circuits at Manchester in connexion with the use of filters on mercury arc rectifiers.* A further series of tests have been carried out on collaboration with the Electrical Research Association, The British Thomson Houston, Ltd., and the International Telephone and Telegraph Laboratories. The L.M.S. Railway have installed a mercury arc rectifier to feed their Manchester-Altrincham line and desired to know whether any of the filter circuits could be omitted from future installations without giving trouble on nearby communication lines. The noise disturbance caused by the rectifier is reduced to about 1/10 by the use of filters and the results of measurements indicated that none of the filters could be taken out of circuit without increasing the noise on P.O. lines considerably.

### Chemical and Physical Investigations.

Amongst the large number of tests carried out, mention may be made of the conclusion of an investigation on the question of a *satisfactory treatment for the textile coverings of jumper wires to prevent attack by moth grubs.* It has been found that the textile covering after treatment during the dyeing process with "Eulan N.K.," a moth-proofiing compound made by the Interesen Gemeinshaft of Germany, is immune from attack. Further experiments are in hand, however, with a view of developing a moth-proof jumper wire for general use containing no wool or silk and which will probably be cheaper than the present type.

*Properties of "Silmalec" aluminium alloy wire.* This alloy, which had been proposed as suitable for aerial line wire, has been fully examined. Chemical composition, Specific Gravity, Resistivity, Coefficient of linear expansion and mechanical properties have been determined. The material appears to resist corrosion to about the same extent as Cadmium Copper, but its fatigue limit is appreciably lower than for the materials at present in use.

*Cotopa.* A form of textile insulating material composed of acetylated cotton yarn has been subjected to tests of its insulating properties under various conditions of humidity. It has been found that the material compares quite favourably with Cellulose acetate artificial silk yarn.

# Outline Notes on Telephone Transmission Theory

W. T. PALMER, B.Sc., Wh.Ex., A.M.I.E.E.

*[The complete Series in Book form, with some additions, price 5/-, can be obtained from Journal Agents. A limited number of copies only will be available.]*

SECTION XV.

## Causes of Cross-talk in a Cable and Cable Balancing.

Most telephone cables laid in this country since 1927 have the conductors arranged on the "*star quad*" principle, *i.e.*, the cable contains a number of four-wire units (quads), each quad being formed by twisting the four insulated conductors symmetrically about a common axis. (See Fig. **54**). The wires diagonally opposite

FIG. **54**.—STAR QUAD.

in the quad constitute pairs. Thus, in Fig. **56**, AB and CD are the pair circuits or "side" circuits.

Another principle on which telephone cable conductors are constructed is the "*multiple twin*" principle. In paper-core multiple twin (P.C.M.T.) cables there are also a number of four-wire units, but the single insulated conductors are first twisted into pairs and then two pairs are twisted together to form a four-wire unit, sometimes called a "core," but more correctly called a "quad." See Fig. **55**. The

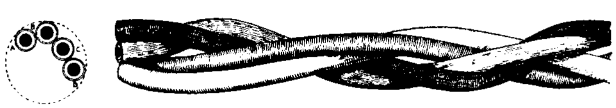


FIG. **55**.—MULTIPLE TWIN.

diagram shown in Fig. **56** is also used to represent the four wires of a multiple twin quad.

Now cross-talk in a cable may be caused by one or more of the following unbalances:—

- *a. Capacity unbalance.* (See later paragraphs).
- *b. Conductor resistance unbalance,* i.e., unequal resistances of the two wires of a pair.
- *c. Insulation resistance* or *leakance unbalance.*
- *d. Inductance unbalance.*

Of the foregoing causes, three of them (*b, c* and *d*) can be rendered negligible during manufacture of the cable—by the high degree of uniformity made possible by modern processes. The remaining cause, capacity unbalance, although it can be kept to a small magnitude in individual manufacturing lengths of about 200 yards, cannot be rendered negligible for a whole length of cable, such as a loading coil section (2,000 yards or more), unless special methods of jointing successive lengths of cable are employed. Briefly, such methods aim at joining lengths of "positive" capacity unbalance to lengths having corresponding "negative" unbalances and by so balancing one against the other the resultant is brought to low limits, so reducing the cross-talk to a low value. The following paragraphs give necessarily only the barest outline of capacity balancing and the student should read the references given at the end of the Section, those marked by an asterisk being the most useful, for fuller and more exact details.

**Capacity Unbalance.**—In any quad, such as a star-quad or multiple-twin quad, there are *ten capacities* existing between the wires ($\omega/\omega$ capacities) and between the wires and earth ($\omega/\epsilon$ capacities), known as "true" or "direct" $\omega/\omega$ and $\omega/\epsilon$ capacities. If a measurement of capacity is made, say between A and D in Fig. **56**, the actual reading obtained is the

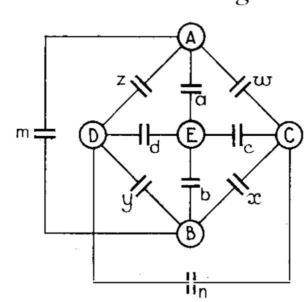



FIG. **56**.

resultant of the network of capacities between A and D and in most capacity unbalance work the capacities concerned are these " resultant " or combined capacities. In the early days of capacity balancing efforts were made to reduce the capacity differences of the " true " or " direct " capacities, *i.e.*, $w-x$, $z-y$, $a-b$ . . . etc., to small values, but later it was found simpler in practice to deal with the differences of certain combined or " resultant " capacities.

*Side to Side Interference.* Consider Fig. **56**. This can be replaced by the equivalent network shown in Fig. **57**, where W, X, Y, Z are the resultant capacities as already explained. The mutual capacities M and N are not included because they either shunt the circuit AB or CD, *i.e.*, the source or detector of the Wheatstone bridge indicated in Fig. **57**.

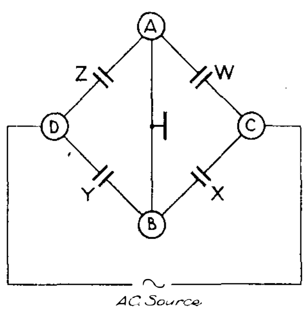



FIG. **57**.

When speech or a tone be applied to AB (or CD) then when a telephone receiver is connected across CD (or AB) there will be nothing heard in the telephone if $\frac{W}{X} = \frac{Z}{Y}$. If the arrangement is not balanced it can be balanced by adding a condenser, such as K, to X or Y (Fig. **58**) and the value of this condenser is a measure of the capacity unbalance—called side to side unbalance—and is a positive or negative depending on the movement right or left of the condenser K.

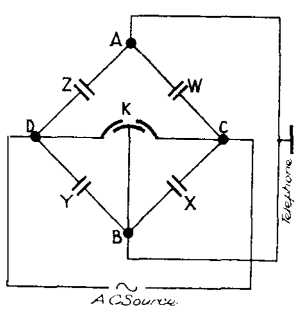



FIG. **58**.

It can be shown, by writing the values of W, X, Y, Z in terms of $w$, $x$, $y$, $z$, $a$, $b$, $c$ and $d$, that $K \fallingdotseq (w-x)-(z-y) \fallingdotseq p-q$ where $w-x=p$ and $z-y=q$. See P.O. Technical Instruction—Lines, Underground, G.1000-1099.

*Phantom to Side Interference.* Fig. **59** shows the diagrammatic arrangement required to measure the phantom to side unbalance capacity.

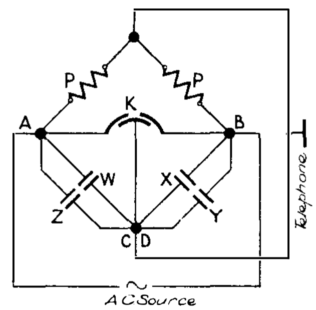



FIG. **59**.

Two arms of the bridge P,P are non-inductive resistances, and the two conductors CD in Fig. **59**, (A,B in Fig. **60**), and joined together at one corner of the bridge. The arms P,P join, in effect, the two wires of the remaining pair and thus the telephone is virtually across the phantom circuit in both Figs. **59** and **60**. Thus if the capacities are such that (W + Z) = (X + Y) there will be a balance of the bridge and no cross-talk from phantom to AB (Fig. **59**). Similarly if (W + X) = (Z + Y) in Fig. **60** there will be no phantom to CD cross-talk. As before if the capacities do not balance the bridge they can be made to do so by means of the condenser K.

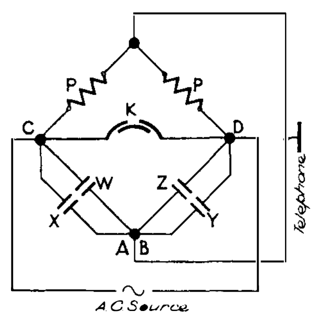



FIG. **60**.

The value of the change required in K is a measure of the phantom to side capacity unbalance and is equal to (W − X) + (Z − Y) in Fig. **59** and (W − Z) + (Z − Y) in Fig. **60**, where W, X, Y, Z are *resultant* capacities as already explained and include both ω/ω and ω/ε values.

If we write down the values of W, X, Y, Z in terms of $w, x, y, z, a, b, c$ and $d$ it can be shown that provided $a + b \fallingdotseq c + d$ then the *phantom to AB unbalance* is :—

$$(w - x) + (z - y) + \tfrac{1}{2}(a - b)$$

and *phantom to CD unbalance is* :—

$$(w - z) + (x - y) + \tfrac{1}{2}(c - d)$$

Measurement of capacity unbalance is not made by means of a differential condenser (K) in the Post Office method of measuring unbalances, but a form of capacity double bridge is used. (See Technical Instructions, Lines, Underground, G.1000 Series).

