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The Automatic Traffic Recorder

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Introduction.

IT has long been recognised that it would be advantageous if the laborious manual method of recording traffic in automatic exchanges, generally known as " switch counting," could be superseded by automatic or semi-automatic methods and as long ago as 1921 the Department experimented with automatic methods of traffic recording. The automatic traffic recorder is now available and is described in subsequent paragraphs of this article.

Before dealing with the manual and automatic methods of recording traffic, it will be advisable to touch lightly on the theory involved. In an automatic telephone exchange the quantity of apparatus to be provided to give a predetermined " grade of service " is dependent upon the total number of calls passing, the number of simultaneous calls, and the average holding time. The unit adopted for the measurement of traffic must, therefore, include a time factor. The unit adopted, the Traffic Unit, is defined by the statement that " in any given volume of traffic the traffic flow for the specified period is said to be unity when the average number of simultaneous calls during the period is unity." Thus, if on any group of trunks the average number in use simultaneously during the busy hour is determined, then this number will be the traffic, in traffic units, carried by the group during the hour. This number may obviously be obtained by counting the number of trunks in use at regular short intervals and calculating the average of the observations.

Up to the present all such observations have been made manually, men being employed to examine the selectors visually at intervals of three minutes and to record the number observed to be engaged. In the case of apparatus where visual indication of the engaged condition is not given, as in the case of junctions, relay sets, etc., resort is made to testing each trunk electrically, with a test lamp or similar means. At the end of the observation period the numbers recorded are added and the total divided by the number of observations. The limitations of the scheme are obvious. The number of circuits on which one man can make observations is limited, as also is the number of men who can be accommodated at once in an exchange. Moreover, it has been found that three minutes is the minimum interval between counts obtainable in practice; the degree of accuracy is consequently rather low. Observations are made at intervals of about three months and occupy about two weeks. It is difficult to withdraw the relatively large number of skilled men required from other work and there is a certain loss in efficiency due to inexperienced men having to carry out the work. Apart from the need for reliability, however, the scheme is costly.

Facilities Required.

The recorder has been designed, not only to measure the traffic carried by the apparatus in automatic exchanges, but also to analyse the traffic flow over the various individual gradings in order to allow of dispensing with analysis meters and frames and the associated cabling.

For the purpose of recording the traffic automatically a lead is brought from each piece of apparatus on which it is required to take records. In the standard scheme, this lead is arranged to be earthed whenever the associated apparatus is busy. It should here be explained that when dealing with traffic recording, the term apparatus may be extended to any selector, relay set, junction, etc., on which records are required and that the term busy includes any condition in which the apparatus is not free to accept an offered call for any reason whatsoever. The recorder tests these leads at regular intervals and a meter of the veeder type is operated once for every lead found engaged. In the case of apparatus held during conversation, *e.g.*, selectors, the recorder is arranged to test the leads every half-minute, but in the case of short holding-time apparatus, *i.e.*, common apparatus such as directors and senders, the leads are tested every twelve seconds. If the total number of engaged tests during the period of test is divided by the number of tests made during the period, the result will give the traffic in traffic units carried by the group of apparatus under test. It has not hitherto been possible to take records on common apparatus, as with the holding time of about twenty seconds usual in this class of equipment, the recording interval of three minutes obtained under manual conditions introduces errors so large as to render the record useless.

When overflows occur on any grading it is the present practice to use analysis meters to determine from which group the overflows are coming, in order that the outlets in the grading may be redistributed if required. When the analysis meters indicate that the overflows are all coming from one or two particular groups of the grading, an individual switch count is taken in order to determine the traffic carried by these groups so that the amount of redistribution may be estimated. When the recorder is introduced, it will no longer be necessary to have analysis meters, for by re-arrangement of the meters on the recorder it will be possible, not only to measure the traffic on the grading as a whole, but also to estimate the traffic carried by each group of the grading with an accuracy sufficient for the purpose. Consider the grading shown in Fig. **1**.

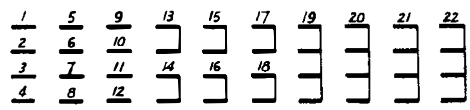

FIG. **1**.—22 OUTLET GRADING.

This grading has 22 outlets and by connecting one meter to the wiper of the access selector testing over the outlets it is possible to record the traffic in bulk on one meter. If, on the other hand, the recorder connexions are changed so as to use one meter for the testing on outlets 1, 5 and 9, a second meter on outlets 2, 6 and 10, a third meter on 3, 7 and 11, a fourth meter on 4, 8 and 12 and a fifth meter on outlets 13 to 22, then the first four meters will record the traffic which is carried by the individual outlets of each group. Now, the individual outlets in a grading giving a reasonably good grade of service carry a large proportion of the total traffic; so much so that it may be said that in any two groups of a grading the total traffic carried by each group will be proportional to the traffic carried by the individual outlets. If, therefore, the total traffic carried by the grading under consideration, as given by the summation of the traffic recorded by the five meters, is divided in the proportions indicated by the traffic variously carried by the four individual contact meters, then the results may be taken as the amounts of traffic carried by the four groups in the grading. In this particular case, letting A, B, C, D and E be the traffic as shown by meters one to five respectively, then the traffic carried on group one will be

$$\frac{A}{A + B + C + D} \times (A + B + C + D + E).$$

Each traffic recorder unit has a maximum capacity for 294 recording leads, compared with the modest capacity of 125 of the first practical model. The 294 recording contacts on each recorder are divided into three groups of 98 each and this represents the greatest number of recording leads which can be tested by one meter. In an exchange, however, there are usually numerous groups with but few trunks per group, so provision has been made to associate meters with groups of trunks as small as two.

For cabling considerations it is found necessary to cable the recording leads from the apparatus to the recorder in apparatus shelf order, but it is obvious from the above that the connexions to the recording contacts must be made in " grading " order to allow of the analysis facility. This means that a jumpering field must be provided between the exchange apparatus and the recorder. This field has been made an integral part of the recorder and the jumpering will be of a semi-permanent nature and will need altering only as a result of grading changes.

A recorder of sufficient dimensions to allow of a complete record being taken on the whole of a large exchange at once would be a formidable piece of apparatus and the cost of such a recorder would be prohibitive. It is, therefore, intended that in any exchange, a traffic record on all apparatus may be taken in not more than three sections with the proviso that any common equipment which may be fitted shall always form a fourth section. Thus, if traffic records in any large exchange must be taken on each of three specified days in the week, the taking of a complete record would extend over three weeks. The recorder for each exchange will be arranged, so far as is reasonably practicable, so that the records taken on the apparatus in each of the three sections may be self-checking. As an illustration of this the first sectional record in a non-director exchange might well cover (*a*) all traffic carried by first selectors and (*b*) all traffic carried by all the outlets from the first selectors. As these outlets are recorded at the same time, the traffic on (*a*) should equal that on (*b*). This gives an automatic check on the accuracy and functioning of the recorder. In smaller exchanges it is probable that the recorders normally designed to cover an exchange in not more than three sections will in actual fact allow all records to be taken in two, or even one section. Common apparatus must always be recorded separately.

Description of Recorder.

The recorder itself may be divided into three distinct but interconnected sections, the control relay set, which includes the pulse generator, the control selectors and the access, or testing selectors. The complete circuit for the recorder for an exchange without short holding time apparatus, *i.e.*, non-director exchanges is shown in Fig. **2**. The access selector is the 8-level uniselector T1 and it is to the first six levels of this switch that the recording leads are connected. It is desirable for cabling reasons that these switches, together with the necessary jumpering field, shall be situated near to the exchange apparatus. They are, therefore, mounted on special Access Racks, a complete panel being shown diagrammatically in Fig. **3**. Every access rack has accommodation for three or four such panels according as to whether it is an 8′ 6″ rack or a 10′ 6″ rack. Each panel, at the bottom mounts three access

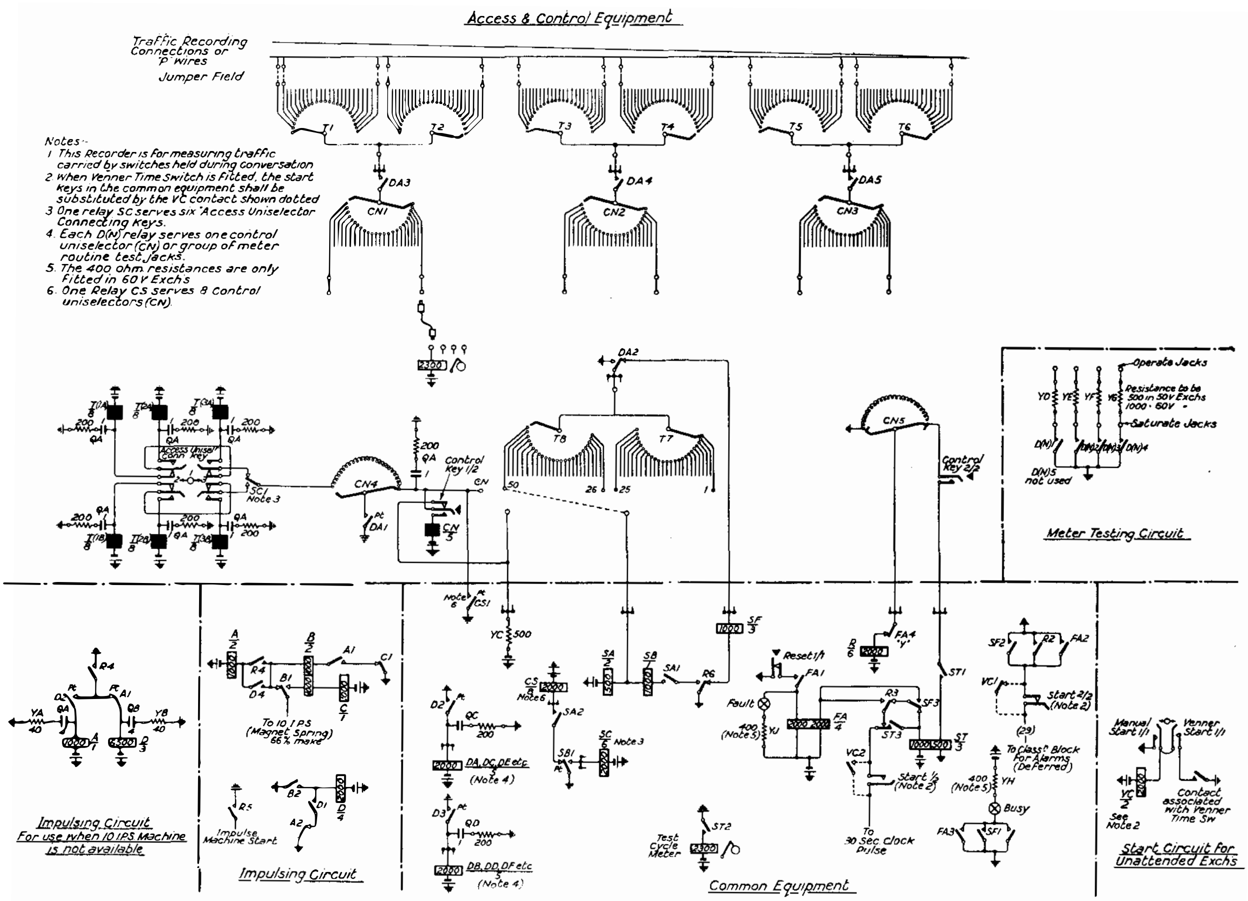

FIG. 2.—TRAFFIC RECORDER CIRCUIT, NON-DIRECTOR EXCHANGES.

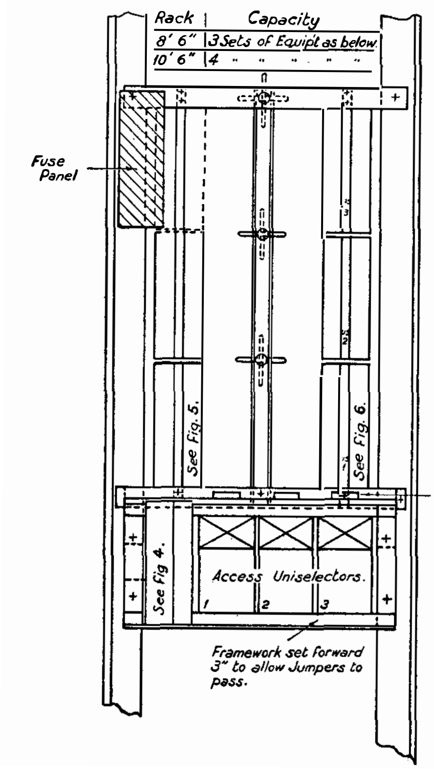

FIG. 3.—ACCESS EQUIPMENT PANEL.

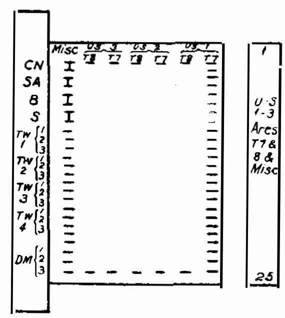

FIG. 4.—CONNEXION STRIP FOR TERMINATION OF ACCESS SELECTORS (ARCS T7-8) AND CONTROL LEADS.

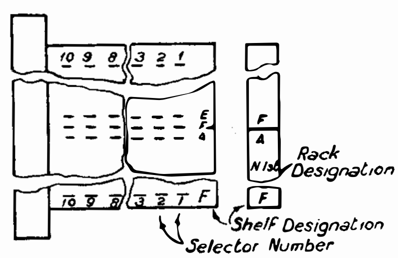

FIG. 5.—CONNEXION STRIP FOR TERMINATION OF RECORDING LEADS.

selectors and a connexion strip (shown in Fig. **4**) for the control jumpers and connexions. On the left hand side of the panel are mounted the connexion strips (Fig. **5**) for the cables incoming from the apparatus on which recording is desired, *i.e.*, the recording leads. Exchange apparatus is almost entirely mounted in shelves of ten, or multiples of ten, and in order to facilitate identifying the incoming leads without having to resort to a card index system, these blocks will be ten tags deep. This will allow of the shelf designations being sign - written

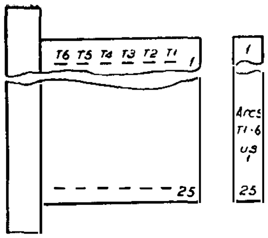

FIG. 6.—CONNEXION STRIP FOR TERMINATION OF ACCESS SELECTORS (ARCS T1-6).

on the edge of the block, but renders it necessary to use switchboard wire in place of jumper wire for jumpering purposes. The testing banks of the uniselectors are wired in bank order to further blocks on the right hand side of the panel (Fig. **6**). Standard double jumper rings are placed between the two sets of blocks and and the uniselector mountings are set forward so that each rack forms one large jumpering frame. All other apparatus connected with the recorder will be mounted on the Control Rack (Figs. **7**, **8** and **9**).

The recording leads being permanently jumpered to the access selectors, the latter must be provided in sufficient number to cover all recording leads in the exchange together with reasonable spare space for growth and additional spare contacts as may be required by the sizes and types of gradings to be accommodated. The reason for this will be seen when following the circuit operation. Since all outlets in the exchange need only be tested in three sections it follows that not more than one third of the access selectors will be in use at one time, or, in other words, the control switches, which also act as "meter connectors," need only be connected to one third of the access selectors at one time. Control switches are provided to deal with records on one third of the exchange at a time and there are, therefore, three access selectors connected to each control switch by a key which will only join one access switch to the corresponding control switch. The circuit is designed, however, so that two access switches are used, the one after the other, for each

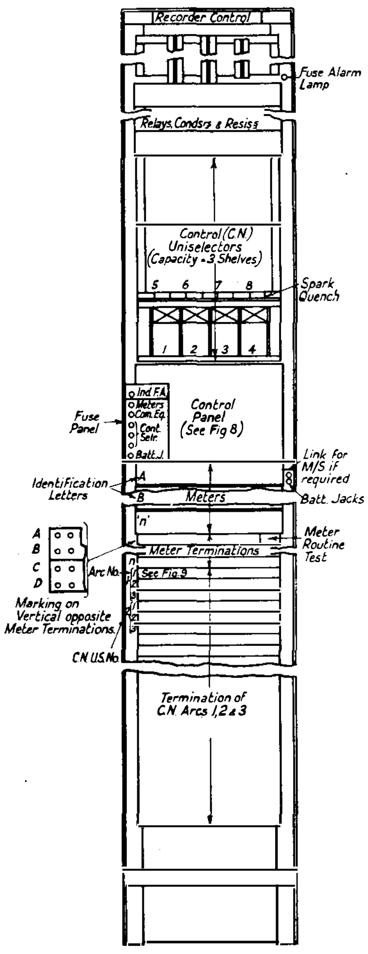

FIG. 7.—RECORDER CONTROL RACK.

test, by each control switch, and there are thus three pairs, or six, access selectors connected to each control by the Access Uniselector connecting key, which is so wired as to connect only one pair in each of its three positions. Timing and test cycle control is carried out by one relay set—labelled "Common Equipment" in Fig. **2**. This relay set, with the addition of one D(N) relay for every control switch, can control the recorders for any size of exchange. The method of use of the recorder and its functioning can best be described by giving the detailed circuit operation.

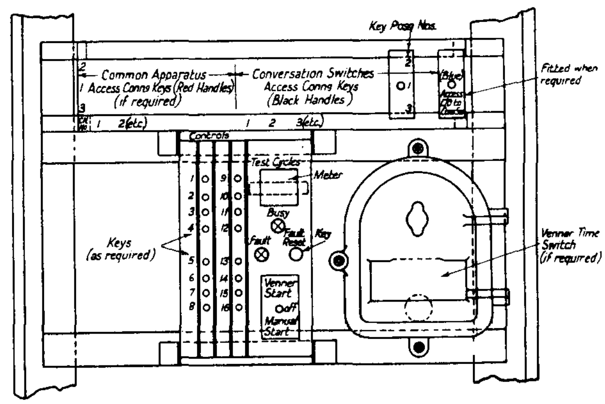

FIG. 8.—CONTROL PANEL ON CONTROL RACK.

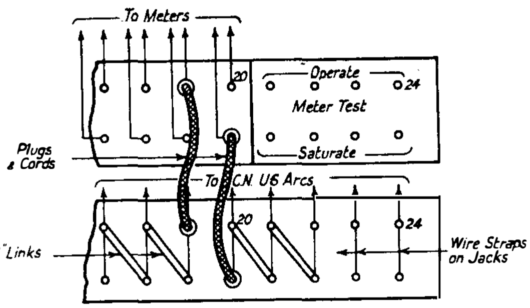

FIG. 9.—METER CONNECTING STRIPS ON CONTROL RACK.

Circuit Operation.

As the apparatus in non-director exchanges is all held during conversation, if the few cases where senders are employed be ignored, a recorder for a 30 second test cycle only has been designed for these exchanges. It is this recorder which is shown in Fig. **2**.

In order to allow the meters ample time, both for operation and release, the recorder is driven by a pulse of 5 i.p.s., which has a 66% make. Two circuits have been designed to generate this pulse, one for use in exchanges where no machine generated pulse of 10 i.p.s. is available, and the other for exchanges where such a pulse is available. Both circuits are shown in Fig. **2**. When a generated pulse is not available, two interacting relays are used. When the recorder is required to step, contact R4 is made, thus operating relay D. Relay A is operated at D2 and in turn releases relay D at A1, causing the release of relay A at D2. The operating characteristics of the relays together with the values of the condensers and resistors are chosen so that relay D generates the necessary 5 i.p.s. pulse. The operation of the circuit used when there is a pulse machine in the exchange is as follows :—Contacts R4 and R5 are kept operated when the recorder is required to run. The first pulse (earth) from the machine, operates relay A but keeps relay B short-circuited when A1 makes. Upon the release of this pulse relay B operates in series with relay A and operates relay D. The next pulse from the machine holds relay B and operates relay C, which in turn releases relay A, but relay D locks over D1 until relay A is again operated. At the end of this pulse relays B and C release and the whole circuit except relay D returns to normal. The nett result of this series of operations is that if the circuit is operated from a 10 i.p.s. pulse with a 66% make ratio, relay D will generate a 5 i.p.s. pulse and the make ratio will still be 66%. Whichever circuit is used the D relay operates relief relays DA, DB, DC......, one of which is provided for each control switch and one for the meter test circuit. The operation of the recorder may now be followed.

When it is required to take a record on any particular group of apparatus, the Access Uniselector connecting key concerned is thrown to the position which will connect to the control switch the access uniselector serving the group. The Control key for this particular control switch is also operated. The necessary strapping is made on the meter connexion points on the control switch arcs 1, 2 and 3 and the meter(s) connected. All this work is done in accordance with schedules which are supplied with the recorder. The meters are read and, when the record is to commence, the main Start key is thrown. The next half-minute time pulse from the clock circuit will operate relay ST, which locks to the earth time pulse at ST3. This is necessary as the duration of the time pulse earth is approximately one second which, if ST were not locked to it, would afford sufficient time for the control switch to drive off normal, release ST and operate the alarm circuit. Relay ST, at ST1, operates relay R *via* the control key and normal contact of any control switch in use, and relay R in turn starts the pulse circuit. Relay DA will now commence pulsing at 5 i.p.s. The first pulse will operate CN magnet from DA1 *via* the home contact of CN4 bank. Upon release the magnet steps the wipers of CN to the first contact, causing relay R to be held operated from arc CN5 for as long as the control switch is off normal, and releasing relay ST. The second pulse causes the access switch to be driven to the first contact from DA1 *via* arc CN4 off normal and the connecting key. On the next operation of relay DA, the access switch magnet T will again be operated from DA1 and the three recording leads connected to the three first contacts of arcs T1, T3, and T5, will be severally tested by the three meters connected to the first contacts of arcs CN1, CN2 and CN3. Thus it will be seen that three recording leads are tested simultaneously by each recorder in use. On the release of DA the meters will be disconnected from the recording leads by contacts DA3, DA4 and DA5, and the T magnet will be released at DA1, causing the testing switch to drive to the next set of recording leads. The next operation of DA will cause the next set of recording leads to be tested by the same set of meters. This sequence of operations continues until it is desired to change the group to the next set of meters. Suppose that, of the recording leads connected to arc T1, it is desired to meter the first four on the first meter and to record the following ones on the next meter. Then the last recording lead to be tested by the first meter will be on contact four of arc T1, or contact 5 if the home contact be counted, and the corresponding contact on arc T7, *i.e.,* contact 4 (or 5 if the home contact be counted) must be strapped to the CN tag. Assume that the access switch is standing on the last contact of the first group of testing leads. The next operation of relay DA will cause these leads to be tested by the first set of meters and at DA1 will operate the T magnet, and from earth at DA2 will operate the CN magnet *via* the wiper and corresponding contact of T7, the inserted strap to CN tag and the control key. On the release of DA the testing meters will be disconnected from the recording leads, the T magnet will be released, driving the access switch to the next set of recording leads—which commence the next group; the CN magnet will be released, thus driving the control switch to the next set of contacts to connect the next set of meters. The straps which are inserted between the bank contacts of arcs T7 and T8 and the CN tag will, of course, be of a permanent nature, because any particular access switch will be permanently connected to certain groups of exchange apparatus.

This feature of strapping arcs T7 and T8 to the CN tag introduces one of the limitations of the recorder. Whatever grouping of the meters is called for by the recording leads on arcs T1 and T2 it must of necessity be duplicated on arcs T3 and T4 and arcs T5 and T6, as there can be only one set of straps to operate the CN magnet controlling the meter distribution on all three sets of arcs.

The sequence of testing described continues until the whole of the recording leads on arcs T1 and T2, and, therefore, on arcs T3, T4, T5, and T6 have been tested. The whole of this testing will have occasioned 50 steps of the access switch which, at the testing speed of five steps a second, will have taken ten seconds. As the testing cycle is repeated only every 30 seconds, there is ample time left to test over the banks of another access switch, provided that the strapping on arcs T7 and T8 is such that the control switch has not made a half revolution during the testing of the first access switch. This second testing is made possible by strapping the last contact of the T8 arc of the access switch just used to the S tag. When the last recording lead on the first of the pair of access switches is being tested, relay DA operates to perform the testing at DA3, DA4 and DA5, and, at the same time, operates the T magnet of the access switch at DA1 and operates relay SA from earth at DA2 *via* the wiper and last contact of arc T8 and the inserted strap. Relay SA prepares a circuit for relay SB, which is short-circuited by the earth on DA2 at this stage, and operates relay CS at SA2. Relay CS, in turn, operates the CN magnets of all control switches in use. On the release of DA, the T magnet is released, thus allowing the access switch just used to return to its home position and, following the removal of earth at DA2, relay SB operates in series with relay SA, both relays holding to earth at contact R6. The operation of relay SB operates relay SC and releases relay CS, the latter then releasing the CN magnets and causing the control switches to step and join up a further set of meters to the testing contacts. Relay SC changes over the pulse drive to the second access switch of the pair. The next operation of DA drives this switch off normal and the testing of a further set of recording leads commences. It will therefore be seen that a maximum number of 2 × 49 or 98 recording leads may be tested by the meters on one meter connecting arc of the control switch. As there are three such arcs, the maximum capacity of one recorder is, at each test, 3 × 98 or 294 recording leads.

The recorder connexions must be so arranged that at the end of the testing of the leads on the second of the pair of access switches the recorder returns to normal to await the next half-minute time pulse. The control switch must therefore make a half revolution, *i.e.*, 25 steps. The first step is given automatically by the first operation of relay DA and, in order to give the remaining 24 steps, there must be one strap from the last contact of arc T8 of the first access switch of the pair and a total of 23 straps from the appropriate arc contacts of T7 and T8 of the first and also of the second of the pair of access switches. Upon the completion of the test cycle, the second of the pair of access switches and the control switch will both return to their home positions on the release of relay DA for the last time. The homing of the control switch will, at CN5, release relay R which in turn will release relays SA and SB and then SC and will also stop the pulsing circuit. The recorder then remains at rest until the next start time pulse.

The guard and alarm circuits are of interest and are worthy of attention. As the corresponding wipers of no less than six access switches—nine in the director case—are commoned together, it is of considerable importance that no access switch shall be allowed to be off normal except the one actually being used for recording, for not only would false records be obtained, but, should more than one access switch in any group of six or nine be off normal, the recording leads would be in contact. As in the case of earth testing apparatus the recording lead is teed to the P wire, the need for this protection will be obvious. As stated already, certain bank contacts on arcs T7 and T8 are strapped to either the CN tag or to the S tag. All the remaining bank contacts are strapped to the B tag. Thus under all conditions there will be a battery connected through a resistance to the bank contacts of T7 and T8 arcs, except in the case of the home contact on T7 which is left entirely disconnected. Should the recorder not be in use, and should any access switch be accidentally moved off normal, relay SF will immediately operate, *via* contacts R6, DA2, the wiper of the switch off normal and any bank contact to battery either through relay SA or through resistor YC, the control key being normal. Relay SF, at SF1, lights the recorder busy lamp and, at SF2, relays earth to the exchange deferred alarm system. If the recorder is in service and any access switch other than those being used at the time be accidentally moved off normal, or should one of those in use stick off normal, then SF will operate at the end of the test cycle when relays DA and R both release. In this case, SF2 is disconnected from the alarm system, but when the next half minute time pulse occurs, instead of relay ST operating, relay FA will be operated over SF3 operated. Relay FA locks at FA1 and lights the fault lamp and at FA4 prevents further operation of relay R. This latter function is to prevent the recorder continuing to run if any fault is in existence, and is considered necessary because a fault on a traffic recorder will not be shown up in the records obtained from it unless the fault is of an extensive nature, but such records will, nevertheless, be quite unreliable. Contacts FA2 and FA1 are provided so that in the event of the officer restoring the start key during the existence of a detected fault, the fault lamp will be lit and the alarm system will be operated. Should a control switch be accidentally moved off normal when the recorder is not in use, relay R will be immediately operated and will perform the same functions as relay SF at R1 and R2. If any misoperation of a control switch should occur during a record, the fact will be detected at the next time pulse, for if more than one control switch is in use relay R will never release, as although one control switch is on the home position another will be off normal. The next time pulse will therefore be relayed to relay FA at R3 operated. If only one control switch is in use, it may be assumed that in the event of a misoperation the access switch will not be " home " simultaneously with the control switch, and relay SF will therefore operate the alarm. This arrangement of the alarm system also guards against the testing cycle not being completed within the specified time limit for, in that case, the next time pulse will occur when R is still operated and will so operate relay FA. It has been found impracticable to guard against fast operation of the circuit other than by periodically timing the test cycle by means of a stop watch. During use the stopping of the recorder at the end of an exact time period could not be guaranteed and a Test Cycle meter is therefore provided. This records the number of test cycles performed during the record, and the difference of the readings of the recording meters will be divided by the difference shown by this meter in order to obtain traffic units.

Recorder for Director Exchanges.

The recorders used in automatic exchanges of the director type must be capable of recording on directors, senders, coders and other apparatus of like type on which the holding time is only of the order of from 12-20 seconds. It is quite obvious that a testing cycle of 30 seconds is unsuitable for this owing to the lack of accuracy obtainable, and the recorder is arranged to test such apparatus with a cycle of 12 seconds. This time interval is chosen because at such exchanges there is available a clock time pulse of six seconds which may readily be built up to 12 seconds in the recorder. As it will not be necessary to take records on this apparatus when records on " long holding time " apparatus are in progress it has been found possible to design the recorder for use with either test cycle. The arrangement of the access and control switch arcs together with the control keys and meter connexions are the same as at non-director exchanges (shown in Fig. **2**). Additional access switches are, of course, required, and these are connected as in Fig. **10**. As the cycle is one of 12 seconds, there is time to test only

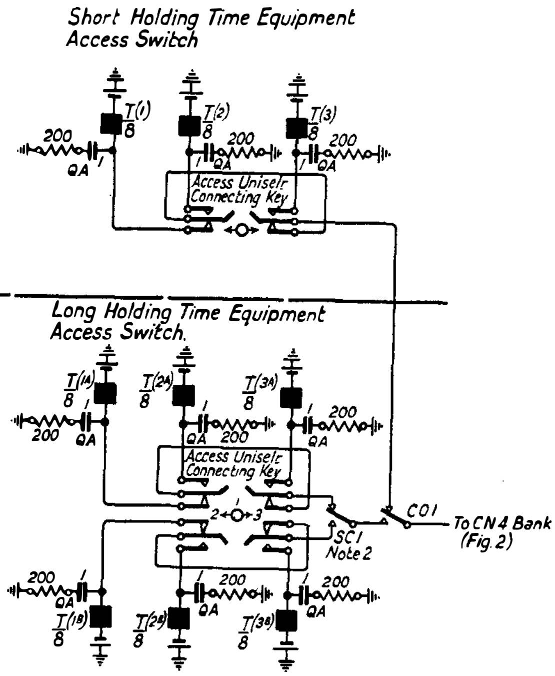

Fig. **10**.—Arrangement of Access Selectors, Director Exchanges.

over one access switch, taking 10 seconds, and the " pairing " facility used in the case of " long holding time " apparatus is not incorporated. The short holding time access switches are therefore only connected to the Access Uniselector connecting keys in sets of three. The control relay set used with the recorder for non-director exchanges is replaced by the relay set shown in Fig. **11**. When it is desired to take records on long holding time apparatus, the Access Change-Over key is thrown, permanently operating relay CO. At CO1 (Fig. **10**) this relay connects the set of six long holding time access selectors and their connecting key to the control switch, and the access change-over key itself connects the half-minute earth to relay ST and allows relays SA and SB to function as in Fig. **2**. The operation of the circuit is then precisely as described for the non-director case. When records on short holding time apparatus are required, the Access Change-Over key is left in the normal position. With relay CO normal, the sets of three access switches jumpered to this apparatus are connected to the control switch. The correct group on which records are required is selected by setting the Access Uniselector Connecting key and the Control key, the correct meter connexions also being made. After reading the meters, the main start key is operated. The next six second time pulse operates relay SA and, when SA1 makes, maintains the short-circuit on relay SB. At the end of the pulse, relay SB operates in series with relay SA. The next six second time pulse will operate relay SD and hold relay SB. Relay SD releases relay SA and operates the start relay ST. The recorder now proceeds to test over the recording leads as described in the non-director case. As the cycle must be completed by the testing of one access switch only, there must be 24 straps from T7 and T8 banks of that switch to the CN tag, and the S tag will not be used. When the access switch has tested over all its testing arcs, the control switch will return to the home contact and the recorder will then wait until the next start pulse, which will occur twelve seconds after the last, since every intermediate six second clock pulse is absorbed by relays SA and SB.

Unattended Exchanges.

Up to the present it has only been possible to take traffic records in exchanges at long intervals on account of the high cost involved, and in non-director exchanges it has not been possible to obtain any periodical record of the originated traffic as can be and is done in director exchanges, by reading the director call count meters. The introduction of the recorder will make possible the recording of originated traffic by the simple expedient of taking a traffic record on the subscribers' first selectors. To

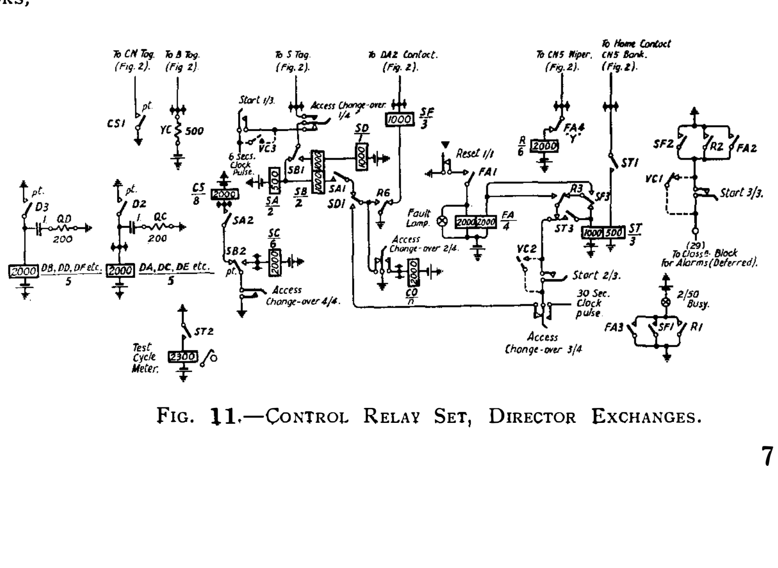

Fig. **11**.—Control Relay Set, Director Exchanges.

cater for unattended exchange records, provision has been made for the inclusion of a special type of time switch in the recorder. The time switch can be seen on the diagram of the control panel (Fig. **8**) and it has one make contact which is shown in Fig. **2**. The contact is used to complete the operating circuit for relay VC as an alternative to the Venner Start key. The normal start key is replaced by contacts of the relay VC. The time switch is driven by clockwork and embodies a 15-day clock; it can be set to close its contacts at any given time on any single given day of the week and to open them at any given later time on the same day. The following example will make this clear. Suppose that it is desired to take a record of originated traffic in a particular unattended exchange periodically on Tuesday mornings from 10 a.m. to 11 a.m. The recorder would normally be kept set up with the meters connected for such a record, and the clock would be wound about every seven days by the maintenance officer on routine visits. During his last visit prior to a record being required and which must be within a week of the record, he will read the meters and throw the start key to the Venner Start position. On the following Tuesday at approximately 10 a.m.—the time switch having been set for these times for this exchange—the time switch will start the recorder, and at about 11 a.m. will stop it. The record has been taken and at his next visit, which must again be within a week of the record, the maintenance officer will read the meters again and restore the start key. The record will not necessarily be for an exact period of one hour, but this will not materially affect the accuracy of the result, for the test cycle meter will give the exact number of test cycles made from which the traffic in T.U's may be calculated.

Meter Test Circuit.

The meters fitted to the recorder are the standard small reverse drive type. The meters are capable of operating correctly at high speeds, but as they will be called upon to operate at the rate of five steps a second when passing over consecutive engaged recording leads, a special meter testing circuit is provided. This is shown in Fig. **2** and consists of four pairs of meter connexion jacks wired to four D(N) contacts. In order to test the meters they are connected, four at a time, to the operate jacks; any control key is thrown, together, in director exchanges, with the access change-over key, and the start key is then operated. The recorder commences to drive and in each test cycle the D(N) relays will pulse once to step the control switch off normal and a further one hundred times to step the pair of access switches one complete revolution each. The four meters under test should therefore make 101 steps each. The meters are thus tested at full working speed and, when connected to the operate jacks there is a 500 ohm resistance in series with each, thus testing them primarily for speed of operation. After this test the meters are transferred to the saturate jacks, when they are operated at full speed to a full battery and so tested for releasing speed.

Recording Leads.

In all standard automatic exchanges a recording lead is provided for each piece of apparatus on which it is likely that records will be required. These leads are terminated on one tag block per rack of apparatus concerned and may be readily cabled from these blocks to the access racks of the recorder. The recording leads are, in " earth testing " circuits, simply a tap on to the P wire, but in " battery testing " circuits, such as directors and A digit selectors, even a 2300 ohm meter cannot be connected momentarily to the P wire without risk of false testing. In such cases special relay contacts are incorporated in the apparatus to earth the recording lead provided when the apparatus is engaged. The straightforward tap on the C wire is used in Siemens' No. 16 type exchanges, as the high resistance—2300 ohms—in the battery testing lead is found not to cause any false testing.

Grouping of Meters and Recording Leads.

It will have been gathered that the recording leads are not merely distributed over the access switch banks in random order. In the paragraph dealing with facilities a typical small grading was considered and it was shown that, to obtain what may be called the analysis feature, it is necessary to connect the individual outlets in the grading to the access switch so that they can, when desired, be recorded on by separate meters. This principle must be folowed in all groups of outlets covered by a grading, but certain other considerations modify the exact procedure. Thus the facility is not required for gradings with two or three groups only, because in these gradings it is not possible to afford relief to any one group in the grading without automatically giving relief to the other group or groups. In gradings with only one individual outlet per group, the traffic measured on this one outlet would not be sufficiently representative for use for regrading and so with such gradings each pair of adjacent groups are considered as one group for recording purposes. Some gradings have five or more individual outlets per group, but the meter groupings of the recorder render the separate metering of such large groups of individuals inconvenient, and as the separate metering of the first three or four individual outlets gives sufficient accuracy for the purpose, it is not necessary to use more.

Fig. **9** shows the arrangements made for connecting meters to the metering points on the control switches and for commoning these points. The meters are wired.to meter jacks, there being one jack per meter. The meter connexion points on the control switches are each wired to two jacks situated the one above the other. One strip of these jacks is provided for each metering arc of each control switch, three such strips being required for each control switch. To connect a meter to any metering point, a double ended plug and cord is used between the jack for the chosen meter and either of the two jacks wired to the meter connexion point. To common several metering points to one meter, U links are inserted to connect the pairs of jacks concerned and a meter is connected to the spare jack at either end of the group by a cord and plugs. In the typical grading given in Fig. 1 each of the individual groups would be connected to one metering contact and the remaining outlets to one or more other contacts, but by inserting the necessary U links, the whole grading could be tested by one meter.

In a complete cycle of the non-director recorder, two testing switches will step over and test 294 contacts which may be connected to recording leads, but this testing is taking place in three sections simultaneously. Considering only the T1 and T2 arcs of the two testing switches and arc CN1 of the control switch, the testing switches will test 2 × 49 contacts while the control switch passes over 24 metering contacts. The most nearly equal division of recording leads to meters will therefore be 11 groups of 4 and one group of 5 for each testing switch. This will mean that, taking the home contact as the first on arc T7, contacts 5, 9, 13, 17, 21 and 25 of this arc and contacts 4, 8, 12, 16 and 20 of the T8 arcs for each of the two switches will be strapped to the CN tag. In addition, contact 25 of the T8 arc for the first switch will be strapped to the S tag and contact 25 of the T8 arc for the second switch to the CN tag. It must, of course, be remembered that this grouping will also hold good for the remaining two sets of arcs (T3, T4 and T5, T6) of the access switches under consideration, but that any other pairs of access switches may have different groupings. This even grouping will be the one most frequently used for normal small gradings and for junction groups. For instance, the grading of Fig. 1 might be for an outgoing junction group, the other groups being similar, with perhaps two or four individual outlets per group in some cases and full availability in others. The meter grouping just given would probably be chosen, in which case the outlets of the grading in Fig. 1 would be arranged—

Outlets 1, 5 & 9 on T1 contacts 2-4.
T1 contact 5 left spare.
,, 2, 6 & 10 on T1 contacts 6-8.
T1 contact 9 left spare.
,, 3, 7 & 11 on T1 contacts 10-12.
T1 contact 13 left spare.
,, 4, 8 & 12 on T1 contacts 14-16.
T1 contact 17 left spare.
,, 13-22 on T1 contacts 18-25 and T2 contacts 1 & 2.

The 22 outlets shown in the grading would undoubtedly be accommodated on 30 banks or the equivalent and to allow of growth to the maximum, contacts 3-12 on T2 would be left spare. The next group or grading would be commenced on T2 contact 13. When there are large numbers of similar gradings, the meter grouping may be varied to suit the gradings in a variety of ways, always providing that the 98 testing contacts on each set of testing arcs are divided into 24 metering groups. When the recorder is used for short holding time apparatus, and the pairing facility is not used, it is necessary to divide the 49 testing contacts on each set of testing banks into 24 metering groups.

Although the estimation of quantities for the recorder and the work of making out the jumpering schedules for any particular exchange is no light undertaking, the actual work of taking traffic records is simple and the reduction of staff and time involved should make the recorder a welcome addition to automatic exchanges.

The evolution of the traffic recorder has occupied six years of uninterrupted development including the full scale experiments necessary to test its efficiency. Its final development has only been rendered possible by the close co-operation given to the officers responsible for traffic recording and trunking by the circuit designers and by the District staffs in their whole hearted assistance in the tests of the equipment.

An Operator's Amplifier with Constant Level Output

Frequent complaints have been made by Toll operators that calls received under straight forward junction conditions are often unpleasantly loud. Owing to the wide range of speech levels received by these operators it is not possible to overcome the difficulty by a general reduction in level. It was found that a device was required which would effect a reduction of about 15 db. in the level of loud speech without introducing any loss during the reception of faint speech.

An operator's amplifier with constant level output has been designed which appears to meet the requirements indicated above. It consists of a variable attenuation network, incorporating metal rectifiers, followed by a valve which serves the dual purpose of (*a*) supplying control current to the network to increase its attenuation during the reception of loud speech and (*b*) amplifying faint speech. The control is such that a change of input level of 30 db. results in a change of level in the operator's receiver of about 3 db. without the introduction of any perceptible non-linear distortion.

The amplifier can be operated entirely from a 50 volt exchange battery, the total current consumption being about 200 milliamperes. The mounting will probably be of the jack-in type with cover, the base being about 8 ins. by 4½ ins.

The apparatus is at present in the experimental stage and several are being constructed for trial in actual practice.

A Teleprinter Broadcast System

R. N. RENTON

WITH the introduction of the teleprinter to the public, the usefulness of the printed message led to a demand for a teleprinter system whereby messages could be transmitted simultaneously, or " broadcast " from a central office to a number of stations. Simultaneous telephonic transmission has sometimes been used, but broadcast traffic which demands a written record of the transactions is more efficiently handled by a teleprinter system.

Such a system has been provided and several installations are now in operation in this country. The service is particularly suitable for, although not limited to, the needs of Police Administrations; it affords, for example, instant communication between a Police Headquarters and divisional stations for the dissemination of urgent messages concerning wanted persons, stolen cars, etc.

The provision of a private wire network is regarded as essential for speedy communication, although the lines may be used for alternative telephone service. If two nearby administrations have a large mutual interest, the two systems may be connected by a tie line for the reception of broadcast messages, or the telex service may provide for communication.

Equipment has been designed for 10, 20, or 30 lines ultimate capacity, with provision for one to four teleprinters at the headquarters, according to the traffic to be handled. The equipment at Headquarters comprises a switchboard, an apparatus rack, and a common battery installation. Direct current teleprinter signalling is employed, and the teleprinter and subsidiary apparatus at the outstations are mounted on a steel table, as in the case of the tariff A private wire installation.[1]

Control of the system is vested in the headquarters station which is able to broadcast messages to all or to any number of the stations, or alternatively to effect simplex communication with any outstation. Simplex connections and " partial " broadcasts may be made simultaneously within the limits of the number of machines provided at headquarters. Inward calls to headquarters may be originated by any outstation, but the design does not provide for intercommunication between outstations, or for outstations to broadcast messages.

The Switchboard is of the cordless type, and each line terminates on a key. The two operations of the key give access to two teleprinter positions. The 20 and 30 line switchboards are equipped for four headquarters teleprinter positions, this capacity being obtained by providing two keys per line, as is done on the larger cordless telephone switchboards. With each line are associated a white calling lamp and a green acknowledgment lamp. In addition, each teleprinter position has a " broadcast " key and an engaged lamp.

The Apparatus Rack is designed in unit form, and Fig. 1 shows a twenty-line rack, equipped for one teleprinter position, together with a twenty line switchboard. Each headquarters teleprinter position requires one " local " relay for simplex working, and also one " broadcast " relay for every ten lines capacity. All relays are worked in the neutral condition, hence they are interchangeable and can be quickly replaced in the event of a fault.

The Line Units, one of which is shown with the cover removed in Fig. 1, contain the filter, shunted condenser, supervisory relays, and test jacks which are individual to each line. The resistances of all lines are equalised by means of the tapped resistance coils of the shunted condenser.

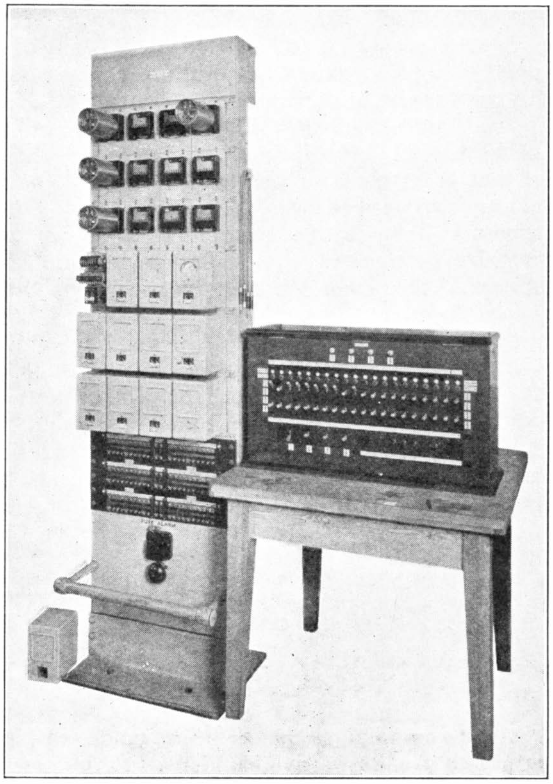

FIG. 1.—20-LINE RACK AND SWITCHBOARD.

At the right hand side of the rack will be seen the test unit, comprising a centre-zero milliammeter and test jacks. Connexion to any line unit is readily made by the use of a double-ended cord. The fuse panel is placed below the line units.

The 20-line and 30-line racks are fitted with line

[1] See P.O.E.E.J., Vol. 26, Part 2: " Teleprinter Private Wires on By-Product Circuits."

units and a test unit on both front and rear of the rack, the 10-line rack being equipped on the front only.

