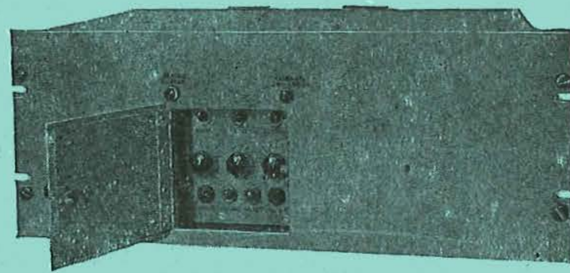
THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

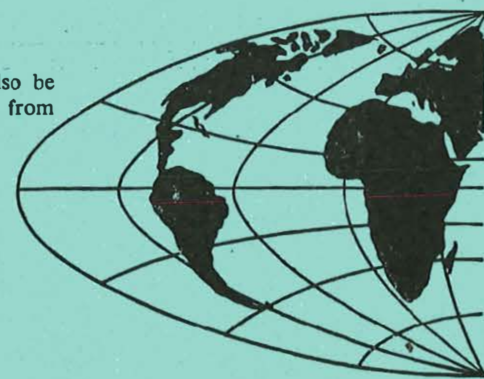
Vol. 47 OCTOBER 1954 Part 3

CONTENTS

Price 2/6 net

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS





Train your mind to SUCCESS

THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

Vol. 47 October 1954 Part 3

The Congestion and Delay Announcer

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With the introduction of automatic trunk switching a controlling operator encountering congestion or delay must be made aware, automatically, of the condition and of the point in the route at which it arises. The authors describe equipment designed for this purpose which provides seven different announcements from glass-disc recordings, distributed to operators, as necessary, via overflow outlets on the trunk switches.

Introduction

FOR many years operators in the London toll area have been able to dial calls through the London toll automatic exchange to distant exchanges in the toll area, and when the route forward from London has been "in delay" they have heard the amount of delay quoted by a Mechanical Delay Announcer in London.[1] The automatisation of trunk circuit switching at zone centres, which began with the opening of the London (Faraday) trunk automatic exchange in February 1954, makes it necessary to extend automatic announcing facilities. When a trunk call dialled through a tandem zone (or sub-zone) centre meets "congestion" or "delay" on the route forward from the tandem, the controlling operator must be made aware of the condition, and of where it is occurring, so that she may know how to deal with the call and what to tell the calling subscriber. If she hears a congestion announcement "No lines at . . .", she can decide whether to dial again or attempt alternative routing, and she will know at what point along the route she can ask for assistance in completing the call. If she hears a delay announcement she will not make a repeat attempt or try alternative routing, and again she will know where to seek assistance. If she receives busy tone she will know that the busy condition is beyond the terminal trunk exchange on a junction or the subscriber's line, or it is occurring on some inter-switch circuit; and she can, if necessary, begin checking with help from the terminal centre. The importance of announcements of where congestion and delay are occurring on trunk circuits and of the amount of delay can be appreciated by considering what cumbersome and dilatory checking procedures would be necessary if all busy conditions were indicated by ordinary busy tone.

An automatic congestion and delay announcer has been designed and the first one installed at London (Faraday) trunk automatic exchange. It provides a congestion announcement, "No Lines at London"; five delay announcements, "Delay ½ hour, London", "Delay, 1 hour, London", "Delay, 2 hours, London", "Delay, 3 hours, London" and "Refer to Records, London"; and a "Test call" announcement which is used in automatically routining trunk circuits outgoing from selector levels to manual exchanges—the routiner sets up a test call and connects the announcement to inform the manual exchange operator that it is a test call she is answering. Except for "Test call," which is repeated three times in 5 seconds, the announcements are transmitted once in every 5 seconds and a third of the 5-second cycle is silence. A circuit switched to a congestion or delay announcement is in the unanswered condition, and if it is a Signalling System A.C. No. 1 circuit, transmission in the backward direction over it may have to be interrupted at the incoming relay set for 1 second in every 5 seconds, to allow the forward clearing signal (which on an unanswered circuit is of 6 seconds' duration) to be effective in clearing down the equipment at the incoming end. The interruption is effected at the incoming relay set because it is required on calls encountering continuous (N.U.) tone as well as on those meeting announcements. Thus, to avoid mutilation of the announcements, not only must there be a gap in the announcements of slightly more than 1 second in every 5 seconds, but this silent period must be synchronised with the interruption at the incoming relay sets. This is simply arranged by deriving the 1 second in 5 seconds pulse supply to the relay sets from a cam-operated springset on the congestion and delay announcer. The pulse supply is automatically changed over on failure of the announcer to the normal main and standby pulse-generating machines.

It will be seen that the form of the congestion and delay announcements has been very largely determined by the requirements of the Signalling System A.C. No. 1.[2] This system may also have an effect on the quality of the announcements, in that it is important they should not imitate either of the V.F. signalling frequencies used in the system to such an extent as to cause false circuit operation. Circuits switched to announcements are in the unanswered condition and on an A.C. No. 1 circuit in the unanswered condition the normal guard against signal imitation by speech is not fully operative. Hence this consideration may determine what voice is used in recording, and it is possible that the A.C. No. 1 signalling frequencies present in the announcements may have to be attenuated.

Announcement Access Relay Sets and Selecting Switches

The outgoing trunk circuits from a zone (or sub-zone) trunk automatic exchange are connected to the banks of motor uniselector group selectors divided into two groups:

† The authors are, respectively, Executive Engineer, Telephone Development and Maintenance Branch and Executive Engineer, Post Office Research Station.

[1] "Trunk Delay Announcing." H. Corkett and A. C. Lynch. *P.O.E.E.J.*, Vol. 35, p. 73.

[2] "Signalling System A.C. No. 1 (2 V.F.)." D. C. Smith. *P.O.E.E.J.*, Vol. 44, pp. 66 and 114.

A

the "local" group for traffic from the trunk control centre manual boards of the zone, and the "tandem" group for through-dialling operators. Each trunk level has up to eight overflow outlets following its working outlets, and the numbers of overflow outlets of the local and tandem groups are equal. Corresponding overflow outlets of the two groups are commoned, and connected to announcement access relay sets, which are cabled via the I.D.F. to the wipers of announcement selecting switches of rotary type, which are provided one per trunk level (that is one per route, except on trunk routes with a very large number of circuits). The banks of the announcement selecting switches are multipled to the six announcement feeds. The selecting switches are provided on a Delay Control Panel or Rack, which may be some distance (up to 200 yards) from the announcing machine and its amplifiers.

Each announcement amplifier has an 820 ohm load resistor connected across its output feed and each feed terminates in a 14 : 1 step-down distribution transformer mounted on the Delay Control Panel or Rack. The output impedance of an announcement channel is therefore of the order of 4 ohms. Also, the load on the amplifier, and therefore the output voltage of the announcement, varies little with the number of calls simultaneously connected to it. In practice, even at the largest zone centres, the average number of simultaneous busy hour overflow calls meeting congestion announcement, or of intended through calls switched to one particular delay announcement, should be well under 100, the figure to which the announcement amplifier has been designed.

The low announcement output impedance minimises cross-talk between simultaneously connected circuits. Such cross-talk currents as are set up are attenuated by a 400 ohm resistor and 2 microfarad capacitor series-connected in each wire of the speech pair in each announcement relay set. A trunk operator setting up a call which encounters a congestion or delay announcement will usually dial the remaining digits before she hears the announcement, and these ineffective digits pulsed into the announcement must not mutilate the announcements for other operators listening to them.

Normally, congestion announcements are returned by all overflow relay sets in the trunk auto exchange, but when an announcement selecting switch is set to a delay announcement that delay announcement is returned by the overflow relay sets for that trunk route; also the working outlets of the route on the "tandem" group of switches are busied by operation of a busying relay in the outgoing relay set; this relay cannot be operated from the announcement selecting switch if the relay set is engaged on a call, but is operated immediately on the call being released. Thus, without interrupting any calls in progress, the forward route in delay is denied to through-dialling operators immediately the announcement selecting switch for the route is set to any of the five delay announcements.

Operation of any announcement selecting switch to any delay announcement brings into service the power unit (No. 2) supplying the amplifiers for "Delay 1 hour . . .", "Delay 2 hours . . .", "Delay 3 hours . . .", and "Refer to Records." Power Unit No. 1 supplying the amplifiers for "No lines at . . .", "Delay half-hour . . ." and "Test call" is continuously energised. Hence when routes are being put into delay, announcements will not be returned via the overflow relay sets of any route set to a delay greater than "Delay half-hour . . ." until Power Unit No. 2 and its four announcement amplifiers have warmed up; busy tone is transmitted in the interim period.

Busy tone is also switched at the announcer rack in place of any announcement which fails, by release of the alarm relay associated with the amplifier, as described later. Again, busy tone is received by any call dialled to a level on which all working and overflow outlets are in use: such a call is switched to the last bank contact of the selector. Busy tone is also returned when a call meets congestion between ranks of selectors, but as each rank of selectors is provided for a grade of service of one lost call in 500, this congestion should be rare.

Description of the Announcer

The general design of the machine follows that adopted for the Mechanical Delay Announcer,[1] but experience gained with the existing machine has shown the need for certain modifications which have been incorporated in the new design. These include the rearrangement of the optical system to prevent dust collecting on the working surfaces, and the use of a motor with tropicalised insulation to withstand the temperature existing under the covers.

The required announcements, seven in number, are recorded photographically as concentric sound tracks on a glass disc 12 in. in diameter. The dual bilateral variable area system of recording was used.[3]

The make-up of each sound track is as follows: Delay or congestion announcement in the first third of a revolution, the place name in the second third, and a silent period for the remaining third. Between the first and second third a silent period of 0·367 second duration is inserted. Superimposed on the announcements on each sound track and extending over the whole circumference, is an 80 c/s tone which is used for alarm purposes.

The Reproduction System.

A projection method of reproduction from these sound tracks is employed and the system is illustrated in Fig. 1. The glass disc is mounted on a shaft carried in ballraces and is rotated at 12 r.p.m. by a mains operated synchronous motor driving through a worm and wheel reduction gear.

An exciter lamp is mounted on one side of the disc and a special condenser lens produces a band of intense illumination radially across the sound tracks.

On the opposite side of the disc is placed a projection lens which with the aid of a reflecting prism produces an enlarged image of the sound tracks upon the scanning slit situated below. Underneath the scanning slit are located the channel amplifiers with their photoelectric cells. Between the scanning slit and each photocell is a collector lens, the function of which is to direct the light produced from the image of the sound tracks upon the scanning slit, on to the cathode of the photocell.

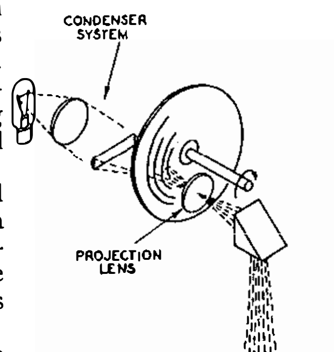

Fig. 1.—Projection Method of Reproduction.

As the glass disc is rotated, the image of the seven sound tracks moves across the scanning slit above seven corresponding photocells. The width of the light beam on the slit

[3] "A Photographic Technique of Sound Recording on Glass Discs." A. J. Forty. *P.O.E.E.J.*, Vol. 47, p. 19.

above each photocell varies in accordance with the announcement recorded on the appropriate sound track and the ensuing modulated light falling upon the photocell cathode produces an electrical signal.

The disc speed of 12 r.p.m. used is much slower than in usual practice. Its advantage lies in the fact that the complete announcement cycle can be recorded in one revolution of the disc thus avoiding the use of complicated shutter mechanisms or electrical switching methods for the synthesis of the announcements. The difficulties arising in using this slow speed are the production on the glass disc record of adequately short wavelengths in the sound tracks to give an intelligible announcement, and ensuring the consistency of the speed of drive necessary to avoid "wow", this being particularly difficult to overcome at slow speeds. The satisfactory resolution of these difficulties together with the simplicity of the system led to its adoption.

The exciter lamp used as the source of illumination is a British Standard No. EL8 lamp intended to operate from a 27V 1A supply. It has a rated life of 100 hours. In this equipment the lamp is under-run from a 23V supply and takes a current of 0·875A. This modification increases its life to more than 1,000 hours. The supply is obtained from the 50V exchange batteries, the balance of voltage being dropped across a resistor.

It was found necessary to operate the lamp from a D.C. supply because when it was fed from an A.C. source, the 100 c/s ripple held in the alarm circuit of the amplifiers against fault conditions. Subsequently to the production of this machine, a smoothed supply circuit has been developed for operation from A.C. mains and which does not have this effect.

The condenser lens used in conjunction with this exciter lamp contains a cylindrical element which is instrumental in producing the band of illumination required. An explanation of the way in which this band is produced is given in the earlier article.[1]

The exciter lamp and condenser lens are mounted together in one unit which is adjustable in a direction perpendicular to the disc. This permits the accurate placing of the unit in order to obtain maximum light transmission through the optical system, which necessitates the focusing of the lamp filament to produce an image within the projection lens. Provision is also made on this unit for the adjustment of lamp filament height and a slight orientation of the light beam upon the disc.

The projection lens is of $2\frac{1}{2}$in. focal length and $f/1{\cdot}9$ aperture mounted on a circular plate which in turn is held on a small cast bracket. Also fixed to this plate is a barrel which contains a right-angled prism coated on its hypotenuse with silver. This coating is applied by sputtering and is afterwards covered with a film of perspex to protect it. A window is cut in the underside of the barrel for the passage of the light rays through the optical system. The bracket carrying the projection lens and prism is free to move in machined slides perpendicularly to the disc for the purpose of accurate focusing of the image of the sound tracks onto the scanning slit.

An adjustment is provided whereby the plate carrying the lens and prism may be moved laterally and by a further adjustment the barrel containing the prism may be rotated through a small angle. These two adjustments allow the accurate orientation and alignment of the image of the sound tracks upon the scanning slit so that they lie exactly over the photocells. To simplify this adjustment, upon the accuracy of which depends the quality of reproduction, two radial marks are sited on the glass disc for orientation, and a mark is engraved upon the scanning slit mounting for alignment of the sound tracks.

The scanning slit is 4 mils in "length" as measured in the direction of motion of the image of the sound tracks. It is produced photographically from a negative which in turn is produced by exposing a photographic plate placed behind a mechanical slit consisting of two accurately ground metal knife-edges placed 4 mils apart. By adopting this method, the subsequent production of scanning slits for future machines or for replacements is considerably simplified. The glass plate containing the scanning slit is held, emulsion side downwards, in a metal mounting plate which also holds the collector lenses.

The collector lenses are simple converging lenses and their use is necessary for the following reason. The rays of light forming the individual sound tracks are diverging when they pass through the scanning slit. By the time they reach the photocells a portion of their width would miss the photocell cathodes completely, causing a clipping of the signal peaks. The collector lenses are inserted to direct the whole ray on to the cathode of the photocell, and are so arranged to produce a line image on the cathode instead of a point image which might fall upon an insensitive spot. In addition to a loss in signal level, the rays of light passing the photocell cathode might cause optical cross-talk between adjacent sound tracks.

The Channel Amplifiers.

In order to reduce the time which the equipment might be out of service due to a faulty amplifier, it was decided to construct the channel amplifiers as separate units which could be jacked into position. A view of the finished amplifier is illustrated in Fig. 2.

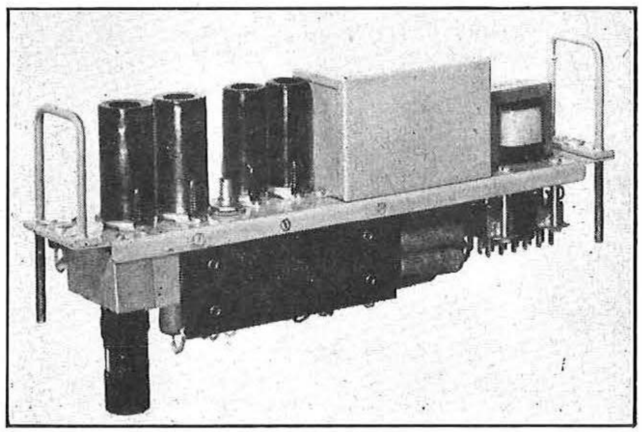

FIG. 2.—CHANNEL AMPLIFIER.

The units are inserted into position from the front and rear of the equipment alternately, the photocells interleaving and lying under the collector lenses. Each chassis carries two guide pins mounted on diagonal corners. These guide pins engage in bushes and serve to direct the units into position without fouling the adjacent units. Once in position, the amplifiers are locked home by a fastener placed at each end. Two handles are fitted one at each end to facilitate removal and to serve as supports upon which to rest the amplifier when it is being serviced.

Supply, output, and other connections are effected by means of an 18-way plug and socket. The amplifying and alarm valves are mounted on the front of the chassis together with the spindle of the gain control, the choke used in the alarm circuit and the output transformer which is mounted under a protecting cover. The photocell and the first amplifying valve are mounted opposite one another and the space between them which contains the coupling components is completely screened. The body of the potentiometer used as a gain control is also fitted with a screening shroud.

The circuit diagram of the amplifier is shown in Fig. **3**. The output of the photocell, V1, which is a miniature vacuum type with a caesium-antimony cathode, is coupled to the first amplifier stage V2. The amplifier has two resistance-capacitance coupled voltage-amplifier stages utilising valves CV 2135 and an output stage using a valve CV 136 transformer-coupled to the load. Approximately 10 db. of negative feedback is provided on the last two stages, and a variable gain control is fitted on the input to the second stage. This is provided to compensate for the deterioration of the exciter lamp with age and for small residual differences in intensity of illumination over the projected field. The amplifier circuit demands approximately 18 mA from a 240V H.T. supply, and gives an output of about $1\frac{1}{4}$W, which is adequate to supply the maximum of 100 simultaneous connections stipulated in the specification. In addition to the normal H.T. supply the photocell requires a polarising potential of about 90V. This is derived from a part of the Power Unit. A curve of the frequency response of the amplifier is reproduced in Fig. **4**.

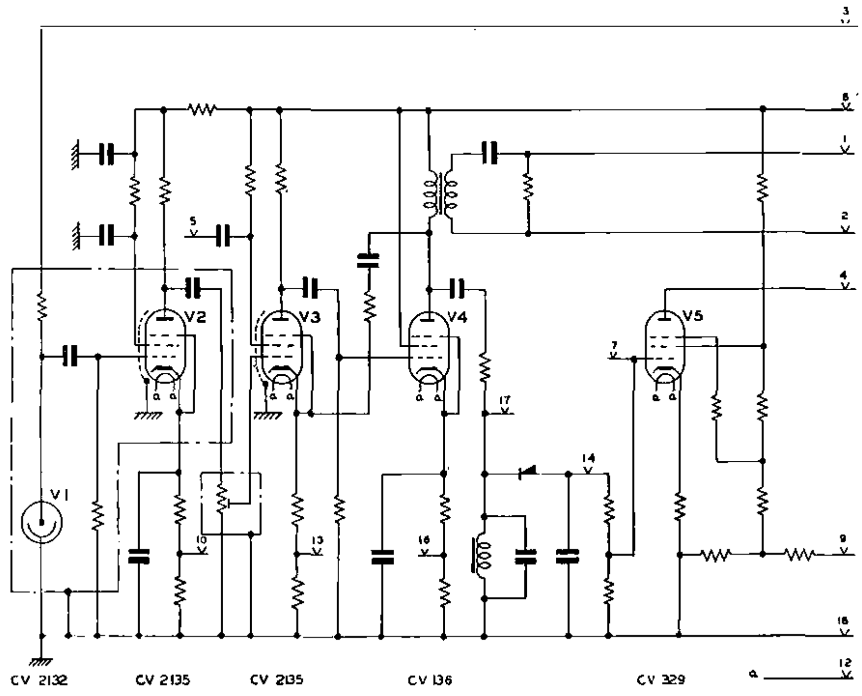

FIG. **3**.—CIRCUIT DIAGRAM OF CHANNEL AMPLIFIER.

The Alarm Circuit.

The equipment makes use of an alarm system which operates in the event of any one or more of the following conditions arising:—

(*a*) the cessation of rotation of the disc;
(*b*) the failure of the exciter lamp;
(*c*) the failure of a channel amplifier;
(*d*) the failure of either power unit.

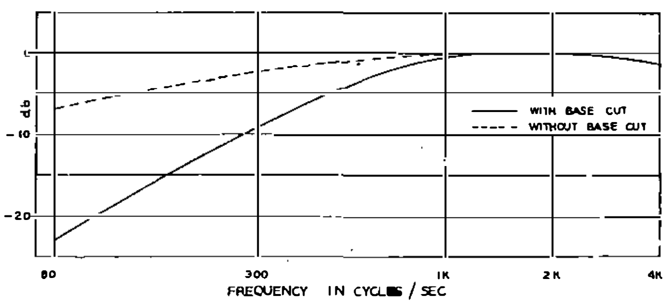

FIG. **4**.—FREQUENCY RESPONSE OF CHANNEL AMPLIFIER.

When the alarm system operates a visual indication is given on the Test and Monitor panel (see later) against the channel concerned and Busy Tone is substituted for the announcement. In the event of all the channels failing, it is assumed that this is due to the disc failing to rotate and in addition to substituting Busy Tone on the channels the 1 second in 5 seconds pulse supply from the cam-operated spring sets is changed over to the normal main and standby pulse-generating machines. An indication to this effect is also given on the Test and Monitor panel.

The action of the alarm circuit is as follows: The 80 c/s tone superimposed upon the announcement is selected by means of a filter at the anode of the output valve in the amplifier and is rectified and fed to a potential divider, the tapping point of which is connected to the grid of the transitron alarm valve, V5 in Fig. **3**. If the 80 c/s signal decreases in level from its normal value the control grid of V5 becomes more positive and the screen current increases. The screen current is supplied by a resistor which also supplies the suppressor grid. Since the screen current increases, the voltage drop across this resistor increases and hence the voltage on the suppressor grid falls. This causes a reduction in anode current. Since, however, the total cathode current remains nearly constant for a change in suppressor voltage, the screen current now increases still further accompanied by a corresponding drop of the suppressor voltage and in turn of the anode current. This action is rapid and cumulative and continues until the anode current is cut off. The Alarm Fail relay is connected in the H.T. supply lead to the anode and so, when the anode current cuts off, the relay releases and actuates an alarm relay mounted on the Relay Panel, which in turn substitutes the Busy Tone and gives the visual indication. If the 80 c/s signal returns to its normal value, the voltage applied to the grid of the alarm valve becomes more negative and the trigger circuit restores. An excessively large signal will cause the alarm valve to be biased beyond cut-off and so give a "high-level" alarm.

In order to prevent the 80 c/s tone from reaching the line, a "base-cut" capacitor is provided in the secondary side of the output transformer. The effect of this capacitor on the frequency response of the amplifier is illustrated in Fig. **4**.

The Test and Monitor Panel.

Provision is made on this panel for the following facilities:—

(*a*) the monitoring of the announcements on each channel;
(*b*) the measurement of the output levels of each channel;
(*c*) the proving of the alarm circuit of each channel;
(*d*) the measurement of the output voltages of the two power units;
(*e*) the testing of the performance of a channel amplifier jacked into the Test position.

The meter fitted to this panel is a modified Micro-ammeter No. 5. An arbitrary zero at about three-quarters deflection was selected and from this zero a scale has been engraved marked with $\pm$ 1 db. and $\pm$ 2 db. Placed just inside this scale is an arc coloured red which extends over a range of $\pm$ 10 per cent. The resistors in the switching circuits associated with this meter are of such a value that all measurements lie on this zero for the correct value.

The monitoring of the announcements is effected by setting a rotary "Select Test" switch to a position labelled "Test Output". This brings into circuit a second rotary switch, "Select Announcement", by means of which any one of the channels is connected to a telephone receiver attached to the panel. In the lead to the receiver is connected an attenuating pad to reduce the level of the announcement being monitored to a value comparable with that which would be heard by the remote operator connected through to the machine.

The Select Announcement switch also permits the output level of each channel to be measured by connecting the meter via a suitable resistor to U-point 14 of the channel amplifier concerned (see Fig. **3**). The meter thus indicates the level of the rectified 80 c/s signal. This method was adopted to avoid the use of an instrument rectifier and the complication of additional switching arrangements.

Other positions of the "Select Test" switch enable measurements to be made of H.T. and photocell polarising voltages of each power unit.

A Test position is provided adjacent to the working positions of the channel amplifiers and should it be necessary to check the performance of an amplifier it is jacked into this position, and its gain control set to "maximum." The 18-way socket fitted to this position is associated with the Select Test switch, and suitable positions of this switch enable measurements to be made of the cathode currents of the amplifying valves. Upon insertion into this Test position, U-point 4 connects with a resistor which simulates the Alarm Fail relay and enables a measurement of alarm current to be made.

To measure the gain of the amplifier in the Test position an input must be provided. Two methods were considered for this. In the first method the amplifier photocell could receive a light signal from the optical system. This was rejected on account of the uncertainty of the brightness of the source of illumination due to the ageing of the exciter lamps, even if successive lamps were of exactly equal brightness. The second method, which was adopted, is to inject a test signal into the amplifier, the test signal being derived from the "Refer to Records" channel. The amplifier jacked into this position has a connection made via the 18-way plug and socket to U-point 17 in Fig. **3**. This connection taps off the 80 c/s tone before it is rectified, reduces it to a convenient level by a potential divider, and injects it into the photocell polarising voltage connection (U-point 3) on the amplifier in the Test position. The measurement of gain is made in the way used to measure the output level of the channel amplifiers but the level of the Refer to Records announcement is first adjusted accurately.

On the Test and Monitor panel are mounted seven "Test-Alarm" keys each with its "Alarm Fail" indicator lamp. By pressing the appropriate key, U-point 14 of that channel amplifier is earthed, which cuts the input to the alarm valve and causes the alarm circuit to operate if it is in working order. Also fitted on this panel are the exciter lamp switch and the "Receiving Attention" key and indicator lamp used in conjunction with the "Rack Fail" alarm circuit.

The Power Units.

As mentioned previously, the channel amplifiers are divided into two groups, each group being supplied by one power unit. Power Unit No. 1 is continuously energised, and Power Unit No. 2 is energised by the selection of a Delay announcement. In addition to supplying the channels quoted, Power Unit No. 2 supplies the Test position. For this reason an alternative start switch is provided on the Test and Monitor panel.

In the consideration of the design of the power units, since each unit has to feed a number of three-stage amplifiers, it was decided to adopt a stabilised circuit, the output impedance of which could be adjusted to approximate to zero in order to eliminate cross-talk between the channel amplifiers connected to one power unit.

The circuit used consists of a full-wave rectifier valve (CV 575) feeding into a capacitor-input single-stage filter which is series-stabilised by two valves CV 345 connected in parallel. The control valve is a pentode CV 2135 which draws its reference voltage from a CV 449. The circuit is

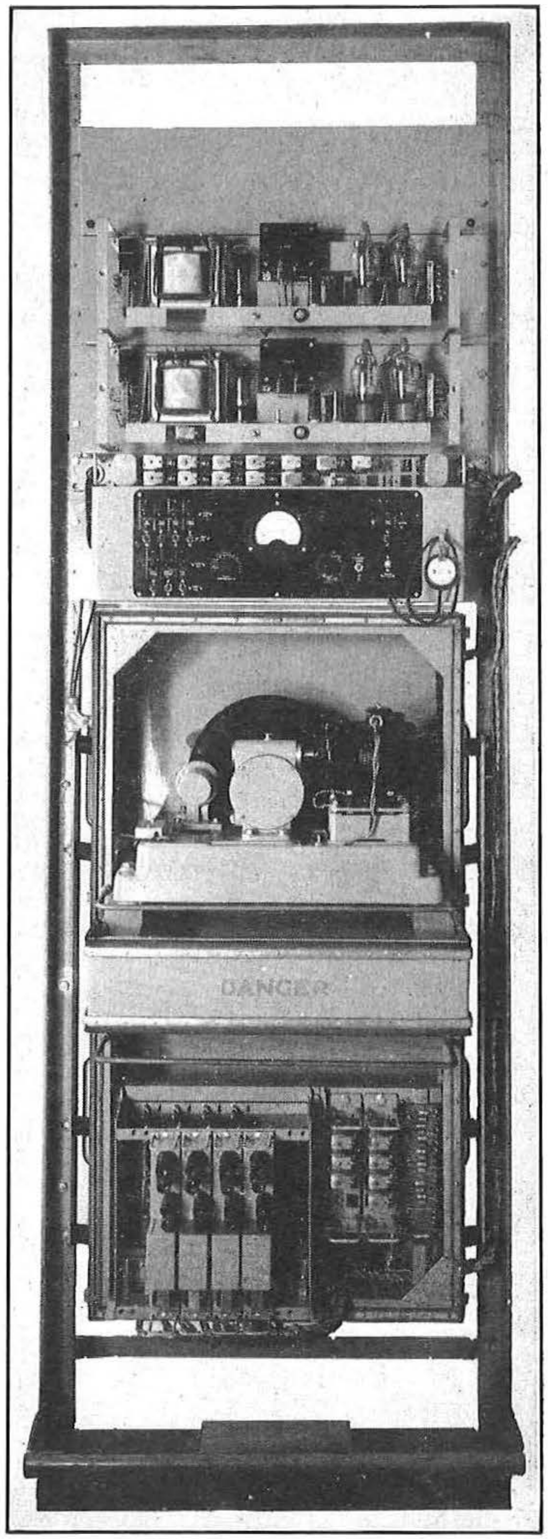

FIG. **5**.—THE EQUIPMENT RACK WITH COVERS REMOVED (PROTOTYPE ONLY).

compensated for variations of input voltage and load current and is capable of delivering 150 mA at a nominal voltage of 240V. Under test in the laboratory, the prototype gave a constant voltage output for a load current variation from zero to maximum and for variation of mains voltage input to the transformer between 220V and 260V.

The recommended maximum polarising voltage for the photocells is 90V and since the anode of the reference valve is connected via a resistor to a point in the power unit circuit at 350V, the inadvertent removal of the CV 449 would have a disastrous effect upon the photocells. The risk is avoided by making the polarising voltage supply connection by way of the internal connection to the anode incorporated within the valve.

The balance condition of the stabilising circuit is set up upon initial installation by adjusting a potentiometer until interruption of the full load current produces no change in the reading of a voltmeter connected to the output terminals. Power units adjusted in this way have a measured output impedance of less than half an ohm. The power units also supply 5A at 6·3V A.C. for the amplifier valve heaters. This L.T. supply is fitted with a hum-balancing potentiometer. Both the potentiometers fitted to each power unit are provided with friction locks and screw caps covering the spindles to prevent inadvertent alteration.

The Relay Panel.

The final item, completing the equipment, is a standard relay panel. This carries the Alarm Relays, one per channel, which substitute Busy Tone for the announcements under fault conditions, a number of miscellaneous relays associated with the equipment and two transformers. One of these steps up the Busy Tone supply voltage to the requisite value and the second supplies the Test Call output.

Arrangement of Equipment

The general arrangement of the items forming the Congestion and Delay Announcer is illustrated in Fig. **5**. The equipment is designed to mount within a 2000-type Miscellaneous Apparatus Rack, 8 ft. 6 in. high and 2 ft. 9 in. wide. Referring to Fig. **5**, starting at the top of the rack the items are: the Exciter Lamp Feed panel, Power Unit No. 1, Power Unit No. 2, the Relay panel, the Test and Monitor panel, and the Sub-Rack assembly. This last item consists of all the components forming the reproduction system illustrated in Fig. **1**.

The Sub-Rack assembly is carried in a frame made up of 3in. × 1½in. channel iron and is secured to the rack by flexible mountings, the purpose being to prevent external vibrations from affecting the system. Under working conditions, two split covers, front and rear, are clamped tightly against rubber seatings on the Sub-Rack frame by means of toggle-type clamps.

Precautions have been taken to ensure that no holes exist in the frame and covers of the Sub-Rack assembly, and these, together with the tightly clamped covers should ensure no ingress of dust. This, unfortunately, prevents ventilation for the motor, exciter lamp and amplifier heaters, but a tropicalised motor is fitted and a heat run carried out on a prototype equipment showed a final steady-state temperature well below the maximum quoted for the various components. Experiments were conducted, however, to try the effect of fitting two large low-pressure air filters, but the improvement was not considered sufficient to justify the use of them.

Exchange equipment regulations demand that all wiring carrying high voltage be protected by conduit and all panels containing high voltage equipment be provided with adequate means of locking. The A.C. mains supply is fed into the equipment on the left-hand vertical by V.I.R. cable carried in ¾-in. conduit, connection to the Sub-Rack assembly being made in flexible conduit. The H.T. wiring between the power units, the Test and Monitor Panel, and the Sub-Rack assembly is carried in conduit on the right-hand side of the rack, connection again being made in flexible conduit to the Sub-Rack assembly.

The covers to the power units and to the Test and Monitor panel are secured by means of fasteners, and the toggle clamps on the covers for the Sub-Rack assembly are fitted with close-fitting shrouds which make it necessary to use a screwdriver to open the clamps. The Alarm Fail relays used in conjunction with the channel amplifiers are located under the Sub-Rack covers because they are connected to the amplifier H.T. supply. This eliminates the need for provision of a means of protection to the Relay panel which otherwise would have been the obvious site for these relays.

It should be pointed out that the equipment illustrated in Fig. **5** is the prototype assembled in the laboratory, neither the conduit nor the common services to the rack being shown.

Conclusion

To date, two Congestion and Delay Announcer equipments have been constructed in the Research Station workshops; one has been in service at Faraday Buildings since January and the second is at the time of writing being tested after installation at Kingsway. It has been found necessary to make slight modifications to overcome difficulties made apparent in the assembly of the second equipment, but apart from these the machines appear satisfactory.

A spare mechanism consisting of the base unit containing the meter, gearbox, shaft assembly, optical system, etc., is held as a standby for either machine.

Acknowledgments

The authors wish to acknowledge the assistance and advice received from their colleagues in the Research and Telephone Branches.

Book Review

"Handbook of Industrial Electroplating," 2nd Edition. E. A. Ollard, A.R.C.S., F.R.I.C., F.I.M., and E. B. Smith, Iliffe and Sons Ltd. 366 pp. 122 ill. 72 tables. 30s.

This is the second edition of a book which was first published in 1947. It is mainly concerned with the practical aspects of electroplating, all theory of processes being omitted from the text. In presenting the second edition the authors have taken the opportunity to incorporate all the more important developments of the past seven years.

The subject matter dealt with includes: electrical equipment required for plating, plating plant, formulae of pickling, plating and anodizing solutions, control and operating conditions of these solutions, testing of deposits, safety precautions and plating shop costing. There is included at the back of the volume a vast amount of useful information, given principally in tabular form, which covers some 75 pages. The book can be thoroughly recommended to those concerned in any way with electroplated coatings. E. V. W.

Post Office Standard P.A.B.X.s

J. J. ROCHE†

Part 3.—The P.A.B.X. No. 3

U.D.C. 621.395.24

This series of three articles concludes with a description of the P.A.B.X. No. 3, which provides for 50 extension lines and over, and is the largest in the range. Some details are also included regarding satellite working with P.A.B.X. No. 3 equipment, e.g. where it is desired to centralise the manual board for two or more separate installations.

Introduction

CONCURRENTLY with the development of the smaller P.A.B.X. units described in the previous articles,[1] the P.A.B.X. No. 3 was designed to provide for the larger installations exceeding 50 automatic extension circuits. Its introduction was somewhat later, the first installation, of 350 lines (extension circuits), being completed in 1952. Considerable progress has been made since then, and some 100 installations have been completed or are projected, totalling approximately 25,000 lines.

Standardisation is not so complete as for the P.A.B.X.s Nos. 1 and 2. Components and circuits are standard for all installations but manufacturers are free to arrange and interconnect the equipment in a manner best suited to individual manufacturing and installation methods, always provided the installation as a whole conforms to approved current practice. Within these terms there is little scope for any important differences between installations and the smaller installations do, in fact, follow a common pattern. Larger installations invariably need to be arranged in accordance with the circumstances of the particular case and are to that extent "tailor made." Complete uniformity, even if it could be attained, would, in any case, be undesirable economically, and all the advantages of standardisation from the maintenance angle have been realised while leaving an essential measure of flexibility.

The equipment has been designed with the average case in mind but a limiting size has not been laid down. The largest installation so far has been one of 2,400 lines and enquiries have been made for installations up to 4,000 lines. The size of the manual board extension multiple must of course be kept within reasonable limits and with the type of manual board normally used, the limit is approximately 2,400 lines. This limit can, however, be exceeded if main-exchange-type manual boards are used.

Fig. 1 gives a picture of the apparatus for a 500-line installation and at first sight it might seem that public exchange automatic equipment could be readily adapted for large P.A.B.X.s. While in principle there is much in common between the two, important differences are apparent when their respective functions are more closely studied. Apart from some differences in the facilities required, the special design of P.A.B.X. equipment is necessary because:

(1) The standard methods of signalling used for main exchanges cannot be applied to P.A.B.X.s. The main exchange to P.B.X. connection is by means of ordinary exchange lines, and signalling is thus limited in scope to that provided for the direct exchange line. The necessity for designing a P.B.X. network which must have through access over this link is a controlling factor in the choice of signalling methods throughout the whole of the P.B.X. network.

(2) The transmission and signalling limits for exchange line connections must not be greater than those allowed for the D.E.L. This factor introduces problems in design because most P.B.X. circuits must be capable of connection to exchange circuits.

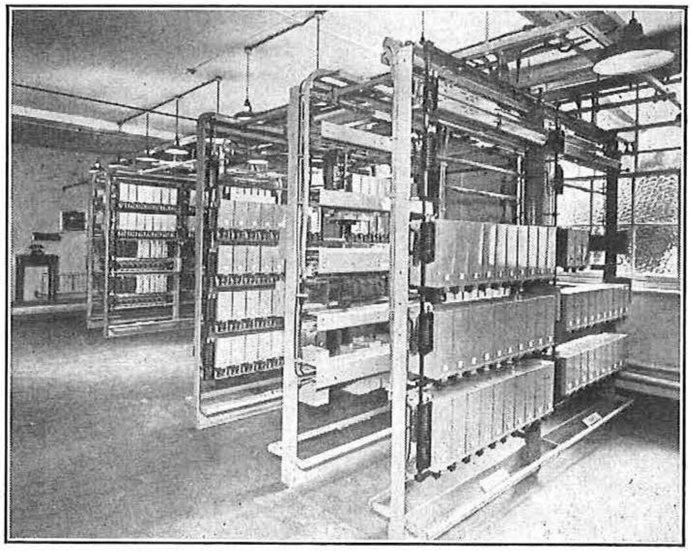

FIG. 1—TYPICAL 500-LINE INSTALLATION OF P.A.B.X. NO. 3.

(3) Incoming exchange calls must always be dealt with manually, and it follows therefore that a manual multiple of extension circuits should be provided as the best means for setting up exchange connections. Such manual connections must permit through signalling and dialling.

(4) Sleeve-control principles cannot be economically applied to P.B.X. working.

Outline of Equipment

The P.A.B.X. No. 3 employs 50-point uniselectors as line finders, with 2,000-type group selectors and final selectors. The relay sets are for the most part of standard "jack-in" type and all equipment is mounted upon open-type racks. The layout of the equipment varies somewhat between manufacturers, but, in general, an installation consists of three main types of rack,

(*a*) Line and Final Selector rack,
(*b*) Group Selector Rack,
(*c*) Relay Set Rack.

It is usual for small installations to combine the group selectors and relay sets into one rack, and one manufacturer uses a design whereby all the equipment for a 50/100-line installation is mounted upon one composite rack. Generally, 7 ft. 6 in. equipment racks are used, this height being suitable for most subscribers' premises and affording easy access for maintenance. For large installations, where the accommodation allows, 8 ft. 6½ in. racks may be employed. The mounting of equipment on racks is such that an installation may be easily extended in multiples of 50 lines and is arranged in units, as far as practicable, to facilitate stock provision.

Automatic Equipment.

Fig. 2 shows three typical "basic" racks. The line and final selector rack (Fig. 2 (*a*)) is equipped for 100 extensions with 10 final selectors. Some investigation was made to

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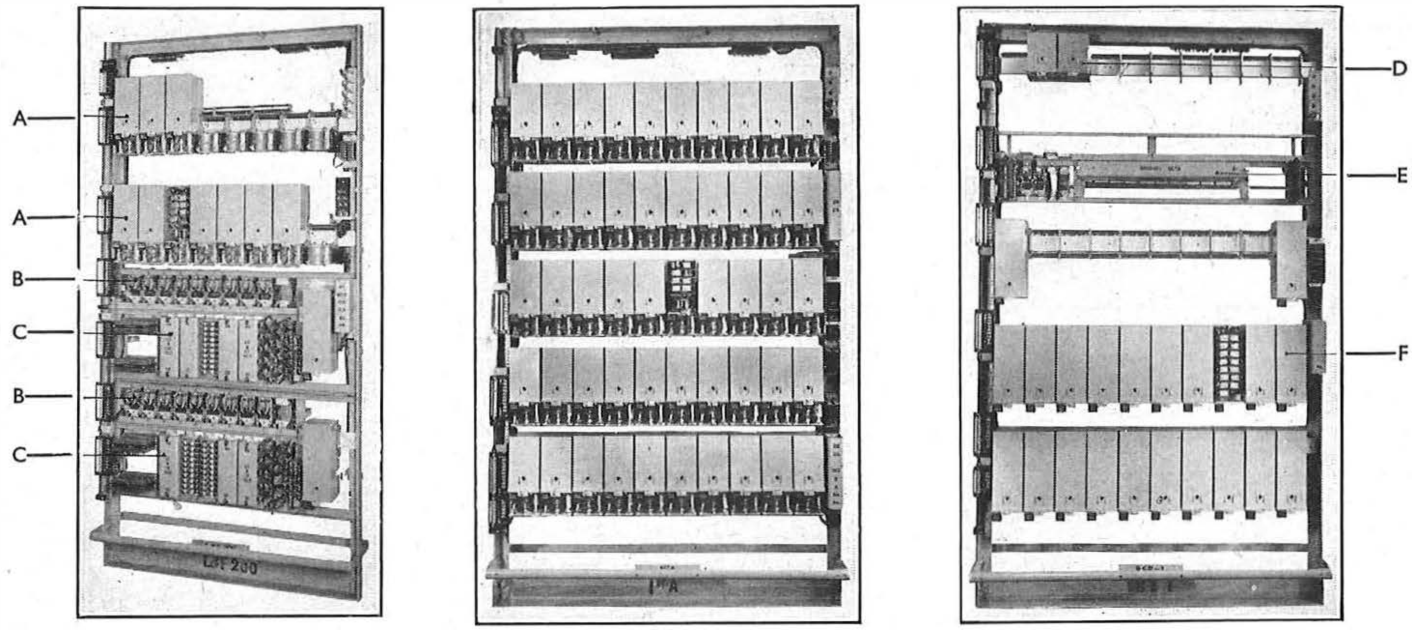
[1] *P.O.E.E.J.*, Vol. 46, p. 159, and Vol. 47, p. 41.



(*a*) Line and Final Selector Rack.
A.—Final Selectors
B.—Line Finders
C.—Line Circuits

(*b*) Group Selector Rack.

(*c*) Relay Set Rack.
D.—Miscellaneous Relay Sets
E.—Enquiry Circuit
F.—Exchange and I/S Line Relay Sets

FIG. 2.—TYPICAL AUTOMATIC EQUIPMENT RACKS.

determine the maximum traffic likely to be encountered at the average installation, and it was found that a provision of 10 linefinders per 50 extensions and 14 final selectors per 100 extensions would meet the majority of cases. Thus, 50 extension line circuits and 10 linefinders are mounted on a composite shelf and each rack accommodates two such shelves, making a 100-line unit. The final selectors are mounted above, the rack shown providing for a maximum of 16. The number of final selectors per rack depends upon the particular manufacturer's standard and in the event of a greater number being required they must be mounted elsewhere. Connection between the final selector multiple and the corresponding extension line circuit is by means of permanent cabling on the rack, but limited I.D.F. facilities are available on the final selector shelf multiple strips.

Fig. 2 (*b*) shows the group selector rack, on which grading facilities are provided on the shelf tag blocks. The wiring of the shelves of the relay set racks (Fig. 2 (*c*)) has been arranged so that it is possible to accommodate either exchange or inter-switchboard line relay sets on the same shelf.

Manual Board.

P.M.B.X. 1A sections are used for the manual board as previously described for the P.A.B.X. No. 2 except that a multiple of extension circuits is now required. A 4-panel multiple is used and for sizes up to 800 lines an individual "0" level calling lamp per extension is provided. (This is known as "lamp per line" working and was described in the previous article). Only one lamp appearance is permitted and distribution of the "0" level traffic is accomplished by fitting lamps to the extension circuits in selected panels only.

When 800 lines are exceeded "0" level working is used and the whole multiple space is made available for extension jacks. The total number which can be accommodated with a standard P.M.B.X. 1A section is 1,200. By increasing the height of the sections, a multiple of 2,400 can be provided. Above this capacity, the manual boards will be specially constructed and will be similar in physical design to main-exchange-type manual boards. The circuits will, however, conform in all respects to the standard P.A.B.X. arrangements.

GENERAL DESCRIPTION

Facilities.

The facilities provided are very similar to those of the P.A.B.X. No. 2. Automatic transfer of calls is not provided, however, and it follows that "dial 8" night service cannot be given. Automatic transfer would greatly increase the complexity of the switching arrangements and, as an operator is available to transfer calls, would not be a worthwhile provision. Again, "dial 8" night service is considerably less important for larger P.A.B.X.s and the more conventional methods of providing night service are followed. The enquiry facility is retained but is available only on exchange line calls. Free-line signalling and ancillary working are available on exchange and inter-switchboard circuits, and P.B.X. final selectors, 2-10 lines, can be provided. Manual extensions can be provided as desired with, or without, incoming automatic access.

Trunking Arrangements.

Fig. 3 shows a typical trunking scheme for a P.A.B.X. No. 3. Depending upon the size of the installation, 3-digit, mixed 3- or 4-digit, or 4-digit numbering is used for extensions. Level "0" is used for manual board assistance and level "9" for direct access to the public exchange. Levels "7" and "8" are either trunked direct or via second selectors to give dialling access to inter-switchboard lines working on an automatic signalling basis.

Extension Line Circuit.

The line circuit is the same as that previously described, having "P.G. lock-out" facility. Extensions can be individually barred from direct access.

Linefinders and Group Selectors.

One hundred outlet selectors are used for both first and second group selectors; 10 linefinder-first selector circuits can be provided per group of 50 extensions and will handle the maximum traffic normally encountered. While it may be

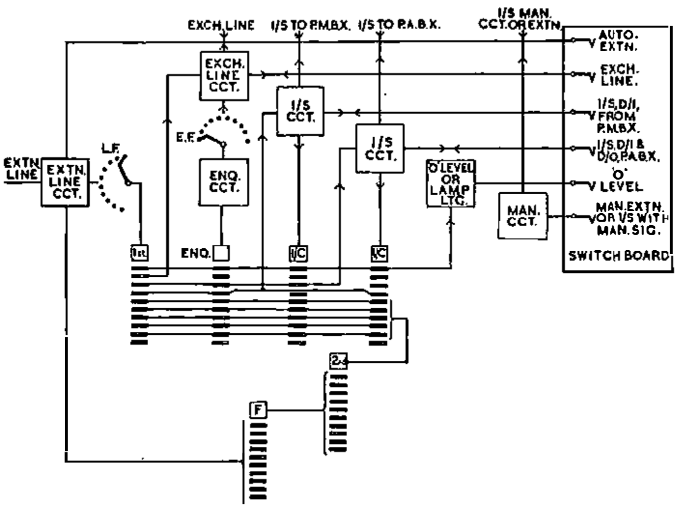


Fig. 3.—Typical Trunking Diagram of P.A.B.X. No. 3.

necessary to allocate heavily worked extensions to even out the traffic over 50-line groups, no case has yet arisen where additional first selectors have been required. To keep within the standard scheme the number of extensions per group could be reduced if such a case arises or, alternatively, special arrangements would have to be made. The first selector circuit arranges for the P.G. condition to be applied if dialling is delayed, and for N.U. tone to be returned if spare levels are dialled or if a "barred" extension dials the exchange. It is also forcibly released when the operator answers an "0" level call.

The linefinder start arrangements are similar to those of the P.A.B.X. No. 1 in that test circuits of the first group selectors serving each linefinder group are arranged in the form of a chain, the start condition being connected through the pulse circuit to distribute the traffic over the first selectors and to reduce the possibility of lost calls if a selector becomes faulty.

The Final Selector.

Again, 100 outlet selectors are used, ordinary, or with 2-10 P.B.X. facilities. The facilities given by the final selectors follow common practice with the exception that N.U. tone is returned from the selector on a P.G. or when an unallotted number is dialled; also, first party release is given. The discrimination is done over the hold (H) wire of the line circuit. Fig. 4 shows the elements of the circuit. Relay HT tests the conditions on the H-wire during the release time of relay E (operated during rotary stepping). If the line circuit is free, HT will operate to the 250-ohm battery of the line circuit and during the release time of E will operate

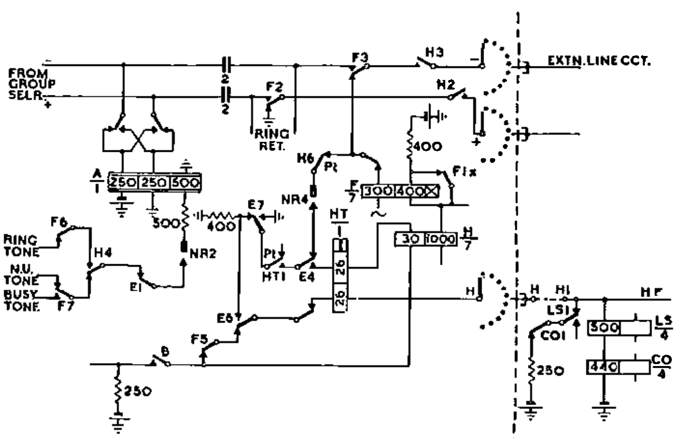


Fig. 4.—Testing and Switching Elements of Final Selector.

H. If the engaged condition, earth on the H-wire, is met, HT does not operate until the release of E, when F will also be operated to return busy tone. Under P.G. conditions relay CO will be operated and the testing battery removed, or if unallotted, the H-wire is left disconnected. HT will not operate under these conditions and with F and H unoperated N.U. tone is returned to the caller.

The Exchange Line Circuit.

The exchange line circuit is perhaps the most complicated of the P.A.B.X. No. 3 circuits. It must provide:—

(*a*) Direct routing of incoming exchange calls to the manual board, and supervisory control.

(*b*) Direct access to the exchange line from the 9th level of the first selectors.

(*c*) Upon the receipt of the "enquiry" signal, for holding the exchange connection and connection of the extension through to the enquiry circuit.

(*d*) "Disconnect clearing" (described in the first article on the No. 1 equipment).

(*e*) Follow-on call trap.

(*f*) Free-line signalling or ancillary working if required.

Additionally, the circuit must work to any type of main exchange, but to avoid including equipment which will be rarely used, a separate "adaptor" relay set is fitted when the main exchange is either C.B.S. or magneto.