Using the following nomenclature, viz. :—

$$w - x = p$$
$$z - y = q$$
$$w - z = r$$
$$x - y = s$$
$$a - b = \mu$$
$$c - d = v$$

we can write the preceding equations for capacity balance of a quad (as shown diagrammatically in Figs. **56** to **60**) :—

For Side to Side balance :

$$p - q = 0 \quad ..............(1)$$

For Phantom to AB balance :

$$p + q + \tfrac{1}{2}\mu = 0 \quad ......(2)$$

For Phantom to CD balance :

$$r + s + \tfrac{1}{2}v = 0 \quad ......(3)$$

And further, since (2) and (3) could be satisfied with large values of earth unbalances, $u$ and $v$, it is desirable to keep $\mu$ and $v$ as small as possible in practice to prevent earth tone interference. Therefore in the ideal case for perfect balance of earth capacities we get two other conditions, viz. :—

$$\mu = 0 \quad ..........................................(4)$$

$$v = 0 \quad ..........................................(5)$$

The following figures are given to show the order of magnitude of the quantities involved :—

Capacity Unbalances (in μ.μ.F.) of Star Quad Cable.

| Length. | $p - q$ | | $2(p + q) + \mu$ and $2(r + s) + v$. | | $\mu$ and $v$. | |
|---|---|---|---|---|---|---|
| | Mean. | Max. | Mean. | Max. | Mean. | Max |
| Manufacturing Length (176 yds.) ... | 50 | 200 | — | — | 150 | 600 |
| Balanced Loading Coil Section (2000 yds.) ... | 30 | 60 | 300 | 600 | 100 | 200 |

*Selection.* Before loading coils are joined up each intermediate loading section of cable must be balanced, as already indicated, so as to bring the overall capacity unbalance to a minimum value. There are many ways of obtaining the desired result. A common method of procedure is to divide the loading section into eight equal parts marked A, B, C - - - H in Fig. **61**. The joints between manufacturing lengths within each of the sections A - - - H can either be straight or joined according to some systematic

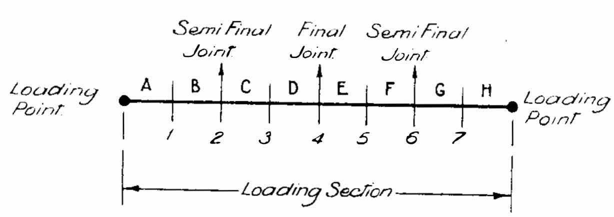



Fig. **61**.

scheme of crossing the wires. This leaves seven " test " joints 1 - - - 7 at each of which the capacity unbalances already discussed are measured and from these measurements selection is made for the wires to be joined together. This selection is made so that the unbalances tend to neutralize, the *largest unbalances being dealt with first* and so on, in order of magnitude, to the lowest. This selection enables joints 1, 3, 5 and 7 to be made so that loading section is now in four equal parts. Test selected joints are then made at 2 and 6 as a result of measurements taken at those points, thus leaving two halves of the cable to be tested from 4—called the " final " joint—at the middle of the section. The overall unbalance by this process can be reduced to very low figures—much less than any of the individual length figures—and the section is also uniformly balanced for capacity.

In selecting which way two quads shall be jointed through there are eight possible combinations, shown in Fig. **62**, and when phantom to side as well as side to side and side to earth unbalances have to be reduced to a minimum, the selection of the quads to be joined together requires much consideration. Space does not permit of treating the effect of all the crosses, shown in Fig. **62**, on the resultant capacity unbalances, but in the case of the $(p - q)$ values a little consideration will show that when the wires are jointed straight then the $(p - q)$ values must add algebraically, but must be subtracted algebraically if the wires of one of the pairs be crossed with respect to the other.

*Another method of cable balancing* consists of the addition of suitable condensers at each of selected points along the cable section in order to reduce the measured unbalances of the circuits to zero. This is used in England only when the foregoing crossing method cannot be economically employed, but such auxiliary condenser methods are used generally in Germany. The Patent Specifications below refer.

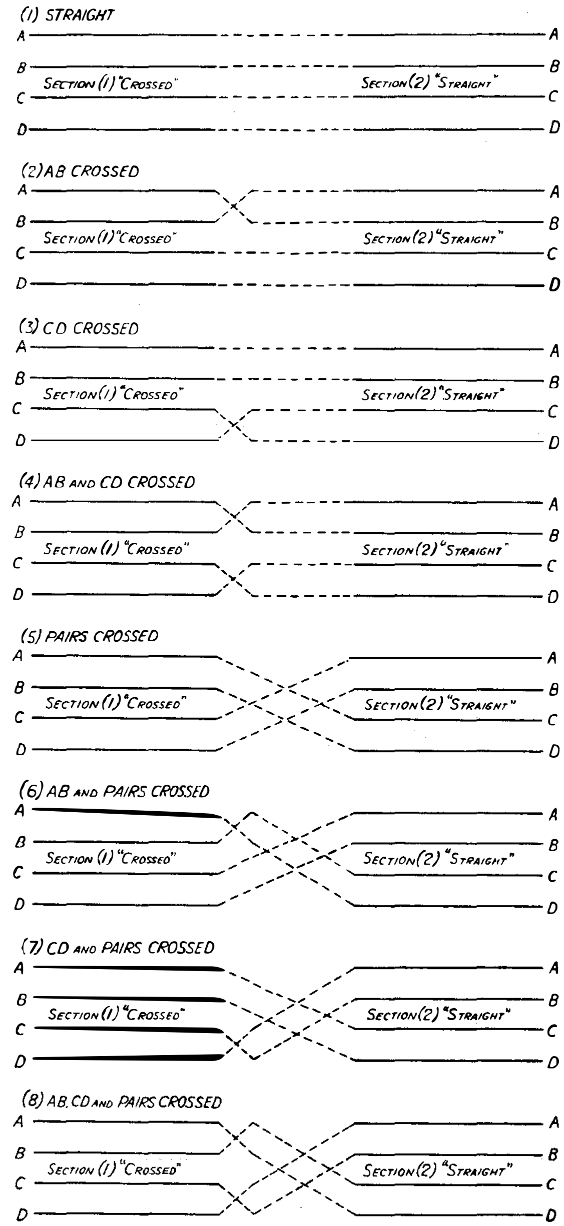



Fig. **62**.—Permissible Crosses between Quads.

*Useful References for Section XV.* :—


*Post Office Engineering Dept. Technical Instructions—Lines, Underground, G.1000-1099.

" Balancing of Telephone Cables required for Superposed Working." By S. A. Pollock. P.O.E.E.J., Vol. VII., Parts 1 to 4.

*" Interference between Circuits in Continuously Loaded Cables." By A. Rosen. J.I.E.E., Vol. 64, p. 849, 1926.

" Some Aspects of Electric Capacity of Telephone Cables." By A. Morris. P.O. E.E.J., Vol. 20, Part 1, 1927.

*" British Patent Specification " No. 147,013 of 1919. Siemens and Halske.

*" British Patent Specification " No. 223,307 of 1923. Western Electric Co.

" Cross-Talk in Telephone Cables and Its Reduction.'' By K. Kupfmüller. Archiv. fur Elektrotechnik, May 5th, 1923.

*See also References at end of Section X.*

## SECTION XVI.

### Localisation of Impedance Irregularity in Long Loaded Cables.

An impedance irregularity will be caused by a contact between the wires of a pair, or a high resistance in one conductor of a pair as well as by corresponding faults in loading coils and apparatus. Each of these kind of faults can be localised by well-known D.C. methods, (See end of Section for references to fault localisation literature), but A.C. at audio-frequencies can also be employed for localisation purposes.

The big advantage of the A.C. methods is that variation of the fault resistance (a common trouble) during the period of testing does not seriously affect the accuracy of the results as is the case with most D.C. methods. And in addition, of course, the A.C. methods are applicable in cases of faults where D.C. methods are of no use, such as inductance unbalances caused by short circuited turns in a loading coil, etc.

*Theory of Procedure for A.C. Localisation.*

When a fault occurs in a cable pair, if A.C. at audio-frequency is sent into the line some of the electrical energy will be reflected back to the sending end from the fault and the remainder will travel to the distant end. The reflected portion at any given frequency, $f_1$, when it reaches the sending end will have travelled a distance $2x$ and be different from the phase at the sending end by an angle

$$2\alpha_1 x + \phi_1$$

where $x$ = distance to the fault F (See Fig. **63**).

$\phi_1$ = change in phase produced at the fault.

$\alpha_1$ = wave-length or phase constant of the line at the frequency, $f_1$, considered.