Circuit operation. A circuit diagram is given in Fig. **2**. Teleprinter signalling, employing transmission on one line, and reception on the other, is similar in principle to the tariff A system previously referred to. Filters are inserted at the sending ends and shunted condensers at the receiving ends : the shunting resistances are adjusted to provide for a current of 20 milliamps on each line. All transmitting contacts are equipped with spark quench circuits.

cast relay repeats the signals to ten lines. Where an indication of the satisfactory receipt of a message is important, this is given by the illumination of the green lamp on the switchboard. For this purpose, an " acknowledgment " key is fitted on the outstation table, and when depressed it causes the current in the " B " line to increase to a sufficient value to operate the C relay, which does not respond to teleprinter signals.

As shown in Fig. **2**, provision is made for the inclusion of an automatic transmitter and a receiving perforator where required. Whenever a message is being transmitted or received by perforated tape, a

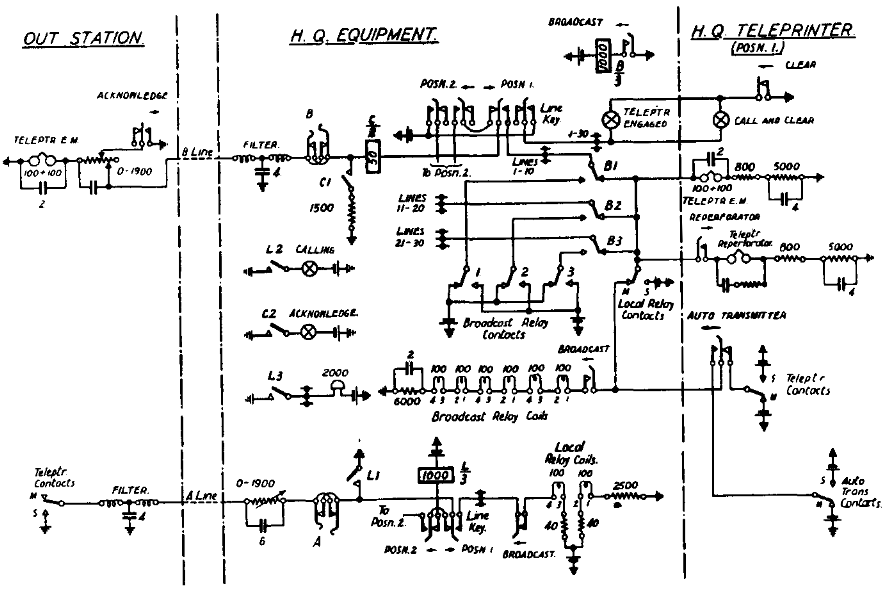

FIG. 2.—CIRCUIT ARRANGEMENT WITH BROADCAST FACILITY.

An outstation operator calls the switchboard by starting the teleprinter motor and depressing the space bar, thus operating the L relay and completing circuits for the calling lamp and alarm bell. Operation of the line key puts the two teleprinters into instant communication, and the call is cleared by restoration of the line key. The outstation teleprinter controls the local relay, and transmission from the headquarters machine is direct from the teleprinter tongue.

For a broadcast transmission the keys of all lines to be connected are operated to the same position, and the broadcast key is thrown. This key disconnects all the A lines, so that no station can interrupt a message, and connects the teleprinter tongue to the coils of the broadcast relays. Each broad-

printed copy is obtained simultaneously and serves as a useful check on the message.

The switchboard is usually controlled by the teleprinter operator, but provision is made to enable the teleprinters and switchboard to be operated from separated offices, by inclusion of the engaged lamps and clearing key shown in the diagram.

The Common Battery is a duplicate 40-volt + 40-volt installation with facilities for charging from the mains. Owing to the fact that the discharge rates on the positive and negative 40v sections are unequal, a switch, intended to be operated daily, changes over the positive and negative sides.

The system operates satisfactorily and experience has shown the fault liability to be small under conditions of long and continuous use.

Modern Developments in South African Telephone Exchange Design

H. LEIGH, B.Sc.(Eng.), A.M.I.E.E.

Introduction.

THE years 1931-34 have marked great progress in the automatizing of the two largest telephone networks in the Union of South Africa, namely, the Johannesburg and Capetown areas, and at present ten automatic exchanges in the former and four automatic exchanges in the latter have been brought into service, whilst extensions to both areas are in hand. In addition, Capetown has been equipped with a new automatic trunk board to cater for demand working and a similar board is being provided at Johannesburg. 1935-6 will also see the completion of 13 new automatic exchanges in the Durban area. Capetown and Durban are non-director areas having an ultimate capacity of approximately 45,000 and 26,600 lines respectively, whilst the Johannesburg area is worked on a two-digit director system and is expected to grow to 60,000 lines in 1949 in six zones.

In the three areas the latest British Post Office practice has, in the main, been followed. Line finders are supplied throughout and the later exchanges are also equipped with the P.O. 3000-type relay and the new small-type meter. In addition, however, there are many innovations not at present in general use in British Post Office exchanges. Some of these have already been described by Mr. H. A. Johnson, B.A., in his article on " The Witwatersrand Automatic Telephone System."[1] Others are the use of ballast resistors to improve transmission on trunk calls, the provision of a special train of switches in each exchange over which trunk calls are completed and the introduction of traffic recorders of a type similar to that recently standardized by the British Post Office, whilst in the Durban area an impulsing scheme employing Neon Lamp control is being adopted in order to meet the impulsing conditions imposed by the nature of the network.

In addition to the foregoing, complete departures from British practice have been made regarding the methods adopted for handling coin box and trunk traffic. Both of these schemes have a number of interesting features which are described below.

Corlett Call Office Scheme.

In converting the Johannesburg, Capetown and Durban areas to automatic working, the South African authorities were faced with the expense of changing all the existing coin-boxes, if they were to adopt the British method of handling call office traffic. The existing call offices were all worked on a post-payment basis and were, for the most part, fitted with single denomination coin-boxes having one chute for threepenny pieces or " tickies " as they are called in South Africa. A number of post-payment multi-coin boxes with chutes for threepenny, sixpenny and shilling pieces also existed. The coin-operated springs in these boxes were arranged to send a train of low-frequency earth pulsations to line when a threepenny piece was inserted; two such trains when sixpence was inserted in a multi-coin box and a single train of higher frequency pulsations when the shilling slot was used. Mr. W. D. Corlett, of the South African Administration, made use of this existing condition and designed circuits which automatically count the trains of low-frequency pulses received and switch the subscriber through on calls up to three or more unit fees, without the intervention of an operator. Mr. Corlett's circuit further arranges for the subsequent timing of the call and disconnexion after three minutes unless a further fee is inserted in the coin box.

Briefly, the operation is as follows. The caller lifts the receiver at the call office. The associated line finder finds the calling line and extends it *via* fee determining and timing apparatus to a 1st selector, from which the caller receives dialling tone. The caller then dials and the impulses step a fee determining switch in parallel with the selector train until sufficient digits have been received by the former to determine the fee payable. Ringing tone (or busy tone) is fed back to the caller in the usual manner and when the called subscriber answers the caller can hear him but cannot speak, as battery is fed out on both A and B wires from the local speaking bridge in the fee determining apparatus. The caller has then to insert the requisite fee which is counted in by a fee counting switch. When the correct number of coins has been inserted, normal speaking conditions are given. The fee counting switch then takes over the function of timing the call and at the end of three minutes' conversation warns the caller, by applying a zip-zip tone, that a further fee is required. If this additional fee is inserted it is counted in as before and the circuit re-set for another three minutes. If the extra fee is not inserted, the line is disconnected after a grace period.

It will be appreciated that the fee counting apparatus is not able to distinguish between the low frequency pulsations received from the threepenny and sixpenny springs and the high frequency pulses received from the shilling springs. It is therefore necessary that all fees to be counted automatically should be made up of sixpenny or threepenny pieces. This limitation is not serious in any of the three areas in which this call office scheme is being used in South Africa, as the maximum fee for a call which can be

[1] P.O.E.E.J., July, 1933.

completed automatically is ninepence in each case. The shilling slot of the multi-coin boxes is therefore only used under the direction of an operator on trunk or phonogram calls.

The circuit arrangements of the fee collecting and timing apparatus vary in detail according to the type of exchange to which the call office is connected. The circuit used at Capetown non-director main exchange is given in Fig. **1**. The main items of apparatus are two uniselectors, one (FD) for fee determination and the other (FC) for fee counting and timing. These uniselectors together with their controlling relays are associated with each call office 1st selector and can either be located in the selector base or in an associated relay-set.

If the first train of impulses is sufficient to determine the fee payable, the FD3 wiper will then be standing on a contact connected to a fee determining relay as follows :—

Single Fee	...	Relay SF
Double Fee	...	Relay DF
Triple Fee	...	Relays SF and DF
No Fee	...	Relay TR

The release of relay C at the end of the impulse train will complete the circuit for the appropriate fee relay to operate *via* the FD3 wiper and subsequent trains of impulses will not affect this circuit.

If the first train alone is not sufficient to determine the fee, the FD3 wiper will be standing on a disconnected contact and the switch will again step in

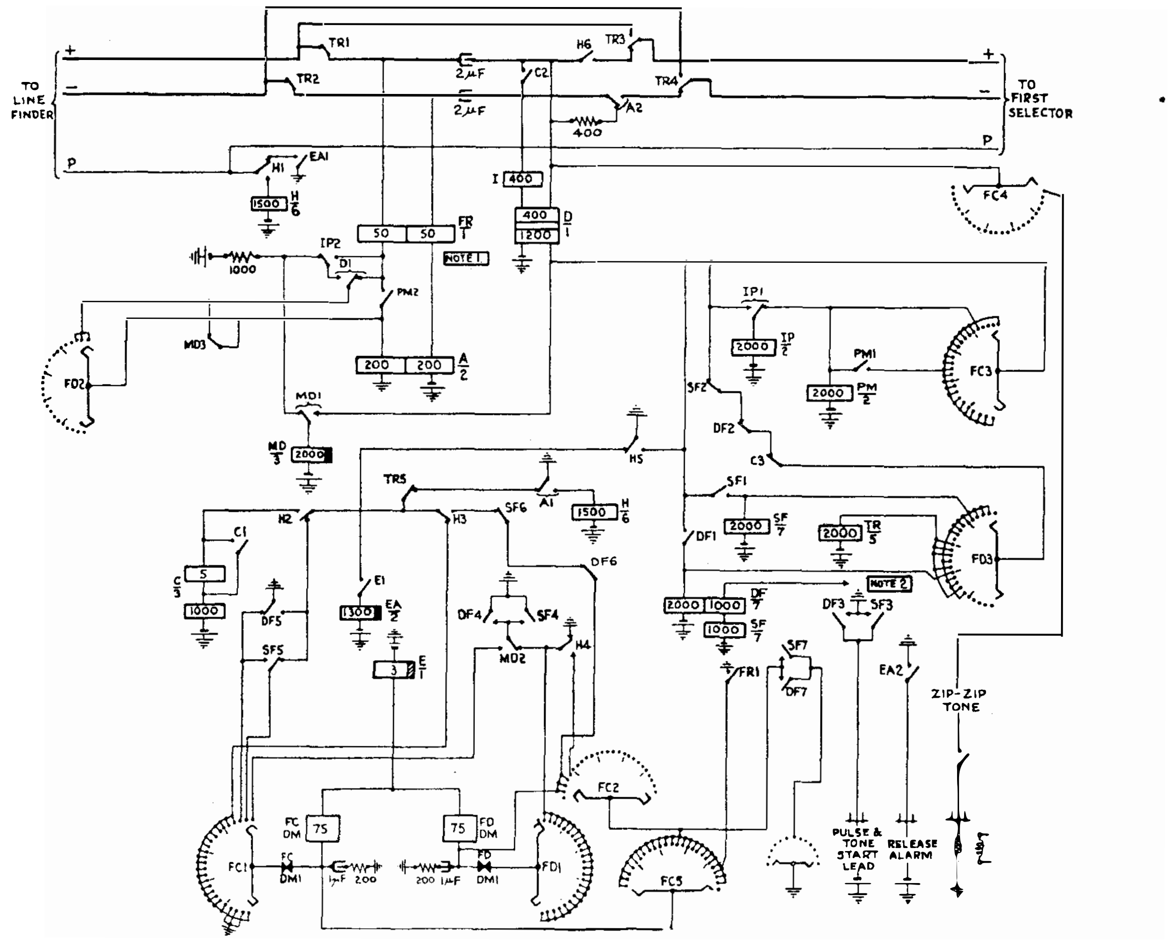

Fig. **1**.—Circuit of Call Office Auxiliary Equipment. Non-Director Main Exchange.

Circuit Operation.

When the apparatus is engaged, relay A is operated over a loop *via* the line finder and energizes relay H, which holds to the P-wire. The dialled trains of impulses are received on relay A and are relayed to the subsequent selectors by A2. The first, or first and second trains, as required for fee determination, also step FD switch. Relay C operates on the first release of A and holds until the end of the impulse train.

accordance with the second train of impulses. The FD3 wiper will then be standing on a contact representing the sum of the two digits dialled and this contact will be connected to the appropriate fee relay.

Single Fee Call. If the call necessitates the payment of a single unit fee only, relay SF will operate as above and FD switch will then home. When the called subscriber answers, relay D operates, energizes relay MD and disconnects one side of the feeding bridge, so that the caller can hear the called subscriber, but not speak to him. MD2 causes the FC switch to step off normal and the earth connexions on contacts 1 and 2 cause the switch to drive to the third contact. The stepping of the FC switch also completes the timing circuit for the FD switch by connecting the 10-second earth pulse lead *via* FC2 to the FD driving magnet. The caller is now allowed a grace time of three 10-second pulses, *i.e.,* from 20 to 30 seconds, to insert his fee. If he fails to do so, the stepping of FD2 wiper to the fourth contact releases relay A and so causes the release of the subsequent selectors.

If the fee is inserted in time, the earth pulse received from the coin box causes relay FR to operate once, which steps FC switch once. FC3 wiper then rests on the fourth contact and operates relays PM and IP. PM2 restores the speaking bridge feed and conversation can proceed.

The FC switch then takes over the function of timing the call and the FD switch is returned to normal by the first 10-second pulse (1.5 seconds duration). FC steps every 10 seconds from this pulse. After 2 minutes, 50 seconds conversation, a warning zip-zip signal that a further fee is required if conversation is to continue, is given to the calling subscriber *via* wiper FC4. This signal is maintained during the 1.5 second duration of the 18th pulse and, at the termination of this pulse, the FC switch is restored to normal and then drives to contact three. Relay PM is released, but the calling subscriber's transmitter feed is maintained *via* FD2 wiper, D1 and IP2. FD switch again commences to measure the grace period allowed for the insertion of the fee. If this is received relay FR is operated once and the FC switch is stepped to the fourth contact, re-operating relay PM. The call is then set up for another three minutes. If the further fee is not inserted within the grace period, the connexion is automatically released.

The clear from the calling station will release relay A which opens the loop to the 1st Selector and releases relay HA. This causes all selectors to be released and the uniselectors in the auxiliary apparatus to be returned to normal.

Two-Unit and Three-Unit Fee Calls. If the call is to an exchange in the second fee area, relay DF is operated by the FD3 wiper instead of relay SF as above. This causes FC switch to step to the second contact instead of the third as in the case of a unit fee call. Two earth pulses are received when the caller inserts the double fee and this causes FC switch to step twice, *i.e.,* to the fourth contact. From this point the operation is similar to that for a unit fee call.

Similarly on three unit fee calls both relays SF and DF operate and in this case the FC switch waits on the first contact. The insertion of the correct fee causes three pulses to be sent which step the switch three times, *i.e.,* again to the fourth contact, and allows conversation to proceed.

Service Calls. On calls to trunks (0), enquiry (91), etc., the code dialled causes relay TR to operate *via* the FD3 wiper. The caller is then switched straight through to the selector and any collection of fees and timing which may be necessary is left under the control of the operator.

In satellite exchanges and in director areas different methods of fee determination are used. In general a fee determination circuit in the D.S.R. or first code selector, similar to that used in the regular ranks of these switches for multi-metering purposes, is made use of to ascertain the fee payable. This allows the FD switch in the auxiliary equipment to be dispensed with and also has the advantage over the scheme described above, that it does not impose an additional restriction on the numbering scheme. That is, codes like 82, 91 and 0, etc., which all total ten impulses, need not necessarily have the same fee. In this connexion, it should perhaps be mentioned that meters are not fitted on call office lines in South Africa so the added complication of multi-metering on these lines does not arise.

Automatic Trunk Board.

In conjunction with the introduction of automatic working in the local exchanges of the Cape Peninsula, the South African authorities decided to introduce " On Demand " trunk working so far as their main line network would allow. To accomplish this they adopted a scheme incorporating an automatic trunk board (Fig. **2**) recently developed by Messrs. Siemens Bros. Under this scheme all trunks and junctions appear on the banks of switches and the connexions are set up from cordless switchboard positions by means of dials and controlling keys. Operators are not eliminated, but it is claimed that the many operating aids afforded by this type of board result in a greater operating efficiency. A somewhat similar type of board is also being constructed by Messrs. Automatic Electric Co. for the Johannesburg trunk exchange.

As in British practice there are separate positions for demand, special control and incoming working, and, in addition, a few positions are allocated for Long Distance circuits, such as radio links, ship-to-shore circuits and the longer distance inland trunks. The sections used for these different positions at Capetown are of the same design and vary only in the equipment fitted. A typical keyshelf lay-out is given in Fig. **3**. Each position has a number of cordless connecting circuits which, in conjunction with the position circuits, give all the standard operating facilities. Timing facilities are provided in the panel opposite each connecting circuit, whilst lamps in the panel also record the state of each trunk group.

In addition to the main suite of positions, a Supervisor's Desk is provided, equipped with ancillaries of the demand and incoming call displays and with meters to show the number of waiting calls in excess of the number of display lamps provided. Further, a set of lamp signals is provided for each trunk group showing how many operators are waiting for a free trunk in each group. When the number of waiting calls exceeds a certain limit, depending on the number of trunks in the group, the Supervisor can introduce delay working on the route in question.

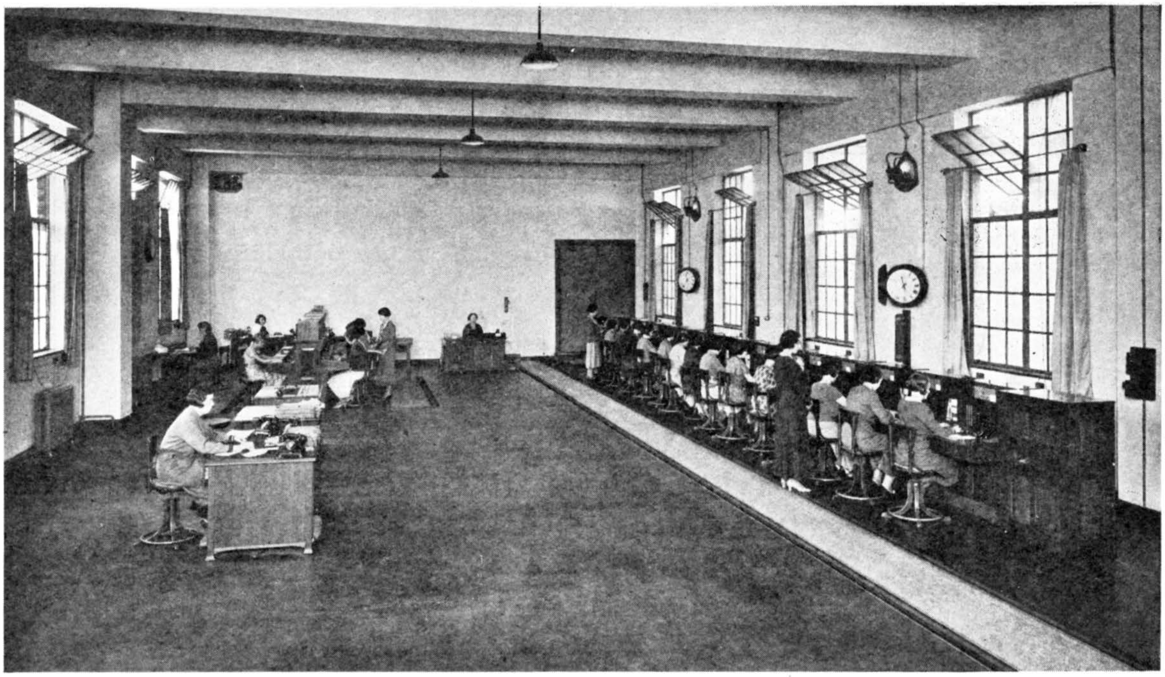

Fig. 2.—Switchroom, Capetown Trunk Exchange.

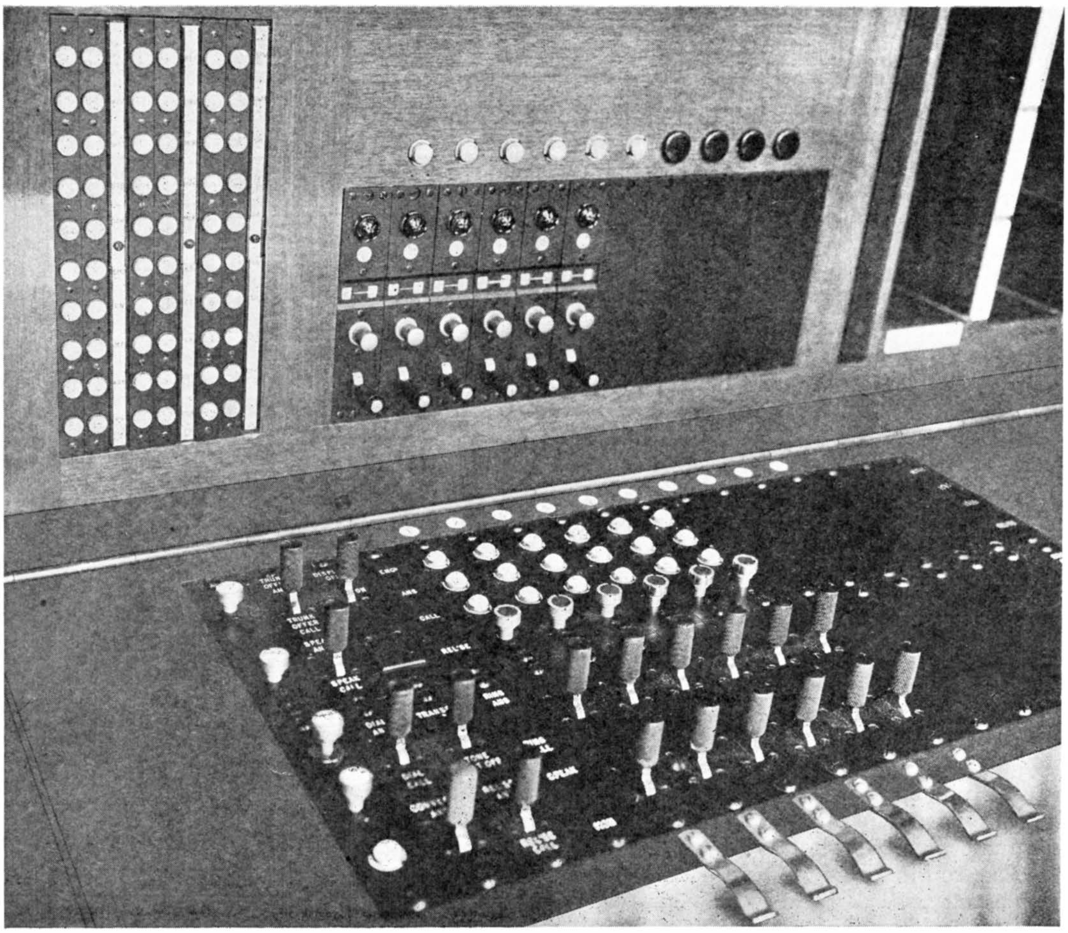

Fig. 3.—Demand Position—Panel and Keyboard Lay-out.

Trunking. (Fig. 4).

Incoming calls from subscribers or other trunk exchanges are received on distribution switches and the calling signals are ancillaried over the appropriate positions. The circuit arrangements are such that every call is lined up and answered in the order of its arrival. To answer a call, the operator throws the Speak key of a free connecting circuit and the Connect Answer key of her position circuit. The displayed by means of lamps on the Supervisor's desk, so that this officer may determine when delay working should be introduced on any route. The state of each route is also recorded on each position by means of duplicate lamp signals. The first lamp of each pair has a green opal and when alight indicates that all trunks in the group are engaged, whilst the second has a red cap and glows when delay working has been introduced.

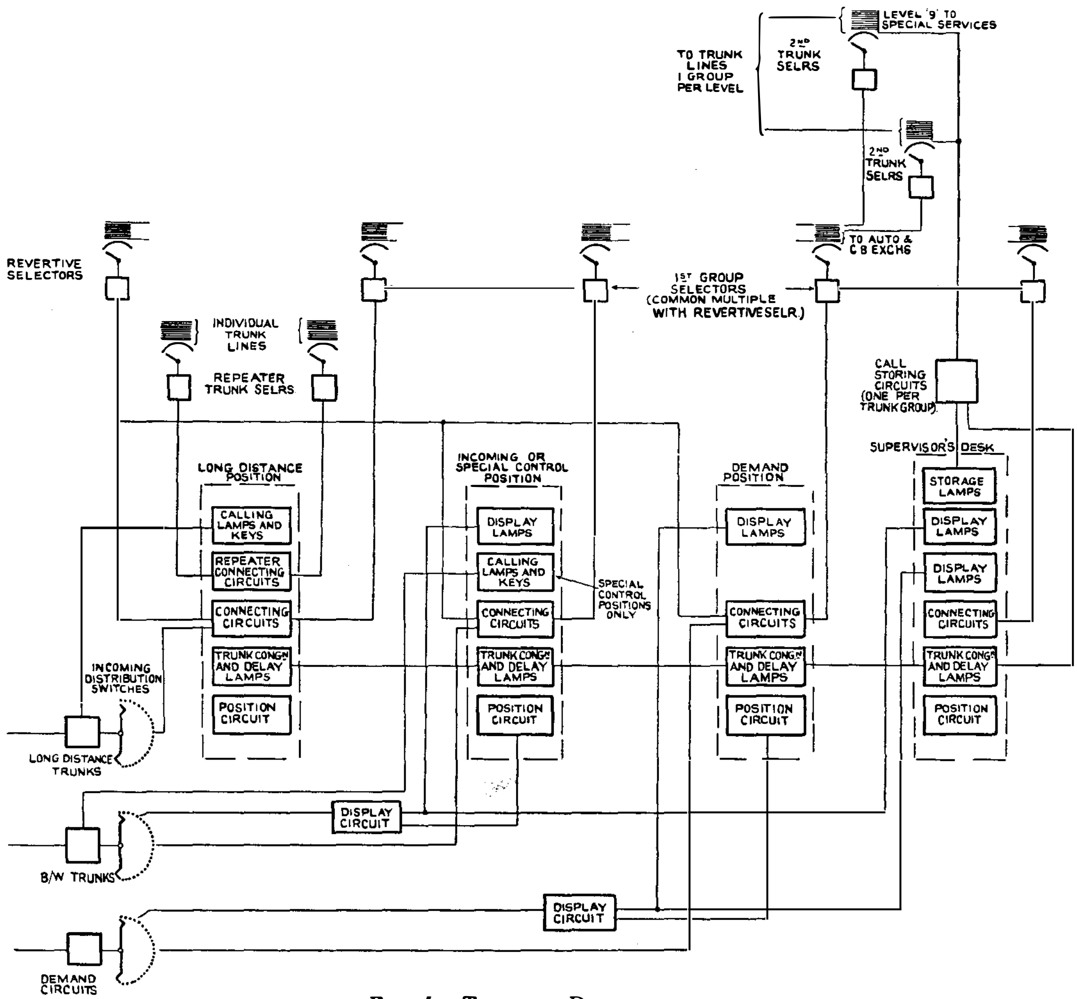

FIG. 4.—TRUNKING DIAGRAM.

first waiting call is then automatically connected. On the outgoing side each connecting circuit is terminated on a trunk selector, through which access to any trunk group and to the local network can be obtained. The numbering of the trunk groups is so arranged that, for calls to the local network, a prefix to the ordinary subscribers' numbers is unnecessary.

Should any trunk group be engaged, call storage facilities are provided whereby the operator can wait on the group and receive a signal on the supervisory lamp of the connecting circuit when any trunk in the group becomes free. Throwing her Speak key will then engage the trunk. The number of calls being stored in each group is recorded automatically and

Demand Circuit. (Fig. 5).

When a subscriber dials " 0," which is the code for trunks, he is connected to a circuit similar to that shown in Fig. 5. Relay L is operated over the loop and causes relay B to be energized. Trunk busy tone is fed back to the subscriber's P-wire to warn any incoming trunk operator that the subscriber is engaged on a trunk call. B2 completes the circuit for the driving magnet of the distribution switch, which drives to one of the first eight contacts connected to the calling lamp display. Relays S and T operate to battery in the display circuit (Fig. 6) and ringing tone is connected to the calling subscriber.

The calls are lined up in the calling lamp display

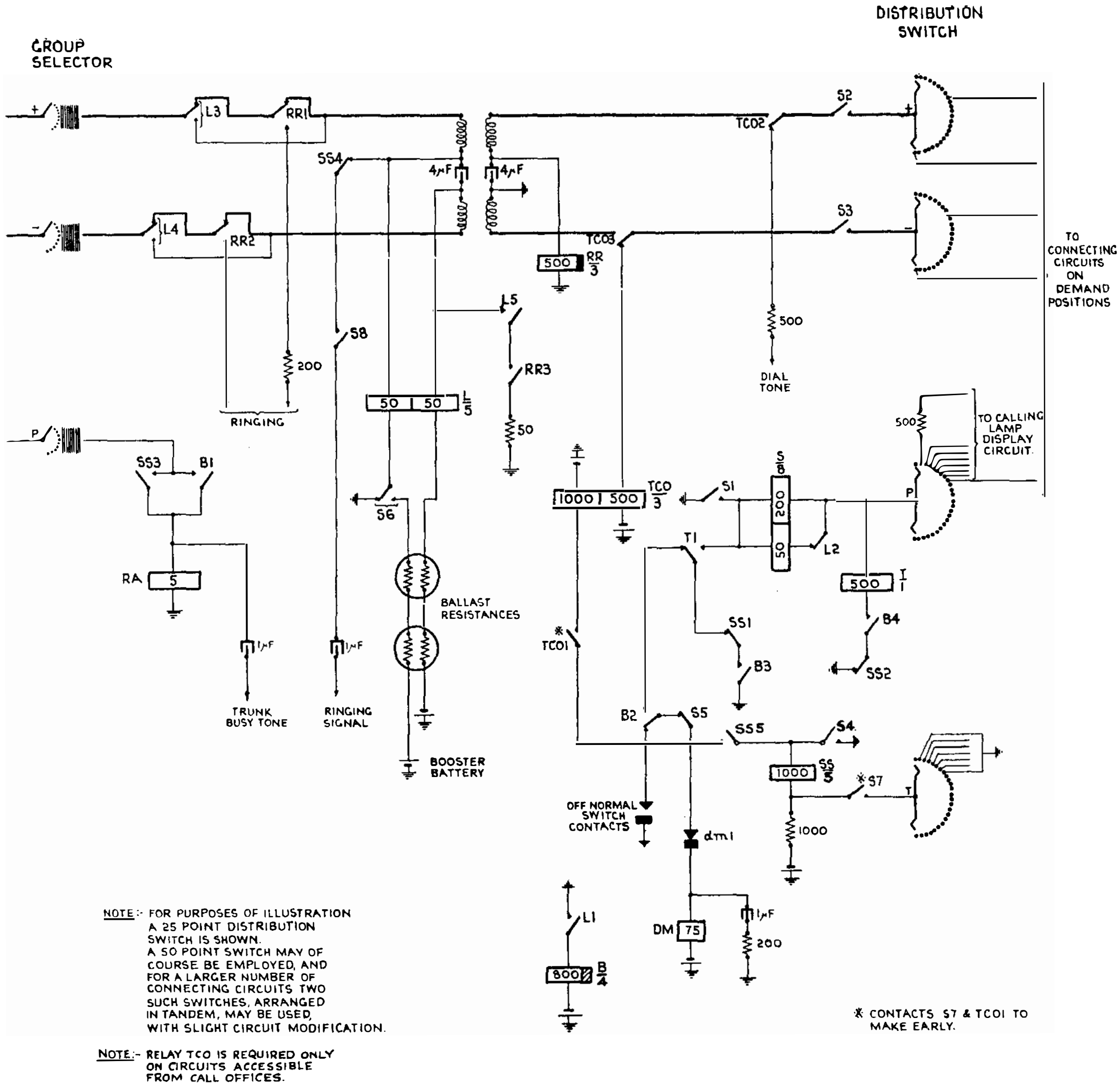

FIG. 5.—DEMAND CIRCUIT FROM SUBSCRIBERS AND CALL OFFICES.

and, as each preceding call is answered, the distribution switch makes one step until it arrives on the 8th contact. The call is then first in the queue and when the next operator throws her Connect Answer key, battery on the P-wire is disconnected, relays S and T release, and the switch commences to hunt over its remaining outlets to which are wired all the connecting circuits on the demand positions. The distribution switch tests in to the marked connecting circuit, relay T operates and energizes relays S and SS which disconnect ringing tone and extend the positive and negative wires through to the connecting circuit. Relay T releases.

If the call is from a call office, the demand operator receives dial tone to warn her that the necessary fee must be collected. By throwing her Tone Cut Off key, she can operate relay TCO and restore the circuit to normal conditions.

Operator hold and re-ring facilities are provided and the release of the connexion is effected from the Release key in the connecting circuit.

Calling Lamp Display. (Fig. **6**).

As described under the Demand circuit, each incoming call causes a distribution switch to step to one of the first eight contacts which are connected to the calling lamp display. If no other calls are waiting to be answered, the switch will drive to the eighth contact, where it will test in to battery, operating relay A and thus causing the first lamp in the display to glow. Subsequent calls received before the first has been answered will test into contacts seven, six, etc., operating relays B, C, etc., respectively, and thus completing the circuits for the second, third, etc., calling lamps.

When an operator is ready to take a call, she throws the Speak key of a free connecting circuit and her Connect Answer key. This applies a 25-volt

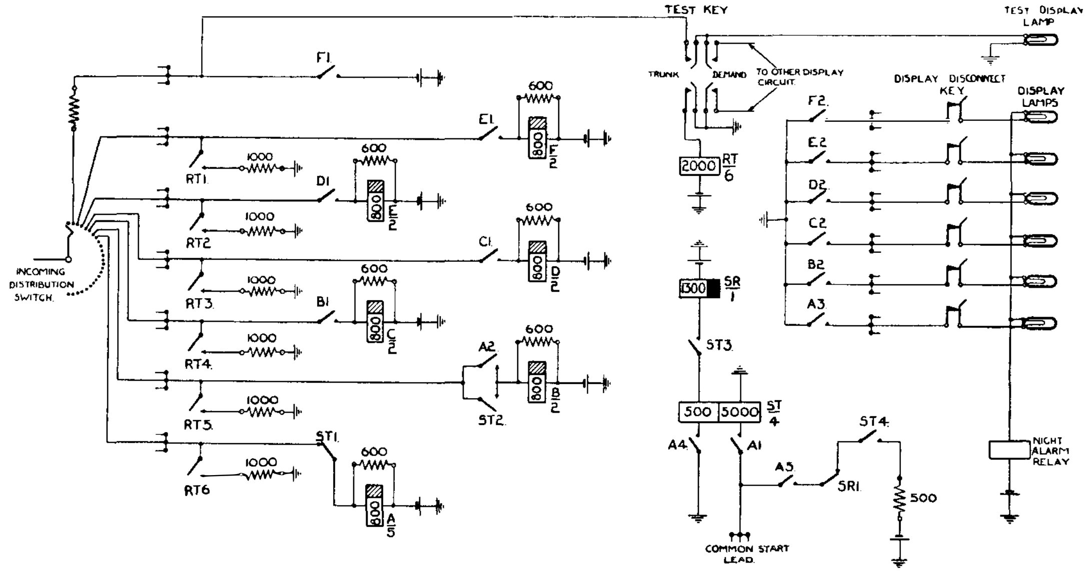

FIG. 6.—CALLING LAMP DISPLAY CIRCUIT.

battery potential to the start wire from the position circuit and operates relay ST. Relay SR, which is slugged, operates in series with the holding coil of relay ST and battery is connected momentarily to the start wire during the operating time of SR, causing the start signal from the position circuit to be removed. ST also disconnects the circuit of relay A and releases the distribution switch standing on this outlet. The distribution switch then hunts for the marked connecting circuit.

The release of A causes the release of relays ST and SR which, in turn, release relay B and the distribution switch standing on the seventh outlet steps to the next contact and re-operates relay A. Similarly any switches waiting on contacts six to one step forward into the next position.

Two separate displays are provided, one for demand calls and the other for incoming trunk calls. Both displays operate in the same manner.

Connecting Circuit and Position Circuit. (Fig. **7**).

In order to accept an incoming call, the operator throws the Speak key in a free connecting circuit and the Connect Answer key in her position circuit. Relays SK and SL operate and cause the operation of relay MN. Also battery *via* relay CN is fed out to the start wire. The momentary battery connected to the start lead by the calling lamp display circuit causes the operation of relay CN, which holds *via* the Connect Answer key and removes the start conditions from the start lead. When the distribution switch has found the connecting circuit, relay B operates and causes the Circuit Engaged lamp to glow. The operator restores the Connect Answer key and relay CN releases. The operator can now speak to the calling subscriber.

To complete a connexion, the operator throws the Dial Call key, which causes relay DC to operate, and dials the required code or subscriber's number into the trunk selector associated with the connecting circuit. As soon as the dial is moved off normal, relay DK operates and energizes relays DD and SD, completing the circuit to the 1st trunk selector. When dialling is completed, the restoration of the Dial Call key releases relays DC, DK, DD and SD.

To ring on the circuit, the Ring Call key is thrown and battery is fed out on the positive wire to operate a ringing relay in a subsequent circuit. During conversation between the two subscribers, the Speak key is restored and relays SK, SL and MN release, leaving the speaking wires free from any bridging apparatus. When conversation is completed, the connexion is broken by throwing the Release key.

To originate a call on the answering side of the connecting circuit, the operator throws the Dial Answer key and the Speak key of the connecting circuit. Relays SK, SL and DA operate and complete the circuit for the driving magnet of the finder switch which steps off normal and hunts for a free switch in the revertive trunk selector group. When a free outlet is found, relay T operates, cuts the drive, and energizes relay TA. This switches the connecting circuit through to the revertive trunk selector and relays CG, B and AS operate in series over the P-wire. Subsequent operations over this circuit are similar to those described for the calling side of the connecting circuit.

The same connecting circuit is used for all classes of call except those requiring repeater assistance.

Bothway Trunk Line Circuit. (Fig. **8**).

All trunk circuits are connected to the banks of the trunk selectors and to the distribution switches *via* suitable relay-sets. A typical relay-set is that for a bothway generator signalling trunk.

In this case, the ringing current from the distant exchange operates relay L, causing the switch to step off normal. The switch then hunts for the marked

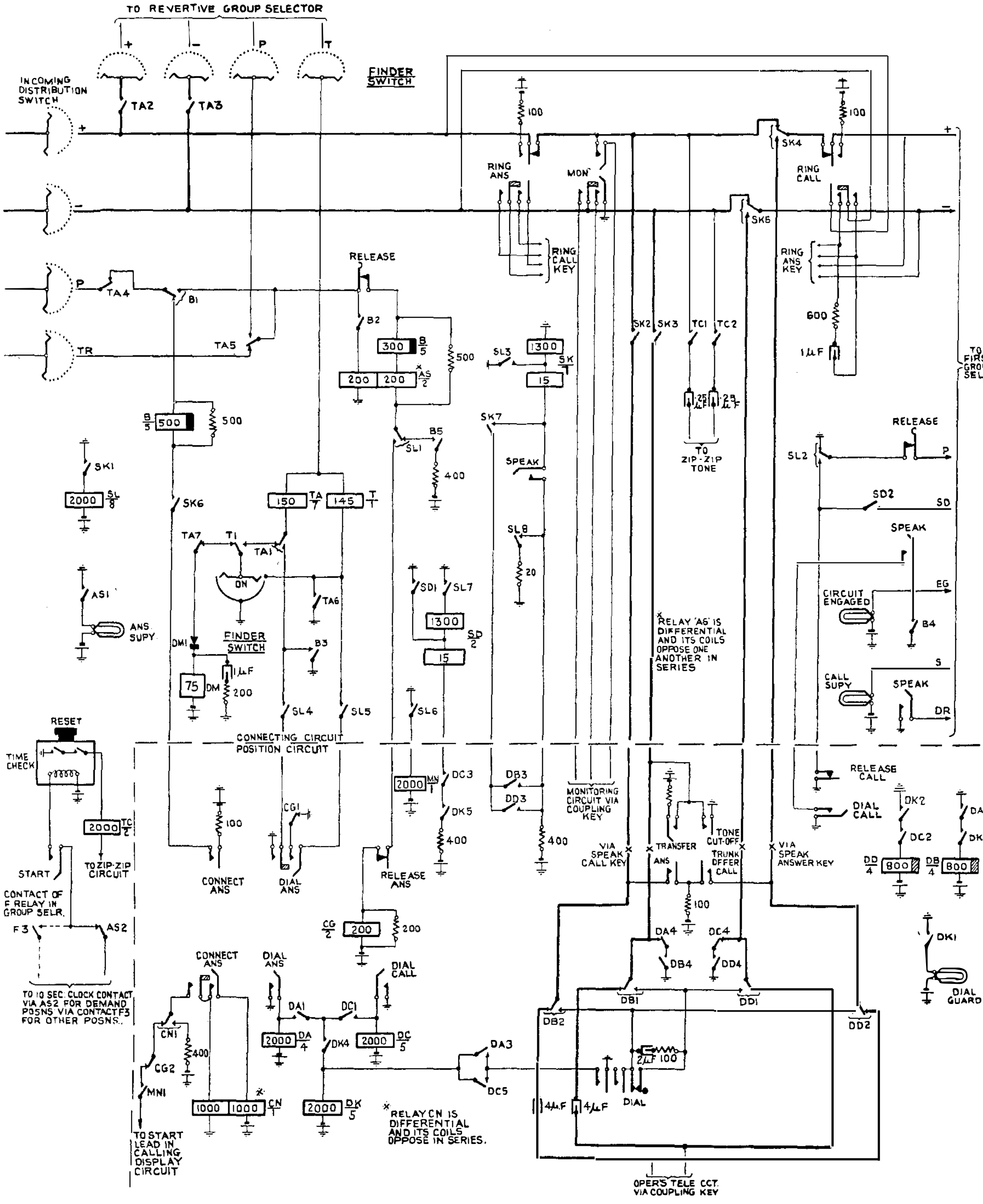

FIG. 7.—CONNECTING CIRCUIT AND POSITION CIRCUIT.

contact connected to the calling lamp display. Here the call is lined up in a manner similar to that described for the demand circuit and is connected to a connecting circuit in its turn. If the call is to be timed at the incoming trunk exchange, tone is fed to the operator to advise her and is removed by the operation of relay TCO when she throws her Tone Cut Off key.

Should the distant exchange wish to call in the incoming operator on a set up connexion, she applies ringing current to the line and the re-operation of relay L operates relay Z, which holds *via* its own contact. Z3 causes relay LF to be intermittently operated and thus intermittently short circuit the coil of relay DR in the P-wire circuit to the connecting circuit, causing the answering supervisory lamp in the connecting circuit to flicker. When the incoming operator answers the operation of her Speak key in-

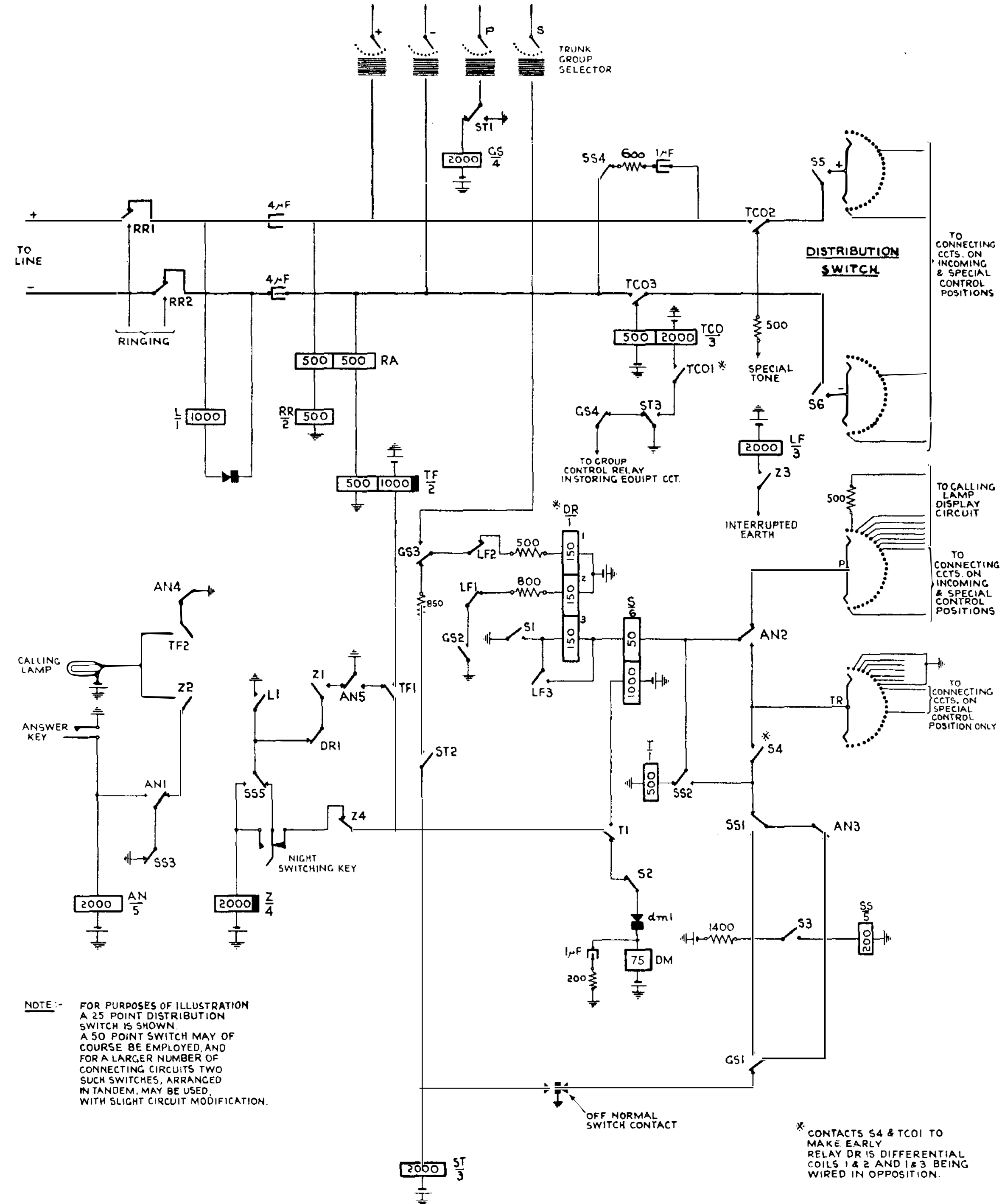

FIG. 8.—BOTHWAY TRUNK LINE CIRCUIT.

creases the current in the P-wire and causes the operation of relay DR upon the first release of relay LF; DR releases relay Z.