Inter-Switchboard Circuits and Through Dialling.

The demand for interconnection between P.B.X.s is growing and standard circuits have been designed to provide for the various types of connection required. All circuits provide for both-way working as it is rare for unidirectional circuits to be provided. There are four main types of circuit as follows:—

(*a*) Both-way dialling, P.A.B.X. to P.A.B.X., with joint access from the P.A.B.X. manual board at each end.

(*b*) Both-way P.A.B.X. to P.M.B.X., with access from selector levels and manual board at the P.A.B.X. and "dialling-in" from the P.M.B.X.

(*c*) As above, but without "dialling-in."

(*d*) Manual to manual.

(*a*) and (*b*) are used where possible, i.e. whenever the circuit length is within pulsing limits; (*c*) is used for circuits beyond pulsing limits, but where D.C. signalling can be used and (*d*) where A.C. signalling methods must be employed. Incoming access to the P.A.B.X. manual board in the case of (*a*) and (*b*) is obtained by dialling "0" but the seizure of an "0" level circuit or lamp-lighting circuit causes the calling lamp of the circuit concerned to light and the circuit to be switched directly to the manual board, releasing the I/C selector.

In the general case, P.B.X.s are not required to give "tandem" or "through switching," but there is a limited demand for the facility where a number of installations are linked together by private circuits. Signalling terminations are therefore arranged to give supervision when through connections are made, but "backward through-clearing" cannot be provided. The P.A.B.X. No. 3 has been designed to provide for through dialling and thus a P.A.B.X. can be used as a "tandem" switching centre within a group of associated P.B.X.s.

Enquiry and Operator Recall.

The enquiry facility is available on exchange line calls only. If it is desired to transfer a call from one extension to another, the P.A.B.X. operator must be called into the circuit to set up the new connections. As shown on the trunking diagram, Fig. 3, the enquiry circuit is connected directly to a first selector and to a finder which searches for the exchange line circuit on which enquiry is being made.

The normal provision of enquiry circuits is one per ten exchange lines. A single depression of the recall button on an extension telephone connected to a public exchange call, either direct or via the P.A.B.X. manual board, will cause the enquiry finder to hunt for the exchange line circuit. The extension will be connected to an enquiry first selector and the exchange connection held. An enquiry call can be made and a second depression of the recall button causes a return to the previous connection. Two consecutive depressions of the recall button will recall the operator by flashing the exchange line calling lamp, and should the enquiry circuit be engaged this will automatically happen on the first depression.

"O" Level.

"Lamp per line" working, as described for the P.A.B.X., No. 2 is used for the majority of the installations. While this method of calling has advantages from an operating standpoint, it is expensive in manual board space and the extension line lamps cannot be accommodated if the number of extensions exceeds 800. Separate "0" level circuits are therefore provided for all large installations. To economise in switching equipment, the circuits are used to book the call only, the operator setting up the connection over the extension multiple. For an "on demand" call, the "0" level circuit and selector are automatically released when the operator plugs into the multiple jack.

Night Service Switchboard.

Direct extension night service, i.e. the connection of selected extensions to exchange lines by plugging through at the manual board, is available and satisfies the needs of most subscribers. There is the special case where a separate manual board is required, upon which certain exchange lines may be concentrated with access to the main automatic equipment. These cases are most usually met by the provision of a "subsidiary night service switchboard," which has been specially designed for the P.A.B.X. No. 3. This switchboard is generally remote from the manual board and has no function during normal hours. It is brought into use when the night service keys are operated on the manual board and is a cordless board, providing for the extension of four exchange lines (maximum six) with directly associated both-way circuits to the P.A.B.X.

Fig. 5 shows the arrangement schematically. The contacts marked NS refer to the night service key on the manual board. When this key is operated the exchange line circuit is disconnected from the manual board and transferred to the night service switchboard. Four "0" level circuits or lamp-lighting circuits are specially arranged so that they will provide access to the automatic equipment via specially allocated extension line circuits and also call

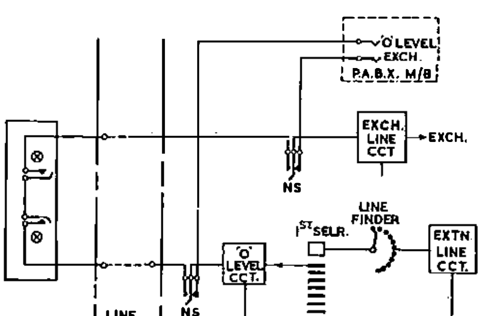


Fig. 5.—Night Service Arrangements.

the night service switchboard if a P.A.B.X. extension dials "0." When the main switchboard is unstaffed, therefore, exchange line calls are received at the night-service switchboard and the night service operator may dial over the "0" level and extension circuit, connecting the caller to the required extension. Alternatively, any extension dialling "0" may be connected to an exchange line. The night service switchboard has been designed primarily to be simple to operate (the operator may be a night watchman) and flexible switching has not been provided. If an "0" level call and exchange line call are received simultaneously on the same circuit, the "0" level call is forcibly released and the exchange circuit connected. The "0" level caller must recall. If more elaborate arrangements are required, then a standard switchboard can be used or alternatively a section of the main switchboard would remain staffed at night.

Power Supplies and Miscellaneous Services.

Ringing and tone supplies are generated from vibrating relays, and timed pulses from a stepping uniselector. One set of common equipment is provided per 200 extension circuits. Alternatively, especially on large installations, ringing machines may be installed. It is probable that ringing machines will become the standard provision in the future.

A 6V A.C. supply is provided for F.L.S. and multiple answering lamps. In the case of the latter, the primary appearance is fed from the P.A.B.X. battery and the secondary appearances from 6V A.C. The primary appearances will thus continue to function in the event of a mains failure.

A single battery float scheme at a nominal 50V is used, charged from a rectifier having automatic compensation. A.C. mains are normally available but if D.C. mains supplies must be used, special arrangements are made.

Automatic equipment alarms are given at the manual board but at larger installations, where full-time maintenance staff are available, main exchange practice is followed.

Satellite Working

General.

A standard satellite scheme is a recent development. Its economic advantages can be used in cases where large groups of external extensions would otherwise be necessary or where it is desirable to centralise the manual board of two or more separate installations. Its disadvantages are that an operator must dial satellite numbers; full P.A.B.X. No. 3 facilities cannot be given to satellite extensions, and unless a self-contained numbering scheme is used, a common directory for main and satellite numbers is not possible.

Where possible, standard P.A.B.X. No. 3 circuit design and equipment have been used, but some changes have had to be made, primarily to extend essential facilities over the main-to-satellite circuits. The facilities concerned are:—

(*a*) *Trunk Offering.*—A satellite extension will not appear on the manual multiple and thus the final selectors must provide for trunk offering.

(*b*) "0" *Level.*—To retain "0" as a single code for the satellite extension, the satellite-to-main relay set must be capable of discrimination, and route an "0" call direct to the manual board.

(*c*) *Alarm Extension.*—Means must be provided for the automatic extension of urgent satellite alarms to the main.

(*d*) *Night Service.*—Automatic switching of satellite extensions to inter-switchboard circuits is necessary to provide night service facilities.

It has not been found practicable to give enquiry or direct exchange access via the main. Direct exchange access can only be given to exchange lines connected directly to the satellite, which would be unidirectional, O/G circuits only.

Trunking and Numbering Scheme.

Fig. **6** shows a typical trunking arrangement. The satellite 1st selectors do not provide for discrimination on the 1st digit, thus self-contained numbering schemes can

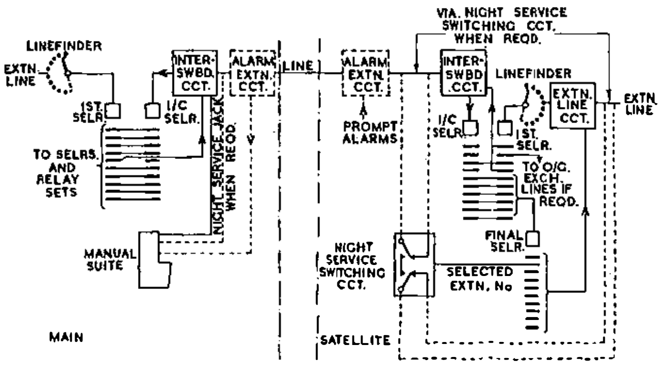


Fig. **6**.—Typical Main–Satellite Trunking Scheme.

only be used where 2nd selectors are employed, making it possible to connect the inter-switchboard circuits to 2nd selectors at both main and satellite. While the main may be large enough to require 2nd selectors it is most unlikely that the satellite would be. In any case, mixed 3- and 4-digit numbering could not be employed. Self-contained numbering schemes are therefore ruled out in the general case on the grounds of economy. In the example shown in Fig. **6** access between main and satellite is over level 6, main to satellite, and level 7 satellite to main. Thus extension numbers at the main must be prefixed by 7 when dialled from the satellite, and satellite numbers prefixed by 6 when dialled from the main. A typical numbering scheme in this case would be:

	Main	*Satellite*
Level 0	Manual board	Manual board
,, 9	Direct exchange access	Direct exchange access
,, 8	Inter-switchboard circuits	Spare
,, 7	Inter-switchboard circuits	Main
,, 6	Satellite	F/S 200-699
,, 5	F/S 300-599	F/S 200-699
,, 4	F/S 300-599	F/S 200-699
,, 3	F/S 300-599	F/S 200-699
,, 2	F/S via 2nd sel. 2000-2699	F/S 200-699
,, 1	Spare	Spare

The range 300-599 is duplicated at main and satellite and thus the satellite numbers must always be referred to as 6200 to 6599, although the digit 6 would not be dialled within the satellite. This duplication can be avoided by the use of 2nd selectors or, where the satellite is small, by using levels 6, 7 or 8 at the satellite for extension numbers.

Trunk Offering.

The trunk offering facility is available on all regular or 2-10 final selectors at the satellite. The addition to the final selector is the incorporation of a series relay in the feed circuit, differentially connected. Circuit elements are shown in Fig. **7**. To trunk offer, the operator rings on the engaged circuit and the signal is sent over the inter-switchboard circuit, by the operation of MB, as an earth on both lines. This operates relay OC which causes the circuit to be switched through to the engaged subscriber. Replacement of the extension receiver automatically completes the re-ring circuit and the offered call can be completed without further work by the operator. To avoid the possibility of

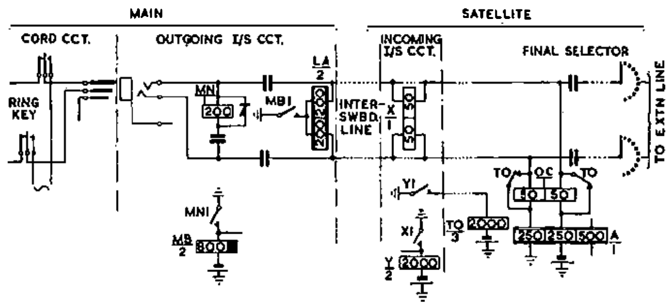


Fig. **7**.—Trunk Offering Circuit Elements.

OC being operated from an extension call the initial "seizing" signal from the manual board is a momentary earth on both lines. This operates relay X which in turn operates TO in the final selector.

Inter-Switchboard Circuits, Main to Satellite.

Terminating circuits for both-way and unidirectional working between main and satellite are available. Normally such circuits would be worked both-way; but unidirectional circuits are made available so that advantage can be taken of economy in equipment where the number of circuits and traffic warrant unidirectional working. The normal calling condition is by loop but, in the case of relay sets at the satellite, joint access is given from the "0" level and when "0" is dialled an earthed loop is connected. The receipt of this signal at the main causes the manual board calling lamp associated with the inter-switchboard circuit to be lighted. In the reverse direction an earthed loop is used for the trunk offering facility as previously explained.

Alarm Extension.

Urgent satellite alarms are given at the manual board at the main. The last choice, inter-switchboard circuit, is intercepted at each end by alarm extension relay sets as shown dotted in Fig. **6**. One wire earth calling is used as a signal over the inter-switchboard circuit to differentiate between an alarm and a normal calling signal. The alarm extension relay sets are switched out of circuit when the normal calling signal is given.

Night Service on Satellite Extensions.

Night service is given on satellite extensions by switching them to the manual board at the main, via inter-switchboard circuits, where they may be plugged through to exchange lines as required. The switching relay set is associated with a selected extension number and to switch the extensions to night service, the operator dials this number. The application of the trunk offering signal operates the switching relays which hold. A distinctive tone is returned to the operator to indicate that switching has been accomplished. A similar procedure is used to restore the switching relays. N.U. tone is returned to any caller who may dial the switching number, and switching cannot take place unless the trunk offering signal is given. All the inter-switchboard circuits can be used for switching with the exception of the one used for setting up.

Conclusion

This series could not be closed without referring to the contribution of the manufacturers to the development of standard P.A.B.X.s. The whole of the development was done through the B.T.T.D.C., the major portion of the work falling upon Standard Telephones & Cables Ltd., as liaison manufacturer, and, at a later stage, upon the Automatic Telephone & Electric Co. as liaison manufacturer for the satellite development. The author is indebted to both manufacturers for their assistance in preparing the articles.

A Small Experimental Electronic Automatic Telephone Exchange

F. SCOWEN, B.Sc., A.Inst.P., A.M.I.E.E.†

Part 3.—Ringing and Metering; the Subscriber's Unit; and Expansion of the Exchange to 10,000 Lines

U.D.C. 621.395.34:621.318.572:621.395.722

Part 3 continues the description of the common equipment by explaining the operation of the supervisory, ringing and metering units, and shows how a subscriber's line is so connected to the exchange that he can set-up connections and have such connections metered, and be called by another subscriber. The expansion of the exchange to a 10,000-line size is also explained.

Ringing and Metering Unit.

EACH cord circuit has a ringing and metering unit associated with it (see Part 1[1]) whose function is to take over the control of the ringing of the called line's bell after the register-marker drops out and to control the operation of the calling line's meter when the called line answers. A block schematic diagram of a ringing and metering unit is shown in Fig. **13**.

When a cord circuit is taken into service to form part of a connection between calling and called lines, a hold signal will appear on the forward hold lead of the associated ringing and metering unit. This hold signal has come from the register-marker. In the unit the forward hold signal is turned back on to the backward hold lead. When the register-marker sends forward a ringing control signal, that signal causes the subscriber's unit attached to the called line to send a 17 c/s ringing current to the called line in the manner explained later. Some of that current appears on the backward hold lead from that line. The positive half-cycles switch on the line's pulse train, so that what is received in the ringing and metering unit on the backward-hold-from-called-line lead is a 17 c/s on-off appearance of the backward hold signal. That signal operates trigger TG1 and also passes through the high-pass filter HP and opens the gate G1 once during each cycle of the 17 c/s backward hold signal. Each time G1 opens a burst of 400 c/s tone is sent over the speech path back to the calling line and forms the ringing tone signal that is heard by the calling subscriber.

An output from the operated trigger TG1 causes trigger TG2 to operate. An output from TG2 opens gate G2 which allows a ringing control tone to be transmitted over the forward speech path to the called line, there to continue to make the subscriber's unit transmit the 17 c/s ringing current to the called line. TG2 remains operated until its output, delayed by delay unit T1 for about one second, operates trigger TG3 which, in operating, sends a signal to restore TG2 and closes gate G2. An output from TG3 opens gate G3 which allows a ringing control signal, interrupted at the familiar machine ringing period, to be transmitted to the called line. Meanwhile the register-marker will have dropped out of the connection and the ringing of the called line's bell is now under the control of the ringing and metering unit; as before, part of the ringing current appears on the backward-hold-from-called-line lead and opens gate G1 to transmit interrupted ringing tone to the calling line. If for any reason the 17 c/s signal is not received in the ringing and metering unit, no ringing tone is sent to the calling line; this is referred to again later.

When the called subscriber answers, the backward hold signal from the called line becomes continuous and is then able to pass through the low-pass filter LP to operate trigger circuit TG4. One output from TG4 restores trigger circuit TG3 and gate G3 closes, so stopping the transmission of ringing control signal to the called line, and another output operates trigger circuit TG5. This trigger circuit, when operated, opens gate G4 so allowing a meter operating tone to be transmitted to the calling line and, after a time delay produced by delay unit T2, trigger TG6 operates. One output from TG6 restores TG5 and closes gate G4 and, after a delay produced by delay unit T3, TG6 resets itself. When the connection is broken down at the end of the call, the disappearance of forward hold resets any of the trigger circuits TG1-4 which may still be operated. The trigger circuits TG1 to TG6 each include a cold-cathode gas-filled tube which may be struck or extinguished to give the two stable states required by a trigger.

Two band-stop filters BS1 and BS2 are fitted in each ringing and metering unit to eliminate frequencies around 4·2 kc/s. This frequency is that of the meter controlling tone and the band-stop filters are provided to prevent speech components at and around the control frequency from mis-operating the meters.

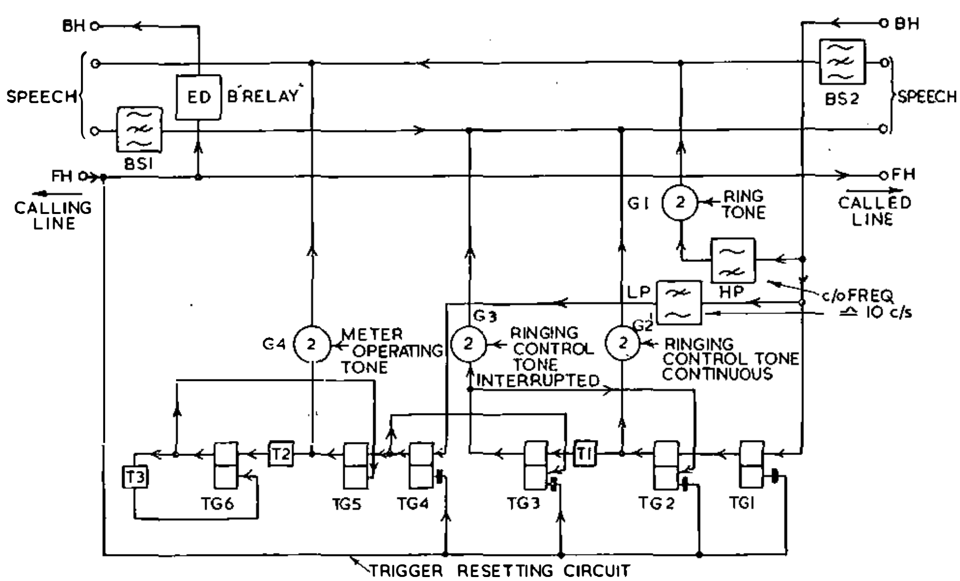


FIG. **13**.—BLOCK SCHEMATIC DIAGRAM OF RINGING AND METERING UNIT.

Subscriber's Unit.

Each line is connected to a subscriber's unit in which a 4-wire circuit is derived from the 2-wire subscriber's line and which contains the ringing and metering control equipment individual to the line. Fig. **14** is the circuit diagram of a subscriber's unit.

The microphone current is provided by a 60V battery which is connected to the line through

† Senior Executive Engineer, Post Office Research Station.

[1] *P.O.E.E.J.* Vol. 47, p. 3.

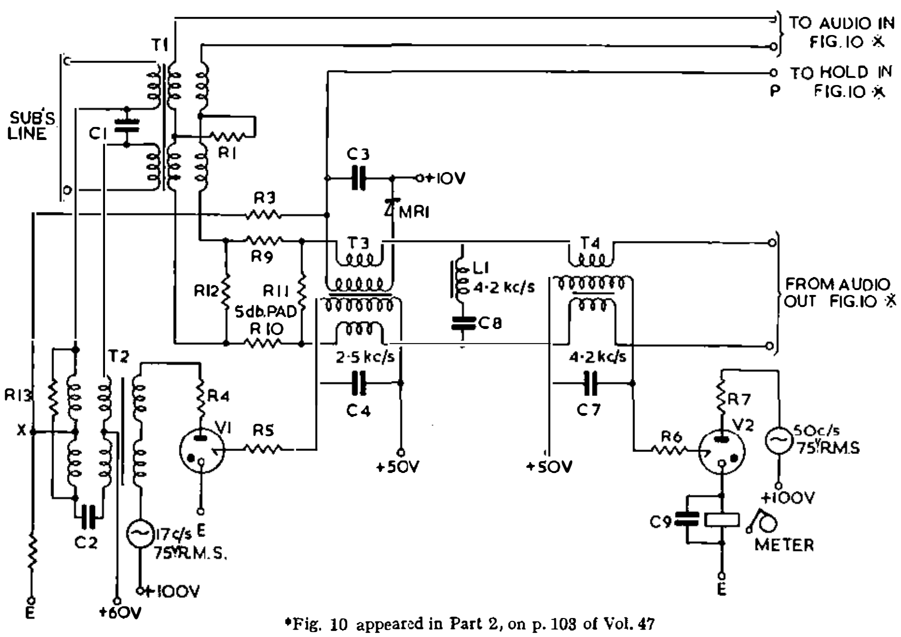


*Fig. 10 appeared in Part 2, on p. 103 of Vol. 47

FIG. **14**.—CIRCUIT OF SUBSCRIBER'S UNIT.

transformers T2 and T1. When the line is disengaged the point X is at earth potential; when the line is looped the potential of the point rises by at least 10V. Rectifier MR1 clamps the rise to 10V and the potential of tag P is thus at earth potential when the subscriber's handset is on its rest and 10V above earth when the handset is off its rest. Tag P is connected to tag "hold in" of a modulator similar to that shown in Fig. **10** (Part 2[2]).

Transformer T1 is wound as a hybrid transformer and couples the subscriber's 2-wire line to the transmit and receive branches of the 4-wire circuit. In the receive branch of the 4-wire circuit are two tuned transformers, T3 and T4. Transformer T3 is tuned to 2·5 kc/s and responds to the ringing control tone. The secondary winding of the transformer applies the 2·5 kc/s ringing control tone to the striker of gas-filled cold-cathode thyratron V1. To the anode of V1 is connected a 17 c/s supply and a 100V bias supply. The combined voltage at the anode drops once every cycle to less than the maintaining voltage of V1 for a time that exceeds the de-ionization time of the valve. Normally the valve is non-conducting, but when a ringing control tone is received the striker-to-cathode gap of the valve breaks down and the anode-to-cathode gap conducts each cycle from the time when the supply voltage exceeds the anode-to-cathode striking voltage until the supply voltage drops below the anode-to-cathode maintaining voltage. So long as the ringing control tone is present on the receive branch of the 4-wire path a current, interrupted at 17 c/s, flows in the anode-to-cathode circuit through the windings of transformer T2. This transformer is wound and connected as a hybrid transformer and conjugate pairs of terminals are joined to capacitors C1 and C2; to C1 is connected the subscriber's line, through the windings of transformer T1. The capacitors C1 and C2 are of equal capacitance and if no line is connected to transformer T1, no 17 c/s voltage will appear at point X; if a normal length of subscriber's line is connected to T1, and no bell set is connected at the far end of the line (or if the bell set is connected but has an internal open-circuit) some 17 c/s voltage will appear at point X but the voltage will be insufficient in magnitude to allow the line's modulator to transmit pulses on to the switch's highway. Only if an intact bell set is connected to a good line will the hybrid transformer T2 be sufficiently unbalanced for the line's modulator to allow pulses to be transmitted to highway H1 of Fig. **6** (Part 1) and thence to travel over the cord circuit to the ringing and metering unit. As that 17 c/s signal in the ringing and metering unit controls the transmission of ring tone to the calling subscriber, it will be seen that each time a line is rung a test is made of the called line. Although not incorporated in this model, it is envisaged that the register would print or display the called line's number should the test indicate a fault, and take such other action as will advise the calling subscriber that the connection cannot be completed.

When the called subscriber answers, the line is looped and a continuous line current flows. The clamping current that then flows through rectifier MR1 biases it to its conducting region and the rectifier and capacitor C3 then act as a low resistance shunt across the tuned transformer T3. As that transformer is connected in series with the receive branch the short-circuiting of the transformer is necessary to prevent a loss to speech at the tuned frequency of 2·5 kc/s when the call is in progress.

Transformer T4 is tuned to 4·2 kc/s, the frequency of the meter operating tone, and its secondary winding is connected to gas-filled cold-cathode valve V2. This valve has an anode supply similar to that of the ringing valve, V1, and the subscriber's meter is connected in the anode-to-cathode circuit of valve V2. The capacitor C9 in parallel with the meter smooths the current through the meter. The operation of the valve is similar to that of the ringing control valve, V1. The series-tuned circuit L1, C8 is also tuned to 4·2 kc/s and, with the 5 db. attenuator pad R9, R10, R11, R12, prevents speech components from the 2-wire line at and around 4·2 kc/s from operating the meter.

THE MODEL EXCHANGE

The model has been available for experimental purposes since February 1951 and was demonstrated to H.R.H. the Duke of Edinburgh when he visited the Research Station on 28th October, 1952. Figs. **15**, **16** and **17** show the exchange; Fig. **15** is a general view of the three racks of equipment, the left-hand rack carries the pulse generating apparatus, the middle rack carries the t.d.m. equipment and the ringing and metering units, and the right-hand rack carries the master and slave selectors. Fig. **16** is a close-up photograph of the t.d.m. transmission units showing the plug-in construction employed, and Fig. **17** is a close-up view of the master and slave selectors.

EXPANSION OF THE EXCHANGE

The exchange described has a capacity of 99 external circuits; only subscribers' lines have been described but junctions can be connected through apparatus similar to the subscriber's unit. If the exchange has more than 99 circuits connected to it, more switches must be provided.

Fig. **18**(*a*) is a trunking diagram of an exchange of the type that has been described so far in this article. The switch has two sides; the bank side to which the external circuits are connected; and the selector side to which are connected the cord circuits and registers. The switches have a capacity of only 99 external circuits; if the

[2] *P.O.E.E.J.* Vol. 47, p. 103.

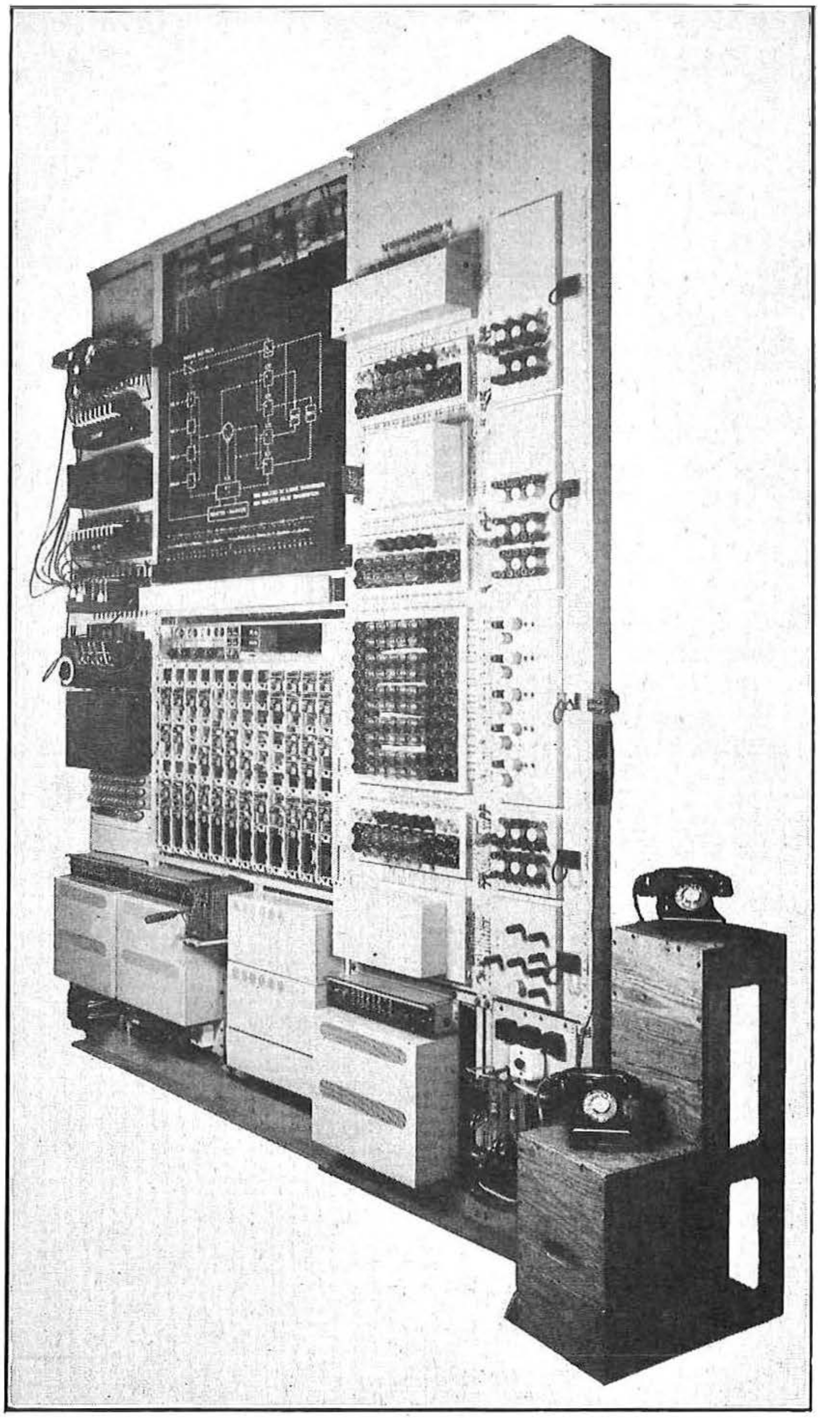


FIG. 15.—THE ELECTRONIC AUTOMATIC TELEPHONE EXCHANGE, GENERAL VIEW.

exchange has from 100 to 198 external lines two switches could be used as shown in Fig. **18**(*b*), the cord circuits being interconnected between the switches; the registers are connected to the two switches through a register switch. For up to say 400 lines the exchange might be constructed as shown in Figs. **18**(*b*), but for more than that number of lines the trunking shown in Fig. **19** becomes economical. In this type of exchange a number of primary switches PS, to each of which may be connected up to 99 external lines, are used to concentrate the traffic on to the secondary switch, SS, which is identical with the switch used in the exchange as first described in this article. As junction traffic is already concentrated it is likely that junctions would be connected directly to the secondary switch. Only 99 circuits can be connected to the bank side of the secondary switch. If that number of circuits is insufficient to carry the exchange traffic more secondary switches can be used as shown for example in Fig. **19**(*b*). As the traffic increases and the number of cord circuits also increases, it will become worth while to put another switching stage between the incoming selectors on the secondary switches and the cord circuits. Fig. **20** shows an exchange in which an intermediate switch (IS) has been so connected. Such a construction could be used in a 10,000-line exchange. In the trunking diagrams shown in Fig. **19**(*a*) and Fig. **20** the trunks connecting the primary switches to the secondary switches are used as both-way trunks and the remaining trunks are used as one-way trunks.

The setting up of a connection through the 10,000-line type of exchange falls into two parts; first the calling line is connected to a free register; then the called line is marked and a connection is made from the marked called line to the register and later, when the register drops out, to the calling line. In this type of exchange the first phase, the connection of a calling line to a free register, is automatic since it is not necessary to connect a calling line to any particular register. The second phase of the setting-up requires a particular called line to be connected to a particular register and great advantage results if such connections are set up through the exchange only one at a time. This obviously requires a very fast setting-up operation, but using electronic techniques there is no difficulty in the design and construction of apparatus that will take no longer than 50 milliseconds to find a free called line and to connect it through the various switching stages to a particular register, and the one-at-a-time principle is thus easily realisable.

In the exchange of Fig. **20** the secondary switches are identical in construction with the switch of the 4-line exchange described earlier. The primary switches and intermediate switches are similar to but simpler than the secondary switches.

Each primary switch has an allotter whose function is to mark one of the free primary switch-secondary switch trunks. As soon as such a marked trunk is taken into use the allotter searches for and marks another free trunk. This allotter is similar to the cord circuit allotter in the 4-line exchange. In Fig. **21** is shown the part of a primary switch used to connect a calling line to a free primary switch-secondary switch trunk. The pulses of all subscribers who have their receivers off the rest are present on the lead "from highway H1" and on the lead "from pulse leads of all slave selectors in switch" appear the pulses of those subscribers who are connected through the switch. These two leads are connected to gate G1 in such a way that pulses on the first lead are suppressed if they also occur on the second lead. Thus on the output (CPH) from gate G1 appear only the pulses of the subscribers who are not connected, that is of the calling lines. These pulses are applied to the master selector, I, which selects and identifies one pulse and transmits the identification to all the slave selectors in the switch. The one associated with the trunk marked by the allotter operates and generates a pulse train

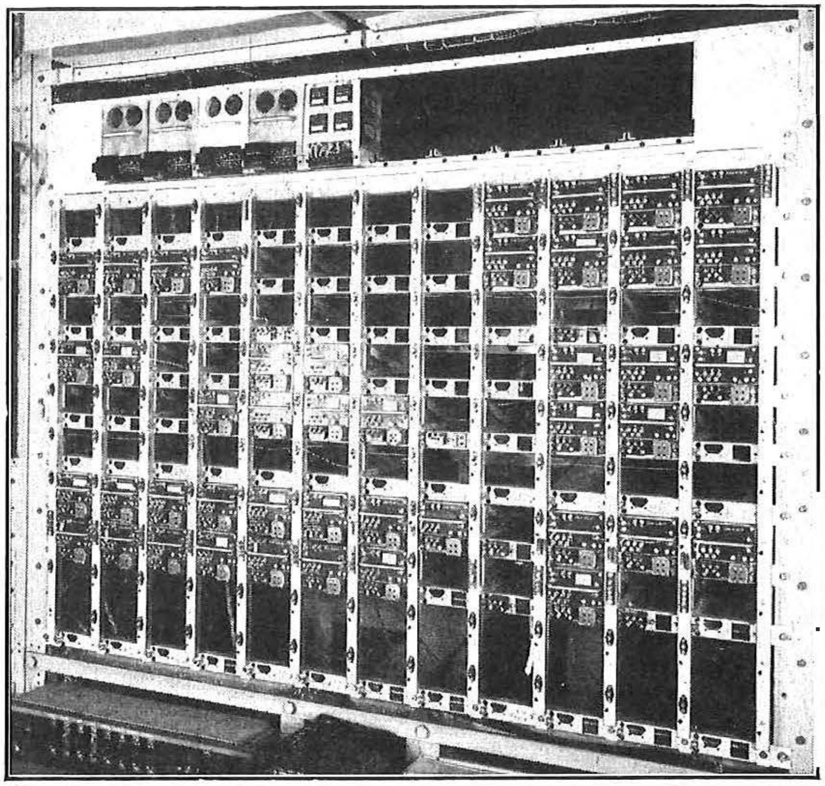


FIG. 16.—ELECTRONIC AUTOMATIC TELEPHONE EXCHANGE. ABOVE, SUBSCRIBERS' LINE UNITS AND METERS. BELOW, SWITCH MULTIPLEX EQUIPMENT.

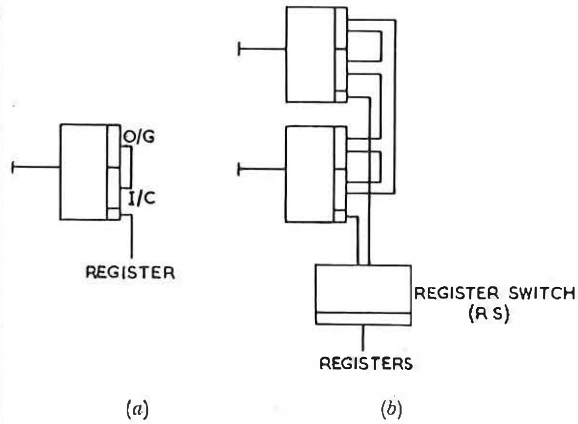


FIG. 18.—TRUNKING DIAGRAMS OF SMALL ELECTRONIC EXCHANGES.

synchronous with that of the selected calling line. The latter is thus connected through the switch to the marked primary switch-secondary switch trunk and the hold signal from the calling line is transmitted through the switch to the trunk where it is used to keep in operation the trunk's slave selector. The other end of the trunk is connected to a secondary switch and the forward hold signal causes connection of the trunk (and therefore of the calling line) to a register as was described in Part 1.

Sufficient registers are provided to cater for the busy hour traffic. They are in use only

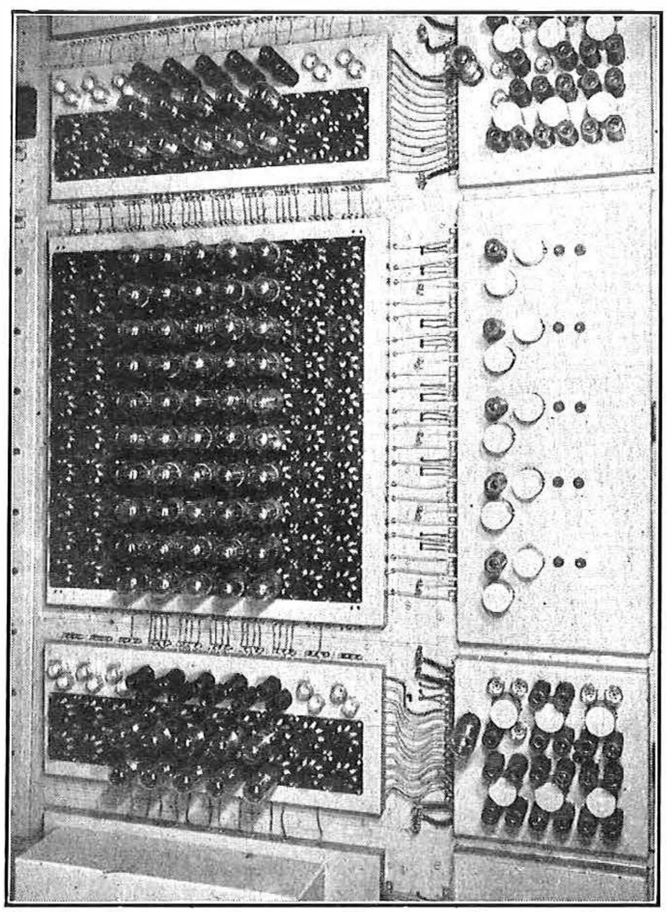


FIG. 17.—ELECTRONIC AUTOMATIC TELEPHONE EXCHANGE. CENTRE, SLAVE SELECTORS. ABOVE AND BELOW, MASTER SELECTORS.

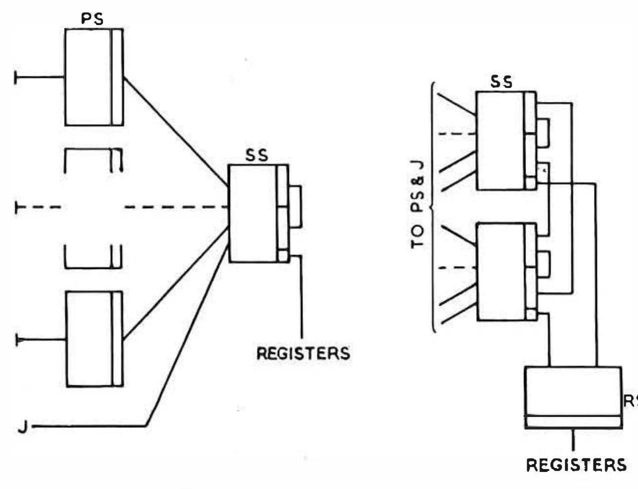


FIG. 19.—TRUNKING DIAGRAMS OF LARGER ELECTRONIC EXCHANGES WITH TWO RANKS OF SWITCHES.

during the receiving of the dial impulses and the setting up of the connection to the called line, and approximately as many would be provided as there would be directors provided in a similar electro-mechanical exchange. Only one marker is provided and a register calls for the use of the marker as soon as it has received sufficient information for the connection to be completed. When the marker becomes free it selects one of the calling registers and obtains from it the digits representing the called line, or group of lines, or the required group of outgoing junctions. All such lines are marked by the marker and the pulse trains of the marked lines appear in the switches to which the lines are connected. Fig. 22 shows how the marking pulses appear in a primary switch.

Each line connected to a primary switch has its own gate G1 which may be opened by a signal from the marker and

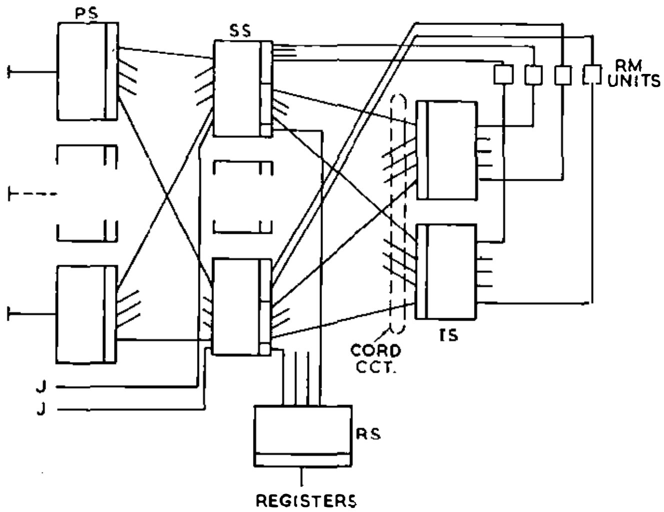


FIG. 20.—TRUNKING DIAGRAM OF 10,000-LINE ELECTRONIC EXCHANGE WITH THREE RANKS OF SWITCHES.

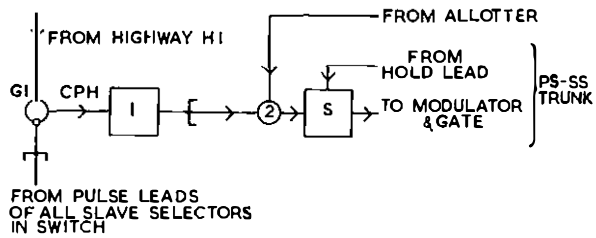


FIG. 21.—CONNECTION OF CALLING LINE THROUGH PS TO A PS-SS TRUNK.

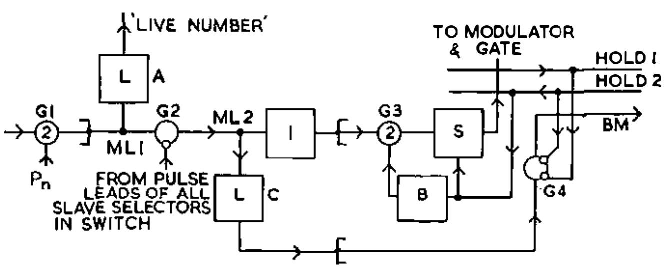


FIG. 22.—BACKWARD MARKING OF PRIMARY SWITCH-SECONDARY SWITCH, SECONDARY SWITCH-INTERMEDIATE SWITCH AND INTERMEDIATE SWITCH-SECONDARY SWITCH TRUNKS.

which, when open, lets a train of pulses, synchronous with those connected to the line's modulator and gate, appear on marker lead ML1. Pulses appearing on that lead are pulse-lengthened in pulse lengthener A and the resultant signal is transmitted on the live number lead to the registers. A gate G2 connects marker lead ML1 to marker lead ML2 and the gate is closed to the pulses of lines that are already connected. Thus on pulse lead ML2 appear only the pulses of free called lines. Master selector I isolates and identifies one of the pulses and transmits the identification to all the slave selectors, S, in the switch. The pulses on ML2 are pulse-lengthened in C and the resultant signal is transmitted to all the free trunks that are connected to the switch, appearing on the backward marking lead, BM, of each idle trunk. Thus, when the marker operates to mark a called line or group of called lines, one of the free called lines in a switch is identified and all idle trunks connected to a switch on which is a free called line are backward marked.

The backward mark signals on primary switch-secondary switch trunks become the marking leads on the secondary switches to which they are connected and a similar selecting and backward marking operation occurs, so that in any secondary switch that has idle trunks connecting it to a primary switch or switches to which are connected free called lines, one of the backward marked free trunks is selected and identified and all idle secondary switch-intermediate switch trunks are backward marked. A similar selecting and backward marking occurs in the intermediate switches to which are connected backward marked secondary switch-intermediate switch trunks, and in each such intermediate switch one of the trunks is selected and all idle intermediate switch-secondary switch trunks (cord circuits) are backward marked. In the exchange all inter-switch trunks that have access to the free marked called lines are backward marked and in each switch one of the backward marked trunks connected to its bank sides has been pre-selected.

The register that has the use of the marker transmits a signal to identify the secondary switch it is connected to, and that switch then selects one of the backward marked intermediate switch-secondary switch trunks (cord circuits) that are connected to it. This selection makes use of a cord circuit allotter similar to that described in Part 1. The register transmits forward hold over the trunks to the secondary switch and, as in the model, the slave selector of the selected cord circuit starts to generate a pulse train synchronous with that of the primary switch-secondary switch trunk connected to the register. The forward hold from the register then appears on the hold wire of the selected cord circuit and the intermediate switch slave selector of the cord circuit is set to generate the pulse train of the secondary switch-intermediate switch trunk already pre-selected by the intermediate switch master selector. The cord circuit thus becomes connected through the intermediate switch to an intermediate switch-secondary switch trunk and the forward hold from the register appears on that trunk.

In the secondary switch that trunk is connected to, the trunk's slave selector sets itself to generate the pulse train of the pre-selected backward-marked primary switch-secondary switch trunk and the connection from the register becomes extended to that trunk. In the primary switch the selected trunk becomes connected in a similar way to the pre-selected called line connected to that switch. As in the model the register then sends forward a ringing current control signal and as soon as it receives the ringing tone signal the register drops the marker and itself drops out of circuit. When the marker is dropped it removes the marking signal from the called lines and the backward marking signals disappear; the marker is then free to mark another register's called line or lines. The register, when it drops from the circuit, leaves the calling line connected through the secondary switch to the selected called line. Clearing of the connection occurs on the disappearance of the calling line's forward hold signal, as was described in the earlier sections of this article.

CONCLUSIONS

The design and construction of the model exchange formed part of a long-term investigation carried out by the Switching (RF) Division of the Research Branch, of which the author is a member and spokesman. The object of the investigation was to explore the possibilities of a fully electronic automatic telephone exchange. The particular solution that has been outlined in this article provided valuable information on electronic techniques and costs. It is not economically competitive with current electro-mechanical exchanges but the experiment has shown that a wholly electronic telephone exchange can be made and has suggested new lines of research which, in conjunction with the continual progress in component development, strengthens the view that, stage by stage, we shall be able to realise a practical and advantageous system of electronic switching.

Banbury Radio Measuring Station

P. N. PARKER, A.M.I.E.E., and G. GREGORY†

U.D.C. 621.396.722: 621.317

Banbury Radio Measuring Station has been developed to collect engineering information on radio conditions for the planning of radio services for use at International Radio Conferences. Since 1951, increasing emphasis has been placed on radio monitoring to assist the implementation of the Agreement reached at the Extraordinary Administrative Radio Conference (Geneva, 1951),[1] and the Atlantic City (1947) Radio Regulations and Frequency Allocation Tables.[2] The station, its equipment and the type of work performed are briefly described.

Introduction

BANBURY Radio Station was used as the United Kingdom receiving station of the Cairo-to-U.K. link of the high-power, long-wave, Empire Radio Network—the transmitter for the outward circuit being at Leafield, Oxfordshire. With the introduction of the short-wave ("beam") system the long-wave circuit to Cairo was taken out of use and the station was used only occasionally for field work until late 1940, when it became a laboratory for several groups evacuated from the Radio Laboratories at Dollis Hill. After the war it became increasingly apparent that there was a need for additional data for use in the preparation of frequency assignment plans and this largely influenced the decision to employ Banbury for radio monitoring work.

The International Radio Regulations, Atlantic City, 1947, contain tables showing revised allocations of frequencies in the range 10 kc/s – 10,000 Mc/s between the various types of radio services on both world-wide and regional bases; tables of new frequency tolerances for both existing and new transmitters; tables of tolerances for the intensity of harmonics and parasitic emissions; and the frequency bandwidths required for various types of radio communication. Agreement was reached at the Extraordinary Administrative Conference, Geneva, 1951, to approach the implementation of the Atlantic City Frequency Allocation Tables by Administrations voluntarily transferring their frequency assignments into the appropriate bands. This agreement required Administrations, including the U.K., to find replacement frequencies for many existing assignments. Consequently, Banbury Radio Measuring Station was developed on somewhat different lines from the well-established Post Office monitoring stations at Baldock[3] and Brentwood (which are mainly concerned with the day-to-day operation of British radio services). Its function, on a long-term basis, is to study radio conditions as an aid to planning and, on a short-term basis, to supply monitoring information to assist and to assess the progress of agreed projects for implementing international radio agreements and plans.

General Details

Site and Layout of Station.

The site covers eight acres and forms part of Bodicote Grounds Farm, about 1 mile S.E. of Banbury. The accommodation consists of two main single-storey buildings, referred to as Block A and Block B, and several smaller buildings. Block A, shown in Fig. 1, contains the receiving rooms, frequency standards laboratory and the staff offices; Block B contains working and spare laboratories, the workshop and the domestic offices.

Power Supplies.

Power is supplied by a three-phase 11-kVA overhead power line, and a transformer feeds 400-V, three-phase, 50-c/s current to the engine room switchboard. A standby 57-h.p. diesel engine and a 37-kW, three-phase, 400-V generator can be brought into operation to provide an alternative supply under fault conditions. Separate, stabilised, float-charged battery supplies are provided for the frequency standard and its ancillary apparatus, which render it immune to normal mains supply failures. A 230-V, 50-c/s supply, essential for the thermostats incorporated in the frequency standard, is provided automatically during mains failures by a small battery-driven rotary converter.

Aerials.

The aerials consist of a group of six inverted-V's forming a maypole-like structure as shown in Fig. 2; each aerial is terminated at each end and can be used for reception in either direction. There are also six omni-directional aerials of various types. Most of the aerials terminate in amplifiers giving two outputs per amplifier. The interception positions are able to select any aerial rapidly, as required, so enabling the directive properties of the V-aerial system to be used to full advantage for the elimination of interference or to attain maximum signal levels. Provision is also made for

† The authors are Executive Engineers, Radio Planning and Provision Branch, E.-in-C.'s Office.

Fig. 1.—Banbury Radio Measuring Station.

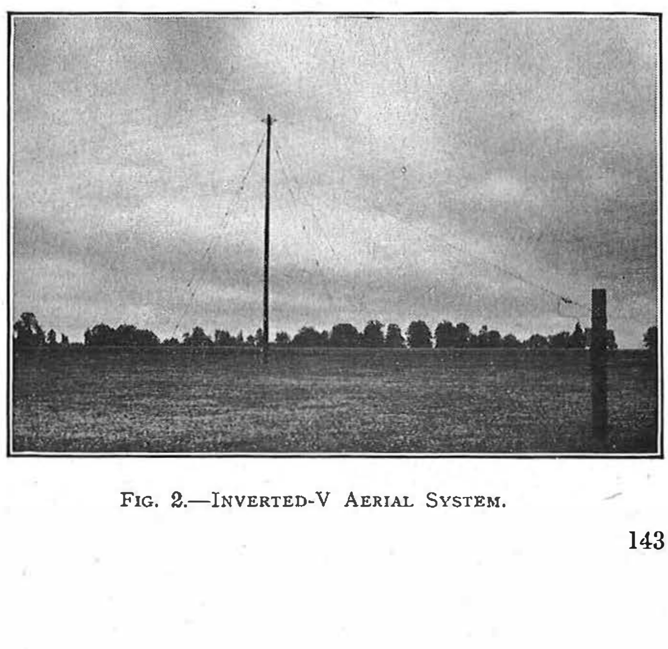


Fig. 2.—Inverted-V Aerial System.