Naturally if the frequency of supply is now continually varied this phase angle will continually change so that sometimes the reflected wave will be in phase with the sent wave and sometimes opposite in phase. Hence any measurement of current, or impedance, at the

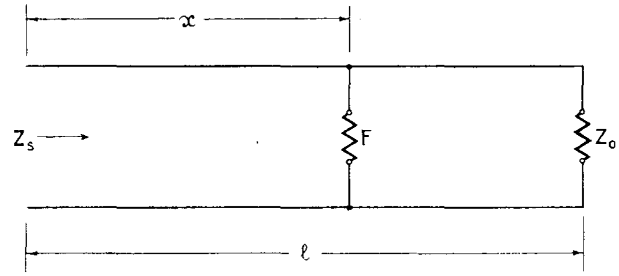



FIG. **63**.

sending end will show maximum and minimum points at regular intervals separated by a phase of $2\pi$ radians. Thus if two successive maximum points are found at $f_1$ and $f_2$, in an impedance-frequency curve taken on the faulty pair, the difference between the phase of the reflected wave at $f_1$ and that at $f_2$ will be $2\pi$. Hence:—

$$(2\alpha_2 x + \phi_2) - (2\alpha_1 x + \phi_1) = 2\pi$$

$$\therefore \quad x = \frac{\pi + \frac{1}{2}(\phi_1 - \phi_2)}{\alpha_2 - \alpha_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Generally $\phi_1$ and $\phi_2$ are small and nearly equal: and in a loaded cable $\alpha \fallingdotseq \omega\sqrt{CL}$. (See Section II., pp. III.). Equation (1) therefore becomes:

$$x = \frac{\pi}{\alpha_2 - \alpha_1} = \frac{\pi}{(\omega_2 - \omega_1)\sqrt{CL}}$$

$$\therefore \quad x = \frac{1}{2(f_2 - f_1)\sqrt{CL}}$$

$$\text{or} \quad x = \frac{K}{f} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where $f$ = the mean frequency interval between successive maximum points of an impedance-frequency curve taken at the terminals of the faulty circuit (See Fig. **64** for example of

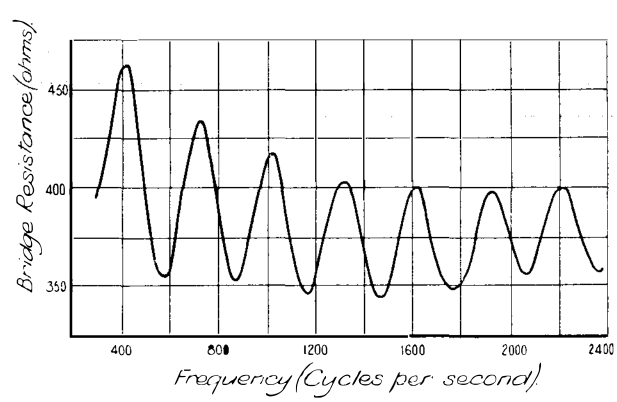



FIG. **64**.—EXAMPLE OF $Z_0/f$ CURVE OBTAINED FOR DETERMINATION OF K.

$Z_0 - f$ curve on a faulty circuit) and $K = \frac{1}{2\sqrt{CL}}$

*i.e.*, $K = \frac{1}{2}$ (velocity of propagation).

*The value of K* can be measured by introducing at a *known distance, l,* along a similar circuit (say the distant end) a known contact resistance. The $Z_0 - f$ curve is then measured over the usual audio-range and K is obtained by substituting in the equation

$$K = l \times f' \quad \text{(See equation 2.)}$$

the mean interval $f'$ of the experimental $Z_0 - f$ curve.

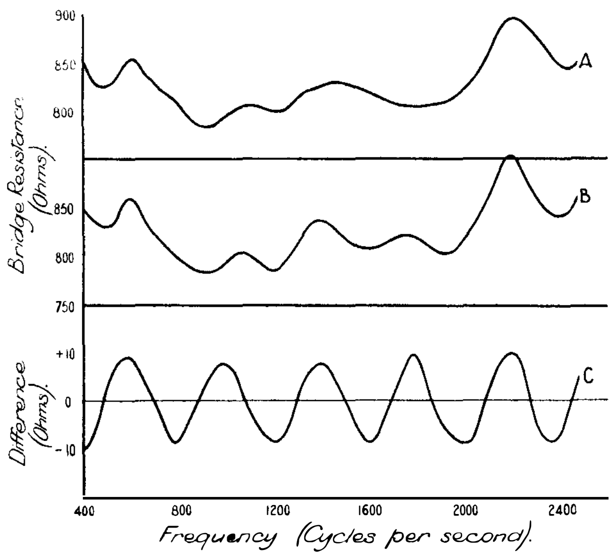



FIG. 65.

A. Normal impedance-frequency curve on a circuit of a coil-loaded cable.
B. Impedance curve on the same circuit with a contact fault.
C. *Difference* between ordinates of curves A and B.

This procedure is applicable to long loaded circuits having contact faults or high conductor resistance faults as well as for obscurer causes of impedance irregularity such as short-circuited turns in loading coils, etc.

*Difference Curves.* Sometimes the normal impedance frequency curve of a circuit is so irregular that when a fault occurs it is difficult to distinguish definitely the maximum points required. If the normal curve ordinates are *subtracted* from the corresponding faulty ordinates the difference curve so obtained will show distinctly the maximum points due to the fault. The equation $x = \frac{K}{f}$ is then used as before. See Fig. **65**.

NOTE.—*If the A.C. bridge shown in Fig.* **52** *is used for the localisation tests it is only necessary to plot bridge resistance readings and work with these bridge resistance readings instead of calculating the impedance at each frequency for fault localisation purposes.*

*Useful References for Section XVI.* :—


"A.C. Methods of Fault Localisation in Telephone Cables." By W. T. Palmer and M. E. Tufnail. P.O.E.E. Journal, Vol. 23, 1930, p. 43.

"Telephone Circuit Unbalances." By C. P. Ferris and R. G. McCurdy. Bell Reprint No. B-134-1, July, 1925.

"The Anglo-French (1930) Submarine Telephone Cable"—The Appendix. By F. E. A. Manning. P.O.E.E.J., Vol. 23, Part 1, April, 1930.

"Telephone Cable Testing"—Part II. By W. T. Palmer and E. H. Jolley. I.P.O.E.E. Printed Paper No. 138.


[*This concludes the Series of Outline Notes on Telephone Transmission Theory and the complete Series in Book form, with some additions, can be obtained from Journal Agents.*]

# Notes and Comments

## King's Birthday Honours

WE have learned with very great pleasure of the inclusion in the King's Birthday Honours List of Mr. A. B. Hart, Assistant Engineer-in-Chief, who has been awarded the O.B.E., and Mr. S. C. Bartholomew, Assistant Staff Engineer, who has been awarded the M.B.E. We offer our heartiest congratulations to Mr. Hart and Mr. Bartholomew on the conferment of these honours by His Majesty.

## G.P.O. 3,000 Type Relay

A description of the proposed Post Office standard relay was given in Volume 24, Part 3 of this Journal in October of last year. The " Knife-edge, Buffer block relay " described has been adopted in principle by the Department, and will be known as the " G.P.O. 3000 Type Relay."

The final details of design; namely dimensions, etc., are now being worked out in the light of maintenance, costs, and manufacturing requirements. A description of the final design will be published in due course.

## " Alta Frequenza."

*A Review of Radio-technology, Telephony and Applied Acoustics.*

We have received from the publishers a copy of the first number of a new quarterly magazine devoted to high frequency electricity and its practical application in Radio and Telephone Communication and Acoustics. In addition to many other items of interest this number contains important articles on " The detection of ultra short waves," " Electrical Methods for the measurement of pressures and displacements," " A study of an amplifier for very low frequencies or continuous current " and " Experimental Research on the propagation of an electromagnetic wave in an ionised magnetically active medium."

The fact that the new magazine is issued under the direction of G. Vallauri, assisted by a distinguished group of editors, is sufficient guarantee of its value and indispensability to all communication engineers and students. The new magazine is well printed and illustrated and summaries of the more important articles are given at the end in English, French and German. The first number contains 160 pages.

We wish the new magazine every success. It is obtainable from the office of " L'Elettrotecnica," Via San Paolo 10, Milan. The price per single copy is 12 lire and the annual subscription is 30 lire.

## Mr. H. H. Harrison, M.I.E.E.

We have learned with much pleasure that the Senate of Liverpool University is conferring the degree of M.Eng. on Mr. H. H. Harrison, M.I.E.E., on the 2nd July, 1932. The honour is being conferred in recognition of Mr. Harrison's contributions to the art of Machine Telegraphy.

Mr. Harrison is well known as the author of " Printing Telegraph Systems and Mechanisms " and he has contributed numerous papers to the Institution of Electrical Engineers and other learned bodies.

## Kempe Memorial Fund

Subscribers to the above fund will be interested to hear that the oak choir stalls installed in Christ Church, Brockham, were dedicated at the evening service held in the church on the 8th May, 1932. The inscription which has been cut in the oak back panel of the front seat, reads as follows :—

" These stalls are the gift of friends of Harry Robert Kempe, Member Institute of Civil Engineers, in affectionate appreciation of life long service for others. 1932."

A Dedicatory Inscription has also been hung in the Vestry of the church.

## Capt. John Bourdeaux, O.B.E.

The many friends and colleagues of Capt. John Bourdeaux will regret to learn of his death which occurred on the 10th March, 1932, at Paignton, Devon. Capt. Bourdeaux served on the cable-repair ships H.M.T.S. " Alert " and " Monarch," finally completing his service with the Department as Submarine Superintendent. He was awarded the O.B.E. for his services during the war in maintaining and repairing the numerous submarine cables under highly dangerous conditions. Capt. Bourdeaux retired in 1922 and settled down in Diss, Norfolk, but two years ago he removed to Paignton, Devon, where he has been laid to rest at the age of 68 years. A kindly soul, a pleasant acquaintance and a sincere friend, he will be missed by very many colleagues.