At the completion of conversation, relay S is released from the connecting circuit, the switch drives home to normal, and all relays release.

When the circuit is engaged from the trunk group selector for an outgoing call, relay GS is energized and operates relay SS. When the operator throws her ringing key, relay RR is energized and connects ringing current to the line. Ring back signals from the distant exchange to call in the operator at the outgoing end cause the flicker signal to be passed back *via* the S lead to the connecting circuit due to the operation of relays Z and LF as described above for an incoming call.

If desired, a call on this circuit can be transferred from an incoming to a special control position. This is accomplished by throwing a transfer key in the position circuit of the incoming position. Under this condition, relay TF is operated and causes the individual calling lamp on the special control position to glow. The operator on this position depresses the associated Answer key and throws the Speak key of one of her connecting circuits. This causes the distribution switch to release from the incoming position, restore to normal, and re-hunt for the marked connecting circuit on the special control position.

Under night conditions, the Night Switching keys are thrown and each trunk circuit calls on its individual calling lamp on the special control position.

Call Storage Equipment. (Fig. **9**).

If all the trunks in a group are engaged, the relative GP relay is operated since all short circuiting

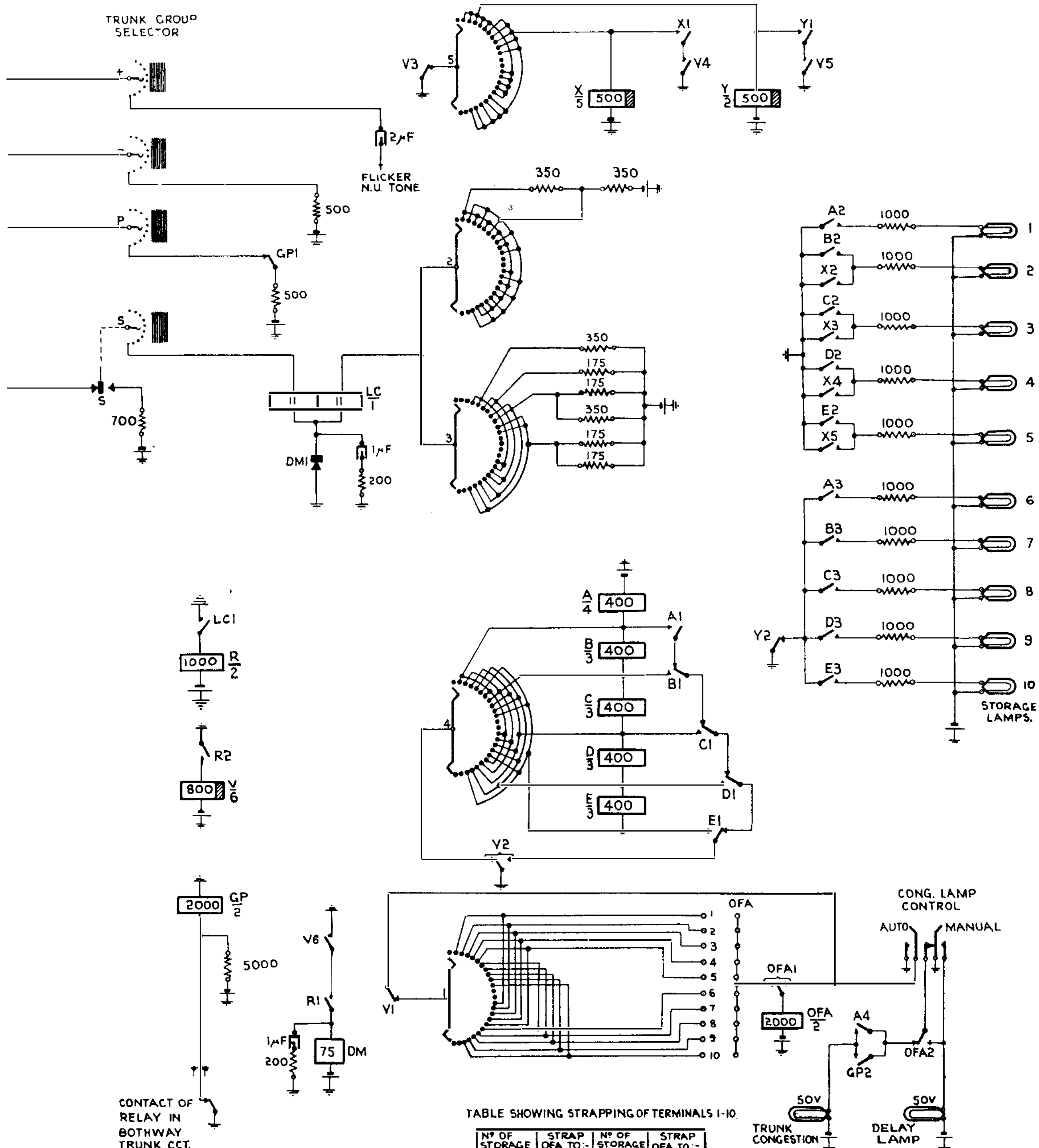

TABLE SHOWING STRAPPING OF TERMINALS 1-10.

Nº OF STORAGE LAMPS	STRAP OFA TO:-	Nº OF STORAGE LAMPS	STRAP OFA TO:-
1	1 - 10	6	6-10
2	2 - 10	7	7-10
3	3 - 10	8	8 - 10
4	4 - 10	9	9-10
5	5 - 10	10	10

FIG. 9.—CIRCUIT OF CALL STORAGE EQUIPMENT.

earths from the trunk relay-sets are removed. If a further trunk selector endeavours to find a free outlet in the group, it will rotate to the eleventh contact causing the operation of relay LC. Relays R and V operate in turn and complete the circuit for the uniselector driving magnet, the contacts of which open and release relay LC; LC releases R and the magnet circuit is broken. Relay V also releases and the switch steps once. The circuits are now completed for both windings of relay LC and as these are connected differentially and each winding is connected to a 700-ohm battery, the relay does not operate. Relays A and Y operate *via* the fourth and fifth wipers of the uniselector and light the first of the storage lamps.

A further selector driving to the eleventh contact will place another 700-ohm coil in parallel *via* the S-wiper to one coil of relay LC, thus reducing the resistance in this circuit to 350 ohms. The resultant unbalance between the two windings of relay LC causes it to operate and the uniselector steps once as in the case of the first overflow call. On the third contact, 350 ohms resistance to battery is connected to the second winding of LC, thus restoring the balance between the windings, and LC releases.

Similar conditions obtain for each subsequent call arriving on the eleventh contact, and each time the uniselector steps once. The position of its wipers therefore indicates the number of calls waiting and relays A-E in conjunction with relays X and Y light the corresponding lamp on the Supervisor's desk.

When a trunk becomes free, relay GP is released. This connects battery to the P-wire of all waiting selectors and operates a relay in each of these switches, causing a flashing signal to be sent back to the trunk board. When the first operator throws her Speak key, the rotary release of the associated selector is actuated and the selector then re-hunts for the disengaged line.

Should any of the waiting selectors be released before a trunk has become free, the removal of its 700-ohm coil will unbalance relay LC, which operates and completes the driving circuit of the uniselector. This switch drives until the correct resistance to restore the balance has been found.

In addition to the Storage lamps, Congestion and Delay lamps are provided and are multipled over the switchboard positions. The congestion lamp of each group is controlled from the GP relay and glows when all circuits in the group are engaged. The delay lamp can be controlled either automatically or manually and indicates to the operator that calls to a particular route should be ticketed and passed to the delay position. If the delay lamp is arranged to glow automatically, it is controlled by relay OFA which operates when a pre-determined number of calls is waiting.

Long Distance Positions.

The long distance trunks do not call in the common calling lamp display, but have individual calling lamps which appear on all the long distance positions. The method of working is similar to that described for special control working.

The connecting circuits on the long distance positions are divided, some ordinary and some repeater circuits being provided. The latter are connected with repeaters and with special repeater trunk selectors *via* which are obtained both the trunks suitable for repeater working and their associated balances. A special feature is incorporated in these selectors which allows the switch to camp on an engaged trunk. When the line becomes free, the throwing of the Speak key in the connecting circuit will complete the connexion.

The repeater connecting circuits provide general facilities similar to the ordinary connecting circuit and also include a gain control key by means of which the operator can control the degree of amplification applied.

Advantages.

The most important of the advantages offered by this type of board over the trunk board used in this country is that of being able to store calls for any group of trunk lines and receive a signal as soon as a line in that group becomes free. It is found in Capetown that the average time a call remains in the storage equipment is 2.2 minutes and that, in such cases, the average time taken to seize a line after it has become free is 1.8 seconds. This illustrates that the call storage equipment is of considerable assistance in obtaining the maximum use out of a heavily loaded group of trunk lines. An equally important feature is that the operator is saved the distraction of having to watch a group of idle circuit indicating lamps for an average period of 2.2 minutes, which would occur each time she was unable to obtain immediately a free line under a manual system.

Most of the other advantages, such as the concentration of calling signals, the absence of a multiple, the control of all calls from keys on the key shelf, etc., result in a reduction in operating fatigue and cause a consequent increase in operating efficiency.

Against the advantages must be weighed the disadvantage of increased cost of the equipment.

Acknowledgments.

The author wishes to acknowledge his indebtedness to the Chief Engineer of the South African Post Office for the supply of information and for permission to publish this article, and to Messrs. Siemens Bros. for the supply of the illustrations.

Broadcast Interference Investigation— "Post Office Radio Service"

A. C. WARREN, B.Sc.

A FLEET of light vans, labelled "Post Office Radio Service," now patrols the country as guardians of the ether. This article describes the growth of electrical interference leading to the provision of those vans and the way in which the staff who man them is equipped for the tracing and suppression of interference with broadcast reception.

Introductory.

The growth of broadcasting in this country has been very rapid, the number of licenses increasing from 60,000 in 1923 to 2,600,000 in 1928 and to practically 7 million in 1934. This growth is due largely to the vast improvements in receiver design and to the increase in power and quality of transmitting stations.

Receivers have advanced by rapid strides from the early crystal set with headphones or simple detector with L.F. amplifier and horn type loud-speaker, to the modern all-mains radio gramophone of superheterodyne type with automatic volume control and moving-coil loud-speakers. The popularity of all-mains sets has undoubtedly been brought about by the increased use of electricity supply for lighting and domestic power.

Recent years may truly be described as the commencement of the Electric Age. Domestic appliances such as fans, vacuum cleaners, refrigerators, washing machines, sewing machines, ultra violet ray apparatus, etc., have a place in almost every modern labour-saving house. Electric motors are also fitted to almost every labour-saving device employed by tradespeople and in industry.

The introduction of the grid system has led to the conversion of many distribution systems from D.C. to A.C., but in others D.C. has been retained, conversion of A.C. to D.C. in bulk being obtained by the introduction of mercury arc rectifiers.

All these devices, and others besides, give rise to radio frequency disturbances which are propagated through the ether or along the supply mains and give rise to interference with radio reception. The extent of such interference naturally varies with (*a*) the strength of signal used in radio reception; (*b*) the extent to which receivers are fed from the supply mains; (*c*) the use of electrical appliances which cause interference, and (*d*) the area covered by the supply mains or other medium through which the interference is propagated. All these features have, in recent years, contributed in such a way that electrical interference with broadcast reception has increased, until at the present time as many as 10% of the listeners are, or have recently been, affected by it.

The following paragraphs set out briefly the manner in which the Post Office has tackled the problem on behalf of both listener and plant owner, and particularly the way in which the growth of interference complaints has been met.

The Post Office Service to Broadcast Listeners.

The Post Office, as the authority in Great Britain and N. Ireland responsible for the administration of the Telegraph and Wireless Telegraph Acts, is the sole authority empowered to issue licences for wireless transmission and reception. As such it endeavours to protect the interests of its licensees, whether these are companies operating commercial radio telegraph services or broadcast listeners. Thus the Post Office undertakes to investigate all complaints of electrical, oscillation, or morse interference.

The last two types of interference are caused by licensees and the Postmaster-General has powers to compel them to eliminate any interference due to their equipment. In the case of electrical interference the Postmaster-General has no power to compel owners of electrical plant to eliminate such interference, but can only investigate and trace it with a view to securing its elimination through the goodwill of the owner of the plant.

The actual work of investigation of complaints and negotiations with plant owners is undertaken by the Engineering Department.

This problem has now become of such importance that in 1933 the I.E.E. appointed a committee to examine the question with a view to alleviating the position. Such widespread interests as the following are represented on this Committee:—Central Electricity Board, Incorporated Association of Electric Power Companies, Railway Companies Association, Municipal Tramways and Transport Companies Association, B.E.A.M.A., B.E.A.I.R.A., Radio Manufacturers & Retailers Associations, the B.B.C., and the G.P.O. Pending the acceptance of the reports of this committee and the putting into force of its recommendations the Post Office must continue its service on behalf of listeners who make complaints.

To facilitate the registering of a complaint a questionnaire system was introduced, these forms being issued by the B.B.C. or the Engineer-in-Chief of the Post Office. This arrangement involved considerable clerical work and in October, 1933, questionnaire forms were made available at Post Offices, the address of the local Sectional Engineer to whom they were to be returned being printed thereon.

The Growth of Broadcast Interference.

Not only has the modern listener a wide range of powerful stations which his receiver permits him to select, but he is now able to enjoy a quality of reproduction which surpasses anything that he could have hoped to obtain a few years ago. Thus electrical interference which would scarcely have degraded reception five years ago is regarded as intolerable to-day.

At the same time improvements in receiver design have been such that interference due to oscillation has decreased.

These tendencies are well shown by the following figures :—

Year ended 31st Dec.	*Licences.*	*Electrical Interference Cases.*	*Oscillation Cases.*
1931	4,329,000	8,570	4,150
1932	5,263,000	12,150	4,390
1933	5,974,000	17,910	3,110
1934	6,850,000	34,500	2,500

The figures are influenced by the publicity given to the Post Office service, but clearly indicate the increased extent of interference and intolerance of the listener. Each case may represent one or even hundreds of affected listeners, so that it is safe to say that at the present time at least a quarter of a million listeners are affected by electrical interference.

Organisation for the Investigation of Interference.

In the past the work has been undertaken by workmen in the districts on overtime or on a part time basis. In some instances men would handle only a few cases per annum, their sole training being that obtained from brief technical instructions or workmen's pamphlets. The extent of the work was such that full time officers were not justified except in concentrated areas as London. The rapid growth in the last two or three years has justified the introduction of full time staff. A complete reorganisation was initiated in 1933 and is briefly as follows :—

The Engineer-in-Chief's Office undertakes the co-ordination of the work of the districts, collection of data, development of suppression devices and testing equipment, preparation of technical instructions, staff training, co-operation with manufacturers, etc.

In the Districts one or more Wireless Investigation Enquiry Officers are located in each Engineering Section. The senior men are full time officers, their assistants being full time or part time as necessary. The work, which is mainly received directly in the Sectional Engineer's office and issued to the men, is co-ordinated from District Headquarters, the necessary supervision and assistance being given to Sections for the clearance of difficult cases. Major and difficult cases requiring prolonged investigation circulate to the Engineer-in-Chief and to assist in their treatment a special organisation has been set up. The country is divided into three zones, South East England, Western England and N. Ireland and Eastern England and Scotland; co-operation with the districts embraced in these zones is maintained by officers who visit the districts periodically for the purpose of giving assistance.

With the introduction of this new organisation a complete scheme of staff training for both workmen and supervising officers was introduced in November, 1933. Each officer engaged on the work receives one month's training at Dollis Hill Training School, the course including elementary radio theory, interference investigation—technical and procedure and licence enquiries. Already more than 200 men have successfully passed through this school.

Technical instructions have been completely re-written and issued as a new series in such a form that they meet the demands of both workmen and supervising officers.

Each enquiry officer services a considerable area and utilises a varied stock of testing equipment. To facilitate the work, light vans have been provided in the last few months. At the present time 75 vans are in use and it is anticipated that the number will be increased to 100 before next winter.

Provision of Testing Equipment.

In the early days of interference investigation, no special equipment was available for tests on interfering plant, such items as condensers and resistances being requisitioned from the Stores Department and tried out. Coils were wound by taking a certain length of wire or cable and winding it as a hank of a given diameter. Gradually condenser units were developed and portable receivers provided for tracing interference.

The suppression of interference frequently necessitates the fitting of filters to offending plant, or to the complainant's supply mains. Such filters may consist of condensers, chokes, chokes and condensers, or resistances and condensers. No standard suppression device can be quoted for a given case if economy is to be considered. Interfering sources may vary from devices carrying a few milliamperes to items of power equipment carrying hundreds of amperes. It is necessary, therefore, for enquiry officers to carry a considerable amount of apparatus. In order to facilitate the work special testing units have been developed permitting the rapid trial of a wide variety of filter arrangements. These units include condensers and inductors covering a complete range from 3 to 100 amperes. (Inductors R.F. 1A to 6A, Fig. 1).

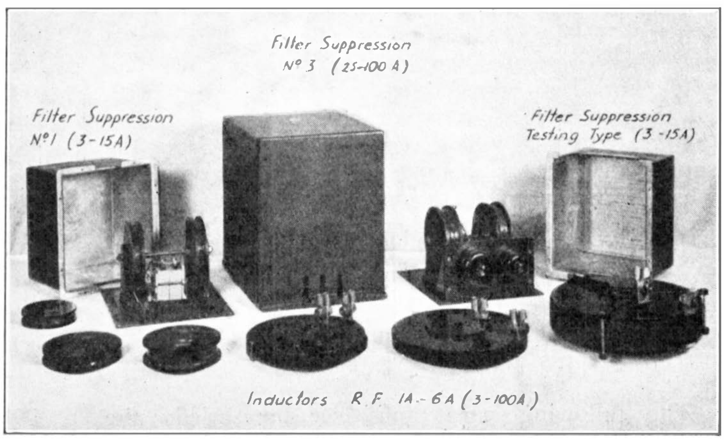

Fig. 1.—Filter Testing Equipment.

Tests are conducted employing these units and the appropriate filter is specified to the plant owner or complainant. Filters have been designed and stocks provided for sale to the public. It is interesting to note that several radio manufacturers have adopted these designs of suppression units and are now marketing them. In addition special items such as high current inductors, trolley bus suppressors, etc., have been designed and are held by the Engineer-in-Chief.

For tracing interference,, ordinary portable broadcast receivers of various types have been employed in the past, but with modern development the later patterns of these receivers have increased in weight to such an extent that they can no longer be regarded as easily portable. To facilitate the location of interference a special receiver termed an interference locator has been designed. It is essentially a superheterodyne receiver, with pick-up by search coil or aerial, and with headphone or loud-speaker reception. The weight has been reduced as far as possible and does not exceed 30 lbs., and the sensitivity is as high as the average 5 or 6 valve super-heterodyne receiver. On the search coil, full loudspeaker output is obtained on a signal of 50 microvolts per metre. Photographs of this receiver are shown in Figs. **2** and **3**.

Other items of testing equipment are provided so that the complete equipment of an enquiry officer includes :— interference locator, units condenser, filters suppression-testing type, inductors R.F. 1A-6A, resistance spools, screened down leads, detector, megger, hand lamp, etc. This equipment is housed in specially designed compartments in a cupboard fitted in the van as shown in Fig. **4**.

Development and Research.

All testing apparatus which has been developed has been thoroughly tested out in the Radio Section laboratories at Dollis Hill. Suppression items have been developed for domestic equipment such as hair driers, sewing machines, vacuum cleaners, incubators, flashing and neon signs, and the efficiency of T.C.C., Muirhead, and Belling Lee suppression devices, Metropolitan Vickers and English Electric trolley bus coils, etc., has been measured.

Double Wave trolley bus coils have been developed both by Messrs. Metro-

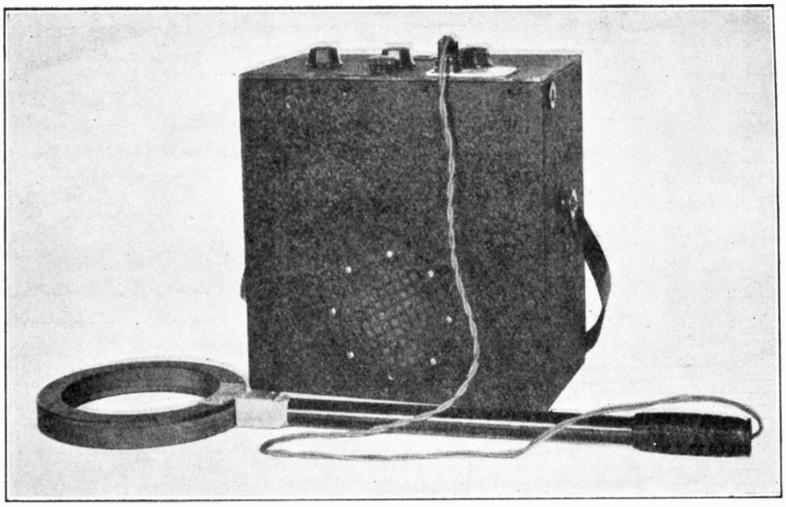

FIG. 2.—PORTABLE RECEIVER WITH SEARCH COIL.

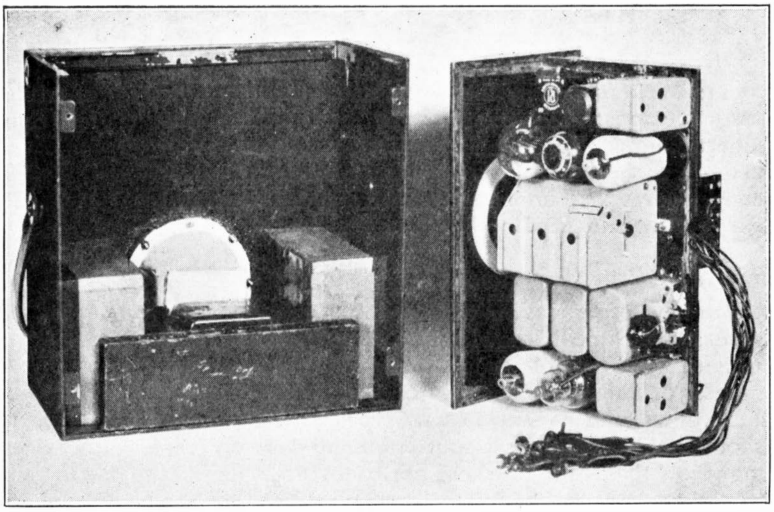

FIG. 3.—PORTABLE RECEIVER—REAR VIEW.

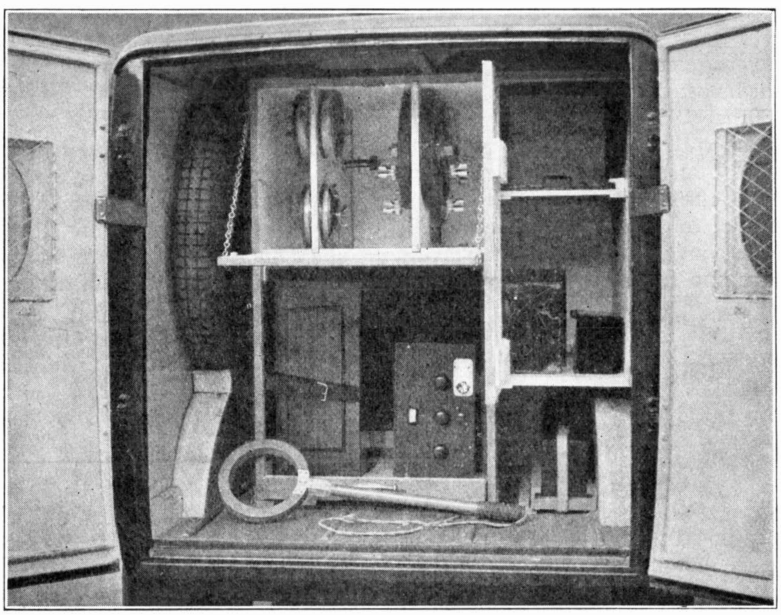

FIG. 4.—REAR VIEW OF VAN SHOWING TESTING EQUIPMENT.

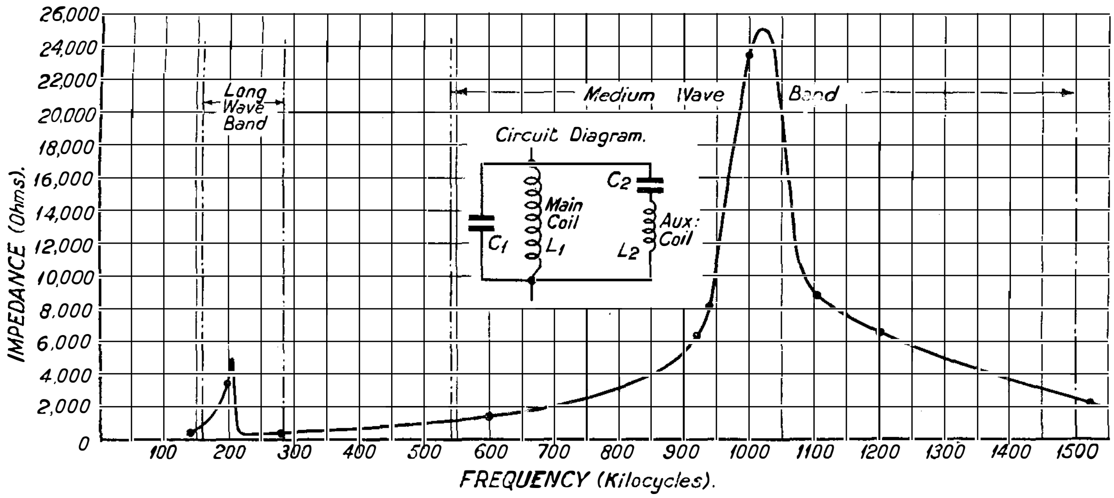

FIG. 5.—TYPICAL IMPEDANCE-FREQUENCY CURVE OF A SUPPRESSION COIL.

politan Vickers and by the Department and are now being demonstrated to tramway and trolley bus undertakings. These coils afford suppression on medium waves and on the long wave National wavelength. A typical impedance curve of a departmental coil is shown in Fig. **5**.

Effects of Reorganisation.

The new organisation with changes in personnel, increased technical knowledge due to training, and technical instructions, the introduction of new equipment and transport, has not had sufficient time to settle down and to show what increase in efficiency is obtainable, but it is apparent to all actively engaged on the work that the clearance of cases has been materially speeded up. Ninety per cent. of the cases are cleared in two months, including negotiation and payment and in such cases the actual interference is frequently cleared in a few days.

Fig. **6** shows the number of cases handled and the average cost per case expressed as a percentage above or below the average for the quarter ended September 30th, 1933, for three monthly periods. The full time staff and training were introduced at the end of that quarter and it will be observed that prior to that date the average cost was 100% whereas it has now fallen to a figure well below 80%. This last figure does not include the cost of training since such costs are non-recurrent, but even including the whole cost of training the average costs for 1934 would still be less than 90% of those for 1932 and 1933.

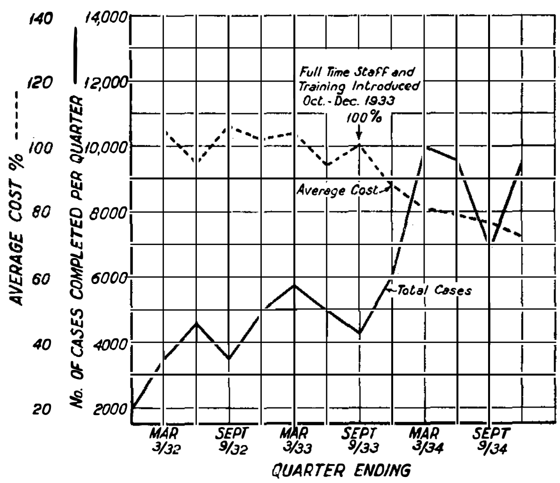

FIG. 6.—NUMBER OF CASES DEALT WITH AND AVERAGE COST.

This improvement augurs well for the future and is a striking tribute to the enthusiastic manner in which officers used only to the handling of telephone and telegraph equipment have devoted themselves to an entirely new development and have kept abreast of an ever growing load of work.

The Valveless Differential Echo-Suppressor

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

ABSTRACT.

A NEW form of echo-suppressor is described in which echo-suppression is effected by introducing variable attenuation networks in the " go " and " return " signal paths. The network attenuations are controlled by a steady current flowing through them in such a manner that when the attenuation of one network increases, the attenuation of the other network tends to decrease.

Very short operating times are obtained, together with constant hang-over times, independent of the input level. The suppressor is practically immune from false operation troubles, and it can be applied to 2-wire circuits and at the ends of 4-wire circuits, as well as at an intermediate point.

This echo suppressor is now under trial by the Department.

GENERAL PRINCIPLE OF THE ECHO-SUPPRESSOR OPERATION.

The echo-suppressor consists essentially of two variable attenuation networks connected in the " go " and " return " circuits respectively, the attenuations of which are changed by a common control current. With the control current normal, *i.e.*, in the quiescent state, the networks have only small attenuations so that both the " go " and " return " circuits are open to pass signals without appreciable loss. A signal applied to the " go " circuit unbalances a D.C. bridge from which the network control current is derived and produces a change in the control current. This increases the attenuation of the network in the " return " circuit and at the same time tends to reduce the low attenuation of the network in the " go " circuit. The reverse effect occurs when a signal is applied to the " return " circuit. The differential nature of the control current operation ensures that it is impossible to operate both sides of the echo-suppressor simultaneously.

The echo-suppressor can be divided into three separate circuit arrangements :—

(*a*) The variable attenuation networks controlled by a common direct current.

(*b*) The D.C. bridge from which the control current is derived and which is unbalanced by rectified A.C. signals from either the " go " or " return " circuits.

(*c*) The signal rectifier circuit from which the grid bias voltage is derived.

THE VARIABLE ATTENUATION NETWORK.

This consists of rectifier elements arranged in series and shunt in the speech transmission circuit. " Unbalanced " and " balanced " types of networks that have been found suitable as a switch are shown in Figs 1 (A) and (B). The cuprous oxide rectifier, having a maximum current rating of 10 milliamps,

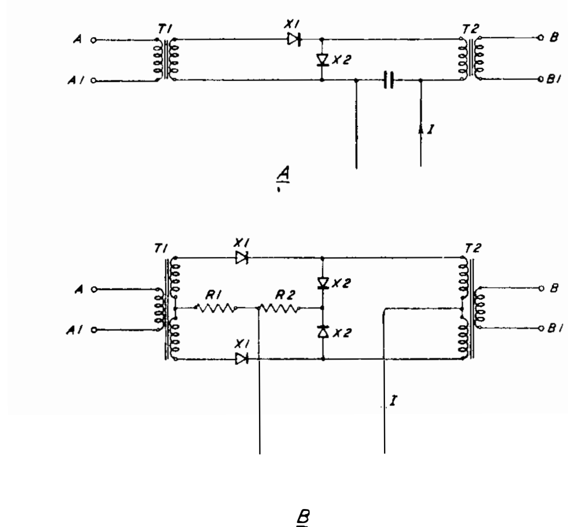

FIG. 1.—UNBALANCED AND BALANCED TYPES OF RECTIFIER ATTENUATION NETWORKS.

has been found very satisfactory, and the static resistance-current characteristics of such a rectifier element are shown in Figs. 2 and 3. The A.C.

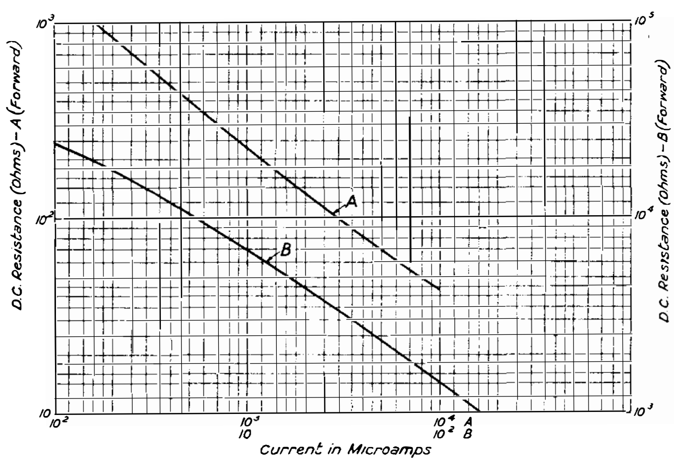

FIG. 2.—D.C. RESISTANCE-CURRENT CHARACTERISTIC OF RECTIFIER ELEMENT, FORWARD.

resistance of the rectifier with steady current superimposed is the slope of the D.C. voltage-current characteristic at that value of the steady superimposed current. The capacity of the rectifier element (Fig. 5), which is between 2,000 and 5,000 micro-micro-farads in the case of the 10 milliamp or " H " type rectifier, is shunted across this A.C. resistance. The

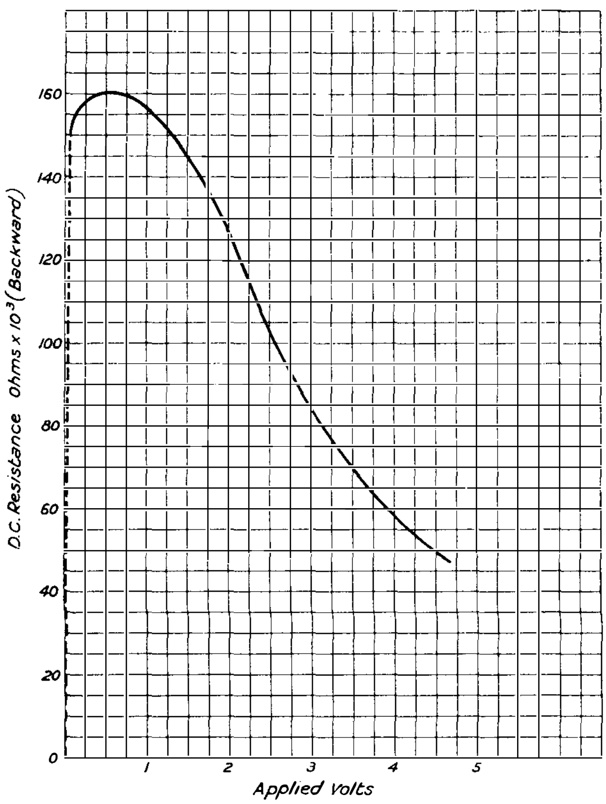

FIG. 3.—D.C. RESISTANCE—APPLIED VOLTS CHARACTERISTIC OF RECTIFIER ELEMENT, BACKWARD.

effect of this capacity is only important in relation to the " backward " impedance of the rectifier. Fig. 4 shows the low A.C. impedance of a typical rectifier element over the range of variation of steady " control " current from 0 to 10 milliamps, whilst Fig. 5 shows the corresponding high A.C. impedance with the steady reverse applied voltage varied from 0 to 5 volts.

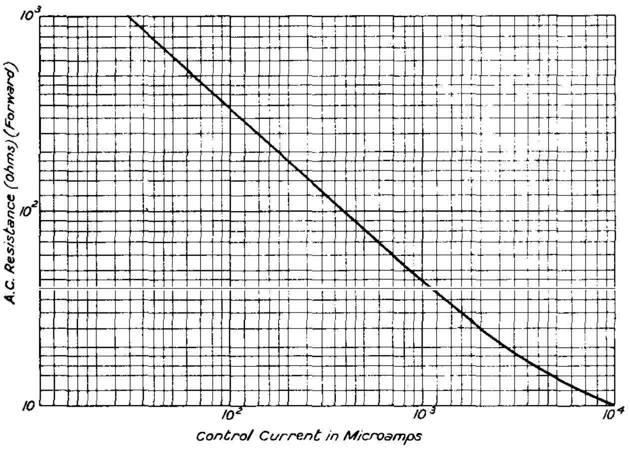

FIG. 4.—A.C. RESISTANCE-CURRENT CHARACTERISTIC OF RECTIFIER ELEMENT, FORWARD.

The Operation of the Attenuation Network.

Referring to Fig. 1, when the steady control current I flows in the direction shown, the impedance

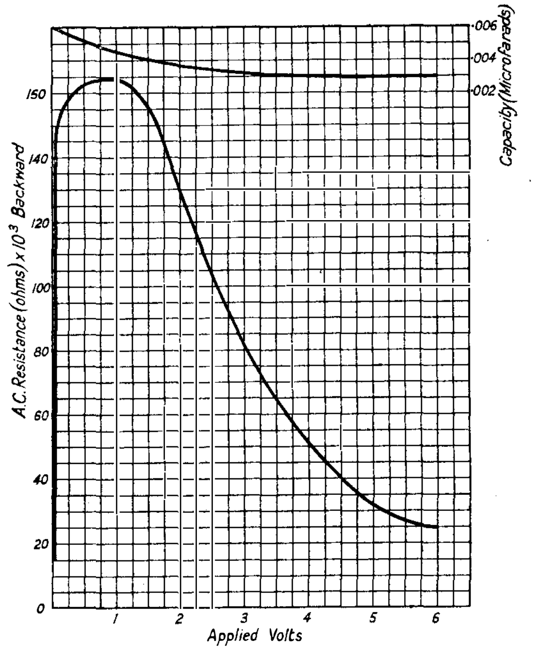

FIG. 5.—A.C. RESISTANCE AND CAPACITY—APPLIED VOLTS CHARACTERISTIC OF RECTIFIER ELEMENT, BACKWARD.

of the series rectifier elements X1 is high, and that of the shunt elements X2 is low so that the attenuation between the points AA1 and BB1 is large. If the control current is reversed the series elements X1 become low and the shunt elements X2 become high impedance and the attenuation of the network is small. The main change in attenuation occurs when the control current is at or near zero. The attenuation-control current characteristic for small A.C. signals, using the balanced network (Fig. 1, B), is shown in Fig. 6, curve A. The attenuation characteristic with small control currents is shown on an enlarged scale in curve B.

" Balanced " and " Unbalanced " Attenuation Networks.

Since, for a balanced network only one half of the control current flows through each side of the network, the change of attenuation for a given change of control current is less rapid than with the unbalanced type. However, the windings of the transformers T1 and T2 are non-inductive to the balanced control current so that the time of operation is reduced as compared with the unbalanced type. Also any change in the control current is not passed into the main transmission circuit. The non-linear distortion produced by a network in the transmitting range is less with a balanced than with an unbalanced type, and the former type is therefore preferable.

The Shape of the Attenuation-Control Current Characteristic.

The optimum characteristic for a network operating as a switch is one in which the attenuation is zero with all control currents below a certain value and infinite or very large with all control currents above this value. The shape of the attenuation control current characteristic depends on the impedance attenuation networks. The attenuation-control current characteristics shown in Fig. **6** were obtained with the A.C. signal applied to the network small as compared with the D.C. control current. The instantaneous current and voltage applied to the rectifier elements is the sum of the D.C. and A.C. components and therefore, for satisfactory operation, the D.C. must be large compared with the A.C. For use as an echo-suppressor, the attenuation network can be inserted in the circuit on the input side of a repeater and the A.C. signal kept small. The input level to the repeater can be adjusted to − 10 decibels or less referred to the terminal input level so that the maximum level of the signal is approximately − 5 decibels referred to a 1 milliwatt level. The steady voltage applied across the shunt rectifiers when a control current of less than 4.0 milliamp is fed into the network to pass through the series elements, is insufficient to ensure that the shunt resistance of the rectifiers is always high and the resultant attenuation characteristic of the rectifier network is as shown in Fig. **8**, dotted

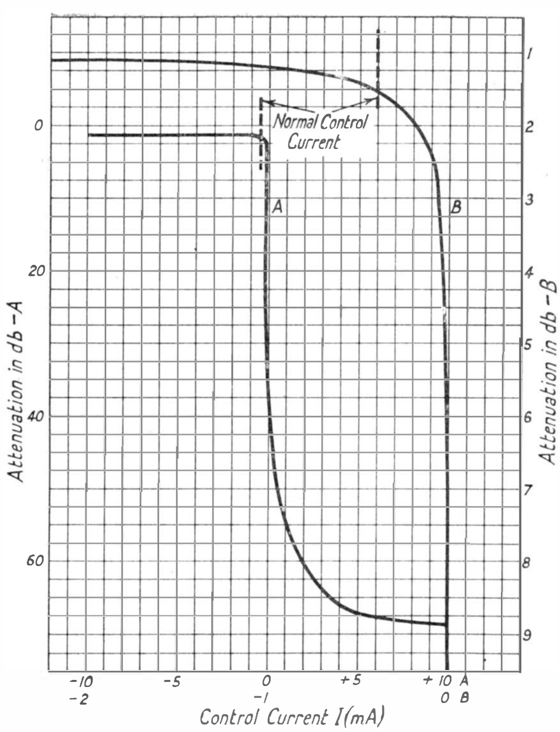

Fig. 6.—Attenuation-Control Current Characteristic of Balanced Network.

of the transmission path associated with the network, together with the size and number of the rectifier elements in the shunt and series arms. The normal maximum current rating of the rectifier should not be greatly in excess of the maximum control current that will flow through it. The impedance of the series elements in the low attenuation condition in relation to the impedance of the associated transmission path should be small, whilst the impedance of the shunt elements should be correspondingly large. In practice single element rectifier units of the " H " or 10 mA type for both series and shunt elements, have been found most satisfactory. A special rectifier unit, see Fig. **7**, has been designed by Messrs. Westinghouse Brake & Saxby Signal Co., Ltd., in conjunction with the Post Office Research Station and accommodates two complete balanced

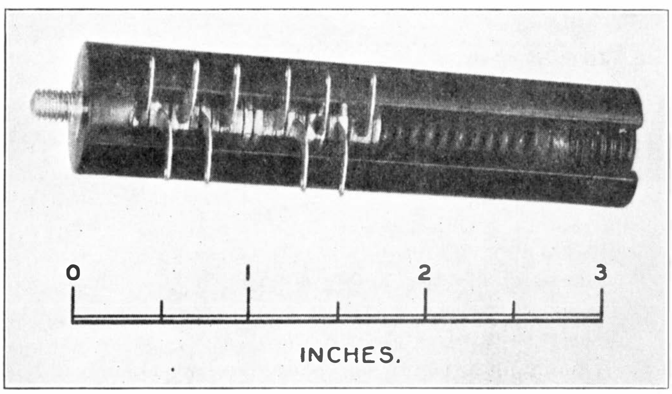

Fig. 7.—Rectifier Unit.

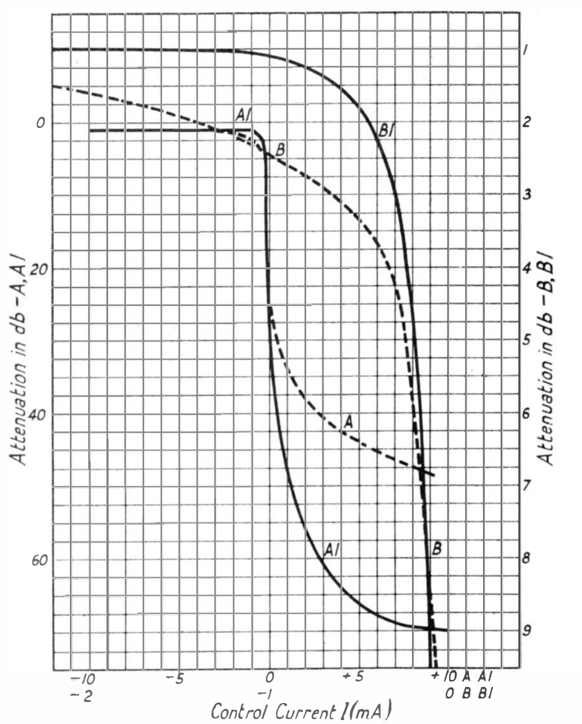

Fig. 8.—Attenuation-Control Current Characteristics.

curve A. Attenuation accompanied by amplitude distortion is being introduced. The introduction of a resistance R_1 of 200 ohms into the control current path (Fig. **1**, Network B) increases the steady voltage across the shunt rectifiers, so that the shunt loss remains small and the resultant attenuation-control current characteristic, when the network is transmitting, is shown in curve A1.

The non-linear distortion, with a control current of 4.0 milliamps, is so small that the harmonic introduced into the signal is less than 65 decibels below the level of the main signal. Since a signal of this amplitude incoming to the repeater will fully load the output valve under normal operating conditions[1] so that the harmonic distortion introduced by the valve is approximately 30 decibels below the level of the main signal, the distortion introduced by the attenuation network is absolutely negligible.

The attenuation of the network with input signals of -5 decibels referred to 1 milliwatt is limited to about 45 decibels (Fig. **8**, dotted curve A), but this is adequate for satisfactory echo-suppression. If, however, a greater attenuation is desired, a resistance R_2 of 200 ohms introduced into the control current path (Fig. **1**, B), increases the steady backward voltage applied across the series elements so that it is greater than the applied A.C. signal voltage and the resultant network attenuation characteristic is shown in Fig. **8** (full curve A1). The attenuation characteristics with small control currents are shown on an enlarged scale in curves B, B1, corresponding to portions of the curves A, A1, on the complete characteristics.

The D.C. Bridge for the Control Current Derivation.

The network control current is derived from a differential bridge circuit associated with the anode circuits of two valves. The arrangement is shown in Fig. **9**. The resistances 1 and 2 and the D.C. anode impedances of the valves 3 and 4 form the four arms of a D.C. bridge of which the anode battery is the supply voltage. The normal currents that flow through the attenuation networks 5 and 6 through the resistance 9, are made equal by adjusting the value of resistance 1 to balance the bridge. These currents are of such a magnitude that the networks have a low attenuation, but require only a small change of control current to increase the attenuation.

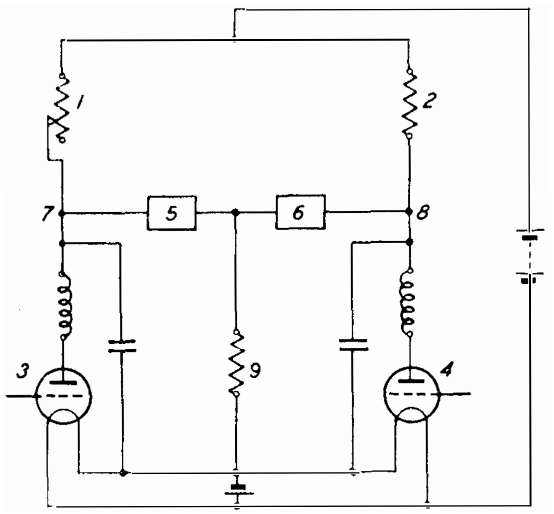

FIG. 9.—D.C. BRIDGE FOR CONTROL CURRENT DERIVATION.

[1] The signal level applied to the input of the repeater associated with the echo-suppressor is not greater than -10 db. and the output level is $+10$ db. referred to the terminal 2-wire level.

The valves 3 and 4 are the associated repeater output valves and since A.C. signals are only transmitted through one of these valves at a time (for when the " go " amplifier is transmitting signals the " return " path is disabled, and *vice versa*), the grid bias voltage of the valve that is not transmitting A.C. signals, is decreased to cause the bridge to become unbalanced.

When an A.C. signal passes through the valve 3, a portion of the signal is rectified and applied to the grid of the valve 4 to cause the grid voltage to become positive and so increase its anode current. The potential of the point 8 with respect to the cathode is reduced and a secondary current from point 7 to point 8 flows through the networks. This increases the normal current in network 5, and is in opposition to the normal current in network 6. These current changes have practically no effect on the attenuation of network 5, but ensure that no distortion will be introduced into the A.C. signal that is being transmitted. They also cause a large increase in the attenuation of network 6, associated with the echo signal path, so preventing the " echo " signal from being transmitted.