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the aerials to be connected directly to the receivers when it is essential to exclude the possibility of spurious signals being produced in the aerial amplifiers by intermodulation between very strong signals from nearby transmitting stations.

Even though the characteristics of the inverted-V aerials vary with frequency, particularly their horizontal-plane directivities, they do possess sufficient directivity to be very useful. Tests on a model of the system at Banbury have shown that the effect of coupling between the aerials does not result in marked changes in directivity as compared with an isolated unit aerial of the same type.

Receivers.

The receivers include a number of commercial communication receivers of various types covering the range 50–30,000 kc/s, and Post Office single-sideband receivers covering the range 10–30,000 kc/s, which are capable of translating a radio-frequency band 6 kc/s wide to audio frequency for spectrographic or other analysis. Communication receivers are also employed with the five sets of automatic scanning equipment described later.

Scope of the Work and the Equipment Employed

The work includes:—

The interception of radio signals and observations of their:

(i) Identity
(ii) Frequency
(iii) Bandwidth
(iv) Field-strength
(v) Direction of arrival
(vi) Fading characteristics

together with the systematic collection of information on:

(vii) The occupancy of various frequency bands
(viii) The frequency and bandwidth tolerances that are, in fact, observed by working transmitters throughout the world.

Identification of Signals.

The identification of intercepted signals is one of the most difficult problems for a monitoring station. This is partly due to the increasing use of complex telegraph and telephone systems, to multi-lingual broadcasting, and to the long intervals between call-signs from some stations. With the object of improving matters the C.C.I.R. is studying how simple call-sign signals can be superimposed on the more complex types of emission. The significance of the problem may be appreciated from analyses made at Banbury where it was found that less than 40 per cent. of a batch of 5,000 intercepted transmissions could be identified. It has not been practicable to equip Banbury with translating apparatus for all types of emissions in present use, but equipment for the simpler types, including frequency-shift detectors, high-speed morse recorders, 45·5 and 50 baud teleprinters, speech inverters and magnetic-tape recorders are installed.

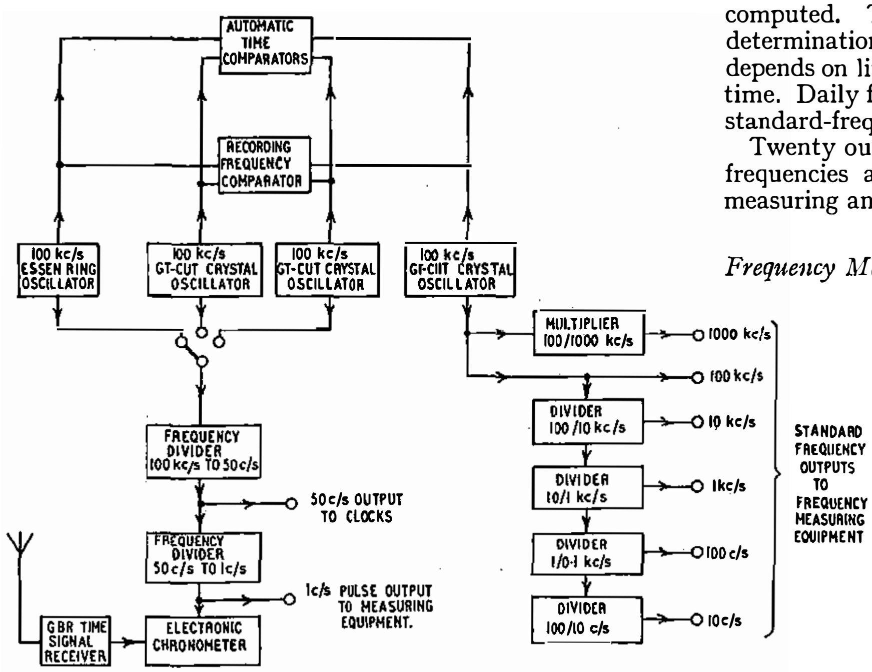


Fig. 3.—Schematic Diagram of Frequency Standard Equipment.

Frequency Standard.

The station's basic tool is its frequency standard, which is a replica, on a small scale, of the Post Office Primary Standard of Frequency at Dollis Hill.[4] It could act as an emergency standby to the Dollis Hill Standard and for this reason is more precise than is actually required for monitoring work.

The installation is shown diagrammatically in Fig. 3. It comprises one 100-kc/s "Essen" Z-cut ring and three 100-kc/s "GT-cut" quartz crystals in evacuated, sealed containers with associated bridge-stabilised maintaining amplifiers. The crystal temperatures are controlled to about ± 0·01°C by 50-c/s resistance-bridge thermostats and the complete oscillators are maintained at an ambient temperature of 30°C. Frequency dividers and multipliers provide a decade series of standard frequencies from 1,000 kc/s to 0·01 kc/s for distribution throughout the station. The original synchronous-motor clocks have recently been replaced by electronic equivalents which provide pulses, nominally at one-second intervals, for comparison with standard time signals, and the standard 50 c/s is used to control the apparatus room clocks. Automatic time- and frequency-comparators continuously inter-compare the oscillators, and one oscillator is checked against time signals from the Royal Observatory. These time signals, radiated by Rugby GBR, 16 kc/s, are received by a specially stable receiver, and the time difference between the signal and a second's pulse from the local clock is read off the dials of an electronic chronometer. From similar readings taken at successive 24-hourly intervals the rate of the clock, and hence the mean frequency of its controlling oscillator, is computed. The absolute error of the mean frequency determinations does not exceed two parts in 10^8 and largely depends on limitations in the astronomical determination of time. Daily frequency comparisons are also made with the standard-frequency transmissions radiated by Rugby, MSF.

Twenty outputs of each of the decade series of standard frequencies are available for distribution to the various measuring and testing positions.

Frequency Measurement.

The Radio Regulations set out the agreed frequency tolerances to be observed by various types of transmitter. The C.C.I.R. recommends that the accuracy of frequency-measuring equipment shall be $\pm$ 2 c/s in the range 10–400 kc/s; $\pm 5\times10^{-6}$ in the range 400–4,000 kc/s; and $\pm 2\times10^{-6}$ in the range 4,000–50,000 kc/s.

The frequency measuring equipment at Banbury consists of three sets with accuracies of one part in 10^7, so that the requirements mentioned above are adequately met. Two other sets are used for approximate frequency checks to within one part in 10^4.

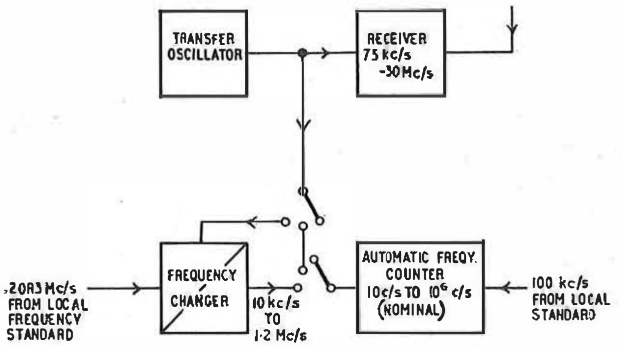


FIG. **4**.—SCHEMATIC DIAGRAM OF FREQUENCY MEASURING SET USING ELECTRONIC COUNTER.

Two methods are used for precise frequency measurement; both employ commercial electronic counters. One method, shown schematically in Fig. **4**, consists in synchronising, in the receiver, a harmonic of a stable variable-frequency oscillator, called the transfer oscillator, with the signal to be measured. The fundamental frequency ranges of the transfer oscillator are 125–250 kc/s and 2–4 Mc/s, and its frequency is measured directly by using the electronic counter to count the number of oscillation cycles executed during a one-second interval. The maximum counting rate is 10^6 c/s, so that it is necessary to convert the output frequency of the H.F. range of the transfer oscillator to a value of 10^6 c/s or less for counting. This is done by heterodyning with a selected 2,000- or 3,000-kc/s standard frequency and selecting the difference frequency with a low-pass filter. The counter displays the oscillator frequency on six decade dials, and the order of the oscillator harmonic synchronised with the signal is known from the receiver's calibration. The other precise measuring sets employ an "intermodulation method" (see Fig. **5**). In this, standard-frequency harmonics of 1,000 kc/s are modulated by the output of a stable-frequency oscillator, f_o, the oscillator frequency being adjusted so that its sum or difference frequency with the nth 1,000-kc/s harmonic ($1{,}000\ n \pm f_o$) coincides with the signal frequency f_s. From a knowledge of f_o, of the harmonic order, n, and whether the sum or difference frequency is being used, f_s is determined. The value of f_o is always less than 10^6 c/s in this method, and is measured to the nearest 1 c/s by the counter. Knowledge of the approximate value of f_s from the receiver calibration indicates both the harmonic order and whether the sum or difference product is being used.

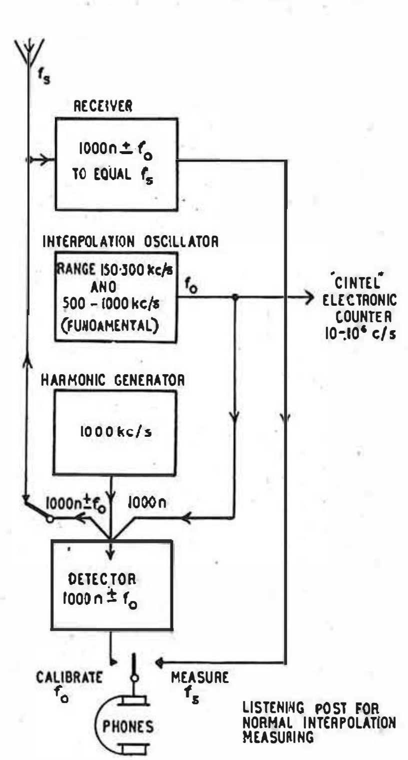


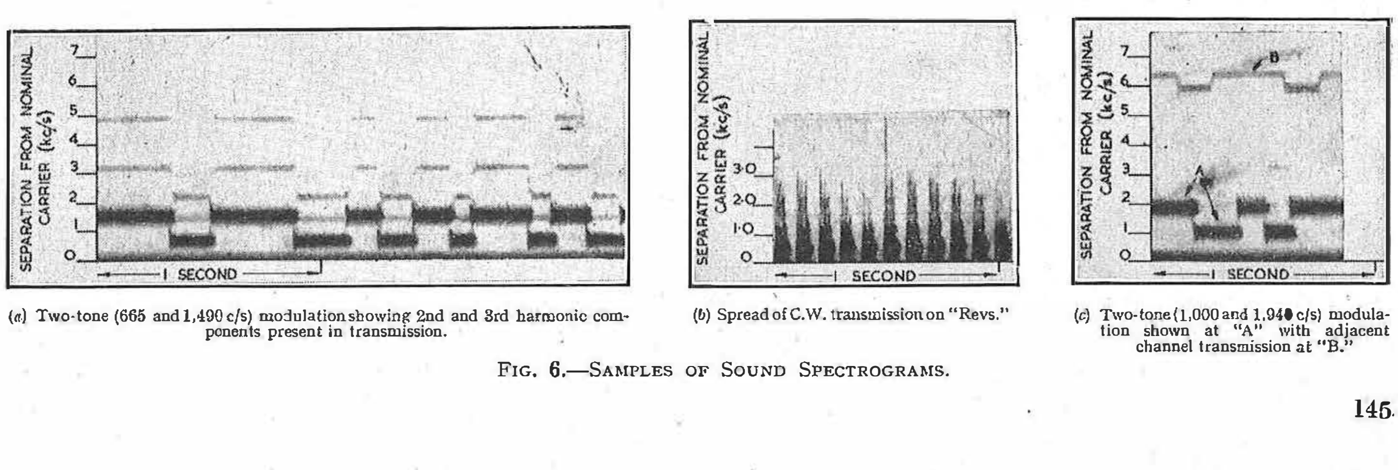
FIG. **5**.—SCHEMATIC DIAGRAM SHOWING INTERMODULATION METHOD OF FREQUENCY MEASUREMENT.

The precise frequency-measuring sets are used to make routine frequency measurements of fixed service stations operating between 5,000 and 27,500 kc/s. The measurements are analysed in terms of deviation from nominal and from mean frequencies, and enable the stipulated frequency tolerances to be compared with those actually achieved. The results also reveal the inherent stability of the transmitters, and by how much their mean frequencies are offset from their assigned values.

Bandwidth Measurements.

The Radio Regulations define the bandwidth occupied by an emission as the band of frequencies comprising 99 per cent. of the total radiated power, extended to include any discrete frequency on which the power is at least 0·25 per cent. of the total radiated power. In one method of bandwidth measurement the single-sideband receiver is used to translate a 6-kc/s-wide band from radio frequency to audio frequency for examination with a sound spectrograph. This latter instrument produces, on "Teledeltos" paper, a record of the signals in the selected 6-kc/s band over a period of a few seconds. Fig. **6** is a typical record, which shows the upper sideband spectra of two different types of radiotelegraph emission and indicates the effect of keying-frequency harmonics in increasing the bandwidth occupied by the signals. This method has proved to be of most use for identifying the frequencies of the components of a signal, but has the disadvantage that it does not permit a very accurate assessment of their relative amplitudes to be made.

An instrument for the precise measurement of bandwidth in the range 3,000–30,000 kc/s, developed by the



(*a*) Two-tone (665 and 1,490 c/s) modulation showing 2nd and 3rd harmonic components present in transmission.

(*b*) Spread of C.W. transmission on "Revs."

(*c*) Two-tone (1,000 and 1,940 c/s) modulation shown at "A" with adjacent channel transmission at "B."

FIG. **6**.—SAMPLES OF SOUND SPECTROGRAMS.

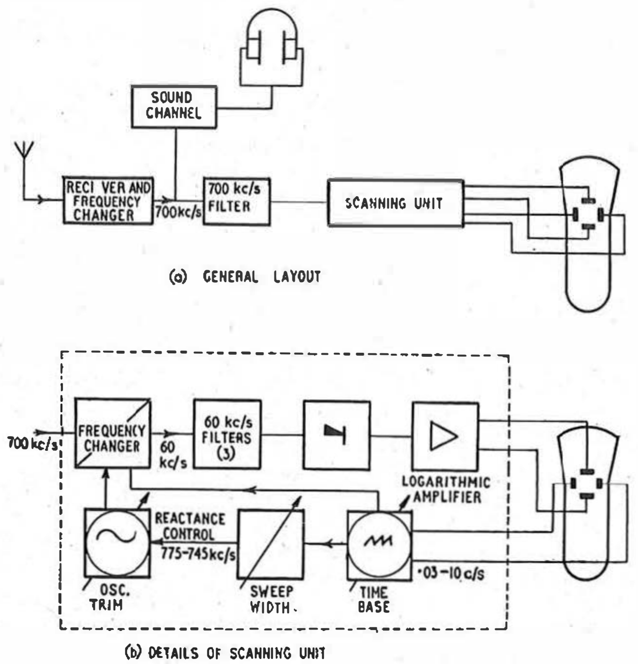


FIG. 7.—SCHEMATIC DIAGRAM OF RADIO FREQUENCY SPECTRUM ANALYSER.

Post Office and known as a Radio Frequency Spectrum Analyser, is used at Banbury and is shown schematically in Fig. 7. The intercepted signal is first translated to 700 kc/s, and 700 kc/s outputs are fed to a sound channel (a simple receiver for audio monitoring) and through a band-pass filter to the scanning unit. The scanning unit contains further frequency changers with a reactance-controlled oscillator, 60 kc/s filter and amplifiers (not shown), detector and oscilloscope Y-deflection amplifier, time-base generator and X-deflection amplifier. The oscillator frequency is swept across a band centred on 760 kc/s, and up to 30 kc/s in width, by the reactance modulator-valve under the control of the time-base generator. Thus, each component of the 700 kc/s signal is translated in turn to 60 kc/s, selected by the 60 kc/s filter, detected and passed on to the Y-deflection amplifier which has an approximately logarithmic input/output amplitude response over a range of 30 db. A signal-level range of 30 db. is displayed on the oscilloscope screen. However, the design is such that measurements can be made over a 60-db. range in two stages, and the gain of the 60 kc/s amplifier can be changed by 30 db. to permit this. The frequency (X) scale of the oscilloscope is a linear one, and its calibration can easily be checked by injecting a signal modulated with 1 kc/s harmonics into the receiver.

This instrument has been principally used at transmitting stations where high-level signals are available, and some typical spectra photographed with the associated camera are shown in Fig. 8. The use of the instrument at monitoring stations for the analysis of weak and fading signals is clearly more difficult. Nevertheless, it has proved of great value in assisting transmitting stations emitting signals with excessive spread to adjust their equipment.

Field-Strength Measurements.

Field-strength measurements are made with a commercial set employing a loop aerial and a substitution signal oscillator, and with a four-metre vertical aerial and an associated single-sideband receiver and standard-signal generator. The measuring set is housed in a wooden hut provided for the purpose and is fairly remote from the station and aerials. However, this set, with its small loop aerial is not sufficiently sensitive for much of the routine field-strength work required in the fixed service bands. The system, shown in Fig. 9, gives increased sensitivity

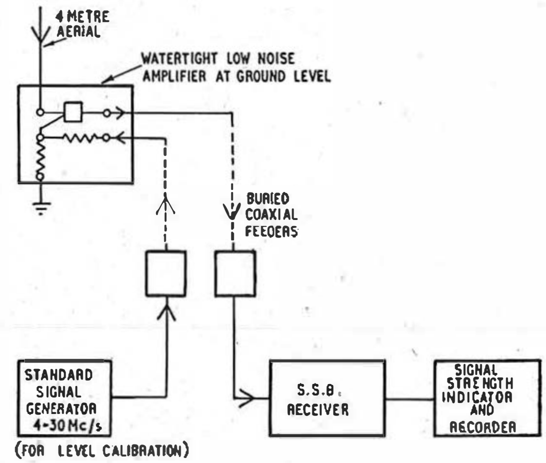
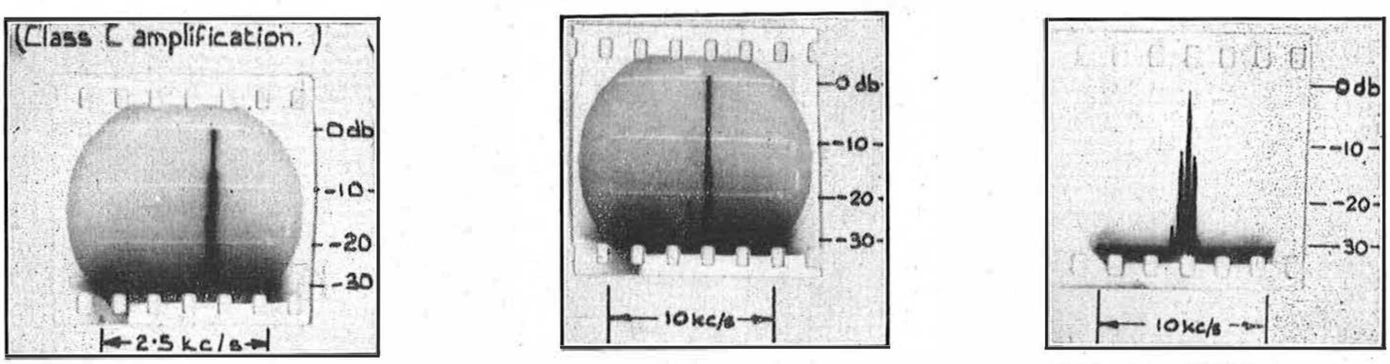


FIG. 9.—SCHEMATIC DIAGRAM OF FIELD-STRENGTH MEASURING EQUIPMENT.

by using a four-metre vertical aerial and pre-amplifier with a high gain single-sideband receiver. The aerial, which is remote from the station's buildings, is connected to the receiver by buried coaxial cable, and a second, similar cable is used to transmit a calibrating signal of known value to a resistor in series with the aerial. A recording meter can be connected in series with the signal strength indicator of the receiver for making continuous recordings of field strength, and the receiver's automatic frequency control maintains it correctly tuned.

This equipment is in daily use on a long-term investigation of signals scattered from the E-layer in which recordings are made of the field strength of the signals of a



(*a*) A1 emissions (C.W.).

(*b*) A2 emissions (M.C.W.) with amplitude modulation.

(*c*) A2 emissions (M.C.W.) with frequency modulation.

FIG. 8.—SPECTROGRAMS OF H.F. MORSE 50-BAUD EMISSIONS.

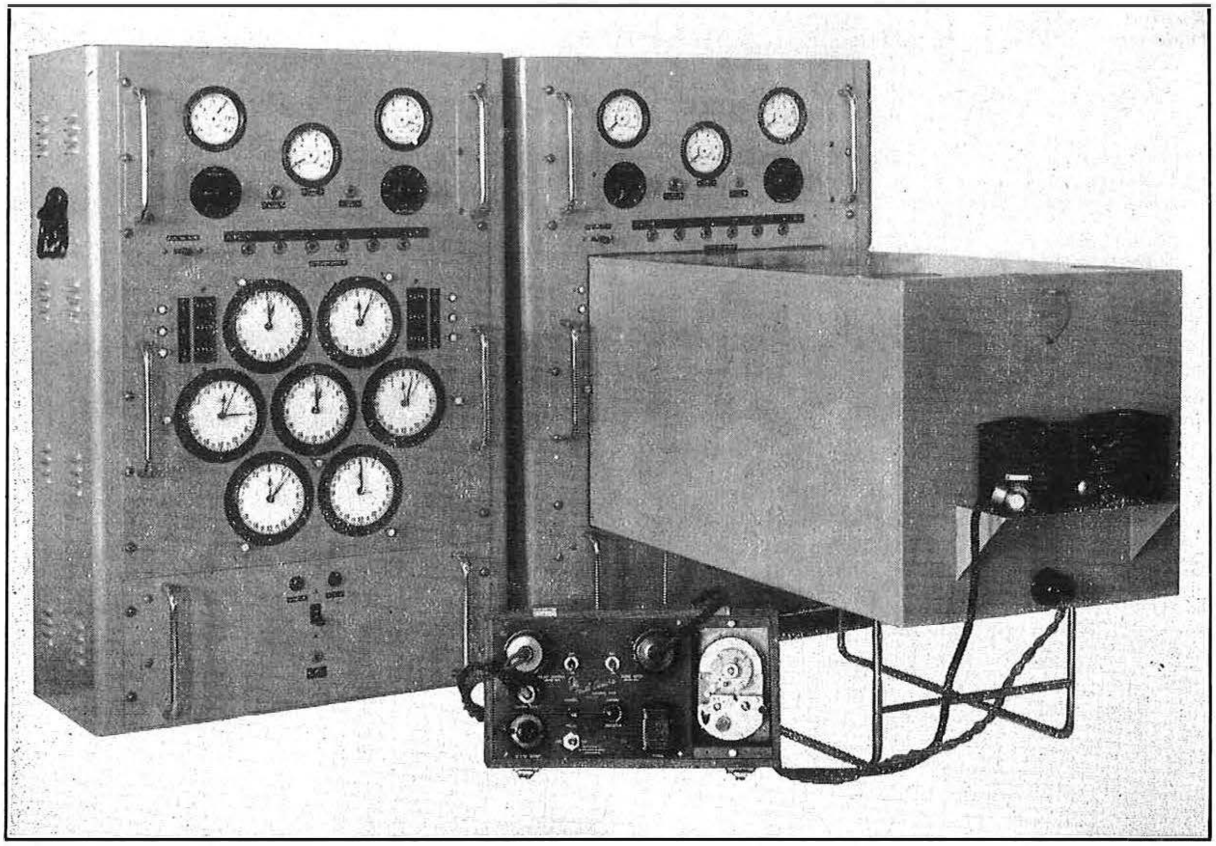


FIG. 10.—LEVEL DISTRIBUTION ANALYSERS. (RIGHT-HAND ONE WITH PHOTOGRAPHIC ATTACHMENT.)

Europe-U.S.A. circuit operating on about 15,000 kc/s for which Banbury lies in the "skip" zone. The results are being studied with a view to correlating the variations in field strength with occurrences of Sporadic E and abnormal magnetic activity.

Routine field-strength measurements are also made of signals from the nearby high-power Rugby, GBR, transmitter to assess possible changes in the effective height of the aerial.

Direction Finding.

No direction-finding equipment is as yet in use at Banbury but an "Adcock" system, of range 1,500–20,000 kc/s, which is about to be installed, will be remotely controlled from Block A. The set will be used mainly as an aid in the identification of signals.

Fading.

The Post Office has developed an instrument known as a Level Distribution Analyser, which uses trigger circuits, associated relays, synchronous electric clocks and four-figure counters, to determine the characteristics of fading signals.

The total time over which observations are taken is recorded on a master clock and other clocks and counters record the time for which, and number of times, a signal falls below predetermined levels in six steps over a range of 80 db. The shortest fade that can be recorded is governed by the operate-time of the clocks and is 0·1 sec.

Fig. **10** shows two such analysers, as installed at Banbury, with and without photographic equipment. Counter and clock displays can be photographed automatically at predetermined intervals and, if set for hourly recordings, the apparatus will operate without attention for seven days. This equipment, in conjunction with the field-strength measuring set previously referred to, is used to study the rapidity, depth and amplitude-time distribution of short-period fading, and day-to-day variations in hourly-mean signal level on circuits, taking into account such variables as frequency, path length, geography and solar activity.

Spectrum Scanning.

The demand for frequencies for new communication services and for the out-of-band services which, following the Extraordinary Administrative Conference, Geneva, 1951, have to be transferred into the appropriate Atlantic City bands, has resulted in a large amount of aural and automatic spectrum scanning. The aural work, in which the identities and approximate frequencies of stations are required to be known, has been largely performed by skilled radio operators loaned to Banbury by the Wireless Telegraphy Section of the Post Office.

The automatic monitoring work has been carried out with automatic scanning receivers[5] which have been used to build up a record of the pattern of frequency usage in the Atlantic City Fixed Service bands covering seasonal and other trends.

ACKNOWLEDGMENT

The authors wish to thank their colleagues at Banbury Radio Measuring Station and in the Radio Planning and Provision Branch who have helped in the preparation of this article.

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Modern Indoor Lighting

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Part 2.—Design Methods and Practical Details

U.D.C. 628.972

Following the description of the general principles and design factors applicable to indoor lighting schemes, given in Part 1, the article continues with a discussion on the various design methods now in use by lighting engineers. In conclusion, the author briefly describes typical lamps and fittings, and the control circuits needed for fluorescent lighting installations.

DESIGN METHODS

Illumination Method.

MOST design methods are basically illumination methods, i.e., the minimum illumination on the working plane is fixed and the lighting is designed so that the illumination does not fall below this minimum. The methods are well known and will be mentioned here only briefly.

General Lighting.—The number of lumens (F) required in any given room of area A is given by $F = \frac{EAK}{U}$

where,

E = minimum illumination required.

U = utilisation factor and is the proportion of light emitted by the lamps which reaches the working plane. It depends on the type of fitting, the size of the room and the mounting height. Tables are available, based on practical experience, giving the utilisation factor for various combinations of these variables.

K = a constant which must be introduced to allow for variation in the illumination over the working plane and for deterioration in lamp output and the conditions of decorations and fittings. Its value is usually about 2.

The minimum number of lighting units required to give these lumens is then decided, having regard to the mounting height, spacing, symmetry, furniture layout and architectural features.

Local Lighting.—The illumination at any point in a horizontal plane due to local lighting may be calculated by the "point-by-point" method which uses the fundamental formula,

$$E = \frac{I \cos^3 \theta}{h^2}$$

where,

I = luminous intensity of the source in the required direction.

h = vertical height of source above plane.

θ = angle of incidence.

Polar distribution curves are used to determine the luminous intensity of the source in any required direction.

The above formula applies strictly only to point sources but a lighting fitting can be treated as a point source if h is large compared with the dimensions of the fitting. The formula cannot conveniently be used where long line sources are used.

Considering the source in Fig. **4**, of length l, mounted at a height h above a point P opposite one end of the source,[11] the illumination at P on a horizontal plane AA parallel to the source is given by:—

$$E_P = \frac{i}{2h}\left[\tan^{-1}\frac{l}{h} + \frac{lh}{l^2 + h^2}\right]$$

where i = intensity per foot length in candelas normal to the length, in the direction of P.

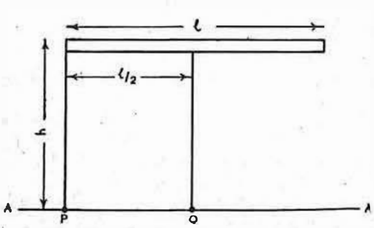


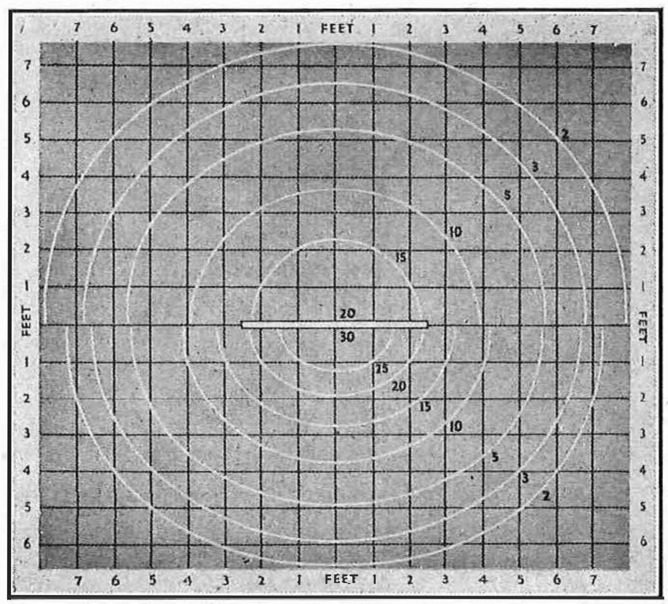
FIG. **4**.

The illumination at Q is obtained by considering the source in two halves each of length $l/2$.

$$\text{Thus, } E_Q = \frac{i}{h}\left[\tan^{-1}\frac{l}{2h} + \frac{2lh}{l^2 + 4h^2}\right]$$

Although the above formulae apply strictly only to a perfectly diffusing surface, a bare fluorescent lamp may be taken as approximating to this. Fittings with reflectors or louvres may not do so, and in such cases some corrections will be necessary.

To avoid calculations, iso-illumination diagrams can be used. Fig. **5** shows a typical diagram for a fluorescent fitting.



Upper Half: 80W lamp mounted 5ft. above plane of reference
Lower Half: 80W lamp mounted 4ft. above plane of reference

FIG. 5.—ISO-ILLUMINATION DIAGRAMS FOR 80W FLUORESCENT LAMP IN TROUGH-TYPE REFLECTOR: LAMP OUTPUT 3040 LUMENS (ILLUMINATION IN LUMENS/SQ. FT.)

Combined Lighting.—General and local lighting must often be combined in places where a high illumination is required over fairly limited portions of the working plane, e.g., machine shops or on workbenches and counters. In such cases it is usually desirable for the local lighting source to be concealed from direct view by using opaque reflectors or by using a "spotlight" technique with directional filament fittings recessed into the ceiling. The latter method is often used with fluorescent general lighting for decorative lighting and for spotlighting particular items for publicity purposes.

It must be emphasised that an adequate level of general lighting must be provided to avoid overhead gloom and excessive luminance contrasts. The I.E.S. Code recommends minimum values of general illumination for various values of local illumination as shown in Fig. **6**.

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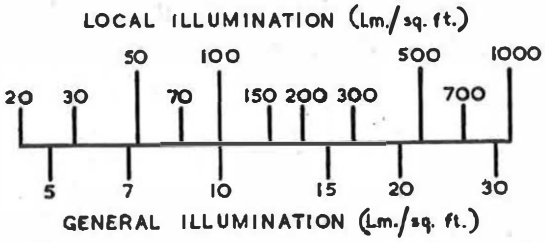

Fig. 6.—Minimum General Illumination for Various Degrees of Local Illumination as per I.E.S. Code Recommendations.

"Brightness" Method.[12,13]

The designer of an installation should always endeavour to produce a layout which will give a good luminance distribution, by the use of well-designed, well-placed fittings and fairly light decorations, and by avoiding heavy contrasts. The "Brightness" method of design goes further by considering statistically the luminance distribution over the whole field of view. This does not, however, involve calculation of the luminance of every object within the field of view. Since the glare effect of a bright object at a given distance is proportional to its area, consideration need be given to the luminances of large continuous surfaces only, such as floors, walls and ceiling. In fact, a room with large areas of unrelieved uniform luminosity may be dull and depressing. Relief is normally provided by furniture, pictures, doors and decorations having reflection factors different from those of the background walls, ceiling and floor.

It is generally agreed that, for comfortable seeing, limits should be laid down for the ratio of the luminances of adjacent surfaces, but there is, as yet, no agreement as to what these limits should be. A ratio of 3 has been suggested, but it is thought that this figure is idealistic and that it takes no account of the luminance of the task or of the size of the glare source. A more logical method is to determine the maximum luminance of the glare source for threshold of discomfort and then decide on the maximum luminance for "pleasant" conditions.

For instance, for a room with a task luminance of 6·4 foot-lamberts (ft-L) the maximum comfortable glare source luminance, calculated from the formula

$$L_G = \frac{KL_A^{0 \cdot 3}}{\omega^{0 \cdot 25}}$$ given in Part 1*, would be:—

Size of glare source (subtended solid angle, ω)	0·001	0·01	0·1
Maximum comfortable glare source luminance, L_G (ft-L).	740	415	234
Ratio maximum glare source luminance to task luminance, L_G/L_A	116	65	37

Taking a "safety factor" of five to ensure pleasant conditions, the permissible luminance ratios are, respectively, 23, 13 and 7 for the three sizes of glare source. The figure of five is only a suggestion and as yet unsubstantiated by practical experience.

One essential requirement is to have a reasonably simple method of calculating the luminances expected in a given installation, and inter-reflection tables, based on experimental observation, have been published by the American Illuminating Engineering Society[14] to enable this to be done.

The tables have been simplified by the fact that the percentage of light absorbed by a room is a function of its proportions rather than of its size. Thus the percentage absorption of a rectangular room of any dimensions can be given in terms of an equivalent square room by using a "room co-efficient" K_r, where $K_r = \frac{h\,(w + l)}{2\,w\,l}$ and l, w and h are respectively the length, width and height of the room. K_r equals 1 for a cubic room and h/w for a square room.

* *P.O.E.E.J.* Vol. 47, p.69.

The tables give the ratio of average ceiling, wall and floor luminances to average illumination for all combinations of the variables affecting the luminance distribution, i.e., room coefficient, reflection factors of walls, ceiling and floor, and type of lighting (direct, indirect or general). Table 1 is a typical example. To illustrate its use, consider a room

TABLE 1
Ratio—Average Ceiling Luminance/Average Illumination

Ceiling refl. factor	0·8			0·7			0·5		
Wall refl. factor	0·5	0·3	0·1	0·5	0·3	0·1	0·5	0·3	0·1
Room Coeff.									
0·1	0·564	0·563	0·561	0·523	0·622	0·621	0·425	0·424	0·423
0·2	·634	·637	·612	·589	·591	·593	·478	·480	·481
0·3	·703	·712	·699	·651	·660	·669	·527	·535	·543
0·4	·769	·789	·792	·711	·731	·751	·574	·590	·607
0·5	·835	·869	·891	·771	·803	·838	·619	·645	·675
0·7	·967	1·036	1·104	·888	·953	1·026	·704	·757	·819
1·0	1·166	1·305	1·465	1·061	1·190	1·345	·824	·929	1·065

General diffuse lighting; floor reflection factor = 0·1]

with general lighting, a room coefficient of 0·7, ceiling and wall reflection factors of 0·5 and floor reflection factor of 0·1. From the table, the ratio of average ceiling luminance to average illumination is 0·704, and, if the average illumination is 10 lumens/sq.ft., the average ceiling luminance is 7·04 ft-L.

Luminance Analysis.—Considering an office 40 ft. × 20 ft. × 14 ft. high with general lighting by enclosed fittings having a luminance of 500 ft-L and mounted 7 ft. above the working plane and 9 ft. 6 in. above the floor, as in Fig. 7, the average illumination is calculated by normal methods to be 9 lumens/sq. ft.

$$\text{Room coefficient, } K_r = \frac{14\,(40 + 20)}{2 \times 20 \times 40} = 0 \cdot 525$$

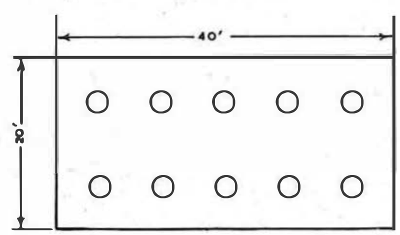

Fig. 7.—Office Layout for 150W Lamps Mounted 9 ft. 6 in. Above Floor-level.

Fig. 8.—Appearance of Office Illuminated on Basis Shown in Fig. 7.

TABLE 2

	Average Luminance (ft-L)						Luminance Ratios				
	Top of Wall L_T	Middle of wall L_M	Ceiling L_C	Floor L_F	Work L_W	Source L_S	L_W/L_M	L_W/L_F	L_C/L_T	L_S/L_C	L_S/L_T
Line 1	3·8	3·4	5·5	0·7	7·2	500	2	10	1½	90	130
Line 2	4 to 6	5 to 8	5 min.	1	6 to 7	500 av.	—	—	—	—	—
Line 3	3·9	3·5	6·2	2	7·2	300	2	3½	1½	50	80

Take the reflection factors as:—

ceiling 0·7
walls 0·5
floor 0·1
work 0·8

From these data and the inter-reflection tables the luminances and luminance ratios can be calculated as in Line 1 of Table 2. Line 2 shows the luminances actually obtained and Fig. **8** shows the appearance of the office, with the principal luminances marked on.

These results may be regarded as satisfactory except for the source luminance. If the latter were reduced to 300 ft-L by using suitably designed fittings, and the reflection factors increased to 0·8, 0·5 and 0·3 for ceiling, walls and floor respectively by lighter decorations and floor covering, the figures given in Line 3 are obtained. These are better and, although the ratios L_S/L_C and L_S/L_T are higher than the ideal, further reductions would be difficult and expensive. There is no doubt that the installation is quite comfortable for seeing. Experiments in this country have suggested that a ratio of 30 for source luminance to surround luminance is acceptable.[15] The figures calculated above relate to average luminances, and in practice the luminance of that part of the ceiling near to the fitting is higher than the average. Thus the change in luminance is gradual, not sudden. Lighting units which have a graduated luminance are an additional help in reducing the contrast between the edges of the unit and its immediate background.

At present the brightness method of design is useful mainly as a check upon orthodox methods and for special designs such as those involving indirect lighting.

Fig. **9** shows that an installation having a good brightness distribution can be designed by orthodox methods allied to sound experience without recourse to brightness methods.

Field Flux Method.[16]

This method is based on the theory that ideal lighting is such that the distribution of light flux over the visual field corresponds to that normally encountered out-of-doors in temperate areas of the world. The flux is specified by dividing the visual field into six zones and is measured in each zone by a special meter. An indoor lighting installation is checked by measuring the flux to see whether, within limits, the flux from each zone is in the right proportion.

This method, like the "Brightness" method, is in its early stages and is based on assumptions which are not yet completely verified by scientific investigations and large-scale trial.

TYPES OF LAMPS, FITTINGS AND CONTROL CIRCUITS

Lamps.[17]

The provision of good, adequate lighting has been made easier in the last few years by the rapid development of the tubular low-pressure mercury fluorescent lamp, of both hot-cathode and cold-cathode types. These lamps have an efficiency of about three times and a life of three to ten times that of filament lamps. Fluorescent lamps can be obtained in a wide range of "whites" and are considerably cooler than filament lamps. The luminance of a bare fluorescent lamp is only about one twentieth that of the bright spot of an internally frosted ("Pearl") filament lamp. The long tubular shape of the fluorescent lamp can be utilized to reduce shadows and, for some installations, has the advantage that the lamps can be hidden behind cornices or beams or arranged in a continuous line over long, narrow working planes such as counters or rows of switchboards.

Extensive trials and investigations into the physiological effects of fluorescent lighting have increased confidence that no harm normally results from the spectral distribution of the energy output or from the cyclic variation in the light output of the lamp.

There are many cases, however, where filament lamps have advantages because the lamps and fittings are much cheaper than for fluorescent installations; no control gear is needed; maintenance is simpler; and lamp changing and cleaning may be done by less skilled labour. Furthermore, the shape and length of filament lamps often favours their use.

Although high-pressure discharge lamps have high efficiency, the colour of the light emitted makes them unsuitable for most indoor installations except in special cases such as high bay

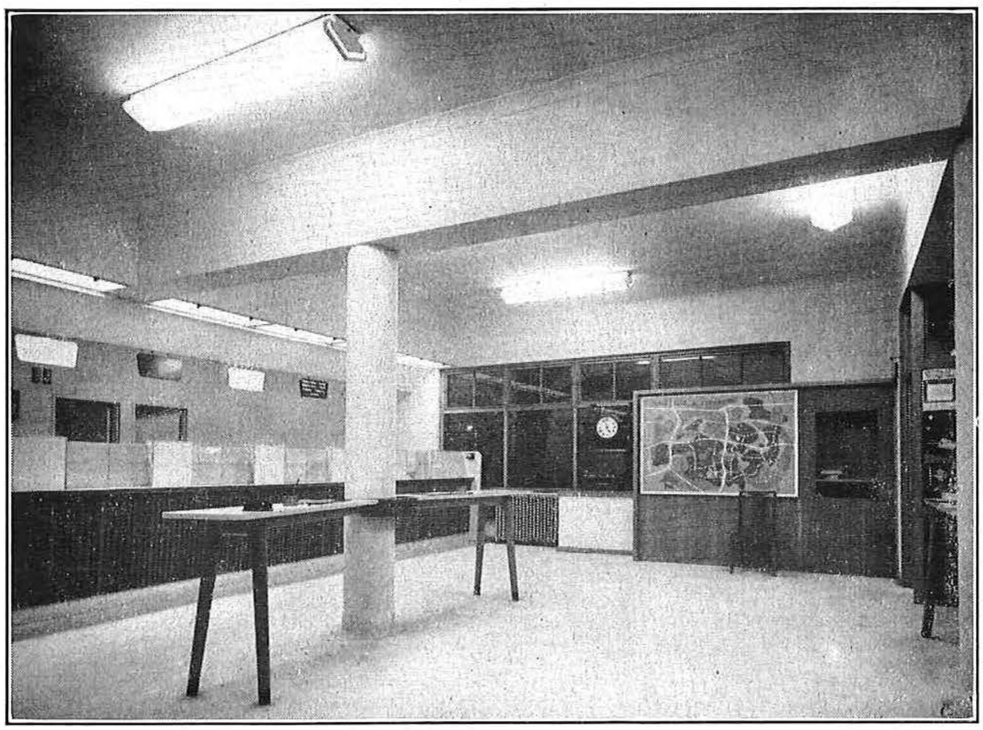

FIG. 9.—A WELL-DESIGNED LIGHTING INSTALLATION.

lighting in factories and workshops. Colour correction can be obtained by incorporating fluorescent powder in the lamp envelope or by using filament and discharge lamps in pairs.

Typical data for filament and hot- and cold- cathode fluorescent lamps[18] are as shown in Table 3:—

TABLE 3

Typical Data for Filament and Fluorescent Lamps

	Filament		Fluorescent		
			Hot Cathode		Cold Cathode
Lamp Wattage	15	200	15	80	7 } Per
Average Lumens	113	2,725	380	3,000	250 } foot
Average Lumens/watt (including control gear)	8	14	19	31	26
Length (in.)	$3\frac{5}{8}$	7	18	60	To suit
Diameter (in.)	$2\frac{1}{8}$	$3\frac{1}{8}$	1	$1\frac{1}{2}$	$\frac{3}{4}$
Life (hours)	1,000		2,500	3,000	10,000
Maximum Luminance (ft-L)	8,000	75,000	1,200	1,500	1,500

There have been no major improvements, of recent years, in general service filament lamps although the efficiency has been increased slightly. With fluorescent lamps there has been a large increase in efficiency and in life. The figures quoted above for hot-cathode lamps are from the appropriate British Standard, but most manufacturers now claim 5,000 hours life and up to 30 per cent. higher efficiency. Also, fluorescent lamps are available in a range of "whites" ranging from "daylight" and "colour matching" to the warmer "De-luxe warm white" which gives colour rendering similar to that of the tungsten filament lamp.

Cold-cathode lamps have the special advantages of long life and the ability to be "tailor made" in most shapes and sizes. Where maintenance is difficult or the lighting is to be concealed in architectural features cold-cathode lamps may be preferable in spite of increased capital cost. As neon-filled tubes without a fluorescent coating, giving the characteristic red discharge, can be mixed with the usual mercury-filled tubes, colour control can be effected more easily with cold-cathode lamps. Other advantages are that the lamps will remain alight even though the voltage drops to 50 per cent. of normal and that life is not reduced by constant switching as is the case with hot-cathode lamps. The data given for them are only typical; the electrode drop is fixed at about 190V per lamp and the potential drop in the tube is about 50V per foot at 120mA. Thus efficiency and operating voltage depend on the length of tube.

Fittings.

Lamps are usually housed in fittings or specially designed architectural features. The fittings may be suspended, ceiling- or wall-mounted, or built into the ceiling. The objects of putting the lamps in a fitting may be summarised as direction, diffusion and decoration. As already indicated, it is desirable to direct the light on to the working surfaces, but at the same time to avoid high luminance ratios. Most fittings incorporate reflecting surfaces which direct the light to a desired degree. As the luminance of any bare lamp in the field of view is too high for comfort, diffusers are often necessary. It is often desirable to use lighting fittings both as light sources and as part of the general decorative scheme and this is usually possible.

For filament lamps, enclosed diffusing fittings with opal glassware are used in the majority of cases. Modern versions of the semi-direct fitting can, however, be both decorative and more efficient than a diffusing fitting. Fluorescent fittings usually have the additional functions of housing the control gear, and screening the flicker at the ends of hot-cathode tubes, which is due to the oscillating movement of the arc on the filament. Reeded and opal perspex is used extensively for diffusers and reflectors. The use of louvres in place of diffusers results in an increase in the downward light distribution without excessively increasing the luminance of the fitting within the normal field of view. A logical development of the louvred fitting is the louvred ceiling where the lamps are mounted uniformly over a suspended "egg-crate" louvre extending over the whole ceiling. This results in an even luminosity pattern of comparatively low intensity and is especially useful where high, shadow-free illumination is required. Maintenance and capital costs are high however.

Control Circuits for Fluorescent Lamps.[19]

Cold Cathode.[20]—Fig. **10** shows a typical circuit for operating three 8 ft. 6 in. cold-cathode tubes in series.

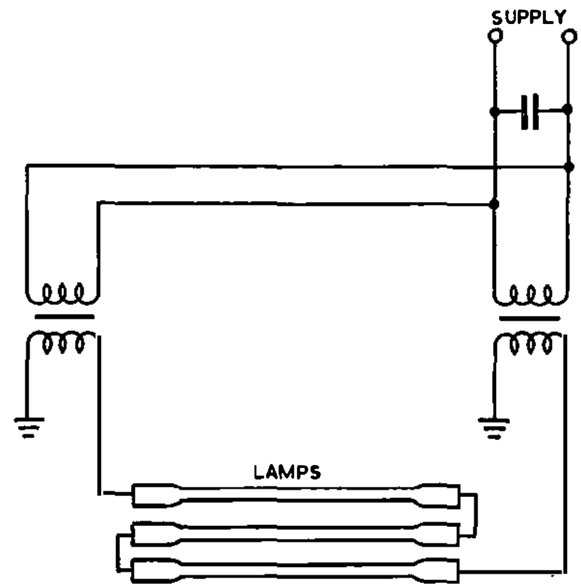

FIG. **10**.—CONTROL CIRCUIT FOR 3 COLD-CATHODE LAMPS IN SERIES.

The total E.M.F. required on load is about 1,800V. This is supplied by two high reactance transformers which give a much higher E.M.F. at no load to facilitate starting. The use of two transformers halves the output voltage required and enables them to be housed in a smaller fitting. The un-improved power factor is less than 0·5 and so a power factor improvement capacitor is required.

Hot Cathode.[21]—Figs. **11-13** are circuit diagrams for a hot cathode lamp with the following types of control gear: (1) Inductive ballast, glow switch start; (2) Inductive ballast, auto-transformer start; (3) Lamp ballast, auto-transformer start.

The first method of control (Fig. **11**) is well known and has been adequately described elsewhere.[22] On failure it is not always easy to determine whether lamp or starter is

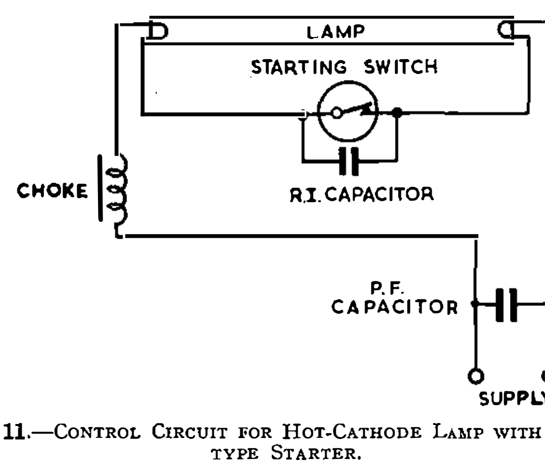

FIG. **11**.—CONTROL CIRCUIT FOR HOT-CATHODE LAMP WITH GLOW-TYPE STARTER.

faulty, with the result that both items are often replaced, one unnecessarily. Also a faulty starter switch can easily ruin a good lamp by repeated operation and in such cases the nuisance effect is high.

The replacement of the starter switch by an auto-transformer as shown in Fig. 12 involves slight extra cost

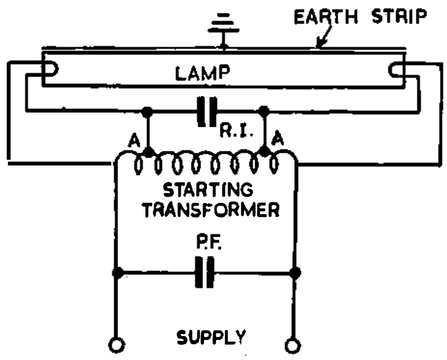

FIG. 12.—CONTROL CIRCUIT FOR HOT-CATHODE LAMP WITH AUTO-TRANSFORMER START.

and losses but virtually limits maintenance to the lamp only. This is the standard Post Office type. When the supply is switched on, mains voltage is impressed across the lamp and the auto-transformer supplies current to heat the filaments. When the latter are sufficiently hot, local discharges around the filaments rapidly link and the discharge between the filaments is produced. The lamp current increases the voltage drop in the choke and the drop across the lamp is reduced to its normal running value of about 120V. Earthed metal close to the tube, usually in the form of a strip running along the tube between lamp caps, is necessary to facilitate rapid striking of the arc. The filaments are permanently energised (although at reduced dissipation after starting), unlike the starter switch circuit where, after starting, the filaments are heated by the discharge only. For lower supply voltages (say 200/220) the supply leads are connected to points A to give a slight step-up of lamp voltage.