# District Notes

## London District

### GROWTH OF TELEPHONE SYSTEM.

| | |
|---|---|
| Direct Exchange Lines ... ... | 451,633 |
| Telephone Stations ... ... | 754,384 |

Increase during Quarter: 27,956 exchange lines and 40,164 stations.

### NEW P.B.X. AT SELFRIDGES.

The installation of a new Private Branch Exchange for Messrs. Selfridge & Company, Oxford Street, was completed on April 30th.

Mr. E. T. Campbell, M.P., on behalf of the Postmaster-General, in a short speech outlining the growth of the firm's telephone business, declared the Private Branch Exchange open.

The installation consists of 22 Sections C.B. No. 10A equipped for 150 Exchange Lines, 20 Private Wires and 680 Extensions.

A special feature is the Telephone Order Department where 40 operators, located at four tables with special multiple circuit arrangements, are continuously engaged in receiving telephone orders from customers.

Arrangements are also made whereby 120 extension points are switched over to a special recording clock and used as signalling points by the night watchman when patrolling the building.

### LAYING PIPES ACROSS THE RIVER THAMES.

In the issue of the Journal for January, 1932, under the heading "North Eastern District Notes" there is an interesting account of the laying of three 4″ steel pipes across the River Ouse at Boothferry. Particulars of a somewhat similar job which has been carried out in the London Engineering District recently will perhaps be of interest.

In connexion with the provision of additional plant in the Molesey Exchange area, it was decided to lay three 4″ pipes across the River Thames between Hampton Court and Hurst Park Race Course, thereby saving approximately 1.25 miles of cable route. The bed of the river consists partly of clay and partly of gravel. A 36 H.P. motor driving a centrifugal pump mounted on the deck of a concrete barge (Fig. 1) was employed for removing the gravel from the trench, while mounted in the hold of a steel barge a jib-crane with a grab, capable of picking up 15 cwt. at one grip, was used for removing the clay. Two other barges were employed for carrying away the excavated gravel and clay.

The services of a diver with a barge equipped with the necessary air pumps and diving gear, were hired from the Thames Conservancy to examine the trench, and to see that the work was properly carried out (Fig. 2).

The excavation of the trench was begun from the Surrey side of the river and ballast pumped ashore by the suction plant. The pump was continuously being choked up with empty fruit tins that had been thrown overboard by trippers, and also by fresh water mussels which are found in the river bed at this point. Clay was encountered about 38 feet from the Surrey shore at a depth of 6 feet and the grab was used in this section. Nearing the Middlesex shore the pump was again brought into use, continuing until the completion of the trench. This portion of the work was in progress during August, 1931, and the heavy rain storms experienced at that time had the effect of washing a good deal of silt into the trench and the suction plant had to be used to re-excavate the whole of the trench to the original depth.

The pipes were drawn into the trench by means of a steel hawser fixed to a crab winch stationed on the Middlesex shore. The end of the hawser on the Surrey side was connected to a specially constructed steel plough. The plough was fitted with three solid

Fig. 1.—Motor Pump Mounted on Barge.

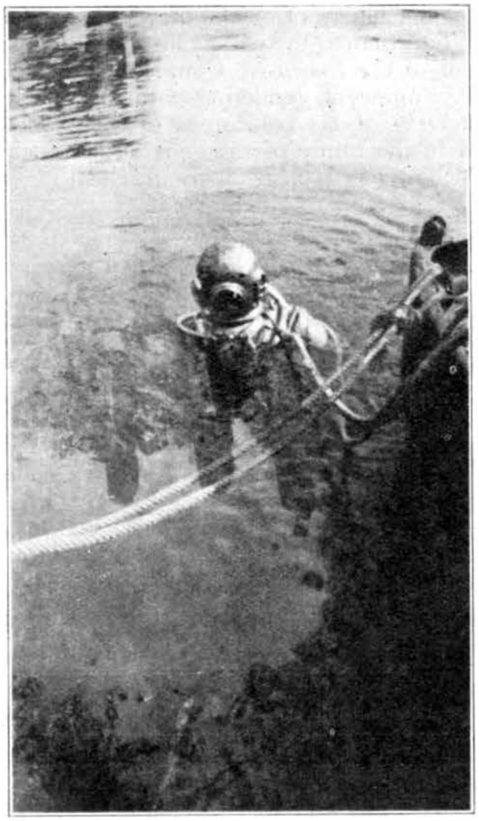


Fig. 2.—Diver Preparing to Examine Trench.

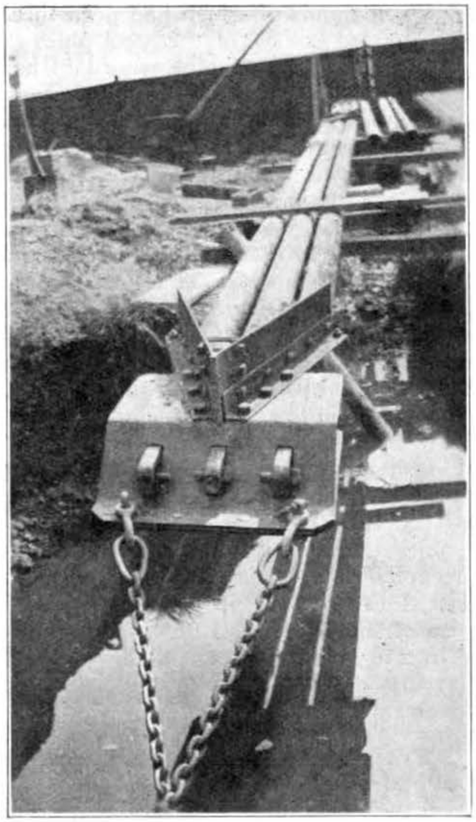


Fig. 4.—Plough with Pipes attached.

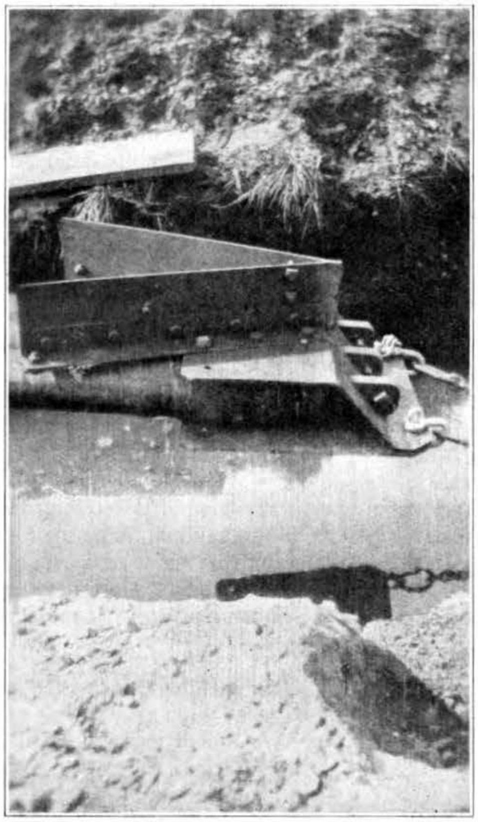


Fig. 3.—Nose of Steel Plough.

Fig. 5.—Pipe in Stirrup Support.

steel shafts, the ends of which had been threaded to take the screwed collars of the steel pipes (Figs. **3** and **4**). Three lengths of pipe were laid horizontal and screwed into the steel shafts. A three-way clip was placed midway on each group to keep the pipes in their horizontal position. As the pipes were drawn into the water the successive lengths were jointed as the drawing-in proceeded. The actual time taken to screw each group of three pipes and to cover the joints with wrapping and compound was approximately 35 minutes. This excellent time was due to the use of a stirrup (Fig. **5**) designed for the work by Commander Hucks, the Contractor who carried out the work. The pipe to be jointed was placed in the stirrup which was supported on small sheer legs adjusted to the right length. The stirrup is fitted with ball races and once a pipe was placed in position it was an extremely easy matter to turn the latter by means of a specially constructed stock.

From the time the first pipe was joined to the plough until they reached the Middlesex shore the work occupied approximately 36 hours. After they had been drawn across, it was found that further silting up of the trench had taken place. This was cleared by the suction plant and the trench filled in with clay to a depth of three feet in order to prevent any movement of the pipes.

## Eastern District

T. COBBE.

On May 31st, 1932, the Department lost a loyal servant and valued friend in Mr. T. Cobbe, Sectional Engineer, Southend-on-Sea. Had he lived until October this year Mr. Cobbe would have retired after nearly 40 years' service with the Engineering Department. Entering the Post Office service in 1890, Mr. Cobbe was transferred to Manchester in 1901 and was appointed to the Testing Branch of the Engineering Department as sub-engineer in London in 1905. Later he was transferred to the Cambridge Section and thence to the Technical Section of the Superintending Engineer's office, Cambridge, where he was responsible for the preparation of the first underground development schemes carried out in the Eastern District. He was appointed Sectional Engineer, Southend, in October, 1927.

Mr. Cobbe will be greatly missed at the meetings of the local centre of the I.P.O.E.E. When he rose to his feet a wave of anticipation rippled over the audience, for Mr. Cobbe had a gift of humour which made his sound commonsense observations all the more effective.