The Optimum Values of the Bridge Resistances 1 and 2.

The optimum value of these resistances, which include the resistances of any anode chokes, lamps or alarm relays that may be inserted in the valve anode circuits, to give the maximum control current change for a given grid bias voltage change of either of the valves 3 or 4, depends on the anode impedance of the valves. The following table shows the change of control current resulting from a grid bias voltage change of 1.5 volts for different values of the bridge resistance when valves VT 25 or VT 75 ($\mu = 7$, $Z = 6000$ ohms) are used, and the attenuation networks are as shown in Fig. **10**.

Bridge Resitance (ohms).	Change in Control Current (mA).
500	.32
1000	.44
1500	.51
2000	.55
3000	.58
4000	.59
6000	.58

Whereas the optimum resistance is approximately 4000 ohms, it is not considered advisable to use a value larger than 1400 ohms as any additional sensitivity results in a large loss of anode voltage applied to the valves. Since the resistance of the alarm relays and lamps is approximately 570 ohms, only 800 ohms additional resistance is required, which reduces the effective anode voltage by about 6 volts.

The Operation of the Echo-Suppressor.

The change in grid bias voltage of the D.C. bridge valve 3 (Fig. **9**) is obtained by rectifying a portion of the signal voltage derived from the output of the amplifier valve 4. The complete echo-suppressor circuit and associated repeater is shown in Fig. **10**.

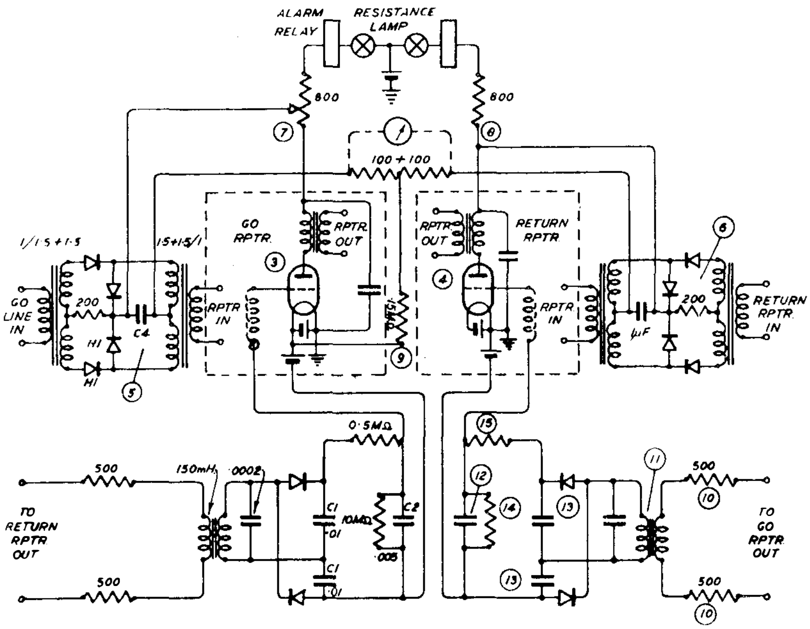

FIG. **10**.—ECHO-SUPPRESSOR AND ASSOCIATED REPEATER CIRCUIT.

The operation is as follows :—

The rectifier network 5 has a low attenuation in the quiescent state due to the control current flowing from the point 7, through the network 5 and the resistance 9 to battery. An A.C. signal incoming from the line, therefore, passes through the rectifier network 5 and is amplified, passing *via* the repeater output to line in the normal manner. At the same time, the output voltage is applied *via* series resistances 10, 10 to a step up transformer 11 which is bluntly tuned to have a maximum impedance at approximately 1000 c.p.s. The signal is rectified and applied across condenser 12 to reduce the negative grid-cathode potential of valve 4. The network control current will now flow from point 7 to point 8 and increase the attenuation of network 6 so that the return " echo " signal cannot pass into the " return " repeaters. When the signal ceases the condensers 12 and 13 discharge through the resistance 14 and the " backward " impedance of the rectifiers. The control current restores to normal so that the attenuation of network 6 becomes low and any signal received from the " return " line can pass through the " return " repeater and operate the echo-suppressor in the reverse direction.

The Signal Rectifier Circuit.

The signal rectifier circuit forms a shunt load on the output of the repeater and the loss is sensibly that due to the total series resistance of 1000 (or 2000) ohms at all frequencies, *i.e.*, 2.2 (or 1.2) decibels, except near the resonant frequency of the transformer when its additional series impedance decreases the loss to 1.0 (or 0.5) decibels. If the input level to the suppressor is above about −10 decibels referred to 1 milliwatt, the transformer is shunted by the increased rectifier load caused by the valve grid current that flows and so the shunt load across the output once more approximates to 1000 (or 2000) ohms. The loss is then increased as the input level to the suppressor increases until, with an input level of about 1 milliwatt, the variation of shunt loss over the frequency range is less than 0.7 decibels in the case of the 1000 ohms series resistance and 0.3 decibels in the case of the 2000 ohms series load.

The harmonic introduced into the repeater output due to the non-linearity of the echo-suppressor shunt load caused by the variations in impedance of the associated signal rectifiers at frequencies between 200 c.p.s. and 3000 c.p.s. and signal levels of −20 decibels to +10 decibels referred to 1 milliwatt, is always at a level of at least 40 decibels and 50 decibels below the level of the main signal voltage when the total resistance in the shunt load circuit is 1000 ohms and 2000 ohms respectively.

The rectifiers used are Westector type WX6, having a backward impedance greater than 10 megohms at 65° F. The condensers 12 and 13 are provided with a discharge resistance (14) of 10 megohms in addition to the backward impedance of the rectifiers, so that the discharge or " hangover " time is not seriously affected by variations of the backward impedance of the WX6 rectifiers due to temperature variations.

The rectified signal voltage applied to the grid circuit of the complementary repeater requires to be smoothed to prevent the A.C. component of the rectified signal from being amplified and passing out into the transmission circuit. With a decoupling resistance (15) of 0.5 megohm, the maximum level of this cross-talk signal is about 40 decibels below the level of the speech signals applied to the echo-suppressor input.

The time the suppressor remains operative after the signal ceases depends on the value of the condensers 12 and 13 in conjunction with the discharge resistance. The hangover time is approximately 250 milliseconds, and is independent of the input level of the signal to the suppressor if that level is above about −10 decibels referred to 1 milliwatt, due to the limitation (caused by the grid current) of the D.C. voltage obtained across the condenser 13. This limitation of hangover time is very effective, being inherent in the echo-suppressor design, and is produced without any additional cost or apparatus. It will also be observed that the operation of the echo-suppressor is not caused by reducing any valve anode currents, but rather by increasing them so that any anode current alarms normally associated with the repeater can be retained.

Further Operational Details of the Echo-Suppressor.

The Stability of the Control Current Bridge.

Once the control current bridge has been balanced by adjusting the resistance 1 (Fig. **9**), changes of the control current in the quiescent state are only produced if the anode current of one of the bridge valves changes with respect to the other. Both valves are affected practically to the same extent by supply voltage changes, so that supply voltage changes of at least 20% are necessary before the change in control current exceeds 0.1 milliamps. From observations made on the variation of the anode currents of a number of repeater output valves (P.O. type VT 75; 4v; 0.25 amp, filament; $\mu = 7$ and $Z = 6000$ ohms) over a long period, the change in control current due to this cause is very unlikely to exceed 0.2 milliamps during a period of 6 months with the repeaters in operation continuously (24 hours per day). It is recommended that a check of the control current when the echo-suppressor is not operating should be made every one or two months and any variations greater than 0.1 milliamps should be corrected by adjusting the anode resistance 1.

The balance of the control current is readily checked by connecting a differential milliammeter across the two equal resistances of 100 ohms in the centre of the control current circuit as shown dotted in Fig. **10**.

Since a resistance of 10 megohms is connected between the grid of each of the second stage valves of the repeater and the corresponding grid bias points, it is essential that the valve grid-cathode resistance and the insulation resistance between the windings of the intervalve transformer should be nominally infinity, or well above 1000 megohms.

The Normal Bias Control Currents of the Attenuation Networks.

Referring to Fig. **6**, it is seen that if the normal bias control current is −0.4 milliamps the attenuation is only 0.35 decibels more than the attenuation when the control current is −4.5 milliamps, which is the normal maximum control current when the grid bias voltage of one of the bridge valves is zero. Under this condition the network loss is substantially that due to the transformers associated with the attenuation network. These transformers are required to isolate the attenuation network, which is at the H.T. potential, from the line input to the repeater. If through any cause the control current in the quiescent state changes to −0.1 milliamps (a change of 0.3 milliamps) the network attenuation is only increased by 1.0 decibel. No serious attenuation change occurs until the control current varies more than 0.35 milliamps. A change of control current of 0.54 milliamps produces an attenuation of 30 decibels, which is increased to over 50 decibels for larger control current changes.

The Echo-Suppressor Sensitivity.

A change of control current of 0.54 milliamps to operate the suppressor corresponds to a change of

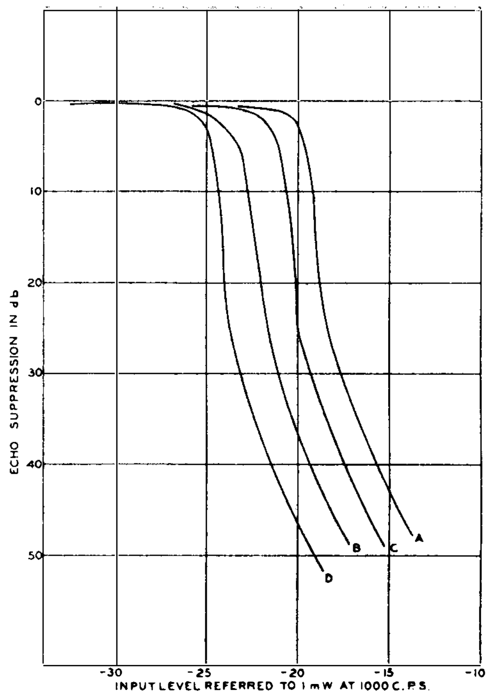

Fig. **11**.—Attenuation-Input Level Characteristic.

anode current of one valve of 1.3 milliamps which is produced by a change of 1.3 grid bias volts of the repeater valve type VT. **25** or VT. **78**. This change is produced by a signal level of −**19** decibels applied to the suppressor input (frequency 1000 c.p.s.). The attenuation-input level characteristic is shown in Fig. **11**, curve C, whilst the sensitivity-frequency characteristic for an echo attenuation of 30 decibels is shown in Fig. **12**, curve C.

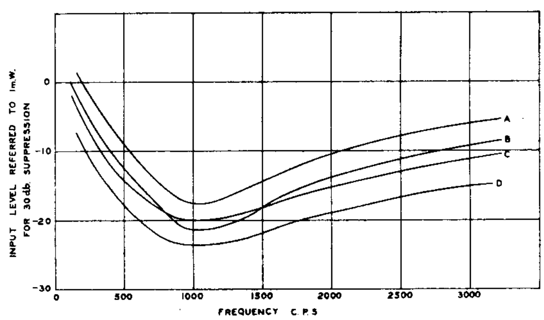

Fig. **12**.—Sensitivity-Frequency Characteristic.

The sensitivity is increased if the mutual conductance of the associated repeater valve is increased. For example, when operated in conjunction with a valve type VT. 81 ($\mu = 12$, $Z = 6000$ ohms) the sensitivity is increased by about 4 decibels as is shown in Fig. **11**, curve D.

The sensitivity obtained when the resistances 10, 10 in series with the transformer 11 are each 1000 ohms is shown in Fig. **11**, curves A and B. The shunt loss across the output of the repeater is decreased to 1.2 decibels.

The corresponding sensitivity-frequency characteristics for a 30 decibel echo attenuation are given in Fig. **12**. The suppressor sensitivity curve is far more constant than that of the grid jamming type, as the relation between the polarising network current and the network attenuation is practically identical for all rectifiers of the type used. This factor is important when liability of false operation on zero attenuation circuits is investigated.

The normal echo-suppressor sensitivity shown in Fig. **11**, curve C, has been found to be adequate for effective echo-suppression on all zero attenuation circuits when the input to the suppressor is obtained from the output of a repeater at a +10 decibel level.

Cross-talk between Halves of Repeaters via the Control Current Circuit.

The only cross-talk that can be detected across the repeater output with the repeater giving maximum gain (40 decibels) is due to the fluctuations of control current in the attenuation network around a mean value of zero control current, and is at least 50 decibels below the output level of the associated repeater. Since it is of a very low frequency, the normal L.F. cut-off of a telephone circuit due to the series condensers and transformers reduces this cross-talk to a very much smaller and entirely negligible level.

Margin against False Operation.

False operation or operation of the complementary suppressor by echo signal currents, which causes clipping of the main signal current, has been found to occur with non-differential type echo-suppressors when operating on zero attenuation circuits. Under these conditions the level of the echo current applied to the complementary echo-suppressor may be practically equal to that of the normal signal current. If the latter current is not quite large enough to cause signal suppression in the complementary circuit and the sensitivity of the complementary suppressor is greater, this suppressor will operate and cause clipping or fading. Unequal or incorrect levels at the echo-suppressor input terminals will cause unequal effective suppressor sensitivities. These incorrect levels are less likely to be obtained using terminal suppressors than centre suppressors, as the terminal level conditions are fixed and checked frequently.

The operation of the differential suppressor is as follows :—

The application of a signal to one repeater A to produce a change in the network current of i, which change is insufficient to cause appreciable attenuation in the complementary circuit of repeater B, will cause an increase of i in the current through the network associated with repeater A. The echo signal current applied to repeater B will now have to produce a change of at least $2i$ in the polarising network current before the current through the network associated with repeater A is decreased sufficiently to cause signal attenuation in the main signal path through repeater A. Thus the level of the echo current must be 6 decibels above the level of the main signal current as compared with a value only equal to it in the case of a non-differential type of echo-suppressor, before false operation can occur. This additional margin has been found in practice to exist and the level of the echo signal on a " zero " attenuation circuit with a loss round the termination of 12 decibels, has to be raised 6 decibels above the normal level before false operation at low signal strengths occurs.

Speed of Operation and Hangover Time.

The hangover time has been adjusted to be about 250 milliseconds so that when the echo-suppressor is installed on a circuit over which " Telex " is used, the " mechanical reply " to the " Who are you " signal, which occurs after a delay of 310 milliseconds, is not mutilated. A hangover time of 250 milliseconds should be adequate for all British circuits even when using a terminal suppressor. Variation of the " hangover " time is effected by changing the condenser 12 (Fig. **10**). With condensers 12 and 13 equal to 0.005 and 0.01 microfarads respectively, the operating and hangover times are given in Figs. **13**

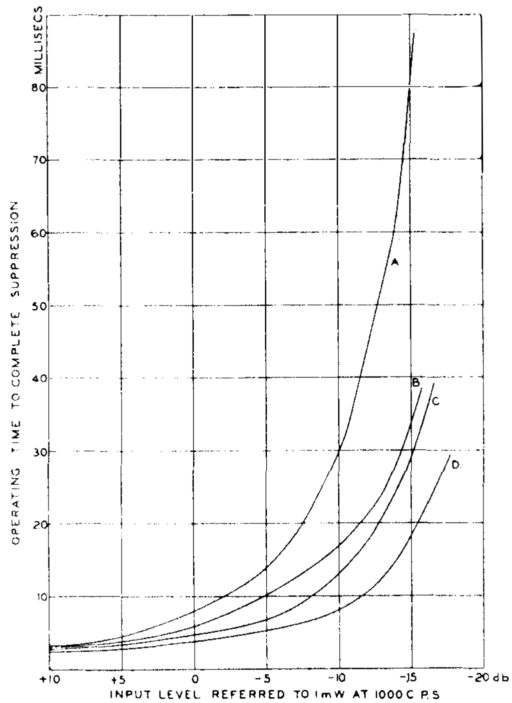

FIG. **13**.—OPERATING TIMES.

and **14**, in which the frequency of the operating signal is 1000 c.p.s.

The hangover time is regarded as the time taken by the signal to attain approximately 0.8 of its normal amplitude.

Oscillograms showing the " operating " and " hangover " times due to a 1000 c.p.s. signal with an input level to the suppressor of +10 decibels and −10 decibels are shown in Fig. **15**.

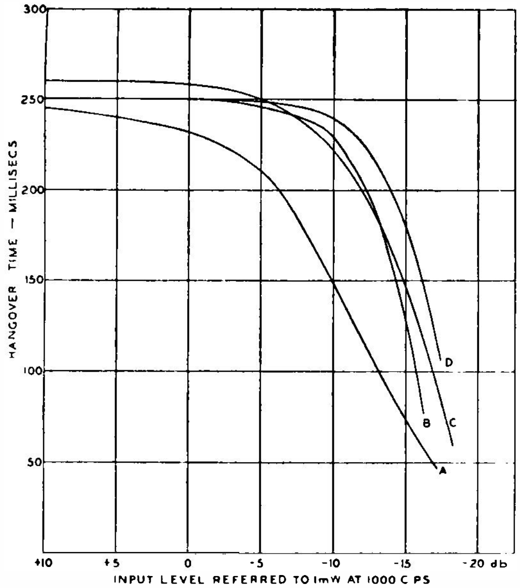

FIG. 14.—HANGOVER TIMES.

The Effect of a Short Operating Time on the Echo-Suppressor Operation.

These short operating times are obtained because only a small change of anode current, and consequently a small grid voltage change, is required to produce complete echo attenuation. The power required to produce the necessary grid voltage change is therefore small and can be obtained without amplification. Furthermore, the change in the anode current of the echo amplifier valve need not be so rapid that an unduly large signal impulse is transmitted into the echo circuit.

The operating times are sufficiently short to enable the suppressor to be used on 2-wire circuits or at the end of 4-wire circuits where echo time is extremely short.

It is of interest to note that whereas a grid potential change in the repeater valve (VT. 25 or 31) of only 1.3 volts is required to produce 30 decibels echo-suppression with the later type of apparatus, the grid voltage change to produce the same echo-suppression with the grid jamming type is approximately 25 volts. To reduce this value, first stage valve suppression has usually been used where 2-stage repeaters are employed and this requires approximately 6 volts grid bias change to give echo-suppression. Unfortunately, whereas the 25 volts grid bias change of the second stage repeater valve produces a rather large signal impulse into the echo circuits, the corresponding impulse voltage obtained from the first stage repeater valve grid bias change is approximately 10 times as great or over 100 times as great as that produced with the new type of suppressor described here.

The Importance of the Differential Nature of the Echo-Suppressor Operation.

Since it is impossible to produce attenuation in the two rectifier networks simultaneously, the signal impulse in the echo circuit caused by the suppressor operation cannot produce any attenuation in the main signal amplifier circuit.

If line noises are present on the circuit the change in control current, which would be produced by the noise in the " go " circuit, is in opposition to that produced by the noise in the " return " circuit, so that the line noise effects tend to cancel each other out.

It has already been shown how the differential action improves the margin against false operation by the echo signal.

The satisfactory operation of the echo-suppressor when used at the end of a 4-wire circuit, or in conjunction with a 2-wire repeater and having a negligible echo time, is largely due to its differential nature. Because the signal in the main path must occur very slightly before the echo signal and is equal to, or greater than it, the control current always changes to produce echo attenuation, since the anode current change of the D.C. bridge due to the main signal occurs slightly before the anode current change due to the initial echo signal and is equal to or greater than it.

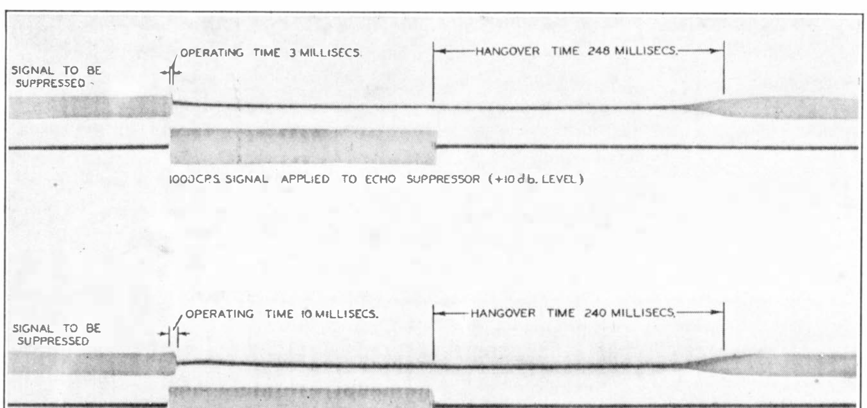

FIG. 15.—OSCILLOGRAMS OF OPERATING AND HANGOVER TIMES.

Operation as a 4-wire Terminal Suppressor.

When used at a terminal station, it is desirable to insert a 6 decibel pad in the 2-wire circuit adjacent to the suppressor. The output of the " return " repeater is then at a +10 decibel level to give a " zero " overall circuit, and the input of the " go " repeater is at a −10 decibel level. Furthermore, the level of the signal from the 2-wire extension that is applied to the output of the " return " repeater tending to produce operation of the wrong suppressor, is −10 decibels as compared with the level of +10 decibels obtained at the output of the " go " repeater and applied to the suppressor to be operated. Thus the signal tending to cause false operation is very much smaller than the main signal and it results in a negligible change of the anode current of the valve carrying the signal current.

The use of terminal suppressors in place of centre-circuit suppressors reduces maintenance. All modifications necessary when the circuit is to be used for V.F. telegraph or for any one-way transmissions can be made at the terminal stations. The line levels at which the suppressors are operating are not liable to alter so much as if they were in the centre of the circuit. For example, the normal lining up of the circuit to " zero level " must ensure that the " return " repeater output level is +10 decibels, and the level changes of the " go " repeater output are caused only by changes in the gain of that repeater, as the signal only passes through that repeater after entering the 4-wire circuit.

Operation as a 2-wire Echo-Suppressor.

Two-wire zero attenuation circuits on high grade cables have been obtained with addition of this echo-suppressor. The only change necessary is the introduction of a 4-wire repeater and associated terminations in place of one 2-wire repeater. The outgoing level to line is arranged to be +6 decibels.

The Construction of the Echo-Suppressor.

The whole of the equipment is mounted on one side of a panel 7″ × 19″, shown in Fig. 16, and so occupies the same rack space as the associated repeater. It can then be mounted alongside on an adjacent rack which simplifies wiring. Provided the grid bias voltage connexion to the repeater is screened, however, the echo-suppressor and repeater can be placed any reasonable distance apart. The echo-suppressor equipment consists of three distinct portions, *i.e.* :—

(1) The two attenuation networks, each consisting of two line transformers and the rectifiers comprising the attenuators.

(2) The two signal rectifier circuits, each comprising a transformer, a voltage doubler rectifier and the associated small condensers and resistances, which can conveniently be mounted in a transformer pot.

(3) The additional anode resistances and potentiometer in the control current circuit to complete the valve bridge circuit. Since the potentiometer tap does not require to be adjusted, except after long intervals, a U-link connection to an 800 ohm resistance with 100 ohm taps, is used. An initial half section can be short-circuited to give a finer adjustment.

To Cut Out the Echo-Suppressor.

This is most conveniently done by strapping together the grid bias connexions on the tag strip so that no change of grid bias voltage can be applied to the repeater valves, and then increasing the steady bias control current of each network to 4 milliamps by short-circuiting a portion of the resistance (9 in Fig. 9) controlling the bias current. The attenuation networks are still inserted in the transmission circuits, but will not affect the signals transmitted, and no change in the overall attenuation of the circuit is incurred.

Alternatively, the attenuation networks and the associated transformers can be isolated from the transmission circuit by means of eight U-links—four associated with each network. This changes the overall attenuation of the circuit, and experience has shown that no trouble is ever experienced from the rectifier network. This facility is not essential and only increases the cost of the apparatus.

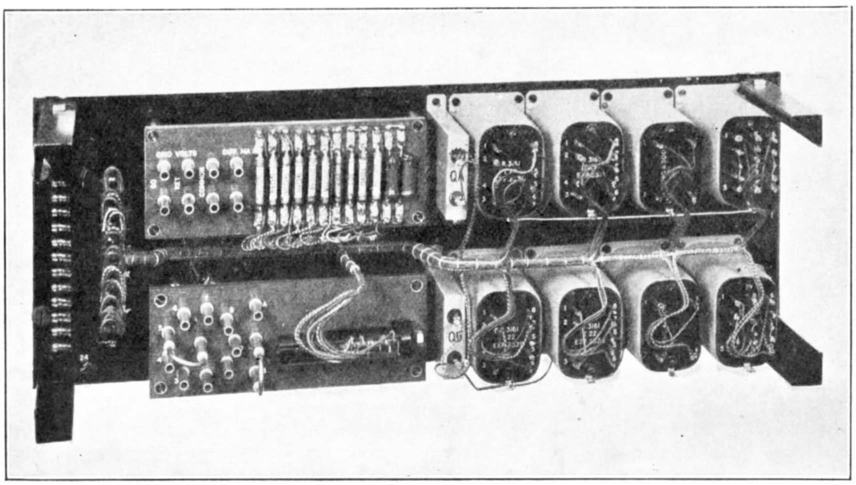

Fig. 16.—The Valveless Echo-Suppressor.

The Use of Additional Amplifier Valves to increase Sensitivity, etc.

If it is considered desirable an additional single stage amplifier can be inserted between the repeater output and the signal rectifier circuit. The shunt load across the repeater output can then be reduced to a negligible amount, and the auxiliary amplifier valves can be used in the D.C. bridge circuit in place of the existing repeater valves. No alterations to the valve circuit of the repeater need then be made, and the repeater characteristics, *e.g.*, output power, harmonic distortion and cross-talk, are unaffected by the echo-suppressor. An increase of up to 30 decibels in the sensitivity of the suppressor can be obtained.

False operation of the suppressor by line and room noises will occur with any material increase of sensitivity. This will prevent signals in one direction from being transmitted unless special means can be provided to enable the operation of the echo-suppressor by the noise to be overcome, so that stronger signals in the reverse direction can take control and be passed through the circuit. This necessitates some form of " break-in " circuit, together with means to prevent the echo signals themselves from "breaking-in" and causing "clipping."

Increased sensitivity has been found necessary with voice-operated 2-wire stabilised circuits when the weakest speech signals must cause operation in order to be transmitted, and " break-in " circuits have been provided.

For general use on normal 2-wire and 4-wire circuits, however, the performance of the valveless echo-suppressor has proved to be satisfactory.

A Summary of the Principal Features of the Valveless Echo-Suppressor.

(1) It is cheap and compact. There are no valves or any moving parts incorporated in it so that maintenance costs are very small.

(2) The differential nature of its operation ensures that both halves of the echo-suppressor can never operate or partially operate simultaneously. This feature eliminates many of the troubles normally associated with echo-suppressor operation and provides a greater margin against false operation.

(3) A very small operating time is obtained as compared with other known types, which increases the effective speech sensitivity without increasing the sensitivity to false operation by steady line noises.

(4) The very small operating time, in combination with the differential feature, makes this echo-suppressor equally suitable for use as an intermediate or terminal 4-wire suppressor, or as a 2-wire echo-suppressor.

(5) A saturation effect inherent in the design ensures that the " hangover " time remains constant for all input levels to the echo-suppressor greater than -10 decibels (or -20 decibels at the incoming end of the circuit).

(6) The sensitivity is such that a 1000 c.p.s. signal level of -19 decibels applied to the echo-suppressor (corresponding to -29 decibels at the incoming end of the circuit) produces an echo attenuation of at least 30 decibels. A greater sensitivity can be obtained by using a valve having a higher mutual conductance than 1.2 in the associated repeater.

Telegraph and Telephone Plant in the United Kingdom

TELEPHONES AND WIRE MILEAGES. THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 31st DEC., 1934.

Number of Telephones owned and maintained by the Post Office.	Overhead Wire Mileages.				Engineering District.	Underground Wire Mileages.			
	Telegraph.	Trunk.	Exchange.*	Spare.		Telegraph.	Trunk.	Exchange.*	Spare.
862,423	542	6,747	47,215	5,532	London	36,340	215,982	3,762,361	162,162
106,897	2,144	16,816	48,397	7,373	S. Eastern	4,828	67,573	378,054	62,207
121,889	4,166	36,993	76,820	5,589	S. Western	24,104	55,328	296,548	97,006
84,608	4,014	39,349	72,161	11,655	Eastern	15,455	69,150	177,537	63,300
133,259	5,685	44,482	58,291	14,580	N. Midland	9,141	177,399	343,333	119,397
107,225	3,357	27,454	67,040	9,414	S. Midland	9,310	69,695	327,460	74,705
72,741	3,032	27,001	58,982	8,225	S. Wales	6,193	61,091	168,104	37,762
144,595	4,452	25,081	60,793	12,910	N. Wales	9,003	90,590	459,001	104,406
188,115	1,024	6,866	27,625	9,193	S. Lancs.	7,613	129,124	674,889	76,962
121,827	5,131	23,423	40,983	8,005	N. Eastern	11,332	96,756	347,893	54,303
80,193	1,231	16,490	28.432	12,189	N. Western	4,898	53,762	255,822	49,820
61,914	1,358	13,927	22.875	7,760	Northern	3,955	53,988	186,091	30,920
30,909	3,205	11,277	12.652	970	Ireland N.	265	5,762	73,784	17.725
89,132	4,279	28.529	42,341	7,882	Scotland E.	1,480	56,101	181,046	51,519
111,672	3,700	22,790	34,708	5,712	Scotland W.	9,562	52,635	278,362	43,640
2,317,399	47,320	347,225	699,315	126,989	Totals.	153,479	1,254,936	7,910,285	1,045,834
2,256,740	47,514	366,200	683,262	111,934	Totals as at 30 Sept., 1934	155,628	1,196,270	7,869,823	1,059,940

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

The Jointing of Lead Cable Sheaths by Lead Burning known as Duct Splicing

W. A. ADAMS

THE increasing number of cases of sheath corrosion of telephone cables in recent years has led to means being sought to cut down the expenditure on stripping, lengthening, and re-sheathing the faulty lengths, which in the majority of cases was the method adopted to remedy the fault.

Some cases lent themselves to a treatment which merely required the faulty length to be cut off, and a spare length to take the place of the damaged portion, " duct spliced " on, as it was termed in the early days. This method was also considered suitable for jointing together comparatively short lengths of stock cable so that requisitions could be met from one or more short lengths which would otherwise be scrapped.

The results obtained could not be regarded as satisfactory and in view of the growing need for a suitable method, the problem has been investigated by the Birmingham Testing Branch. The process evolved has given highly satisfactory results and is described in the following notes.

In order that the terms used may be clear to the reader it should be explained that " Leadburning " is defined as the autogenous welding of lead by means of an oxy-acetylene flame directed by a blow-pipe and that " Duct splicing " is the name originally applied to the joint made between two lengths of the same size cable, the diameter of the joint being not more than $\frac{1}{8}$ in.—$\frac{1}{4}$ in. greater than that of the cables jointed.

The requirements of a welded joint in lead sheathing are :—

(1) The external diameter of the joint must not exceed that of the cables jointed by more than $\frac{1}{4}''$.

(2) The joint must be as strong or stronger than the cable itself.

(3) The joint must be flexible, to enable the jointed cable to be redrummed, if necessary, without the joint breaking, thereby indicating a bad weld or burnt lead, in the strict sense of the term.

(4) The paper insulation must not be burnt.

In October, 1932, experiments were commenced in an endeavour satisfactorily to lead-burn a sheet of lead over a joint between two lengths of paper-core cable, in such a manner that the finished article would satisfy the four requirements aforementioned as well as the electrical requirements of the jointed cables. Numerous difficulties were encountered, but all were eventually overcome, and experience and skill gained, until, in February, 1933, a perfectly sound joint was made, and from then onward the work has progressed successfully.

The apparatus used for the operation is shown in Fig. 1. The oxy-acetylene supply is obtained from two cylinders, one containing oxygen and the other acetylene. The pressure is reduced to a maximum of 10 lb. per square inch at the jet by two special regulators. The minimum working pressure is about 3 lb. per square inch and this range adequately covers the necessities for the operation.

The blow-pipe, Fig. 2, consists of two tubes leading to a common jet, one tube conveying the oxygen and the other acetylene, the quality of the mixture being controlled by two conical valves on the blow-pipe marked " A " and " O " respectively. The jets which are screwed into the end of the blow-pipe are of 5 sizes, numbered 1 to 5. Number 1, the smallest, is used for delicate work. Nos. 2 and 3

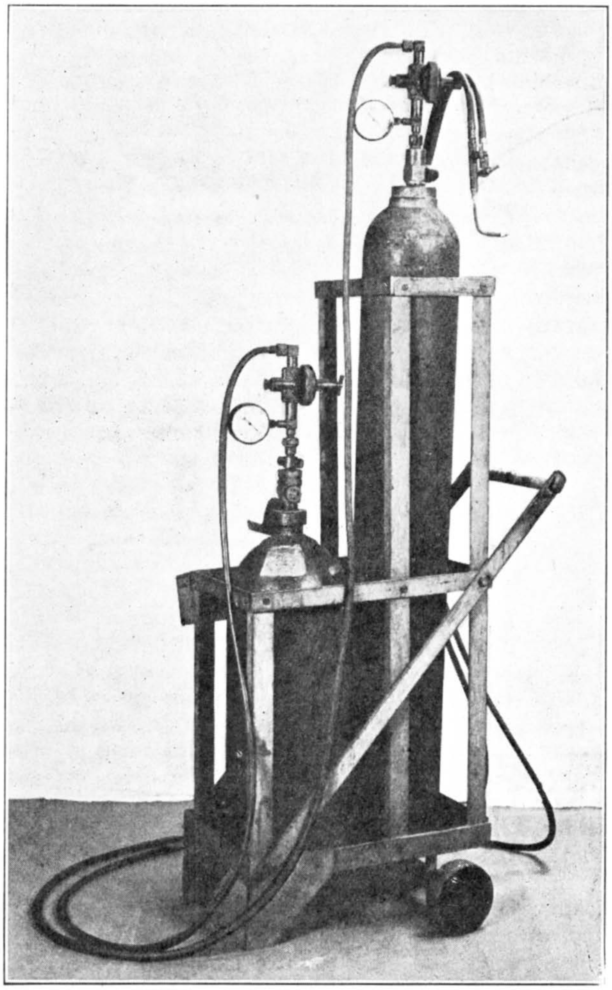

FIG. 1.—OXY-ACETYLENE LEAD-BURNING APPARATUS.

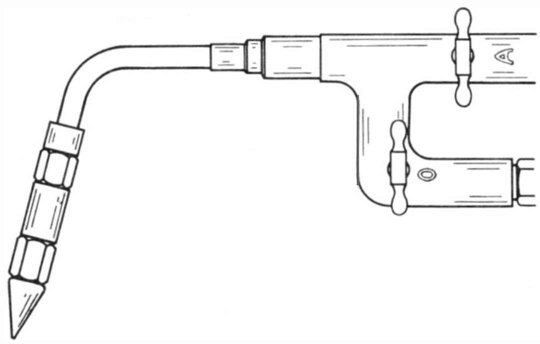

FIG. 2.—BLOWPIPE.

are used on 5 and 8 lbs. lead respectively. Nos. 4 and 5 are for heavier work and not suitable for lead-burning on cable.

The blow-pipe is connected to the cylinders by two stout rubber tubes differently coloured for identification purposes, viz., black for oxygen and red for acetylene. All fittings common to the acetylene apparatus have left-hand threads, whilst those of the oxygen apparatus have the usual right-hand threads. This precaution obviates any possibility of confusion.

The flame should be about 5 to 6 inches long, including the streamer, and should taper to a fine point, the hottest part being about 1 or 1½ inches from the jet which is also the thickest portion of the flame—Fig. **3.**

FIG. 3.—BLOWPIPE FLAME.

In order to protect the operator's eyes, goggles are supplied with several interchangeable tinted glasses of various shades of green, to be used according to the strength of the flame required. It is most essential that these should be worn during the actual welding operation as serious injury may otherwise result due to the brilliance of the flame and also to spurting lead.

Method of making lead joints.

The method adopted in making flat-butted joints is followed in principle throughout the work and is described below.

The two edges of the lead to be joined are first cleaned with a shavehook and butted together. The flame is adjusted, as previously described, and a thin strip of lead prepared for filling. The jet is held in the right hand, and a strip of lead in the left, as shown in Fig. **4**, the flame being allowed to play on the end of the strip which is held just above the seam. As the strip is melted, the jet is directed on to the seam so as to fuse the edges together, the additional lead forming a thickened portion—Fig. **5**. The joint is burned again to give added strength. A good seam when completed should have a herringbone appearance, this being obtained by directing the movement of the blow-pipe as illustrated in Fig. **6**. The heavy black dots represent pauses in the movement of the jet where lead is added from the strip.

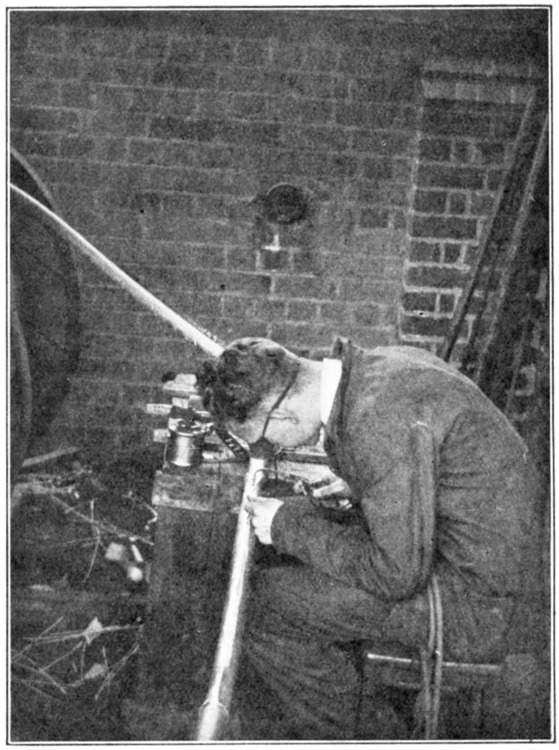

FIG. 4.—LEAD-BURNING.

As no flux is used in leadburning, the cleaning operation should not be carried out until the operator is ready to burn the joint.

Procedure.

Owing to the difficulty experienced in burning the under portion of the joint, arrangements have to be made to enable that portion to be burned on the top. Fig. **7** shows how this is accomplished. The drums are placed parallel to each other at a distance of approximately 6 to 8 feet and are jacked up. The ends of the cable are raised to a convenient height and made fast. The sheathing is thoroughly cleaned with kerosene to a distance well above the length of

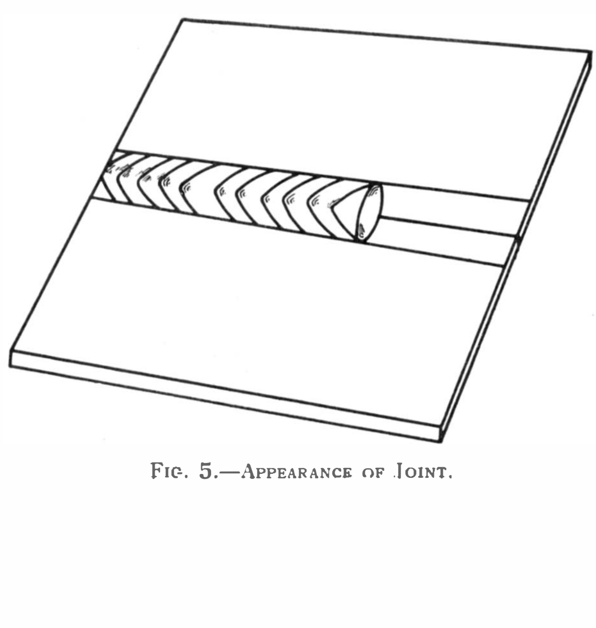

FIG. 5.—APPEARANCE OF JOINT.

the proposed joint. In this type of joint, it is necessary for the completed splice to be 50% longer than the normal sleeve joint, to enable the conductor joints to be well staggered and so preserve the diameter of the sheathing to within the quoted limits. The sheath-

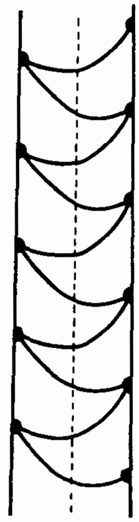

FIG. 6.—MOVEMENTS OF BLOWPIPE ALONG SEAM.

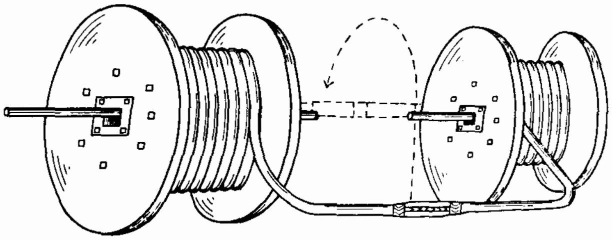

FIG. 7.—ARRANGEMENT FOR BURNING UNDER PORTION OF JOINT.

ing is stripped in the usual manner and the conductors jointed. Two layers of paper insulating and one of asbestos tape are lapped round the conductors, the latter being a precaution in the event of the joint being overheated, thus preventing damage to the insulation. The tape is then secured with twine.

The sleeve is prepared from sheet lead of the same weight as that of the cable sheathing. The circumference of the cable is measured and the sheet lead cut accordingly. A wooden mandril of approximately the same diameter as the cable is used as a former for the sleeve. This is shaped with a dresser, as shown in Fig. **8**, *i.e.*, in the form of a " U." The

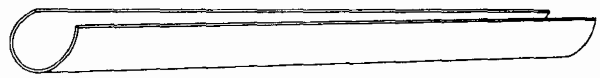

FIG. 8.—PREPARED SLEEVE.

ends of the cable sheath are now dressed down slightly and cleaned with a shavehook. The sleeve is placed on the joint with the seam on the top and dressed to the shape of the cable—Fig. **9**. The

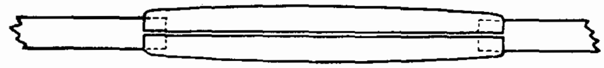

FIG. 9.—SLEEVE DRESSED IN POSITION.

sleeve is now cleaned at the ends and down the seam with a shavehook. The splice is now ready to be burned and the seam is spotwelded to prevent opening during the process—Fig. **10**. The whole of the

FIG. 10.—SEAM SPOTWELDED.

seam and the ends, as far as possible, are welded. The whole joint is then strengthened temporarily by a splint of wood lashed along its length, Fig. **11**, and

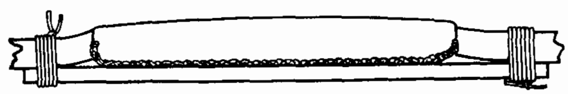

FIG. 11.—WOOD SPLINT LASHED IN POSITION.

the joint taken over the drum, bringing the underside on top. This is welded and the joint is completed.

A New Telephone Tester for Service Officers

A new form of Tester No. 51 has been designed to facilitate the testing of subscribers' installations by Service Officers. It consists essentially of a small " pick-up coil " which can be readily clipped to the receiver of the telephone to be tested, a compact two-valve amplifier and an auxiliary receiver. The " pick-up coil " has small speech voltages induced in it by electromagnetic induction from the subscriber's receiver. These speech voltages are amplified by the amplifier and reproduced as speech by the auxiliary receiver, of the same quality and volume as that produced by the main receiver, so that the Service Officer is able to listen to the sounds heard by the subscriber who is using the telephone normally. No electrical connexions need be made to the subscriber's circuit.

The Service Officer can thus observe the progress of a telephone call made by the subscriber himself under working conditions, and determine the source of any difficulties experienced by the subscriber.

The instrument is completely self-contained and including the necessary batteries is fitted in a small leather case measuring $9\frac{1}{2}'' \times 7\frac{1}{2}'' \times 4''$. The total weight of the instrument is about eight pounds.

A Field Strength Measuring Set Using Thermal Agitation Noise as the Calibrating Source

A. H. MUMFORD, B.Sc.(Eng.), A.M.I.E.E.
and
P. L. BARKER, B.Sc.(Eng.), A.M.I.E.E.

Summary.

THE article briefly reviews the normal methods of field strength measurement and describes the use of thermal agitation noise arising in the input circuit of a receiver for calibration purposes. A description of a field strength measuring set, using this principle, is described in some detail and its calibration, operation and applications described.

1. General Discussion of Methods of Measurement.

In general, the methods adopted for the measurement of the field strength of a transmitting station at any given site are based upon a comparison of the E.M.F. induced in an antenna by the desired signal and by a locally generated E.M.F. of the same frequency.

In the case of a strong field near a radio transmitting station, it is possible to measure the current in a receiving antenna directly by means of a thermal instrument, but for weak fields a comparison method must be employed and a radio receiver used in conjunction with an antenna to indicate when the E.M.F's induced in the antenna by the distant and local sources are equal.

At low radio frequencies the receiving antenna is usually in the form of a loop, the effective height of which can be readily calculated. The local comparison E.M.F. is inserted at the centre point of the loop and its magnitude is such that it produces the same receiver output as the signal, arrangements being made to eliminate the signal during this part of the measurement. Under this condition the voltage induced in the loop by the signal equals the known locally generated E.M.F., and since the effective height of the antenna is known, the field strength can be obtained by simple calculation.

In order to determine the value of the locally generated E.M.F. a measurable current is commonly attenuated by a known amount and passed through a known impedance in the centre of the loop. The value of this impedance must be kept as low as possible and should preferably be purely resistive. Great care must be taken to screen the local oscillator to avoid undesired throw-in to the loop circuit. The attenuating networks must be accurate, or have a known calibration over the entire frequency range of the equipment.

At high frequencies the construction of such attenuating networks operating at the signal frequency is difficult and in order that low values of field strength may be accurately measured, elaborate screening of the local oscillator is essential, the minimum measurable high frequency current being relatively large. Such a system is illustrated schematically in Fig. 1.

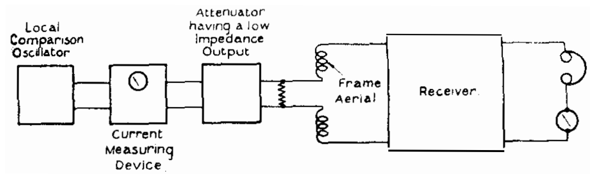

Fig. 1.—Field Strength Measuring System employing H.F. Attenuator.

A field strength measuring system,[1] developed by H. T. Friis and E. Bruce of the Bell Telephone Laboratories, avoids these difficulties and has been widely adopted. An essential feature of this system is the transfer of the attenuator to the intermediate frequency stages of a double detection receiver, the elaborate screening of the comparison-oscillator being no longer necessary and the construction and calibration of the attenuator, which is now working at a lower fixed frequency, considerably simplified. This transfer is only permissible provided the frequency changer translates signals from the high to the intermediate frequency in a linear manner.

The method of measurement may be illustrated as follows :—

Assuming the input circuit of the first detector of the double detection receiver to have been tuned to the required frequency, the intermediate frequency attenuator is adjusted to an attenuation ratio n to give a convenient output on a meter included in the anode circuit of the second detector. The input voltage to the attenuator is thus n times larger than the output voltage. The local signal oscillator is then caused to induce a voltage, at the mid-frequency of the acceptance band, in a small coupling coil connected in series with the input circuit, this composite circuit being connected directly between the grid and filament of the first detector. Referring to Fig. 2 the magnitude, v volts, of the voltage developed between the grid-filament of the first detector is measured by switching off the first beating oscillator and using the first detector as a valve voltmeter. The beating oscillator is then switched on again and the attenuator adjusted to a ratio of p to give the same output as before. The voltage developed across the grid-filament circuit of the first detector by the incoming signal is therefore :—

[1] " A Radio Field-Strength Measuring System "—H. T. Friis and E. Bruce. Proc. I.R.E., August, 1926.