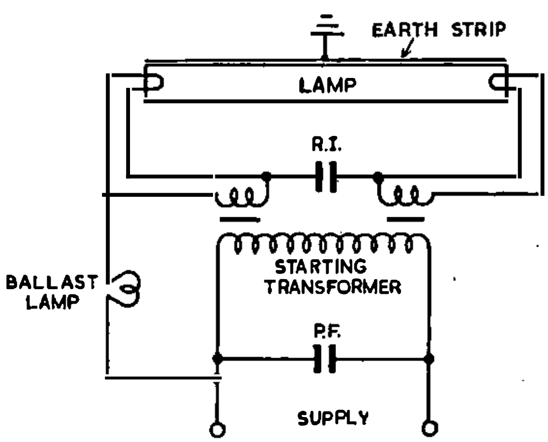

FIG. 13.—CONTROL CIRCUIT FOR HOT-CATHODE LAMP WITH LAMP BALLAST.

The third circuit (Fig. 13) uses a filament lamp as ballast instead of the normal choke. Some of the energy dissipated in the lamp is given out as light to augment that from the fluorescent lamp. The resultant colour is somewhat warmer than that of the fluorescent lamp alone and the cost of the fitting is reduced. The efficiency of this arrangement is about half-way between those of filament lamps and inductively controlled fluorescent lamps; its use is, therefore, largely restricted to small installations, such as for domestic purposes, where initial cost is a more important consideration than low running costs.

Other circuits are in use employing a pulse start technique to give "starterless" starting andat the same time avoid the need for lamps with earth strips. As there is a tendency for the pulse to be applied before the filaments are fully heated, this method sometimes results in short lamp life.

CONCLUSION

In an article of this length only general treatment of the subject has been possible but references have been given to more detailed treatment of the various aspects.

Although Post Office work has not been dealt with specifically, most of what has been said applies equally to the design of Post Office installations. In addition there are several types of installations, such as telecommunications apparatus rack lighting, which need specialised techniques.

As regards future trends it seems probably that the present move towards higher illumination will continue, especially where fluorescent sources are used.

To ensure that lighting installations are well designed, it is desirable that designers should have long and specialised experience in lighting. Alternatively, all the considerations referred to in this article should be catered for by general rules, which can be readily applied to specific cases. The latter course is under consideration in the Post Office, but presents difficulties and cannot be expected to do more than ensure that a good average standard is maintained. Unusual cases would still demand individual attention by specialists.

ACKNOWLEDGMENTS

The author wishes to thank his colleagues in the Power Branch for their helpful criticisms and suggestions, many of which have been incorporated into the article.

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An Introduction to the Principles of Waveguide Transmission

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W. A. RAWLINSON, B.Sc.†

Part 2.—Attenuation, Amplification and Measurement

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In Part 1 of this article the fundamental concepts of electromagnetic wavemotion in waveguide, and methods of launching these waves, were outlined. Part 2 describes means for detecting the waves and shows how they can be attenuated, filtered, amplified and their amplitude measured.

Termination and Attenuation

WAVEGUIDE transmission conditions must be accurately measurable and capable of exact specification if complicated multi-channel communication systems are to be carried. It is essential to be able to amplify, or to attenuate, or detect the waves, to filter out parts of the frequency range in preference to other parts, and, in particular, to measure their strength.

As in line technique, it is necessary to match the load to the characteristic impedance of the line if maximum power is to be transferred. This is particularly important with microwave circuits because energy reflected from a mis-termination may upset the stable operation of the oscillator source, and, also, the time delay on signals suffering multiple reflections in a waveguide circuit causes undesirable distortion of the initial signals. For test purposes a matched load is often required. In waveguide it usually comprises a resistive element inserted in the guide to dissipate the energy. A number of dissipative materials have been used for low-power loads, such as wood, carbon film on cards, a mixture of finely divided iron with a plastic binder, or nichrome deposited on glass sheet. Since any sudden change in the material filling the guide constitutes a discontinuity, a reflection of energy will take place where the resistive material is inserted. Reflections are minimised by making the resistive element with a stepped face so that, in the aggregate, the reflections from the steps cancel. Carrying this process to the limit, a sloping or tapered face is often made on the resistive material as shown in Fig. **13**. The taper can be regarded as an infinite number of steps, from which the sum of the reflections is zero. An external view of a termination having a resistive vane of the kind shown in Fig. **13** is given in Fig. **14**. The vane is a piece of bakelised card coated on one side with carbon, giving a surface resistivity of about 200 ohms per square. The loss

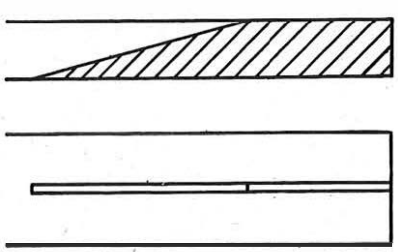

Fig. **13**.—Vane-type Termination or Load.

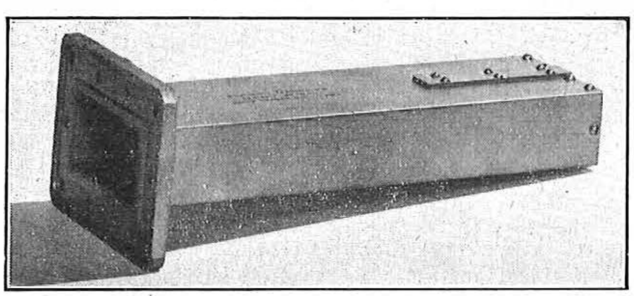

Fig. **14**.—Waveguide Termination as illustrated in Fig. **13**.

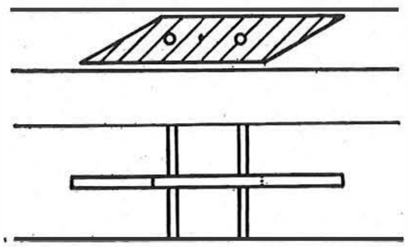

Fig. **15**.—Vane-type Attenuator.

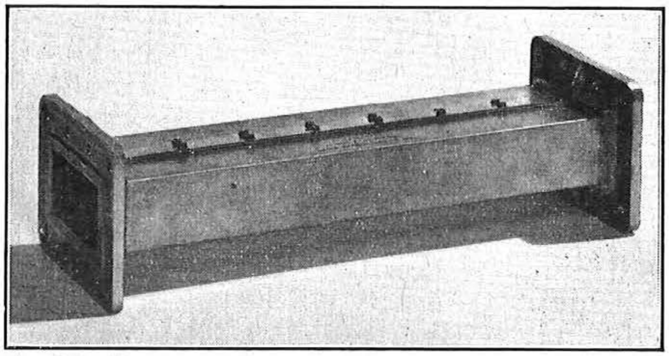

Fig. **16**.—Waveguide Attenuator as illustrated in Fig. **15**.

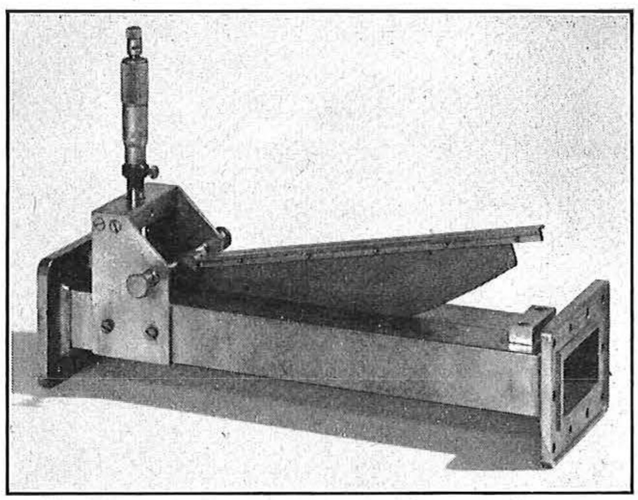

Fig. **17**.—Variable Attenuator using Resistive Card in face of Waveguide.

through the whole of the load needs to be great enough to attenuate to a low value any reflection from the end cover of the waveguide.

Attenuators are built similar to terminations except that the matching taper is introduced on both ends of the resistive element. A typical arrangement for a card or glass vane attenuator is shown in Fig. **15**, and an external view of such an attenuator is shown in Fig. **16**. A form of

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variable attenuator, in which a resistive card passes through a slot in the centre of the face of the guide, is shown in Fig. 17. A micrometer adjustment is provided to vary the amount of card in the electric field. In this case the profile of the card is curved so that at whatever setting the card is placed there is a tapered front to the leading and rear edges of the card.

Detection of Microwave Energy

The detection of microwave energy is usually made by means of crystal diodes. The simplest form of detector is a crystal diode placed across the narrow dimension of the waveguide, i.e., parallel with the electric field, as shown in Fig. 18. The detected output is fed by coaxial cable to the indicating device. The simple arrangement, as shown, often mismatches the guide impedance and causes reflection of energy, and the more refined forms of detector include devices to reduce reflection. For instance, the reactive effect of the diode assembly may be eliminated by arranging the end short-circuit of the guide to be a sliding plunger, thus forming a tuning stub beyond the diode. The resistive mismatch is commonly minimised by using a transforming device such as the cross-bar feed shown in Fig. 19. Fig. 20 shows more clearly the screw adjustment of the short-circuiting plunger. The crystal diode is situated in the turret and the elongated coaxial line output is filled with annular iron dust cores to attenuate to a very low level any microwave energy which has passed the diode.

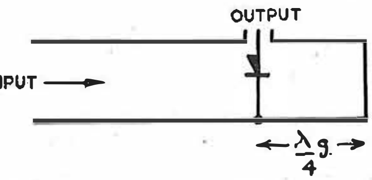

Fig. 18.—Simple Detector of Waveguide Energy.

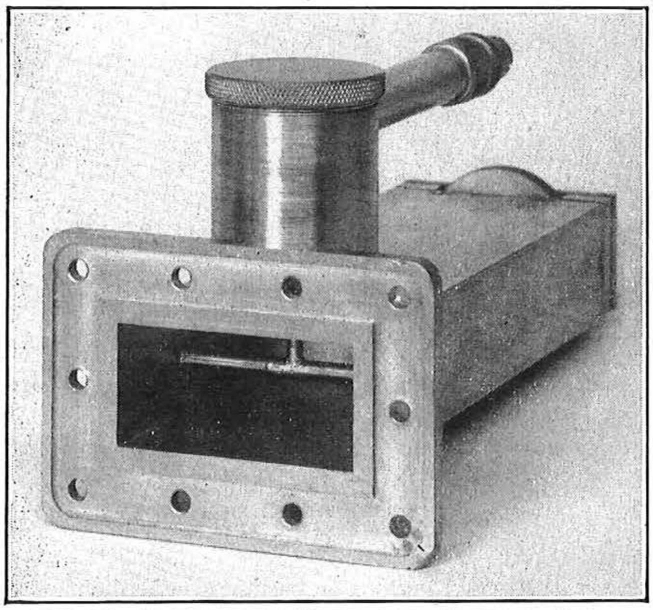

Fig. 19.—Transforming Device with Cross-bar Feed.

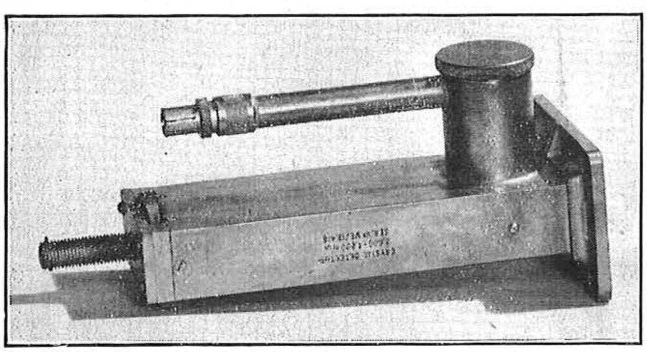

Fig. 20.—Device illustrated in Fig. 19, but showing Screw Adjustment of Short-circuiting Plunger.

Standing-Wave Test Equipment

It has been shown in Part 1[1] that standing waves are produced by a mismatch in the waveguide. The detection and measurement of standing waves is performed by means of a standing-wave meter, of which a simple sketch is given in Fig. 21 and a photograph in Fig. 22. The waveguide has

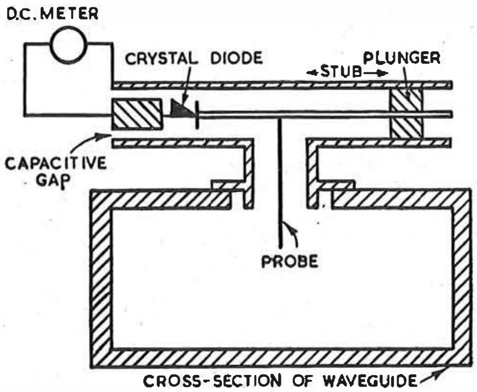

Fig. 21.—Outline sketch of Standing-Wave Meter.

a narrow axial slot along the centre of one wide face for a distance of about two wavelengths. It will be remembered that the current streamlines in this part of the guide are parallel with the axis. Because of this, no appreciable potential difference is developed across the slot and so no energy escapes as radiation into space. If the slot is placed off the axis the current streamlines will be intercepted and the resulting potential difference across the slot causes an electric field to couple with free space. The slot then radiates. In the standing-wave indicator a shielded probe projects through the slot into the guide in line with the electric field at the point of maximum field strength in the guide cross-section. The energy coupled to the probe is detected by a crystal diode and measured on a D.C. microammeter. The probe is mounted on a carriage which can be moved along the guide to measure the field strength at any point under the slot. The device is somewhat analogous to a voltmeter tapped across a line. The impedance is made high by allowing the probe to project only a small distance into the guide, and the detector is made resistive by tuning it with an adjustable short-circuited stub (see Fig. 21). In making the analogy with a voltmeter, however, it must be understood that the standing-wave indicator does not, in fact, measure the *voltage* between the upper and lower faces of the guide, but it indicates electric field strength.

The magnitude of the standing wave is measured by sliding the carriage along the guide and noting the maximum and minimum readings of the detector meter. For some purposes, for example, in determining the impedance of a waveguide component, the position of the carriage at a standing-wave minimum is also required. This is read by means of a scale and vernier on the instrument. The ratio of the minimum to the maximum value of electric field strength in the guide gives the voltage standing-wave ratio, or V.S.W.R. It is necessary, in using the standing-wave meter described, to take into account that the diode detector is a square-law device; hence the V.S.W.R. is found from the microammeter readings by taking the square

[1] *P.O.E.E.J.*, Vol. 47, p. 63.

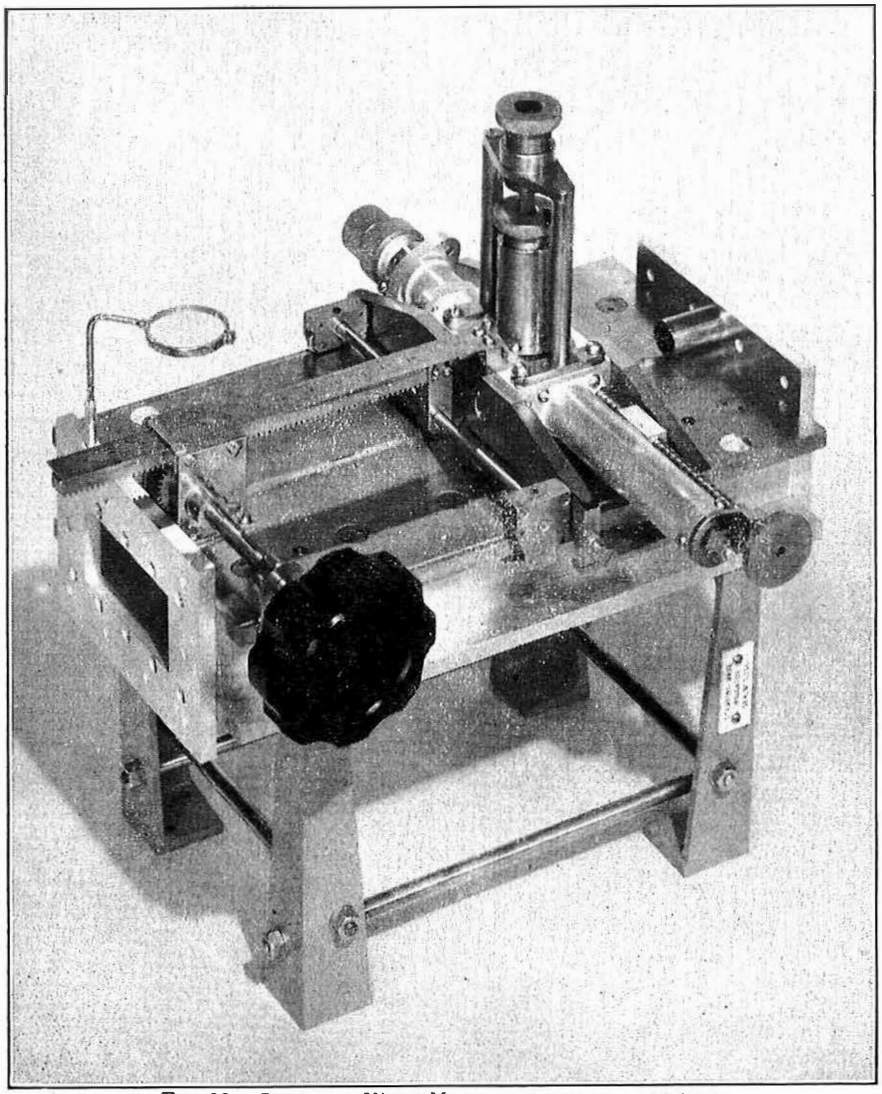

FIG. 22.—STANDING-WAVE METER FOR USE AT 4,000 Mc/s.

root of the division of the minimum by the maximum reading. The value of the V.S.W.R. thus lies between zero and unity. The American practice is to use the inverse definition in which values of V.S.W.R. lie between unity and infinity. In both cases unity V.S.W.R. corresponds with the perfectly matched or reflectionless condition.

Generally, the V.S.W.R. can be regarded as a measure of the match between the input impedance and the waveguide impedance. Familiarity with the technique quickly results in regarding V.S.W.R. as the criterion of goodness of a circuit connection, in the same way as is return loss or reflection coefficient at line frequencies.

The relationships between V.S.W.R., reflection coefficient and terminating impedance are:

V.S.W.R., $$S = \frac{1 - |r|}{1 + |r|}$$

Modulus of Reflection Coefficient,

$$|r| = \frac{1 - S}{1 + S}$$

Normalised Terminating Impedance,

$$Z = \frac{1 + r}{1 - r}$$

Return Loss, in decibels

$$= 10 \log_{10} \frac{1}{|r|^2}$$

$$= 10 \log_{10} \left[\frac{1 + S}{1 - S}\right]^2$$

A typical arrangement of test equipment for the measurement of V.S.W.R. is shown in Fig. 23. The device being

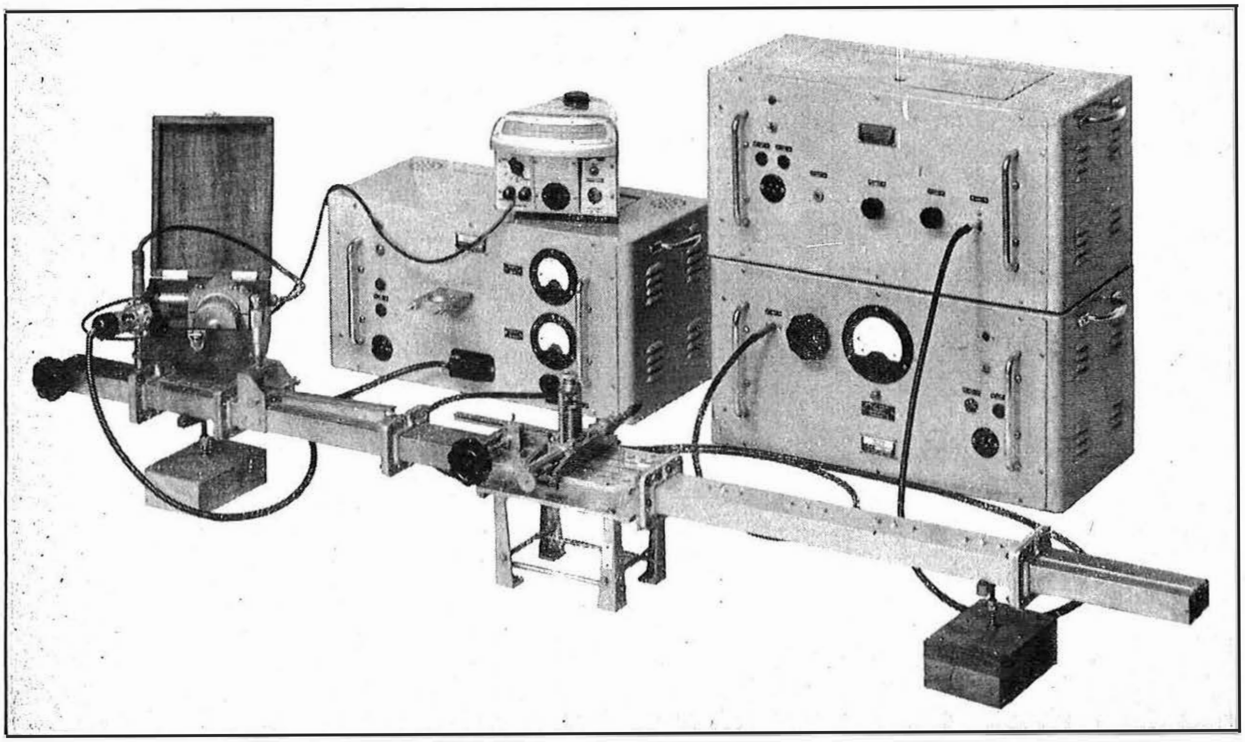

FIG. 23.—V.S.W.R. MEASURING EQUIPMENT FOR WAVEGUIDE COMPONENTS.

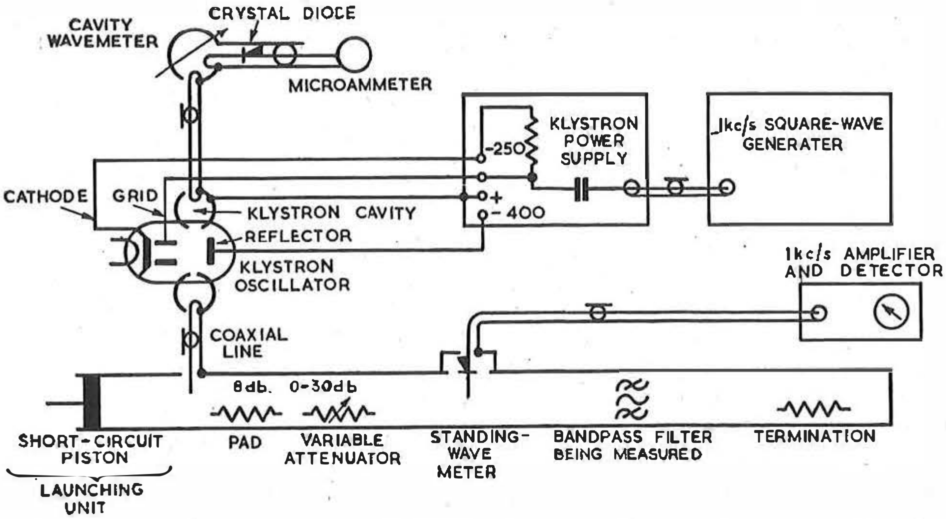

FIG. 24.—SCHEMATIC DIAGRAM OF V.S.W.R. MEASURING EQUIPMENT SHOWN IN FIG. 23.

measured is a waveguide filter and the apparatus used is shown diagrammatically in Fig. 24. The waveguide run comprises a launching unit with a variable short-circuit and probe antenna, a fixed attenuator to improve the impedance of the oscillator, a variable attenuator to adjust the level of energy in the circuit, a standing-wave indicator, a band-pass filter (described later) which is the device being measured, and a matched termination. The method of detection used with the standing-wave meter is slightly different from that previously described. In order to obtain greater sensitivity in this V.S.W.R. measuring equipment the klystron is pulsed with 1,000 c/s square wave on the grid, giving amplitude modulation of the microwave power. The detected output from the standing-wave indicator is therefore a 1,000 c/s square wave whose amplitude is proportional to the square of the electric field strength in the waveguide. The detected output is amplified in a high-gain amplifier tuned to 1,000 c/s and its amplitude is displayed on a microammeter.

A cavity wavemeter is shown connected by a coaxial line to the klystron. A larger external view of the wavemeter is shown in Fig. 25. A small amount of energy is extracted from the klystron cavity and used to excite the cavity of the wavemeter by means of a small fixed loop. A plunger can be moved into the wavemeter cavity by means of a micrometer head until the natural resonance of the cavity coincides with the klystron frequency. Resonance in the cavity is detected by extracting energy from the wavemeter cavity using a second loop (not the exciting loop), connected to a crystal diode and a microammeter. With the aid of a calibration chart the frequency is read from the micro-ammeter setting of the wavemeter.

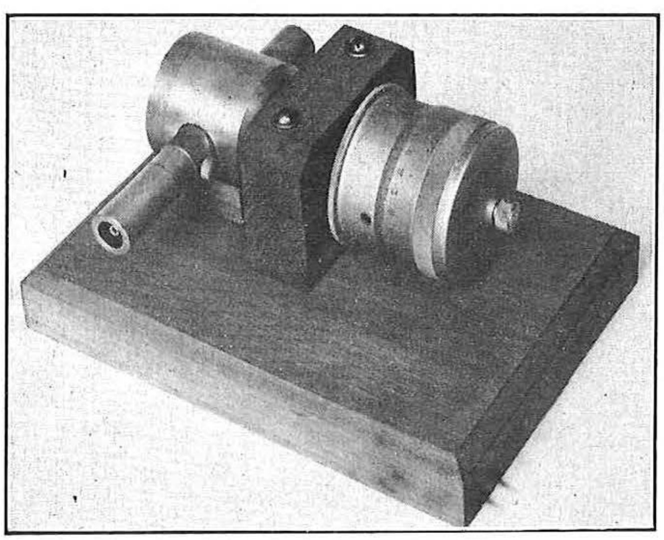

FIG. 25.—WAVEMETER N.P.L. TYPE 2B (2,000-5,600 Mc/s).

INSERTION-LOSS TEST EQUIPMENT

The measurement of insertion loss is possible in several ways, one of the simplest of which will be described here. The method is the microwave equivalent of that commonly employed at lower frequencies, in which the device to be measured is inserted into the line connecting an oscillator and detector. The level at the detector changes by the magnitude of the insertion loss as the device is inserted. In a waveguide circuit the insertion of the device to be measured is performed by means of switches. Since the switches at microwave frequencies are novel, as compared with their low-frequency counterparts, they will be described in detail.

A photograph of one type of waveguide switch is shown in Fig. 26. The switching operation is performed by hand-

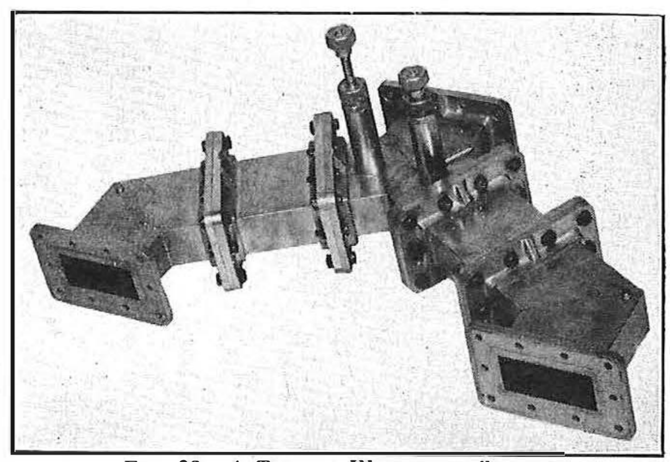

FIG. 26.—A TYPICAL WAVEGUIDE SWITCH.

operated plungers which direct the electromagnetic energy entering the stem of the Y into either of the two remaining arms. The vertical motion of the plungers is limited by adjustable stops at the extremities of the plunger travel. In the "up" position the plunger is flush with the inside surface of the top face of the guide and does not impede the transmission of energy. In the "down" position the plunger acts as a short-circuit in the guide, and, at the same time, behaves as a reflector to deflect the energy down the adjoining branch of the Y, in which the plunger is withdrawn. The transmission path can be directed to the other outlet of the switch by changing over the settings of the two plungers. Corners are introduced into the two outlets to bring the axes of the guides connected to them into parallelism. The corners have deflecting posts fitted where the screwheads appear in Fig. 26 to direct the energy to the outlets without reflection back to the input.

A complete assembly for the measurement of insertion loss is shown in Fig. 27, and diagrammatically in Fig. 28. The launching of the energy is identical with that for the measurement of V.S.W.R. already described. The two Y-switches enable the energy to be transmitted either through

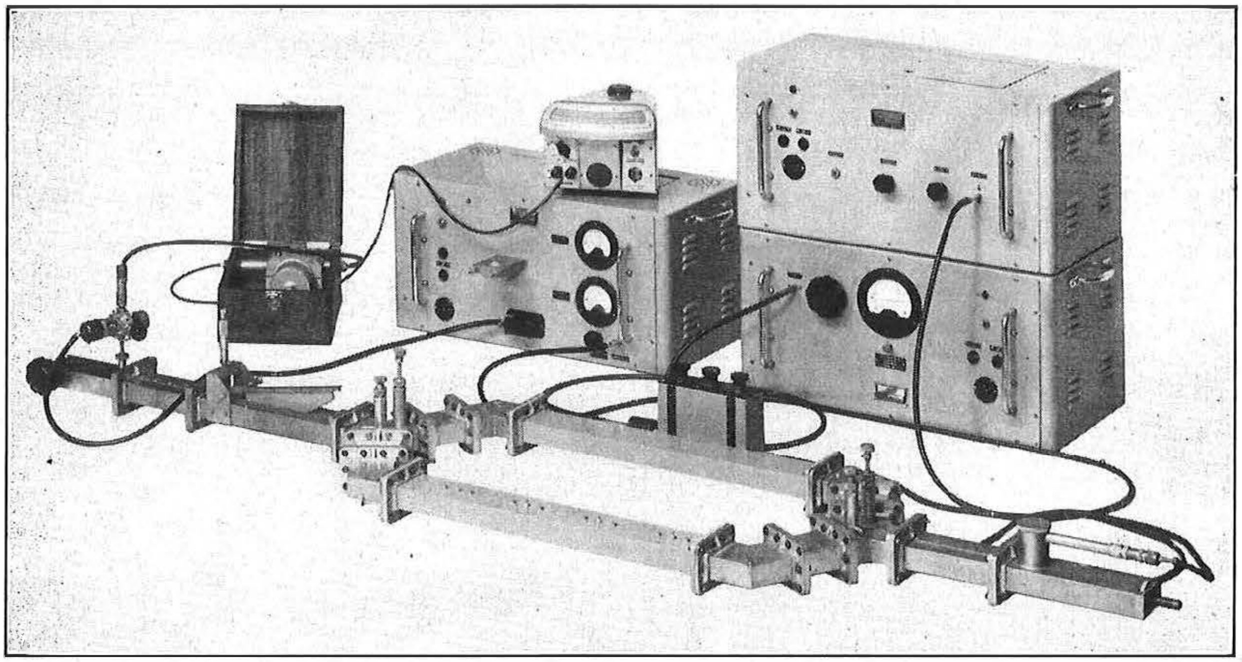

FIG. 27.—INSERTION-LOSS MEASURING EQUIPMENT FOR WAVEGUIDE COMPONENTS.

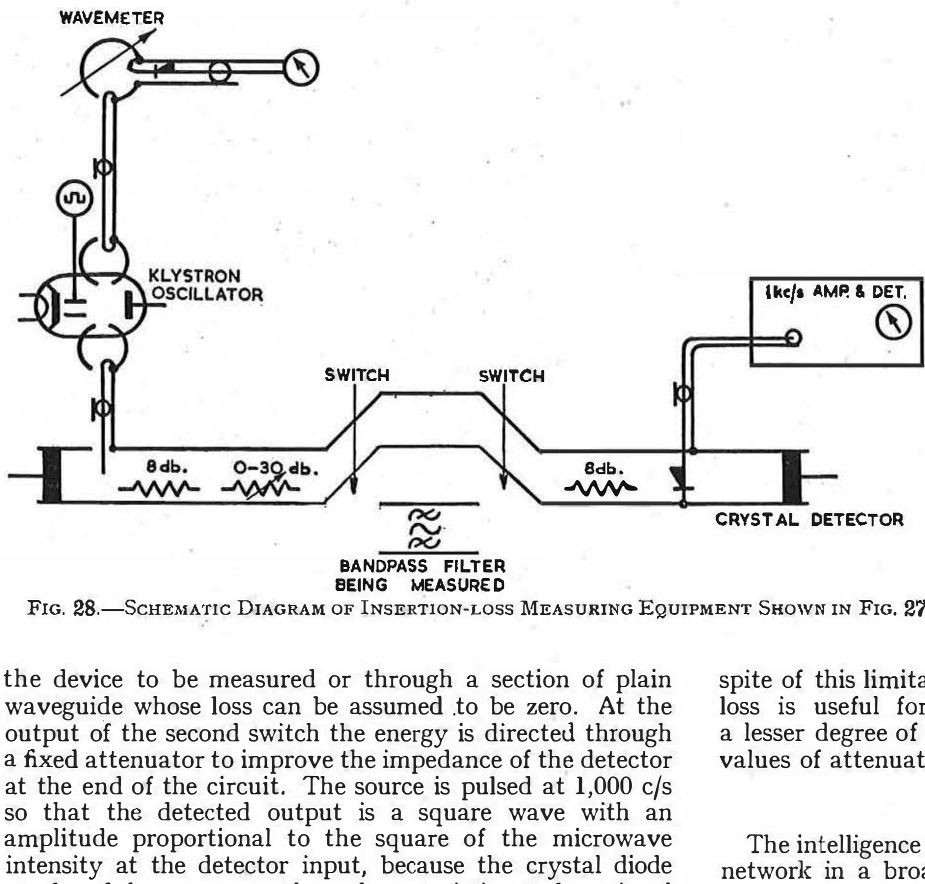

FIG. 28.—SCHEMATIC DIAGRAM OF INSERTION-LOSS MEASURING EQUIPMENT SHOWN IN FIG. 27.

the device to be measured or through a section of plain waveguide whose loss can be assumed to be zero. At the output of the second switch the energy is directed through a fixed attenuator to improve the impedance of the detector at the end of the circuit. The source is pulsed at 1,000 c/s so that the detected output is a square wave with an amplitude proportional to the square of the microwave intensity at the detector input, because the crystal diode employed has a square-law characteristic at low signal levels. The 1,000 c/s output of the detector is extended through a precision variable attenuator to a 1,000 c/s tuned amplifier and detector which is used as a level indicator.

The measuring process is as follows. Energy is first directed through the device to be measured. With the precision audio-frequency attenuator set to zero loss and the 1,000 c/s amplifier and detector set to high gain, the microwave attenuator is adjusted to give a suitable indication on the meter of the 1,000 c/s amplifier and detector. The microwave energy is next switched through the section of plain waveguide and the audio-frequency attenuator adjusted until the meter indication on the 1,000 c/s amplifier and detector is the same as before. The setting of the audio-frequency attenuator then shows twice the insertion loss, in decibels, of the microwave device being measured. The factor "two" is introduced into the attenuator reading because of the square-law characteristic of the detector.

The detector is assumed to be square-law throughout the range of microwave energy level presented to the detector. In practice the law may depart from the ideal, especially when measuring high values of insertion loss. It is therefore necessary to calibrate the detector output against microwave input, for accurate results, and also to ensure that the initial level at the input of the detector is known. In spite of this limitation the method of measuring insertion loss is useful for losses up to 30 db. provided that a lesser degree of accuracy can be accepted for the higher values of attenuation.

FILTERS

The intelligence to be transmitted through a transmission network in a broadband microwave radio system usually occupies only a relatively small frequency band, say 100 Mc/s at the most. Even if the filter passband is as wide as 100 Mc/s the relative bandwidth is only 2·5 per cent. when it is centred on a frequency of 4,000 Mc/s. This is an important consideration for it results in a simplification in the physical form of the filter, because resonant elements can be used rather than inductance and capacitance elements. This simplification is akin to using quartz crystals in lower frequency filters. The resonant element in microwave filters is commonly a resonant cavity constructed in the waveguide itself. When two obstructions are inserted into a waveguide at a distance L apart along the length of the guide, the section of guide between the obstructions becomes resonant at a frequency whose wavelength in the guide is $2L$, or an integer multiple of $2L$. This is analogous in principle to the sound resonance in a closed organ pipe. The two obstructions behave as planes between which the energy reflects to and fro, each reflection at the input being in phase with the energy introduced at that end. The obstacles are usually metal plates or posts across the guide. In Fig. 29 a four-cavity waveguide filter is shown with

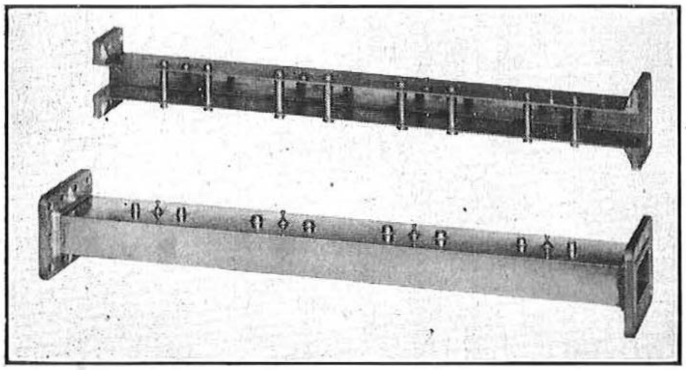

FIG. 29.—4,000 Mc/s POST-TYPE WAVEGUIDE FILTER.

posts as obstacles in the resonant cavities—the cavities are identifiable as the sections of waveguide having a small tuning screw between the pairs of posts. The cavities are carefully spaced relative to one another and are each tuned to the midband frequency of the filter. Energy is introduced into the cavity at the first of the pair of posts and extracted at the second. The diameters and positions of the posts can be calculated by mathematical design processes to give a bandpass filter which reflects very little energy in the pass band, i.e. it has low pass-band attenuation, and which reflects very nearly all the incident energy, i.e., gives high attenuation, at frequencies above and below the pass band.

The diameters of the posts are large, say up to a fifth of the broad dimension of the guide, for narrow-band filters, and small for wide-band filters. The sharpness of cut-off at the edges of the pass band is determined by the number of cavities employed and by the graduation of the post diameters throughout the length of the filter. Bandwidths from 8 Mc/s to 50 Mc/s are common, with a V.S.W.R. in the pass band better than 0·9. The insertion loss in the stop regions varies, according to the design, from 10 db. to 100 db. at three times the bandwidth from the midband frequency—the bandwidth being specified between the frequencies for a given V.S.W.R. at the edges of the pass band and not between the frequencies for 3 db. loss as is common in capacitor-inductor type filters.

It is also possible to make, not only band-pass filters, but band-stop filters, and filters which attenuate certain modes of transmission in the guide while transmitting other modes. Bands of frequencies in the same waveguide may also be branched one from the other into separate waveguides as, for instance, when several transmissions are received from the same aerial. In all filtering problems at microwave frequencies, however, the precision of mechanical construction is a feature of major importance which becomes all the more critical as the frequency is increased.

AMPLIFIERS

The amplification of broadbands of energy at microwave frequencies is not a straightforward matter. Three methods are commonly employed, according to the prevailing circumstances. The first, using a suitably constructed triode valve, requires amazingly fine tolerances in the construction of valve electrodes that are themselves only a few thousandths of an inch apart. Triodes are satisfactory at 2,000 Mc/s but are unlikely to become as widely used as the klystron or, for really wide band systems, as the travelling-wave valve. Both of these types of amplifier have already been adequately described in this Journal[2] so no details will be repeated here.

The travelling-wave valve is proving as epoch-making in microwave radio communication technique as the introduction of negative feedback was to amplifiers for coaxial cable transmission. Undoubtedly there is much scope for development, on the part of valve manufacturers, in the design of high-power and lower noise types of travelling-wave valve. As their research bears fruit, engineers should be able to provide long-distance microwave trunk systems that are equal in performance and comparable economically to the best coaxial cable installations.

CONCLUSION

In conclusion, it must be emphasised that microwave engineering is relatively new in the British Post Office and there is still much development to be done before a microwave radio system can provide as many circuits, conforming to the accepted standards of trunk transmission, as a wide-band trunk cable system. Progress will certainly be rapid, and the Post Office Engineering Department has shown its faith in the outcome by offering every encouragement to microwave system development.

[2] *P.O.E.E.J.*, Vol. 43, Part 3, p. 148 *et. seq.*

Book Reviews

"A Textbook of Servomechanisms." John C. West, B.Sc., Ph.D., A.M.I.E.E., A.M.A.I.E.E. English Universities Press, Ltd. 238 pp. 140 ill. 25s.

The subject of servomechanisms became of extreme importance and was largely developed during the last war, when automatic-control mechanisms were introduced and successfully used under operational conditions. The automatic tracking of an aircraft in flight by a radar aerial was probably one of the first applications of automatic control, and this enabled auto-following searchlights to be constructed, and led to the automatic laying and training of large guns both on land and sea. Instrument-type servomechanisms formed the basis of analogue computers used as predictors for gunnery.

It appears that many Universities have introduced the subject into the engineering curriculum at undergraduate level, and this book is written for such students. It assumes an elementary knowledge of the Calculus, and of Electronics. The subject is developed from simple examples, and for this purpose a model is described early in the text, and used for reference throughout the book—an excellent idea. Argument is invariably from the comparatively simple particular case to the more recondite generality, and is clear and concise. Of particular interest is the treatment of servomechanisms according to the well-known stability theory of Nyquist, long applied to feed-back amplifiers.

Each chapter concludes with worked examples culled from University Examination papers, and the book is to be recommended to any concerned in the art—despite the astonishing revelation (p. 35) that ". . . . tachometer-generators have quite a small maximum-load current, because the armature is wound with many turns of fine wire . . . ." with the implication that such an arrangement makes armature reaction negligible. Surely Dr. West has heard of Ampere-turns?

A. W. M. C.

The Measurement of Speech Level

J. N. Shearme and D. L. Richards†

U.D.C. 621.317.725: 621.317.34: 621.395.81

The waveforms of electrical speech signals are very complex, but speech levels on telephone circuits may be measured with very simple apparatus provided it is carefully specified. The precision thus obtainable, however, is rather poor owing to uncertainties introduced by the observer. For laboratory use a rather more complicated measuring tool has been developed which eliminates observer errors.

Introduction.

THE level of speech on a line or at a particular point in a telephone circuit can be crudely measured with very simple apparatus, namely an ordinary A.C. rectifier-voltmeter. It is only when relatively precise measurements are required that serious difficulties manifest themselves. These difficulties arise from the complex nature of the waveform of speech and the correspondingly complex movement of the pointer of an A.C. voltmeter to which it is applied. Fig. 1 shows typical movements of a rectifier-voltmeter pointer during about 10 sec. of continuously

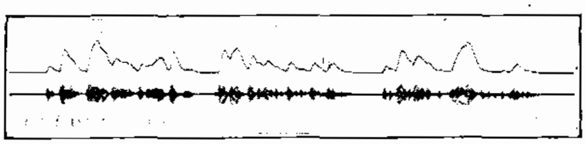

FIG. 1.—WAVEFORM OF SPEECH (LOWER TRACE) AND CORRESPONDING DEFLECTIONS OF VOLTMETER NEEDLE (UPPER TRACE).

spoken speech. It is not surprising that the interpretation by the observer of these movements presents considerable difficulty even when he is assisted by a "rule" such as that recommended by the C.C.I.F. The C.C.I.F. method is to observe that level which is, on the average, exceeded once every 3 sec.

A "peak reading" instrument having a short rise time but a long decay time (e.g., B.B.C. Peak Program Meter) proves to be no easier to read on speech.

The extent of the range of amplitude of speech waveforms is illustrated by Fig. 2. Curve (*a*) shows the distribution of instanteous amplitudes while Curves (*b*), (*c*), (*d*) and (*e*) give distributions for the power integrated over several values of duration. The dynamic characteristics of conventional A.C. voltmeter-type speech voltmeters are such that the distribution of readings on a given sample of speech would be represented by a curve approximately in the region of Curves (*c*) or (*d*).

When a quantity is varying widely, a stable reading can often be obtained by averaging over a relatively long period of time. It is not difficult to devise apparatus which reads the r.m.s. value integrated over, say, 15 sec. or more. A measurement with such a meter is useful on continuously spoken speech where the "silent gaps" are a relatively small proportion of the whole and are due only to pauses between sentences, etc. Telephone conversational speech, however, is extraordinarily fragmentary, partly owing to its both-way nature, and "utterances" average about 3 sec. and practically never reach 15 sec. Many "utterances" in telephonic conversation are of only one or two words and last less than 1 sec. The fragmentary characteristics of telephone conversation, therefore, prohibit the general use of a long-time integrating method. It is possible, however, to use a device which integrates over, say, 1 sec. and holds the reading until released by the operator. A number of samples can then be taken while speech is present, the readings for each sample being subsequently averaged.

Specification of a Conventional Speech Voltmeter.

In principle a reading taken using a conventional A.C.

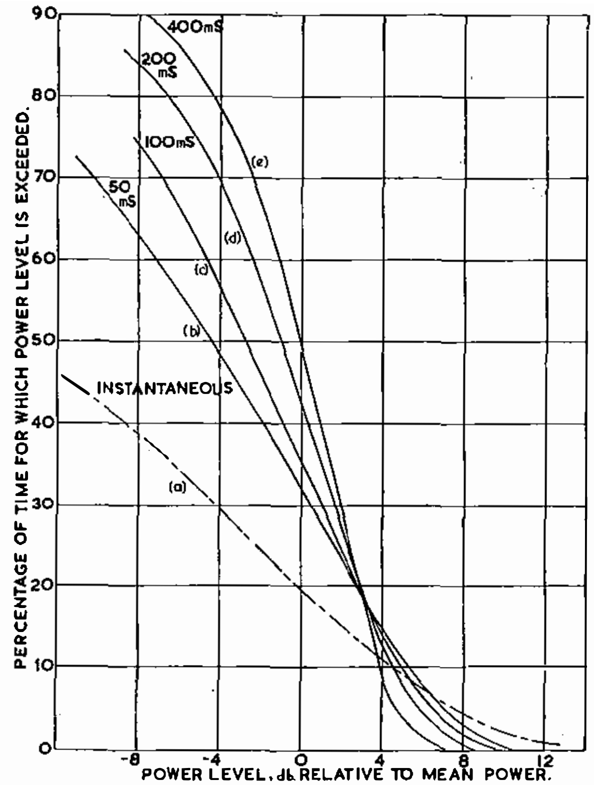

FIG. 2.—DISTRIBUTION OF MEAN SPEECH POWER AVERAGED OVER INTERVALS OF 50, 100, 200 AND 400 mS.

rectifier-voltmeter type of speech voltmeter can be defined by specifying the following.

(1) *The reference level* or voltage of pure tone (say 1,000 c/s) which defines the zero db. mark on the speech voltmeter. The voltages corresponding to 6 mW or 1 mW in 600 ohms have been used, but the British Post Office Speech Voltmeter is calibrated relative to 1V.

(2) *The integration time;* defined as the duration of a constant amplitude pulse of pure tone which will cause the needle to rise to a value which is 63 per cent. of the angular deflection which would have been obtained if the same amplitude had been applied indefinitely. Integration times of 100 to 200 mS are used for different meters. Alternatively the 99 per cent. (or 90 per cent.) rise time may be specified; this is the time which must elapse after application of a constant level of pure tone before the needle has risen to 99 per cent. (or 90 per cent.) of the final angular deflection. The American vu-meter is specified in this manner. The relationship between integration time and rise time is somewhat complicated because it is a function also of overswing.

(3) *Overswing;* unless the meter movement is critically damped or over-damped it will rise to a maximum value higher than the final value. The amount of overswing is usually small, from 0 to 5 per cent. of the final angular deflection.

(4) *Law of rectification;* the relationship between the instantaneous output from the rectifier and its instantaneous input can be expressed, for a single polarity, in the form: output = constant × $(\text{input})^k$. The index k is ideally equal

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to 2 (square-law rectification) but values from 1 to 2 may be used.

(5) *Method of interpreting the deflections;* The effect of the physical variables (2), (3) and (4) for a given method of interpreting the readings (actually the C.C.I.F. method already referred to above) may be summarised as follows. For a given integration time (2) and law of rectification (4), the effect of varying the overswing from 0 (critical damping) to 5 per cent. (the practical range) is very slight and may be neglected.

The effect of varying the integration time is as follows, expressing the reading relative to an integration time of 100 mS.

100 mS	150 mS	200 mS	250 mS	300 mS
0	— 0·6 db.	— 1·2 db.	— 1·9 db.	— 2·6 db.

This relationship is practically independent of whether the measurement is made on high quality or commercial telephone speech signals.

The effect of varying the law of rectification (4) depends somewhat on the type of speech signals. The results for three laws of rectification, defined by the value of the index k are tabulated below. Full-wave rectification is essential because speech waveforms are frequently unsymmetrical. The results are expressed relative to $k = 2$.

k	2	1·5	1·0
High-quality speech	0	— 1·1 db.	— 2·8 db.
Commercial (British Post Office sets) speech	0	— 1·6 db.	— 3·6 db.

When the foregoing are known, allowance may be made for them in comparing readings taken in different circumstances; the human element in interpreting the deflections, however, introduces considerable uncertainty. The error due to the human observer may be separated into two parts: a random component and an observer bias. The random error is a measure of the inaccuracy with which a given observer can repeat his reading on a given speech sample. This component is such that a trained observer will yield 5 per cent. of readings as much as or greater than 2 db. away from the mean value he would obtain if he were to make a large number of observations on the same speech sample.

The observer bias is a measure of the extent to which the mean readings for different observers differ from each other owing to differences in the precise interpretation of the reading instructions. Even with trained observers a total range of 4 db. is encountered.

Comparison of certain Conventional Speech Voltmeters.

In spite of the difficulties which have been mentioned there are many purposes for which the conventional A.C. rectifier type of speech voltmeter is suitable. These include controlling the speech level to the correct value at the input to a circuit or apparatus, and other applications where continuous monitoring of the level is required. In such applications, measurements obtained after some delay are not acceptable even though they may be more precise. Three important examples of conventional speech voltmeters are the C.C.I.F. Volume Indicator, the British Post Office Speech Voltmeter and the American vu-meter. The first two are read by the C.C.I.F. method referred to earlier but the vu-meter is read differently, namely by taking the average of the peak deflections about every 10 sec. after excluding the two or three highest. This yields a reading some 3 db. lower than the C.C.I.F. method. (The exact difference is at present being investigated.)