Mr. Cobbe will be remembered with affection for his kindly disposition and unfailing optimism which oiled the machinery of official life. It was characteristic of him that to the end of his career he occupied the chair of the Executive Committee of the Society of P.O. Engineers, rendering enthusiastic service in the interests of his colleagues of all grades. His interest in the future of the generation which would succeed him was typical of his unselfish devotion to any cause he undertook.

## South Wales District

RETIREMENTS.

Mr. A. E. Land, Assistant Engineer in the Technical Section, and Mr. W. O. Balcombe, Higher Clerical Officer in the District Office, retired in the beginning of 1932 and in both cases testimonials were presented to the retiring officers by their colleagues. Before these notes appear in print, Mr. C. H. McMurray and Mr. T. Devereux, Assistant Engineers in the Cardiff Section, will also have retired from the service.

## South Western District

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

Albert Gray, Assistant Superintending Engineer, South Western District, who joined the Department in December, 1885, retired on the 31st May, 1932, after 44 years of established service.

A large and representative gathering assembled at a Smoking Concert held at St. Stephen's Restaurant, Bristol, on the 21st May to take official leave and wish Mr. Gray a long and happy retirement.

The evening opened with musical items and a presentation of a Wireless Set was made by the Chairman, Mr. P. Thornton Wood, on behalf of the Staff of the South Western District and colleagues not now in the District, but who wished to be associated. Mr. Gray is well known in many parts of the Country, having many friends at York, where he served as Sectional Engineer for a number of years. High tribute was paid by many present who have had the privilege of knowing him and enjoying his friendship.

Mr. Gray was one of those officials with a hard exterior and a kind heart; was satisfied with nothing but the best from all in the Department's service, but was ever ready to assist with the work and would help anyone along a difficult path, provided the cause was just.

Always most popular with his colleagues and esteemed by the Staff wherever he has been stationed, his loss to the District will be very real. He enters on his retirement with the heartiest of good wishes from all for his future happiness and prosperity.

S.G.G.

# The Institution of Post Office Electrical Engineers

## Annual Meeting, 10th May, 1932

The President of the Institution, Col. Sir T. F. Purves, Engineer-in-Chief, occupied the chair at the twenty-sixth annual meeting held in the Institution of Electrical Engineers, London, on the 10th May, 1932. In opening the proceedings, the President made happy reference to the good work done by the Institution during the past twenty-six years and congratulated the Council on its efforts during the past year.

The Annual Report of the Council was read by the Secretary, Mr. J. Innes, and the Financial Statement for the year 1931-32 was presented by the Hon. Treasurer, Mr. B. O. Anson. The adoption of the Annual Report and Statement of Accounts was moved by Mr. S. C. Bartholomew and seconded by Col. A. S. Angwin. A hearty vote of thanks to retiring Members of Council was moved by Mr. J. Prescott, seconded by Capt. H. Hill and replied to by Mr. A. C. Smith.

PRESENTATION BY THE PRESIDENT OF MEDALS FOR SESSION 1930-31.

*Senior Silver Medals* to Messrs. H. Faulkner, B.Sc. (Hons.), A.M.I.E.E., and G. T. Evans, for their joint paper "Developments in Telegraph Technique as applied to Radio Circuits."

*Senior Bronze Medal* to Capt. N. F. Cave-Browne-Cave, B.Sc., M.I.E.E., for his paper "Sound and Hearing."

The President announced that Mr. J. Hedley and Mr. S. C. Bartholomew would be Chairman and Vice-Chairman respectively of the London Centre for the session 1932-33.

PRINTED PAPERS.

The following is a list of the printed papers issued to the membership during the Session :—

No. 134. "Sound and Hearing," N. F. Cave-Browne-Cave, B.Sc., M.I.E.E.

No. 135. "The Electrical Control of Time Services in the British Post Office," A. O. Gibbon, M.I.E.E.

No. 136. "Developments in Telegraph Technique as applied to Radio Circuits," H. Faulkner, B.Sc. (Hons.), M.I.E.E., and G. T. Evans.

The meeting concluded after the reading and discussion of a paper on "Standardization—An unattainable ideal or an essential to Progress," by Mr. G. F. O'dell, B.Sc., A.K.C., M.I.E.E.

# Junior Section Notes

| Reg. No. | Name of Centre. | Number of Members. | Chairman. | Vice-Chairman. | Hon. Secretary. | Hon. Treasurer. |
|---|---|---|---|---|---|---|
| 1. | Edinburgh ... | 40 | J. J. McKichan. | P. S. S. Biggers. | M. Craig. | J. M. Edmonstone. |
| 2. | Dundee ... ... | 25 | H. G. Tissington. | J. Mathewson. | J. Donaldson. | W. V. McWalter. |
| 3. | Blackburn ... | 15 | W. R. Farnworth. | J. Hawarth. | T. Gibson. | H. Angles. |
| 4. | Bristol ... ... | 55 | S. G. Gay. | J. S. Hazell. | A. H. Goss. | A. S. Biggs. |
| 5. | Preston ... ... | 30 | J. W. Gould. | J. A. Hull. | L. Hall. | W. S. Whitehead. |
| 6. | Stoke-on-Trent ... | 20 | J. S. Tebbitts. | J. T. Yates. | F. W. Pickford. | F. A. Dale. |
| 7. | Rochdale ... | 23 | C. W. Jones. | F. Howarth. | G. V. Stansfield. | H. Rowson. |
| 8. | Newcastle ... | 55 | E. J. Jarrett. | J. B. Croney. | E. U. Peel. | F. Hill. |
| 9. | Southport ... | 18 | W. Siddall. | E. H. Denton. | W. C. Watson. | G. Thompson. |
| 10. | Sunderland ... | 32 | J. A. Jack. | A. L. Donaldson. | A. F. Stafford. | G. H. Smith. |
| 11. | Bolton ... ... | 28 | C. L. Cleary. | T. Rogerson. | J. A. Ditchfield. | J. A. Ditchfield. |
| 12. | Taunton ... ... | 22 | S. W. Lowther. | H. Strachan. | G. Stoneman. | S. J. Potter. |
| 13. | Middlesbrough ... | 30 | J. I. Smith. | J. F. Chapman. | J. H. Mann. | J. N. Parker. |
| 14. | Barnstaple ... | 30 | R. C. Brown. | J. Tout. | O. A. K. Ferguson. | T. W. Gully. |
| 15. | London ... ... | 500 | E. P. Neate. | A. H. White. | C. E. C. Skuse. | A. Webster. |
| 16. | Research ... | 85 | K. L. Beak. | L. W. Barratt. | F. D. Redington. | T. A. J. Kerwin. |
| 17. | Manchester ... | 93 | T. Lester. | J. Frost. | W. H. Fox. | S. V. Dixon. |
| 18. | Gloucester ... | 41 | W. Day. | F. E. Huckfield. | E. Blewitt. | G. A. Probert. |
| 19. | Belfast ... ... | 43 | A. H. Jacquest. | W. Brooks. | R. Patterson. | J. R. Connor. |
| 20. | Colwyn Bay ... | 17 | J. H. Watkins. | R. V. C. Williams. | G. Glover. | A. S. Douglas. |
| 21. | Birmingham (Engr.) | 70 | C. N. Cartwright. | F. E. Pritchard. | W. Rowlands. | L. J. A. Reeve. |
| 22. | Shrewsbury ... | 18 | R. W. S. Bell. | T. E. Hughes. | R. W. Lloyd. | R. W. Lloyd. |
| 23. | Birmingham (Test) | 30 | W. H. Albry. | G. A. Blower. | L. Guy. | F. L. Larner. |

## Inauguration

The inauguration of the Junior Section is proceeding rapidly throughout the country. Details are given above of the Centres which have been registered to date together with the names of the officers of the Centres. The number of members given, is the number at registration and there have been considerable increases in certain Centres since their inauguration. There is every indication that the junior grades are welcoming the opportunity given to them through the Junior Section, of sharing their knowledge and experience with their fellow members. Such free interchange of ideas is of inestimable benefit to everyone, and will assuredly result in increased efficiency in every direction.

## London Centre

The inaugural meeting of the Centre was held at Denman Street on the 23rd May, 1932. The Chair was taken by Mr. W. C. Burbridge, who welcomed Mr. Gomersall to the meeting and invited him to address the gathering of nearly 200 members.

Mr. Gomersall expressed his very great pleasure at being given such an opportunity. He stated briefly how in 1931 it was thought that it would be beneficial both to the staff and to the Department to form a Junior Section and he was very happy to see that the idea had materialised. The Junior Section would be a self-governed and self-supporting body, but it would be closely linked with the parent Institution through its President. He congratulated the Junior Section in having a very popular and capable President in Mr. C. W. Brown. In wishing the Centre every success, Mr. Gomersall hoped that this auspicious occasion would be a milestone in the history of efficiency for the staff and the Department.

After giving a brief account of the inauguration of the Junior Section the Chairman stated that the enrolments for the London Centre now totalled 502 members including the Circuit Laboratory staff of 52 who desired to join forces with the London District. He suggested that, until the Centre had surmounted the difficulties which they were bound to meet with in the first year, the committee should consist of one representative from each London Section (Internal and External to count as one), one from the Electric Light and Power staff and one from the Circuit Laboratory. This would give a committee of 10 in addition to the usual Officers of the Committee.