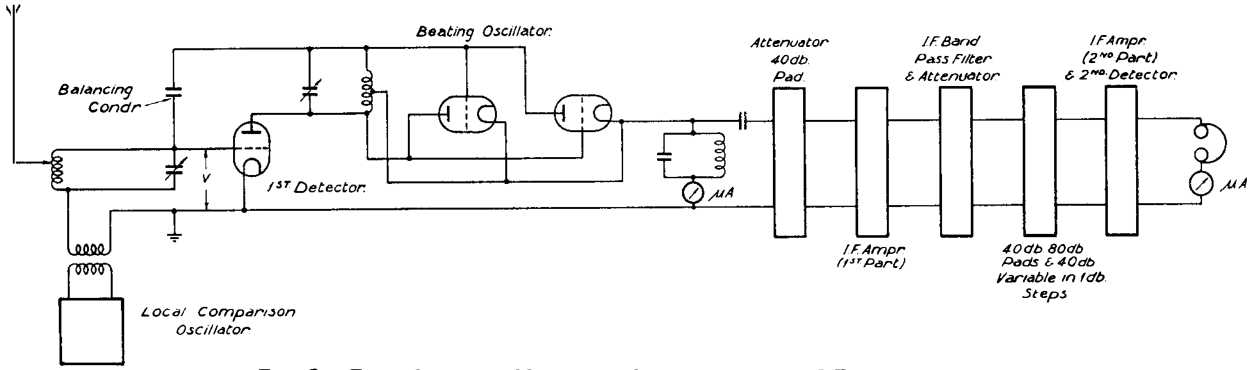

FIG. 2.—FIELD STRENGTH MEASURING SYSTEM EMPLOYING I.F. ATTENUATOR.

$$\frac{v}{\frac{p}{n}} \text{ volts}$$

Referring to Fig. 3, the coupling coil is then connected directly betwen the grid and filament of the first detector and the attenuator adjusted to a ratio q

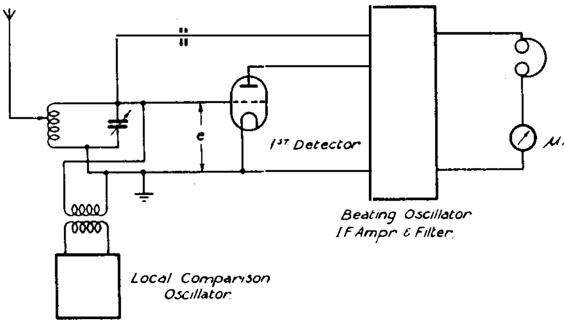

FIG. 3.—MEASUREMENT OF VOLTAGE STEP-UP.

to give the reference output. Thus, the voltage step-up, *i.e.*, the ratio of the voltage v developed across the grid-filament circuit to the induced voltage e, is :—

$$\frac{p}{q}$$

Thus the voltage induced in the aerial by the signal is :—

$$\frac{v}{\frac{p}{n} \cdot \frac{p}{q}} \text{ volts}$$

Knowing the effective height of the aerial, the field strength may be readily obtained.

It will be appreciated that the systems so far described for the measurement of relatively weak fields, essentially utilise a local oscillator for comparison with the incoming signal and necessitate the measuring of the oscillator output. Obviously a system, which would eliminate the necessity for a separate local oscillator, has many advantages and it is now proposed to describe such a system and its incorporation in a specific instrument.

2. THE USE OF THERMAL AGITATION AS A CALIBRATION SIGNAL.

The noise due to the thermal agitation of electricity is the most fundamental source of noise in a receiver. In a perfect receiver all other sources of noise would, at the output of the receiver, be at a lower level than the noise arising from thermal agitation in the input circuit. The origin of this source of noise is the larger number of free electrons at any instant moving in one direction in a conductor than in the other, thereby developing a voltage across the terminals of the conductor. The velocity of the electrons is a function of the temperature. Although the voltage will vary from instant to instant in an irregular manner in accordance with the predominant motion of the electrons, the mean square voltage developed across the terminals of an impedance is directly proportional to the resistive component of the impedance and its absolute temperature, the energy being uniformly distributed over the frequency spectrum if the impedance is a pure resistance. The magnitude of the voltage produced by thermal agitation can be calculated from the formula

$$V^2 = 4kT \int_{f_1}^{f_2} R \, df \qquad (1)$$

where

k = Boltzmann's constant = 1.37×10^{-23} joules per degree.

T = absolute temperature.

R = resistive component of the impedance producing the thermal agitation voltage. (R may be a function of frequency).

f = the frequency.

If the impedance is limited to a pure resistance, and the absolute temperature is taken as 300° then

$$V_T^2 = 1.64 \times 10^{-20} R (f_1 - f_2)$$

If the impedance is a simple tuned circuit, and the temperature again 300° the formula becomes

$$V_{TC}^2 = 0.26 \times 10^{-20} C^{-1} \left(\tan^{-1} \frac{f_1 - f_2}{f} \cdot \frac{\pi}{\delta} \right)$$

Where C = tuning capacity

δ = decrement.

It is important to note that the change in the thermal agitation voltage for a temperature range 0 to 50° C is only 0.7 db. Thus since the thermal agitation noise in the input circuit masks any other source of noise in a well designed receiver, we have available at the receiver input a calibrating source, inherently of a high degree of constancy, having a magnitude amenable to calculation or measurement.

If, therefore, in such a receiver we determine the amount of attenuation necessary to reduce an incoming signal to the same strength as the input circuit noise, measured in the absence of any external signal, the magnitude of the incoming signal has been as effectively determined as if a local comparison oscillator had been used. Attenuation of the incoming signal may be made at either the high or intermediate frequency of the receiver. Determination of the effective height of the antenna can be made by means of well-known methods, although it is normally easier to determine the effective height and input circuit noise from a direct comparison with a standard field strength measuring set.

It is interesting to note that an effect, which sets a limit to the minimum receivable signal and hence is detrimental from the point of view of commercial reception, can, in the manner indicated, form a useful source for calibration purposes.

3. Description of a Field Strength Set for Broadcast Wave-lengths Using Thermal Agitation as the Calibrating Source.

Wherever possible standard broadcasting components have been used in the construction of the receiver, which consists of a simple broadcast set of the superheterodyne type, thereby keeping the cost of the set low. High frequency amplification, preceding the first detector, is essential in commercial practice in order to increase the image channel selectivity but, for the sake of simplicity, it was decided to dispense with this feature in this case. Thus sufficient amplification of the first circuit noise has had to be obtained, mainly at the intermediate frequency, 100 kc., to produce a voltage at the second detector large enough to give a measurable change of anode current in the anode circuit of the detector, operating as an anode bend detector. This has been obtained by the use of three transformer-coupled stages of amplification using screen grid valves. Air core transformers have been used in preference to iron cored in order to remove the danger of saturation of the core with large applied voltages. The selectivity of this amplifier is such that it has been found impossible to gang the signal frequency and beating oscillator circuits and still use the thermal agitation noise as the calibration signal, hence ganging is not used.

In the particular design, schematically shown in Fig. 4, the antenna, a four foot rod, is connected directly to the grid of the frequency changer which utilises an octode valve; between the grid and filament is the input tuned circuit in which the calibration thermal agitation voltage arises. The octode consists in effect of a triode and pentode within a common glass envelope, the triode portion being utilised for the beating oscillator. By this means a voltage at the intermediate frequency is developed across the impedance in the anode circuit of the octode when signals differing from the oscillator frequency by an amount equal to the intermediate frequency are applied to the control grid. Ferrocart coils have proved sufficiently stable to be used for the oscillator and input circuit coils and are coupled for the purpose of waveband switching. The intermediate frequency amplifier consists of three stages of transformer coupled amplification using air cored transformers and screen grid valves. The output from the intermediate frequency amplifier is applied to the second detector which is a triode valve operating as a square law detector. The anode current of this valve is observed on a 0-250 micro-ampere meter; high resistance headphones may be jacked into the anode circuit for monitoring purposes.

Some of the more important features of this set will now be described in detail.

3.1. *General Construction.*

The receiver is mounted on an aluminium panel and base which is enclosed within an aluminium box, approximately $18\frac{1}{2}'' \times 9\frac{1}{2}'' \times 8\frac{1}{2}''$. The rod antenna projects through a small hole in the top of the box. The weight of the receiver, without batteries, is approximately 25 lbs.

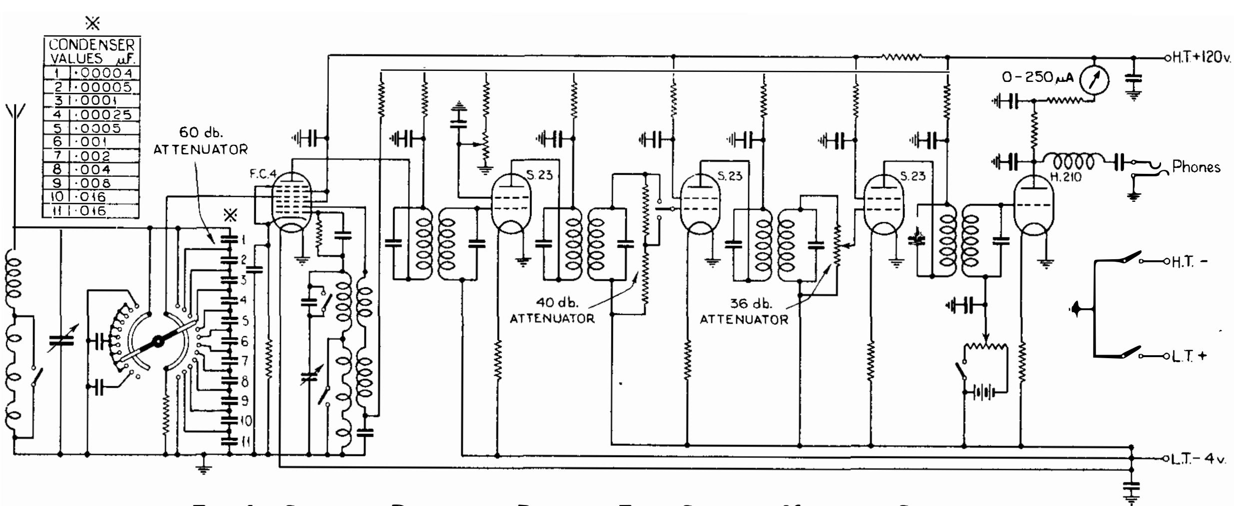

Fig. 4.—Schematic Diagram of Portable Field Strength Measuring Set.

Photographs of the receiver are shown in Figs. **5**, **6** and **7** and, in view of the novel design, working drawings have been included in Figs. **8**, **9** and **10**.

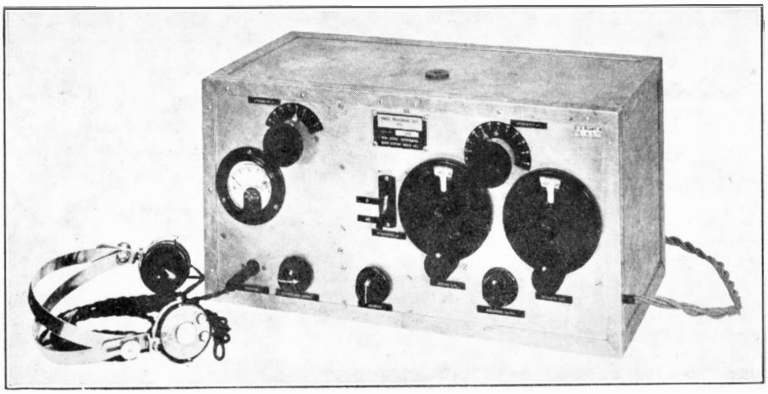

Fig. 5.—Front View of Set.

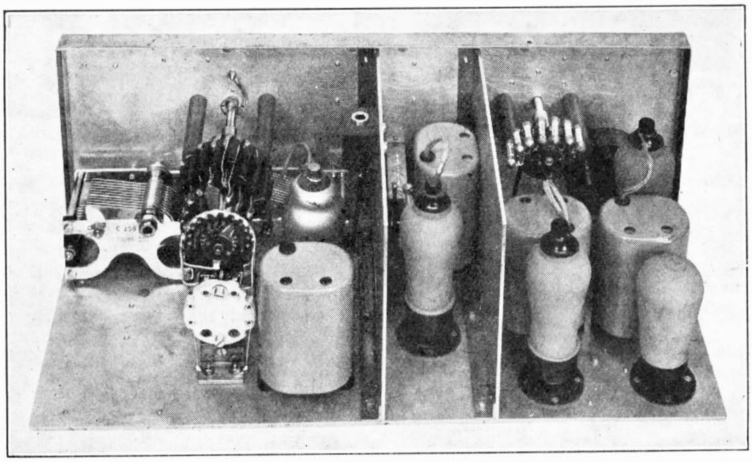

Fig. 6.—Rear View of Set.

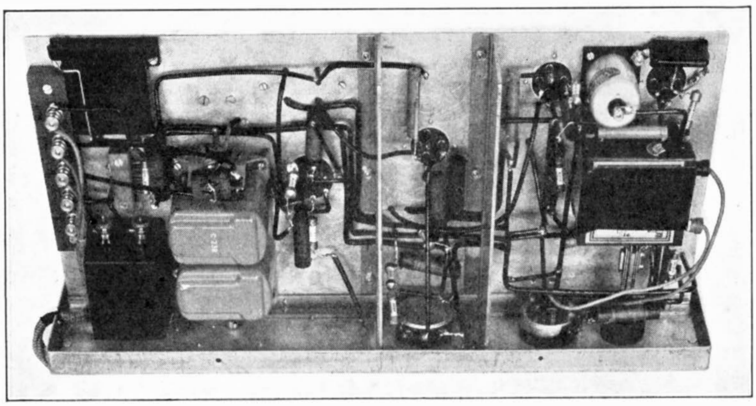

Fig. 7.—Underneath View of Set.

3.2. *Gain Controls.*

The gain of the receiver is adjustable by the following means :—

1. By a potentiometer controlling the screen grid potential of the first intermediate frequency amplifier valve. This control is used for adjusting the gain of the set to a constant value by means of the first circuit noise as will be described later.
2. By a fixed pad of 40 db., consisting of two metallised resistances of 100,000 and 1,000 ohms, controlled by a low capacity key and located between the first and second intermediate frequency stages.
3. By a 36 db. potentiometer, variable in 6 db. steps, also consisting of metallised resistances, controlled by a rotary switch and located between the second and third intermediate frequency stages.
4. By a 60 db. potentiometer, variable in 6 db. steps, consisting of condensers, controlled by a rotary switch and located between the input circuit and the first detector valve.

As will be observed, the capacity potentiometer operates at the signal frequency and has been found to function satisfactorily at frequencies as high as 1,500 kilocycles per second, without elaborate precautions being taken in its design. The condensers are mounted side by side round a rotary switch and the only precaution found necessary has been to arrange for the lead to the grid of the octode to be short.

The overall capacity of the potentiometer is 16 micro-microfarads which makes the values of the individual capacities convenient commercial sizes. On account of the grid cathode capacity of the valve being comparable with the overall capacity of the potentiometer the valve capacity must be considered in determining the values of the first three individual capacities, but for the subsequent ones it is negligible for the desired accuracy. The capacity from the grid and the grid lead to the cathode is of the order of 16 micro-microfarads and the switching of this capacity over the first two steps of the potentiometer would necessitate a slight re-tuning of the input circuit; to allow for this, compensating capacity has been arranged by means of small pre-set condensers on a duplicate switch coupled with the potentiometer switch and adjusted to compensate for the inter-electrode capacity of the valve and its associated leads, so that the input circuit requires no re-adjustment as the input potentiometer is varied.

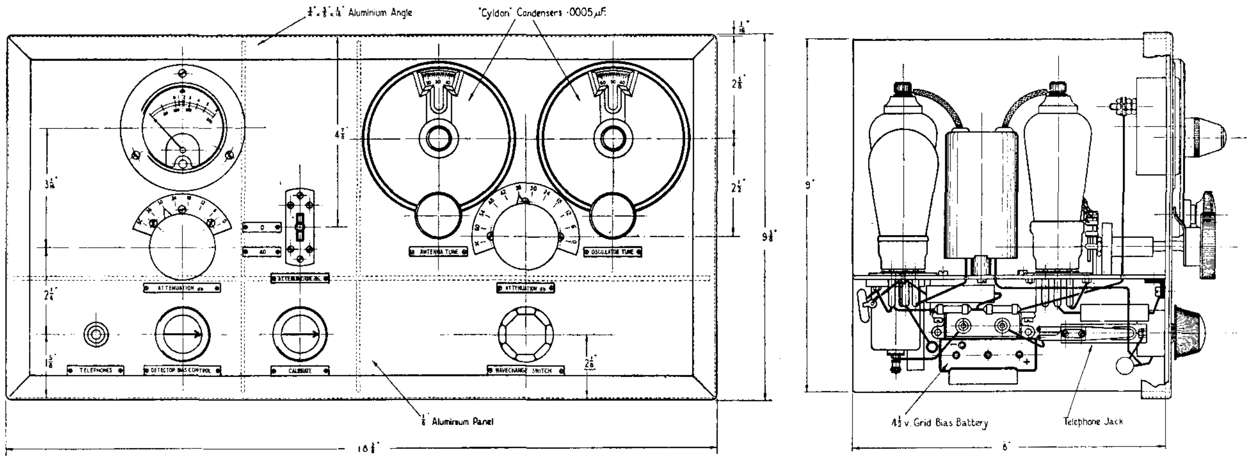

FIG. 8.—FRONT AND SIDE ELEVATIONS OF SET.

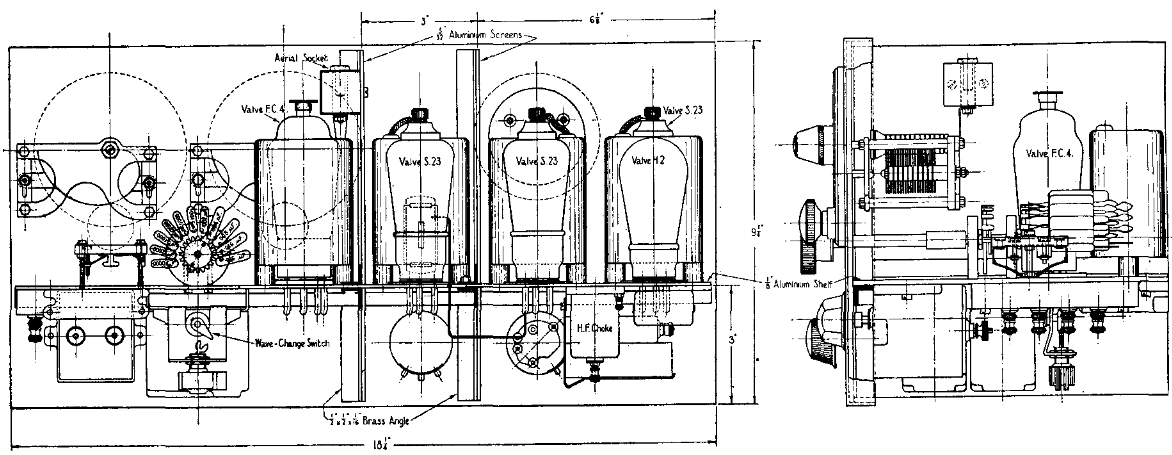

FIG. 9.—BACK AND SIDE ELEVATIONS OF SET.

3.3. *Power Supplies.*

The receiver is designed for battery operation and requires a four volt low tension and a 120 volt high tension supply. The necessary grid bias voltages are obtained from the low tension battery except for the second detector which requires an additional 4½ volt battery. The filament consumption is approximately 1.0 ampere and the anode and screen consumption approximately 15 milliamperes.

4. INITIAL CALIBRATION OF THE SET.

The principle of operation of the set for the measurement of signal field strengths is that, if the gain is always adjusted to a constant level on a given frequency, then the attenuation for a given second detector output from a signal is proportional to the field strength.

In order to adjust the gain of the set to a constant level, use is made of the thermal agitation voltage developed across the input circuit as a calibrating source, and this voltage is appreciably constant and can be used for this purpose, provided there is no other source of noise in subsequent parts of the receiver. This is determined by de-tuning the input circuit with no incoming signal, when the noise output, as measured by the adjustment of the attenuator to maintain a constant deflexion on the second detector meter, should decrease by some 3 to 6 db. If this is not the case it denotes some source of noise in the receiver which must be reduced before proceeding. The set may then be calibrated against a standard field strength measuring set of a type described earlier in this paper and the value of the constant (k) obtained for determining the absolute value of the field strength in subsequent operation.

The procedure for calibration is as follows :—The receiver is set up conveniently near the standard field strength measuring set at an open site, and tuned to a transmission on the frequency at which it is desired to determine the value of the constant, k. The field strength of the station is measured on the standard field strength measuring set. Having tuned the portable set to the same transmission, the antenna is removed and enough loss inserted in the intermediate frequency attenuators to ensure that there is no deflexion on the second detector meter due to signal or noise. The bias of the second detector is then adjusted by means of the potentiometer controlling

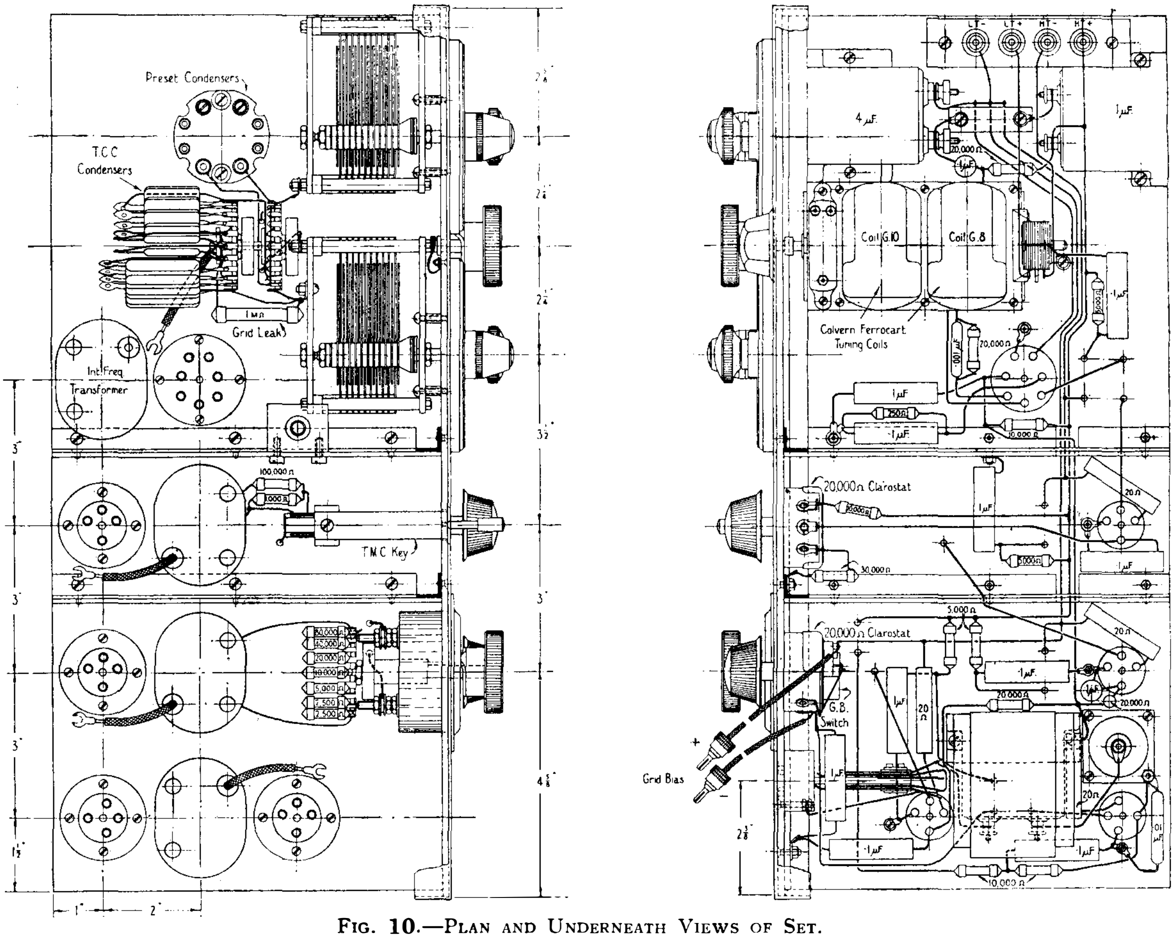

FIG. 10.—PLAN AND UNDERNEATH VIEWS OF SET.

it to produce a steady anode current of 50 microamperes. The attenuators are then reset to zero loss and the aerial circuit retuned slightly (to allow for the removed antenna capacity) until the second detector output on noise is a maximum. It should be ascertained while doing this that the detune ratio is of the order of 3 to 6 db. for the reason mentioned above. The second detector deflexion due to thermal agitation noise in the input circuit is then adjusted to 100 microamperes by means of the potentiometer controlling the screen voltage of the first intermediate frequency amplifier stage; the gain has then been set to the level which will be used for all subsequent measurements.

The antenna is then replaced and the receiver retuned to the desired signal, the attenuators being adjusted to produce as nearly as possible the previous output deflexion of 100 microamperes. As the attenuators are in 6 db. steps, the output current will generally be at some value between 100 and 250 microamperes and as this range corresponds to a change of 6 db. in the input to the detector under the conditions obtaining, the meter is calibrated in 1 db. steps over this range and the value obtained must be added to the attenuator readings. The value of k in decibels is then given by

(Field strength expressed in db. relative to 1 microvolt per metre) – (Attenuation in db. to give standard deflexion).

By determining the value of k in this manner on several frequencies a calibration chart is obtained for use in subsequent field strength measurements, the gain being always adjusted to the reference level in the manner described above.

In actual operation, it is desirable first to add attenuation in the I.F. variable attenuator, then, if the signal is sufficiently strong, add attenuation in the H.F. attenuator to avoid overloading of the frequency changer and first I.F. amplifier, and then if still more attenuation is needed, utilise the combinations of the fixed and variable I.F. attenuators.

5. PERFORMANCE OF THE SET.

The wave-length range of the receiver is approximately 200-600 metres and 1000-2000 metres.

The intermediate frequency amplifier has a band width of approximately 4 kilocycles per second and the attenuation 10 kilocycles from the mid-band frequency is 70 db. The high frequency circuit is comparatively flat over this band and does not control the overall shape of the characteristic appreciably. A typical frequency characteristic is given in Fig. 11.

The sensitivity of the set using the four foot rod antenna is always better than 1 microvolt per metre

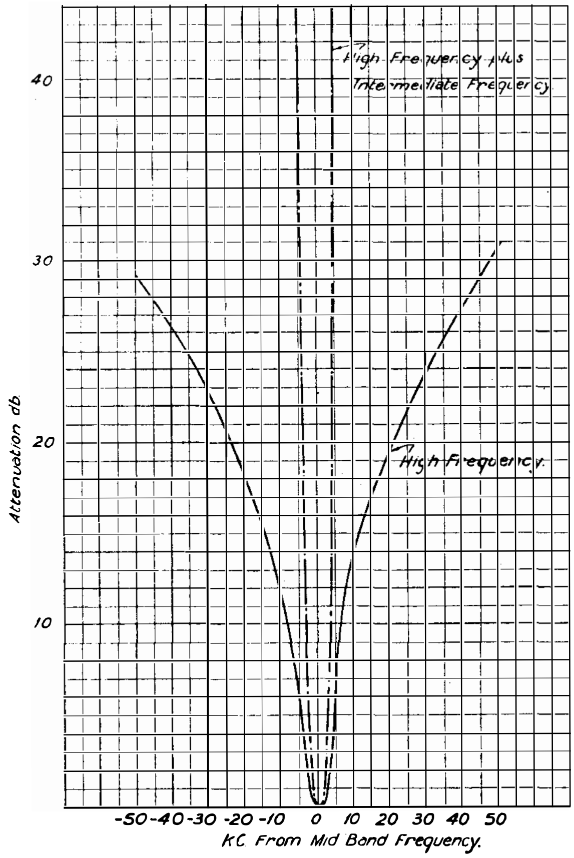

FIG. 11.—OVERALL SELECTIVITY AT 750 K.C.

for the standard output of 100 microamperes. Sensitivity characteristics are given in Fig. **12**.

The accuracy of the set is within 2 db. Increased accuracy could be obtained by paying more careful attention to the values of the components used for the attenuators; in the present instrument the specified accuracy of these components is $\pm 5\%$.

The accuracy of the intermediate frequency attenuators has been checked by direct comparison with a well designed T type attenuator. It is found that although the error in any individual step may be as great as 1 db. it is not cumulative and for any value of attenuation the total error is not more than 1 db.

The high frequency capacity potentiometer is also accurate to within 1 db. when measured at the intermediate frequency and for a check at high frequency it has been directly compared with the intermediate frequency attenuators. For this test the receiver is tuned to a broadcast signal, which is not strong enough to overload the first two stages when attenuation is inserted only at the intermediate frequency for the standard output. The intermediate frequency attenuation is then removed in 6 db. steps and a corresponding amount is inserted at high frequency to keep the total nominal attenuation constant. If the high frequency attenuator is attenuating correctly the receiver output will remain constant at each stage of the operation. It is found that the output remains constant to within 1 db. over the whole range of 60 db. of the capacity potentiometer, which indicates that it is as accurate at 1000 kilocycles per second as it is at 100 kilocycles per second.

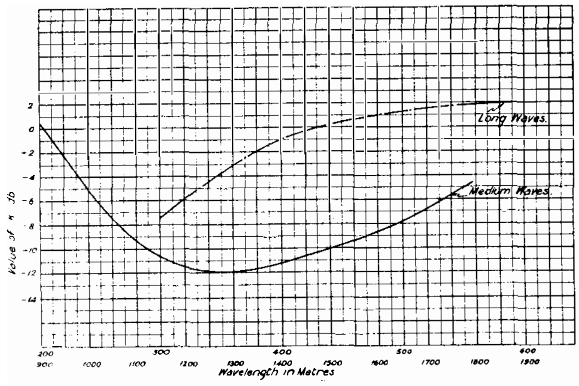

FIG. **12**.—VALUE OF CONSTANT k.

6. OPERATION OF THE SET.

The operation of the set for the actual measurement of field strengths follows very closely the procedure adopted in the initial calibration. This may be briefly summarised as follows :—

(i) Set the normal second detector anode current to 50 microamperes by means of the grid bias potentiometer (in the absence of an incoming signal or the calibration noise).

(ii) Tune the receiver to the desired frequency by means of the thermal agitation noise, and with the antenna removed and no attenuation in the I.F. stages, adjust the gain of the receiver (by varying the screen grid volts on the first I.F. amplifier valve) to produce a total deflexion of 100 microamperes on the second detector meter, the output being due to thermal agitation effects.

(iii) Detune the input circuit to ensure that this noise output is due to thermal agitation in the first circuit and not to noise in any subsequent part of the receiver.

This being so

(iv) Replace the antenna and retune the receiver to the desired signal.

(v) Adjust the attenuators in the manner indicated in Section 4 so that the output deflexion is again 100 microamperes and note the attenuation. The field strength is then obtained by adding the constant k db., determined in the initial calibration, to the attenuation used in this last measurement, the field being given in db. relative to one microvolt per metre.

NOTE :—Steps must be taken to ensure that the receiver satisfies test (iii).

7. APPLICATIONS OF THE SET.

The immediate application of the set is its use as a portable field strength measuring set for the measurement of the field strength of broadcast transmissions.

It may also be used directly for the measurement of the " equivalent " field strength of electrical interference (with broadcasting, etc.) in those cases in which the noise has a uniform and continuous distribution. The apparatus is not directly suitable for the objective measurement of interference due to " clicks," etc., which matter is under consideration at the present time. A subjective measurement may be made by determining the amount of attenuation which must be inserted by the H.F. attenuator in order to mask the incoming click (or other source of interference) by means of the noise arising in the receiver subsequent to that arising in the input circuit. The first circuit noise cannot be used, of course, since adjustment of the H.F. attenuator will affect the noise output of the receiver initially in direct proportion to its effect on an incoming signal, until the unattenuated noise in subsequent circuits predominates when increase of attenuation will only affect the incoming signal.

The set has also obvious applications as a voltmeter. In such a case it is desirable to insert a high resistance, say 20,000 ohms, in series with the normal aerial input, the E.M.F. to be measured being applied between earth and the remote end of the resistance. The set will need to be recalibrated for such a purpose. A set modified in this manner has been found convenient for the measurement of the effective height of receiving aerials, the set being first used as a voltmeter for measuring the voltage induced in the antenna and then as a field strength measuring set. The ratio between the two readings (expressed in suitable units) gives the effective height.

Obviously the principles used in the design of this set can be readily applied to sets intended for measurements on short or ultra short waves; moreover loop antennæ could be used in place of vertical if so desired.

It is also possible to envisage an application of the measurement of thermal agitation voltage to the determination of the resistive component of impedances of various kinds and more particularly to the determining of the decrements of tuned circuits. The measurement of losses in dielectrics could also be effected by determining the change of the resistance component in a tuned circuit due to the presence of selected samples of dielectrics.

It can therefore be concluded that the possibilities of utilising thermal agitaton noise as a source of E.M.F. for measurement purposes are very great and are likely to be developed extensively in the near future.

Automatic Teleprinter Message Sender

An automatic transmitter has recently been developed which will send continuous repetitions of a fixed message in teleprinter code. In the present arrangement the message is restricted to a total of 100 characters, but the principle of the sender is such that it is possible to increase the total number of characters if desired. The sender can be arranged for transmitting a test message for testing teleprinters and teleprinter circuits, and it should therefore prove particularly useful when frequent or protracted tests are required. The sender can also be adapted for the sending out of operating instructions on teleprinter exchange circuits. A number of such instructions could be provided on one transmitter, the required instruction being selected at will.

The transmitter, which is arranged for $7\frac{1}{2}$ units working, is of the rotating brush and distributor plate type and therefore sends out essentially perfect teleprinter signals. The five code segments of the distributor are connected to five wipers on a rotary switch, of the type used in automatic exchanges. The driving magnet of the switch is operated once per revolution of the transmitter, the operation being timed so that the wipers step while the transmitter is sending out the Stop signal. The bank contacts are wired up so that for each position of the wipers the polarity on the code segments, to which they are connected, corresponds to the code signal for the required character.

In this form of sender a facility has also been provided whereby, if desired, the letters may be transmitted at half the normal rate which is a useful facility for certain tests. This does not mean that the speed of transmission of the letters themselves is altered. The time occupied in the transmission of a letter is 150 milliseconds. The normal rate of sending is therefore 400 letters per minute and, when sending 200 letters per minute, there is an interval of 150 milliseconds between each letter.

Telephone Transmission V.

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

THE previous articles have demonstrated how attenuation of telephone currents takes place during transmission, and it will now be shown how Telephone Engineers have overcome the difficulty of attenuation, and the means by which this is done will be investigated.

For years a repeater for amplifying telephone speech current was the dream of inventors. Each one was faced with the problem, that whilst a single way repeater was simple, it was extremely difficult to obtain duplex or two-way operation. The earliest successful repeaters were of the receiver transmitter type, the amplification being given by the power drawn from the transmitter battery. The Shreeve repeater was used to establish the Atlantic-Pacific service by the American Telephone & Telegraph Co. just before the War. The Brown repeater was developed in this country, and was put into experimental service early in 1914.

To obtain satisfactory two-way working the repeater must operate in such a manner that subscribers talking on the circuit are not conscious of the line being in any way different in quality from an ordinary line. To this end the repeater must transmit in either direction with equal amplification and speed of operation, and without appreciable distortion. There were two ways open to inventors, (I) a bridge system balancing the line on either side, or (II) a switching system which would change the repeater connexions by the operation of speech currents.

The first system was investigated and patented by Edison at the end of the last century, but owing to the difficulty of balancing a bridge system against the fluctuations of an aerial line impedance, no great success was achieved.

The second system was very largely the work of S. G. Brown, and several ingenious schemes were tried experimentally by the Post Office early in 1914. In these systems speech, amplified by the repeater, actuated a reed relay sensitive to telephone current, and changed over relay contacts so as to reverse the direction of transmission when required. Troubles always arose, however, due to the fact that line noises gave rise to false operations, and the line was thrown out of service when it was still workable without the repeater. Further, if the speech switches were set less sensitively they would not operate with small speech volume.

Early in 1914 the thermionic valve was sufficiently developed to show great promise as an amplifier. The valve was not subject to the maintenance difficulties of receiver-transmitter relays, and gave a great impetus to research work. The cable problem, as then appreciated, had also been solved, and satisfactory cables could be constructed for long distance work.

These two factors changed the whole outlook of repeater research since, with an underground circuit, a stable balance for a bridge could be obtained, and the valve gave a ready means of amplifying with a minimum of distortion.

The bridge system adopted is shown in Fig. 1. The transformer in the line is used to pick up the

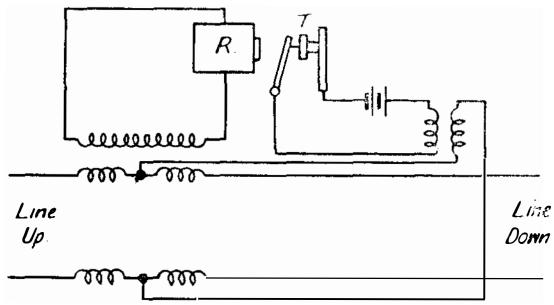

Fig. 1.—Bridge Type of Repeater.

incoming speech currents and pass them to the receiving element of the repeater. In this case, for simplicity, a receiver-transmitter type of relay is shown. The retransmitted speech, amplified by the fresh power supply to the transmitter, is fed to the centre point of the line transformer and passes to line differentially through the line windings. If the two connecting lines be of equal impedance then no retransmitted current can be picked up by the receiving winding. With underground lines it was usually possible to ensure that the lines on both sides of the repeater were equal in impedance over the frequency range of speech. A good measure of success was therefore obtained.

The next step was to work two of these repeaters in a line, and immediately a difficulty arose. It will be noticed in Fig. 1 that the amplified speech splits through the line transformer, and passes both ways into the line system. If now two repeaters are put into a line, amplified currents circulate from repeater A to repeater B and back again until damped out by attenuation. This gives rise to bad articulation and eventually to instability when the amplification is raised to too high a degree. In order to avoid this interaction the " double valve " system was evolved. This system is shown in Fig. 2 where each line is

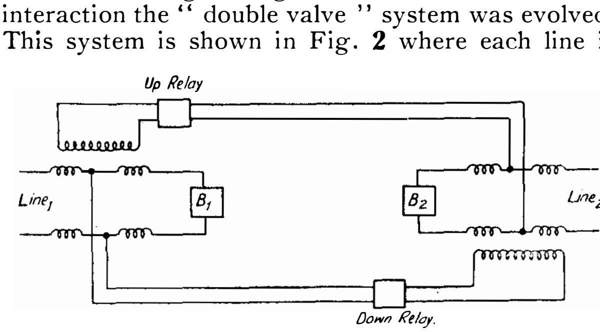

Fig. 2.—Bridge Type of Repeater using Line Balances.

balanced against an artificial network in which the undesired amplified currents are absorbed. A further advantage is gained since lines which are dissimilar can be used on either side of the repeater. This system is now used universally for 2-wire repeaters.

Examining Fig. **2** more closely it can be seen that there are two wires between the up side transmitting element and the centre point of the down side differential transformer. Likewise there is a pair of wires on the other side in a similar position. If we now consider these two pairs of wires, as pairs in a long underground line fitted with unidirectional repeaters to annul attenuation, the 4-wire system becomes evident. The 4-wire system was evolved naturally from the 2-wire system in this way, and as a corollary it is evident that there is only one fundamental system—the 4-wire. The so-called 2-wire system is a series of 4-wire systems each confined to a repeater station and joined by 2-wire links.

This method of regarding repeaters is most useful in dispelling the illusion that a 2-wire and a 4-wire circuit are fundamentally different.

A 2-wire circuit has one definite disadvantage in that the line has to be balanced against an artificial network. It is hardly necessary to say that no network can give a perfect balance over the necessary speech frequency range. Hence it follows that each balance is a potential source of instability when the gain of the repeater is increased sufficiently. The longer the line, the more repeaters are required, and the overall efficiency of the line must be lowered to allow for the loss of stability at the balances. The 4-wire circuit, on the other hand, has only two balances and thus is inherently more stable.

For this reason all long lines utilise the 4-wire principle and by the use of light gauge conductors can be made economical propositions.

Balances to simulate lines, in order to make 2-wire repeater circuits efficient and stable have been the subject of much work. The matter has been dealt with in official instructions as well as published articles; it is outside the scope of this series.

The chief difficulty, with loaded lines, is the variation of impedance due to uneven distribution of electrical constants, which gives rise to waves on the impedance frequency curves. Further a cable, loaded with lumps of inductance, has the effect of a filter and cuts off all transmission beyond a certain frequency. The impedance, however, rises rapidly near the cut off point and then later drops to a relatively small figure. Since the impedance curve is very sensitive near the cut off point to small electrical inequalities, it is obviously desirable to avoid having to balance this range of frequencies, which are not transmitted effectively through the cable. A filter is therefore inserted in the repeater circuit, so that no amplification takes place beyond a point which may be taken as 0.8 times the cut off frequency.

As stated above, the 4-wire circuit is the standard for all long distance trunk circuits in the world. Provided care is taken in cable construction so that the "go" and "return" circuits do not cross-talk to an extent which would cause oscillation, a 4-wire circuit can be set up at an overall value of 3 db. almost irrespective of length. Three difficulties arise which must be solved before long circuits of this description become commercial.

The first difficulty arises due to the fact that on all lines the attenuation frequency curve is not flat. The attenuation always rises with frequency, but the law governing the rise is not the same for loaded and unloaded cables. In the loaded line the curve of attenuation-frequency is convex viewed from the frequency axis and in the unloaded line it is concave.

Taking the loaded cable as being the most typical, Fig. **3** shows a curve of attenuation-frequency for a medium heavy loaded cable, *i.e.,* 176 mh spaced at 1.136 miles. If a repeater having a gain of one unit be used at the end of the first section to pass on the power to a second section similar to the first, and if the repeater amplifies all frequencies equally, then the resulting attenuation at the end of the second section will be shown by the dotted curve labelled (1).

At 400 p.p.s. the attenuation is 0.9 units, and the repeater gain being 1.0, the power transmitted to the second section is at a level of 0.1 units better than that at 800 p.p.s. Hence the attenuation at the end of the second section is $0.9 - 1.0 + 0.9 = 0.8$ units.

Similarly at 2000 p.p.s. the attenuation at the end of the second section is $2.35 - 1.0 + 2.35 = 3.7$ units. Table I gives results for a number of frequencies.

The "gain" in the repeater can be regarded as a negative attenuation, and hence the minus sign in the third column shows that the attenuation loss in the first section is more than completely annulled and therefore the power sent into the second section is greater than that sent originally into the first section at that frequency.

Following out the same reasoning the curves of sections of equal attenuation and having several

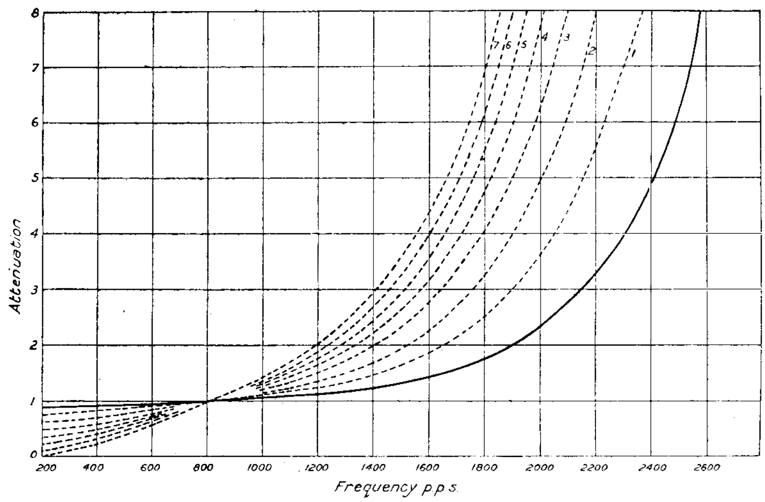

FIG. 3.—ATTENUATION-FREQUENCY CURVES OF MEDIUM-HEAVY LOADED CABLE.

repeaters are shown in Fig. **3** and labelled numerically as to the number of repeaters involved.

TABLE I.

Frequency.	Attenuation of 1st Section.	Level into 2nd Section.	Attenuation over 2 Sections + Repeater.
200	0.87	− 0.13	0.74
400	0.9	− 0.1	0.8
800	1.0	0.0	1.0
1200	1.13	+ 0.13	1.26
1600	1.43	+ 0.43	1.86
1800	1.75	+ 0.75	2.5
2000	2.35	+ 1.35	3.7
2200	3.3	+ 2.3	5.6

Table II gives figures from which the curves were plotted.

TABLE II.

Frequency.	Attenuation at end of $n + 1$ sections where n is						
	1	2	3	4	5	6	7
200	0.74	0.61	0.48	0.35	0.22	0.09	−0.16
400	0.8	0.7	0.6	0.5	0.4	0.3	0.2
800	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1200	1.26	1.39	1.51	1.64	1.77	1.9	2.03
1600	1.86	2.29	2.72	3.15	3.58	4.01	4.44
1800	2.5	3.25	4.0	4.75	5.5	6.25	7.0
2000	3.7	5.05	6.4	7.75	9.1	10.45	11.8
2200	5.6	7.9	10.2	12.5	14.8	17.1	19.4

From these results it is easy to see that as the number of sections increases the attenuation frequency distortion also increases, with the result that the frequency band available is decreased as each section is added.

If the value of 5 units of attenuation be taken as a limit above which speech is cut off, then, with one section of cable only, frequencies up to 2400 are transmitted. If seven sections with 6 repeaters be taken, no frequencies above 1670 p.p.s. are transmitted whilst the low frequencies are badly over emphasised.

To avoid this distortion, all 4-wire repeaters are fitted with compensators, consisting of a tuned circuit damped as required with resistance, in the coil circuit of the first stage, so that the repeater has a gain frequency curve which is the reverse of the line.

The second difficulty is the presence of electrical echo brought about by the reflection of power from the telephone at the far end.

This is easily overcome by means of an echo-suppressor, a piece of apparatus consisting of an amplifier, which in turn energises a rectifier. A new type of echo-suppressor has been invented by Dr. Ryall, of the Department's Research Section, and is described in this Journal. The rectifier builds up a unidirectional pressure which is used to vary the grid bias on the repeater in the opposite direction and thus render it inefficient. Fig. **4** shows a schematic diagram of the present standard echo-suppressor. A current passing down the " go " line energises the suppressor connected to repeater 1 which renders repeater 2 inefficient. The echo current, returning along the " return " line, reaches the repeater 2 at an interval of time later than the original current in the " go " line, depending upon the transmission time of the circuit. It is necessary therefore to arrange for repeater 2 to be inefficient over a time interval such that no echo current is passed. This is catered for by the resistance and capacity in shunt in the rectifier circuit. The capacity takes a definite time to discharge through the resistance and thus holds over the opposite line repeater for the designed period of time.