Particulars of these meters together with their relative readings (allowing for differences in calibration level) are as follows:

Meter	Zero-reference level	Integration time (mS)	Over-swing (per cent.)	99 per cent. rise time (mS)	Rectifier law	Relative Reading	
						C.C.I.F. method	vu-meter method
B.P.O. Speech Voltmeter	1 volt	100	2·5	230	$k=2$	0	—
C.C.I.F. Volume Indicator	6 mW in 600 ohms	200	0·5	(410-650 depending on over-swing)	$k=2$	−6·8 db.	—
Vu-meter	1 mW in 600 ohms	(120)	1-1·5	300	$k=1·4$	(*a*) +0·5db. (*b*) −0·1	(−3db.)

Notes.—Figures in brackets are approximate only:
(*a*) high-quality circuit.
(*b*) commercial telephone circuit (B.P.O. Subscribers' Sets using Transmitter Inset No. 13).
The figures in the penultimate column are reliable to within about ± 1 db.

Reference Telephonic Power is defined by the C.C.I.F. (in the documents of which it is termed *volume de reference*) as that speech level which will produce a 0 db. reading on a C.C.I.F. Volume Indicator. From the above data such a speech level would yield a reading of between + 5·8 and + 7·8 db. on a speech voltmeter.

The above relationships are valid for both continuously spoken speech (e.g., passages read from a book) and telephonic conversational speech. They do not apply, however, for such speech material as single words or syllables used in articulation testing, nor for specially chosen phrases such as "can con by dace also," "one two three four five" or "Paris, Bordeau, Le Mans, Saint Leu, Léon, Loudun," which are used for loudness balancing.

For continuously spoken speech it is possible to determine other relationships as follows which are expressed here relative to the speech voltmeter reading:—

Measurement	Circuit	
	High Quality	Commercial B.P.O. Sets
Speech Voltmeter reading	0	0
Mean power (db. rel. to 1 volt) ..	— 6·9 db.	— 8·2 db.
Level not exceeded for 99% of time (db. rel. to 1 volt)	+ 5·1 db.	+ 6·0 db.

A slight departure from the conventional A.C. voltmeter type of speech voltmeter, in which the rise and decay times are equal, is a "peak" rectifier voltmeter having a very short rise time (say 2 mS) and a comparatively long decay time (perhaps 2,000 mS). The B.B.C. Peak Program Meter is of this type and, on speech, yields readings 1 or 2 db. above the 99 percentile levels given in the table above.

In spite of the apparently slower movements of the needle of this instrument it proved no superior to the conventional types from the point of view of observers' random error or observer bias.

A Speech Voltmeter which is Free From Observer Errors.

For many laboratory purposes the observer errors indicated above are not acceptable. The apparatus to be described below was developed from an attempt to interpret in a precise manner the C.C.I.F. method of reading a conventional speech voltmeter. It proved impossible, however, to use this interpretation quite literally, but most of the basic principles have been retained.

The apparatus, referred to as the Speech Voltmeter Type 4A, consists first of an attenuator (as sensitivity control), amplifier and full-wave square-law rectifier (see **Fig. 3**). Instead of connecting the rectifier output direct to a moving-coil voltmeter or milliammeter (as in the conventional type

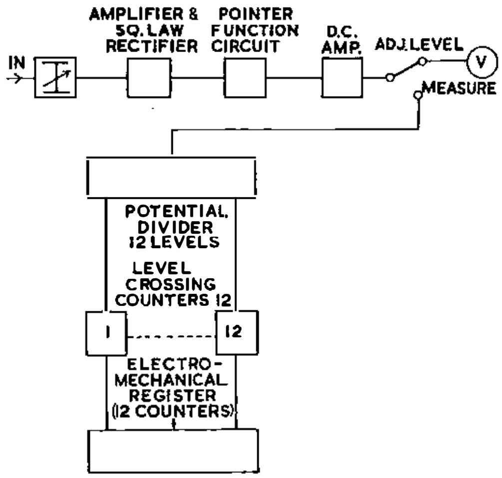

FIG. 3.—SPEECH VOLTMETER TYPE 4A.

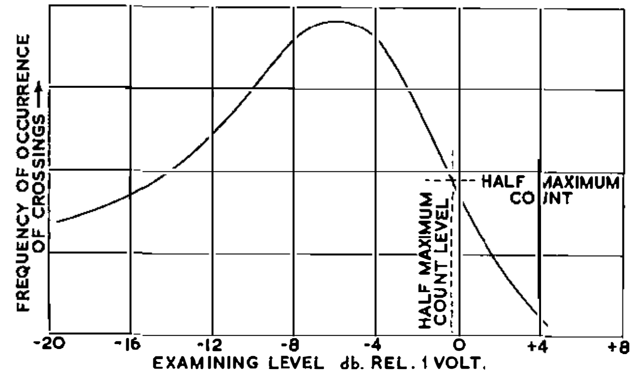

FIG. 4.—TYPICAL DISTRIBUTION OF LEVEL CROSSINGS OF A POINTER FUNCTION.

of speech voltmeter) it is connected to an electrical circuit (termed a "pointer function" circuit) whose electrical constants are analogues of the mechanical constants of a moving-coil instrument. In this way the output from the pointer function circuit is an electrical analogue of the angular deflection of the moving-coil instrument which it replaces. (An example is the upper trace of Fig. **1**.)

The pointer function circuit output (or pointer function itself) is connected to a potential divider which has 12 outputs at 1 db. intervals.

Each output is connected to an electronic trigger which emits a pulse every time a certain voltage level (actually 10V) is exceeded. The number of pulses emitted (or the number of times a given level of the pointer function has been exceeded) is counted on a mechanical counter (subscriber's meter).

In a given time the number of "level crossings" is a function of the "examining level" as shown in Fig. **4**. For continuously spoken speech the maximum value of this curve corresponds to a rate of 1·5 per sec. for a pointer function circuit having 100 mS integration time. For continuously spoken speech this maximum rate varies little from one speech sample to another; with conversational speech, of course, this maximum depends on the proportion of silent intervals in the speech sample.

A single value of level can be derived in a useful manner from this curve by taking the level at which the count rate is half the maximum value. The level corresponding to the C.C.I.F. definition is somewhat higher than this and a value of 3 db. higher has been determined empirically. (Once every 3 sec. corresponds to a count rate of 0·33 per sec. which is about 0·22 of the maximum value).

The Speech Voltmeter Type 4A is, therefore, used to obtain the level for "half maximum count rate" and 3 db. is added to give the derived Speech Voltmeter reading in accordance with the C.C.I.F. method of interpretation. Used in this manner the Speech Voltmeter Type 4A can be used to give a reliable reading (repeatable to say 0·1 db. on a given sample of speech) even for the most fragmentary conversation.

Book Review

"Electronics." A. T. Starr, M.A., Ph.D., M.I.E.E. Sir Isaac Pitman & Sons, London. 395 pp. 350 ill. 32s. 6d.

The University of London has recently split the subject of Telecommunications, one of several which can be offered for the degree of electrical engineering, into two—Telecommunications and Electronics. The growth of the subject, and the large industry dependent on it, can be held to justify the split. Dr. A. T. Starr, well known for his book on electric circuits and filters, set himself the task of writing separate books to cover the two new syllabuses; the first, on Electronics, is now published.

Plenty of facts, derivations and descriptions are packed into the book, which is divided into chapters on: physical fundamentals; valves; rectifiers; circuit theory; amplifiers, oscillators and detectors; and applications. The first three (and some of the fourth) can be studied with advantage by students of physics, and some of all the chapters by students preparing for appropriate Higher National certificates and graduateship of the I.E.E.

To pack the whole of the physical fundamentals of electronics required by a student into 55 pages is a task beyond any author. A brave attempt is made, never losing a sense of proportion, but here and there the brevity necessary may puzzle some readers and may be the cause of errors noted. Thus when metastable states are dealt with the text implies that metastable states are reached by electrons being raised in energy without mention of partial falling; moreover the diagram is misleading in showing direct transitions between metastable states and the ground state. Similarly, the chapter on valves is not free from mistakes, for much the same reason. Impurity centres (in galena) can not *be* positive holes, though they may *give rise* to them. There is no "complex interaction between the electrons of the scanning beam, the photo electrons and the secondary electrons" of a television camera tube. Moseley is credited with establishing the modern theory of the atom. The section on Geiger counters in particular contains several misleading sentences.

Rectification seems adequately dealt with and the chapter on circuit theory contains analyses of all the more important passive networks. The author's choice of subject matter in the next chapter, on amplifiers etc., seems sound; non-linear distortion receives less treatment than is usual. Nyquist's criterion for stability is mentioned for feedback amplifiers, but Bode's alternative is not, perhaps because minimum-phase-shift networks are not.

Some of the applications described are hardly electronic—except in so far as conduction in copper, or ferromagnetism, is electronic—e.g. the metadyne, and amplidyne and strain gauge. The chapter lacks the force of some of the earlier ones. The last 60 pages are devoted to Appendices; algebraic and trigonometric functions, Laplace transform pairs, some vector equations and many useful formulae are listed.

Many questions from examination papers are answered in the text and others set at the ends of chapters. The book goes a long way towards fulfilling its purpose and should be a good investment for many students. The price is reasonable.

J. R. T.

Inter-dialling between a Director Area and a surrounding Non-director Area

H. S. WATERS†

Part 2.—Facilities required for a Tandem Dialling Scheme using Register-Translators

U.D.C. 621.395.636

It was shown in Part 1 that the preferred long-term solution of the director fringe area problem is, from the engineering viewpoint, a solution which calls for the provision of register-translator equipment at each originating exchange. The register-translators, which give the same basic facilities as the director, would be taken into use only for outgoing junction calls, the existing procedure for calls within the local numbering scheme being unchanged. Part 2 discusses the scheme now being developed to cater for the interim extension of 4-fee dialling by non-director subscribers situated in the fringe of a director area. The scheme differs from the preferred long-term plan in certain respects, but follows the same general lines in order not to complicate any future extension of the subscribers' dialling range.

Review of Existing Subscriber-Dialling Facilities.

In addition to dialling 3-letter codes for calls within the director area, subscribers connected to director exchanges equipped for multi-metering can now dial to exchanges in the fringe which are within 15 miles chargeable distance of the central group of exchanges, e.g., up to 20 miles of Oxford Circus in the case of London. The codes comprise two letters and one numerical digit for access to 4-digit non-director and unit automatic exchanges, e.g., WA2 for Watford, and two letters for access to 5-digit non-director exchanges, with the first numerical digit accepted as the 3rd code digit, e.g. SL for Slough.

In the reverse direction, non-director subscribers in the director fringe can dial to director exchanges in the central area by dialling the digit 7 and 3-digit numerical codes, all calls being multi-metered at a fixed fee for the route. These subscribers also dial level 8 codes for access to other exchanges within 15 miles, including director exchanges outside the central area, when the required exchanges are directly connected.

At present, however, non-director subscribers are not allowed dialling access to indirectly connected non-director, unit automatic and manual exchanges—or to indirectly connected director exchanges outside the central area.

General Comments on Extension of Dialling Facilities.

In 1948/9 an Engineering Department Study Group examined the problem of extending the subscribers' dialling range beyond the present limit of 15 chargeable miles and made recommendations which included the allocation of 3-digit exchange codes for dialling up to 25 or 30 miles. The many difficult problems of an administrative, traffic and engineering nature involved in such an extension of dialling range are under discussion.

There is an immediate need, however, for non-director subscribers in director fringe areas, particularly around London, to be able to dial to *all* director exchanges within 4-fee range; also to dial to all other exchanges within 4-fee range to which dialling is practicable, i.e., to include dialling access to indirectly connected exchanges.

Whilst the long term solution for an extended subscribers' dialling range of 25 chargeable miles is one in which 4-digit codes may be used for access to director exchanges, the immediate need is to cater for the present range of 15 miles, which can be met by using 3-digit codes. A block of 40 3-digit codes in each 1st digit series could be allocated to the director exchanges in accordance with one solution mentioned in Part 1.[1]

To retain the existing procedure for calls within the local numbering scheme, and to avoid unnecessary disturbance to existing equipment it is necessary for outgoing junction calls to be initiated by dialling a prefix digit, followed by the wanted exchange code and subscriber's number.

To simplify the dialling instructions and procedure the codes used must be the same for all originating points. This demands the provision of register-translators at the originating non-director exchanges in order that the codes may be translated into the required routing digits, which will vary depending on the location of the originating exchange within the network.

Thus the basic requirements to be satisfied by the register-translator equipment are the determination, from the 3-digit code, whether the call is to be allowed or barred, the fee for an allowed call and the routing digits needed to direct the call to its destination. As these functions take place during the setting-up of the call, the register equipment needs to be associated only for this comparatively short time. These facilities can be provided by fitting level relay sets, each of which includes a hunter for associating the register-translator equipment and can store information on the fee to be charged.

The foregoing covers untimed calls up to 4-fee range but if, at a later date, the subscribers' dialling range is extended to say 25 miles, retention of the present basis of charging would require the provision of timing equipment. Moreover, at least around London, such an extension of the dialling range would probably require an increase in the code capacity above that proposed for the interim scheme. These aspects are discussed at greater length later in this article.

Use of Level "1" of 1st Selectors at Non-Director Exchanges.

At non-director exchanges level 1 of 1st selectors has not been used in the past owing to the incidence of false calls due to "flicks" and tapping line faults. However, this level is suitable for trunking to register equipment because false calls in most cases would not lead to wrong numbers but to incomplete register set-up and the connection of N.U. tone.

Accordingly, it is proposed to connect the register equipment to level 1, with the result that all dialling codes will be preceded by the prefix digit 1 and 1st selector levels 2 to 8 inclusive will be available for subscribers' multiple.

Trunking Scheme.

The trunking scheme is shown in Fig. 1. Separate groups of relay sets are provided for traffic from:—

(*a*) ordinary subscribers,
(*b*) C.C.B. lines,
(*c*) satellite exchanges,
(*d*) dialling-in operators and other non-director exchanges,
(*e*) local operators.

By means of strapping in the relay sets, C.C.B. lines are barred all calls except to unit-fee automatic exchanges, and ordinary subscribers may be restricted as needed; e.g., to exchanges within 4-fee range.

The relay sets are connected to standard group selectors and include hunters which give access to a group of register-translator equipments common to the exchange.

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† Senior Executive Engineer, Telephone Development and Maintenance Branch, E.-in-C.O.

[1] *P.O.E.E.J.*, Vol. 47, p. 85.

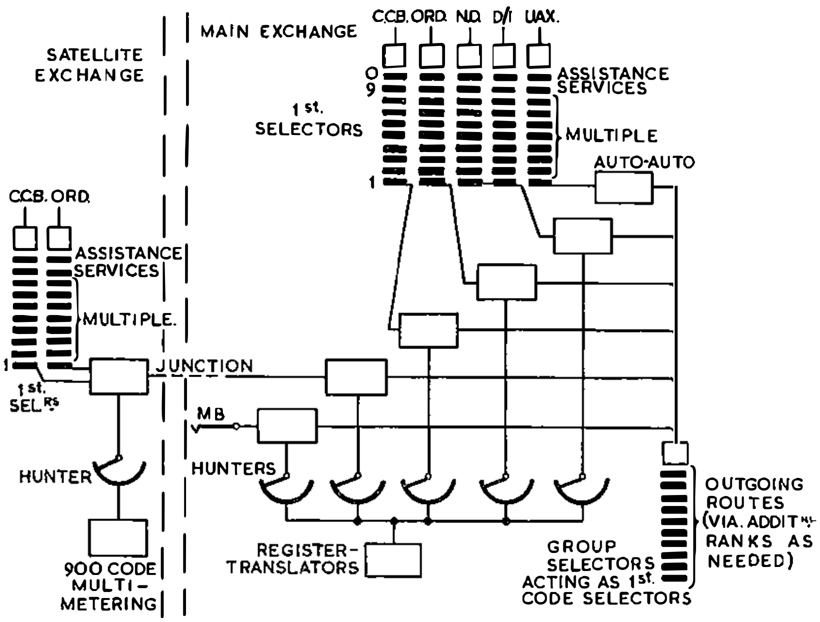


Fig. 1.—Main and Satellite Exchange Trunking Scheme.

Register-translator equipment for U.A.X.s is not being developed initially and U.A.X. subscribers will be given access to the former level-8 routes by dialling the routing digits directly.

Equipment at Satellite Exchanges.

All subscribers in a non-director multi-exchange area will have access to the same exchanges (using the same codes), except that a satellite exchange with its own charge list is not allowed dialling access to any of those exchanges which are beyond its own multi-metering range.

As all calls from satellite exchanges to exchanges outside the linked numbering scheme circulate via the main exchange, there is no need to fit register-translator equipment at the satellite exchanges because the main exchange equipment can be used for control of routing. It is necessary however to provide 900-code multi-metering equipment at the satellite exchanges to avoid sending metering signals over the junctions and to cater for dissimilar fees for satellite exchanges having their own charge lists.

To permit the use of a single group of junctions from a satellite exchange for this traffic, it is necessary to provide C.C.B. discrimination in the multi-metering equipment, so that C.C.B. users have access only to unit-fee automatic exchanges.

The satellite exchange level relay set is connected via a two-wire junction direct to a relay set at the main exchange as shown in Fig. **1**.

Dialling Codes.

It has not yet been decided in what form the dialling codes for director exchanges will be published but it is assumed in the following paragraphs that they will comprise all-numerical digits.

The codes, prefixed by the digit "1", are allocated as follows:—

Director exchanges:	3-digit codes.
4-digit N.D. exchanges:	3-digit codes.
5-digit N.D. exchanges:	2-digit codes with the 1st numerical digit treated as the 3rd code digit.
6-digit N.D. exchanges:	1-digit codes with the 1st and 2nd numerical digits treated as the 2nd and 3rd code digits.
3- and 4-digit U.A.X.s:	3-digit codes.
Manual exchanges:	3-digit codes (code only).

The total code capacity of the register is 900 3-digit codes or their equivalent, which not only meets the initial requirements but also the ultimate numbering plan discussed in Part 1. For convenience in reference the codes are designated "CDE" codes. By allocating the nine 1st-code digits ("C") in the series 2-0 inclusive there is the advantage of not using the digit 1 which is the most likely false digit to follow an initial false digit 1 (i.e., 11).

Access to Exchanges with 3-, 5- *and* 6-*digit Numbering Schemes.*

As in director working, the register equipment is designed to deal with a normal complement of seven digits comprising 3-code and 4-numerical digits (also with "code only" calls to manual exchanges). In addition, the register must be suitable for dealing with calls to 3-digit U.A.X.s and to 5- and 6-digit non-director exchanges.

When the register receives the code relative to a 3-digit U.A.X., it recognises that only 3-numerical digits will follow and is conditioned not to expect a 4th numerical digit.

Access to a 5-digit exchange is given by allocating a 2-digit code so that the 1st numerical digit takes the place of the normal 3rd code digit, and the number of digits received by the register is seven. In this case the digits comprising the code and the first numerical digit mark a translation which, after sending the last routing digit, repeats the 1st numerical digit. It will be appreciated therefore that each first selector level used at the wanted 5-digit exchange requires the equivalent of a separate 3-digit code and a separate translation.

In a similar way access to a 6-digit exchange would be given by using a single-digit code with the 1st and 2nd numerical digits accepted as the 2nd and 3rd code digits and repeated as the last two translation digits. At present, however, there are no 6-digit exchanges within 15 miles of any director "fringe" exchange.

If access were to be required to a multi-exchange area containing both 5-digit and 6-digit exchanges, the exchanges would be allocated 2- and 1-digit codes, respectively, if different names were published for the 5-digit and for the 6-digit exchanges. If, however, a common name were used for the area, a single digit code must be used for all the exchanges in the area as subscribers cannot be expected to differentiate between 5- and 6-digit numbers. In this case the register would recognise the first selector levels used for 5-digit numbers and would function correctly with a total of six instead of seven digits, as in the case of dialling to 3-digit U.A.X.s.

Translations.

The register-translator equipment for the London "fringe" exchanges requires a minimum capacity of 400 translations. A smaller number of translations may suffice for some provincial "fringe" areas.

In all cases the 1st translation digit is used for metering discrimination and the number of translation digits available for routing the calls is thereby reduced by one. Repetition of the first, or first and second, digits of 5- or 6-digit numbers also reduces the number of translation digits available for routing purposes.

Outline of Main Facilities.

On dialling the digit 1, the first selector hunts for a free relay set and on seizure of the level relay set its register hunter searches for a free register. The three-code digits and the three- or four-numerical digits are accepted by and stored in the register, the three-code digits marking the required translation. The first translation digit determines the fee at which the call is to be metered when the called subscriber answers. The register then sends the routing digits required to route the call to the wanted exchange, followed by repetition of the numerical digits. The register is then released and is available for other calls.

It is arranged that a subscriber is unable to dial through the relay set, except into the register. He is thus prevented from setting up calls irregularly by dialling additional digits directly into the network, following release of the register.

If the call is to circulate via a tandem exchange provided with register-translator equipment, one of these equipments is brought into use because the number of translation digits which the originating register-translator can provide may be insufficient to route the call to its destination. The register translator at the originating exchange sends a translation comprising the metering digit, the digits required to position local selectors and the digit 1. The last digit causes a register at the tandem exchange to be associated (trunked from level 1 of the "N.D." group as shown in Fig. 1). The register at the originating exchange repeats the full code and wanted subscriber's number to the tandem register which then controls the routing of the call to its destination. The originating register is released as soon as it has transferred the information forward.

More detailed information regarding the facilities to be given and a description of an electro-mechanical register-translator equipment will be given in Part 3. The advances being made in electronic techniques however may result in their use in the final design.

Typical Routing of Calls.

A non-director exchange (A) 18 miles from the centre of the London director area might have routes to other exchanges as shown in Fig. 2. Typical trunking is shown in Fig. 3. The required translations for metering discriminations (derived from Fig. 2) and for routing the calls (derived from Fig. 3) are given in Table 1.

TABLE I

Typical Codes and Translations for Calls from N.D. Exchange "A"

To	Routed via	"CDE" Code	Fee from "A"	Translation (1st digit determines fee)	Repeated by Register at "A"	Remarks
B (Director)	Direct	386*	2	20	4N	
C (Director)	Tandem	070*	4	4878	4N	
D (Director)	Tandem	704*	3	33753	4N	
E (Manual)	Tandem	405*	4	387●†	Nil	Operators only. No fee.
F (Non-director)	Direct	85	3	369 + 1stN	4N	5 digit exchange.
G (U.A.X. 14)	F	843	4	4691	843 + 4N	Transln. at F.–198 (1 fee from F)
H (U.A.X. 12)	F and G	825	3	3691	825 + 3N	2986 (2 fee from F)
J (U.A.X. 13)	F	861	3	3691	861 + 3N	190 (1 fee from F)
K (Manual)	Direct	733	2	264	Nil	Code only.
L (U.A.X. 14)	Direct	754	3	362	4N	
M (U.A.X. 12)	L	710	4	4624	3N	

*The "D"-digit for these exchanges in the director area is 7, 8, 9, or ●. For the remainder it is 1, 2, 3, 4, 5, or 6 (see Part 1).

†First translation digit (8) bars subscribers.

It is of interest to see that the translations at exchange A for access to exchanges H and J are identical. This is because these two exchanges are the same fee from exchange A and control of these calls is transferred to the register-translators at the tandem exchange F. It is the tandem exchange register-translators which provide the different translations for routing calls to exchanges H and J.

Subscribers in the "fringe" are not given dialling access to manual exchanges in the director area as the

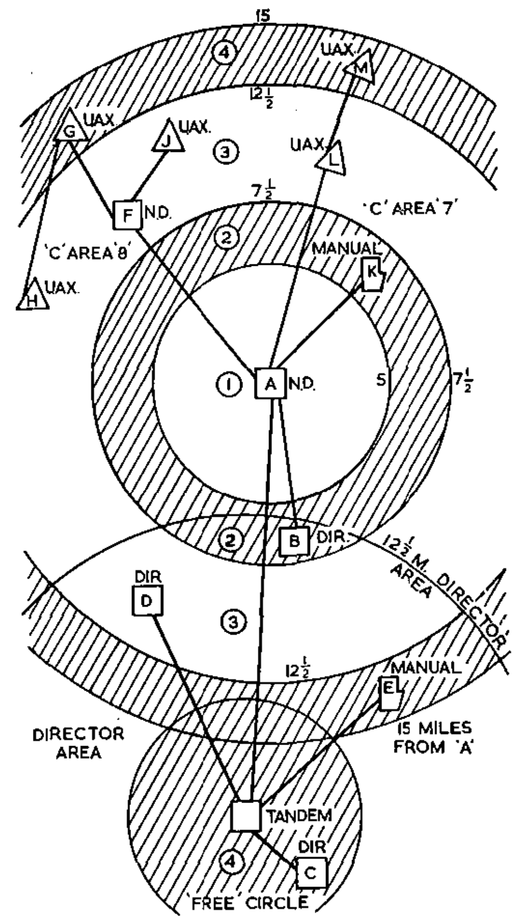


FIG. 2.—TYPICAL ROUTINGS AND FEE BELTS.

junction routes from the tandem exchange (e.g. London Toll B) to the manual exchanges are used by operators who require standard supervision when the manual exchange operator answers. If non-director subscribers were given dialling access to these manual exchanges, the provision of a separate group of junctions from the tandem exchange to each manual exchange would be required to ensure that the metering conditions would not be applied until the wanted subscriber had answered.

Additional Facilities required for Extension of Subscribers' Dialling Range.

If the subscribers' dialling range were extended beyond 4-fee distance it may be necessary to include means for associating timing equipment but this depends on the basis of charging to be used. If this equipment is required it would be brought into use only on timed calls and would time the call, effect repeat metering at specified times and apply the three-minute tone signals towards the end of each three-minute period.

Moreover, at least around London, the capacity of 900 codes would be insufficient for an extended dialling range of 25 chargeable miles, after allowing for growth and the loss of codes due to using 2-digit codes for access to 5-digit exchanges. It is possible however to provide the required code capacity by fitting two groups of 900-code register-translators and by using a somewhat different level relay set.

On dialling the digit 1, a register in the first group would be seized as already described and would deal with all CDE codes in, say, the series 311-000 (800) which would be allocated to exchanges outside the director area. The codes for the director exchanges would be 4-digit, the first of which would be the digit 2.

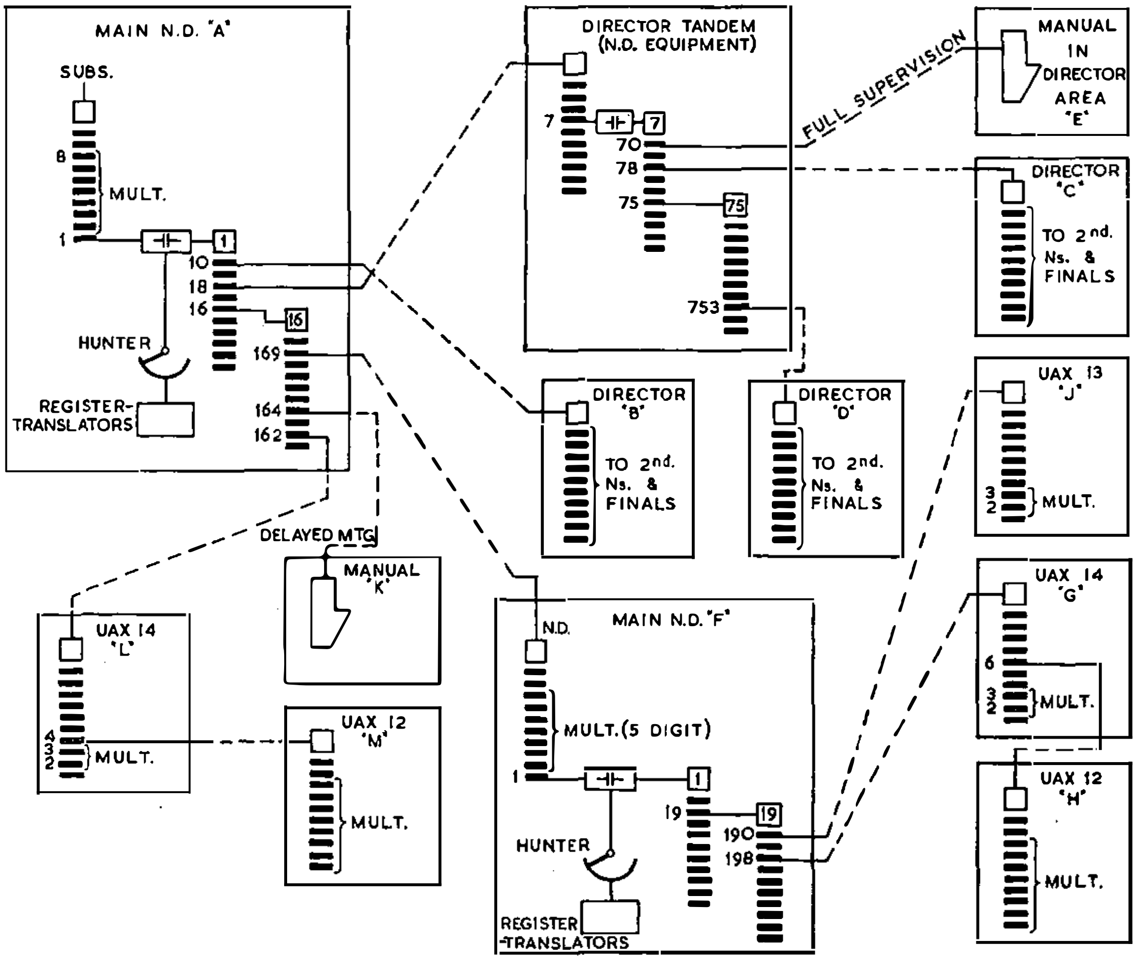


Fig. 3.—Typical Trunking for Exchanges in Fig. 2.

A discriminating relay in the level relay set would be operated on receipt of the digit 2 and would cause the hunter to release the register already seized and to hunt over its later contacts to find a register in the second group. The digit 2 would be absorbed in the level relay set and not transferred to the register which would then deal with the next three code digits.

The total code capacity would be:—

3-digit codes (311-000) for exchanges outside the director area:	800
4-digit codes (2211-2000) for director exchanges:	900
Total	1,700

In effect the director exchanges would be allocated 3-digit codes preceded by the 2-digit prefix 12.

It may be found desirable to allocate the prefix 12, not only to the director exchanges, but to all exchanges in the Zone Group which includes the director area. This arrangement has certain advantages with respect to calls passed forward to registers at tandem points and makes available more codes for the surrounding Groups.

Accordingly, if it were decided to extend the subscribers' dialling range beyond the present 4-fee distance, it is probable that the register-translators would meet the requirements without needing modification. The level relay sets and hunters would probably need changing to the type giving access to two groups of registers but the recovered items could be used elsewhere in the country where a single group would suffice.

So far as director exchanges are concerned, an extension of the subscribers' dialling range beyond 4-fee distance would require the provision of 3-digit register-translators to cater for the increased number of dialling codes and to provide the facility of passing the full code and number forward to a register at a tandem exchange when the number of routing digits exceeds the capabilities of the equipment at the originating exchange. It is visualised that these register-translators, designed to meet the requirements of director exchanges, would be trunked from level 1 of the A-digit selectors which would be modified to suppress the present facility whereby the digit 1 is absorbed. Thus the method of dialling calls within the director area would be unchanged. Moreover, director and non-director subscribers would dial the same prefix digit (1) and the same codes for access to exchanges outside the director area, so that their dialling procedure for such calls would be identical.

Conclusion.

The scheme described enables non-director subscribers in the fringe of a director area to dial many calls for which it is now necessary to enlist the aid of an operator by dialling 0. It also increases the multiple capacity at these exchanges by trunking all junction calls via level 1. The scheme is not only economical for dealing with calls up to 4-fee range but it has been designed to facilitate an ultimate extension of the subscribers' dialling range, if required. A full description of an electro-mechanical register-translator equipment designed to meet these requirements will be given in Part 3.

(*To be continued.*)

The Transistor

E. A. SPEIGHT, Ph.D., A.R.C.S., and J. I. CARASSO, B.Sc.†

Part 3.—Material Aspects: the Production of Transistor Grade Germanium

U.D.C. 621.314.7:546.289

This part of the series details the sources from which germanium is obtained and discusses its extraction and refinement, first to a commercial standard of purity (about 1 impurity atom in 10^7) and finally to "intrinsic" germanium (less than 1 impurity atom in 10^9). After doping intrinsic germanium with the required impurity (e.g. antimony), the final material for transistor manufacture is produced in the form of monocrystals of great physical perfection which are cut into wafers, lapped and etched.

Raw Material, Extraction and Refining

The element germanium, as now processed for transistor applications, is probably the purest substance ever handled in quantity by man. It has been of special interest to chemists ever since its existence was predicted by Mendeléeff, in 1871, on the basis of his Periodic Classification of the elements, though it was not actually isolated (by Winkler) until 1886. Almost exactly as Mendeléeff had forecast, it is a greyish-white brittle "metal" of specific gravity 5·47 and melting point 950°C, which forms a series of chemical compounds closely following Mendeléeff's bold predictions. Although traces of germanium are very widespread, only two, comparatively rare, minerals, argyrodite and germanite, contain the element in appreciable amount. Germanium therefore remained something of a chemical curiosity until towards the end of the second world war, when its newly-discovered electronic possibilities, and the demand which these stimulated, gave a major impetus to the search for more suitable sources.

An economically attractive source of germanium was found in the residues obtained in the course of refining zinc derived from certain American ores. These residues contain, in an enriched form, most of the germanium present as traces in the original ores and, for some years, they formed the main commercial source of germanium for the world. They still supply the bulk of the germanium produced in the United States, but, in view of the ever-increasing demand for the element, and of the fact that the scale of germanium production from such a source is necessarily linked to the scale of zinc production, it is likely that American industry will have to seek alternative sources of supply.

The production of germanium in Great Britain depends on the ability which some primordial plants appear to have had of absorbing traces of germanium from the soil with the result, first demonstrated by Goldschmidt in 1930, that certain British coals contain significant amounts of the element though these are far too minute to repay direct extraction. Under suitable conditions of combustion, however, a high degree of enrichment can occur. Thus, in 1937, Morgan and Davies showed that when gas-works coke is burned in a restricted supply of air in producer-gas plants, most of the germanium originally present in the coal volatilises in the form of germanous oxide or sulphide and condenses in the cooler parts of the flues. Though the amount of germanium contained in the flue dusts from such plants is still only 0·2—2 per cent., even when the most suitable (Northumbrian and Durham) coals are used, the whole of the present British production of the element is derived from these dusts. The development of an efficient process for extracting the germanium and purifying it from the host of unwanted elements was due to a collaborative effort by two British companies, and this process will now briefly be described.

The flue dust is first smelted with reducing agents, copper oxide and fluxes which remove the preponderant impurities—silica and other non-reducible oxides—as a slag and convert the reducible oxides of copper, germanium, gallium, arsenic, etc., to the corresponding metals. Due to the "collecting" action of the copper, the metals segregate as a fusible "regulus" which is tapped off and granulated by pouring into cold water after about ten 1-ton charges of dust have been smelted. The granulated regulus, which contains about 3—4 per cent. of germanium, is treated with chlorine and a solution of ferric chloride which converts all the metals to a solution of their chlorides. Strong sulphuric acid is added to the solution which is then distilled. Under these conditions the chlorides of germanium and arsenic are volatile and the non-aqueous part of the distillate consists of crude germanium tetrachloride containing up to about 20 per cent. of arsenic trichloride. Fractional distillation under carefully controlled conditions reduces the arsenic content to about 10 parts per million. By prolonged heating in contact with copper turnings (which slowly take up the arsenic) and a final distillation, the germanium tetrachloride attains a very high degree of purity. Next, it is hydrolysed, by treatment with highly purified water, to give germanium dioxide, a white powder, which is the usual commercial form of the material. At this stage, the only impurity which is chemically detectable is a minute trace of arsenic—1 part in 10^7 or less—but, even so, further processing is required to produce transistor grade germanium. This is described below and is usually carried out by the transistor manufacturer.

Further Processing of Commercial Material

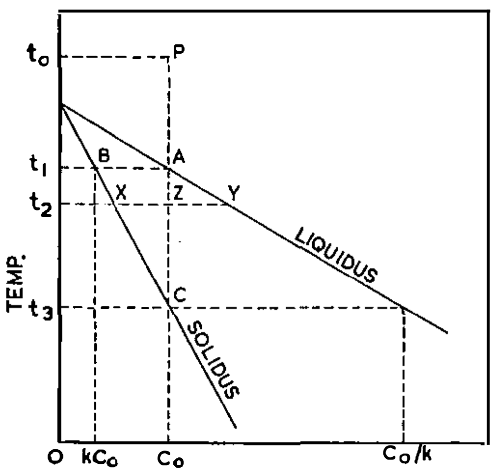
Purification by Recrystallisation.

The germanium dioxide is reduced to germanium powder by heating at 650°C in a fast stream of hydrogen and is then melted by heating to about 1,000°C and cast into an ingot in a hydrogen or inert gas atmosphere. Such ingots are found to be quite unsuitable for transistor applications due to the fact that their content of arsenic (which is a donor impurity in germanium), though so small, is excessive and unevenly distributed. Furthermore, other donor or acceptor impurities may be present, though not in chemically detectable amounts, and since these, too, are distributed inhomogeneously, the properties of small pieces cut from this material are variable and unpredictable. It is therefore necessary to purify further the germanium until the concentration of electrically important impurities is reduced below significance and then to convert this "intrinsic" material to a single crystal of germanium after "doping" it with the requisite amount of the desired impurity. Only by making the final product monocrystalline can a reasonably homogeneous electrical behaviour be attained, since, as will be explained, intercrystalline boundaries are regions of abrupt change in impurity content, and consequently in electrical properties. Furthermore, the final crystal should be as perfect as possible since crystal imperfections can simulate the behaviour of both acceptor impurities and "deathnium" centres (see later).

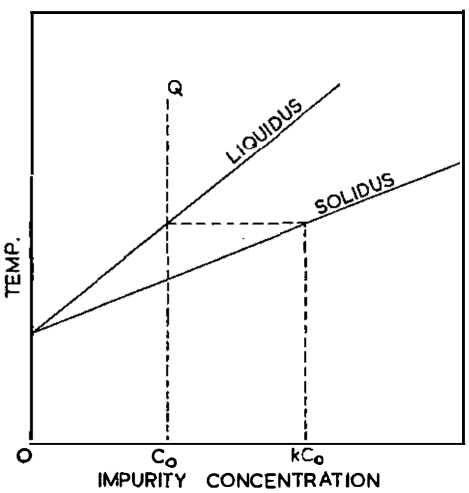
Both the thorough purification of germanium up to

† The authors are, respectively, Principal Scientific Officer and Senior Scientific Officer, Post Office Research Station.

intrinsic quality and its subsequent doping usually involve recrystallisation techniques. Fundamentally these depend on the fact that an impurity atom cannot enter the lattice of a growing crystal with just exactly the same ease as do the atoms of the main constituent and hence, according to its nature, may be either rejected or preferentially absorbed at the growing crystal face. If, for simplicity, it is first assumed that only a trace of a single impurity is present, the germanium can be regarded as a very dilute binary alloy and the phenomena which occur on solidification can then best be described by reference to "Phase Diagrams" which illustrate the behaviour of such systems. For the present purpose two types of impurity must be considered, viz. those which are more and those which are less soluble in liquid than in solid germanium and will therefore respectively lower and raise the freezing point of the main constituent. Two different types of phase diagrams will be relevant and portions of these, for very low concentrations of impurity (minor constituent) will resemble Figs. 7(*a*) and 7(*b*) respectively.



a) The impurity lowers the freezing point of the main constituent (more soluble in liquid than in solid).



b) The impurity raises the freezing point of the main constituent (less soluble in liquid than in solid).

FIG. 7.—EQUILIBRIUM DIAGRAMS OF A VERY DILUTE BINARY ALLOY

In such diagrams the temperature variation of the solubility of the impurity in the liquid, and in the solid just about to crystallise from it, are represented by the "liquidus" and "solidus" curves respectively. The ratio of the slopes of these two curves at points corresponding to any given temperature is termed the *segregation or partition coefficient* and is characteristic of the particular impurity. Within the low range of impurity concentration relevant to the present work, the liquidus and solidus curves approximate very closely to straight lines and it is legitimate therefore to speak of the *segregation constant* of the impurity. Again, for the same reason, both the liquid and the solid do not differ greatly (in a chemical sense) from pure germanium and this constant, usually designated k, may be regarded as equal to the ratio of the solubilities of the impurity in solid and in liquid germanium respectively at temperatures near the melting point of the latter. Values of k for some of the impurities of current interest are shown in Table 1.

TABLE 1

Segregation Constants of Impurities in Germanium

(J. A. Burton *et al.*, 1953)

Impurity	*k*	*Impurity*	*k*
Phosphorus	0·12	Gallium	0·10
Arsenic	0·04	Indium	0·001
Antimony	0·003	Thallium	4×10^{-5}
Bismuth	4×10^{-5}	Copper	$1{\cdot}5 \times 10^{-5}$
Boron	>1	Gold	3×10^{-5}
Aluminium	0·10	Nickel	3×10^{-6}

Consider the slow cooling of a germanium melt whose initial condition is represented by the point P in Fig. 7(*a*), i.e., of a melt at temperature t_o containing a concentration C_o of one particular impurity which lowers the freezing point of germanium. At point A, corresponding to t_1, where the ordinate through P intersects the liquidus line, solidification commences. The composition of the solid first formed is shown by point B at which the abscissa through A and t_1 intersects the solidus line, i.e., the solid has an impurity concentration kC_o where k is less than unity. Impurity is therefore rejected by the growing crystal, and its concentration in the remaining liquid must increase, in turn causing the concentration in the solid deposited from this more impure liquid also to increase. As the temperature is lowered, say to a temperature t_2, and more and more of the liquid solidifies, the composition of the remaining liquid, and of the solid crystallising from it, are represented by tie-lines such as XY, and the relative proportions of solid and liquid are as ZY/XZ, until the whole of the charge becomes solid at temperature t_3 corresponding to the point C where the ordinate through P intersects the solidus line. The composition of the last remaining drop of liquid then reaches the value C_o/k. If this freezing of a melt containing an impurity which lowers the freezing-point of germanium is carried out from end to end of a long narrow ingot it results, therefore, in considerable segregation of the impurity towards the "tail" of the ingot.

In the case of a melt (such as Q, Fig. 7(*b*)) containing a concentration C_o of an impurity which raises the freezing-point of germanium, the first solid to be deposited will again have the composition kC_o, but since k is now greater than unity the impurity will be concentrated towards the "head" of the ingot.

The distribution of impurity along an ingot frozen from end to end has been expressed by W. G. Pfann[1] in terms of the fraction solidified, g, and the segregation constant k, as

$$C = kC_o\,(1-g)^{k-1}$$

where C_o is the original impurity concentration in the melt. Although a number of simplifying assumptions, which can only be approximately realised in practice, are made in its derivation, this simple equation satisfactorily describes the actual segregation behaviour of impurities during "normal" end-to-end freezing, provided the impurity distribution in the melt is kept uniform throughout the crystallisation

[1] *Journal of Metals*, 1952, 747.

by efficient stirring. Thus, if only a small fraction of a large melt is solidified, the impurity concentration in the solid should remain practically constant if the value of k is not too large. When, on the other hand, the whole of the melt is solidified, C varies smoothly with the fraction solidified, increasing or decreasing with g according to whether k is smaller or greater than unity. For $k \ll 1$, C varies inversely as $(1-g)$, the fraction remaining liquid.

If both ends of the ingot are removed and the main body once again crystallised from end to end, further segregation of the remaining impurity will take place, and in theory there is no limit to the amount of purification which may be brought about by repetition of this process provided that impurity pick-up from the atmosphere, crucible material, etc., can be avoided. Purification by repeated crystallisation is most conveniently carried out by the technique of "zone melting." The charge is arranged as a relatively long, narrow ingot, and a short molten zone is made repeatedly to traverse, unidirectionally, the length of the charge. This method of freezing results in a segregation of impurities similar to that discussed above, in that the impurities are segregated towards the "head" or "tail" of the ingot according to whether their segregation constant is greater or less than unity, but offers the important advantage that it is not necessary to expose the charge, and cut away its ends, between crystallisations. A further advantage of the zone melting technique lies in the wide variety of useful impurity distributions which can be achieved by varying the arrangement of the initial charge and the size, number and, direction of travel of the molten zones. In particular, one modification of the technique—"zone-levelling"—can be used to give a substantially uniform distribution of a deliberately added impurity.

Using the zone-refining technique, it is a relatively easy matter to prepare germanium of such purity (less than 1 impurity atom in 10^9) that it is electrically intrinsic at room temperature. Material of any desired resistivity and type can then be prepared by remelting the intrinsic germanium with the required addition of donor or acceptor impurity and solidifying the melt from end to end. A knowledge of the segregation constant of the doping impurity is obviously required.

Production of Single Crystals.

The primary reason for producing the final material in the form of a monocrystal is the fact that only thus can a reasonably homogeneous sample be obtained. Polycrystalline material exhibits "coring", namely a radial change of composition within each crystal or grain, due to the normal segregation processes discussed above, which causes the electrical properties of the material to vary continuously across each grain, and abruptly at the grain boundary. Monocrystalline samples, on the other hand, show very little variation of electrical properties except for a gradual and controllable one in the direction of growth, where normal segregation must necessarily take place.

Of the many techniques for producing single crystals from the melt, that of Kyropoulos, as modified by Teal and Little, has been used most widely for germanium. The charge, contained in a graphite crucible, is heated to just above its melting point. A small single-crystal seed, cut in the desired crystal orientation, is dipped into the melt and, when thermal equilibrium is established, smoothly withdrawn at the rate of a few inches per hour. As "pulling" proceeds, molten germanium is drawn up by surface tension, and freezes in the same crystal orientation as the seed, until the whole of the melt has solidified. It is usual to stir the melt during crystallisation, by rotating either the crystal or the crucible, so as to avoid concentration gradients in the liquid which would render the impurity distribution along the crystal more difficult to control and to calculate. A photograph of a typical crystal grown by this technique is shown in Fig. 8.

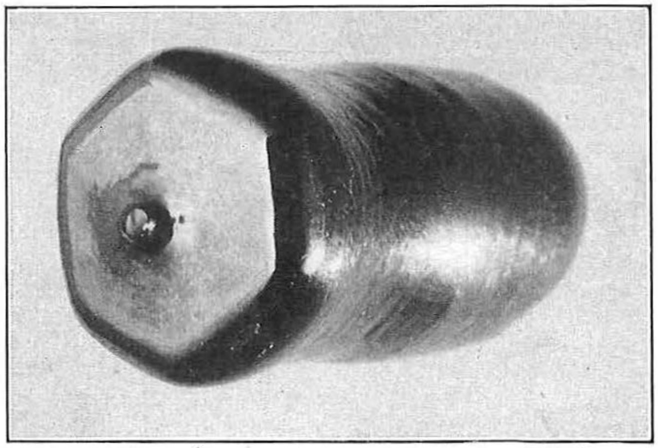


Fig. 8.—A Single Crystal of Germanium. The (111) Crystal Axis is parallel to the Direction of Growth.

As an example of the results obtained in practice, a 50-gram charge of intrinsic germanium, doped with 100 micrograms of antimony and crystallised with stirring, will yield a crystal having approximately the following n-type resistivity profile as a result of impurity segregation during freezing:

Location	*Resistivity ohm-cm.*
Top of the crystal	8
Half-way down the crystal	4
Bottom of the crystal	< 1

The variation in resistivity along the length of the ingot is a disadvantage which in theory cannot be completely avoided in this method. Considerable interest has therefore been shown recently in a seeded zone-levelling process carried out in a long, narrow silica crucible, which yields a substantially uniformly doped monocrystal.

The greatest attraction of the Kyropoulos method of crystallisation, however, lies in the freedom from mechanical constraint at the solid-liquid boundary, since crystallisation takes place out of contact with the walls of the containing vessel, thus enabling samples possessing a high degree of crystalline perfection to be produced. The perfection of the crystal lattice is reflected by the recombination time-constant or "lifetime" of minority carriers, since crystal imperfections (of which "edge dislocations" are thought to have the greatest effect) make available energy levels within the forbidden gap which can act as recombination centres. It has been calculated that in a truly perfect germanium lattice, in which hole-electron recombination could take place only via photon emission, the lifetime would be of the order of one second. Although this has never been achieved in practice, lifetimes as high as several milliseconds can be produced by the pulling method whereas much shorter lifetimes (tens of microseconds) are obtained when the material is crystallised in contact with the walls of the crucible.

It is important to be able to control the lifetime of the material since this parameter plays a part second only to that of the resistivity in determining the characteristics of the final device. In one direction, lifetime control can be achieved by doping the melt with "deathnium" impurities (nickel and copper are the best known) which provide additional recombination levels, but, since this method will yield only material having a lifetime shorter than that obtained without added "deathnium," one must be able to produce crystals of lifetime longer than will be

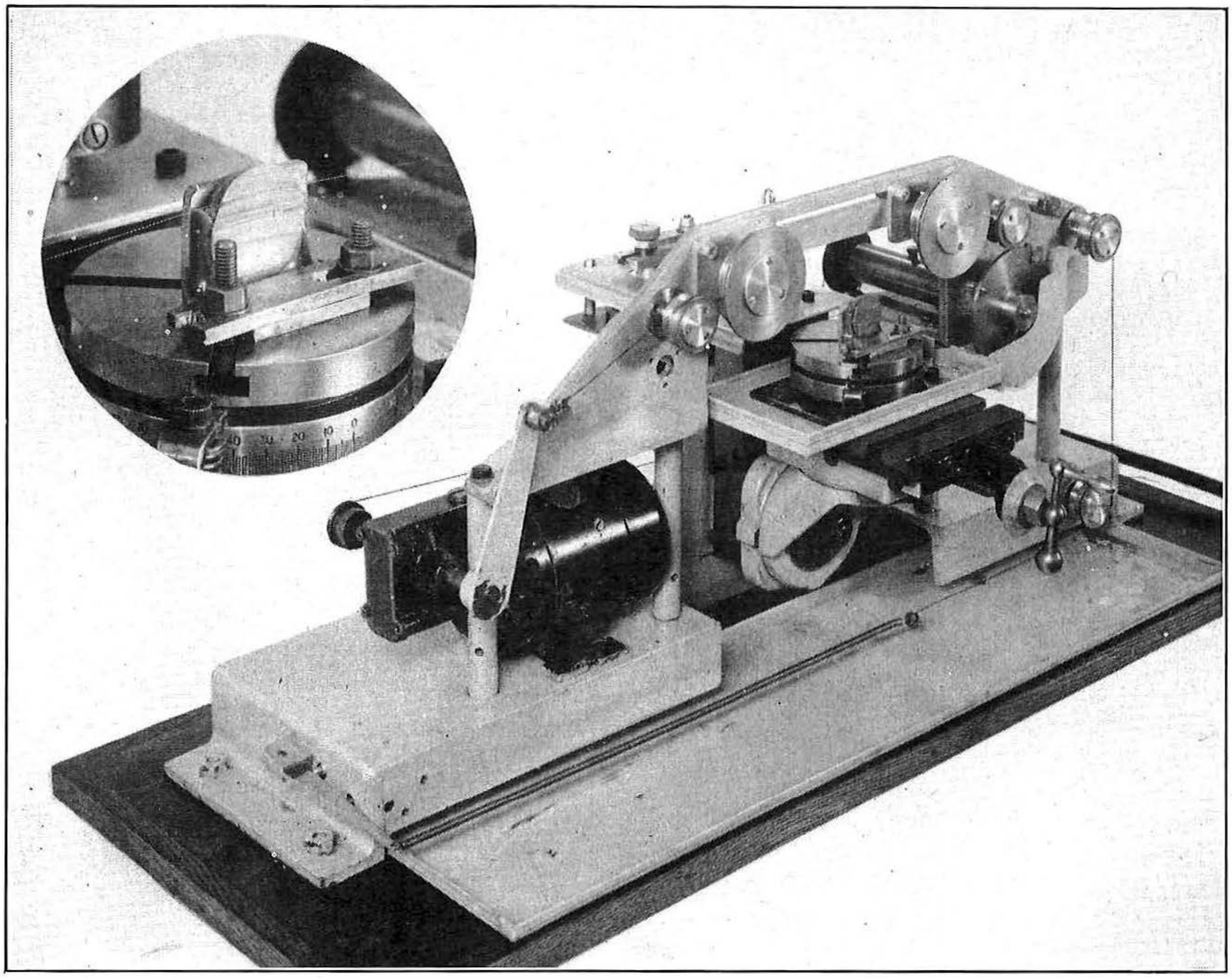


FIG. 9.—GERMANIUM SAW, WIRE-TYPE: INSET—CLOSE-UP VIEW OF WAFER BEING CUT OFF A MONOCRYSTAL.

required in order to be able to degrade it to the desired level by the appropriate addition of, say, nickel.