The President, Mr. C. W. Brown, gave the Inaugural Address, outlining the objects and aims of the Junior Section, in promoting the advance of communication engineering among the men, the free interchange and expression of ideas, and the advancement of their knowledge of the intricate work carried out by the Department. The President made reference to the very valuable facility given by the parent Institution in throwing its library open to the members of the Junior Section for the nominal fee of sixpence per member per annum. As they would realise, this fee did not in any way compensate for the value of the facility. The parent Institution had also announced that prizes of £2 2s. 0d. each would be offered annually for the five best papers written and read by members of the Junior Section throughout the country. In conclusion, the President made reference to the assistance given by Mr. Gomersall and his staff in forming the London Centre which he felt sure would maintain the standard set by the parent Institution.

The meeting then proceeded to elect the Centre Officers and members of Committee.

## Gloucester Centre

It has been decided to establish a Local Centre of the Junior Section at Gloucester and a General Meeting of the staff was held at Gloucester on the evening of 2nd June, 1932, at which the Centre was inaugurated. Up to date 41 members of the staff have joined.

After some introductory remarks by Mr. Terras, as Chairman of the South Wales Centre of the parent Institution, in the course of which he congratulated the Gloucester Staff on the progressive spirit shown by the formation of a Junior Centre and stressed the great importance of acquiring the widest possible technical knowledge, Mr. F. J. B. Clarke, Secretary of the South Wales Centre, outlined the scheme in detail and answered various questions.

Mr. Day also addressed the meeting and emphasized the advantages to the staff of making the fullest use of the facilities which the Junior Section would provide. He also appealed to all the members to maintain a lively personal interest in the scheme in order that the greatest possible measure of success might be assured.

## Manchester Centre

The inaugural meeting was held on the 6th April, 1932. Mr. Stretch explained the objects of the Junior Centre and answered various questions regarding the Constitution. Very great interest was displayed by the audience and the meeting closed after the election of the officers and committee.

The first General Meeting was held on the 25th May, when an enthusiastic gathering of members listened with keen interest to the presentation of the following papers :—

"The Manchester Plug Ended 'B' Suite"—Mr. J. Lawton.

"Routine Testing in Auto. Exchanges"—Mr. C. Wood.

The Centre was honoured by the attendance of the Superintending Engineer, T. E. Herbert, Esq., M.I.E.E., and the Assistant Superintending Engineer, Mr. T. T. Partridge, M.I.E.E. The Whitley Committee was represented officially by the Vice-Chairman of the Staff Side and several members of Committee. Several members of the parent Institution also attended.

Mr. Herbert in opening the meeting said that the occasion was an historic one in that it marked the commencement of the activities of the Manchester Junior Section. He observed that the sphere of electrical communications could be considered of more importance than any other branch of electrical science, and to be successfully engaged therein called for a far wider technical knowledge than is necessary in any other branch. He referred to the opportunities that the meetings of the Section would afford to members for a useful interchange of ideas and the solution of problems with which they were frequently confronted in the performance of their duties. He desired to see the Section prosper in the management of its own affairs.

The reading of the papers evoked much praise and the ensuing discussion which was contributed to by several members, proved most enlightening. Not the least praiseworthy feature was the manner in which the authors replied to the many questions put to them.

A vote of thanks accorded the authors was carried with acclamation.

The Centre membership is now approximately 100 and the success of this meeting augurs well for its future welfare.

W.H.F.

## North Wales District

Great interest and activity prevail as the result of the inauguration of Centres of the Junior I.P.O.E.E. At the moment five new Centres are in being within the District at Stoke-on-Trent, Colwyn Bay, Birmingham (Engineers), Shrewsbury and Birmingham (E.-in-C's Testing Branch, Fordrough Lane). The formation of two other Centres is imminent, at Macclesfield and Wolverhampton. To have attained such results in a comparatively short time is a distinction of which the parent Centre feels justifiably proud. Whilst the number of members in the individual Centres is encouraging (in some cases surprising) the genuine enthusiasm with which the proposal has been met has been a noteworthy feature of the inaugural meetings. Every encouragement is being offered to the Juniors by the members of the Institution locally, not merely verbally, but in tangible form, and this, coupled with the undoubted talent that exists among the members themselves and the organizing ability of the local officers leaves no doubt as to the consummation of every ideal with which the project has been launched by the Council.

## Edinburgh Centre

The first meeting was held on the 4th April, 1932, when two papers entitled "Motor Transport in relation to Telephone Engineering" and "The Properties of the Telephone Circuit" were read by Mr. A. P. Robertson and Mr. M. Craig, respectively. Numerous questions were asked and animated discussions took place.

The Annual General Meeting was held in the Y.M.C.A. Hall, South St. Andrew Street, on the 2nd May. Mr. J. J. McKichan presided. The reports of the Secretary and Treasurer were unanimously adopted.

After the business had been concluded, a paper entitled "Wireless Interference" was read by Mr. T. Nesbit. The paper proved of great interest and evoked a good discussion. Mr. Nesbit was complimented on his delivery of the paper and treatment of the questions put to him.

Rapid progress has been made since the inauguration of the Centre and the members are looking forward to the coming session with every confidence. Several interesting papers have been promised, and visits to places of interest are being arranged. A syllabus is being prepared for distribution to the members.

M.C.

## North Western District

Considerable enthusiasm is being shown in this District for the Junior Section and, so far as can be foreseen, a successful first session is assured.

Preliminary meetings held at Blackburn, Bolton, Preston, Rochdale and Southport were well attended and after an explanation of the aims and objects of the Junior Section had been given by the Local Secretary (Mr. H. Howarth) resolutions were passed unanimously that Local Centres be set up.

The programme arrangements have not yet been completed, but the following papers have been promised :—

*Blackburn* :

"Secondary Cells." Mr. J. Haworth.
"P.A.B.X. (Standard)." Mr. H. Angles.
"P.A.B.X. (Relay)." Mr. A. W. Green.
"Tungar Rectifiers." Mr. O. N. Barlow.
"Wayleaves and Surveys for A.N. work." Mr. C. H. Brownbridge.

*Bolton and Preston* : Meetings are being arranged.

*Rochdale* :

Oct., 1932. "Elementary A.C." Mr. H. Cheetham.
Nov., 1932. "Cable Faults." Mr. R. Dixon.
Dec., 1932. "Introduction to Automatic Telephony." Mr. C. W. Jones.

*Southport* :

"Miscellaneous items of interest in Telephony." Mr. G. Thompson.
"The Working of the Teleprinter." Mr. W. Clayton.
"The Rural Automatic Exchange." Mr. E. H. Denton.
"Underground Maintenance and Construction." Mr. W. H. Ward.

**H.H.**

# Book Reviews

"Alternating Current Bridge Methods." By B. Hague, D.Sc. (Lond.), Ph.D. (Glas.), D.I.C., A.C.G.I., M.I.E.E., M.A.I.E.E., F.P.S.L. Third Edition. Sir Isaac Pitman and Sons, Ltd. Price 15/- net.

The second edition of this handbook, in which the author thoroughly revised and enlarged the original work, appeared as recently as 1930. The publication of the third edition, after a comparatively short interval, indicates the increasing importance of bridge methods applied to the rapidly widening field of alternating current measurements.

The present volume is a reprint of the text of the 1930 edition, with the addition of some thirty pages of Supplementary Notes, in the form of an Appendix.

The new matter includes notes on the design of self inductance standards, fuller discussion of impurities in Mutual Inductances, and descriptions of standard condensers for high voltage testing. Further treatment of other subjects dealt with in the text, and abstracts of the considerable amount of material published since 1930 dealing with A.C. Bridge measurements, are also given in the new Appendix.

The extremely useful feature of including full references is continued, the student is thus kept abreast of up-to-date developments in the technique of bridge measurements at audio-frequencies.

J.E.P.

"Experimental Electrical Engineering." By E. T. A. Rapson, A.C.G.I., D.I.C., Wh.Ex., A.M.I.E.E. Sir Isaac Pitman and Sons, Ltd. Pp. 166. Price 3/6.

This book is designed to cover the Laboratory experimental work necessary for students taking the National Certificates in Electrical Engineering and also the B.Sc., and A.M.I.E.E. Examinations. Explanation of theoretical principles which can be obtained from text-books is not given, but the deductions which can be drawn from the experiments are indicated.

Ninety-seven experiments are given, ranging through the measurement of resistances, calibration of instruments, determination of the characteristic curves of generators, motors, transformers, mercury arc rectifiers and valves, polar diagrams and efficiency of lamps, etc.

The book is very well illustrated with circuit and vector diagrams and can be confidently recommended to all in charge of Laboratory work, as well as to students.

J.R.