The third difficulty to be overcome is that, as all frequencies are transmitted at varying speeds, there comes a time on a long line when the spreading of the frequencies becomes noticeable and affects articulation. This condition is due to " transient condition " and is referred to as " phase distortion."

Since the line has definite characteristics which give rise to this phenomenon, it is reasonable to assume that by reversing the characteristics, an artificial line can be made up which compensates for this phase distortion. Compensation is actually added to long lines, and is essential for the perfect reproduction required for such high grade transmission as picture telegraphy. For speech compensation is only necessary on modern lines of say 500 miles and over.

The 2-wire circuit has a balance provided at each repeater station for either direction, *i.e.*, two balances at each station. The efficiency of the circuit depends on the balance being maintained. If a loading coil becomes faulty, the impedance curve of the line concerned alters over the whole frequency range, with the result that the balance provided is only adequate at points where the mean curve is cut by the actual curve. Degradation of the circuit in efficiency must inevitably take place before the line can become free

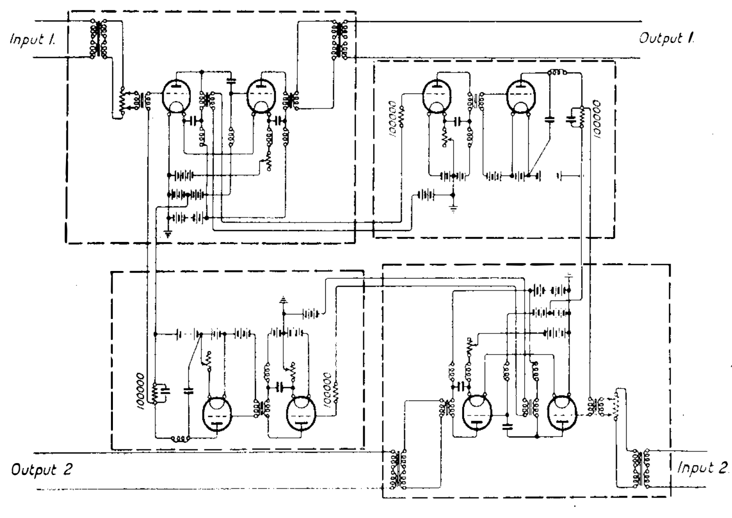

FIG. **4**.—SCHEMATIC DIAGRAM OF ECHO-SUPPRESSOR.

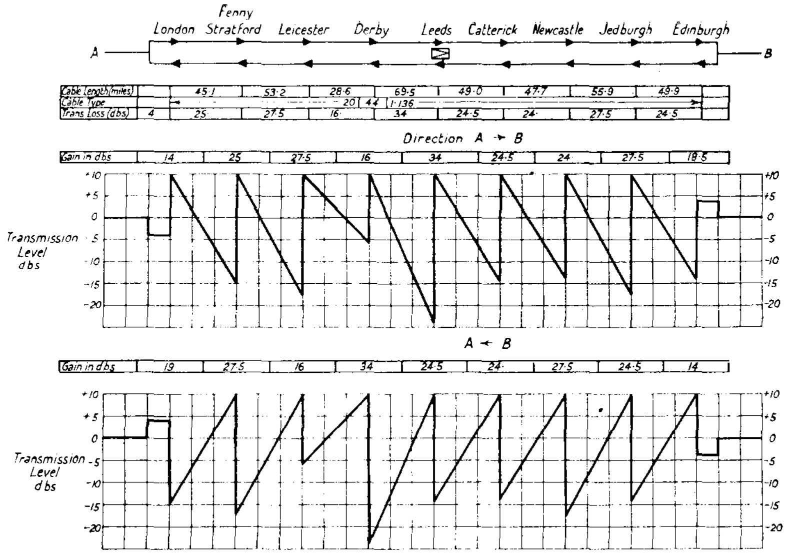

Fig. 5.—Typical Level Diagram of 4-Wire Circuit.

from oscillation. Variations of lengths between loading points, due to circuits being led in and out of an exchange, give rise to similar difficulties. Hence the 2-wire repeater circuit can be looked upon as a circuit sensitive to conditions to a marked degree. The 4-wire circuit on the other hand is free from this trouble and is thus more robust.

This brief description of the two types of repeatered lines provided will be sufficient to enable the student to grasp the general ideas of modern line provision. It is now necessary to examine the main points to be watched in design and maintenance.

Two considerations are involved in the provision of all repeater circuits which govern the spacing of repeaters and the design of cables. It is obvious that there must be a limit to the amount of power that can be handled by any piece of apparatus. With repeaters the valve is the determining factor. Having in mind the power supply question, size of valves, etc., the modern valve adopted can handle efficiently without overloading and with a margin of safety for peaks of current which are always present in speech, a power of 10 db. above the level at which speech enters the line. In practice measurements are made to ensure that the power does not exceed 10 db. above 1 milliwatt, and this gives a good margin of safety. The upper limit of power is thus given and it is necessary to see that this is not exceeded at any station.

The lower limit, that is the extent to which the power can be allowed to diminish without encountering other difficulties, is found as follows :—A cable can be designed so that the cross-talk between pairs can be made extremely small, and can be so constructed that interference from external sources is also negligible, but there is an economic limit beyond which it is not reasonable to go. This limit has been found in practice to be such that the speech power in a telephone cable should not fall below 25 db. less than 1 milliwatt. The two limits being thus defined, all that remains is to design the route so that the space, electrically speaking, between two repeater stations does not exceed 35 db. In practice this figure, representing the limit, is not fully used, and a factor of safety is allowed depending on conditions.

In this country, where so many large towns have to be served, 50 miles has been taken as the spacing of repeater stations for normal cases, and the cables are so designed that the various services can be met most economically. This means that rarely has the limiting condition been met.

When 4-wire repeaters are used, it is usual to have two stages of amplification giving a possible repeater gain of about 40 db. Two-wire repeaters are never built as double stage, since the gain which can be used is limited by the degree of balance. These repeaters therefore are limited in gain to about 20 db.

It is most important to note that, where 4-wire repeaters are concerned, the loss between repeater stations must be taken at the highest frequency to be transmitted, since this figure determines the maximum repeater gain in order to compensate for the line distortion.

Fig. **5** shows a typical level diagram for a 4-wire line, and Fig. **6** shows an overall transmission curve from which it is easy to realise the marked effect of the attenuation compensation.

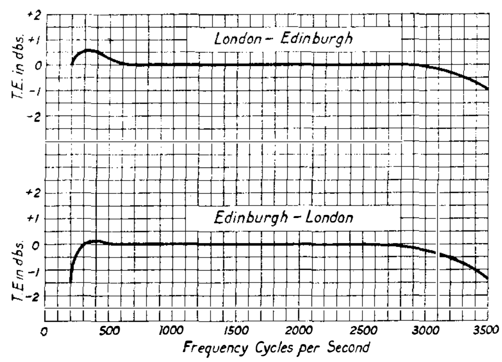

Fig. **6**.—Transmission-Frequency Characteristics of a London-Edinburgh 4-Wire Circuit.

For design work it may be taken that all 4-wire circuits fitted with echo-suppressors can be worked without attenuation loss. Two-wire circuits are operated at 3 db. where one repeater is involved and at 5 db. when two repeaters are required.

Various schemes are on foot for increasing the efficiency of 2-wire circuits, but as yet no method has been proved entirely satisfactory. A 2-wire circuit, dependent on a balance against the line, must be seriously affected by line irregularities, whereas the 4-wire circuit is free from this inconvenience.

On the Hunting of Line Finders

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THE present paper deals with some probability problems in connexion with the hunting of line finders. Each call is supposed to start a certain number of non-homing finders, all moving with the same velocity. In §1, rotating finders are considered. On the assumption that the starting switch first reaching the call will seize it, the average number of steps hunted over by this switch (the average hunt) is calculated. In §2, the same calculation is performed for switches with to- and fro-motion. Obviously in this case the result will be different for calls from different contacts. §3 treats the same arrangement as §1, but with the different assumption that two or more finders reaching a call simultaneously will block each other, the call being seized by the nearest *single* switch. In §4, finally, is treated a phenomenon, occurring on finders with rotating as well as radial motion. A switch, moving to a calling contact at the end of a radial bank, can be " stolen " by a later call originating on an earlier contact in the same bank. The problem consists in investigating the influence of this " stealing " on the average hunt to the last contacts.

§1. *Rotating finders without blocking*.

Consider the arrangement of Fig. 1 with a group of n rotating switches, hunting over a contact bank with N contacts. The switch first reaching the calling contact is assumed to seize it. If two or more switches reach it simultaneously, one of them will seize it. The problem is to find the average number of steps hunted over by the engaged switch.

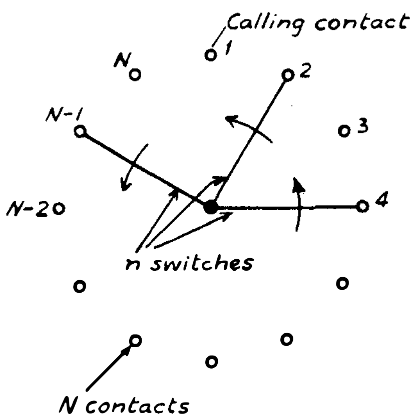


FIG. 1.—n ROTATING SWITCHES, HUNTING OVER N CONTACTS.

We number the contacts from 1 to N in the direction *opposite* to the motion of the switches, beginning with the calling contact. The arrangement can then be alternatively drawn as shown by Fig. 2 and our problem can be formulated as follows :

n switches are distributed at random over the N contacts 1 to N. A call arrives on contact 1 and is seized by the nearest switch. Calculate the average number of steps hunted over by this switch.

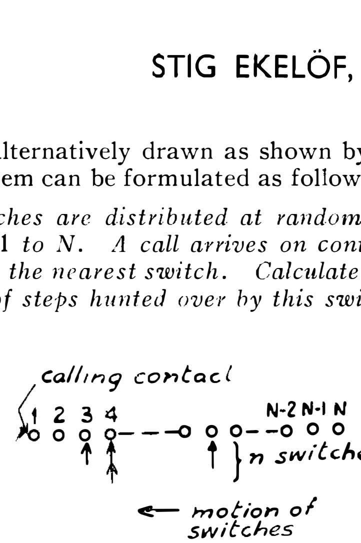


FIG. 2.—ARRANGEMENT EQUIVALENT TO FIG. 1.

We begin by computing the probability R_m of the first m contacts being free from switches. Evidently

$$R_m = \left(\frac{N-m}{N}\right)^n ; \quad \ldots\ldots\ldots\ldots (1)$$

Our next step is to find the probability S_m that none of the n switches rests on contacts 1 to $m-1$, but at least one on contact m. It is easily seen that

$$S_m = R_{m-1} - R_m ; \quad \ldots\ldots\ldots\ldots (2)$$

The number of steps from contact m to contact 1 being $m-1$, we have immediately for the average hunt :

$$l = \sum_{m=1}^{N} (m-1)\, S_m = \sum_{m=1}^{N} R_m ; \quad \ldots\ldots (3)$$

or

$$l = \frac{1^n + 2^n + 3^n + \ldots\ldots + (N-1)^n}{N^n} = \frac{\sigma_n(N-1)}{N^n} ; \quad (4)$$

if we introduce the symbol

$$\sigma_n(x) = 1^n + 2^n + 3^n + \ldots\ldots + x^n ; \quad \ldots\ldots\ldots\ldots (5)$$

The σ_n can be expressed in the Bernouillian polynomials $B_n(x)$:

$$\sigma_n(x) = \frac{B_{n+1}(x+1) - B_{n+1}(0)}{n+1} ; \ldots\ldots\ldots\ldots (6)$$

The most straight-forward calculation is however afforded by the following recursion formula, deduced in Appendix I :

$$\sigma_n(x) = n \int_0^x \sigma_{n-1}(x)dx + x\left[1 - n\int_0^1 \sigma_{n-1}(x)dx\right] ; \ldots (7)$$

The appendix gives $\sigma_n(x)$ for $n = 0$ to 12. As will be seen there, $\sigma_n(x)$ has the form

$$\sigma_n(x) = \frac{x^{n+1}}{n+1} + \frac{x^n}{2} + \frac{n}{12} x^{n-1} + 0(x^{n-2})\,; \quad \ldots(5')$$

($0(x^{n-2})$ = terms of the order of magnitude x^{n-2}).

Inserting (5′) in (4) we obtain

$$l = \frac{N}{n+1} - \frac{1}{2} + \frac{1}{12}\frac{n}{N} + 0\left(\frac{n^2}{N^2}\right),$$

i.e., if we neglect terms of the order of magnitude $\left(\frac{n}{N}\right)^2$, we have

$$l = \frac{N}{n+1} - \frac{1}{2} + \frac{1}{12}\frac{n}{N}\,; \quad \ldots\ldots\ldots\ldots(4')$$

This formula is generally quite sufficient for practical use.

Table I gives the results of some numerical computations from (4) and—within brackets—(4′). The values for n = 1, 2 and 3 are also given by Berkeley : " Traffic and Trunking Principles in Automatic Telephony, London, 1934," p. 222, Table XXI.

TABLE I.

Number of switches n =	Average hunt l for number of contacts N = 25		50		100	
1	12.0	(12.0)	24.5	(24.5)	49 5	(49.5)
2	7.84	(7.84)	16.2	(16.2)	32.8	(32.8)
3	5.76	(5.76)	12.0	(12.0)	24.5	(24.5)
5	3.68	(3.69)	7.84	(7.84)	16.2	(16.2)
8	2.30	(2.31)	5.07	(5.07)	10.6	(10.6)
12	1.46	(1.46)	3.37	(3.37)	7.20	(7.20)

§2. *To- and fro- moving finders without blocking.*

We now proceed to the somewhat more complicated case that the finders have a to- and fro-motion between two extreme positions. Except in these positions, a switch can rest on N contacts. For simplicity, we assume the same distance between the extreme positions and the contacts 1 and N as between two neighbouring contacts.

In distributing n switches at random, we have, from the probability point of view, to give them two positions before each of the N contacts, one for each direction of motion. These positions are equivalent to each other and to the extreme positions (see Fig. 3). We have therefore G = 2N + 2 possible positions, all with equal probability.

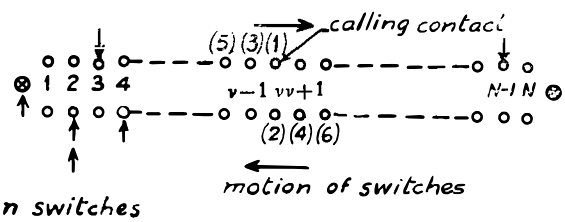


FIG. 3.—n TO- AND FRO-MOVING SWITCHES, HUNTING OVER N CONTACTS AND TWO EXTREME POSITIONS.

We suppose that a call arrives on contact No. ν $\left(\nu \leq \frac{N}{2}\right)$ and re-number the G positions with regard to the number of steps from the different positions to contact No. ν. If the switch seizing the call starts from

position (1) or (2) in Fig. 3 the hunt is 0 steps
,, (3) ,, (4) ,, ,, ,, ,, ,, 1 ,,
,, (5) ,, (6) ,, ,, ,, ,, ,, 2 ,,
etc., etc.

We can now draw a scheme (Fig. 4) equivalent to that of Fig. 3, but resembling that of Fig. 2 in that the switches hunt in one direction only and that the calling contact is at the end.

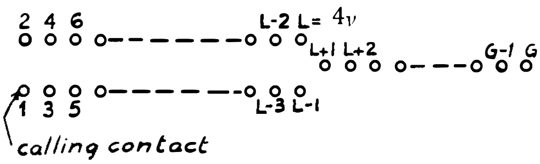


FIG. 4.—ARRANGEMENT EQUIVALENT TO FIG. 3

We get in Fig. 4, $\frac{L}{2} = 2\nu$ contact pairs, the two contacts of a pair having the same hunting distance. As in §1 we obtain

$$R_m = \left(\frac{G-m}{G}\right)^n; \quad \ldots\ldots\ldots\ldots\ldots\ldots(1')$$

$$S_m = R_{m-1} - R_m\,; \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

The average hunt becomes

$$l = \sum_{m=1}^{G} l_m S_m \quad \ldots\ldots\ldots\ldots\ldots\ldots(8)$$

where l_m = the number of steps from contact 1 to contact m in Fig. 4. The figure gives us

$$\begin{cases} l_1 = l_2 = 0 \\ l_3 = l_4 = 1 \\ \ldots\ldots\ldots\ldots \\ l_{L-1} = l_L = L/2 - 1 \end{cases} \qquad \begin{cases} l_{L+1} = L/2 \\ l_{L+2} = L/2 + 1 \\ \ldots\ldots\ldots\ldots \\ l_G = L/2 + G - L - 1 \\ \quad = G - L/2 - 1 \end{cases}$$

Thus

$$l = \sum_{t=1}^{\frac{L}{2}-1} t(S_{2t+1} + S_{2t+2}) + \sum_{t=1}^{G-L} (L/2 + t - 1) S_{L+t}$$

and with the aid of (2) :

$$l = \sum_{t=1}^{\frac{L}{2}-1} t(R_{2t} - R_{2t+2}) + \sum_{t=1}^{G-L} (L/2 + t - 1)\,(R_{L+t-1} - R_{L+t})$$

By introducing

$$\sum_{t=1}^{\frac{L}{2}-1} tR_{2t+2} = \sum_{t=1}^{\frac{L}{2}-1} (t-1)R_{2t} + (L/2-1)R_L$$

$$\sum_{t=1}^{G-L} (L/2+t-1)R_{L+t-1}$$

$$= L/2.R_L + \sum_{t=1}^{G-L} (L/2+t)R_{L+t};\ (R_G = 0\,!),$$

we further obtain

$$l = \sum_{t=1}^{\frac{L}{2}} R_{2t} + \sum_{t=1}^{G-L} R_{L+t} = (R_2 + R_4 + R_6 + \ldots\ldots + R_{4v})$$
$$+ (R_{4v+1} + R_{4v+2} + \ldots\ldots + R_{2N+1}),$$

and using (1′) :

$$l = \frac{1}{2^n(N+1)^n}\{2^n[N^n + (N-1)^n + \ldots\ldots + (N-2v+1)^n] + [(2N-4v+1)^n + (2N-4v+2)^n + \ldots\ldots + 2^n + 1^n]\}$$

hence

$$l = \frac{1}{(N+1)^n}\left\{\sigma_n(N) - \sigma_n(N-2v) + \frac{1}{2^n}\,\sigma_n(2N-4v+1)\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots ;\ (9)$$

Table II gives l for $N = 50$ and different v and n.

TABLE II.

(N = 50)

Number of switches n =	Average hunt l for a call from contact No. v =			
	1	9	17	25
1	48.4	35.6	27.8	25.0
2	31.5	21.1	18.3	16.5
3	23.1	14.5	12.4	12.25
5	14.7	8.6	8.02	8.01
8	9.1	5.3	5.18	5.18
12	5.8	3.45	3.44	3.44

§3. *Rotating finders with blocking.*

In this section we return to the arrangement of §1, but assume that two or more switches simultaneously reaching the call will block each other. We then have to solve the following problem :

n switches are distributed at random over N contacts 1 to N. A call arrives on contact 1 and will engage the nearest, single switch. What is the average hunt for this switch?

This problem as well as that of §1 has been formerly treated by T. C. Fry (" Probability and its Engineering Uses, London, 1928," p. 364-367). The following calculations are, however, based on a method quite different from that of Fry. The author therefore hopes that the deductions as well as the numerical results will still be of a certain interest. Fry moreover puts the problem in a slightly different manner, so that his formulæ are also a little different from those obtained here. In most practical cases, however, the difference can be neglected.

We begin with the determination of the probability $S_v(p)$ of p switches being blocked on contacts 1 to v, contact $v + 1$ having one and only one switch. We can write

$$S_v(p) = U_v(p) \cdot W_v(p) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

where $U_v(p)$ = the probability that if p switches are on contacts 1 to v, they are all blocked (no contact with only one switch),

$W_v(p)$ = the probability that of n switches p are on contacts 1 to v, one on contact $v + 1$ and the rest $n - (p + 1)$ on the remaining $N - (v + 1)$ contacts.

It is obvious at once that

$$W_v(p) = \frac{\lfloor n}{\lfloor p \ \lfloor 1 \ \lfloor n-(p+1)}\left(\frac{v}{N}\right)^p\left(\frac{1}{N}\right)\cdot \left(\frac{N-(v+1)}{N}\right)^{n-(p+1)}; \quad \ldots\ldots\ldots\ldots (11)$$

$U_v(p)$ can be calculated as the ratio between the number of ways in which p switches can be distributed on v positions, no position having only one switch, and the total number of ways, in which the same distribution can be done.

If we consider the expression

$$(x_1 + x_2 + \ldots\ldots + x_v)^p,$$

an arbitrary term

$$x_\alpha{}^a x_\beta{}^b \ldots\ldots x_\lambda{}^l$$

in its development can be said to correspond to a distribution of the p switches with a switches on position α, b switches on position β, etc. The coefficient for the term in question gives us the total number of ways, in which the corresponding distribution can be performed.

The total number of ways for distributing the p switches on v positions is equal to the sum of all the coefficients in the development, *i.e.*, to the value of $(x_1 + x_2 + \ldots\ldots + x_v)^p$ for $x_1 = x_2 = \ldots\ldots = x_v = 1$, that is v^p. This result is also immediately obtained by a direct calculation.

The number of ways where blocking occurs is, on the other hand, equal to the sum of the coefficients for all terms, which are not linear in any of the variables x_1 to x_v. Hence

$$U_v(p) = \frac{\sum_{nlc} (x_1 + x_2 + \ldots\ldots + x_v)^p}{v^p}; \quad \ldots\ldots (12)$$

if the index " *nlc* " (non-linear coefficients) serves to indicate that we have to take the sum of the coefficients for all terms in the development of the expression under the summation sign, which are not linear in any of the variables x_1 to x_v.

From (10), (11) and (12) it follows that

$$S_\nu(p) = \frac{n}{N^n}\binom{n-1}{p}(N-\nu-1)^{n-p-1}\cdot$$

$$\sum_{nlc}(x_1+x_2+\dots\dots+x_\nu)^p;\dots\dots\dots\dots\dots\dots(13)$$

We can now further calculate the probability T_ν of contacts 1 to ν carrying an arbitrary number of blocked switches, contact $\nu+1$ carrying one and only one switch. T_ν obviously is also the probability of a hunt of ν steps. We get

$$T_\nu = \sum_{p=0}^{n-1} S_\nu(p)$$

$$= \frac{n}{N^n}\sum_{nlc}\sum_{p=0}^{n-1}\binom{n-1}{p}(N-\nu-1)^{n-p-1}(x_1+x_2+\dots\dots+x_\nu)^p$$

$$= \frac{n}{N^n}\sum_{nlc}(N-\nu-1+x_1+x_2+\dots\dots+x_\nu)^{n-1};\ \dots(14)$$

The next question is to determine the sum K of the coefficients for all terms in the development of $\psi(x_1, x_2, \dots\dots x_\nu) = (N-\nu-1+x_1+x_2+\dots\dots+x_\nu)^{n-1}$ which are not linear in any variable x_i.

The sum of all the coefficients is $(N-\nu-1+\nu)^{n-1} = (N-1)^{n-1}$. We can further calculate the sum of the coefficients for all terms which are linear in $x_1, x_2, x_3, \dots\dots x_\lambda$—and eventually in other x_i. This value is obtained by inserting $x_1 = x_2 = \dots\dots = x_\lambda = 0$; $x_{\lambda+1} = x_{\lambda+2} = \dots\dots = x_\nu = 1$ in $\dfrac{\partial^\lambda \psi}{\partial x_1 \partial x_2 \dots\dots \partial x_\lambda}$. We call it K_λ and thus have

$$K_\lambda = \Big|_{x_i=1}(n-1)(n-2)\dots\dots(n-\lambda)\,.$$

$$(N-\nu-1+x_{\lambda+1}+x_{\lambda+2}+\dots\dots+x_\nu)^{n-\lambda-1}$$

$$= \frac{\underline{|n-1}}{\underline{|n-\lambda-1}}(N-\lambda-1)^{n-\lambda-1};\ (\lambda \leq n-1);\dots(15)$$

Some consideration will now show that

$$K = (N-1)^{n-1} - \binom{\nu}{1}K_1 + \binom{\nu}{2}K_2 + \dots\dots$$

$$+(-1)^\lambda\binom{\nu}{\lambda}K_\lambda + \dots\dots + (-1)^\mu\binom{\nu}{\mu}K_\mu;\dots\ \dots(16)$$

where μ = the least of the numbers ν and $n-1$.

(The first term is the sum of all coefficients. The second term diminishes this sum by the coefficients for all terms which 1o. are linear in x_1 and eventually in other x_i, 2o. in x_2 and eventually in other x_i, etc. We have then subtracted too much and therefore add in the third term the coefficients for all terms, which are linear in 1o. x_1, x_2 and eventually other x_i, 2o. x_1, x_3 and eventually other x_i, etc., etc.).

(14), (15) and (16) give us

$$T_\nu = \frac{n}{N^n}\cdot K =$$

$$= \frac{n}{N^n}\sum_{\lambda=0}^{\mu}(-1)^\lambda\binom{\nu}{\lambda}\frac{\underline{|n-1}}{\underline{|n-\lambda-1}}(N-\lambda-1)^{n-\lambda-1};$$

$$\dots\dots\dots\dots\dots(17)$$

hence the average hunt

$$l = \sum_{\nu=1}^{N-1}\nu T_\nu =$$

$$= \frac{n}{N^n}\sum_{\nu=0}^{N-1}\sum_{\lambda=0}^{\mu}(-1)^\lambda\cdot\nu\binom{\nu}{\lambda}\frac{\underline{|n-1}}{\underline{|n-\lambda-1}}(N-\lambda-1)^{n-\lambda-1};$$

or if we change the summation order

$$l = \frac{n}{N^n}\sum_{\lambda=0}^{n-1}\sum_{\nu=\lambda}^{N-1}(-1)^\lambda\cdot\nu\binom{\nu}{\lambda}\frac{\underline{|n-1}}{\underline{|n-\lambda-1}}(N-\lambda-1)^{n-\lambda-1}$$

$$= \frac{n}{N^n}\sum_{\lambda=0}^{n-1}(-1)^\lambda\frac{\underline{|n-1}}{\underline{|n-\lambda-1}}(N-\lambda-1)^{n-\lambda-1}\sum_{\nu=\lambda}^{N-1}\nu\binom{\nu}{\lambda};$$

In Appendix II it is shown that

$$\sum_{\nu=\lambda}^{N-1}\nu\binom{\nu}{\lambda} = (\lambda+1)\binom{N}{\lambda+2} + \lambda\binom{N}{\lambda+1},$$

so that we finally obtain

$$l = \frac{n}{N^n}\sum_{\lambda=0}^{n-1}(-1)^\lambda\frac{\underline{|n-1}}{\underline{|n-\lambda-1}}(N-\lambda-1)^{n-\lambda-1}.$$

$$\left[(\lambda+1)\binom{N}{\lambda+2} + \lambda\binom{N}{\lambda+1}\right];\ (18)$$

It is also of interest to know the probability of all the n switches being blocked (no single switch). This probability is given by

$$U_N(n) = \frac{\sum_{nlc}(x_1+x_2+\dots\dots+x_N)^n}{N^n}\dots\dots\dots(19)$$

For $n < N$, which condition will be fulfilled in all practical cases, we obtain in analogy to (15) and (16):

$$\sum_{nlc}(x_1+x_2+\dots\dots+x_N)^n = N^n - \binom{N}{1}M_1 +$$

$$\binom{N}{2}M_2 + \dots\dots + (-1)^n\binom{N}{n}M_n;\dots\dots\dots(16')$$

with

$$M_\lambda = n(n-1)\dots\dots(n-\lambda+1)(N-\lambda)^{n-\lambda};\dots\dots\dots(15')$$

hence

$$U_N(n) = \frac{1}{N^n}\sum_{\lambda=0}^{n}(-1)^\lambda\binom{N}{\lambda}\frac{\underline{|n}}{\underline{|n-\lambda}}(N-\lambda)^{n-\lambda};$$

$$\dots\dots\dots\dots\dots\dots\dots(20)$$

Table III gives some numerical results computed from (18) and (20).

TABLE III.

(N = 50)

Number of switches $n =$	$U_{50}(n)$	l without blocking	l with blocking	Increase %
2	0.02	16.2	15.7	−3.1 (!)
3	0.0_34	12.0	12.5	4.2
5	0.0_48	7.8	8.4	7.7
8	0.0_416	5.08	5.64	11.0
12	0.0_667	3.39	4.08	20.3

As can be seen, the influence of the blocking is rather small for the values of n which can be probably found in practice. In reality it will often be still smaller than given by our calculations, while two switches starting together from the same position will often separate a little during the motion, thus annihilating the blocking. For to- and fro- moving finders, the conditions will be about the same. In this case, two switches generally separate when passing simultaneously an extreme position.

The treatment of Fry differs from that of the author in the following: In calculating T_N, Fry also includes those completely blocked cases given by the probability $U_N(n)$. He therefore obtains two different formulæ for T_ν, one for $\nu = N$, the other for $\nu \neq N$. This naturally also leads to another formula for l, though both Fry's and the author's formulæ will give nearly the same numerical results, as long as $U_N(n)$ is very small, a condition which must always be fulfilled in practice.

§4. *Finders with both rotating and radial motion.*

In this section, we will treat line finders with rotating as well as radial motion. During the rotation a finder tests the entrances to N radial contact banks. During the radial motion all the contacts of a certain radial bank are subsequently tested. As mentioned in the introduction the contacts at the end of the radial bank are at a disadvantage, as a finder moving to a call on such a contact can be " stolen " by a later call from another contact in the same bank. (We need not consider " stealing " from other banks as it will on an average be compensated by " stealing " from the bank in question itself).

We will try to estimate the increase in hunting time for the last contacts, caused by such " stealing." Fig. **5** shows the arrangement laid out in a plane (compare Fig. **2**). We number the contacts of a radial bank 1, 2, 3, ... beginning with the contact nearest to the entrance.

A call is supposed to originate on contact z. We introduce the following new notations;

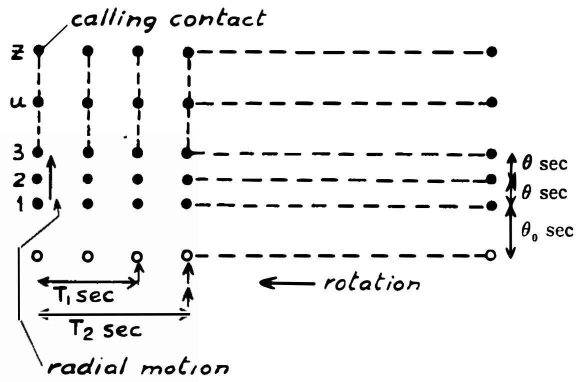


FIG. 5.—SWITCHES WITH ROTATING, AS WELL AS RADIAL MOTION.

ϵ = number of calls per subscriber and unit of time,

s = probability of a contact being busy,

θ_0 = time for the radial motion of a switch from the entrance of the bank to contact 1,

θ = time for the radial motion of a switch between two neighbouring contacts,

T_1 = average time for the rotating motion of the nearest switch to the calling bank (to be calculated as shown in §1).

T_2 = same time for the next nearest switch.

We assume that if contact z does not obtain the nearest switch, it will seize the next nearest and further that all switches stop as soon as one of them has reached the calling bank, thus after the average time T_1.

If now the call on contact z occurs at the time $t=0$, contact u ($u < z$) can obviously make a " stealing " call in the time interval

$$t=0 \text{ to } t=T_1+\theta_0+(u-1)\theta=\Theta_1+u\theta; \qquad (\Theta_1=T_1+\theta_0-\theta).$$

The probability of such a call will be

$$\epsilon(1-s)(\Theta_1+u\theta).$$

Then contact z will not get its switch at the time $t=\Theta_1+z\theta$, but first at

$$t=[T_1+\theta_0+(u-1)\theta]+(T_2-T_1)+\theta_0+(z-1)\theta = \Theta_2+(u+z)\theta;$$
$$(\Theta_2=T_2+2(\theta_0-\theta)).$$

hence with a delay

$$\Theta_2+(u+z)\theta-(\Theta_1+z\theta)=\Theta_2-\Theta_1+u\theta \quad \text{..........(21)}$$

The average hunting time $\tau = \Theta_1 + z\theta$ will thus be increased by

$$\Delta\tau=\sum_{u=1}^{z-1}\epsilon(1-s)(\Theta_1+u\theta)(\Theta_2-\Theta_1+u\theta)$$

$$=\epsilon(1-s)\left[\Theta_1(\Theta_2-\Theta_1)(z-1)+\theta\Theta_2\sum_1^{z-1}u+\theta^2\sum_1^{z-1}u^2\right] \quad \text{....(22)}$$

i.e., a relative increase,

$$f = \frac{\Delta\tau}{\tau}$$

$$= \epsilon(1-s)(z-1) \cdot \frac{\Theta_1(\Theta_2-\Theta_1) + z\frac{\theta}{2}\left(\Theta_2 - \frac{\theta}{3}\right) + z^2 \cdot \frac{1}{8}\theta^2}{\Theta_1 + z\theta}; \quad \ldots\ldots (23)$$

It now remains to compute T_2. For that purpose we return to the conditions of §1 and determine the probability $\bar{S}_m$ of the next nearest finder coming from contact m. We put

$$\bar{S}_m = S_m' + S_m''; \quad \ldots\ldots (24)$$

where S_m' = the probability of one switch resting on contacts 1 to $m-1$ and one or more on contact m, S_m'' = the probability of no switch resting on contacts 1 to $m-1$ and two or more on contact m.

S_m' can be computed as the difference between the probabilities that (*a*) one switch rests on contacts 1 to $m-1$, the rest on contacts m to N and (*b*) one switch rests on contacts 1 to $m-1$ and the rest on contacts $m+1$ to N. We obtain

$$S_m' = \binom{n}{1}\left(\frac{m-1}{N}\right)\left(\frac{N-(m-1)}{N}\right)^{n-1} - \binom{n}{1}\left(\frac{m-1}{N}\right)\left(\frac{N-m}{N}\right)^{n-1}$$

$$= \frac{n(m-1)}{N^n}\{(N-m+1)^{n-1} - (N-m)^{n-1}\}; \quad (25)$$

S_m'' on the other hand is equal to the difference between the probabilities that (*a*) no switch rests on contacts 1 to $m-1$ and at least one on contact m, and (*b*) no switch on contacts 1 to $m-1$ and only one on contact m.

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

$$= \frac{1}{N^n}\{(N-m+1)^n - (N-m)^n - n(N-m)^{n-1}\}; \quad \ldots\ldots (26)$$

(24), (25) and (26) give us

$$\bar{S}_m = \frac{1}{N^n}\{(N-m+1)^n - (N-m)^n + n[(m-1)\ (N-m+1)^{n-1} - m(N-m)^{n-1}]\},$$

or, if the last two terms are transformed according to the relation

$$q(N-q)^{n-1} = N(N-q)^{n-1} - (N-q)^n$$

that

$$\bar{S}_m = n \cdot \frac{(N-m+1)^{n-1} - (N-m)^{n-1}}{N^{n-1}} - (n-1) \cdot \frac{(N-m+1)^n - (N-m)^n}{N^n} \quad \ldots\ldots (27)$$

If we introduce in $\bar{S}_m$ and in the S_m of (2) a new index for the number of starting switches, (27) can be written

$$\bar{S}_m^{(n)} = n \cdot S_m^{(n-1)} - (n-1) \cdot S_m^{(n)}; \quad \ldots\ldots (28)$$

If t_m = the time for a hunt from contact m to contact 1, we have

$$T_2^{(n)} = \sum_m t_m \bar{S}_m^{(n)} = n \cdot T_1^{(n-1)} - (n-1)T_1^{(n)}$$

or

$$T_2^{(n)} = T_1^{(n)} + n[T_1^{(n-1)} - T_1^{(n)}]; \quad \ldots\ldots (29)$$

T_2 is thus completely determined by T_1, which can be computed from §1. It is easily seen that (29) can also be immediately deduced by an intuitive reasoning, but the author has only found the above deduction quite satisfactory. From the approximation formula (4′) we deduce for the number of steps corresponding to $T_2^{(n)}$:

$$l_2^{(n)} = \frac{2N}{n+1} - \frac{1}{2}; \quad \ldots\ldots (30)$$

The relations (23) and (29) give the answer to our problem. Table IV contains some numerical results. Generally the phenomenon treated has very little influence.

TABLE IV.

$N = z = 50$; $\theta = \theta_0$ = the time for one step of the radial motion = 0.05 sec.

n =	f =	
2	1.95 $\epsilon(1-s)$ %	ϵ = number of calls per subscriber and hour; $\epsilon(1-s)$ is accordingly of the order of magnitude 1.
3	1.73	
5	1.51	
8	1.36	
12	1.28	

APPENDIX I.

Summation of $\sigma_n(x)$.

From $\sigma_n(x) = 1^n + 2^n + 3^n + \ldots\ldots + x^n$ follows

$$\sigma_n(x) - \sigma_n(x-1) = x^n$$

If we extend the definition of $\sigma_n(x)$ to non integral numbers, we thus have

$$\sigma_n'(x) - \sigma_n'(x-1) = nx^{n-1} = n[\sigma_{n-1}(x) - \sigma_{n-1}(x-1)]$$

or

$$\sigma_n'(x) - n\sigma_{n-1}(x) = \sigma_n'(x-1) - n\sigma_{n-1}(x-1) = \sigma_n'(x-2) - n\sigma_{n-1}(x-2) = \ldots\ldots \text{etc.}$$

and hence

$$\sigma_n'(x) = n\sigma_{n-1}(x) + \text{const.}$$

or

$$\sigma_n(x) = n\int_0^x \sigma_{n-1}(x)dx + Cx + D.$$

The constants C and D are determined by the conditions $\sigma_n(0) = 0$ and $\sigma_n(1) = 1$, which give

$$C = 1 - n\int_0^1 \sigma_{n-1}(x)dx\,; \qquad D = 0;$$

We therefore obtain

$$\sigma_n(x) = n\int_0^x \sigma_{n-1}(x)dx + x\left\{1 - n\int_0^1 \sigma_{n-1}(x)dx\right\}; \quad \text{....(7)}$$

For $n = 0$ to 12 we obtain the following expressions:

$$\sigma_0(x) = x\,;$$

$$\sigma_1(x) = \frac{x^2}{2} + \frac{x}{2}\,;$$

$$\sigma_2(x) = \frac{x^3}{3} + \frac{x^2}{2} + \frac{x}{6}\,;$$

$$\sigma_3(x) = \frac{x^4}{4} + \frac{x^3}{2} + \frac{x^2}{4}\,;$$

$$\sigma_4(x) = \frac{x^5}{5} + \frac{x^4}{2} + \frac{x^3}{3} - \frac{x}{30}\,;$$

$$\sigma_5(x) = \frac{x^6}{6} + \frac{x^5}{2} + \frac{5x^4}{12} - \frac{x^2}{12}\,;$$

$$\sigma_6(x) = \frac{x^7}{7} + \frac{x^6}{2} + \frac{x^5}{2} - \frac{x^3}{6} + \frac{x}{\;}\,;$$

$$\sigma_7(x) = \frac{x^8}{8} + \frac{x^7}{2} + \frac{7x^6}{12} - \frac{7x^4}{24} + \frac{x^2}{12}\,;$$

$$\sigma_8(x) = \frac{x^9}{9} + \frac{x^8}{2} + \frac{2x^7}{3} - \frac{7x^5}{15} + \frac{2x^3}{9} - \frac{x}{30}\,;$$

$$\sigma_9(x) = \frac{x^{10}}{10} + \frac{x^9}{2} + \frac{3x^8}{4} - \frac{7x^6}{10} + \frac{x^4}{2} - \frac{3x^2}{20}\,;$$

$$\sigma_{10}(x) = \frac{x^{11}}{11} + \frac{x^{10}}{2} + \frac{5x^9}{6} - x^7 + x^5 - \frac{x^3}{2} + \frac{5x}{66}\,;$$

$$\sigma_{11}(x) = \frac{x^{12}}{12} + \frac{x^{11}}{2} + \frac{11x^{10}}{12} - \frac{11x^8}{8} + \frac{11x^6}{6} - \frac{11x^4}{8} + \frac{5x^2}{12}\,;$$

$$\sigma_{12}(x) = \frac{x^{13}}{13} + \frac{x^{12}}{2} + x^{11} - \frac{11x^9}{6} + \frac{22x^7}{7} - \frac{33x^5}{10} + \frac{5x^3}{3} - \frac{691x}{2730}\,;$$

APPENDIX II.

CALCULATION OF $\sum_{\nu=\lambda}^{N-1} \nu \binom{\nu}{\lambda}$.

In order to calculate $\Sigma\nu\binom{\nu}{\lambda}$ we observe that $\nu\binom{\nu}{\lambda}$ is the coefficient of x^λ in the development of $\nu(1+x)^\nu$.

$\sum_{\nu=\lambda}^{N-1} \nu\binom{\nu}{\lambda}$ is therefore the coefficient of x^λ in

$$\phi(x) = \sum_{\nu=\lambda}^{N-1} \nu(1+x)^\nu$$

$$= (1+x)\frac{d}{dx}\sum_{\nu=\lambda}^{N-1}(1+x)^\nu = (1+x)\frac{d}{dx}\,\frac{(1+x)^N - (1+x)^\lambda}{x}$$

The term in x^λ is

$$\frac{d}{dx}\,\frac{\binom{N}{\lambda+2}x^{\lambda+2}}{x} + x\,\frac{d}{dx}\,\frac{\binom{N}{\lambda+1}x^{\lambda+1}}{x}$$

$$= x^\lambda\left[(\lambda+1)\binom{N}{\lambda+2} + \lambda\binom{N}{\lambda+1}\right]$$

and thus

$$\sum_{\nu=\lambda}^{N-1} \nu\binom{\nu}{\lambda} = (\lambda+1)\binom{N}{\lambda+2} + \lambda\binom{N}{\lambda+1}\,;$$

Launch of the S. S. "Orion"
7th December, 1934

E. J. CASTERTON

"I NAME you 'Orion': good fortune attend you always and those whom you bear across the world to their brothers overseas."

With these concluding words and by the operation of a switch, His Royal Highness, the Duke of Gloucester, speaking from Brisbane, Australia, both christened and launched the 24,000 tons liner "Orion" from a shipyard at Barrow-in-Furness. The order of the launching ceremony was as follows:

- The B.B.C. commentator speaking from Barrow, broadcast in Great Britain, in Australia, and to the company at Barrow, a brief description of the scene and the vessel.
- Sir Charles Craven, Managing Director of Messrs. Vickers-Armstrong, Ltd., made a speech from the launching platform.
- Sir Alan Anderson, a Manager of the Orient Steam Navigation Co., speaking from Brisbane, introduced H.R.H. The Duke of Gloucester.
- The Duke of Gloucester spoke and transmitted the launching signal.
- Ovation and launch noises transmitted from Barrow to Australia.
- Reply to His Royal Highness by General Sir Herbert Lawrence, Chairman of Messrs. Vickers-Armstrong, Ltd.
- Closing commentary by B.B.C. commentator.
- All speeches were broadcast in this country and in Australia.

It is not claimed that this is the first occasion on which a ship has been launched over a long distance radio link, but "Orion" was the first ship of the British Merchant Navy to be thus released from the building stocks.

Having been approached jointly by the owners and builders of the vessel, the Orient Steam Navigation Co. and Messrs. Vickers-Armstrong, Ltd., the British Post Office in co-operation with the Australian authorities undertook the entire arrangements.

The first consideration was the provision of suitable lines over which could be passed speech of such a quality as to permit of broadcasting both in this country and in Australia, and of reproduction on loud-speakers at Barrow. Two high-quality unidirectional circuits, one outgoing and one incoming, were set up between the Radio-Telephone Terminal, London, and the launching platform, the launch release gear and amplifying apparatus being housed under the latter. High-quality microphones for transmission of the speeches and noise effects were installed in conjunction with an extensive public address system, by means of which the assembled company at Barrow listened with ease to both the home and the Australian speeches.

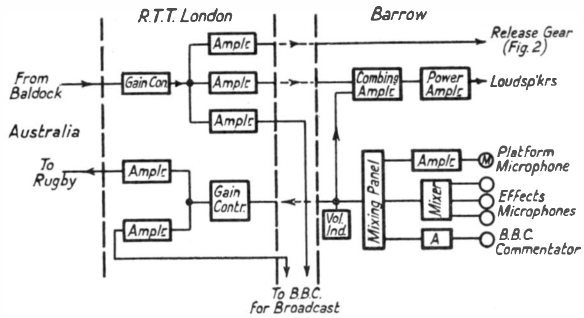


Fig. 1.—Schematic Diagram of Connexions.

Fig. 1 shows the schematic arrangement used in England from which it will be seen that the release gear was in circuit during the transmission of the speeches. The vessel was to be launched by means of a tone of 1,500 cycles per second, transmitted from Australia. As this tone is within the normal

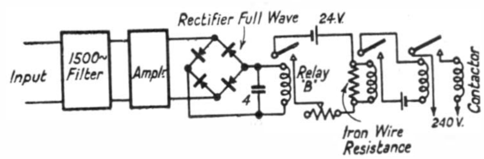


Fig. 2.—Circuit Arrangement.

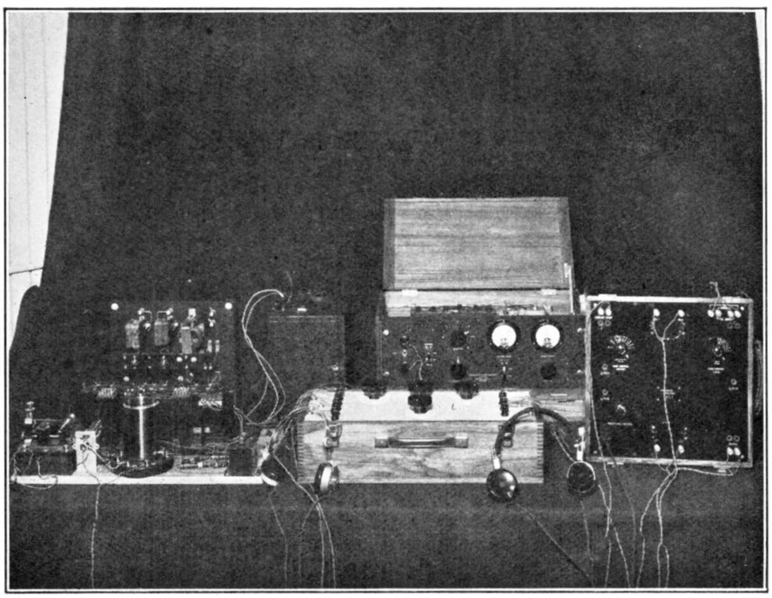


Fig. 3.—Some of the Apparatus used at Barrow.

range of voice frequencies it was necessary to introduce equipment to discriminate between speech and sustained tone. Fig. **2** shows schematically how this was achieved. A 1,500 cycle filter followed by an amplifier and simple full wave rectifier satisfactorily operated a standard relay " B " on which a reliable margin of bias could be applied. In turn were operated, a relay fitted with a delaying resistance, a relay whose local contacts were insulated to withstand 200 volts, and, finally a double-pole contractor to take the place of the switch E (Fig. **7**) normally operated by the person launching a vessel from the launching platform. The delay relay was adjusted to operate on four seconds of sustained tone and its inclusion in the circuit during the entire ceremony was to obviate any form of manual switching.