A high degree of crystalline perfection is desirable also for the reason that there is evidence that edge dislocation lines may act as conducting paths for charge carriers or as channels along which impurities may diffuse more rapidly than through regions where the lattice is perfect. These effects would tend to cause breakdown of p-n junctions at unexpectedly low reverse voltages and general non-uniformity of the material.

Mechanical and Chemical Treatment.

The "pedigree" crystals, prepared as outlined above, are normally cut into circular wafers approximately 0·5 mm. thick which are then lapped to the exact thickness required and diced, to provide blocks of suitable dimensions. Two types of saw are commonly employed: the disc type and the wire type. The former consists of a thin (approximately 0·01 in.) copper disc the edge of which is loaded with diamond dust, or of a thin disc of sintered abrasive, rotating at high speed; the latter, of a 0·003 or 0·005 in. reciprocating tungsten wire, fed with a mixture of carborundum or alumina and oil (see Fig. 9).

The wire saw, although much slower in operation, has the advantage of causing far less surface damage. This is important because surface damage promotes recombination of the carriers. The damaged surface layer is removed by lapping with progressively finer abrasive, and finally by an etching treatment, which can be chemical or electrolytic. The exact form of the final etching treatment depends upon the application envisaged. A treatment suitable for point-contact devices consists of 60 seconds' immersion in a solution containing nitric acid, hydrofluoric acid, acetic acid and bromine, (a particular composition being commonly known as "CP4"), but many other etching solutions have been used successfully.

CONCLUSIONS

Since the end of the second world war the production of germanium of the desired electrical properties has moved from the realm of trial-and-error to that of exact science. It is hoped that this will lead to the achievement of a similar degree of control in the production of actual devices.

(To be continued).

ERRATA: In Part 2 of this series the activation energy for the ionisation of donor or acceptor impurities in germanium, given as 0·04 electron-volt, should be 0·01 electron-volt. Also, Fig. 3 should have been described in the text as a cabinet projection.

A Photographic Method of Taking Traffic Records

L. A. MISSEN†

U.D.C. 778:621.395.364

This article describes a transportable unit consisting of a camera and a block of 100 traffic meters. The equipment is so arranged that, having been connected to the point at which records are required, the traffic meters are automatically photographed, on 35 mm. film, at pre-determined intervals. The results are analysed by using a micro-film reader modified to project, simultaneously, consecutive exposures of each row of meters.

Introduction.

THE idea of photographing meters is not new. This method was used experimentally in 1938[1] to record subscribers' meter readings for accounting purposes but was not proceeded with at the time as it did not prove economic. The possibility of obtaining meter readings by photographic methods, and thus avoiding much laborious work is, however, attractive and when some experimental work arose, in which records were required of traffic flow at ½-hourly intervals over a period of several months, it was decided to develop a unit suitable for this purpose. The difficulty which had been encountered previously of moving the camera so as to photograph a large number of meters in small groups does not arise in this case, and automatic operation of the camera enables exact timing of the intervals between successive records. The photographic method also enables readings to be taken on all meters simultaneously and ensures the accuracy of the readings while maintaining a continuous record. Analysis of the results is facilitated by the use of a modified micro-film reader.

Three photographic units to the present design have been constructed and one has been in use at Thanet exchange since May, 1954. The camera, once started, is automatic in action. It holds sufficient 35 mm. film for over 200 exposures, each 1 in. × 1 in., and taking exposures at ½-hourly intervals is capable of running for 4 days without attention. The camera can be switched off during slack periods if desired and the period of use before reloading is correspondingly increased.

There is no doubt a wider field for this method of obtaining traffic records, but its use will depend on the cost compared with present methods.

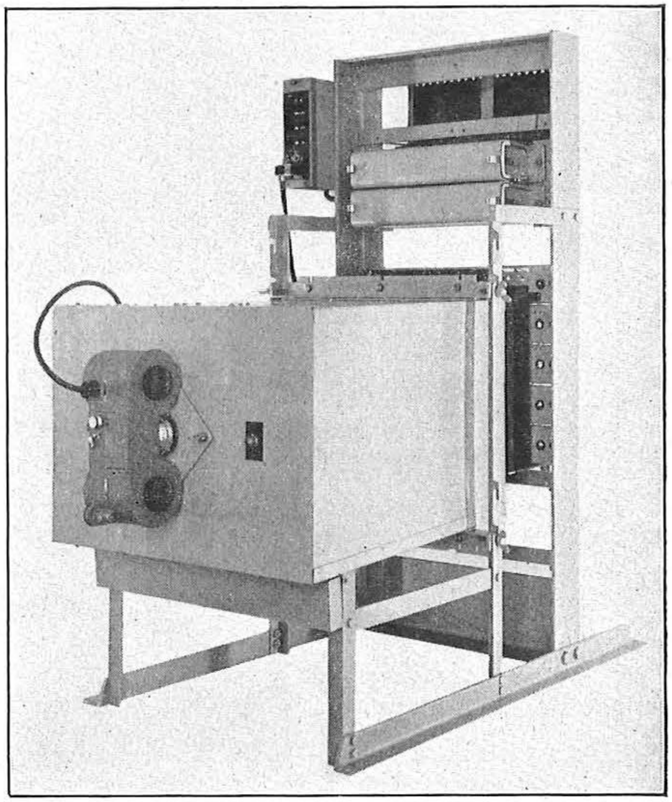


FIG. 1.—TRANSPORTABLE UNIT MOUNTING TRAFFIC METERS, LIGHTING CASE AND CAMERA.

Camera Rack.

For convenience in using the camera, a transportable unit capable of mounting a block of 100 traffic meters of the 100-type is used, as illustrated in Fig. 1. The meters are wired to a connection strip at the top of the rack from which cabling is taken to the points at which records are required. The unit is entirely self-contained and the lighting case and the camera are mounted on a framework secured to and in front of the meters. Alternative mounting positions for the camera are provided so that it is possible to photograph meters alone or a lesser number of meters and two watt-hour meters. Provision is made for mounting a watch on the unit so that a record of the time that each exposure was made is included on the negative. A designation strip at the side of the meters is used to record any other details.

At the left-hand side of the rack are the control equipment keys by which the camera can be operated either manually (single exposures) or automatically according to requirements. An alarm is provided to safeguard the camera operating magnet and also to indicate when the supply of unexposed film in the camera is exhausted.

Lighting and Camera Mounting Case.

The camera lighting case is of sheet metal and resembles a box from which one side has been removed. The open side or front of the case faces the meters.

The camera must be accessible for reloading with film and for making any adjustments necessary. It is therefore bolted to a stout metal plate which is secured with butterfly nuts to the outside of the case opposite to the open end. There is a small circular hole in the case opposite the camera lens.

Inside the case are four rectangular plate glass mirrors approximately 12 in. × 5½ in. Two of the mirrors may be seen in the photograph of the lighting case Fig. 2. Two similar mirrors are fitted on the other side of the case. The views of the lamp to be seen in this photograph are both reflections and show how the mirrors are arranged so that only reflected light falls on the meters. This is to ensure even illumination. Adjustment may be made by moving the mirrors through an angle of about 6°. The source of light consists of two 24V, 60-watt lamps in series mounted at the rear of the case. Metal shields are used to shade the meters and the camera lens from direct light.

A similar lighting unit has been described elsewhere[2] in which the lighting source consisted of double-filament automobile lamps and for the reflecting medium, chromium-plated metal plates were used.

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† Assistant Engineer, Telephone Development & Maintenance Branch, E.-in-C.'s Office.

1 "The Photographic Recording of Subscribers' Meter Readings." L. L. Tolley and W. A. J. Paul. *P.O.E.E.J.* Vol. 31, p. 207, 1938.

2 "A New Message Register Camera." *Bell Lab. Record.* Vol. XV, No. 8, April 1937.

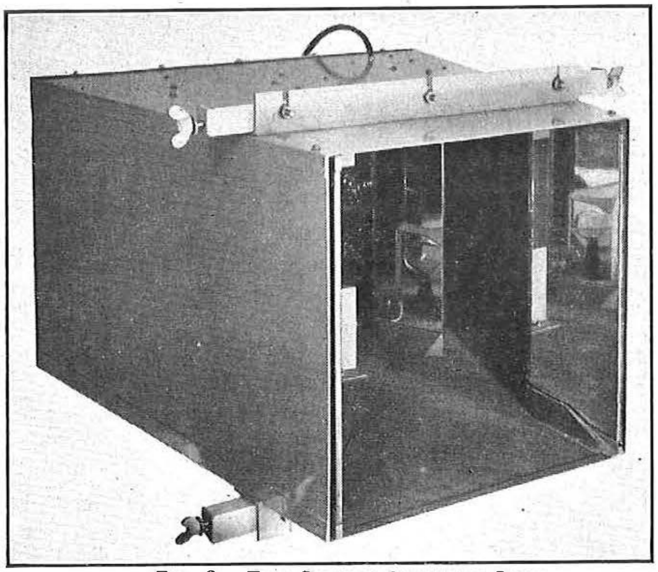


FIG. 2.—THE CAMERA LIGHTING CASE.

Camera.

The camera, which is known as the Auto-Camera (Fig. 3) is of a type originally used in recording the behaviour of aircraft under test conditions. It has an $f3{\cdot}5$ Dallmeyer bloomed lens of focal length 35 mm. Fitted to the lens cell is an iris diaphragm which can be used to vary the lens aperture down to $f16$. The lens cell rotates to adjust the focal distance which can be varied to enable photographs

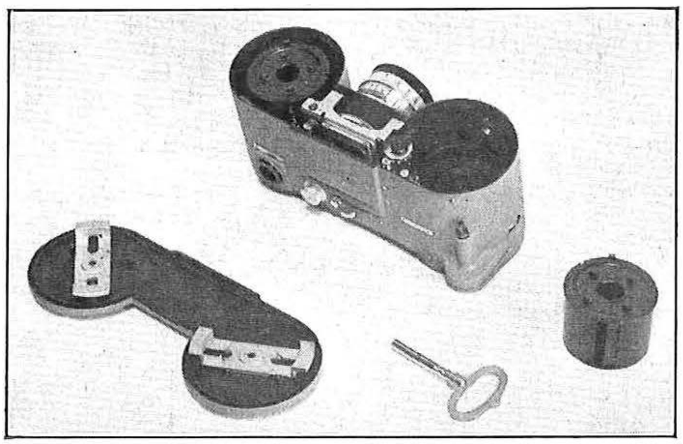


FIG. 3.—COMPONENT PARTS OF THE AUTO-CAMERA.

to be taken from a minimum distance of 7 inches from the lens. Shutter speeds of 1/10, 1/25, 1/50, 1/100 and 1/200 of a second are available and it is also possible to make bulb and time exposures.

Under electrical operating conditions, film winding is automatic after each exposure, the energy being supplied by the unwinding of a spring. The spring is wound manually and when fully wound is sufficient to deal with the 21 ft. of film which the camera can accommodate. An engraved milled disc at one end of the camera rotates as the film moves and provides an indication of the quantity used.

The shutter operation and film winding may be performed manually if required, by means of a lever and press button on the camera body. Light-tight metal reels or cassettes are used for the film and by virtue of the camera design, daylight loading is possible although panchromatic film is used to secure a suitable negative. The camera cover, which must be removed to load the camera, is secured by rotating two knurled knobs. On the underside of the cover are slotted levers which engage in pins on the top of the cassettes and as the knurled knobs are rotated the outer case of the cassettes is turned to open the light trap and thus allow free movement of the film when the cover is in position. A reverse action takes place when the cover is removed and the cassettes are then closed to prevent fogging of the film. The camera is foolproof so far as loading is concerned since it is impossible to replace the cover unless the cassettes are correctly set.

Analysis of Results.

There are a number of ways in which the results can be analysed. Consideration was first given to enlarged prints, but this method was later abandoned in favour of direct projection of the negative. To assist in taking the readings from the projected negative the camera has been mounted vertically so that the horizontal rows of meters appear across, instead of along, the film strip. It is then possible to project on to suitably arranged mirrors so that on the viewing screen the images of the same row of meters from adjacent frames are crossed and appear with the later exposure in the upper position. The difference in the readings can readily be obtained by simple subtraction. It is of course necessary to mask the negative so that only one row of meters from each frame is visible.

A magnification of 12 times is obtained with the equipment used, and the meters are about $\frac{3}{4}$ full size on the projected image.

Camera Settings.

The possibility of a meter reading changing because the meter operates at the instant an exposure is made has to be considered.

An electronic flash* seems to offer a means of arresting the motion by virtue of its short duration i.e. 1/1000 of a second or less. The cost of such an equipment is considerable, however, and there is the added disadvantage of working at a high potential. The alternative is, oddly enough, to allow a relatively long exposure so that the figures before and after movement are superimposed one upon the other and both can be read. The worst condition is when the meter number wheel moves in the middle of the exposure time so that each digit is exposed for a similar period. The chance of this happening is small, however, and the number of readings affected in this way will not be sufficient to cause inconvenience in examining the results. Good negatives are obtained with a lens aperture of $f5{\cdot}6$ and a shutter speed of 1/10th of a second.

A relatively long exposure time has another advantage. Subject to adequate exposure of the film, the best definition is obtained with the smallest lens aperture. In this instance the lens aperture can be set at $f5{\cdot}6$ with a consequent gain in definition at the edges of the negative.

Even smaller lens apertures are possible with certain types of film, but the advantages are offset by the coarser grain of the emulsion, and the best compromise is obtained with the above settings and a fine grain film.

Camera Operating Circuit (Fig. 4).

Operation can either be continuous by supplying a pulse at intervals according to the frequency required, or by individual operations obtained by operating a non-locking key.

Assuming that the "on" and "auto" keys (KO and KA, respectively) are operated, relays A and B will be operated. Relay AL also will have operated but is released when the "alarm resetting key," KAR, is operated. An earth pulse operates relay T. A contact of T will cause relay ST to operate and a contact of ST disconnects relay A. Relay A releases and the camera magnet is energised for the release lag of relay B, which was also disconnected when relay A released. While the magnet is operated, the magnet-

* An extremely bright flash of short duration produced by capacitor discharge.

operated off-normal springs arrest the normal operational cycle of the circuit by short-circuiting relay D.

If the off-normal springs do not restore before relay TP can release, an alarm is given by the operation of relay AL and the magnet circuit is disconnected.

Two pilot lamps at the rear of the lighting case glow to indicate that the equipment is switched on. The sequence of operations when making an exposure is commenced with the full illumination of the exposure lamps. To reduce the thermal delay the filaments of the lamps are maintained at a dull red heat in series with the 6V pilot lamps, and when full illumination is required the pilot lamps are short-circuited and momentarily extinguished. After the release time of relay A has elapsed, the camera magnet circuit is connected for the release lag of relay B. The cycle of operations is recommenced by the operation of relay D, and the equipment is ready for the next earth pulse.

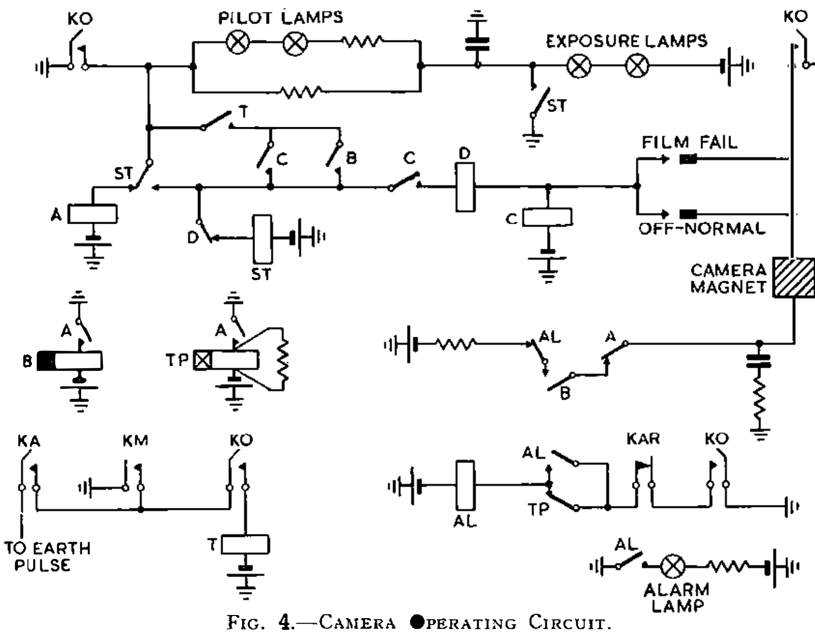


Fig. 4.—Camera Operating Circuit.

The other contact inside the camera (Film fail), is normally separated by the film. When the supply of film is exhausted the contact makes and, by preventing the operation of relay D, causes the alarm to operate. An alarm is also given if the winding of the camera is overlooked.

Acknowledgements.

The author is indebted to the General Electric Company, Ltd., for permission to reproduce the camera-operating circuit diagram, and to his colleagues in the E.-in-C.'s Office who assisted in the preparation of the article.

Book Review

"Radio and Radar Technique." A. T. Starr, M.A., Ph.D., M.I.E.E. Sir Isaac Pitman & Sons, Ltd. 812 pp. 916 ill. 75s.

In must be a great source of satisfaction to radio engineers when they consider how the trail that they and their predecessors blazed in the early days of "wireless" has grown into a great road over which so many others travel today. Now it is often necessary to talk not of "wireless" or even "radio," but of "electronics," in referring to a branch of technology which has its application in almost every field of human activity—from armaments to music, and from navigation and computation to surgery and astronomy; and, of course, to telecommunications itself. In all these activities this country has played a leading part which has not been adequately reflected in the textbooks that have been published since the war. For this reason, Dr. Starr's book "Radio and Radar Technique" is doubly welcome—as an authoritative book covering a field far wider that the title might suggest, and as the most ambitious and the most useful British textbook on the subject published in the last few years.

It is a book—a compendium—which serious workers in all branches of electronics will find invaluable; but it is decidedly not a bookforthe "practicalman." Indeed, the authorpointsout in the preface that to reduce the bulk of his work to a reasonable size he has restricted himself to methods and techniques only, and has described no applications. The result is a book of some 800 pages, cram full of good solid meat except for two extraordinary pages on which are set out the Morse Code and the International Teleprinter Code! The treatment is theoretical with a good sprinkling of degree-standard mathematics, and succinct, in places, to the point of obscurity.

The range of the book is so wide and the treatment, with one or two exceptions, so thorough, that one is amazed that the author should have found the time to digest so much information and present it in so compact a form.

The book opens with a chapter on "Methods of Communication and Physical Limits," which ranges from descriptions of the techniques, and comparisons of the signal/noise ratios, of various pulse-communication systems, to discussions of the principles of various radar systems, including "Doppler Systems," and of the cancellation of permanent echos. There are one or two minor mis-statements: for example, the author seems to think that frequency-shift methods were used on Poulsen arc transmitters because it was erroneously believed that much information could be transmitted in a very small bandwidth in this way. It was merely because an arc does not take kindly to on-off keying and functions far better when left oscillating the whole time.

The next three chapters, devoted to "The Electromagnetic Medium," "Microwave and Short-wave Techniques" and "Antennae," cover what might be described as the "electro-magnetic-theory" and "transmission-line/wave-guide" portions of the book; and here most readers will, I hope, be glad to see that the author uses the M.K.S. system of units.

The propagation of electromagnetic waves in free space, over the surface of the earth, and in transmission lines and wave-guides, is well covered, giving less attention to those aspects of wave-propagation which are affected by the vagaries of nature, i.e. ionospheric and tropospheric transmission, than to other parts. The treatment of circuits is largely concerned with the properties of wave-guides, wave-guide circuit-elements, resonant cavities, and circuits made up therefrom. The chapter on antennae is particularly good. It is important to note, however, that the author tends all the time, and in the reviewer's opinion rightly, to give less attention to the older, lower-frequency portions of the subject, and to concentrate more on discussion of microwave techniques; for example, there is no mention of long-wave or top-loaded medium-wave transmitting antennae, and two-thirds of this chapter covers microwave-antennae elements and the antennae themselves.

The following chapter, on valves, is excellent. The author recognises in the preface "that new tubes are the most important single items in progress, and radio engineers do not have a sufficient understanding of their internal structure, properties and possibilities." He might have added that they are always asking, and will no doubt continue to ask while there is breath left in their bodies, for better and better valves. The more conventional types of valve are treated thoroughly from the low-frequency point of view; high-frequency type triodes are then introduced and the factors that limit their high-frequency performance are analysed. Consideration of transit-time effects leads on naturally to a discussion of velocity-

(*Continued on p.* 175).

A New Cable Test Van

G. H. SLATER, A.M.I.E.E.†

U.D.C. 629.113: 621.315.2

The author describes a new cable test van which gives improved accommodation for test equipment and facilitates testing operations in the field. An important development is the inclusion of a satisfactory heater unit for maintaining suitable atmospheric conditions within the van.

Introduction.

A TEST van was one of the first, if not the first, of the motor vehicles in the Engineering Department fleet, excluding, of course, one or two passenger cars, and a brief reference to the original test van which was brought into service some 40 years ago will serve as an appropriate introduction to the subject.

This vehicle, shown in Fig. 1, was obtained in 1914 for the Research Section for the purpose of testing telegraph and telephone underground trunk cables, and no doubt the testing of the London-Birmingham-Liverpool trunk cable laid in 1914-15 was one of the main factors in mind at that time.

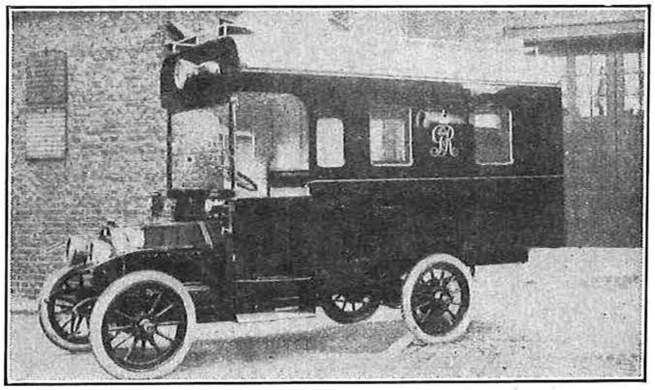


FIG. 1.—THE FIRST G.P.O. CABLE TEST VAN; BUILT IN 1914.

In 1919 only two test vans were in operation, but with the development of the underground cable trunk network and the devolution of cable testing and balancing from the Research Section, the number had increased to 14 by 1927 and to 29 by 1935. To-day the Department has in service some 70 test vans, one of which is shown in Fig. 2, and except for changes in chassis types and methods of body construction, no major changes in the layout of the vehicle have occurred over a period of some 25 years.

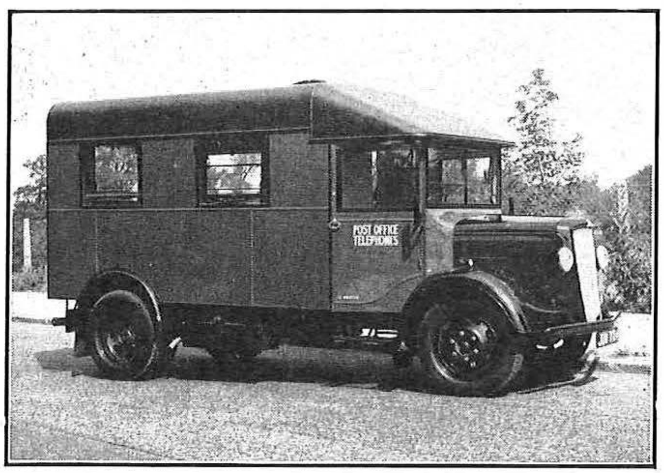


FIG. 2.—TYPE OF CABLE TEST VAN IN GENERAL USE TO-DAY.

That improvements were necessary to facilitate testing operations was apparent as far back as 1938, and immediately prior to the war a redesign of the test van was commenced. The development had then to be suspended for the duration of the war, and although work recommenced in the immediate post-war period, material and financial restrictions made progress slow. The maintenance of existing test vans in service much beyond their normal period of service was therefore necessary.

Features of the New Test Van.

The provision of a dry atmosphere inside test vans to ensure that the electrical insulation of the apparatus is maintained at the level necessary for accurate testing has always been a difficult problem. Various ways of disposing of condensation on the apparatus have been resorted to in practice, none of which was really satisfactory. The locations in which test vans operate preclude the use of mains power for electrical heaters; heaters which are dependent on heat derived from the vehicle engine are also precluded, since the vehicles are required to be stationary for very long periods during the testing operations and to run the engine during these periods would be costly. The use of heaters independent of mains supply and the vehicle engine, such as the usual type of paraffin heaters, has the disadvantage that the combustion products project additional moisture into the atmosphere of the van, thus tending to defeat the object of disposing of the condensation inside the vehicle and on the testing apparatus. A catalytic heater has also been considered. This flameless heater, using petrol as the fuel in conjunction with a platinised asbestos pad, proved to be unsatisfactory in operation as it produced carbon monoxide.

A means of producing the required atmospheric conditions was eventually evolved at the Research Station, using a paraffin heater, and a specially designed flue to carry off the products of combustion to the outside atmosphere.* Heaters of this type have now been incorporated in the design of the new test vans (Fig. 3) recently put into service and have also been fitted to all existing test vans which have a reasonable length of unexpired service.

FIG. 3.—THE NEW CABLE TEST VAN.

† Executive Engineer, External Plant and Protection Branch, E.-in-C.'s Office.

* P.O. Research Report No. 12934.

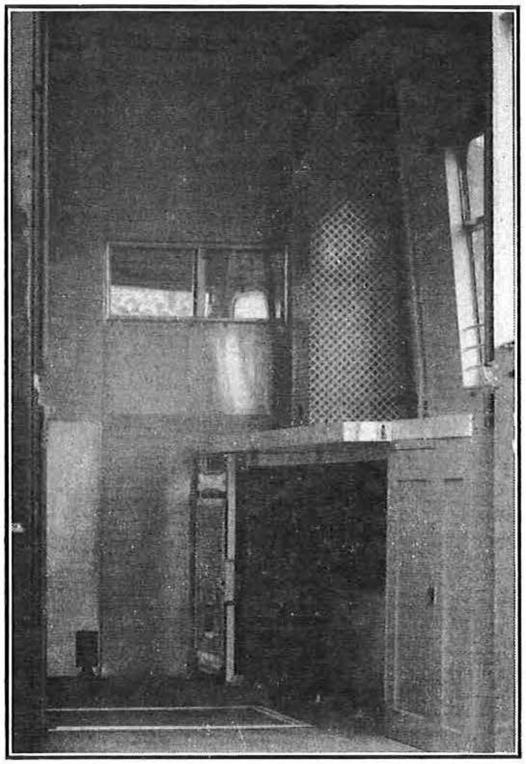


FIG. 4.—INTERIOR VIEW OF NEW CABLE TEST VAN SHOWING HEATER AND FLUE.

The heater, fitted in the body of one of the new vehicles, is shown in Fig. 4. It consists of a heavily constructed fuel container with a capacity of 1 gallon, which is sufficient for 16 hours' burning. A double gauze cylinder surrounds the chimney of the heater which is housed immediately beneath a baffled flue, rectangular in shape and constructed of aluminium alloy. The flue terminates on the outside of the vehicle in a cowl which effectively prevents down-draughts. The heater is capable of producing some 10,000 B.T.U., equivalent to 2·9 kW per hour. The fire risk has been reduced to a minimum; indeed, the heater may be left burning whilst the vehicle is in motion and in garages overnight, thus ensuring a body interior free from condensation in readiness for the day's testing operations. The fuel supply for the heater is carried in two 1-gallon cans which are accommodated in a locked compartment situated outside the vehicle on the offside beneath the floor.

A feature which has been introduced, but which is not obvious from the appearance of the vehicle, is greater heat insulation of the vehicle body effected by the use of a heat-insulating material packed in the space between the outer aluminium alloy and the inner plywood body panels.

Ventilation is controlled by adjustable louvred vents at floor level and ventilators in the roof, which, together with the improved type of adjustable side windows, should ensure adequate natural ventilation reasonably free from draughts.

The rearranged benches provide adequate space for the testing gear and have been simplified by dispensing with the folding facility which, it was found on investigation, was rarely used. The fence rail at the edge of the benches has been improved. It is now produced in light alloy and arranged in sections to facilitate raising and lowering. This, it is hoped, will be of considerable advantage when it is necessary to dispose of the uncomfortable ridge when a section of the bench is used for writing purposes—a discomfort which was often endured in the old vehicles because of the awkwardness of lowering the one-piece rail.

The bench tops have been finished in green linoleum and incorporate the necessary test lead holes and a cable entry flush-fitting flap.

Beneath the benches two cupboards have been arranged, one at the rear of the offside with a hinged door, and one with sliding doors towards the nearside forward end of the body. The cupboards are fitted with adjustable shelves and provide adequate space for stowing equipment. The wheel arches have been squared off and fitted with fence rails to provide additional under-bench stowage space.

Above the offside bench a light alloy rack extending practically the whole length of the body affords convenient accommodation for storing test sheets and the records associated with testing operations. The edge of the rack is padded to provide protection for the head in the event of accidental contact whilst moving about the vehicle.

Interior lighting is provided by battery-operated pendant-type lamps arranged above the benches and a roof light above the rear step. The sets of lights on either side of the body are controlled by separate switches placed at the forward end of the body and the step light by a switch conveniently placed adjacent to the rear door. On each side of the vehicle, immediately above each bench, a conveniently placed plug socket gives access to the 12-V battery supply for testing purposes and, should it be necessary, for a portable bench light.

The provision of ring bolts in the floor, apparatus-securing straps on the benches, and concertina-type blinds to the windows completes the internal equipment of the body of the vehicle, which is finished in green and cream, giving the whole a pleasing appearance and a serviceable finish.

Access to the rear of the vehicle, which incorporates a full-width sliding window in the door, has been considerably improved by the introduction of a built-in step (Fig. 5)

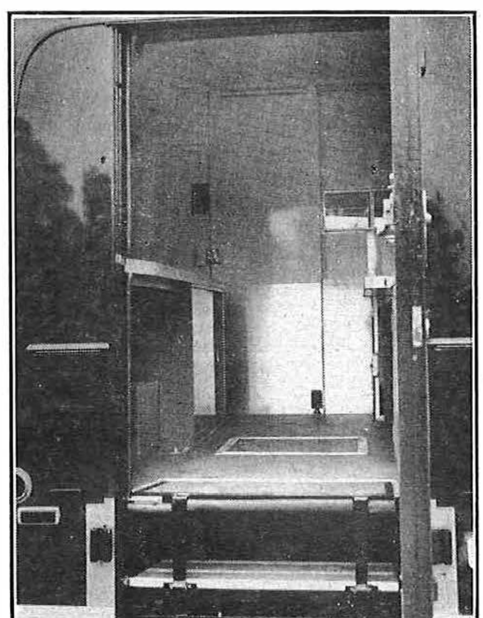


FIG. 5.—BUILT-IN STEPS AT REAR OF NEW CABLE TEST VAN.

which, when not in use, folds into the body of the vehicle. On either side of the rear door two cable entry traps give access to the interior of the body.

The forward control chassis on which the vehicle is built enables much improved cab accommodation to be provided. Seating for four persons, including the driver, is available;

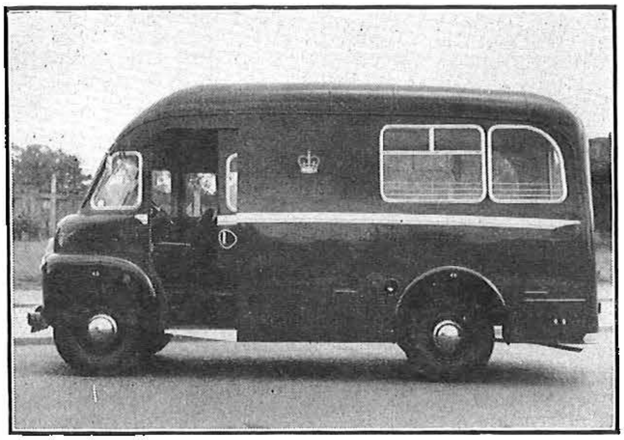


FIG. 6.—SLIDING DOOR OPENED TO SHOW INTERIOR OF CAB OF NEW CABLE TEST VAN.

bucket-type seats for the driver and the front passenger and a bench seat, facing forward and located on the offside of the cab, for the rear passengers. The driver's seat is adjustable for height and in the forward and rearward directions. A view of the cab is shown in Fig. **6**. Beneath the rear passengers' seat are two spacious lockers, which are independently locked, providing ample personal locker space and, if required, additional stowage space for equipment.

Access to the body of the vehicle from the cab is by means of a sliding door (Fig. **5**) which is fitted with a yale type of lock to ensure the security of the contents of the body when the vehicle is left unattended in garages with the cab doors unlocked. A sliding glass panel fitted in the bulkhead partition provides a clear line of vision from the cab, through the body and the large window in the rear door, to the rear of the vehicle. The two 12-V vehicle batteries, provided to cope with the heavy lighting load which occurs when testing operations necessitate the interior illumination of the body, are located beneath the cab in an underfloor locker, access to which is obtained via a floor trap secured by a budget lock.

Accommodation for the Generator No. 2 (Reed Hummer) is provided in a compartment also beneath the cab floor immediately below the front passenger seat. Access to this locker is obtained through a floor trap uncovered by tipping the passenger seat forward. The compartment is felt-lined to provide a reasonably soundproof housing for the Generator No. 2, and has been located in this position so as to be as remote as possible from the test benches within the body of the vehicle. Wiring for connecting the generator is terminated inside the compartment and extends in conduit to a terminal block mounted above the offside test bench.

The vehicle tools, with the exception of the jack handle, are accommodated in another underfloor locker beneath the driver's seat, access to which is gained by sliding the seat forward. The jack handle is housed on the rear passengers' seat supporting rail where it is secured in position by two straps. Two coat hooks, one on either side of the sliding door aperture, and a light for illuminating the cab complete the cab facilities. Access to the cab is gained by a flush-fitting sliding door on the nearside and by a hinged door for the driver on the offside.

To provide for towing a trailer toolcart a detachable towbar was specially designed by the Motor Transport Branch. This towbar slips into two vertical keyways fitted to the ends of brackets which are attached to the rear of the chassis members. When not required the towbar is housed beneath the chassis on the offside along with the spare wheel, access being gained by means of a hinged flap which when closed completes a deep unbroken skirt line for the vehicle body.

Mounted as it is on a well-sprung chassis with adequate shock absorbers, the vehicle is considered to be a considerable improvement on the old type of test van, and it is hoped that it will serve the users well.

Acknowledgments.

It is desired to record acknowledgments to the officers of the Motor Transport Branch who were concerned in transforming the user requirements into a practical form, and to colleagues in the External Plant and Protection Branch.

Book Review

"Radio and Radar Technique"—*continued from p.* 172.

modulation, which in turn forms the first part of a thorough treatment of various types of velocity-modulation valve, namely, coaxial-line valves, Klystrons with two and three cavities, reflex Klystrons, travelling wave valves and cavity-magnetrons. However, surprising to relate, although the author devotes four pages to travelling-wave valves he omits any explicit reference to the use of a longitudinal magnetic field for focusing the beam current, an omission which would of course affect only a newcomer to the subject. Nevertheless, in the next edition, and there will assuredly be one, this should be rectified.

Chapter 6, "C.W. Circuit Technique," is a masterpiece of compression. In 90 pages the author covers the steady-step behaviour of both passive and active lumped circuits. After a useful introduction to the idea of the complex-frequency plane the author proceeds to a general treatment of circuit theory, in which he quotes and discusses a wide and well-chosen range of network theorems. He goes on to consider filters, equalisers and amplifiers, including feed-back amplifiers; but neither here nor anywhere else are oscillators considered.

The seventh and last chapter on "Waveform Circuit Technique" is really complementary to the preceding chapter in considering circuits from the point of view of their time-response rather than their steady-step response. The chapter opens with an introduction to Heaviside's Operational Method and the Laplace Transform, and then proceeds to discuss the step-wave responses of various simple circuits. The later parts of the chapter are devoted to considering the operation of a variety of more complicated circuits widely used in radar and television techniques, e.g. the Phantastron, the Sanatron, etc. The chapter ends with a useful section on dividers and counters.

Rather more than the last third of the book is devoted to thirty appendices, mostly mathematical analyses, which would have made the main text more difficult to read had they been incorporated in it.

The full bibliography, to be found at the end of every chapter and practically every appendix, enhances the value of this excellent book.

H. S.

An Impedance Measuring Set

R. B. ARCHBOLD, B.Sc.(Eng.)†

U.D.C. 621.317.7:621.317.336

This article describes a method of measuring electrical impedance in the audio-frequency range, which was proposed by Dr. Grutzmacher several years ago but which is not generally known in this country. Details of a measuring set based on this principle are given together with comments on its accuracy and limitations. Finally, examples are included to show how the simple and rapid operation of the set makes it particularly useful for measurements on telephone line circuits and apparatus.

Introduction

THERE are many excellent methods of measuring electrical impedance and in general each of them has been designed to fulfil a particular requirement. The choice of method is invariably dependent on a large number of factors such as the nature of the impedance, its approximate modulus and angle, and the degree of accuracy required. Often, however, one of the major considerations is that of time; some impedance bridges are tedious to balance and many involve the user in lengthy calculations. A specific case, where the time involved is most important and precise accuracy is not of necessity required, is that of finding the electrical impedance/frequency characteristics of electro-acoustical transducers, in particular those of telephone receivers. This arises from the fact that the impedance is not generally a simple function of frequency, and a large number of measurements are usually required to define the characteristic.

The impedance measuring set to be described is ideally suited for the determination of these and similar impedance/frequency characteristics. The principle of the method is not new. It was proposed by Dr. Grutzmacher[1] about 1934 and has been recorded elsewhere[2]; it is not, however, in general use in this country. As will be seen from the following paragraphs it is not a precision method, but for the majority of measurements in the audio-frequency range it can be made to give an accuracy of better than ± 2 per cent. in modulus and ± 1° in angle. Its main advantage lies in the fact that it can be used to determine a relatively complex impedance/frequency characteristic quickly even if the sign of the impedance changes in the range of measurement.

Principle of the Measuring Set

In normal use the modulus, angle and sign determinations are made in rotation and the same sequence of operation is given in the following description of the principle of the method.

Stage I—Magnitude of the Impedance.

In Fig. 1(*a*) R_1 is made equal to R_2, $Z\angle\theta$ is the impedance to be measured and R is a variable resistor. V is a valve-voltmeter, the input impedance of which is high. An audio-frequency oscillator is used as the A.C. source.

The valve-voltmeter is switched alternately between points ab and bc, and the variable resistor R adjusted until the same voltmeter reading is obtained in each position, when this is so,

$$R = Z|$$

Fig. 1 (*b*) shows the vector diagram when this condition exists. As the voltage across R is equal to the voltage across Z

$$\text{ab} = \text{bc}$$

$$\therefore \quad \angle\text{bad} = \angle\text{bcd} = \frac{\theta}{2}$$

and because $R_1 = R_2$, d is the mid-point of ac and $\therefore$ $\angle\text{adb} = \angle\text{cdb} = 90°$.

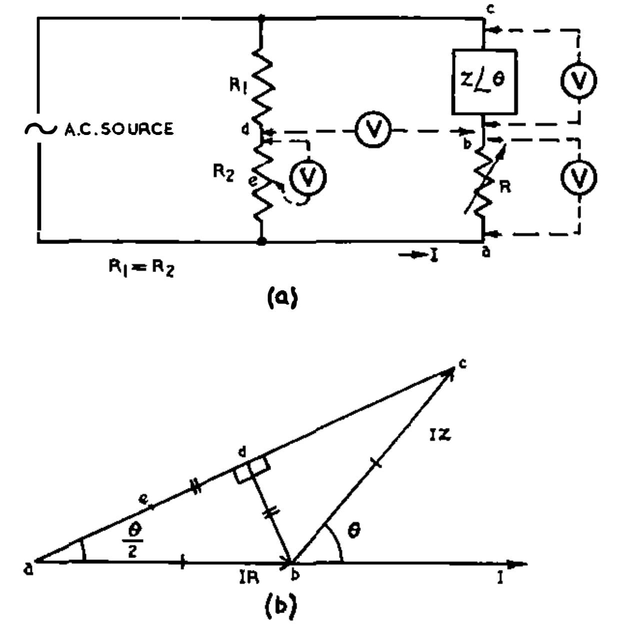


FIG. 1.—SCHEMATIC CIRCUIT AND VECTOR DIAGRAM FOR MEASUREMENT OF MODULUS AND ANGLE OF AN IMPEDANCE.

Stage II—Measurement of θ.

Tan $\theta/2$ could be determined at this stage by direct measurement of the voltages bd and ad, but this would make the method dependent on the voltmeter calibration. It is better to connect the voltmeter alternately between points bd and de where e is a slide on the resistor R_2. By adjusting the slide for equality of voltmeter readings,

$$\text{bd} = \text{ed}$$

$$\text{and,} \quad \tan\frac{\theta}{2} = \frac{\text{bd}}{\text{ad}} = \frac{\text{ed}}{\text{ad}}$$

i.e., the slide may be calibrated directly in terms of θ by using known impedances. Moreover, because the tangent of an angle is approximately proportional to the angle up to 45° (the maximum value of $\theta/2$), the scale of the slider will be almost linear over its complete range of 90°.

Stage III—Determination of the Sign.

To determine the sign of the impedance a capacitor is introduced between R_1 and R_2 as shown in Fig. 2 (*a*), and voltmeter readings bd_2 and bd_1 are taken on each side of the capacitor. The vector diagram of Fig. 2 (*b*) is drawn for the case where the impedance Z is inductive (+ ve angle). The increase of voltmeter reading from position bd_1 to bd_2 is used as an indication of the + ve angle. The corresponding vector diagram for the capacitive case is drawn in Fig. 2 (*c*) where it will be seen that the voltmeter reading reduces from bd_1 to bd_2, thus indicating an impedance with a negative angle.

In the measuring set to be described the three principles stated are applied. In the original method proposed by Dr. Grutzmacher an alternative principle was used for the determination of the sign. A fixed capacitor C was introduced first in series with the variable resistor R and then in series with the unknown impedance, the voltage across each

† Senior Executive Engineer, Post Office Research Station.

[1] "Un nouveau pont pour mesurer le module et l'argument d'une impédance en courant alternatif." M. Grutzmacher, *Annalles des P.T.T.*, Nov. 1934.

[2] *B.I.O.S.* Final Report, No. 606.

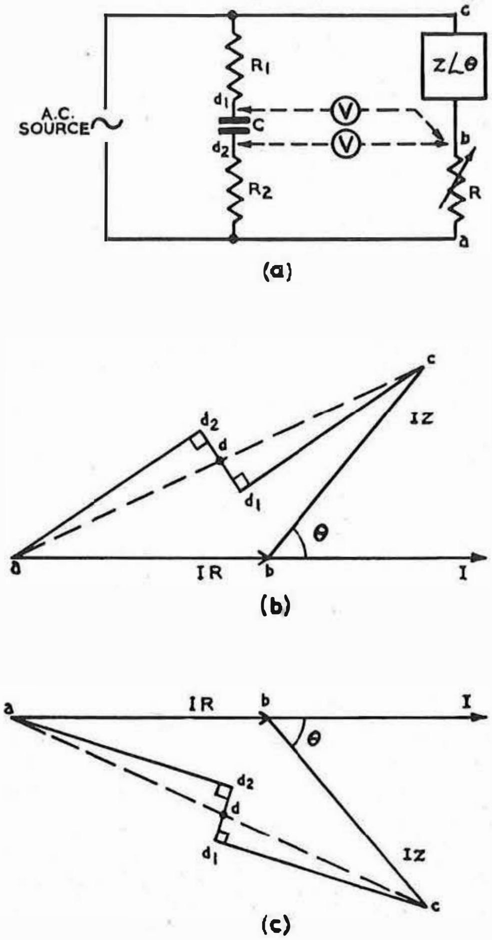


FIG. 2.—SCHEMATIC CIRCUIT AND VECTOR DIAGRAMS FOR DETERMINATION OF THE SIGN OF AN IMPEDANCE.

of the series connections being measured in turn. With this arrangement the sign of Z is determined by the relative magnitudes of these two voltages, i.e.,

$$\text{when } \left| Z + \frac{1}{j\omega C} \right| < \left| R + \frac{1}{j\omega C} \right| \text{ the angle is positive}$$

$$\text{and when } \left| Z + \frac{1}{j\omega C} \right| > \left| R + \frac{1}{j\omega C} \right| \text{ the angle is negative.}$$

The former method is perhaps to be preferred because it involves one less switching operation. Also, as measurements must be made in the sequence, modulus, angle, and sign, it is convenient that the order of voltage in the "sign" determination is very similar to that obtained in the "angle" position.

A Practical Design

In a practical design embodying the principle it was found most convenient to feed the network from a constant voltage source in order to limit the voltage range across the unknown impedance and variable resistor during balance. A 10- or 20-ohm source impedance was found to be suitable.

To obtain a simple circular scale of angle and to arrange for the inclusion of the voltmeter in the slide of resistor R_2, identical wire-wound rotary potentiometers were used for R_1 and R_2. Care was taken in their choice to ensure that they were matched and of sufficiently low inductance to cause negligible error in the angle determination over the required frequency range. Large potentiometers of about 3 in. diameter (1,000 ohms) were found to have a graduation sufficiently smooth to give an accurate measurement of the angle. A high-grade variable resistor was chosen for R.

One rotary three-position switch was used to make the necessary circuit changes for the measurement of magnitude, angle and sign. In addition a single lever switch was arranged to switch to the two alternative voltmeter connections required for each of the three positions of the rotary switch.

For the determination of sign a fixed capacitor of 1 μF was introduced at point d (Fig. **2** (*a*)). This value has proved satisfactory for measurements of telephone apparatus in the audio-frequency range, although at certain frequencies the increase or decrease of voltmeter reading is small. Ideally, if it was required to obtain a large change of reading, the capacitor C would have to be changed with frequency.

In Fig. **3** a Speech Voltmeter Type 3 is shown with the set; this is largely an association of convenience because

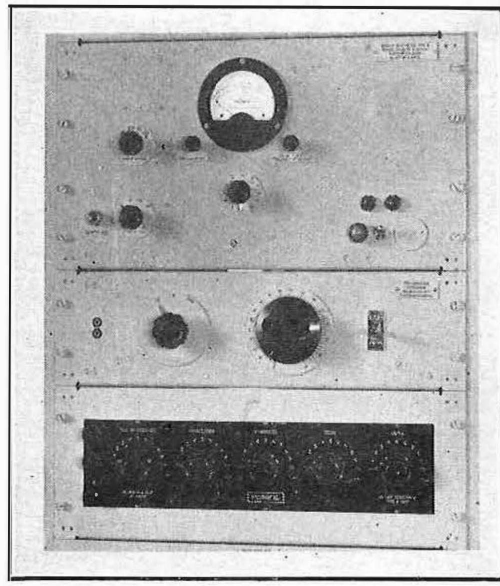


FIG. 3.—THE IMPEDANCE MEASURING SET, USING SPEECH VOLTMETER TYPE 3.

the voltmeter is used for many other acoustical measurements. A Tester **RP 790** or similar level measuring set could be readily adapted to meet the same purpose. The main essential of the voltmeter is that it must have a high input impedance, preferably of 10,000 ohms or more, as otherwise it may introduce errors when measuring the angle. In addition it must have a wide range of measurement, particularly if the instrument is to be used to measure small angles; 40-50 db. would be suitable for most purposes.

Fig. **4** shows the complete circuit of the measuring set, the front panel layout of which is shown in Fig. **3**.

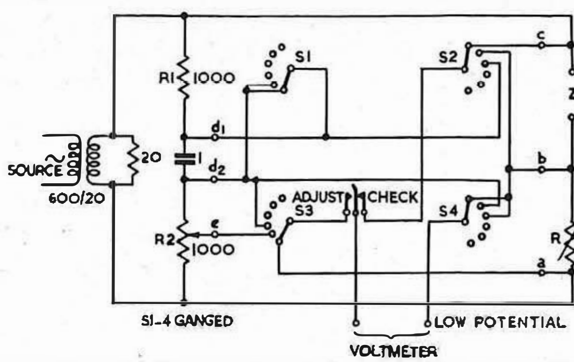


FIG. 4.—CIRCUIT OF THE SPEECH MEASURING SET.

Calibration of the Set

The scale of angle is calibrated by connecting a high-grade resistor and capacitor in series as the unknown impedance.

The values of these are adjusted to give any desired angle and the scale graduated accordingly. As the scale is approximately linear it is generally sufficient to calibrate at 5° intervals and otherwise use linear interpolation, save at the extremities of the range where the last two or three degrees are best calibrated individually. The scale is finally checked over the range of impedance modulus and frequency for which the set is required.

Accuracy of Measurement

It will be seen from the preceding paragraphs that the accuracy is controlled by a number of practical details. For example, the resistive elements should have negligible inductance and capacitance over the required frequency range and R should have an accuracy better than 1 per cent. The input impedance of the voltmeter must be high as otherwise the shunting effect will disturb the accuracy when measuring the angle.