# Staff Changes.

## POST OFFICE ENGINEERING DEPARTMENT.

### Promotions.

| Name. | From | To | Date. |
|---|---|---|---|
| Elston, J. S. ... ... ... ... | Executive Engineer, Lines Section, E.-in-C.O. | Assistant Staff Engineer, Lines Section, E.-in-C.O. | 3-5-32 |
| Fletcher, Capt. J. E. ... ... | Executive Engineer, Leeds Extl. Section, N.E. District. | Assistant Suptg. Engineer, Northern District. | 1-9-32 |
| O'dell, G. F. ... ... ... ... | Executive Engineer, Telephone Section, E.-in-C.O. | Assistant Staff Engineer, Telephone Section, E.-in-C.O. | 1-6-32 |
| McKichan, J. J., O.B.E. ... ... | Executive Engineer, Telephone Section, E.-in-C.O. | Assistant Suptg. Engineer, Scot. East District. | 3-5-32 |
| Brown, C. W. ... ... ... | Acting Executive Engineer, Research Section, E.-in-C.O. | Executive Engineer, Research Section, E.-in-C.O. | 3-5-32 |
| Beattie, W. ... ... ... ... | Assistant Engineer, Technical Section, N.W. District. | Executive Engineer, Stoke Section, N. Wales District. | 1-9-32 |
| Morice, L. F. ... ... ... | Assistant Engineer, Equipment Section, E.-in-C.O. | Executive Engineer, Telephone Section, E.-in-C.O. | 3-5-32 |
| Cleaver, J. ... ... ... ... | Assistant Engineer, Manchester W. Section, S. Lancs District. | Executive Engineer, Plymouth Section, S.W. District. | 22-5-32 |
| Radley, W. G. ... ... ... | Assistant Engineer, Research Section, E.-in-C.O. | Executive Engineer, Research Section, E.-in-C.O. | 3-5-32 |
| Palmer, W. T. ... ... | Assistant Engineer, Research Section, E.-in-C.O. | Acting Executive Engineer, Lines Section, E.-in-C.O. | 3-5-32 |
| | Acting Executive Engineer, Lines Section, E.-in-C.O. | Executive Engineer, Lines Section, E.-in-C.O. | 9-6-32 |
| Hudson, W. E. ... ... ... | Assistant Engineer, Telephone Section, E.-in-C.O. | Acting Executive Engineer, Telephone Section, E.-in-C.O. | 9-6-32 |
| Gawthorne, G. J. ... ... ... | Chief Inspector, London District. | Assistant Engineer, London District. | 29-4-32 |
| Hopper, E. ... ... ... ... | Chief Inspector, N.W. District. | Assistant Engineer, N. West District. | 29-4-32 |
| Williams, E. H. ... ... ... | Chief Inspector, N. Wales District. | Assistant Engineer, N. Wales District. | 29-4-32 |
| Longmore, F. W. ... ... ... | Chief Inspector, Telephone Section, E.-in-C.O. | Assistant Engineer, Telephone Section, E.-in-C.O. | 29-4-32 |
| Sard, P. J. ... ... ... ... | Chief Inspector, London District. | Assistant Engineer, London District. | 29-4-32 |
| Heathcote, A. ... ... ... | Inspector, S. Lancs. District. | Chief Inspector, S. Lancs. District. | 14-8-31 |
| Wilson, W. ... ... ... ... | Inspector, Testing Branch. | Chief Inspector, Testing Branch. | 19-2-31 |
| Ind, G. E. ... ... ... ... | Inspector, Testing Branch. | Chief Inspector, Testing Branch. | 31-1-32 |
| Jarvis, J. W. ... ... ... | Inspector, Scot. East District. | Chief Inspector, Scot. East District. | 5-3-32 |
| Tugwell, P. C. ... ... ... | Inspector, S. East District. | Chief Inspector, S. East District. | 6-2-32 |
| Tombs, T. R. ... ... .. | Inspector, S. Wales District. | Chief Inspector, S. Wales District. | 22-11-31 |
| McLean, H. ... ... ... ... | Inspector, N. East District. | Chief Inspector, N. East District. | 17-4-32 |
| Wall, A. A. ... ... ... ... | Inspector, N. Mid. District. | Chief Inspector, London District. | 17-4-32 |
| Gillman, C. E. ... ... ... | Inspector, London District. | Chief Inspector, London District. | 7-4-32 |
| Stow, G. ... ... ... ... | Inspector, London District. | Chief Inspector, London District. | 3-4-32 |
| Gilbert, J. ... ... ... ... | Inspector, London District. | Chief Inspector, London District. | 7-4-32 |
| Cockshott, W. L. ... ... | Inspector, London District. | Chief Inspector, London District. | 3-4-32 |
| Budd, W. C. ... ... ... ... | Inspector, London District. | Chief Inspector, London District. | 3-4-32 |
| Richardson, A. E. ... ... ... | Inspector (W'less O'seer), E.-in-C.O. | Chief Inspector, E.-in-C.O. | 21-2-32 |
| Gambier, J. E. ... ... ... | Inspector, E.-in.C.O. | Chief Inspector, E.-in-C.O. | 1-4-32 |
| Curnin, H. R. ... ... ... | Inspector, E.-in.C.O. | Chief Inspector, E.-in-C.O. | 2-4-32 |
| Biddlecombe, A. W. ... ... ... | Inspector, E.-in.C.O. | Chief Inspector, E.-in-C.O. | 2-4-32 |
| Douglas, J. H. ... ... ... | Inspector, E.-in.C.O. | Chief Inspector, E.-in-C.O. | 2-4-32 |
| Paul, E. M. ... ... ... ... | Inspector, E.-in.C.O. | Chief Inspector, E.-in-C.O. | 1-4-32 |
| Smith, S. J. ... ... ... ... | Inspector, E.-in.C.O. | Chief Inspector, E.-in-C.O. | 1-4-32 |
| Wilson, G. ... ... ... ... | Inspector, E.-in.C.O. | Chief Inspector, E.-in-C.O. | 2-4-32 |
| Akister, F. ... ... ... ... | Inspector, S. Lancs. District. | Chief Inspector, S. Lancs. District. | To be fixed later. |
| Tansley, R. ... ... ... ... | Inspector, S. Lancs. District. | Chief Inspector, S. Lancs. District. | |
| Hepplestone, H. ... ... ... | Inspector, S. Lancs. District. | Chief Inspector, S. Lancs. District. | |
| Davies, B. ... ... ... ... | Inspector, N. Wales District. | Chief Inspector, N. Wales District. | |
| Sursham, J. W. ... ... ... | Inspector, East District. | Chief Inspector, East District. | |
| Baldey, C. ... ... ... ... | Inspector, S. East District. | Chief Inspector, N. Wales District. | |
| Ashton, H. ... ... ... ... | Inspector, N. West District. | Chief Inspector, North West District. | |
| Huntington, F. ... ... ... | Inspector, N. West District. | Chief Inspector, North West District. | |
| Collins, R. P. ... ... ... | Inspector, N. Wales District. | Chief Inspector, N. Wales District. | |
| Bentley, F. E. ... ... ... | Inspector, S. Lancs. District. | Chief Inspector, E.-in-C.O. | |
| Storey, F. C. ... ... ... ... | Inspector, S. Mid. District. | Chief Inspector, E.-in-C.O. | |
| Coote, F. ... ... ... ... | Inspector, N. Mid. District. | Chief Inspector, Scot. East District. | |
| Wright, C. H. ... ... ... | Inspector, London District. | Chief Inspector, E.-in-C.O. | |
| Clark, H. V. ... ... ... ... | Inspector, E.-in-C.O. | Chief Inspector, E.-in-C.O. | |
| Phipps, E. K. ... ... ... | Skilled Workmen, Cl. I., N. Mid. District. | Inspector, N. Mid. District. | |

PROMOTIONS (Contd.).

| Name. | From | To | Date. |
|---|---|---|---|
| Lane, V. E. ... ... ... ... | Skilled Workmen, Cl. I., N. Mid. District. | Inspector, N. Mid. District. | To be fixe later. |
| Jalland, F. R. ... ... ... | Skilled Workman, Cl. I., Testing Branch. | Inspector, Testing Branch. | 21-6-3 |
| Yates, G. A. ... ... ... ... | Skilled Workman, Cl. II., N. Mid. District. | Inspector, N. Mid. District. | To be fix later. |
| Shaddick, W. G. ... ... ... | Skilled Workman, Cl. I., E.-in-C.O. | Inspector, E.-in-C.O. | 1-1-32 |
| Wilson, L. P. ... ... ... | ,, ,, | ,, ,, | 20-5-31 |
| Roberts, E. ... ... ... ... | ,, ,, | ,, ,, | 8-11-31 |
| Thorn, F. W. J. ... ... ... | ,, ,, | ,, ,, | 9-1-32 |
| Broadhurst, S. W. ... ... ... | ,, ,, | ,, ,, | 21-12-30 |
| Grant, C. G. ... ... ... ... | ,, ,, | ,, ,, | 3-12-31 |
| Barton, A. L. ... ... ... | ,, ,, | ,, ,, | 1-6-30 |
| Barton, B. A. ... ... ... | ,, ,, | ,, ,, | 1-6-30 |
| Dye, F. W. G. ... ... ... | ,, ,, | ,, ,, | 5-3-32 |
| Blois, W. H. ... ... ... ... | Unest. Draughtsman, E.-in-C.O. | ,, ,, | To be fix later. |
| Hartshorn, H. ... ... ... | Skilled Workman, Cl. I., N. Mid. District. | Inspector, N. Mid. District. | 19-4-32 |
| Bridgman, B. B. ... ... ... | Skilled Workman, Cl. I., S. Wales District. | Inspector, S. Wales District. | |
| Coton, W. ... ... ... ... | Skilled Workman, Cl. I., N. Wales District. | Inspector, N. Wales District. | 14-2-32 |
| Saville, E. W. ... ... ... | Skilled Workman, Cl. I., N. East District. | Inspector, N. East District. | 1-2-32 |
| Thatcher, A. C. ... ... ... | Skilled Workman, Cl. I., S. Mid. District. | Inspector, S. Mid. District. | To be fixe later. |
| Weeks, O. J. ... ... ... ... | Skilled Workman, Cl. I., S. Mid. District. | Inspector, S. Mid. District. | |
| Frankland, A. M. H. P. ... ... | Skilled Workman, Cl. I., S. Mid. District. | Inspector, S. Mid. District. | |
| Ingram, C. S. ... ... ... | Skilled Workman, Cl. I., Radio Stn. | Inspector, Radio Station. | 6-5-32 |
| Dawson, R. E. ... ... ... | Skilled Workman, Cl. I., S. Lancs. District. | Inspector, S. Lancs. District. | 20-9-31 |
| Parker, J. ... ... ... ... | Skilled Workman, Cl. I., N.E. District. | Inspector, N.E. District. | 6-11-31 |
| Earnshaw, E. ... ... ... | Skilled Workman, Cl. I., N.E. District. | Inspector, N.E. District. | 27-9-31 |
| Hudson, H. ... ... ... ... | Skilled Workman, Cl. I., N.E. District. | Inspector, N.E. District. | 17-1-32 |
| Iles, S. B. ... ... ... ... | Skilled Workman, Cl. I., S. Lancs. District. | Inspector, N.E. District. | 1-1-32 |
| Turtle, G. R. ... ... ... | Skilled Workman, Cl. II., N. Wales District. | Inspector, E.-in-C.O. | 1-6-32 |
| Thompson, A. J. ... ... ... | Third Engineer, H.M.T.S. "Monarch." | Second Engineer, H.M.T.S. "Alert." | To be fixed later. |
| Sloss, J. ... ... ... ... | Fourth Engineer, H.M.T.S. "Alert." | Third Engineer, H.M.T.S. "Monarch." | |
| Parker, C. ... ... ... ... | Fifth Engineer, H.M.T.S. "Monarch." | Fourth Engineer, H.M.T.S. "Alert. | |