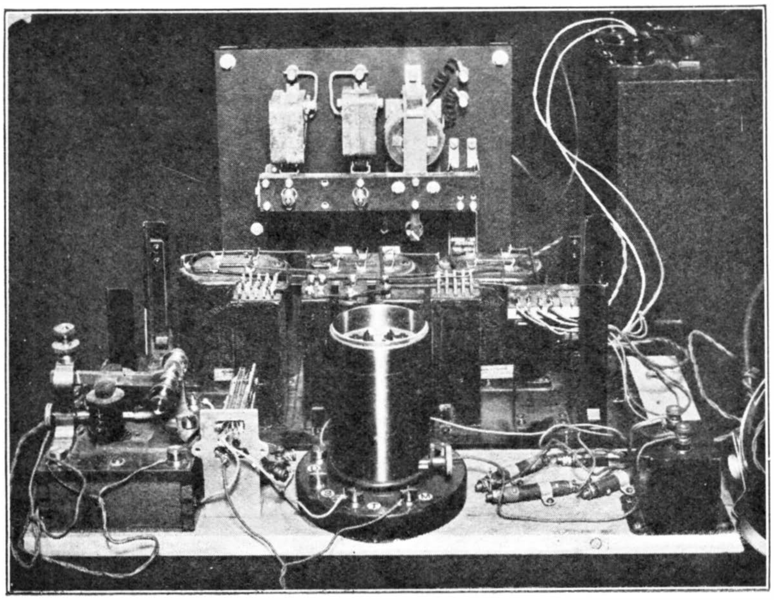


Fig. **4**.—Release Apparatus.

During the speeches from Australia, prior to the launch, the relay standard " B " was in a state of intermittent operation. No fears of a premature launch were entertained, however, since, after many tests, the apparatus had proved thoroughly reliable. On the arrival of the 1,500 cycle tone from Australia, the mechanism operated according to plan and the ship was safely started on her journey to the sea. The apparatus used is illustrated in Figs. **3** and **4**, and the microphone and christening gear will be seen in Figs. **5** and **6**.

To the uninitiated, the appearance of a shipyard just prior to a launch gives rise to thoughts that chaos and confusion reign on every side, and so it seemed to us when first we stood beside the stocks with the great hull towering 50 ft. above us. Subsequent events rapidly dismissed all these ideas and proved that ship-launching is a matter of minute precision and gravest attention to detail.

In launching a vessel of this size there are two slip-ways—the upper and lower—the lower being fixed to ground

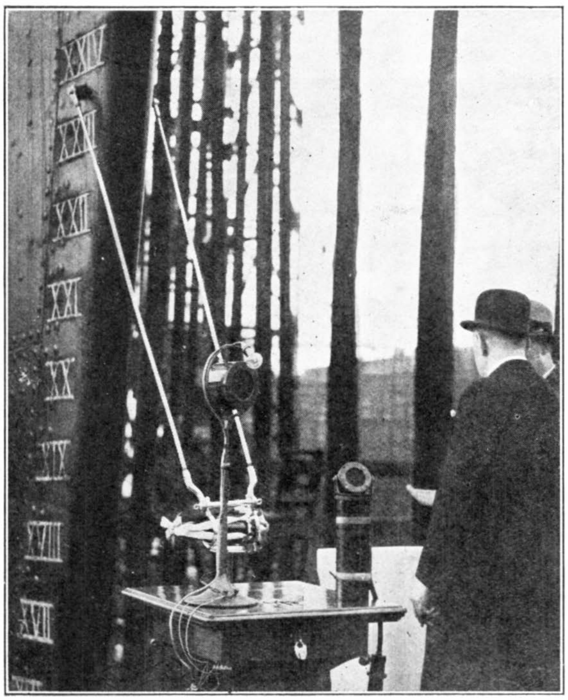


Fig. **5**.—Microphone and Christening Gear.

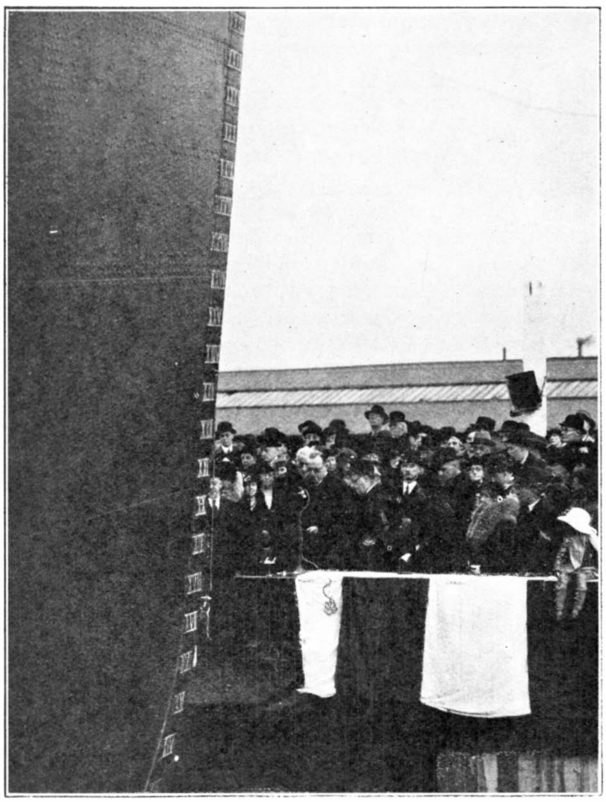


Fig. **6**.—Commander Sir Chas. Craven broadcasting at the Launching Ceremony.

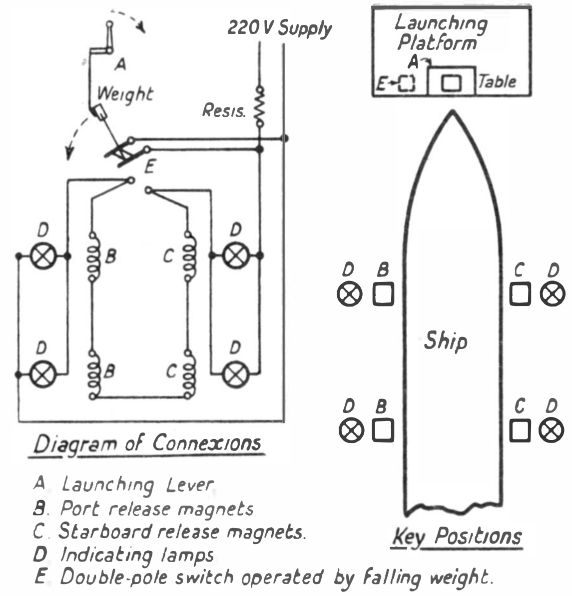


FIG. 7.—STANDARD METHOD OF LAUNCHING LARGE VESSELS.

and the upper fixed to the ship and moving with the ship into the sea. The vessel itself does not slide for obvious reasons.

Fig. **7** shows schematically the standard method adopted by the ship-builders for launching big vessels. When all is ready for the launch the ship is merely held by four triggers fixed to the lower slipway and holding the upper one. By means of a series of counter-weights these triggers are released by the operation of the electro-magnets B and C.

Right up to the moment of the launch there is much shifting of heavy timbers and dragging of chains which are liable to break the cabling to the release magnets. In order to keep a close watch on this possibility it will be seen from Fig. **7** that the pilot lamps D are arranged to give indication of a break in the circuit. Prior to the launching, current is switched on and flows through the pilot lamps, in series with the release magnets B and C. The lamps light to indicate that the circuit is in order, but insufficient current flows to operate the release magnets until the operation of the double pole contactor, which for this ceremony replaced the switch E.

The little tugs were quickly in command, after Sir Herbert Lawrence had advised His Royal Highness that " Orion " had safely taken the water. Fig. **8** shows the ship taking the water. Now " Orion " is afloat and to us who were fortunate enough to take part in her launching, any fragment of news *via* Lloyd's, etc., will bring recollections of a pleasant " job of work."

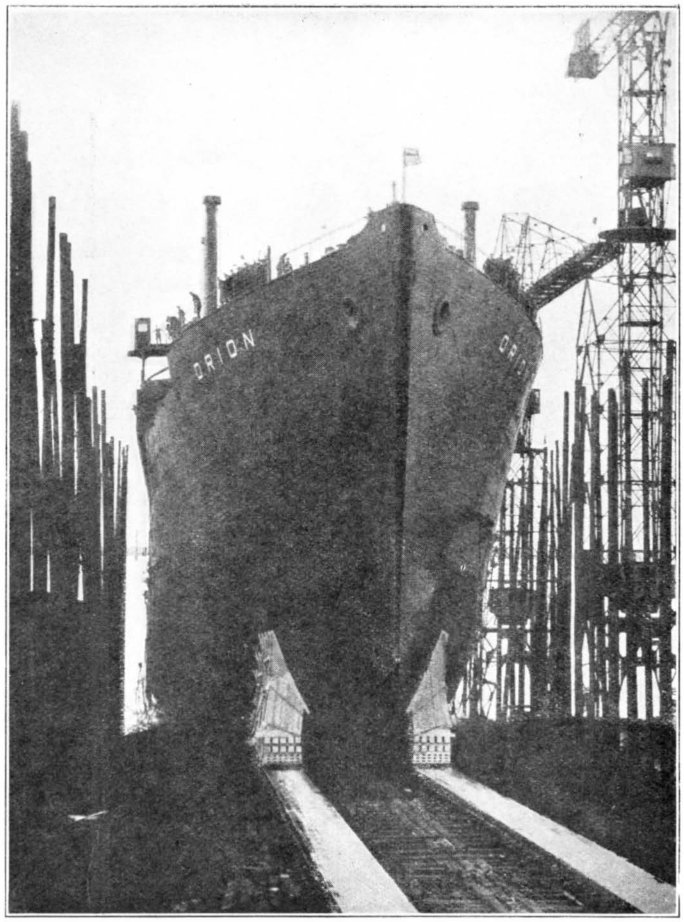


FIG. 8.—THE " ORION " TAKING THE WATER.

The author desires to acknowledge the courtesy and co-operation given by Messrs. Vickers-Armstrong & Co. and their permission to publish the schematic diagram, Fig. **7** of this article.

Book Review

" Art Paint and Vanity." By Arthur LL. Matthison. Published by Heath Cranton, Limited, 6 Fleet Street, London, E.C.4. 356 pages. Price 10/6.

There are still a few members of the Engineering Department who remember the interesting days that followed the introduction of the sixpenny telegram, and this book, written by a Telegraphist, himself typical of the recruits of that time, gives a fascinating picture of the Telegraph Service during its renaissance. Matthison was a member of an enlightened group at Birmingham which also included A. L. Delattre who later became Assistant Engineer-in-Chief of this Department. Another member of that group—Charles Rand Kennedy—was transferred to Hull where he formed a group of men that have found their way into the higher branches of the Service and into Industry.

Matthison is now a prominent paint manufacturer as is also a member of the Hull group—W. H. Screeton. Matthison's sister, Edith, became Mrs. Charles Rand Kennedy, and these two are now the centre of an intellectual circle in the United States. They have charge of the dramatic department of the Bennett School at Millbrook, about 80 miles from New York.

The book is bound to appeal to a large circle of readers in the Engineering Department of the Post Office.

B.O.A.

Central Exchange, London

M. G. HOLMES, B.Sc.(Eng.), Hons., A.M.I.E.E.

Introductory.

CENTRAL EXCHANGE, the first C.B. exchange to be opened by the Post Office in London, having been in service for a period of 33 years, was closed down at 1.30 p.m. on Saturday, March 9th, 1935, and the 6,000 subscribers' lines were transferred to new automatic equipment in Faraday Building South, Queen Victoria Street, E.C.4.

The area served by the new automatic exchange is relatively small compared with the average exchange area in London owing to the very high telephone density, but it embraces a large number of very important business interests in the City of London. When the first exchange was opened by the Post Office in 1902, it was built for a multiple capacity of 5000 lines and served subscribers within a circle of approximately $2\frac{1}{2}$ miles radius, lines being connected from districts such as Holloway in the north, Old Ford in the east, Camberwell Green in the south-east, Westminster and Oxford Circus in the west. Among the more important subscribers were :—Marlborough House, Government Offices including the Treasury, War Office and Somerset House, the Law Courts, the leading newspaper offices in Fleet Street and the Baltic Exchange. As will be indicated later all the above subscribers with the exception of the newspaper offices are now working on other exchanges.

History of the Manual Exchange.

The initial equipment for the Central exchange was installed in 1902 by the Western Electric Co. on the 4th floor, Faraday Building North, the building which is now virtually the telephone centre of the world as it houses the International Telephone Exchange opened in May, 1933, and, in addition, five Inland Trunk Exchanges, the London Repeater Station and City manual exchange, which is to be converted to automatic working in July of this year. As the exchange covered a large proportion of what was then the London telephone area, the growth in lines was rapid and in 1903 the equipment was extended to a capacity of 10,000 lines. Further, owing to a general increase of calling rate throughout the area, two additional suites of " A " positions were built in an adjoining room on the same floor in 1906 and became known as " Central Annexe."

A notable feature of the equipment was that the " B " positions were equipped with key-controlled ringing cord circuits; when the plug was inserted in the required subscriber's multiple jack, a key of the press-button type was depressed and ringing was sent out to line till the subscriber answered; the key then restored by the release of a latch actuated by a small electro-magnet operated by the current in the subscriber's loop. Another press-button was fitted to enable the operator to cut off the ringing mechanically, if so desired.

In 1906, a new C.B. No. 1 exchange with a multiple of 15,000 lines was installed by the Western Electric Co. on the second floor of Faraday Building North and after the transfer of the working lines to this equipment, the exchange on the 4th floor was renovated and re-opened as City Exchange in order to meet the rapid development of business in the City.

In 1909 keyless ringing was introduced on the incoming plug ended junction cord circuits and later in 1910 an automatic order wire machine, comprising a number of large automatic rotary switches was brought into service on the outgoing order wires to other exchanges. This machine represented one of the first attempts in this country to introduce automatic methods into the routing of telephone traffic. The object of the scheme was to ensure that only one " A " operator had access to the order wire at a time, as with a number of operators' instruments paralleled across the long distance order wires, of which there was a considerable number, transmission was seriously degraded. Each order wire was connected to the wipers of the rotary switch and each " A " position to the banks, so that when an order wire button on a particular " A " position was depressed the switch associated with the required order-wire searched to find the calling " A " position. In the early stages difficulty was experienced in ensuring that the finder stopped on the calling contact owing to the high inertia of the heavy shaft and wipers. This difficulty was overcome, but at a later date the apparatus was superseded by more modern apparatus with smaller rotary switches, which worked satisfactorily for many years. It was recovered in 1934 to provide space for A.C. Lamp Racks for the Trunk Suite, 2nd Floor Annexe.

Another interesting feature, common to both Central and City Exchanges, is that there is no subscribers' multiple over the " A " positions, local calls being completed over order-wire transfer circuits to the " B " positions. With the introduction of the four figure numbering scheme in 1927 to meet the conditions of Director working in the London Automatic area, the effective multiple capacity was reduced to 10,000, but jacks above the 9999 figure continued to be used for P.B.X. lines auxiliary to the main four figure numbers. In addition, jacks above the 14,000 figure were used as multiple jacks for the Central 0101, Service P.B.X. extensions.

Up to the opening of Tandem exchange in 1927 Central Exchange was used extensively as a junction lending centre, for which purpose it was admirably suited owing to its large junction network extending to practically every exchange in the ten mile area. It has always served as an emergency routing centre to route calls between manual exchanges whose direct junction routes have temporarily broken down, and the automatic exchange will still be able to deal with such emergency routing by means of an emergency group of 30 lines known as Central 7411, which is connected to the manual " A " suite at Wood Street. Calls arriving at Wood Street on these circuits will be completed over the Metropolitan and National manual board director groups.

Mention may be made of the fact that Central, in common with other exchanges up to 1925, was equipped with an electrophone position for extending subscribers' lines to the electrophone exchange in Gerrard Street in order to pick up theatre and concert performances. This position afforded facilities for connecting electrophone subscribers' lines to music lines to the electrophone exchange and also enabled subscribers to " call-in " by a lamp flash when a change of programme was desired.

Concurrently with the rapid conversion of exchanges in the ten-mile circle to automatic working from 1927 onwards, the number of Coded Call Indicator " B " positions in Central had to be increased and the last extension brought the total number up to 20. These were divided into two suites of ten, the odd positions working as one suite and the even positions as the other, with positions one and two used for concentration. The initial positions were installed by the Automatic Electric Co., Ltd., of Liverpool, in 1927, but all additions have subsequently been carried out by the Department, the equipment having been recovered from manual exchanges converted to automatic working from 1928 onwards. The total number of junctions incoming from automatic exchanges just before the cut-over was 700 of which the groups from Bishopsgate, Farm Street, Gerrard, Holborn, Metropolitan, Monument and National formed a large proportion.

Owing to its key position in the London telephone network, the Central main frame not only accommodated subscribers' and junction lines for that exchange, but a very large number of through circuits comprising subscribers' private wires and external extensions and through junctions to exchanges in the east and north-east of London. The work of diverting these circuits, of which there are approximately 4500, to the frame at the new automatic exchange was a task of considerable magnitude.

The following are the main details of the equipment as it existed early in 1934 before the recovery of the North suite of " A " positions in the Annexe on the 2nd Floor. These positions had to be recovered to make way for an advance suite of Trunk Demand positions and the work involved shifting 400 subscribers' lines from the South Annexe Suite to the main exchange and equipping part of the South Suite as CEN 0101 P.B.X. positions :—

Multiple Capacity	15300
No. of subscribers' Calling Equipments	16340
No. of " A " positions	164
No. of " B " positions (plug ended) ...	62
No. of " B " positions (C.C.I.) ...	20
No. of " B " positions (Trunks) ...	2
Capacity of outgoing junctions multiple	1920
No. of Test Desk positions	10
Capacity of main battery ...	10,000 Ah. 24 volts.
Rating of Charging machine...	1500 Amp. 26/32 volts.

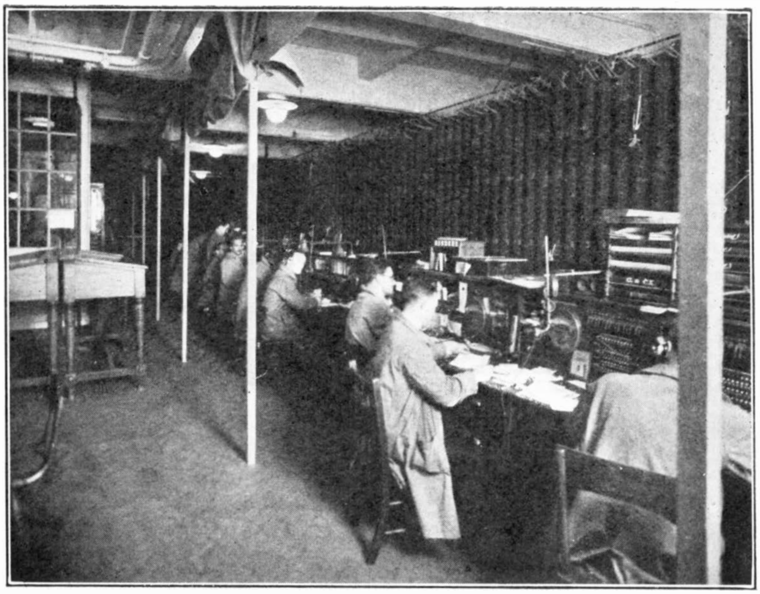


Fig. 1.—Test Desk and Main Frame, Manual Exchange.

Fig. 1 is a photograph of the test desks and main frame with the heat coils taped ready for the transfer.

The power plant arrangements are of interest in that City and Central exchanges were supplied by any two of three 10,000 Ah. batteries worked in parallel with one machine floating during the peak periods of the day. In addition to the Central generator there is a 1000 amp. generator in City test-room and complete flexibility was afforded, so that either machine could charge any of the batteries, or float in parallel with any two batteries. The average daily discharge prior to the closing down of Central manual exchange was 17000 ampere hours, and included not only the City and Central loads, but those for Toll " A ", repeater station filament supply and Transatlantic Telephony Terminal low tension supply.

The New Automatic Exchange.

External Work.

Central is now of course, essentially a " city " exchange and the area has been considerably curtailed since the opening of the first exchange in 1902. The area covered comprises a very large number of subscribers of different professions and trades to whom a quick and efficient telephone service is an absolute business necessity, and there is no doubt that the new automatic equipment will be able to meet the strenuous demands put on it by these subscribers. They comprise all the important newspaper offices in and around Fleet Street, the offices of the legal profession in the Temple, the large printing firms between Fetter Lane and Farringdon Street, the Central Meat Markets, Smithfield, and the furriers' warehouses in the Maiden Lane area.

Prior to the time of the initial preparations for the conversion of Central exchange to automatic working, there was no clear dividing line between the City and Central exchange areas; in fact, there were often subscribers in the same building served from City and Central. The automatic conversion afforded the opportunity of segregating the two areas, which are bounded roughly as follows :—

Central.

South Boundary—River Thames from Southwark Bridge to Essex Street.

West Boundary—Essex Street, Strand, Fetter Lane.

North Boundary—Holborn, Holborn Circus and Central Meat Markets.

East and North East Boundary—Farringdon Street and Queen Victoria Street to Southwark Bridge.

City.

South Boundary—Queen Victoria Street.

West Boundary—Farringdon Street.

North Boundary—Holborn Viaduct, Giltspur Street, Newgate Street, Cheapside, Poultry.

East Boundary—Walbrook.

As the work progressed a number of subscribers' lines were transferred on various directory dates from one exchange to the other and in numerous cases numbers were also changed, when necessary, to fit in with the numbering schemes of the new automatic exchanges. The total number of changes from exchange to exchange was as follows :—

Central—City	1500
City—Central	1300

These changes involved a large amount of complicated work on the old main and intermediate distribution frames.

The automatic plant is housed in Faraday Building South, Queen Victoria Street, E.C.4. This imposing building, designed by the Office of Works, was opened by the Lord Mayor in May, 1933, and installation of the exchange equipment was commenced by Messrs. Ericsson, Ltd., of Beeston, Notts., in January, 1934.

The external cabling for both Central and City exchanges was carried out simultaneously, as the cables are brought into a joint cable chamber and terminated on combined main frames. The cable chamber, which is on the Queen Victoria Street side of the building and runs parallel to that thoroughfare, is 122 ft. in length and 15 ft. in width and is one of the largest in the country. A view from the west end of the chamber is shown in Fig. **2**. It will be seen that there are two sets of racks for cables, one below the subscribers' main frame, the other below the junction main frame, with a cross-over field between them.

The chamber makes a right-angle turn at the west end and continues for a further distance of 73 feet at an average width of 8 feet, whence it is connected to the old Central Basement in Faraday Building North by a 6 ft. tunnel 32 ft. long under Knightrider Street, as shown in Fig. **3**. Forty-two cables enter the new cable chamber by this route and a further 46

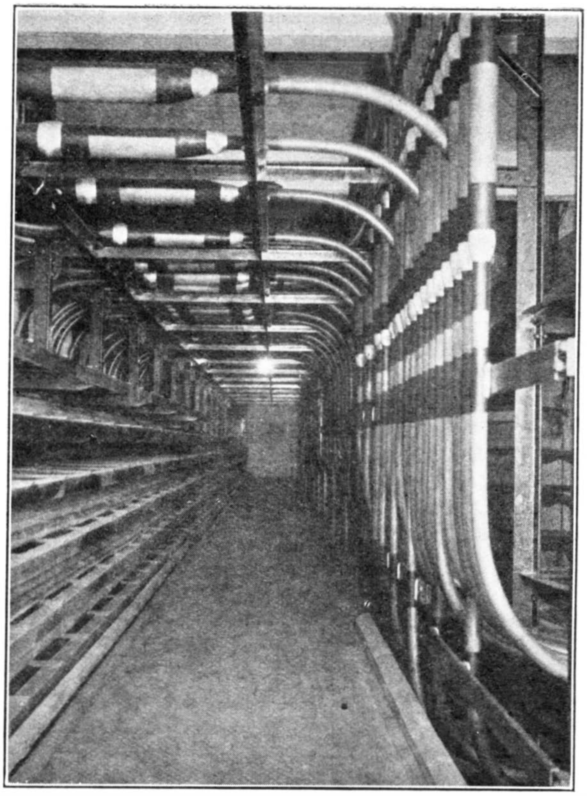


Fig. 2.—Cable Chamber.

enter from Queen Victoria Street near the south-west corner of the chamber. In addition two service cables enter at points in the north wall of the chamber. Of the total of 90 cables, 51 carry junction circuits and the remaining 49 subscribers' circuits.

All the cables concerned were teed into the new

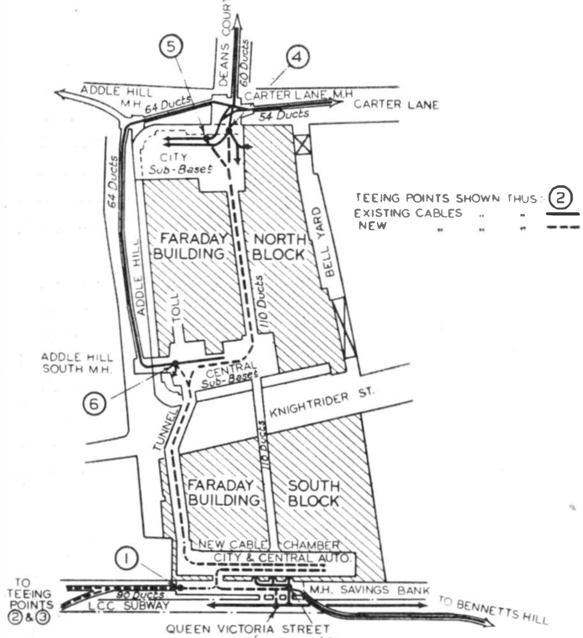


Fig. 3.—Plan showing Cabling Arrangements.

building, there being 8 different teeing points which are all located within a short distance of the exchange building. There are 2 points on the north side, 1 on the west and 5 on the south side of Faraday building as shown in Fig. 3. All the pairs in the cables including spares, were teed, making a total of about 52,000 to be dealt with.

About 2 miles of new cable were drawn into ducts and 5 miles laid on racks in the cable chambers and tunnel. There were approximately 100,000 cable pairs jointed and 70,000 pairs terminated on the main frame. It may be mentioned that although the tees have been *in situ* for periods varying from 4 to 16 months no faults have arisen and it has not been necessary to open any of the joints.

The external work was commenced in October, 1933, and has kept an average of 20 men employed for about 18 months. The removal of the tees, recovery and re-arrangement of cables and miscellaneous work following the transfer will occupy many months.

Description of Automatic Exchange Equipment.

The allocation of the equipment for Central and City Exchanges on the various floors in Faraday Building South is as follows :—

Basement—Batteries.

Ground Floor—Subscribers' M.D.F., Junction M.D.F., Test Desks, Test Jack Frame and P.B.X. and NU Tone fuse panels. Power Plant.

1st Floor—Central Exchange equipment including Line and Cut-off Relays, Line Finders, 1st, 2nd and 3rd Code Selectors, 1st and 2nd Numericals, Final Selectors, A. Digit Selectors, C.C.I. Repeaters and Coders, I.D.F. for subscribers and junctions, and various T.D.F.'s.

2nd Floor—Directors common to City and Central. City Exchange equipment including 1st Codes, 1st, 2nd and Final Selectors, etc. V.F. equipment, City and Central subscribers' meters.

The main feature of the two exchanges is that the "A" Digit Selectors are common to both exchanges, as are also the majority of the 2nd and 3rd Code Selectors. All outgoing junction groups are common, so that the use of combined automatic equipment and line plant for junctions results in considerable overall economies.

Main Frames.

The two frames on the ground floor, one for City and Central subscribers and the other for junctions, run parallel to each other and each has capacity for the termination of 33,500 circuits. There is a horizontal framework between the two frames just below ceiling level carrying jumper rings of which there is one set per vertical to cater for cross-jumpers of private wires and external extensions.

Other interesting features are the mezzanine platforms which are fitted on both sides of each frame at a height of 6 feet above the floor with "strip" lighting on the underside of the platform.

Test Desks.

There are 15 Test Desk positions of which 9 are subscribers' "ENG" positions, 2 junction positions, 2 fault control positions and 2 Advice Note positions. The "ENG" circuits from selector levels on City and Central are terminated as separate calling equipments on the "ENG" positions and are ancillaried so that circuits in both groups are within reach of any position to ensure quick answering time and even loading. The Test Jack Frame adjacent to the Test Desks has an equipped capacity for 2700 outgoing junctions and the P.B.X. Fuse Panel has a capacity for 1750 power leads and 200 ringing leads. Fig. 4 is a photograph of the Test Desks and part of the subscribers' frame.

Power Plant.

There are two 50 volt batteries in the basement each of 12900 ampere hour capacity fully plated. These batteries will supply power to the Central and City automatic equipment. A P.B.X. C.E.M.F. battery, capable of carrying a load of 350 amps. continuously, is also fitted.

The following are the main details of the charging machines, power board and ringers :—

Motor-Generators—

Two machines—output 2000 amps. at 57 volts.

Synchronous motors—400 volts, 3 phase, 50 cycles with control pillars fitted adjacent.

Rating of circuit breakers	... ...	2000 amps.
,, ,, main battery leads	...	1930 ,,
,, ,, main discharge leads for Central and common equipment	... ...	1060 ,,

Fig. 4.—Test Desk and Main Frame, Auto Exchange.

Fig. 5.—Power Room.

Rating of main discharge leads for City ... ... 740 amps.
,, ,, choke coil (oil immersed in Transformer casing).. 2000 ,,
Output of ringing machines 4 amps. 75 volts at 16-⅔ cycles.

The charging and ringing machines were manufactured by the Electric Construction Co. at Wolverhampton, the batteries by the D.P. Battery Co. and the power and ringing panels were assembled by Ericsson, Ltd.

The power switchboard is located so that the generator, battery and main discharge leads are as short as possible. The main conductors from the generators to the power board are lead-covered paper core cables run in chases below the floor. The main battery discharge leads are composed of copper bars taken through the floors to the first and second floor apparatus rooms. Fig. 5 is a photograph of the power room.

Distribution bars of smaller section connected to the main bars are carried along the main aisles to feed each suite of racks, the negative bars being supported on porcelain insulators and enclosed by sheet metal casing along the ends of the suites. Each rack is fed vertically downwards by V.I.R. cable for the negative conductor and a copper bar for the positive conductor. Small fuse panels are connected at the end of each shelf of selectors or relay sets.

Two ringer panels are provided, one for City and one for Central, with a power and a battery ringing machine for each exchange. Two-step starters for the automatic start of the battery machines when the power fails are provided together with two-step manual starting switches. Duplicate transformer equipments are provided for dial tone, ringing tone, busy tone, NU tone (M.D.F.) and NU tone (selectors). The ringers supply the above tones and interruptor springs are fitted to supply interrupted ringing and tone, busy hold, busy flash and tone, intermittent earth and flicker earth.

Automatic Switching Equipment.

The summary given below affords a very good idea of the large amount of equipment fitted. All the various types of equipment are assembled on single-sided racks 10′ 6″ high and manufactured to Post Office standard specifications with pressed steel channel type shelves. All large suites of racks have the latest type of travelling ladders, which can be raised from the floors and hooked on to the guard rails of the racks when not in use. Flood lighting, by which the lamps above the racks on the left of a suite light up the equipment on the right and *vice versa*, is fitted and is controlled by switches on the ends of the racks. Fig. 6 is a photograph of the Director Racks for Level 2. The multiple capacity of the exchange is 9200 with an ultimate figure of 10,000 and the units are subdivided as follows :—

Ordinary finals	10 units.
2/10 P.B.X. finals... ...	68 ,,
11/20 ,, ,, ...	6 ,,
Over 20 ,, ,, ...	8 ,,

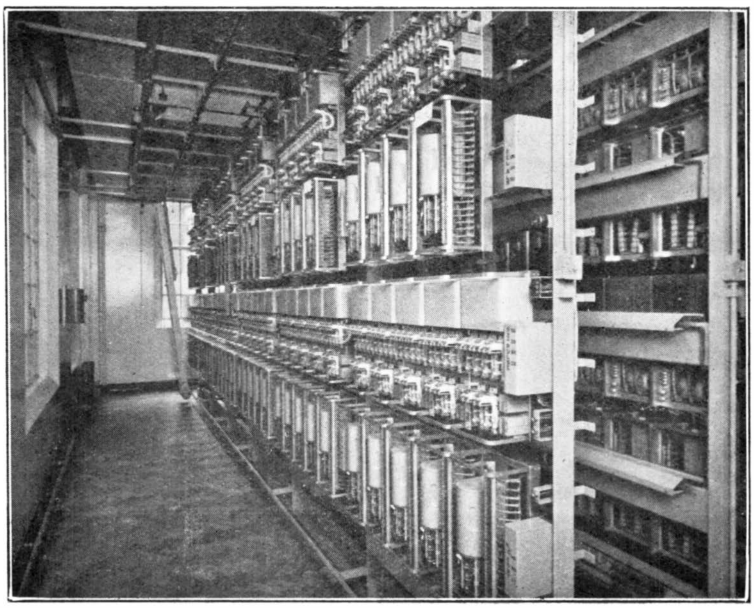


Fig. 6.—Director Racks.

Description.	Switches.	Banks and Wiring.	Racks.
Subs. Line & Cut off Relays :—			
Ordinary ...	7400	7400	13
Barred Tunk ...	380	400	1
Subscribers' Line Finders :—			
Ordinary Primary	592		
	37 grps.	·480	30
Ordinary Auxiliary	666		
Barred Tunk Primary	66	80	3
Secondary Finders ...	307	360	4
1st Code Selrs. Ordinary	899	990	33
1st Code Selrs. Barred Trunk	66	90	3
2nd Code Selectors ...	1448	1690	29
3rd Code Selectors ...	347	440	9
" A " Digit Selectors	257	300	5
Directors Ord.	252	340	34
Man. Board	22		
C.C.I. Relay Sets ...	720	720	6
Coders	58	70	4
1st Numerical Selectors	1710	1920	22
2nd Numerical Selectors	1379	1660	28
Final Selectors Ord.	160	300	40
,, ,, 2/10 P.B.X	1169	2050	
,, ,, 11/20 ,,	296	380	27
,, ,, over 20 ,,	425	540	
V. F. Junction Relay Sets	740	765	9
Senders—4 digit ...	40	40	2
V.F. Relay Sets ...	20	25	2
Trunk Offering Distributors	3	10	
Trunk Offering Finals	92	—	
Test Distributors ...	10	20	
Test Finals	92	—	

Special mention should be made of the line finder equipment as Central is the first large exchange in London to be fitted with the Department's new 200 outlet line finder scheme with partial secondary working.

The line finders are standard two motion switches with a vertical marking bank to direct the line finder to the level of the calling subscriber before rotary hunting takes place. In the ordinary line group there are 16 primary finders, 3 primary and 3 auxiliary allotters, and 18 auxiliary finders per group of 200 subscribers' lines, 82 secondary finders being shared among 10 groups of 200 lines. The line finder equipment is of special interest in that it is equipped entirely with relays of the new Post Office standard " 3000 " type, while the line and cut-off relays are of a smaller and cheaper type.

Manual Board Equipment.

It was decided, upon grounds of economy in accommodation and staff, that the manual boards for City and Central should be combined with those of Metropolitan and National and later London Wall at Wood Street, a distance of 700 yds. from the automatic equipment. On account of this decision it became necessary for considerable additions and changes to be made in the Wood Street building. The work involved the provision of extra positions and equipment by the Automatic Electric Co., Ltd., and multiple rearrangements and supply of miscellaneous equipment by the Department.

The National manual suite was reduced by three positions to 39, the Metropolitan manual suite increased by 2 positions to 48, and the multiples on both suites increased. The Visual Engaged equipment was converted to Visual Idle Indicating equipment, and the answering field on both suites completely rearranged and re-equipped. Keys were also fitted for concentrating on to 9 positions of the Metropolitan suite all the essential circuits for the manual board night traffic from the five automatic exchanges and the G.P.O. P.A.B.X. Keys were also fitted in connexion with the Class " A " and " B " night service facilities for Private Branch Exchanges on City and Central.

Fifty-two Toll positions of the latest two panel sleeve control type were fitted by the contractor to deal with Toll calls from the five exchanges and were equipped with a ticket tube system for finished tickets terminating in a pneumatic distribution position (P.D.P.) in the middle of the room. Four straight forward junction (S.F.J.) positions were supplied to cater for incoming Toll traffic and when these were brought into use the old Metropolitan and National keysending B positions were recovered.

It was laid down as a principle that the Metropolitan I.D.F., 2nd floor, should accommodate all circuits requiring termination on the Central-London Wall-Metropolitan suite, that the National I.D.F., 3rd floor, should accommodate all circuits on the National-City-G.P.O. P.A.B.X. suite and that a new I.D.F. should be installed on the 4th floor to serve the Toll suite and S.F.J. positions. Although the respective S.A.R.'s for Metropolitan and National were increased by additional bays lack of floor space necessitated some of the equipment being fitted on the 4th floor S.A.R. It was, therefore, necessary to increase the existing tie circuits between the two main frames and the three I.D.F.'s by 200 6-wire circuits, 1180 4-wire circuits, 200 3-wire circuits and 1800 2-wire circuits.

The planning of the jumpering scheme thus became a very complicated operation and involved the preparation of very complete and detailed records and schematic diagrams. As an example a National barred trunk assistance circuit, with six appearances on the National suite (one of which had to be switched at night to the concentration suite and the remaining five disconnected) and multipled over the Toll suite, *i.e.,* joint access to Bridge and Sleeve Control type boards, involved six relay sets and the equivalent of 64 single wire jumpers.

The extent of the work in the Wood Street building may be gauged from the fact that approximately 50 men were employed by the Department over a period of five months in construction work, testing and jumpering, while the contractors had a staff of over 30 men continuously employed during this period.

Fig. **7** is a photograph of part of the switchroom. The Toll positions are on the left, the concentration positions on the right and the S.F.J. positions and P.D.P. in the middle of the room.

FIG. 7.—AUTO-MANUAL SWITCHROOM.

THE OPENING OF CENTRAL AUTOMATIC EXCHANGE.

The opening of the new automatic exchange on March 9th with approximately 6000 working lines was the culminating point of over 15 months' continuous effort by the Department and Contractors in building up a very complex machine. In the new automatic exchange an average of 60 men was employed by Messrs. Ericsson, Ltd., in erection and testing; 20 men were employed by the Department in testing out, while 40 men were in the Test Room terminating cables, running jumpers and carrying out dial speed and insulation tests, of which five tests per line were completed before the cut over.

A staff of 20 men had the task of converting the subscribers' apparatus for automatic working; the following figures will indicate the magnitude of the operations involved :—

Exchange lines	6100	
Stations with dials	10400	
Call Offices and Subscribers' Coin Boxes	120	
P.B.X. Cordless Switchboards	900	
,, Non - Multiple Cord Switchboards ...	250	
,, Multiple type, CB No. 9 and 10A	53	positions
P.A.B.X.'s Various	19	,,

A 4 position CB 10 P.B.X. for the CEN 0101 service lines was also installed by the Department on the 7th floor of Faraday Building South. All extensions have direct access outgoing to the automatic equipment and certain of them have final selector numbers for night service purposes.

Central is the 66th automatic exchange in the 10-mile circle to be opened in London and the number of automatic exchange lines in the London area is now 42% of the whole. This percentage will increase rapidly as during the next 21 months a very heavy programme, involving the opening of 25 exchanges embracing 66,000 exchange lines, will be carried out.

A complex organisation had to be built up by the London engineers to ensure a successful transfer. The 60 unattended Call Offices were cut over to the new equipment between 10 a.m. and 1 p.m. by the standard " key " method and facilities to enable callers to complete local calls were afforded by busying all level 2 directors with the exception of the last 8, on which the translations were altered to route Central calls *via* Tandem to Central Manual C.C.I. equipment. At 1.30 p.m. these directors were busied and the rest unbusied, the former being quickly restored to service with their normal Central translation.

At 1.0 p.m. 231 lines belonging to the more important newspapers and news agencies were cut-over in advance of the main groups to ensure continuity of service to such subscribers. In addition an engineer was stationed at each large P.B.X. and P.A.B.X. to test every line after the cut-over.

The main group of subscribers was transferred at 1.30 p.m. in the presence of a distinguished company, including the Director General of the Post Office, Sir Donald Banks, K.C.B., D.S.O., M.C.

The lines were tested after the cut-over direct from the test final selectors, 25 Testers being in use over a period of 2½ hours. Concurrently with the cut-over at Central, I.D.F. change-over keys had to be thrown at 24 other automatic exchanges with direct routes into Central to connect the new junctions and cut out C.C.I. relay sets and at 16 other exchanges director translation changes were made to effect changes in routing of Central calls. After the cut-over all incoming junction groups were tested (the outgoing routes were tested on the morning of the transfer) and test calls were passed from every one of the 65 automatic exchanges in the 10-mile circle, the release of staff at district automatic and manual exchanges being controlled from Central. The total number of men engaged on the transfer including those at District Exchanges and Wood Street approximated to 250, this number being necessary to test all subscribers' lines and junctions to and from all the exchanges in the area.

In conclusion, while there were many regrets at the passing of the old Central exchange, which had given good service for many years, there can be no doubt that the conversion to automatic working will benefit both the subscriber and the administration by the speedy and efficient service afforded by an automatic equipment which includes the latest developments in step-by-step practice.

The Passing of the Central (London) Manual Exchange

On the evening before the transfer of the Central manual exchange, London, a representative gathering of as many as possible of those who had been actively associated with the exchange during its long life was held in the exchange building. Many old friends came out of retirement to bid farewell to old Central and wish good luck to the new.

A feature of the evening was the following message, received by radio from Australia and broadcast to the assembly from Mr. H. P. Brown :—

" What a charming thought it was to ask me to take part in the social gathering. I do appreciate the invitation to speak a few words to my old friends, but how much more should I delight in being with you on this occasion. We can transmit the spoken word round the world in a fraction of time. Last week we held a conference with a delegation sent out from Britain in the hope of establishing a more frequent and expeditious Air transportation service between you and us. We cannot hope for our physical transference over 12,000 miles in a fraction of a second, but we shall soon be able to accomplish it in three or four days; then I might get home to renew some of the old friendships.

It is fortunate for me that the television committee has not got its full scheme into operation at this end for I am not dressed for the occasion, but am lying in bed in the sweltering heat. It is hard to realise that you are closing down Old Central. The thought of Carter Lane conjures up many happy memories and wonderful associations, with colleagues who made life and efforts a joy to me. One of the saddest things in life is to be separated from friends, those with whom one could speak freely with understanding, those with whom one could disagree without the risk of an angry thought. Well, we cannot be denied the consolation of memories and the delights of hearing of the achievements and of the well being of one's old friends. The traditions which you have built up and carry forward are the envy and the admiration of public servants the world over. The home land stands as a beacon in a turbulent world. To us it means sound sense, solidarity and progress, standing for all those things which raise our civilisation to a higher standard.

We in Australia, the place down under, a handful of people in a vast continent, look to you for inspiration. We share your aims and ideals to consolidate the British Empire in the greatest aggregation of democracies the world has ever known—the great hope of the world, the bulwark of civilisation. The Post Office services offer a magnificent medium through which we can play our part; every improvement in our communication adds to the strengthening of the links which unite us. Our colleagues in the British Post Office have helped us immeasurably from the storehouse of their greater experience and they may have the satisfaction of knowing that their contributions to our knowledge are quickly reflected in the improvement of our services, so vital in a land of great distances. Over our internal land line network the telephone user can speak a distance of more than 4,500 miles. In round figures it is 1,700 miles from Perth to Adelaide, 500 more to Melbourne, 600 further to Sidney, 700 to Brisbane and an additional 1,200 to Cairns in the North. We have a great service in this country built up by a staff of keen, enthusiastic, capable men and women who work in harmony with a fine spirit of devotion to serve and to achieve. Their great kindness and support to me are compensation for what were very great sacrifices in losing the intimate friendships of those of you at this gathering and of many others throughout the home service. I think of many who were my associates at Central who may or may not be present with you to-night, but I believe you have with you Miss Heap, Mr. Anson and Mr. Dive, three at least who rendered yeoman service in building up Central.

To all of you I send my affectionate greeting, I wish you happiness, contentment and good health. Now I must leave you to what I hope will be a most enjoyable evening. Good-bye and good luck to all of you."

Notes and Comments

I.E.E. Dinner

THE Postmaster-General, Sir Kingsley Wood, was the guest of the Institution of Electrical Engineers at their annual dinner on the 7th February. We have much pleasure in reproducing the Postmaster-General's speech in proposing the toast of " The Institution " :—

" I wish first to thank the President of the Institution for so kindly asking me to be present to-night and giving me such a good dinner ! It is not often—or, at any rate, not always—that the Postmaster-General is treated in such a generous fashion. There was a strange case at the Post Office the other day of a telephone subscriber who queried the accuracy of his telephone account. So unusual was this incident that it was brought to my personal notice. I was told that this angry subscriber in a moment of desperation, having failed with all my officials, had said ' I cannot remember the name of the present Postmaster-General, but if I address a letter of complaint to the biggest scoundrel in London, he would get it ! ' That particular officer of the Post Office who received the complaint, being well up in the rules and regulations of my department—as I daresay you have noticed all the officials are—replied : ' Well, sir, in that case your letter will be returned to the sender.'

It is therefore a very pleasant thing to me to-night to think that your Institution has asked me to be present at this wonderful gathering. But I think I can claim that the Post Office is intimately associated with the electrical industry in engineering problems. I hope all the influential gentlemen who are present here to-night recognize everything that the Post Office is doing for the electrical industry to-day. Think of those miles of telegraph and telephone wires that have to be maintained overhead, underground, and under the sea, and you will then think of all the money that the Post Office is expending in your particular direction.

One of the parts of the Post Office of which I am certainly very proud is the very fine research station we have, one of the best equipped in the country. It is constantly employed in following the latest developments in the science of electrical communications. Another matter which I rank equally in importance, and in which I think that you gentlemen will agree with me, is that the Post Office engineers have won for themselves a high and honoured place in the electrical world. We can claim quite legitimately that during the past few years the Post Office has done something for the electrical industry itself. The developments that we have been making recently in connexion with the telephone service will result not only in an increase in the amount of orders for new plant—because we shall certainly place this year record orders in that connexion—but also in considerable achievements in the development of communication itself. To a large extent I can only speak as an outsider, but I do say that we are living in an age of miracles. Only a few days ago in the House of Commons I made an announcement of the opening stages in this country of television. At a luncheon this afternoon we were able to enjoy conversations which were heard both in South Africa and in London, and which were very remarkable in their character and marked an important development in our communications. I would venture to suggest to-night that at no time in our history were the science and the practice of communication advancing more rapidly than at this hour.

I am told that so far as your own Institution is concerned you have recently made a grant to radio research in the Polar regions. I do not propose to investigate that matter myself, but I certainly know that your Institution has always made a point of being abreast of the times. Certainly the Post Office, as a large user of the world-wide radio, is keenly interested in a project of that kind.