If these factors are provided for and reasonable care is given to the layout and initial calibration, an accuracy of $\pm$ 2 per cent. in modulus and $\pm$ 1° in angle over a frequency range of, say, 80 c/s–6,000 c/s for impedances up to 10,000 ohms may be readily obtained. This accuracy may be retained at frequencies and moduli outside the range of calibration, but for large impedances, particularly at high frequencies, the stray capacitances of the network elements may reduce the accuracy.

The set is least suited for measuring almost pure resistance and reactance where, in both cases, the stray effects are greatest. In addition, in the first case, the voltmeter is required to measure potentials of very low order in position bd.

It should be noted that the determination is independent of voltmeter calibration.

Typical Measurements

As the set was designed primarily for measuring the electrical impedance of electro-acoustical transducers, an example is included here to show why it is particularly suitable in this field. Fig. 5 shows the impedance/frequency characteristic of a microphone from a sound-powered telephone. The main points of interest are:—

(*a*) The varying nature of the modulus and angle, i.e., the undulations of the characteristic.

(*b*) The non-coincidence in frequency of the peaks and troughs of the modulus and angle curves.

(*c*) The wide range of magnitude of both functions.

(*d*) The change of sign of the angle.

(*e*) That the result is given directly in terms of $Z\angle\theta$ which is the form generally required.

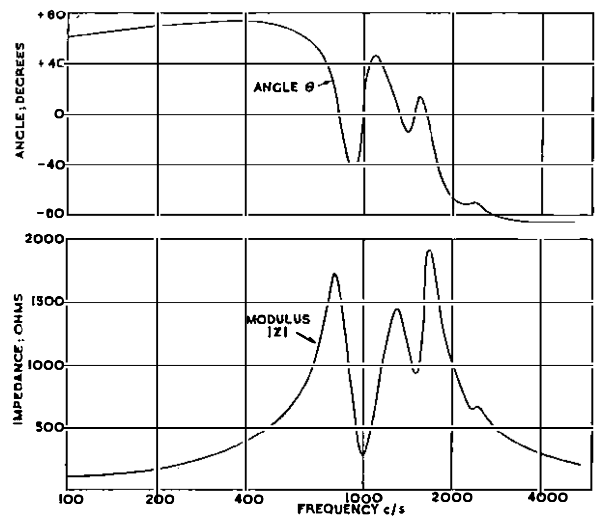


Fig. 5.—Impedance/Frequency Characteristic of Microphone of a Sound-Powered Telephone.

As the measuring set requires no component changes to cover the wide range of magnitudes and the change of sign, switching operations are reduced to a minimum. Furthermore, the peaks and troughs are clearly indicated on the voltmeter so that the number of observations can also be kept to a minimum. Both of these factors contribute to the normal speedy operation of the measuring set.

One additional useful factor is that the voltage across the impedance is monitored so that if the voltmeter is calibrated the impedance may be measured at some specified voltage. This is desirable in certain cases where the item to be measured is non-linear and it is necessary to measure the impedance at a particular voltage.

Although the impedance of a telephone microphone has been chosen as an example, the measuring set has been found extremely useful for the measurement of line impedances. Many measurements on artificial cables, exchange bridges and subscribers' sets have been made in the laboratory; and, indeed, the simplicity and speed of operation particularly recommend it for this form of work.

Acknowledgments

The author wishes to acknowledge the helpful assistance of his colleagues at the Research Station in the preparation of this article and in particular that of Mr. J. O. Ackroyd for his original suggestion to apply Dr. Grutzmacher's principle to impedance measurements associated with acoustical studies.

Book Reviews

"Basic Principles in Electrical Engineering." I. H. Child, B.Sc.(Eng.), A.M.I.E.E. E. & F. N. Spon Ltd. 112 pp., 45 ill. 10s. 6d.

This book does not deal generally with basic principles in electrical engineering but with particular applications to 11 specific points which the author has found are inadequately understood by students. This is the only link between the chapters, each of which is a separate essay and originally appeared as such in a bi-monthly house journal.

The subjects covered are:—

Some stumbling blocks in elementary transformer theory.
Polyphase A.C. fields.
Voltage rise on load.
Alternators in parallel.
Torque of single-phase motors.
Ward Leonard speed control.
Simple basis of smoothing circuits.
Arc control.
Starting rotary convertors on A.C.
Elementary power system studies.
Alternator reactance.

In explaining the basic principles of each the author has for the most part adopted two approaches, the practical and the mathematical. No rigorous treatment is attempted. The author says "The endeavour has been to demonstrate in as simple a manner, in as homely words and with as few frills as possible". He seems to have erred on the side of superficiality.

A. E. P.

The Changed-Number Announcer

U.D.C. 621.395.625.3 : 621.395.722

This note describes a semi-portable equipment used instead of interception operators to answer, with a standard announcement, calls dialled by subscribers to changed numbers immediately following an auto-auto exchange transfer.

MAGNETIC tape recording and reproducing machines have of late years been put to an increasing variety of uses in the telecommunications field, including, in some countries, the provision of various revenue-earning information services on the public telephone network. In Britain, magnetic tape machines are used by the Post Office and others in a number of specialist applications, but so far the only tape machine used by the Post Office to transmit announcements over the telephone network has been the Changed-Number Announcer. This machine is used instead of interception operators to handle calls which subscribers dial to the numbers ceased after an auto-to-auto exchange transfer. It gives continuously repeated announcements reproduced from an endless loop of tape.

The suggestion that the Post Office should use an automatic announcer for this purpose came from Scotland, where there was insufficient accommodation for the portable changed-number interception equipments needed at Edinburgh for the March 1950 transfer of part of the network to director working. Some 6,000 numbers were ceased and the announcer handled 18,000 calls on the first full working day after the transfer, a Monday. By the following Friday, the number of calls had fallen by a half. Undoubtedly a substantial proportion of calls on the first few days were "curiosity calls" stimulated by advance publicity, but notable operating savings were achieved. Use of a changed-number announcer is economically justified at considerably smaller transfers, and nearly a dozen announcers are now more or less continuously employed at transfers in different parts of the country.

The announcement is usually worded: "The number you are calling has been changed. Please consult your new directory"; or similarly. With such an announcement, it is found that the average holding time for the first few days after a transfer is only 20 seconds or so, falling later, so that only small numbers of relay-set equipments are needed for switching calls to the announcer. At present, these relay-sets have to be strip-mounted as required, but a standard equipment is being designed which will have capacity for 60 jacked-in relay-sets. As these relay-sets have only two relays each they will be mounted four per relay-set base, so that the standard equipment will have 15 mounting positions for standard 2,000-type relay-set bases. There are circuit differences between the relay-sets required for switching calls routed to ceased whole selector levels and those required for switching calls dialled to numbers ceased at random in the final selector multiple, and it will be possible to jack in relay-sets of either type up to a maximum of 60 according to the requirements of any particular transfer. (60 relay-sets would be able to handle something like 5,000 calls per hour at a grade of service of 1 in 50, if the announcement were worded approximately as above.)

The standard equipment will be a semi-portable rack accommodating relay-sets as described above and a speech power amplifier and control circuit, the main purpose of the latter being to cause N.U. tone to be transmitted to subscribers on failure of the announcements. Failure of announcements will cause release of an alarm relay in the amplifier and change-over to N.U. tone will be automatic. Such a rack and equipment will be required at each exchange at which numbers are ceased at a transfer, but the announcer itself will be required in only one, to be called the "main" exchange. The main exchange amplifier will transmit announcements over lines to the amplifiers in the distant exchanges, the lines being connected in parallel with the feeds to the main exchange relay-sets.

The announcer itself will not be rack-mounted, but will be a separately transportable unit.

The speech-power amplifier used has a low output impedance, of about 5 ohms, and can handle a speech output power of up to about 3W, so that the output voltage varies little with the load, up to 50 simultaneous connections or more. The low output impedance also serves to minimise cross-talk between connections. Cross-talk attenuation is increased by decoupling resistors and capacitors series-connected in the speaking pair of each relay-set. A subscriber mis-routing a call to a ceased level is very likely to dial further digits into the changed-number announcements, and this must not mutilate the announcements for other subscribers listening to them. Neither must it be possible for subscribers to talk to each other across the common impedance of the amplifier output.

The announcer used is a standard commercial model with loop tape deck. It will later be modified to incorporate a relay for "start-stop" working, to reduce the rate of wear of the mechanism. However, for the present, it is reasonable to run the machine continuously for the first week after a transfer and thereafter to switch announcements off altogether in slack periods of traffic. Another modification, which is being tried experimentally, is the provision of an adjustable tape guide pin to take up the slack in loops of tape, for without this adjustment the length of a loop of tape which the deck can accommodate is fairly critical, which makes for difficulty in recording. A pause of more than a second or two cannot be left between successive announcements since it might allow the amplifier alarm relay to release, and its re-operation by the succeeding short announcement would be uncertain. The tape deck can accommodate long loops of tape by means of a "cassette," in which the tape loop is coiled. (The inside turn of the tape is pulled out of the cassette by the drive capstan to pass over the "erase" and "record/playback" magnetic heads, over the driving capstan head, and back into the cassette on the outside of the coil.) Except during recording, however, it is preferred to use short loops of tape which either do not pass through the cassette at all, or take only a half-turn round it; for there is no point in wearing longer lengths of tape, and longer lengths cannot be stored ready jointed into loops for quick replacement of broken or worn tapes, since they have to be threaded through the cassette when required for use.

The tape speed used is $3\frac{3}{4}$ inches per second, which can give a quality of reproduction more than adequate for transmission over telephone lines.

Motor bearings are simple sleeve, self-lubricating bearings, which are relatively cheap, and require little or no maintenance attention from normal users of commercial-model tape machines. When a machine is subjected to long periods of continuous running as a changed-number announcer, however, occasional sparing lubrication with oil is found necessary.

Magnetic tape machines, of course, give far less reliable service than, for example, announcing machines like the British speaking clocks, in which the announcements are recorded on glass discs for photo-electric reproduction. Their reliability is, however, adequate for changed-number announcing purposes.

D. J. M.

C.C.I.F. Conference, Lahore, December, 1953

U.D.C. 061.3: 621.395

A note on the recent C.C.I.F. Conference held in Lahore to plan, in broad outline, the future extension of the international telecommunications network of the Middle East and Southern Asia.

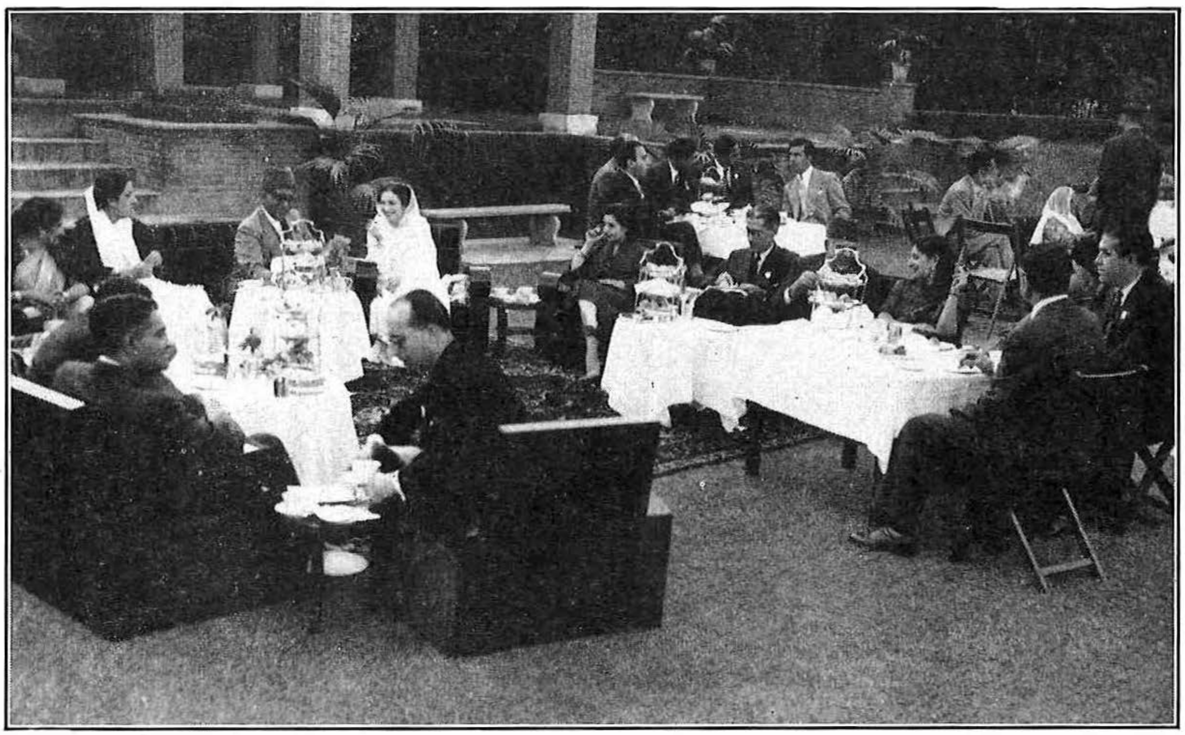
Introduction.

IN Resolution No. 247 of June 1952, the Administrative Council of the International Telecommunication Union called upon the three C.C.I.s: "To study the best way of connecting the countries of the Middle East and Southern Asia with the network of major international telecommunication lines in Europe and the Mediterranean Basin by metallic lines or radio-relay links." As a result, a subcommittee of the C.C.I.F. Joint Committee for the General Switching Programme, with representatives of the C.C.I.R. and the C.C.I.T., met in Lahore, Pakistan, from the 1st to the 14th December, 1953, to prepare the outline for such a plan. The United Kingdom was represented at this Conference by Mr. H. Stanesby of the Post Office Engineering Department, who was later joined by Mr. R. S. Smith, District Manager of Cable & Wireless, Ltd., Persian Gulf. Mr. Stanesby also represented the C.C.I.R. jointly with Mr. van der Mark of the Secretariat.

Work of Conference.

The Conference was formally opened in the Chambers of the Legislative Assembly in Lahore by His Excellency Mian Aminaddin, Governor of the Punjab. Thereafter, however, all meetings were held in Faletti's Hotel. Mr. Mirza, Chief Engineer of the Pakistan Posts and Telegraphs and a well-known figure in international telecommunications circles, was Chairman of the Conference, and Mr. Lalou, who represented the Secretariat of the C.C.I.F., was the Secretary.

Some preliminary information had already been obtained by the C.C.I.F. Secretariat on the circuits existing in the regions concerned, and connecting them to other parts of the world; and on the volume of telephone and telegraph traffic currently handled by these circuits, and the extent to which it was expected to grow in the next few years. During the Conference further data were accumulated from representatives at Lahore in respect of their own countries and by telegram from countries not represented.



GARDEN PARTY GIVEN TO DELEGATES BY THE GOVERNMENT OF THE PUNJAB IN GULISTAN-E-FATIMA.

Representation.

The following countries and international organisations participated:

Afghanistan		Italy
Burma (last two days only)		Lebanon (represented by Egypt)
Ceylon		Pakistan
Egypt		Spain
France		Turkey
India		United Kingdom
Iran		Yugoslavia
C.C.I.T.	C.C.I.R.	W.M.O.

As is usual at conferences of this type most of the detailed work was carried out in working groups of which four were formed, namely:

Working Group No. 1—"Routing," under the chairmanship of Iran. This working group prepared maps indicating:

(*a*) the circuits existing in the regions concerned;

(*b*) the extensions already planned for provision by the end of 1957;

(*c*) routes proposed by the group for principal and subsidiary international arteries;

(*d*) the traffic routing planned, giving the circuits that should be provided between specific points on the arteries of (*c*) above by the end of 1957.

Working Group No. 2—"Traffic and Circuits Assessment," under the chairmanship of India. This working group studied data on the present telecommunications traffic between countries of the regions concerned, and attempted to predict how much the traffic would have grown by the end of 1957. It then computed the number of telegraph and telephone circuits considered necessary to handle this traffic, assuming that the telephone service would be operated manually on a no-delay basis.

Working Group No. 3—"Methods and Systems," under the chairmanship of Italy. This working group considered in general terms the characteristics of the different types of telecommunication system that might be adopted for various sections of the International Network. It then considered each section separately, indicating the method of circuit provision that was, in the group's opinion, best suited to local conditions.

Working Group No. 4—"Tariffs," under the chairmanship of Turkey. This working group reviewed existing methods of computing tariffs, but had difficulty in applying them to the network under consideration.

The United Kingdom representatives devoted most of their time to the meetings of Working Groups Nos. 1 and 3. In particular they were able to give the latter group the benefit of U.K. experience in the use of V.H.F., U.H.F. and S.H.F. radio-relay systems. It was necessary to point out that no general rules could be laid down for determining the relative merits of the various types of metallic and radio-relay system, but that each case must be considered in the light of local conditions. Much information was given, however, on the general characteristics of various systems and on matters relating to radio propagation.

As is no doubt well known, apart from long-distance radio and submarine-cable links, the international telecommunication network of the Middle East and Southern Asia is based almost entirely on the use of open-wire. In preparing plans for the future extension of this network, great emphasis was placed by delegates from the countries concerned on extending and increasing the capacity of these open-wire routes. For this reason cable and radio-relay systems feature only to a small extent in the plans prepared by the Conference. There was, however, some discussion as to whether, in view of local conditions, open-wire routes would, in fact, provide connections of sufficient quality and reliability for very long international circuits.

The Conference was clearly a success in that it accomplished what it set out to do, namely, to plan in very broad outline a telecommunications network for the Middle East and Southern Asia. Moreover, it seems likely that the trunk telephone facilities of these parts of the world will in fact benefit considerably from the work of the Conference.

It is believed that this is the first time that an I.T.U. Conference has been held in Asia. The occasion was therefore regarded as of special importance and the Government of Pakistan with great hospitality arranged a number of receptions and other social functions including a visit to one of the biggest mosques in the world, the Badshahi Mosque, just outside Lahore. These functions were made all the more pleasant by the weather, which was warm and cloudless; and the accompanying photograph shows a scene typical of several very pleasant garden parties to which delegates were invited. H. S.

Seventh Plenary Reunion of the Commission Mixte Internationale, May, 1954

U.D.C. 061.3:621.3.013.7

This note on a recent meeting of the C.M.I. includes information concerning the functions of the C.M.I. and the procedure followed. It also lists the Study Groups which operated.

Introduction.

THE 7th Plenary Reunion of the Commission Mixte Internationale (C.M.I.) took place at the Ministry of Posts, Telegraphs and Telephones, Avenue de Ségur, Paris, from 24th-31st May, 1954. The Commission sat under the Presidency of Mr. C. W. Marshall, Divisional Controller of the South West Scotland Division of the British Electricity Authority, with Mr. M. G. Swedenborg of the Swedish Telephone Administration as Vice-President and M. Valensi of the International Telephone Consultative Committee as Secretary.

The following international bodies were represented: The International Telephone Consultative Committee (C.C.I.F.); The International Conference of Major Electric Systems (C.I.G.R.E.); The International Union of Railways (U.I.C.); The International Union of Producers and Distributors of Electric Power (U.N.I.P.E.D.E.); and The International Union of the Gas Industry (U.I.G.).

There were also present representatives of professional bodies (e.g., The Institution of Electrical Engineers); manufacturers of electrical equipment; research laboratories (e.g., The British Electrical Research Association); tramway associations; and nationalised electricity undertakings (e.g., the Swedish State Power Board).

Approximately 70 delegates, from Austria, Chile, Denmark, France, Italy, Mexico, the Federal Republic of Germany, Great Britain, Sweden, Switzerland and Yugo-Slavia attended the Reunion. A Japanese delegation was also present at one meeting.

The C.M.I.

The C.M.I., or, to give its full title, the "International Mixed Committee on the Protection of Telecommunications Lines and Underground Cables and Pipes," is, as its name implies, a combined committee representing both power and telecommunications interests. Its primary function is to study, at an international level, the effects of the operation of high-power electric networks, such as power-distribution lines and electrified traction systems, on overhead and underground telecommunications lines and other plant (e.g., gas mains), and to secure an interchange of information on such matters.

In general, the C.M.I. operates by the circulation of questions of interest to members, who are invited to record their experiences or opinions.

This circulation is performed by the Secretariat which is normally located in Geneva, Switzerland. The material so produced is then discussed at meetings of the Committee, which are convened by the Secretariat at varying intervals—usually of the order of two to three years. At the recent meeting it was agreed, for instance, that the next Reunion should take place in 1957 and be held in Geneva.

In addition, so-called "Valadatory" meetings are held at irregular intervals. These are convened with the object of enabling delegates to witness field tests which have been suggested at preceding Reunions. Between the 1950 and 1954 Plenary Reunions there were three such meetings. The first took place at Florence, Italy, in October 1951, when a double-bridge method was demonstrated for determining the proportion of the current in a rail of an electric traction system, which leaks from the rail into the earth. The second was staged at Annecy, France, in March 1952, when investigations were made into the magnitude of voltages induced in railway telecommunications lines adjacent to the 20kV 50c/s Aix-les-Bains-Roche-sur-Foron single-phase railway. Finally, the behaviour of various lightning arrestors and acoustic shock absorbers, when connected in turn to lines exposed to induction from a power line, was investigated at Porchefontaine, France, in December 1953.

The proceedings of the Reunion are conducted in the French and English languages, delegates being asked to speak in whichever of these two they are most fluent. Interpreters then translate representatives' remarks from one language to the other as the meeting proceeds.

Procedure.

The discussions of the C.M.I. are divided into two main sections: the first deals broadly with matters relating to magnetic, electric and resistive coupling between power and communication circuits; and the second with problems involving damage to underground plant, principally that due to corrosion.

At the 1954 Reunion, the "First Section" of the C.M.I. was divided into ten, and the "Second Section" into nine Study Groups. Each Group consisted of members of the Committee particularly interested in the matter under discussion and sat under the chairmanship of a "President Reporter" who guided the discussions of the Study Group and summarised its findings. It is the practice for the Secretary of the C.M.I. to suggest as the "President Reporter" a member of the Study Group who is recognised as having a good knowledge of the subject under discussion.

The Study Groups.

The following summary of matters dealt with by the Study Groups during the recent session indicates the wide field covered by the two sections of the Committee. (Study Groups of the second section are numbered in the 20's for the convenience of the Secretariat.)

First Section

Study Group — *Subject*

No. 1—Definition and measurement of the disturbing action of electric power lines on nearby telecommunications lines.

No. 2—Measures to be taken on telephone and telegraph lines to reduce interference due to ionic converters (mercury arc rectifiers) in adjacent power systems.

No. 3—Study of zero phase sequence components in the supply and transmission of electric power.

No. 4—The influence of D.C. and A.C. electrified railway systems on adjacent telecommunications lines.

No. 5—The influence of electric power lines (with or without superimposed high frequency communications circuits) on adjacent carrier current telecommunications lines.

No. 6—Definition, measurement and permissible limits of induced noise on telephone lines.

No. 7—Unbalance of telecommunications circuits.

No. 8—Magnetic or electric coupling between power and telecommunications lines.

No. 9—The influence of high-voltage D.C. power lines on adjacent telecommunications circuits.

No. 10—Equipment for the protection of personnel and plant against danger from power lines.

Second Section

No. 21—Experimental studies of typical cases of electrolysis and measuring apparatus.

No. 22—Study of the production and behaviour of stray currents.

No. 23—Physico-chemical questions relating to corrosion.

No. 24—Means of reducing stray currents.

No. 25—Protection of underground cables and pipes against corrosion.

No. 26—Electrical protection (i.e., cathodic protection).

No. 27—The influence of trolley-bus lines on underground telecommunication systems.

No. 28—Protection of cables against damage due to lightning and causes other than those of an electrolytic or chemical nature.

No. 29—Corrosion of underground cables and pipes by high-voltage D.C. power supply systems.

In the course of its deliberations, each Study Group considered the documents prepared by the various member bodies and then decided upon the future course of action to be taken in each case. It might, for instance, be recommended that a current line of investigation be continued or, alternatively, that new possibilities thrown up by an investigation should be examined. As an example, in the case of Study Group No. 6, discussion of the material before the Group revealed that it would be useful to study the problems involved when installing telecommunications circuits in electric generating stations and high-voltage substations; in particular, the effects of rise of earth potential. As this problem does not fall strictly within the terms of reference of the current Study Group No. 6, it was decided to set up a new Group to be known as Study Group No. 6B. This will be charged with the study of "Resistive couplings between power and telecommunications installations—in particular at high-voltage substations."

As part of the British Post Office contribution to the work of Study Group No. 10, a report was presented on the high-voltage power conductor dropping tests previously described in this Journal.[1] In addition, a cinematograph film showing the tests in progress was exhibited.

A report on the British Post Office experience of corrosion when cathodic protection is applied to the lead sheath of cable in asbestos cement duct was also discussed with interest by Study Group No. 26.

Reports.

In due course, a report on the proceedings of its 7th Reunion will be published by the C.M.I. This report will contain a great deal of very useful information on the subject matter dealt with by each Study Group. The publication will be in French. S. J. L.

[1] *P.O.E.E.J.*, Vol. 47, p. 43.

Notes and Comments

Recent Award

The Board of Editors has learnt with great pleasure of the honour recently conferred upon the following member of the Engineering Department for services rendered to his country:—

Glasgow Telephone Area	Reid, J. M.	Technician IIB	Sergeant, Glasgow Highlanders	British Empire Medal

Appointments

As we go to press the following appointments have been announced:—

Sir W. Gordon Radley, C.B.E., Ph.D.(Eng.), Engineer-in-Chief, to be Deputy Director General in the place of Sir Ben Barnett, K.B.E., C.B., M.C., who will fill, from 18th October, 1954, an additional post of Deputy Director General created for a limited period to deal with the pressure of broadcasting work.

Brigadier L. H. Harris, C.B.E., Controller of Research, to be Engineer-in-Chief.

Mr. G. J. S. Little, C.B.E., G.M., Assistant Engineer-in-Chief, to be Controller of Research.

We offer our warmest congratulations to these officers and hope to publish appreciations in the next issue of the Journal.

Special Commendations

The Board of Editors notes with pleasure that the Postmaster General has personally commended the following members of the Engineering Department:—

Mr. E. H. Eden, Technical Officer, Blackburn Telephone Area—awarded the Royal Humane Society Testimonial on Parchment for his bravery in rescuing three small boys from drowning after they had fallen through the ice on a pond at Edgworth on 30th January, 1954.

Mr. D. C. Campbell, Technician IIA, Aberdeen Telephone Area—awarded the Royal Humane Society Testimonial on Parchment for rescuing a small child from drowning in Kirkwall Harbour basin on 7th September, 1953.

Awards by the Institution of Electrical Engineers

Congratulations are offered to the following members of the Engineering Department who have received individual or shared awards of Premiums for I.E.E. Papers during the 1953-54 Session:—

The Ayrton Premium.

R. J. Halsey, B.Sc.(Eng.) and F. C. Wright (S. T. & C., Ltd.). "Submerged Telephone Repeaters for Shallow Water."

A. H. Roche, B.Sc.(Eng.) and F. O. Roe, B.Eng. (both of S. T. & C., Ltd.). "The Netherlands-Denmark Submerged-Repeater System."

D. C. Walker, B.Sc.(Eng.) and J. F. P. Thomas, B.Sc. (Eng.). "British Post Office Standard Submerged-Repeater System for Shallow-Water Cables with special mention of the England-Netherlands System."

The Blumlein-Browne-Willans Premium.

G. Dawson, B.Sc. (S. T. & C., Ltd.), L. L. Hall, K. G. Hodgson, B.A., (S. T. & C., Ltd.), R. A. Meers, O.B.E., T.D. (S. T. & C., Ltd.) and J. H. H. Merriman, M.Sc. "The Manchester-Kirk o' Shotts Television Radio Relay System."

A Non-Section Premium.

A. Fairweather, Ph.D., M.Sc. "The Behaviour of Metallic Contacts at Low Voltages in Adverse Environments."

P.O. Telephone and Telegraph Society of London

We are pleased to record that the P.O. Telephone and Telegraph Society of London celebrates its 50th anniversary this month, having held its first recorded meeting in October, 1904. Throughout this long period the Society has met regularly each winter, except for wartime interruptions, and we wish it continued success in the future.

The Chairman of the Society during this memorable year is Col. J. Reading, M.B.E., Assistant Engineer-in-Chief.

Institution of Post Office Electrical Engineers

London Centre

The programme arranged for the first half of the 1954-55 Session is as follows:—

Ordinary Meetings†

12th October, 1954.—Chairman's Address. "The Organisation of the E.T.E." W. F. Smith, B.Sc.(Eng.), A.C.G.I., M.I.E.E.

9th November, 1954.—"Future Demands for Telephone Service—Possible Trends and Reactions." J. M. Norman.

Informal Meetings‡

27th October, 1954.—Vice-Chairman's Address. "Is your Stores Problem really necessary?" F. C. G. Greening, B.Sc. (Eng.), A.M.I.E.E.

24th November, 1954.—"Some Personal Views on Mechanised Maintenance."—F. H. Horner & B. H. E. Rogers.

Essay Competition 1954-1955

To further interest in the performance of engineering duties, and to encourage the expression of thought given to day-to-day departmental activities, the Council of the Institution of Post Office Electrical Engineers offers Five Prizes, a First Prize of Five Guineas and four prizes of Three Guineas, for the five most meritorious Essays submitted by members of the Engineering Department of the Post Office *below the rank of Inspector*. In addition to the five prizes the Council awards five Certificates of Merit. Awards of prizes and certificates made by the I.P.O.E.E. are recorded on the Staff Dockets of the recipients.

An essay submitted for consideration of an award in the Essay Competition and also submitted in connection with the Associate Section I.P.O.E.E. prizes, will not be eligible to receive both awards.

In judging the merits of an essay, consideration will be given to clearness of expression, correct use of words, neatness and arrangement, and although technical accuracy is essential, a high technical standard is not absolutely necessary to qualify for an award. The Council hopes this assurance will encourage a larger number to enter. Marks will be awarded for originality of essays submitted.

Hints on the construction of an Essay can be obtained, if desired, upon application to the Secretary at the address given below. Copies of previous prize-winning essays have been bound and placed in the Institution Central Library. Members of the Associate Section can borrow these copies from the Librarian, I.P.O.E.E. (G.P.O.), Alder House, London, E.C.1. Competitors may choose any subject relevant to current telegraph or telephone practice.

† To be held at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, W.C.2, commencing at 5 p.m.

‡ To be held in the Conference Room, 4th Floor, Waterloo Bridge House, S.E.1, commencing at 5 p.m.

Foolscap or quarto size paper should be used, and the essay should be between 2,000 and 5,000 words. An inch margin is to be left on each page. A certificate is required to be given by each competitor, at the end of the essay, in the following terms:—

"In forwarding the foregoing essay of..............................words, I certify that the work is my own unaided effort both as regards composition and drawing."

Name (*in Block Capitals*)..............................

Signature ....

Rank ....

Departmental Address..............................

....

Date ....

The Essays must reach
The Secretary,
The Institution of Post Office Electrical Engineers,
G.P.O. (Alder House), London, E.C.1,
by the 31st December, 1954.

The Council reserves the right to refrain from awarding the full number of prizes or certificates if in its opinion the essays submitted do not attain a sufficiently high standard.

H. E. WILCOCKSON,
Secretary.

Additions to the Library

2203 *Facts from Figures.* M. J. Moroney (Brit. 1953).
A general review of statistical methods.

2204 *Abridged Wiring Regulations* I.E.E. (Brit. 1954).
A shortened edition of the "Regulations for the Electrical Equipment of Buildings."

2205 *Atomic Energy for Military Purposes.* H. de Woff Smyth (Amer. 1948).
The official report of the development of the atomic bomb under the auspices of the U.S. Government 1940-1945.

2206 *Electronic Theory and Chemical Reactions.* R. W. Stott (Brit. 1953).
An elementary introduction to the theory of chemical reactions.

2207 *Relativity.* A. Einstein (Amer. 1945).
Designed to give an exact insight into the theory of Relativity to those who, from a scientific and philosophical point of view, are interested in the theory, but are not conversant with the mathematical apparatus of theoretical physics. Presumes a standard of education equivalent to a university matriculation examination.

2208 *Modern Armature Construction, Winding and Repair.* S. F. Philpott (Brit. 1954).
Deals with the practical aspects of the construction and winding of small and medium-size armatures.

2209 *Electrical Earthing and Accident Prevention.* ed, M.G. Say (Brit. 1954).
Covers the earthing practice in power systems, installations and communication systems.

2210 *The great Palomar Telescope.* H. Wright (Amer. 1953).
The story of the planning and building of the Hale 200-inch telescope.

2211 *Television Receiving Equipment, Vol. 1: Time-Base Circuits.* E. A. W. Spreadbury (Brit. 1954).
Designed to familiarise the maintenance engineer with the wide variety of circuitry. Assumes a knowledge of radio maintenance practice.

2212 *The Revolution in Physics: a non-mathematical Survey of Quanta.* L. De Broglie (French 1954).
The history of the Quantum Theory in non-technical language.

2213 *Relays for Electronic and Industrial Control.* R. C. Walker (Brit. 1953).
Collects together the principal features and potentialities of relays as switching devices.

2214 *Colour and Light at work.* R. F. Wilson (Brit. 1953).
Offers helpful comment on the use, benefits and interpretations of colour, with valuable instances of reactions to colour schemes.

2215 *Automatic Voltage Regulators and Stabilisers.* G. N. Patchett (Brit. 1954).
A general description of the methods of maintaining constant voltage, with extensive references to more detailed works.

2216 *Mathematics for Students of Engineering and Applied Science.* L. B. Benny (Brit. 1954).
Intended for students to degree standard.

2217 *Low-frequency Amplification.* N. A. J. Voorhoeve (Dutch 1953).
Gives a thorough insight into the whole of A.F. equipment from source to signal (one of the Philips' Technical Library volumes).

2218 *Building Construction, Vol.* 3. W. B. McKay (Brit. 1944).
Covers the latter portion of the syllabus in Building Construction, Stage 2, i.e., brickwork, drainage, masonry, mild steel roof trusses, carpentry, joinery and roof coverings.

2219 *Laplace Transforms for Electrical Engineers.* B. J. Starkey (Brit. 1954).
A presentation of the Laplace transformation using methods of explanation familiar to electrical engineers.

2220 *Crystal Rectifiers and Transistors.* Ed. M. G. Say (Brit. 1954).
Gives the electrical engineer an up-to-date survey of the present state of development of silicon and germanium crystal rectifiers and transistors.

2221 *Physics and application of Secondary Electron Emission.* H. Bruining (Brit. 1954).
Provides a survey of the phenomenon of secondary electron emission from substances in the solid state, with emphasis on the entrance side.

2222 *The Insulation of Electrical Equipment.* Ed. W. Jackson (Brit. 1954).
A compilation of lectures delivered at a post-graduate Vacation School.

2223 *Mental Health and Human Relations in Industry.* Ed. T. M. Ling (Brit. 1954).
A comprehensive approach to the main socio-medical problems met with in practice, and an attempt at their prevention and treatment.

2224 *Raw Materials for Electric Cables.* A. King and V. H. Wentworth (Brit. 1954).
Deals with the sources and characteristics of the materials, and the tests to which they are subjected before acceptance.

2225 *An Analytical Calculus, Vols.* 1 *and* 2. E. A. Maxwell (Brit. 1954).
Forms a complete course in Calculus from its beginnings up to the point where it joins with the subject usually known as analysis.

2226 *Magnetic Amplifiers and Saturable Reactors.* Ed. M. G. Say (Brit. 1954).
Sets out to provide an understanding of how saturable reactors, magnetic amplifiers and magnetic modulators function and how they may be applied to particular problems.

2227 *The Oscilloscope at work.* A. Haas and R. W. Hallows (Brit. 1954).
A practical guide, with special reference to radio and television receivers.

2228 *Practical Wireless Circuits.* F. J. Camm (Brit. 1954).
Includes typical circuits from the whole range of receivers and amplifiers.

2229 *Questions and Answers on Electrical Motors.* E. Molloy (Brit. 1954).
Covers all the chief types of D.C. and A.C. motors, installing, connecting up, speed control and reversing, with notes on power factor, simple calculations and re-winding.

2230 *Practical Television Circuits.* F. J. Camm (Brit. 1954).
Gives constructional details of successful television receivers, and of test apparatus and auxiliary equipment.

W. D. FLORENCE, *Librarian.*

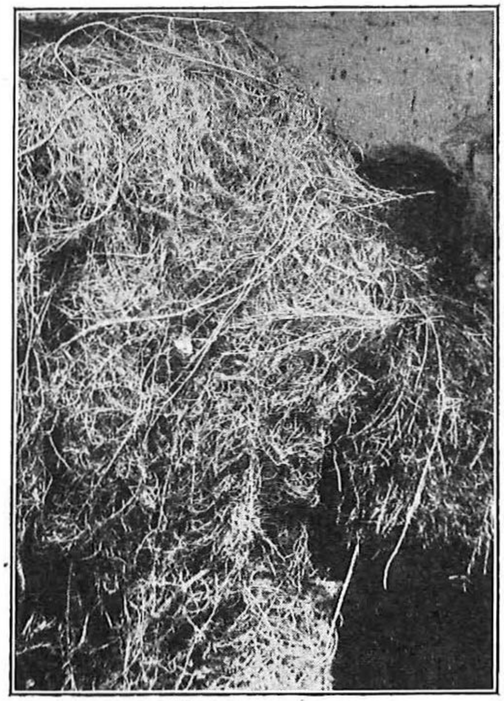
Regional Notes

Home Counties Region

ROOTS IN DUCT

During the survey of the Chatham–Sheerness duct line in preparation for pulling in a new cable, it was seen that in some manholes roots of trees were protruding from the duct, and arrangements were made to rod the duct and clear the roots.

At one manhole in a very isolated part of the track there was a mass of roots spreading along the cables from end to end of the manhole and draped down to the floor, completely hiding



Roots Growing in Manhole.

the two cables and the loading coil. At the duct mouth the mass of roots was almost 1 ft. 6 in. across and individual roots were 1 in. in diameter and so firmly wedged that the cables were forced to the top of the duct. An attempt was made to pull the roots out with a rope but four men were unable to move them. It was then thought that the roots had forced their way in

Roots Removed from Manhole.

through the duct line outside the manhole, from the trees which lined the roadway, but after rodding from the next joint box it was found that the roots had penetrated for a distance of only 4 ft. in the duct. A further attempt to remove them met with success, the withdrawal making a sound similar to drawing a cork from a bottle.

The cables had been completely embedded in the roots and the impression was clearly seen in that piece which came out from the duct.

The duct had not been broken and the only reasonable conclusion was that the growth of the roots had commenced in the manhole, which was full of water, and that the flow of water had directed the fibrous roots through the duct line.

H. C. P.

Wales and Border Counties

RADIO KIOSK AT CAPEL-Y-FFIN

The nature of some of the territory and the persistence of demands for rural kiosks in Wales has led to special consideration of unusual methods of providing service. Capel-y-Ffin, at the head of a very steep valley over 8 miles long, is 20 miles from Abergavenny, nearly 10 miles from the nearest exchange and 4 miles from the nearest pole route. The valley is not straight but by building a route for a distance of 400 yds. beyond the kiosk site it has been possible to gain some 200 ft. in height and this, coupled with the erection of a short spur to the existing overhead route, has given an optical path about 6 miles long.

Excellent communication is obtained using the battery-operated single-channel V.H.F. radio telephone equipment, with a radiated power of 20 mW, described in the Journal.[1] The capital cost of the installation was much less than that of an overhead line or a polythene underground cable and, having regard to the exposed situation, considerable saving in maintenance charges is expected.

C. T. L.

[1] *P.O.E.E.J.*, Vol. **44**, p. 75.

North-Eastern Region

DUCTWORK FOR DURHAM EXCHANGE TRANSFER

In connection with the transfer of Durham C.B. exchange to a new Auto Exchange building nearby, contract ductwork was commenced on 26th April, 1954.

The work involved included the laying of some 116 yds. of 36 multi-way, 8 yds. of 18 multi-way and 5 yds. of 36-way octagonal duct and the building of two large manholes (RT8C).

One of the manholes was built in Claypath which is a narrow, busy and congested thoroughfare carrying a high volume of the traffic passing through the city of Durham. From this manhole, 36-way duct has been laid across Claypath and along the narrow street, Providence Row, adjacent to the H.P.O. and leading to the new exchange building.

Following discussions and several meetings with the City Engineer, Police Authorities, etc., arrangements were made to close Providence Row to vehicular traffic from midnight on Saturday, 1st May, until noon on 8th May, and divert traffic by alternative routes whilst the ductwork proceeded; also to allow single-way traffic, using boiler plates over the duct trench, in Claypath. As Providence Row also leads to the Durham City Fire Station arrangements were made for certain Fire Service staff and equipment to be accommodated elsewhere whilst the street was closed, and traffic diversions, by lamp signalling, were in operation through the city.

The work was very difficult because of the positions of other services in both carriageway and footway necessitating diversions to P.O. plant; and also due to the hilly nature of the busy thoroughfares concerned. The Contractor's men worked continuous shifts during the period when the street was closed to traffic and, using adequate mechanical aids and road traffic signals in the main street, satisfactorily completed the work within scheduled time. All concerned may be complimented on a good performance.

H. E. H.

REMOVAL OF U.A.X.12 FROM AYSGARTH TO WENSLEY

The need for economy in the Post Office Engineering Department has meant that work has to be done with limited stores and with reduced manpower. This led to the thought that perhaps a U.A.X.12, which was to be replaced by a U.A.X.13, could be lifted as a complete unit and fitted in an empty U.A.X. building to permit an urgent conversion to be undertaken. Measurements of the door space in the two buildings showed that if the feet were removed from the units they would just pass through the space between the threshold and lintel.

The construction of a new wooden building at the rear of the existing building had unfortunately left 9 in. less room than the length of the five units (one C, two A and 2 B units). It was considered that the units could be fed into the doorway of the new exchange prior to turning. Examination of the "receiving" building showed that the garden would need to be built up since it dropped some 2 ft. to 2 ft. 6 in. It was decided to have a platform erected at this exchange.

The units were dealt with as follows:—

The wing nuts were removed from the top and bottom of the units. All covers and "jacked-in" items were removed. A piece of "Dexion" angle iron was fitted across the top of the units, back and front, and the bolts with the wing nuts removed were used to tighten the Dexion into place, ordinary nuts being used. Dexion was then fitted across the centre of the units, and long bolts used to pass between the units and lock this into place. The feet were now freed by the removal of the bolts and the feet knocked back sufficiently to allow Dexion to be fitted to the front and under the units, the existing bolts being utilised. The feet were now brought forward and the back freed for fitting Dexion. The units were then lowered on to rollers (1-in. tube) and were free to move. They were rolled out of the building and two bogies fitted under the units as they came out. The unit was dragged on to a low-loader and removed to the new exchange.

The preparation of the units took two men one day. The removal from the old exchange and placing in position in the new took approximately three-quarters of an hour at each end.

The idea was so successful that it was decided to try another such move, this time involving a journey of some 50 miles from Rushyford to Glaisdale and also moving into a building where a U.A.X.5 was already installed. This was carried out in exactly the same way; the lifting of the units at Rushyford commenced at 9.0 a.m. and the units were in place at Glaisdale by 1.30 p.m.

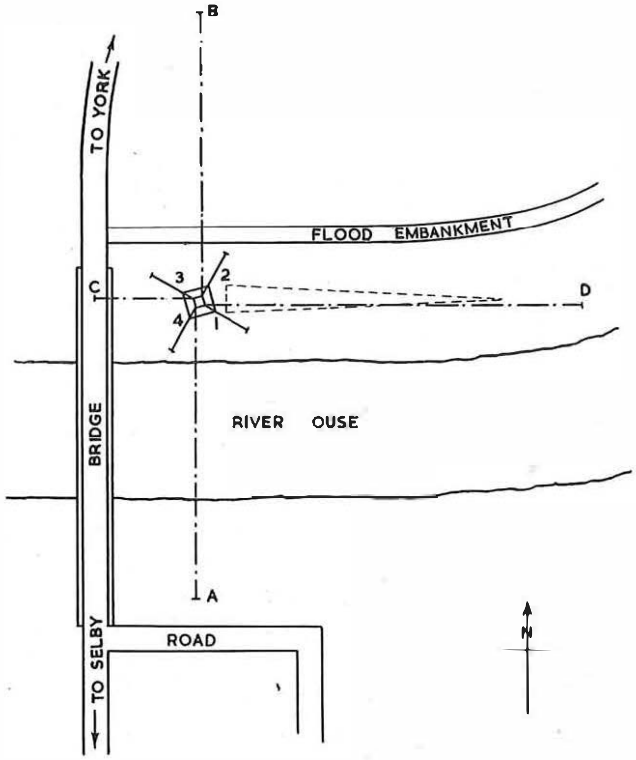
Two aids which were found invaluable during all the work, including the winding of the units on to the low-loader, were crowbars, high lift wheeled, and Slingsby trucks with the centre high wheels removed.

The cost of the removal in the case of Aysgarth to Wensley, including a special platform at Wensley, has been less than the cost of the recovery of the exchange. The same applies at Rushyford where, having no platform to erect, the costs have been considerably less.

The saving in installation work due to the fact that all inter-unit cabling remains in position during the move is considerable and the total saving on the two transactions is expected to be in the region of 800 man-hours. E. A. C.

RECOVERY OF OLD TRUNK ROUTE MASTS AT CAWOOD

River crossings have always been a problem to the communications engineer, and in the Regional Notes in the April, 1954, issue of this Journal, there was described a modern sub-aqueous crossing of the river Trent by a co-axial + audio cable with a capacity for 1,464 trunk circuits. At the turn of the century our predecessors were faced with the problem of providing trunk circuits between York and Selby across the river Ouse at Cawood, and in 1901 two tall steel lattice masts were erected at Cawood to allow 150 lb. wires for 20 trunk circuits to be taken across the river at a height well above the masts of passing shipping. These circuits remained in use until the Selby-York CJ cable was completed towards the end of December, 1941, but the wires and masts were left *in situ* until recently. As part of the York Telephone Area "K" route recovery programme, the York-Selby route was scheduled for complete recovery in the summer of 1953, but the task was postponed because of more urgent works. However, in March, 1954, it was observed that the stays (eight on each mast) were in poor condition and in need of replacement if the masts remained *in situ*. It was decided to go ahead at once with the recovery of the masts. The co-operation of the Radio Planning and Provision Branch of the E.-in-C.'s Office (WP) was sought,



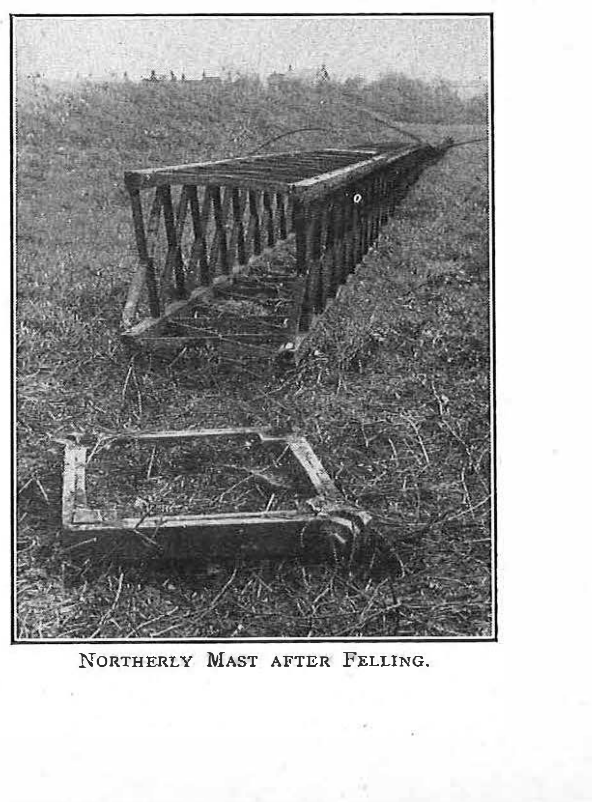
PLAN OF POSITION OF NORTHERLY MAST.

and it was arranged that WP Branch's experienced steel erectors should do the work with some manpower assistance from the York area.

The height of each mast was 116 ft. with a 2 ft. 6 in. finial, square in section, tapering from 2 ft. 6 in. square at the base to 9 in. square at the top. Both masts were stayed from each corner, one set of stays being situated at approximately 110 ft. and the lower set at approximately 75 ft.; the stay base was 36 ft. The fabrication of the masts was not sectionalised to facilitate unbolting and therefore the dismantling had to be done by cutting through the legs of the mast.

After an officer from WP Branch had inspected the work the following scheme for recovery of the masts was adopted.

Mast on Northern Bank—This was positioned between the river and the flood embankment and it was decided to fell the complete mast. The mast was oriented as shown in the



NORTHERLY MAST AFTER FELLING.

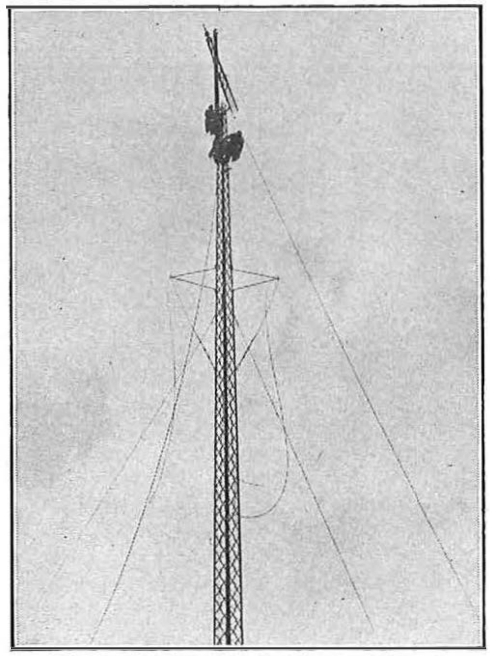
sketch, and as the River Ouse Catchment Board had stipulated that the mast must fall between the flood embankment and the river, special temporary stays had to be used. These were fitted to the top along the line A-B, these two levels being approximately at the same ground level as the mast. Stays fore and aft of the felling line C-D were also rigged, the spread at the position D being well in excess of the mast height. Using an oxy-acetylene cutting plant the legs numbers 3 and 4 were cut clean through. The remaining legs were partly cut through, No. 2 in excess of No. 1. Intermediate stays were successively cut away and the mast was felled by five men pulling on the side D. The photograph shows this mast after felling.

"O fallen at length that tower of strength,
Which stood four-square to all the winds that blew!" . . .
Tennyson.

Mast on Southern Bank—This mast was in a farm-yard near to a dutch barn and haystack and could not be felled as a whole in safety. It was necessary therefore to reduce its height and for this purpose a 24-ft. light pole with pulley attachment at the top was used as a derrick. This was lashed to the mast externally at the height required to lower 13 ft. of fabricated steelwork. Oxy-acetylene equipment was hoisted into position and the 13 ft. length to be removed was cut away and lowered to the ground with a steel hawser. In all, three lengths were cut from the mast, leaving 77 ft. of the mast to be felled. The orientation of the mast was such that it could be felled about its diagonal, and additional stays were fitted before the felling commenced. A section 1 ft. long was cut out of the front leg. The two diagonal legs were cut half-way through and the back leg was cut clean through. The stays away from the direction of fall were then cut away and the mast was felled in the same manner as the previous one.