RESIGNATION.

| Name. | Rank. | District. | Date. |
|---|---|---|---|
| Cottle, Major P. J., O.B.E., M.C. | Executive Engineer. | S. West. | 30-4-32 |

TRANSFERS.

| Name. | Rank. | From | To | Date. |
|---|---|---|---|---|
| Thompson, H. S. ... ... ... | Asst. Staff Engineer. | E.-in-C.O. | S. West (Asst. Suptg. Engineer. | 1-6-32 |
| Eason, A. B. ... ... ... ... | Executive Engineer. | E.-in-C.O. | Scot. West. | 22-5-32 |
| Somerville, H. B. ... ... ... | Asst. Engineer. | E.-in-C.O. | S. East. | 26-4-32 |
| Hudson, A. ... ... ... ... | Asst. Engineer. | E.-in-C.O. | N. Wales. | 22-5-32 |
| Pocock, D. G. ... ... ... | Inspector. | Rugby Radio. | E.-in-C.O. | 10-4-32 |

APPOINTMENTS.

| Name. | From | To | Date. |
|---|---|---|---|
| Mitchell, C. W. A. | Limited Competition. | Probationary Inspectors Training School, E.-in-C.O. | 1-5-32 |
| Gardner, F. W. | | | |
| Smith, G. E. | | | |
| Greenwood, G. C. | | | |
| Pitts, H. E. | | | |
| Hoare, E. | | | |
| Wilson, C. M. | | | |
| Beaumont, E. B. M. | | | |
| Todd, D. W. | | | |
| Woods, A. E. | | | |
| Mayo, S. J. | | | |
| Atkin, E. W. | | | |
| Trimmer, W. J. | | | |
| Peddle, H. W. | | | |
| Palmer, R. N. | | | |
| Thompson, A. J. | | | |
| Hart, J. A. | | | |
| Crooks, R. H. | | | |
| Burton, J. P. | | | |
| Robertson, C. D. S. G. | | | |
| Robins, A. G. | | | |
| Venus, W. A. H. | | | |
| Lawson, A. J. | | | |
| Spooner, J. W. | | | |
| Parker, K. L. | | | |
| Arnold, A. F. | | | |
| Herbert, L. J. | | | |
| Roy, D. W. | | | |
| Bealby, G. | | | |
| Johnson, L. P. | | | |
| Moody, W. R. N. | | | |
| Adam, S. A. F. | Open Competition. | Probationary Inspectors Training School, E.-in-C.O. | 2-5-32 |
| Stanbury, H. C. O. | | | 2-5-32 |
| Colledge, T. A. P. | | | 1-6-32 |
| Crossley, J. | | | 4-5-32 |
| Shepherd, J. | | | 19-5-32 |
| Taylor, F. J. D. | | | 2-5-32 |
| Bunten, B. | | | 2-5-32 |
| Coombes, R. H. | | | 2-5-32 |
| Tucker, D. G. | | | 2-5-32 |
| Liddall, H. | | | 2-5-32 |
| Drinkwater, M. | | | 2-5-32 |

RETIREMENTS.

| Name. | Rank. | District. | Date. |
|---|---|---|---|
| Statters, J. E. | Assistant Staff Engineer. | E.-in-C.O. | 12-4-32 |
| Gray, A. | Assistant Superintending Engineer. | S. West. | 31-5-32 |
| Newton, E. I. T. | ,, ,, | E.-in-C.O. | 8-6-32 |
| Macleod, J. D. | Assistant Engineer. | Scot. West. | 31-5-32 |
| T. Devereux | ,, ,, | S. Wales. | 30-6-32 |
| E. H. Baxter | ,, ,, | E.-in-C.O. | 9-6-32 |
| Armstrong, E. | ,, ,, | S. East. | 29-2-32 |
| McMurray, C. H. | ,, ,, | S. Wales. | 30-4-32 |
| Rickards, J. J. | Chief Inspector. | N. West. | 31-3-32 |
| Smith, A. | ,, ,, | S. Wales. | 1-3-32 |
| Broadhurst, R. A. | ,, ,, | N. East. | 29-5-32 |
| Guy, W. H. | ,, ,, | S. Lancs. | 14-2-32 |
| Tester, H. F. | Inspector. | London. | 31-3-32 |
| Angus, A. W. | ,, | London. | 30-4-32 |
| Kenway, W. W. | ,, | London. | 30-4-32 |
| Miles, R. A. | ,, | London. | 30-4-32 |
| Sharplin, W. G. | ,, | Testing Branch. | 30-4-32 |
| Pipe, S. E. | ,, | Northern. | 19-3-32 |
| Owen, A. | ,, | S. East. | 29-2-32 |
| Greenless, J. E. | ,, | N. Mid. | 26-5-32 |
| Stubbs, E. | ,, | S. Wales. | 25-3-32 |
| Inwood, W. G. | ,, | S. Mid. | 13-3-32 |
| Mann, W. H. | ,, | London. | 3-3-32 |

DEATHS.

| Name. | Rank. | District. | Date. |
|---|---|---|---|
| Cunningham, R. ... ... ... | Executive Engineer. | Scot. West. | 19-4-32 |
| Cobbe, T. ... ... ... ... | ,, ,, | Eastern. | 31-5-32 |
| Gray, W. H. D. ... ... ... | Chief Inspector. | N. Wales. | 29-4-32 |
| Bailey, W. ... ... ... ... | ,, ,, | N. Wales. | 27-3-32 |

CLERICAL GRADES.

PROMOTIONS.

| Name. | At Present. | | To Be | | Date. |
|---|---|---|---|---|---|
| | Rank. | Location. | Rank. | Location. | |
| Bertram, J. ... ... ... ... | Executive Officer. | E.-in-C.O. | Staff Officer. | E.-in-C.O. | 19-3-32 |
| Andrews, G. C. C. ... ... ... | ,, ,, | ,, | ,, ,, | ,, | 19-3-32 |
| Slattery, E. H. M. ... ... ... | Clerical Officer. | Ldn. Dist. | Higher Clerical Officer. | Ldn. Dist. | 6-4-32 |
| Dyson, C. E. J. C. ... ... ... | Act. Exec. Officer. | E.-in-C.O. | Exec. Officer. | E.-in-C.O. | 19-3-32 |
| Dummer, J. F. ... ... ... | Clerical Officer. | ,, | ,, ,, | " | 19-3-32 |
| Maclean, C. ... ... ... ... | ,, ,, | ,, | Act. Exec. Officer. | ,, | 19-3-32 |
| Wilcock, S. ... ... ... ... | Exec. Officer. | ,, | Staff Officer. | ,, | 8-5-32 |
| Maclean, C. ... ... ... ... | Act. Exec. Officer. | ,, | Exec. Officer. | ,, | 8-5-32 |
| Foord, F. C. ... ... ... ... | Clerical Officer. | ,, | Act. Exec. Officer. | ,, | 8-5-32 |
| Morris, W. G. ... ... ... | Higher Clerical Officer. | N. West District. | Staff Officer. | N. West District. | 19-5-32 |
| Davies, D. E. ... ... ... | Clerical Officer. | N. Wales District. | Higher Clerical Officer. | N. West District. | 5-6-32 |

RETIREMENTS.

| Name. | Rank. | Location. | Date. |
|---|---|---|---|
| Bullard, H. J. ... ... ... | Higher Clerical Officer. | London District. | 5-4-32 |
| Whitehead, J. H. ... ... ... | Staff Officer. | N. West District. | 14-5-32 |

DEATH.

| Name. | Rank. | Location. | Date. |
|---|---|---|---|
| Brown, B. M. ... ... ... | Staff Officer. | E.-in-C.O. | 7-4-32 |




## COMMUNICATIONS.

All Remittances and Communications should be addressed to the MANAGING EDITOR, P.O.E.E. JOURNAL, Engineer-in-Chief's Office, Alder House, London, E.C.1.

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