Another matter which comes within my official knowledge is in connexion with my duties in relation to broadcasting. The broadcasting public is certainly indebted to the Institution of Electrical Engineers for all that its wireless section has done to inquire into the difficulties of interference in relation to broadcasting. I wish some of the gentlemen here to-night could see some of the letters that I receive complaining of unearthly noises on the wireless and attributing them to the Postmaster-General of the day. I often think that it may be a case of one section of the electrical industry interfering with another section. The listening public in this respect have, I venture to say, been extremely patient, and I hope that the section will speedily be able to resolve the difficulties which certainly arise in connexion with interference, and will enable a constructive and satisfactory solution to be put in hand. I hope that no one in these days requires legislation, because a good many people take the view that there are a little too many acts and statutes about as it is. Nevertheless, if it is found necessary, I will do my best to help.

In conclusion, let me say how glad I am, having regard to the office which I now hold, to be able to propose to-night the toast of ' The Institution.' Our Post Office engineers have always occupied a very honourable place in connexion with your great organization. To-night, for instance, I see Sir Thomas E. Purves, a past Engineer-in-Chief of the British Post Office, and my friend and colleague Lieut.-Col. A. G. Lee, who occupies that great and honourable position to-day. It is with the greatest possible pleasure that I propose this toast, and couple with it your name, which has such a high and distinguished connexion with this great industry throughout the country. I wish the Institution every possible success and to every member of it health, prosperity, and good luck in the coming year."

An interesting ceremony was also witnessed at the dinner when M. Grosselin, Director of the Société Française des Electriciens, on behalf of the French Government, presented the Institution secretary, Mr. P. F. Rowell, with the Cross of Officer of the Legion of Honour. Mr. Rowell, in thanking M. Grosselin, said that he felt that the French Government in honouring him had honoured the whole Institution. We congratulate Mr. Rowell on the award of this marked distinction.

New Year's Honours List

Readers of the Journal would be pleased to notice that a number of Post Office officials were included in the New Year's Honours List. Among these were the Director-General, Col. Sir Donald Banks, who was accorded the Order of Knight Commander of the Bath, and members of the engineering staff in Messrs. R. A. Weaver, H. J. Burnett and J. Campbell. Mr. Weaver, who has just retired from the post of Superintending Engineer in the North Wales District, was awarded the O.B.E., and Messrs. Burnett of the London District and Campbell of H.M.T.S. " Monarch " Medals of the O.B.E.

Road Signalling Systems

The use of standard Post Office telephone apparatus in other spheres, such as totalisators and remote control apparatus for power stations, is well known and it is interesting to note that the recently standardized 3000 type relay is also being used for other than telephone purposes. In the Auto Flex Road Signalling System the 3000 type relay is used extensively in the control gear and it is hoped to publish an article on traffic signals in the next issue of the Journal.

Erratum

It has been brought to notice that an important link in the continuity of the article on " Automatic Exchanges, Maintenance Replacements : An Outline of the Central Normal Stock Scheme," by A. L. Barton, published in the last issue of the Journal, was omitted. The data which should follow Fig. 1 on page 253 are as follows :—

Regional Area.	Engineering District.	Auto Exchanges (excluding U.A.Xs.).	Subscribers' Exchange Equipments.
London	London	56	277,680
	Eastern	10	14,400
	South Eastern ...	23	23,300
	,, Midland ...	13	19,800
	Totals ...	102	335,180
Manchester	South Lancs. ...	21	43,500
	North Western ...	24	30,500
	,, Eastern ...	25	39,100
	Northern ...	24	31,800
	Scotland East ...	15	32,450
	,, West ...	3	5,200
	Northern Ireland.	—	—
	Totals ...	112	182,550
Birmingham	North Wales ...	58	59,470
	South Wales ...	13	15,800
	South Western ...	21	32,100
	North Midland ...	36	56,300
	Totals ...	128	163,670

The Death of Sir William Slingo

We regret to have to record the death on January 19th of Sir William Slingo, a former Engineer-in-Chief of the Post Office and well known to many of the present staff. Sir William, who was 79, entered the service at fifteen as a telegraphist and spent nearly fifty years of his career in the Post Office service. During this period he took a leading part in the growth of the trunk telephone service, the transfer of the National Telephone Company's plant to the State and the subsequent developments of telephony in Great Britain. He was primarily responsible for the compilation of an inventory of the National Telephone Company's plant on its acquisition by the State, on the basis of which an award of 12½ million pounds sterling was made to the Company instead of the twenty-one claimed.

Besides his work as a telegraph engineer, Sir William Slingo at an early stage in his career found time to enlarge his experience in other directions and held, among other posts, positions as head of the electrical department at the People's Palace in Mile End Road, consulting engineer to the Drapers' Company, principal of a technical college at Dover and the editor of " Knowledge. '

Perhaps better known than these activities was his work in connexion with the Telegraphists' School of Science, which he founded in 1876. This school, beginning with five students, grew to 850 in 1898, when Sir William resigned from the post of principal. Sir William exercised a wide influence during this period in furthering the study of telegraph and telephone engineering and in placing it on a more scientific basis, at a much earlier date than would otherwise have been the case.

After retirement from the Post Office Sir William's interest in communications remained undiminished and, among other enterprises, he acted for the Marconi Company as Administrator General for the Peruvian system of posts, telegraphs and wireless services, a system which he reorganized and placed on a sound basis.

Sir William attained the highest honour available to his profession when he became Engineer-in-Chief of the Post Office. He will be remembered and honoured throughout the profession also for his early services in the education and training of telegraph engineers.

C. Brocklesby, M.I.E.E.

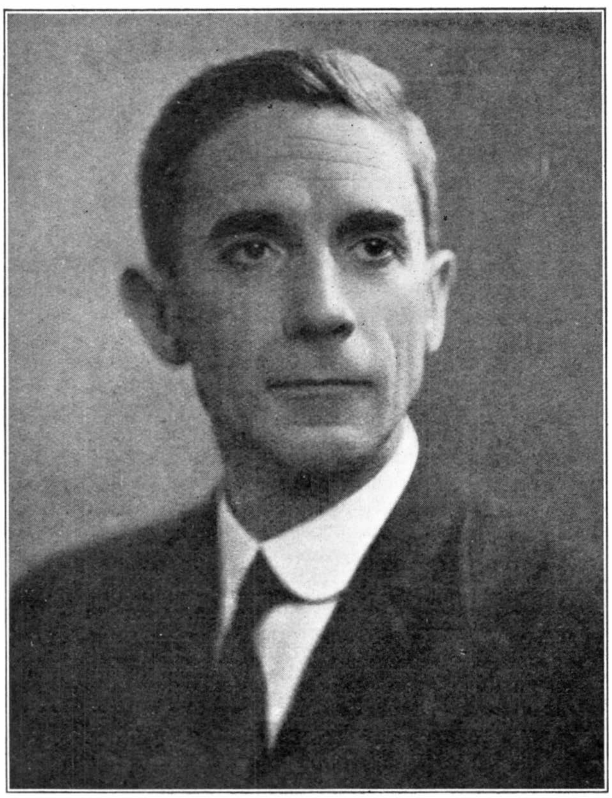
Mr. Brocklesby entered the service of the late National Telephone Company in Manchester in 1895 and took his share in the installation of the Flat Board call wire system. In 1899 he was placed in charge of a staff of switchboard fitters on the work of installing the switchboard in the present exchange premises at Telephone Buildings, Nelson Street, Bradford. At the conclusion of this work he was retained in Bradford as Inspector in charge of exchange maintenance. Subsequently his services were required to assist the local Manager in connexion with underground development in the Bradford area. In 1904 he was promoted to the position of Chief Inspector, and devoted much of his scanty leisure to helping the local staff in connexion with the National Telephone Company's correspondence classes.

On the formation of the Amalgamated Society of Telephone Employees, he became the first Chairman of the West Yorkshire Branch. In 1908 on a re-organization of the staff he was promoted to the rank of Electrician, taking charge of traffic in addition to the internal engineering work.

He was appointed District Electrician to the Birmingham District in 1911. On the transfer of the Company's undertaking to the State in 1912, he was graded as Assistant Engineer.

In 1925 he was promoted to the position of Sectional Engineer (Internal) at Liverpool, and in 1931 he was appointed as Assistant Superintending Engineer to the North Eastern District. At a later date he was transferred in a similar capacity to the North Western District, where he received further promotion to the position of Superintending Engineer on the 1st February, 1935.

T.E.H.



R. G. de Wardt, M.I.E.E.

Mr. R. G. de Wardt, who became Superintending Engineer of the South Eastern District on 1st January, 1935, is a Post Office servant of the second generation, his father, Mr. J. I. de Wardt, O.B.E., being a retired member of the former Secretariat. Mr. de Wardt was appointed 2nd Class Inspector (a rank now obsolete) in 1909. He was employed on the telephone valuation and afterwards joined the Power Section as Assistant Engineer. He was subsequently transferred to Glasgow, nominally as power engineer, but actually with duties covering a wide district and sectional range. In 1922, he came to the Radio Section in London, but left to take charge, as Executive Engineer, first of Leafield and then of Grimsby Beam radio stations. The transfer of the beam services to private control in 1929 caused his return to the Radio Section for another two years. In 1931 he became Assistant Staff Engineer in the Telegraph Section and in 1933 he went to the provinces again as Assistant Superintending Engineer at Bristol.

It will be seen that Mr. de Wardt has had a very varied experience, and it is true to say that he has "acquired great merit" for any work he has undertaken, whether of a specialised character, as in radio and telegraphs, or in the more general duties of the engineering districts. He modestly attributes his success to luck, but it is actually the result of a rare combination of wide basic technical knowledge, energy, common sense and ability to obtain good work from any staff under his control. C.J.M.

H. Faulkner, B.Sc., M.I.E.E.

Mr. H. Faulkner, who succeeds Mr. Weaver as Superintending Engineer, North Wales District, is a native of Nottingham and received his technical training at Nottingham University College, obtaining the B.Sc. Engineering Honours degree of London University in 1911. He then joined Messrs. Laurence Scott and Co., the well known firm of Electrical Engineers who specialise in marine electrical equipment.

In 1914 he passed the Assistant Engineers' open competition examination and took up duty in the Designs Section of the Engineer-in-Chief's office.

During the war period he took up a commission in Royal Engineers' Signal Corps and spent 2½ years on overhead construction in France and Belgium.

In 1919 the Department's increasing activity in radio development led to Mr. Faulkner's joining the Radio Section where in collaboration with the late Dr. R. V. Hansford he specialised on valve transmitters. At this time the largest valve transmitters in existence were of about one kilowatt power. Hansford and Faulkner designed and built transmitters of increasing power at Caister, Stonehaven and Northolt. Faulkner collaborated in the design of the Rugby high power telegraph transmitter which even to-day is still the highest powered valve telegraph transmitter in the world. At the same time he participated in the first two way telephone conversations across the Atlantic which were carried out between England and the U.S.A.

In 1925 he was promoted to Executive Engineer in charge of Rugby Radio Station, which opened for traffic on January 1st, 1926, and the successful operation of that station during the early years can be largely attributed to his skilful management.

In 1929 he returned to Headquarters to take charge of the design and development group at a time when short wave telephony was being developed. In 1932 he was promoted to Assistant Staff Engineer, Radio Section, and transferred to North Wales in 1933.

Faulkner was extremely popular not only with his colleagues in the British Service, but also with the numerous representatives of foreign administrations with whom he came in contact. All will wish him success in his new appointment.

A.J.G.

Retirement of Mr. G. F. Greenham, M.B.E.

George Frederick Greenham was educated at Emmanuel School, Wandsworth, and later at Kings College, London, where he studied under Dr. John Hopkinson. After a year with the Charing Cross & Strand Electricity Supply Company he entered the service of the National Telephone Company in 1895. His first appointment in the National Telephone Company was at Bank Exchange, London, where he joined a small exchange construction staff which was destined to supply a remarkable proportion of senior officers.

In 1899 Mr. Greenham was appointed to Gerrard Exchange as Exchange Manager and, in 1901, as Assistant to the Electrician of the Western London District, he was brought into touch with the construction of the first London Central Battery exchange at Kensington.

Further promotions followed quickly; in 1903, to District Electrician, in 1905, to Metropolitan Maintenance Electrician, and in 1907, at the age of 33, to Metropoltan Electrician. In this position he was responsible under Col. C. B. Clay, the Metropolitan Superintendent, for all construction and maintenance work in connexion with exchange and subscribers' apparatus throughout the Company's Metropolitan area. From that date to the transfer to the Post Office of the National Company's undertaking, Mr. Greenham was largely occupied in improving the organization and technical efficiency of the Company's electrical staffs in London and in completing the programme for the replacement of Magneto by Central Battery exchanges. In all these matters he displayed a rare gift of engineering management and his arrangements for exchange transfers were developed to that precision which is now a common feature of such operations. Mr. Greenham was responsible also for the whole of the engineering work in connexion with the Electrophone Service, which was a worthy, if comparatively diminutive, forerunner of the present broadcast service. In addition he was one of a small group of engineers who undertook the entire conduct of the Company's Correspondence Training Courses.

On the acquisition of the National Telephone Company's undertaking Mr. Greenham was for a short time in the South Metropolitan District as Assistant to Mr. A. Moir and, on the formation of the London Engineering District with Mr. Moir as Superintending Engineer, he was transferred to the new District. His association with Mr. Moir was in every way a happy one and his assistance was invaluable, particularly in the years immediately following the transfer when Mr. Moir carried through so memorably the amalgamation of the Post Office and the Company's London staffs.

During the war, Mr. Greenham was the liaison officer in London between the Air Defence Authority and the Post Office in regard to all communication requirements at the military Headquarters and at control, gun, and searchlight stations.

In 1922, on the departure for Australia of Mr. H. P. Brown, Mr. Greenham left the London Engineering District to take over the vacant position of Assistant Staff Engineer, Telephone Section, and in this position he was concerned with many of the alterations of practice attendent upon the change over from Manual to Automatic equipment.

There is no doubt, however, that Mr. Greenham's preference was for District work and it was a matter for congratulation, both to him and the South Eastern District that, in 1928, as Superintending Engineer, he was again afforded an opportunity of exercising his gifts in District management. In the years that followed, the able administration, and the excellent results obtained, were patent to all who came into contact with the District as, also, was the high regard of the staff for their Chief.

The South Eastern District staff and Mr. Greenham's colleagues in the Engineering Department and in other branches of the Service greatly regret the severance of their official association with him, and wish him many years of happiness and good health in his retirement.

P.J.R.

Retirement of Mr. J. Millner Shackleton

The end of January saw the retirement from the Post Office service of John Millner Shackleton, Superintending Engineer of the North Western District.

Mr. Shackleton was born at Ballitore, County Kildare, Ireland, on the 7th July, 1874, of Quaker stock, and has inherited the downright qualities associated with the principles of that sect. He is, however, a true Irishman with wit and humour predominant and with that generous and lovable disposition of the true sons of Erin.

Educated at Newtown School, Waterford, and at Sidcot School, Somerset, he developed a propensity for Engineering and commenced his business career with a firm of Mechanical and Electrical Engineers in Dublin, but in 1895 he severed that connexion and entered the service of the late National Telephone Company in that city, under Mr. Frank Gill, as Inspector. His rise in the service was rapid and after occupying the posts of Chief Electrician and Engineer in Dublin, he was promoted in 1901 to the position of Local Manager for Belfast. In 1902 he became the District Manager for the South of Ireland District with Headquarters at Cork. His ability in engineering matters quckly brought about his transfer to the Staff of the Company's Engineer-in-Chief in London, where his aptitude for grasping essential details and his thoroughness of application again brought him prominently to the fore and 1909 saw him appointed Metropolitan Engineer in London. On the transfer of the Company's undertaking to the State in 1912, he was graded Assistant Superintending Engineer and attached to the London Engineering District where he found wide scope for his specialized knowledge on Underground Construction and Cable work. His appointment as Superintending Engineer for the North Western District of England, with Headquarters at Preston, was a particularly well-merited one and by his remarkably sound judgment on all matters he has earned the confidence and respect of all members of his Staff.

Mr. Shackleton will leave the Service young in spirit and with vigour unimpaired and it is difficult to imagine that he will stagnate in his retirement. Doubtless his golfing and fishing pursuits will partially fill his leisure,

but his unbounded enthusiasm and energy for men's work will probably urge him to more vital activities. Wherever he may go, and whatever he may do, he is assured of the good wishes of his Staff who feel that in his departure they lose, not only a fine leader, but a charming personality.

C.B.

The Institution of Post Office Electrical Engineers

ESSAY COMPETITION, 1934-35.

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

D. B. Balchin, Research Section.
" Amplifiers in Subscribers' Premises." (E.92).

F. W. Howcroft, Wigan.
" Protection and Protective Devices." (E.93).

F. G. Stubbins, Portsmouth.
" The Preservation of Old Automatic Exchanges." (E.94).

C. Lawrence, E.-in-C's Office.
" The Electro Magnetic Relay." (E.95).

T. S. Wylie, Preston.
" Underground Cables." (E.96).

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

E. F. Scott, Bristol.
" Internal Combustion Engines." (E.97).

C. W. Long, London.
" Carrier Wave, Telegraphy and Telephony." (E.98).

S. Helm, Oxford Radio.
" Artificial Resuscitation in Cases of Electric Shock." (E.99).

J. R. Brinkley, Glasgow.
" Noise Reduction in Wireless Reception." (E.100).

J. Lawton, Manchester.
" The ' ENG ' Scheme." (E.101).

The Judges reported that the average standard of the essays was good, but there was no essay of outstanding merit. The essays are available in the Institution Library, the numbers being given above in parentheses.

RECENT ADDITIONS TO THE INSTITUTION LIBRARY.

1100 Text-book on compound interest on annuities—certain.—R. Todhunter (revised). (1931, Brit.).
1101 Housing England—P.E.P. report.— — (1934, Brit.).
1102 Highways and their maintenance.—W. J. Hadfield. (1934, Brit.).
1103 Electric circuits and wave filters.—A. T. Starr. (1934, Brit.).
1104 Theory of alternating current wave forms.—P. Kemp. (1934, Brit.).
1105 Elementary electricity and magnetism.—R. W. Hutchinson. (1934, Brit.).
1106 Notebook of mathematics.—G. F. H. Cook. (1934, Brit.).
1107 Advanced practical mathematics.—W. L. Cowley. (1934, Brit.).
1108 Elementary practical mathematics : Book II, 2nd Year.—E. W. Golding and H. G. Green. (1934, Brit.).
1109 Introduction to the infinitesimal calculus with applications to mechanics and physics.—G. W. Gaunt. (1931, Brit.).
1110 University of London regulations relating to degrees in engineering for external students.— — (1934, Brit.).
1111 University of London regulations in the faculty of engineering for internal students.— — (1934, Brit.).
1112 Radio Communication : Part I, History and development—Science Museum Handbook.—W. T. O'dea. (1934, Brit.).
1113 Theory of vibrations for engineers : an intermediate course.—E. B. Cole. (1935, Brit.).
1114 Automatic protection of A.C. circuits.—G. W. Stubbings. (1934, Brit.).

Application of electricity and magnetism to transmission in the telephone plant.—American Telephone and Telegraph Co. :

1115 Section I.—Elementary principles—direct currents. (1923, Amer.).
1116 Section II.—Elementary principles—alternating currents. (1923, Amer.).
1117 Section III.—Specific applications—telephone repeaters. (1927, Amer.).

RETIRED MEMBERS.

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

J. W. Ray, 75, Cross Road, Southwick, Sussex.
H. G. Tissington (temporary address), Knutsford Vale House, Laxton, Willisborough, Ashford, Kent.
G. H. A. Wildgoose, 114, Nicolas Road, Chorlton-cum-Hardy, Manchester.
J. Hedley, I.S.O., 60, Markhams Avenue, Woodford Green, Essex.

Junior Section Notes

Aberdeen Centre

Mr. J. P. Haines gave a paper on " Telegraphs Past and Present " at the January meeting. After discussion, the Aberdeen Telegraph Instrument Room was visited. The inspection of working apparatus enhanced the value of the paper.

At the February meeting, Mr. J. Brock read a paper on the " Rural Automatic Exchange " which gave rise to an interesting and helpful discussion.

In view of the installation of a Police Telephone and Signal System at Aberdeen, it has been arranged for Mr. J. McIntosh, of the Parent Section, to deliver a paper on this subject.

Derby Centre

An account of the inauguration meeting of the Centre appeared in a previous issue of the Journal. Five other well attended meetings have since been held, and it is satisfactory to record that the interest shown by the members has been well maintained.

On 11th February Mr. A. T. J. Beard, A.M.I.E.E., of the Engineer-in-Chief's Office, gave an interesting resumé of his paper on the " Provision and Maintenance of Repeatered and Amplified Circuits " which he delivered to the Senior Section on the same date. This paper, illustrated by lantern slides, was given to the Centre in the Derby Repeater Station, and at the close the members made a tour of the Station. The meeting was attended by members of the Post Office Workmen's classes which are normally held in the Technical College.

Two more meetings will be held before the close of the Session, the subjects being " Telephone Transmission " and " Unit Auto Exchanges."

Edinburgh Centre

At the January meeting, Mr. F. Williamson read a paper on " Satellite Exchange Maintenance " which produced a good discussion. A paper prepared by Mr. W. V. McWalter on " Voice Frequency " was read by Mr. P. S. S. Biggers at the February meeting, owing to Mr. McWalter's indisposition. The numerous points raised in the discussion were ably dealt with by Mr. R. S. Lumsden, of the Parent Section.

Guildford Centre

A paper, illustrated by lantern slides, was given by Mr. A. D. Knowers, of the Engineer-in-Chief's Office, on January 23rd, entitled, " Units Amplifying," which proved most interesting and instructive. We were pleased to welcome on this occasion members of the Aldershot Centre and three members of our supervising staff in Mr. F. Lock (Sectional Engineer), who occupied the chair, and Messrs. S. D. Pendry and H. Watts.

On February 16th a visit was paid to the Hackbridge Cable Co.'s works at Sutton and it is with pleasure we are able to record a most enjoyable and instructive Saturday afternoon at the hands of Mr. Dodgson and his colleagues of the Cable Company. The tour, which lasted three hours, kept everyone interested and it was obvious that very little was omitted. At the conclusion, we were entertained to tea. Mr. H. G. Yeatman, our secretary, closed the visit, by thanking the Company for their hospitality.

The success of this, our first outing, may be gathered from the fact that a number of members are already anxious to attend another, and it is hoped that an increase in membership will result.

Manchester Centre

The programme for the current and third Session of the Manchester Junior Section, catering as it does for a diversity of tastes, has so far proved of exceptional interest to a membership of approximately 100. The papers contributed to date have included the following :— " Graphical Statistics relating to the operation of the P.O.E.D. "—W. H. Scrivener. " Modern tendencies in the Supply of Power to Telephone Exchanges "—H. C. Jones, and " The Linefinder System "—W. H. Fox.

Among the visits to places of interest one recently paid to Grid House, Central Electricity Board, N.W. Area Control, proved particularly valuable and educative.

In the local Essay Competition—instituted with a view to encouraging members to contribute papers—Mr. C. Woods' entry " Displayed at East " was adjudged to merit the award of a Certificate and cheque for £1 1s. 0d., and at a meeting held on Monday, January 21st, we availed ourselves of the opportunity afforded by the presence in the district of the E.-in-C., Colonel A. G. Lee, to invite him to make the presentation. Colonel Lee was accompanied by the Supt. Engineer, Mr. T. E. Herbert; the A.S.E's, Messrs. J. F. Fletcher and J. Darke, and members of the local D.W.C. and Senior Section of the Institution.

In his speech Colonel Lee referred to the educational value of the Junior Sections. Speaking about the value of study generally he said he desired to discourage the staff from taking Correspondence Courses where Evening Classes were available and commented upon the higher standard of technical knowledge acquired by staff in large towns where such facilities were afforded. Mr. Herbert spoke favourably of Mr. Woods' essay which he had had the pleasure of reading and briefly expressed his pleasure at the manner in which the Centre was managing its own affairs. On behalf of the members he thanked Colonel Lee for honouring them by his attendance.

Book Reviews

" Electric Circuits and Wave Filters." By A. T. Starr, M.A., B.Sc., A.M.I.R.E. Pitman. 21/- net.

The author has set out to give a complete survey of the theory of electrical networks, starting from first principles, and without doubt an engineer who masters the contents of this book will be excellently equipped for dealing with A.C. network problems. Unceasing developments in the art of electrical communication make more than ever necessary a sound mathematical equipment, but one feels that the engineer who is not at heart a mathematician, in the specialist sense, may find difficulty in relating parts of this book with practical problems.

The theory of ladder-type filters is dealt with in some detail in accordance with Zobel's methods and some of the possibilities of single section bridge filters are indicated. These somewhat complicated structures and their equivalents have received much attention during the last few years, but the high degree of accuracy to which the components need to be adjusted to the calculated values is one of their drawbacks.

The extension of the usual conception of vector representation by substituting the sum of two vectors rotating in opposite directions for the projection of a single rotating vector; the significance of linear phase intercept in connexion with transmission of signals in which preservation of wave form is important; the meaning to be attached to a negative slope of the phase shift-frequency curve of a network; these are mentioned as matters which struck the writer as of particular interest in Mr. Starr's book.

G.J.S.L.

" Radio Round the World." By A. W. Haslett. Cambridge University Press. 196 pp. 5/- net.

This book, as its name suggests, is written for the " man in the street " and not for the expert, yet its outlook is so broad that very few experts will be unable to derive much useful information from one section or another.

The first portion deals with world wide transmission of radio waves and the part played in the transmission by the ionised layers of the upper atmosphere. This section provides a very fine review in plain and simple language of the research work carried out by the Radio Research Board and other organizations and experimenters in various parts of the world and gives the present day picture of the mechanism of radio transmission.

In later portions of the book the author explores the developments which have taken place in recent years in other branches of radio such as ultra short waves, television and medical applications. Succeeding chapters deal with Safety at sea, Radio in war, and Radio and the weather forecaster.

The author not only describes the present state of development of the art, but also looks ahead into the future with the result that both technician and non-technician will find it a stimulating and thought-provoking work.

A.J.G.

District Notes

London Engineering District

NEW PHONOGRAM EQUIPMENT.

On March 2nd the new Phonogram equipment in the Central Telegraph Office was opened for service.

The new installation, which, together with the T.T. equipment completed in September last, occupies the whole West Gallery of the 4th Floor in C.T.O. Building, consists of 12 double-sided tables, providing 176 equipped operators' positions, 14 unequipped positions, and 2 testing positions.

The Phonogram shares with the T.T. equipment such features as the band conveyor system and the sound-absorbent ceiling treatment, but they also have other details in common, among the more important being the operators' amplifiers for received speech, the foot-operated transmitter cut-out switches which leave the operators' hands free for their typewriters, and the flashing facility which eliminates long delays in answering calls by causing any calling lamp not extinguished within 30 seconds to flash at 0.2 second intervals.

The groups of incoming junctions are ancillaried on the various suites of positions so as to allow of efficient team working. A centrally situated switching cabinet controls the calling lamps so that concentration of the junctions may be effected according to traffic conditions. In this connexion a point of interest is the method by which the supervising staff are advised of the amount of traffic being dealt with at any instant. The Chief Supervisor's Desk is fitted with three pairs of meters calibrated in " operators," each pair being associated with one group of four tables. One meter in each pair indicates the number of positions staffed, whilst the other meter indicates the number of positions working.

An outstanding feature of the installation is that the whole of the cabling between the tables and the Apparatus Room at one end of the Gallery is by lead-covered cables accommodated in chases under specially provided flooring.

LONDON TRUNK EXCHANGE.

The initial stages of the engineering work necessary to meet the abnormal evening conditions caused by the introduction of the reduced trunk rates were described in the January issue of the Journal. With the approach of Christmas, this traffic still further increased, and it was necessary to continue working at high pressure in the London Trunk Exchange to meet the conditions and to gain the maximum advantage from the efforts which were being made in other parts of the country to increase the number of extra circuits; the provision of the Liverpool-Glasgow cable being perhaps the most important of these works.

The extent of the efforts made by the London Engineering District can perhaps be gauged by the following particulars of work carried out at the London Trunk and Toll Exchanges, and the associated Repeater Stations, during the three months 1st October to 31st December :—

Trunk and Toll Circuits provided... ...	205
Junction and Internal Circuits provided	571
Repeatered circuits " lined up "	157
Circuits re-arranged on switchboards ...	2410
Number of jumpers run	11046
Jumper wire used (Miles)	43.5

As a result of these efforts, it was possible on Christmas Day to complete no fewer than 15,347 trunk calls.

South Western District

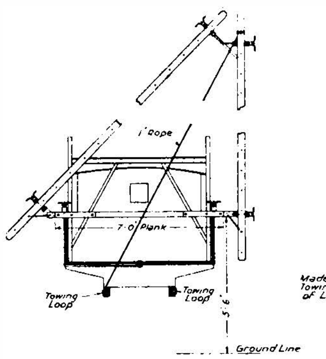
A SIMPLE DERRICK FOR OVERHEAD WORKS.

Readers who know the Exe Valley and its surroundings with its heavily wooded and tortuous roads will appreciate the difficulties of ordinary overhead work in such country. In addition it became necessary during August, 1934, to obtain some means of access to overhead wires in the spans. An adjustable travelling derrick of some sort was obviously required. Mr. H. Trussler, at Minehead, set about the problem and with the willing co-operation of his foremen and gang hands produced a remarkably simple apparatus for use with a 30 cwt. W.D. type lorry which not only solved the problem in hand but has since proved invaluable on all classes of overhead work.

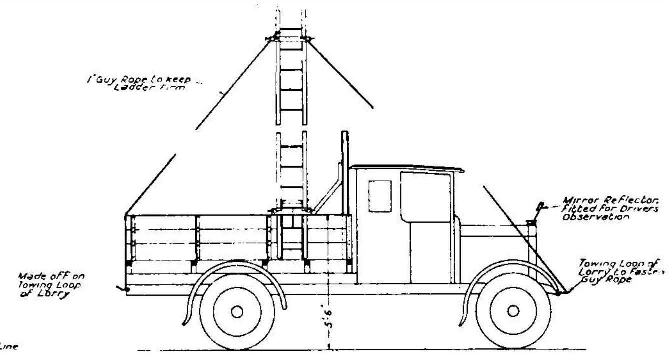
In its original form the derrick consisted of a 9″ builders' plank secured across the body of the lorry near the driving cabin. Two ladders were erected upon the plank and lashed to it outside the sides of the body. The ladders were tied together at the top and rope guy lines were run from this point to the front and rear towing loops of the lorry. Rope lashings were used throughout.

This arrangement met the early requirements, but as the use of the device on other classes of work became obvious the design was improved to meet the following requirements. The rope lashings were inconvenient and adjustments took some time and the extension of the plank over the sides of the lorry was a disadvantage. The fact that all the weight was placed on one rung of each ladder was not altogether desirable. Further, the lorry had to serve four gangs which might be working up to 20 miles apart. The arrangement, therefore, had to be available with and carried by the lorry and had not to interfere with its load carrying capacity.

In the new design an oak plank 7 ft. by 9 ins. by 3 ins. is fixed across the lorry by means of a simple but secure clamping device. A pivoted clamp is fitted at each end of this plank which, when tightened by means of wing-bolts, rigidly holds each ladder by its sides. A similar double clamp, but of slightly lighter material, connects the tops of the ladders together.



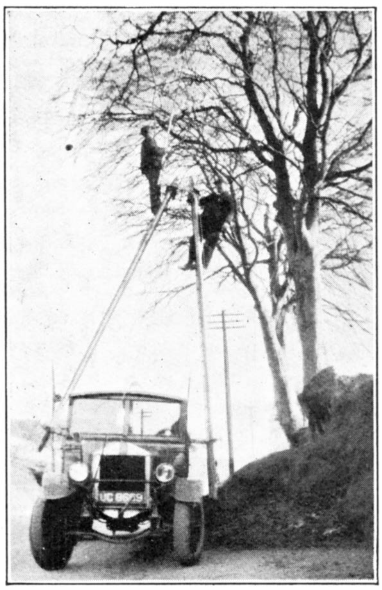
Section of Lorry.



Side Elevation of Lorry Shewing Ladder Position

The clamps permit very quick erection—a few minutes only—and adjustment for height and overhang of the working position at the top of the ladders and the whole arrangement can be swung from one side of the lorry to the other in an equally short time. The overhanging ladder can be inclined 25° out of the vertical with safety. It is interesting to note that the clamps were made almost entirely from such items as old oak arms, arm bolts and swivels stay, while the oak plank was secured to the lorry using oak arms, stay rods with pole roofs for protection of the body of the lorry. Much ingenuity was exercised, as will be seen, when it is stated that rapid, two handed wing bolts were made from the swivels. The plank, clamps and guy lines are carried by the lorry as part of its normal equipment, whilst the foremen use their own ladders as required.

The photographs give some idea of the whole arrangement as it appears in use and the sketch gives details of the fittings.



The derrick has been useful in the following cases which give some idea of its possibilities :—

(1) *Re-arranging Game Guards* for some miles in the Exe Valley. This was the work which originated the idea.

(2) *Tree-cutting.* Most work of this nature can be done with a small saw and a pair of shears and is especially useful where the tree growth is out of reach of pruning rods. It will be obvious that no tree climbing is necessary and that the method is very economical in that all tools are carried by the lorry and little time is spent in moving along a route.

(3) *Wiring.* No laying out of spindles and insulators is necessary since these can be fitted by the man on the derrick, who can also pass the ends of the wires over the arms. Binding in can be similarly accomplished. Ineffective time is reduced since there is no tool carrying and pole climbing involved.

(4) *Special maintenance* is required on lines in the vicinity of Broadcasting Stations. The Western National and Regional transmitters at Washford Cross have given considerable trouble in this respect. The overhead wires naturally pick up Radio frequency currents, which are rectified by such items as bad and even apparently good sleeve or soldered joints, cracked insulators and similar minor items which do not affect ordinary working. The resultant broadcast programme heard on the line is often louder than telephone speech. Location at the source of rectification is no easy matter and it has been found that constant examination of the affected lines at close quarters is invaluable and naturally raises the maintenance of these lines to a very high standard.

(5) *Aerial Cabling.* Aerial cable has been erected by the following interesting method :—

The steel suspending wires were first put in position. The lorry was not available for this work, but could be used for this operation on another occasion.

The actual cabling was accomplished without pulling-in as follows :—The drum of cable was mounted on jacks in the body of the lorry and cable was paid out by man No. 1. Man No. 2 put on the Marline Suspenders at approximately 20" apart and had to work hardest of all in order to keep pace with the running out of the cable. No. 3 passed the cable up to No. 4, who hooked the suspenders on to the steels and closed the hooks with pliers. No. 5, who was also upon the derrick, finally adjusted the suspenders *in situ*. The lorry driver was provided with a mirror so adjusted that he could observe the men working on the derrick and was thus able to assist them by skilled driving. Nearly 1,000 yds. of cable were so erected in one continuous operation at an expenditure of 60 manhours on an acknowledged difficult route. Other advantages will be obvious.

Aerial cable joints have also been repaired from the derrick and recoveries of cable could be carried out by a very similar method.

The cost of the plank and fittings, including Rate Book items used, was just under £3, but the savings which have already been effected by the use of this device are considerable and what is equally important the work is done with much less fatigue to the men.

The device is safe, and two men can work on the top of the ladders with comfort and without risk.

At the time of writing the derrick has not yet been approved officially, but it is to be hoped that it will be made generally available in due course either in its present or in a further improved form so that, to use Mr. Trussler's own phase, " in the quest for efficiency combined with economy, overhead works may be carried out from a ' higher level.' "

North Wales District

BIRMINGHAM, TELEPHONE HOUSE, LEADING-IN ARRANGEMENTS.

Considerable progress has been made with the steel work and building fabric at Telephone House and details of the lead-in arrangements may be of interest. The building will contain the Trunk Exchange, Toll Exchange, Central Auto Exchange and the Repeater Station.

The M.D.F. is built in two parallel rows with a capacity of 100 verticals per row. All junction and trunk cables will be terminated on two rows of 60 verticals and the subscribers' cables on the remaining two rows of 40 verticals. It has been arranged to connect all small cables into larger leading-in cables in order to make the fullest use of the duct space. This applies to trunk and junction as well as to subscribers' cables. A total of 47 junction and trunk cables containing 29,600 pairs will be led into the cable chamber from three directions by 26 cables and a total of 37 subscribers' cables, containing 21,200 pairs will be led into the cable chamber from four directions by 20 cables.

The cable chamber, slightly narrowed at the ends, leads direct into two cable turning chambers, the largest being 16′ × 15′ × 14′ high with a 17′ entrance shaft.

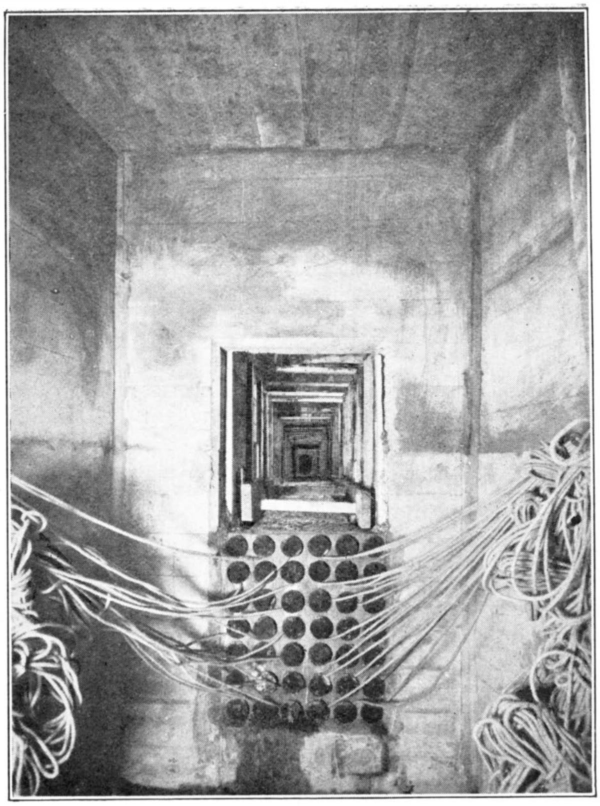
The lead-in ducts on the Lionel Street side are 78 octagonal and 30 square formations and on the Fleet Street side 9 and 15 square duct formations.

The square ducts, which are experimental, are laid in a similar manner to octagonal ducts and although it is too soon, so far as this District is concerned, to express any opinion as to their good or bad qualities, it is certain that they are easier to lay. The cement mixture can more easily be grouted between the separate ducts and it is more certain that all spaces have been filled with the grout. The internal dimensions of the ducts are $3\frac{1}{2}'' \times 3\frac{1}{2}''$ with corners rounded at $\frac{3}{4}''$ radii.

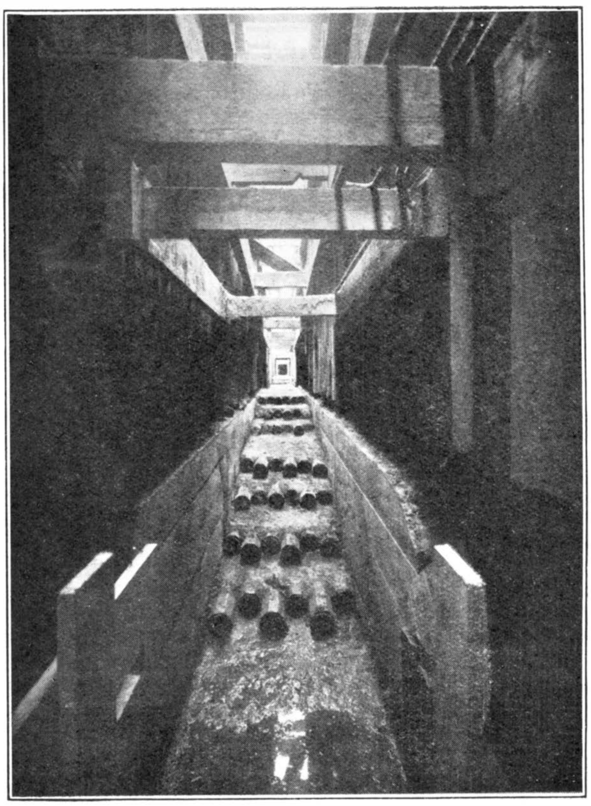
The building is on a site of considerable slope and 78 octagonal lead-in ducts had to be laid at depths ranging from 12′ 6″ to approximately 26′ into the cable turning chamber, the fall being made over a distance of 78 yards. In addition 30 square lead-in ducts were laid at depths varying from 7′ 6″ at the manhole to 26′ 6″ into the cable turning chamber, the fall being made over a distance of 50 yards.

The manholes at the corners of one block have each been constructed in the form of a trapezium, this particular shape being chosen in order to simplify the lay-out of the cables which will be carried on wall bearers. From the larger cable-turning chamber two sets of double sided cable bearers will merge into one set, and carry the cables into the cable chamber where the bearers will diverge into two rows of single side bearers to bring the cables immediately under the parallel M.D.F's. The repeater trunk cables will be carried on special irons fitted to the top of the cable bearer and led to the chute up which they will pass to the repeater room.

It will doubtless be appreciated that 78 octagonal ducts were not laid at the depths mentioned without some difficulties having to be overcome, not the least of which was the fact that nearly all the trench was cut in fairly compact sand necessitating elaborate timbering, and that a large concrete retaining wall, supporting the whole of the carriageway paralleled the trench over nearly the whole distance. Fortunately very little water was struck and during the erection of the retaining wall, a land drain, leading into a deep shaft, was laid to carry away any water which might accumulate on the face of the wall in the future. If necessary, a pump will be installed in the shaft to get rid of any water and it is not anticipated that any trouble will be expected with water getting into the cable chamber.



Ducts entering Cable Chamber.



View of Trench during Laying of Ducts.

Northern District

Sir Stephen Tallents, Public Relations Officer, in proposing the toast of " The Engineering Department " at the Northern District Staff Dinner held at Newcastle on the 23rd February, 1935, said that, without the efficient work of the Engineering and other Departments, the efforts of his Department would be mere " piecrust." He also referred to the impending reorganisation and expressed the opinion that the Engineering Staff of the Northern District could be relied upon to facilitate the introduction of the new organisation.

Mr. B. O. Anson, Assistant Engineer-in-Chief, who replied to the toast, referred to the remarkable *esprit de corps* which had been developed within the Department and said that he would watch with interest the effect of reorganisation upon the scheme of vocational training of workmen and also the future of the Institution of Post Office Electrical Engineers.

Mr. Baldwin, the Superintending Engineer, who presided, proposed the toast of " the Visitors " and referred to the happy relations which had always existed between the Engineering Department and the other Departments of the Post Office locally. Mr. Ferguson, Postmaster-Surveyor, who replied, endorsed the views of Mr. Baldwin.

Messrs. C. A. Taylor, Harvey Smith and J. J. McKichan, Superintending Engineers of the North Eastern, Scotland West and Scotland East Districts respectively, in addition to Capt. Fletcher, Assistant Superintending Engineer, and the several Northern District Sectional Engineers, attended the dinner, and it was particularly pleasing to see several retired members of the Engineering Department's staff. All ranks of the staff were represented and a thoroughly enjoyable evening was spent. Regret was expressed that this was likely to be the last of the annual dinners in the Northern District.

Eastern District

The retirement at the age limit of Mr. W. H. Calveley, Sectional Engineer, Colchester, is noteworthy in that he spent the whole of his service as an Engineer in the Colchester area of the Eastern District, commencing as Sub-Engineer in 1903. The high esteem in which he was held was amply evidenced by the attendance of about 200 of all ranks at a dinner in his honour. By common consent Mr. Calveley is one of the best, whether judged by a technical or by a personal standard, and one whose retirement can only leave the Service the poorer. We wish him most sincerely a long and happy enjoyment of a nobly-earned pension.

Scotland East District

ELGIN AUTOMATIC EXCHANGE.

The telephone system at Elgin, Morayshire, was successfully changed over to automatic working at 2 p.m. on Saturday, the 16th February. This is the first full automatic exchange, apart from exchanges of the U.A.X. type, to be brought into use in the north of Scotland and, in fact, north of Dundee. The number of circuits transferred was 447 subscribers and 60 trunks and junctions.

The automatic plant is of the Department's standard non-director type with homing type uniselectors (booster metering) and 100 outlet first, second, and final selectors. The present equipment is for 560 and the ultimate capacity for 900 subscribers' lines. All the apparatus is mounted on single sided racks and jacking in facilities have been provided. A combined main and intermediate distributing frame is provided, the intermediate portion giving full cross-connecting facilities between the subscribers' calling equipment and multiple. One trunk distribution frame has been fitted and on this are mounted the terminal strips to which the outlets from the various switches are cabled for the purpose of grouping and grading.

The manual board consists of six 2-panel one position sections comprising one incoming jack-ended B position, three A positions, one enquiry position, and one spare position. The circuits are arranged for the sleeve control system and C.T.I. and V.I.I. equipment has been provided in connexion with trunk demand working, Elgin being a group centre.

The exchange equipment was manufactured and installed by the General Electric Co., Ltd.

Elgin is an important junction centre, being connected by 54 direct trunks and junctions to 21 other exchanges.

Dialling-in facilities are provided on 38 junctions from 15 exchanges at which the necessary modifications had to be made. The trunk circuits from Aberdeen and the junction circuits from two U.A.Xs. of the No. 5 type are terminated on the manual board. The junctions to Lossiemouth and Dufftown, which will be converted during the present year to automatic working, are being worked temporarily on the manual board.

Amplifier equipment has been installed by the Department in the automatic apparatus room in connexion with the Aberdeen-Huntly main cable which was recently extended to Elgin, and the Elgin-Inverness main cable at present being laid.

This plant consists of :—

- One equipment amplifying No. 5 15/15.
- One equipment power No. 1 20/20.
- One motor generator No. 9 DC to AC output 230 v. A.C. 4.5 amps. 50 cycles.
- One low tension 6 v. battery, 300 A.H.
- One high tension 136 v. battery, 8 A.H.

The amplifiers, which are the standard A.C. equipment, will normally be run from the A.C. generator. The batteries are provided as a standby in case of emergency, when they are automatically brought into use. Under normal conditions they are continuously trickle charged.

On the afternoon of the 21st February Lord Provost Hamilton of Elgin formally opened the new automatic exchange in the presence of a large and distinguished company. Colonel F. N. Westbury, O.B.E., Secretary to the Post Office in Scotland, was present and addressed the gathering. The Lord Provost passed the first demand trunk call to Miss Ishbel MacDonald at 10, Downing Street, whose response was received on a loud speaker. The Superintending Engineer, Mr. J. J. McKichan, O.B.E., briefly described the new exchange system. Tea was served and the visitors were conducted over the exchange and the operation of the apparatus explained to them.

South Eastern District

Shortly before the retirement of Mr. G. F. Greenham, the Staff of the South Eastern District took an opportunity of signfying their esteem and respect for their Superintending Engineer. Under the Chairmanship of Mr. J. H. M. Wakefield a dinner was given in his honour at Croydon. A number of distinguished guests were present, including, among others, the Engineer-in-Chief, his Deputy and Assistants, the Superintending Engineer of the London Engineering District and his Deputy, the Superintending Engineer of the South Midland District, the Surveyor of the South Eastern District, the District Managers of Brighton and Canterbury and the Chief Inspector of Traffic, Telegraph and Telephone Department. Sectional Engineers and representatives of all ranks under Mr. Greenham's control joined to make the function a success which will long remain outstanding in the social history of the District.

The function was pleasantly terminated with a concert ably provided by members of the Staff.