After felling, the two masts were cut up into suitable lengths for handling so that the scrap metal could be stacked pending despatch. On the whole work, there were used about 200 cu. ft. of acetylene gas and 600 cu. ft. of oxygen. The whole operation took eight days to complete using one WP Branch gang of a foreman and four men, and a Telephone Area gang of a foreman and four men. Mr. S. S. Dalton of the Area staff took photographs of the masts *in situ* and of the main features of the recovery operations.

R. F. F.
W. J. H.



REMOVING TOP OF SOUTHERLY MAST.

Book Review

"The Amplification and Distribution of Sound." Third edition. A. E. Greenlees, A.M.I.E.E. Chapman & Hall, Ltd. 300 pp. 114 ill. 35s.

The declared object of this book is to present a general survey of the principles of sound amplification and distribution, showing the practical considerations involved. It gives a comprehensive review of practice in those aspects of communications engineering generally embraced by the term "Public Address" (though there are omissions of details which are not unimportant) and includes a short section on the extension of the techniques described, to radio relay systems.

The author has avoided mathematical treatment as far as possible, but has included 12 pages on "fundamentals" to introduce the reader to power calculations in resistive and reactive circuits and to the expression of power ratios in terms of the decibel. The attempt in these and other parts of the book to make the subject intelligible, in the space available, to readers who are not familiar with the principles of electrical engineering, has led to some difficulties. These will probably pass unmarked by the reader whose interest is confined to the broader aspects of the descriptive material; they will be readily apparent to the qualified engineer; but they may trouble some students or mislead others according to their knowledge and ability. For example, Chapter II leaves one with the impression that $W = I^2R$ is true only in A.C. circuits without reactance; on p.15 and again on p.197 impedance is not distinguished from resistance and the student may be misled by statements such as Watts = Voltage²/Impedance (p.197 and elsewhere) where care has not been taken to point out that reactance has been neglected; the statement that the parallel resistance chart on p. 286 can be applied to combining impedances in parallel, at least needs drastic qualification. The paragraph on sound pressure (p. 126) is more confusing than helpful.

The student who seriously studies the section on the decibel, with its emphasis on power relationships, will be unprepared for the later use of the decibel to express relative open circuit microphone voltages. He may also question the justification for the decibel scale for frequency response curves (Fig. 29), especially after reading p. 270 where the author explains that the gain characteristic can be expected to have a different shape from the response curve. This difference would not arise if frequency response were measured as variation of insertion gain with frequency, by a method which simulated the working conditions: there is no British (or American) standard definition of frequency response which supports the distinction made.

There is some looseness and inconsistency in the terminology used for components and their properties. For example, one can only guess at what is meant by the "small capacity resistance" mentioned on p. 19.

A most useful standard on the subject of the book is British Standard Code of Practice C.P. 327.300 (1952) entitled "Sound Distribution Systems." No direct reference is made to this, either in the text or the bibliography, possibly because the book may have been in an advanced stage of preparation when the code was published.

To those who are in any way concerned with sound distribution systems the information collected under one cover in the book will give a very useful insight into the kinds of components and apparatus required and the problems involved in system design, specification and operation. In certain aspects of terminology and measurement, however, the author has followed loose practice when he might have pointed the way to improvement. The material included on "fundamentals" and "technical details" will no doubt be useful to many readers who need some introduction to, or reminder of, points which are relevant to the rest of the subject matter. The junior student who reads the book as part of his studies in approaching wider fields of electrical engineering, however, should not regard it as a substitute for more precise textbooks, even where it appears to cover the fundamentals and technical detail in which he may be interested.

F. H.

Associate Section Notes

Edinburgh Centre

The start of what promises to be a most interesting session was in September, when a programme of technical and general interest films was shown at our opening meeting. Trunk mechanisation, photography, home-crafts and coaxial networks are only a few of the topics that will be discussed in the coming months, so there should be something of interest for everyone.

During the summer months quite a number of members took advantage of the outdoor visits that had been arranged, trips being made to a police radio station, aerated water manufacturers and to a commercial photographers. In September a party was taken to a local colliery, and towards the end of the year a visit has been planned for members to be shown over the City Chambers.

There has been an encouraging increase in membership this session and it is hoped that there will be a good attendance at all of the meetings arranged, new members being especially welcome. J. R. H.

Glasgow and Scotland West Centre

At the time of writing, the 1954-55 session has not yet commenced but a full and varied programme has been arranged.

The opening meeting of the session will be on Friday, 8th October, 1954, at 7.30 p.m., when Mr. R. W. Palmer, Assistant Staff Engineer and leader of the British Productivity Team on Maintenance of Automatic Telephone Exchanges, will give his impressions of the team's visit to America.

On Thursday, 21st October, the Centre will visit G. & J. Weir, Ltd., Cathcart, and be shown over the works.

A most cordial and hearty invitation is extended to all former members to renew their membership early and to all interested to join and enjoy with us what we hope will be a most successful session. J. F.

Guildford Centre

The Annual General Meeting was held on 13th May, when the following Officers and Committee were elected for the 1954/55 session:—

President: H. M. Wells, M.I.E.E. (Area Engineer); *Chairman:* A. J. Daborn; *Secretary:* E. N. Harcourt; *Treasurer:* F. B. Amey; *Committee:* E. R. Knott, F. R. Lancaster, R. J. Mercer, J. W. Moon, G. M. Newman, J. Pike; *Auditors:* F. J. Boyd and F. D. Noble.

The Committee, who fully represent the various sections of the engineering staff, are planning an interesting programme which, it is hoped, will receive the full support of the membership of 107.

On Wednesday, 21st July, a party of 28 members visited the headquarters of the London Fire Brigade, where an interesting afternoon was spent inspecting the appliances of both the land and river sections of the brigade, the station watch room, and the headquarters control room.

Arrangements have been made for further visits, to the National Physical Laboratories, Tower Bridge, an aircraft factory, a motor cycle factory, and a creamery.

A programme of film shows and lectures of engineering and general interest, the final details of which are now being arranged, will be presented during the winter months.

E. N. H.

Sheffield Centre

We believe there are over 100 potential members of the Sheffield Associate Section Centre who take this journal and hope they all read these notes, as we in Sheffield still need a good live secretary—and surely there is someone capable and willing among our Sheffield readers. Every assistance will be given to the person who volunteers. Any member who is interested should contact Mr. J. Roach, Sheffield Maintenance Control.

The only "live" part of the Sheffield Section is the library, which is still being used by quite a number of our members.

V. L.

Bath Centre

During a successful Winter Session the following meetings were held:

15th October, 1953.—Col. C. E. Calveley's paper "Some Applications of Electronics," which was well received by a large audience, the demonstration equipment adding greatly to the interest of the paper.

17th November, 1953.—Mr. D. P. Lewis gave a talk on the Traffic Office.

17th December, 1953.—Mr. A. C. Warren, Chief Regional Engineer, presented a National award to Mr. P. E. Smith for his paper "Magnetic Recordings." The paper was read before the centre during the 1952/53 session. After the presentation Mr. A. J. Causey, Area Engineer, gave a talk on the Regional Organisation of the Post Office.

3rd February, 1954.—The annual Telecommunications Ball held at the Pump Room was once again a social and financial success. The Chief Regional Engineer was one of the guests.

22nd March 1954.—The centre welcomed Mr. S. A. R. Packer a founder member and former chairman who is now with the Foreign Office. Mr Packer read a most interesting paper on "Information Theory." The meeting concluded with a general discussion.

6th April, 1954.—The Grid System was the subject of the concluding meeting. Mr. L. B. Law, Systems Operation Engineer, B.E.A., gave a general talk on the Grid System with particular reference to the control systems used.

For the first time the Centre had a stand at the Bath Hobbies Exhibition organised by the Rotary Club. The hobbies of the members were many and varied, and the stand was always the centre of a large crowd.

C. E. M.

London Centre

At the Annual General Meeting held on 25th May, the officers for the 1954/55 session were elected as follows:— *Chairman:* Mr. A. G. Welling; *Vice-Chairman:* Mr A. W. Haddow; *Treasurer:* Mr. W. C. Peck; *General Secretary:* Mr. P. Sayers; *Assistant Secretary:* Mr. M. R. G. Rump; *Librarian:* Mr. F. E. Baker; *Assistant Librarian:* Mr. A. C. Skilton; *Visits Secretary:* Mr. B. C. Hatch; *Editor:* Mr. E. W. Brindle.

The London Centre Committee were pleased to note that three London Centre members received awards in the 1953/54 Essay Competition. Mr. W. P. Skinner, who for many years served on the Committee as Librarian, was awarded a cheque and Institution Certificate for an essay on "Lead Acid Secondary Cell Practice." Mr. R. H. Thornton was awarded a Certificate of Merit for his essay "A Method of Reducing Carrier Leak from Cowan Type Modulators." Mr. G. W. Bates received a Certificate of Merit for his essay dealing with "Photometry and the London Test Section." The above awards were presented at the Annual General Meeting by the Deputy Engineer-in-Chief, Mr. A. H. Mumford.

In spite of these successes the committee feel that London Centre having such a large membership could do better and that more of their members should enter the essay Competition.

The lecture programme for the 1954/55 session was planned to commence on 21st September with a lecture by Col. C. E. Calveley, entitled "The Solution of some Technical Problems which have occurred in the Development of Telecommunications."

The remaining lectures arranged for 1954 are as follows:—

20th October.—Mr. R. W. Palmer, "Auto Maintenance in other Countries."

18th November.—Mr. A. W. Larkshear, "Conceptions of Space and Space Travel."

7th December.—Mr. J. S. Hizzey. "Interference by Harmonic Radiation."

E. W. B.

Staff Changes

Promotions

Name	Region	Date
Snr. Exec. Engr. to Asst. Staff Engr.		
Atkinson, J.	E.-in-C.O.	10.6.54
Area Engr. to Tel. Manager		
Edwards, S. J.	S.W. Reg. to H.C. Reg.	30.8.54
Exec. Engr. to Snr. Exec. Engr.		
Spooner, J. W.	E.-in-C.O.	9.8.54
Legood, F. J.	E.-in-C.O.	5.8.54
Exec. Engr. (Limited Competition)		
Crank, G. J.	E.-in-C.O.	1.4.54
Asst. Engr. to Exec. Engr.		
Morris, A. J.	E.-in-C.O.	4.6.54
Hartley, A. L.	H.C. Reg. to E.-in-C.O.	19.7.54
North, P. W. F.	L.T. Reg. to E.-in-C.O.	28.6.54
Ferguson, O. A. K.	S.W. Reg. to E.-in-C.O.	28.6.54
Robinson, H. E.	E.-in-C.O.	28.6.54
Howlett, A. F.	H.C. Reg. to Scot.	23.8.54
Eastwood, D.	N.W. Reg.	3.7.54
Bish, T. A.	M. Reg.	1.8.54
Ellis, W. A.	E.-in-C.O.	7.8.54
Miles, J. V.	E.-in-C.O.	5.8.54
Mooney, B. H.	E.-in-C.O.	5.8.54
Rae, J. D.	E.-in-C.O.	5.8.54
Barnett, W. J. G.	E.-in-C.O.	23.8.54
Dowden, B. F.	E.-in-C.O.	5.8.54
Asst. Engr. (Open Competition)		
Dix, D. L.	E.-in-C.O.	14.6.54
Merlo, D.	E.-in-C.O.	12.7.54
Asst. Engr. (Limited Competition)		
Bluett, R. J.	S.W. Reg. to E.-in-C.O.	14.6.54
Clarke, A. J.	L.T. Reg. to E.-in-C.O.	14.6.54
Spilsbury, F. A.	H.C. Reg. to E.-in-C.O.	14.6.54
Boydle, J.	N.W. Reg.	17.5.54
Boag, J. F.	Scot.	10.5.54
Johnson, W.	Scot.	10.5.54
Bates, G. W.	E.-in-C.O.	21.6.54
Parrott, C. E. B.	L.T. Reg. to E.-in-C.O.	21.6.54
Roberts, G. L.	E.-in-C.O. to W.B.C.	28.6.54
Turner, D. C.	E.-in-C.O. to M. Reg.	28.6.54
Piggott, I. D.	H.C. Reg. to M. Reg.	28.6.54
Steel, J. R.	L.T. Reg. to E.-in-C.O.	28.6.54
Pike, D. J.	S.W. Reg. to E.-in-C.O.	28.6.54
Gosling, W.	N.E. Reg. to E.-in-C.O.	28.6.54
Stamforth, C.	N.W. Reg. to E.-in-C.O.	28.6.54
Jones, G. I.	E.-in-C.O.	28.6.54
Smith, G. T. C.	L.T. Reg.	21.6.54
Sucksmith, A. V.	N.W. Reg. to E.-in-C.O.	5.7.54
Glasby, P. A.	N.W. Reg. to E.-in-C.O.	12.7.54
Harvey, W. G.	Scot.	28.6.54
West, J. O.	S.W. Reg.	14.6.54
McCulloch, J. H.	M. Reg.	28.6.54
Nimmo, J.	Scot. to E.-in-C.O.	20.7.54
Inspector to Asst. Engr.		
Hayward, E. G.	M. Reg.	24.5.54
Eacock, D. R. N.	M. Reg.	9.7.54
Pitcher, F. G.	L.T. Reg.	13.2.54
Mansfield, E. A. G.	L.T. Reg.	10.3.54
Chick, G. F.	L.T. Reg.	27.2.54
Gooday, W. T.	L.T. Reg.	29.4.54

Name	Region	Date
Inspector to Asst. Engr.—continued.		
Marks, A. V.	L.T. Reg.	16.3.54
Clay, W.	W.B.C.	15.5.54
Farquhar, G. E.	Scot.	17.5.54
Crosby, G.	N.E. Reg.	21.6.54
Jones, N. L.	M. Reg.	29.7.54
Tech. Offr. to Asst. Engr.		
Boardman, S.	N.W. Reg. to E.-in-C.O.	1.7.54
Pritchard, G. C.	W.B.C.	15.5.54
Jones, I. L.	W.B.C.	22.4.54
Milroy, T.	Scot.	22.6.54
Witherow, E.	Scot.	26.6.54
McCann, J.	N. Ire.	31.5.54
Millard, D. R.	E.-in-C.O.	30.7.54
Jones, E. D. J.	E.-in-C.O.	30.7.54
Day, J. E.	E.-in-C.O.	30.7.54
Meads, E. F.	E.-in-C.O.	30.7.54
Crowe, V. E.	E.-in-C.O.	30.7.54
Stephens, W. J. B.	E.-in-C.O.	30.7.54
Carson, I. D.	H.C. Reg.	26.4.54
Markwick, J. C. W.	H.C. Reg.	1.4.54
Tech. II A to Asst. Engr.		
Metcalfe, P. F.	M. Reg. to E.-in-C.O.	1.6.54
Tech. Offr. to Inspector.		
Wood, J. M.	N.W. Reg.	3.6.54
Lee, W.	Scot.	13.3.54
Evans, R. A.	H.C. Reg.	29.12.53
Rickards, H. C. S.	H.C. Reg.	21.4.52
Tech. I to Inspector		
Miles, G. F.	M. Reg.	22.2.54
Rawe, G. M.	M. Reg.	9.6.54
Pemberton, S. H.	N.W. Reg.	19.6.54
Hedge, T. S.	M. Reg.	5.7.54
Brennan, W. E.	N.W. Reg.	20.5.54
Lambert, R. G.	M. Reg.	5.7.54
Munro, D.	S.W. Reg.	17.7.54
Lassey, S.	N.E. Reg.	23.5.54
Beard, J. O.	L.T. Reg.	28.9.53
Jackson, R. D.	L.T. Reg.	23.2.54
Parish, C.	L.T. Reg.	10.3.54
Giles, J.	L.T. Reg.	16.3.54
Marks, H. S.	L.T. Reg.	29.4.54
Deaves, H. A.	L.T. Reg.	27.2.54
Carter, H.	L.T. Reg.	8.5.54
Palmer, R. C.	L.T. Reg.	17.5.54
Slocombe, W. J.	S.W. Reg.	18.2.54
Clark, J. O.	M. Reg.	12.4.54
Grant, G. B.	Scot.	5.4.54
Waddell, T. W. F.	Scot.	14.5.54
Johnstone, D. K.	Scot.	18.6.54
McCullum, W. C.	N. Ire.	3.7.54
Lees, J. L.	N.W. Reg.	16.7.54
Healey, C. M.	H.C. Reg.	17.5.54
Barnes, W. V.	H.C. Reg.	1.7.54
Exptl. Offr. to Snr. Exptl. Offr.		
Shuter, F. C.	E.-in-C.O.	2.6.54
M.T.O. III to M.T.O. II		
Humphrey, M. C.	E.-in-C.O.	11.7.54

Transfers

Name	Region	Date
Exec. Engr.		
Castellano, E. J.	L.P. Reg. to E.-in-C.O.	21.6.54
Middleditch, E. G. H.	E.-in-C.O. to E.T.E.	17.8.54
Aucott, A. T.	E.-in-C.O. to L.P. Reg.	21.6.54
Asst. Engr.		
Ewen, A. B.	E.-in-C.O. to Northern Lighthouse Board	1.6.54
McLeod, A. M.	E.-in-C.O. to Scot.	20.6.54

Name	Region	Date
Asst. Engr.—continued.		
Squire, W. J. S.	E.-in-C.O. to E.T.E.	23.6.54
Shannon, W. M.	E.-in-C.O. to Scot.	1.7.54
Curry, W. R.	E.-in-C.O. to Min. of Supply	26.6.54
Corkett, R. H.	E.-in-C.O. to H.C.Reg.	1.7.54
Brett, S. A.	L.T. Reg. to E.-in-C.O.	1.7.54
Robinson, H. E.	S.W. Reg. to E.-in-C.O.	23.6.54
Skinner, A. H.	E.-in-C.O. to L.T. Reg.	26.7.54
Smith, G. H.	L.T. Reg. to N.E. Reg.	7.8.54
Cowan, R. T. B.	Scot. to Colonial Service	31.5.54

Retirements and Resignations

Name	Region	Date	Name	Region	Date
Area Engr.			*Asst. Engr.—continued.*		
Branson, J. W.	Scot.	4.6.54	Sykes, H. H.	L.T. Reg.	4.6.54
Critchlow, V. G.	N.E. Reg.	30.6.54	Keen, F. L.	M. Reg.	1.4.54
			Parker, A. A. E.	L.T. Reg.	17.7.54
Exec. Engr.			Maynard, W. F.	L.T. Reg.	24.7.54
Harvey, J. A.	N.W. Reg. (*Resigned*)	31.5.54	Jones, A. G.	W.B.C.	19.4.54
Wareham, J. H.	N.W. Reg.	26.6.54	Halligan, M.	Scot.	10.4.54
Wain, S. W.	E.T.E.	16.8.54	Crawford, R.	Scot.	30.6.54
Davis, A. T.	M. Reg.	15.8.54	Robertson, S. N.	E.-in-C.O. (*Resigned*)	8.8.54
Hannah, W. W.	N.W. Reg.	26.8.54	Boydle, J.	N.W. Reg. (*Resigned*)	20.8.54
Burrows, W. N.	N.E. Reg.	14.8.54	Clarkson, J. W.	E.-in-C.O. (*Resigned*)	8.8.54
Blackstaff, H. P.	E.-in-C.O.	31.7.54	Moralee, J. J.	N.E. Reg.	24.8.54
			Anderson, D. S.	L.T. Reg. (*Resigned*)	31.7.54
Asst. Engr.			Stone, K. A.	N.E. Reg. (*Resigned*)	31.7.54
White, A. H.	N.E. Reg.	27.5.54	Luff, F. C.	H.C. Reg.	31.7.54
Hill, R. E.	E.-in-C.O. (*Resigned*)	1.7.54	Raven, F.	E.-in-C.O. (*Resigned*)	27.7.54
Helmore, C. A.	L.T. Reg.	30.6.54	Osborne, E. J.	E.-in-C.O. (*Resigned*)	15.8.54
McBryde, H.	N.E. Reg.	30.6.54	Bristow, W. T.	E.-in-C.O.	31.8.54
Brown, W. H.	Scot.	16.5.54			
Crafter, D. J.	L.T. Reg.	3.6.54	*Inspector*		
Sanger, C.	L.T. Reg.	7.5.54	Ewing, R. J.	N. Ire.	2.7.54
Inscoe, E. S.	M. Reg.	21.5.54	Jones, F. R.	L.T. Reg.	18.6.54
Crowhurst, J. S.	L.T. Reg.	29.5.54	Berry, A. B.	W.B.C.	9.7.54
Hazlewood, S.	N.E. Reg.	14.6.54	Genner, T.	M. Reg.	10.5.54
Robertson, H.	Scot.	6.6.54	McFarlane, J.	N.W. Reg.	31.5.54
Trinder, S. E.	L.T. Reg. (*Resigned*)	30.4.54	Whitehouse, A. H.	M. Reg.	31.5.54
Messenger, M. C.	E.-in-C.O. (*Resigned*)	17.6.54	Sharpe, J. E.	N.E. Reg.	5.7.54
Bowman, J.	N.E. Reg.	21.6.54	Ketchell, A. W. V.	L.T. Reg.	16.5.54
Hunt, J. A.	L.T. Reg.	22.7.54	Mason, W. J.	L.T. Reg.	30.6.54
Southwell, R. A. W. J.	E.-in-C.O.	7.7.54	Beaton, A.	Scot.	15.7.54
Strongman, J. A.	L.T. Reg.	28.4.54	Larkin, A. J. S.	H.C. Reg.	20.7.54

Deaths

Name	Region	Date	Name	Region	Date
Asst. Engr.			*Inspector*		
Geraghty, J. W.	L.T. Reg.	6.7.54	Webb, J. E.	S.W. Reg.	4.7.54
King, W. D.	E.-in-C.O.	16.7.54	Laws, J. R.	N.E.Reg.	22.7.54
Collerson, W. J. Y.	L.T. Reg.	17.8.54	Crosby, G.	N.E. Reg.	24.8.54

DRAUGHTSMEN

Transfers

Name	Region	Date	Name	Region	Date
Ldg. D'man.			*D'man.—continued.*		
Harman, J. F.	Factories Dept. to E.-in-C.O.	23.11.53	Bliss, F. H.	L.T. Reg. to E.-in-C.O.	24.8.53
			Young, A. F. C.	E.-in-C.O. to Colonial Service	29.6.54
D'man.					
Durward, W.	Scot. to E.-in-C.O.	16.11.53	Lockwood, R. R.	H.C. Reg. to E.-in-C.O.	31.5.54

CLERICAL

Promotions

Name	Region	Date	Name	Region	Date
H.E.O. to S.E.O.			*C.O. to E.O.*		
Bourne, H. T. B.	E.-in-C.O.	19.11.53	Cartwright, A. H.	E.-in-C.O.	1.2.54
			Ryan (Miss) K. M.	E.-in-C.O.	1.2.54
			Thomas, I.	E.-in-C.O.	15.3.54
E.O. to H.E.O.			Lovett, F. H.	E.-in-C.O.	10.5.54
Attrill, R. A.	E.-in-C.O.	4.1.54	Drummond (Miss) J. J.	E.-in-C.O.	24.5.54

Transfer

Name	Region	Date
E.O.		
Lucas, L. G.	Min. of Food to E.-in-C.O.	15.3.54

Book Review

"Laplace Transforms for Electrical Engineers." B. J. Starkey, Dipl. Ing., A.M.I.E.E. Published for *Wireless Engineer* by Iliffe & Sons, Ltd. 279 pp. 57 ill. 30s.

This book contains the substance of a course of lectures on the Laplace integral equation given by the author to his colleagues at the Signals Research and Development Establishment. It is intended as an introduction to modern operational methods associated with the Laplace transform theory; these methods are illustrated by applications to bridge and ladder networks as well as to systems containing vacuum tubes. This book, however, is primarily concerned with mathematical theory and the space devoted to practical applications is relatively small.

In his mathematical treatment the author uses the exponential kernal $\exp(-pt)$ introduced by Laplace in 1812, with the result that his image functions are not dimensionally equivalent. This is unfortunate because it ignores the improvement introduced by Heaviside in 1890 in which the Laplacian kernel was replaced by $p\exp(-pt)$. This improvement allows pdt (as well as the index pt) to be made dimensionless, and consequently when the image functions are expanded there is term-by-term correspondence. This is an essential feature for an engineer who wishes to make a dimensional check on any of his operational expansions or to develop well-known standard forms by the direct Heaviside method. Such forms are of long standing and widespread use in electrical engineering, so that any alteration now would be inexpedient.

The failure of this book to make use of the Heaviside improvement leads to unnecessary difficulties in evaluating the integral equations; this is particularly noticeable in those cases where the easiest method of solution is by direct integration. By inverting an integral equation with a Heaviside kernel the Bromwich contour integral is obtained; and from this the best method of solution—whether by partial fractions or by series expansion, etc.,—becomes immediately apparent. But all these valuable features are lost sight of in the Laplace transform method advocated in this book.

The book contains three useful appendices: the first discusses analytic functions of a complex variable, while the second contains definitions of some of the higher mathematical functions that arise in electrical engineering. The third appendix is a valuable and extensive table of inverse Laplace transforms.

H. J. J.

SHORTER NOTICES

"Practical Television Circuits." F. J. Camm. George Newnes, Ltd., 288 pp. 156 ill. 15s.

Written by the Editor of the monthly journal "Practical Television," this book gives constructional details and wiring diagrams of a number of television receivers and associated test equipment suitable for building by amateurs.

"Practical Wireless Circuits." F. J. Camm. George Newnes, Ltd. 217 pp. 139 ill. 10s. 6d.

The companion to the above-mentioned volume, covering radio receivers.

"Problems in Electrical Engineering." S. Parker Smith, C.B.E., D.Sc., M.I.E.E., A.M.Inst.C.E. Constable & Co., Ltd. 342 pp. 18s.

This book contains a collection of problems (with answers) for University students from First to Final Year and for National Certificate studies. A total of 1,879 problems is included and they are arranged under 36 chapter headings. In this, the 6th edition of the book, C.G.S./M.K.S. conversion tables have been included and the majority of problems are stated in both units.

"A Bibliography of Colour Television." Issued by The Television Society. 17 pp. 2s. 6d.

The entries (313 in number) are divided into two sections, Optical and Electrical, arranged in chronological order. An author index is included.

"Radio Valve Data," Fourth Edition. Compiled by the Staff of "Wireless World." Published by Iliffe & Sons, Ltd. 100 pp. 3s. 6d.

The latest edition of this widely-used reference book contains full operating data on over 2,000 types of British and American radio valves and some 200 cathode-ray tubes. Seventeen British valve manufacturers are represented.

The main tables give the electrical characteristics of each valve, and separate tables show their base connections. The main tables further classify the valves into current, replacement or obsolete types, as recommended by the makers. An index enables any valve to be found in the tables immediately, while a valuable new feature is the full list of equivalents.

Communications

All communications should be addressed to the Managing Editor, *P.O.E.E. Journal,* Engineer-in-Chief's Office, Alder House, Aldersgate Street, London, E.C.1. Telephone: HEAdquarters 1234. Remittances should be made payable to "*The P.O.E.E. Journal*" and should be crossed "& Co."

Binding Cases

Cases for binding are available, and may be obtained from the Local Agents for 3s. Subscribers can have their copies of volumes bound, at a cost of 10s. 6d., by sending the complete set of parts to the Local Agents or to the *P.O.E.E. Journal,* Engineer-in-Chief's Office, Alder House, Aldersgate Street, London, E.C.1. Orders for binding for Vols. 1-19 should indicate whether the original binding case with black lettering, or the later pattern with gold, is required. Cases with gold lettering are the only type stocked from Vol. 20 onwards.

Back Numbers

The price of the Journal, which is published quarterly, is 2s. 6d. (2s. 9d. post free) per copy, or 11s. per annum, post free. Back numbers can be supplied, subject to availability of stocks, at 2s. 6d. each (2s. 9d. post free). Orders for back numbers may be sent to the *P.O.E.E. Journal,* Engineer-in-Chief's Office, Alder House, Aldersgate Street, London, E.C.1, or to the Publishers.

Employees of the British Post Office can obtain the *Journal* through Local Agents at the reduced price of 2s. per copy.

Advertisements

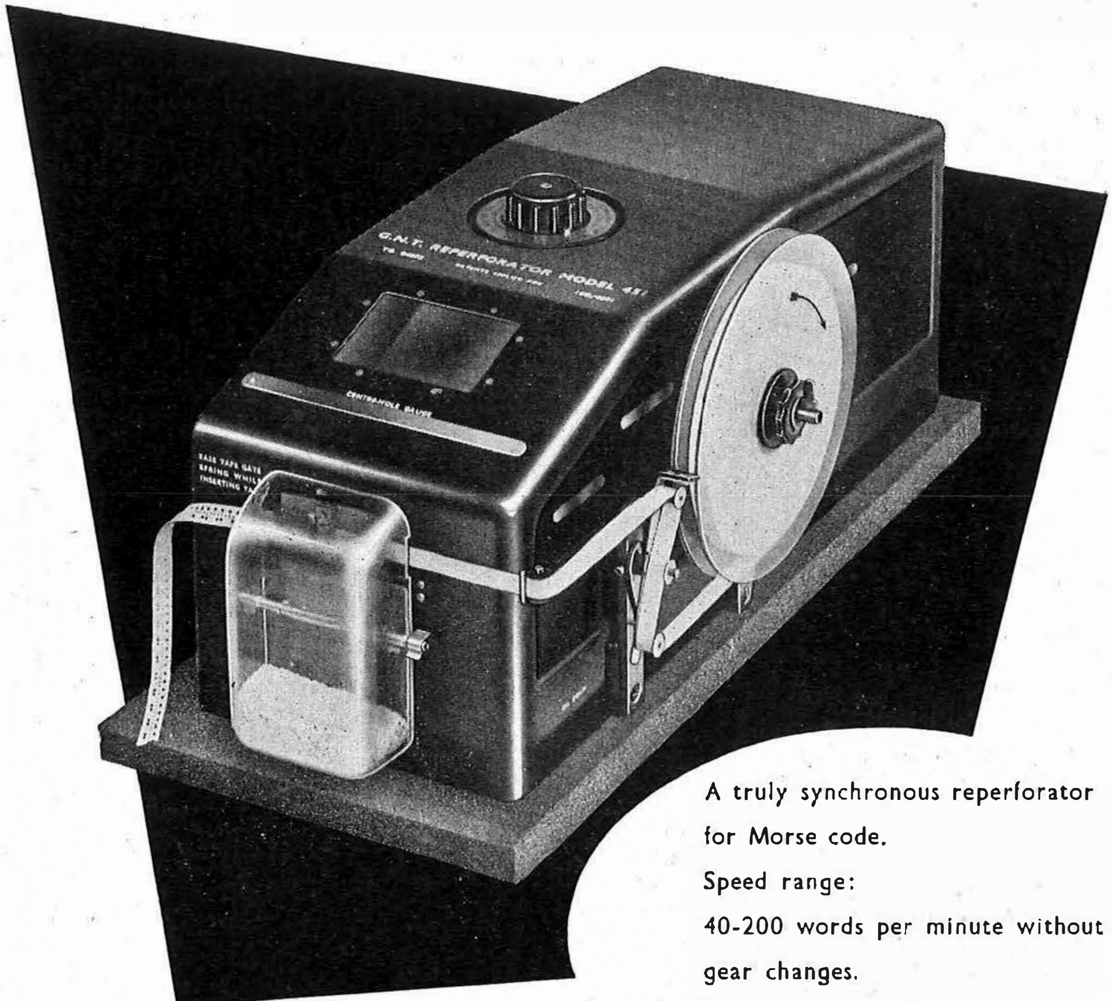
All communications relating to space reservations should be addressed to the Advertisement Editor, *P.O.E.E. Journal,* Alder House, AldersgateStreet, London, E.C.1. Communications regarding advertisement copy, proofs, etc., should be addressed to the Publishers, Messrs. Birch & Whittington (Prop. Dorling & Co. [Epsom], Ltd.), 49 Upper High Street, Epsom, Surrey.

INDEX TO ADVERTISERS

G.N.T.

REPERFORATOR

MODEL 451



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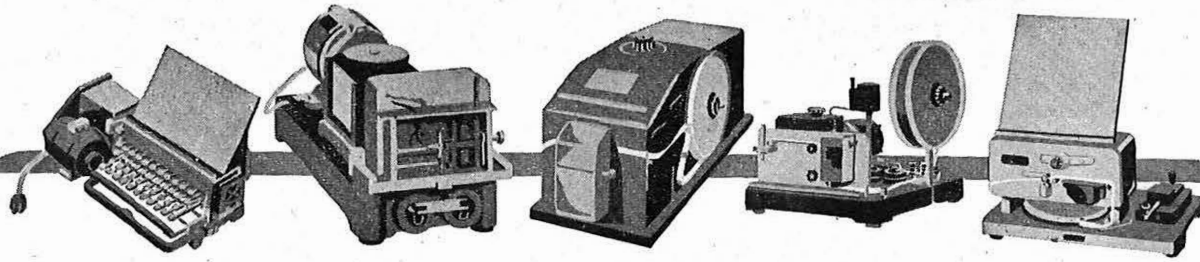

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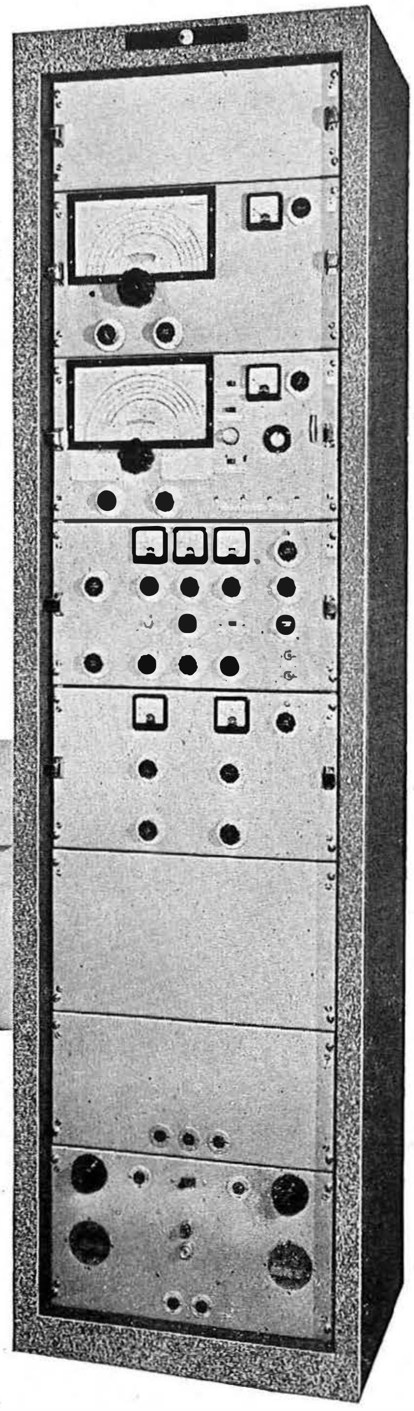

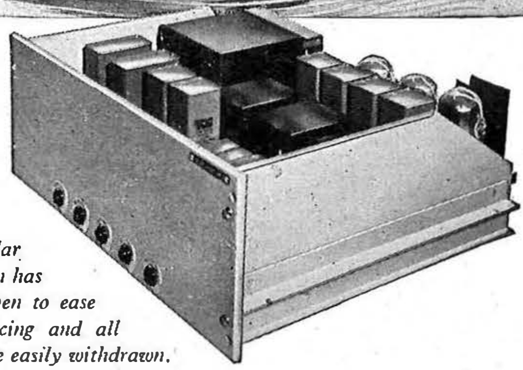

Particular attention has been given to ease of servicing and all units are easily withdrawn.

MARCONI

COMPLETE COMMUNICATION SYSTEMS

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Grinding Mullard 'Ticonal' permanent magnets to required size.
MAGNETIC MATERIALS Extensive research and manufacturing facilities have established Mullard as the leading producers of magnetic materials. They were the first, for example, to introduce Ferroxcube, the world's most efficient magnetic ferrite; 'Ticonal' anisotropic permanent magnets, renowned for their high stability and high energy output; and Magnadur, an entirely new type of permanent magnet with the insulating properties of a ceramic.
The wealth of experience gained from these developments is available to all users of magnetic materials through the Mullard advisory service. An enquiry to the address below will put a team of specialised engineers at your disposal.
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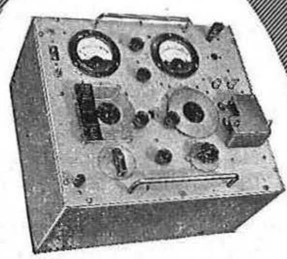
'TICONAL' PERMANENT MAGNETS · MAGNADUR (Formerly Ferroxdure) PERMANENT MAGNETS · FERROXCUBE MAGNETIC CORE MATERIAL
MULLARD LTD., COMPONENT DIVISION, CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2.

(MM395)

Q measurement by Marconi

Famous for years in the field of communication measurement, Marconi Instruments offer TF 329G for determinations in frequency range 50 kc/s to 50 Mc/s, and TF 886A for the range 15-170 Mc/s. While both instruments are primarily designed as direct reading Q meters, either may, of course, be employed for a variety of indirect measurements — such as the capacitance and phase defect of condensers — carried out by the normal reasonance methods. In addition, special jigs are available for T F 329G for the investigation of dielectrics.



TF 329G; 50 kc/s — 50 Mc/s

TF 886A; 15 — 170 Mc/s

TF329G; 50 kc/s—50 Mc/s; 10—500 Q; 40—450 μμF.
TF886A; 15—170 Mc/s; 60—1200 Q; 12—85 μμF.

May we send you our 44-page booklet **"Measurements by Q Meter"?**

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SIGNAL GENERATORS • BRIDGES • VALVE VOLTMETERS • FREQUENCY STANDARDS
WAVEMETERS • WAVE ANALYSERS • BEAT FREQUENCY OSCILLATORS • Q METERS

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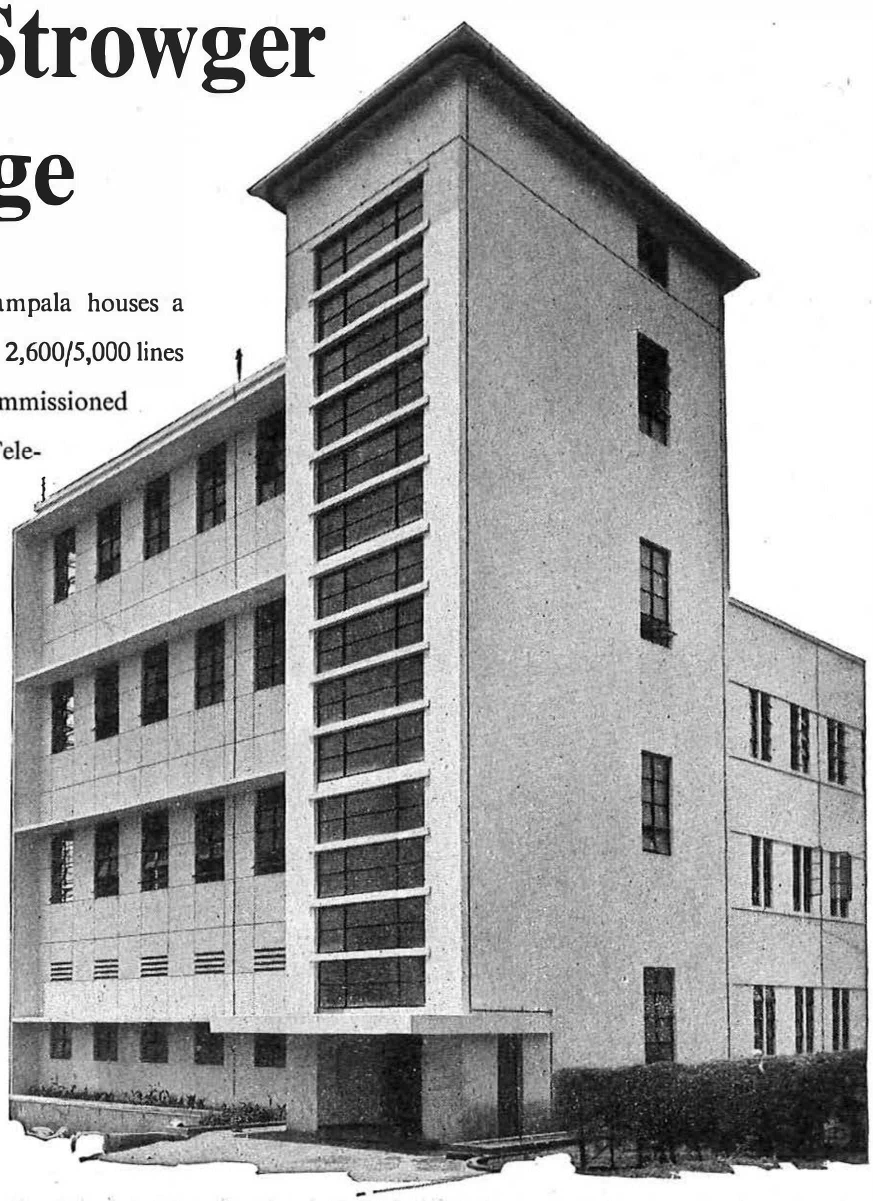
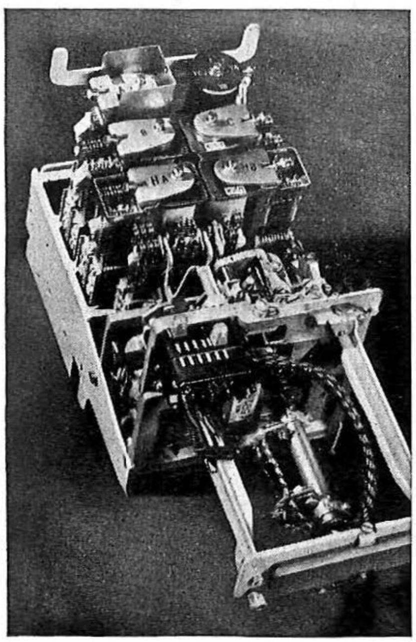
IC 8

Another Strowger Exchange



This fine modern building at Kampala houses a Strowger auto-manual exchange of 2,600/5,000 lines and 10/16 operators' positions. Commissioned by the East African Posts and Telecommunications Administration the exchange forms part of an extensive modern automatic network in which communication between distant areas is established by single frequency V.F. dialling equipment.



The 32A Mark II Selector is the basic selecting mechanism and incorporates in its design all the facilities which many years' operational experience have shown to be necessary whilst retaining the simple straightforward step-by-step principle of operation characteristic of the Strowger system. To-day this selector offers the most suitable basis for automatic telephone systems of any size. Its simplicity, reliability and exceptional ease of maintenance are the factors of principal appeal to telephone administrations in all parts of the world.

AUTOMATIC TELEPHONE & ELECTRIC CO. LTD

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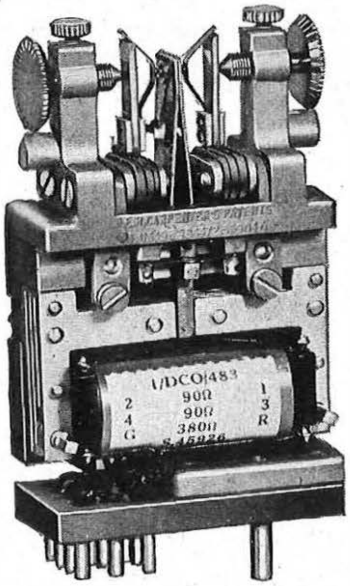
AT7831 A104

CARPENTER POLARIZED RELAYS



have these outstanding features

HIGH OPERATIONAL SPEED • HIGH SENSITIVITY
FREEDOM FROM CONTACT REBOUND
NO POSITIONAL ERROR • HIGH CONTACT PRESSURES
ACCURACY OF SIGNAL REPETITION
EASE OF ADJUSTMENT

The Carpenter Polarized Relay will respond to weak, ill-defined or short-duration impulses of differing polarity, or it will follow weak alternating current inputs of high frequencies and so provide a continuously operating symmetrical changeover switch between two different sources.

Dimensionally the Type 4 relay illustrated is interchangeable with the type " 3000 " Relay and can be supplied to fit directly to the drilling normally provided for the " 3000 " Relay.

Manufactured by the sole licensees

TELEPHONE MANUFACTURING CO. LTD

Contractors to Governments of the British Commonwealth and other Nations

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for SPEED, ECONOMY and BETTER WORK

The news that this famous range of Soldering Irons and Crucibles is again available has been welcomed in numerous branches of industry everywhere. Zeva Tools are unquestionably without equal for efficiency, economy and trouble-free long life.

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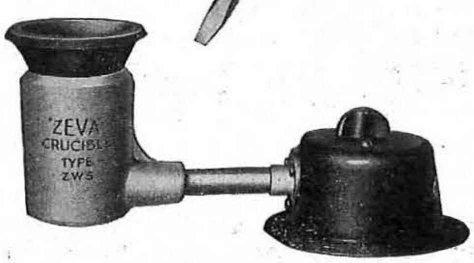
- ZEVA current consumption for rated temperature is less than any other make of tool.
- ZEVA initial cost is the only cost.
- ZEVA Irons are guaranteed.



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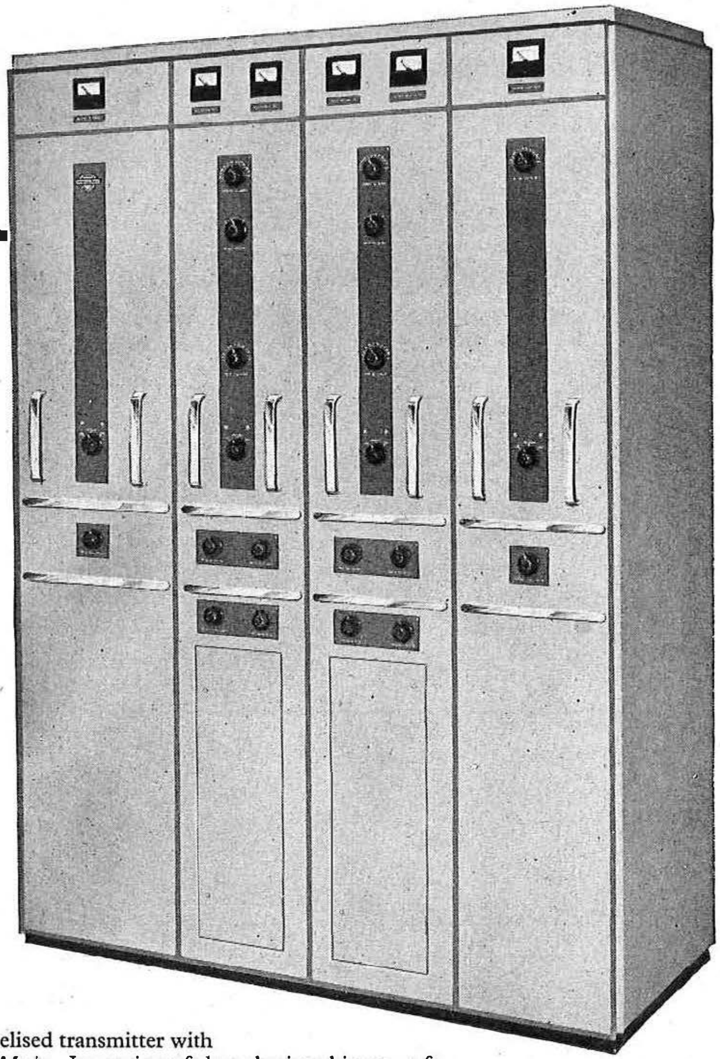
THE AUTOMATIC COIL WINDER & ELECTRICAL EQUIPMENT CO., LTD.
Winder House, Douglas Street, London, S.W.1 *Phone: VICtoria 3404-9*

ZI/PZ/ZWS

1 kW Channelised Transmitter



THE GFT.560 is a 1kW channelised transmitter with a frequency range of 1.5—30 Mc/s. It consists of three basic cabinets—r.f. unit, modulator unit, and power supply unit—combinations of which can be used to provide multi-frequency working as well as a number of different types of emission. The wave change facilities of the transmitter are both rapid and reliable—a valuable asset when the operating frequency is changed many times each day.

The GFT.560 is fully tropicalised, and its unit construction facilitates future expansion of the initial installation, should the need arise.

For use in conjunction with the GFT.560 there are ancillary units that enable the transmitter to be remotely controlled over a two wire telephone circuit: operational adjustments are dialled to the transmitter.

The versatility and reliability of this new Mullard transmitter make it particularly suitable for h.f. en-route, ground-to-air services and point-to-point communication networks. A team of Mullard communication engineers is available to advise on the use of the GFT.560 in such applications. They will also assist in planning complete communication systems, if required.

ABRIDGED DATA

Frequency Range *1.5—30 Mc/s*
Frequency Stability *To Atlantic City, 1947, standards*
Power Output *1 kW*
Types of Emission *c.w., m.c.w., telephony, frequency shift, single and independent sideband. (A1, A2, A3, F1, A3a and A3b)*
Output Impedance *600 ohms balanced twin feeder*
Power Supply *400V, 50-60 c/s. 3-phase*

Mullard

SPECIALISED ELECTRONIC EQUIPMENT

MULLARD LTD · EQUIPMENT DIVISION · CENTURY HOUSE · SHAFTESBURY AVENUE · WC2
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F

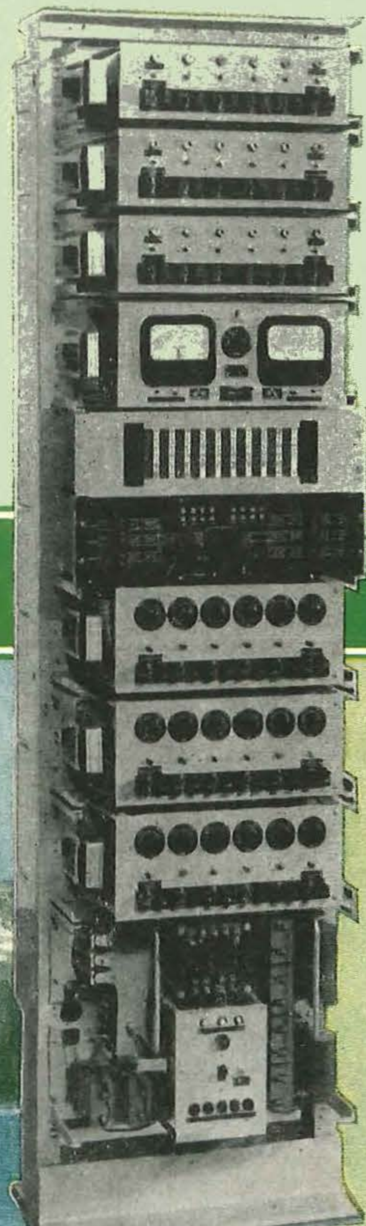
degrees of latitude or temperature

cannot impair the efficient operation of the new
ERICSSON V.F. TELEGRAPH EQUIPMENT.

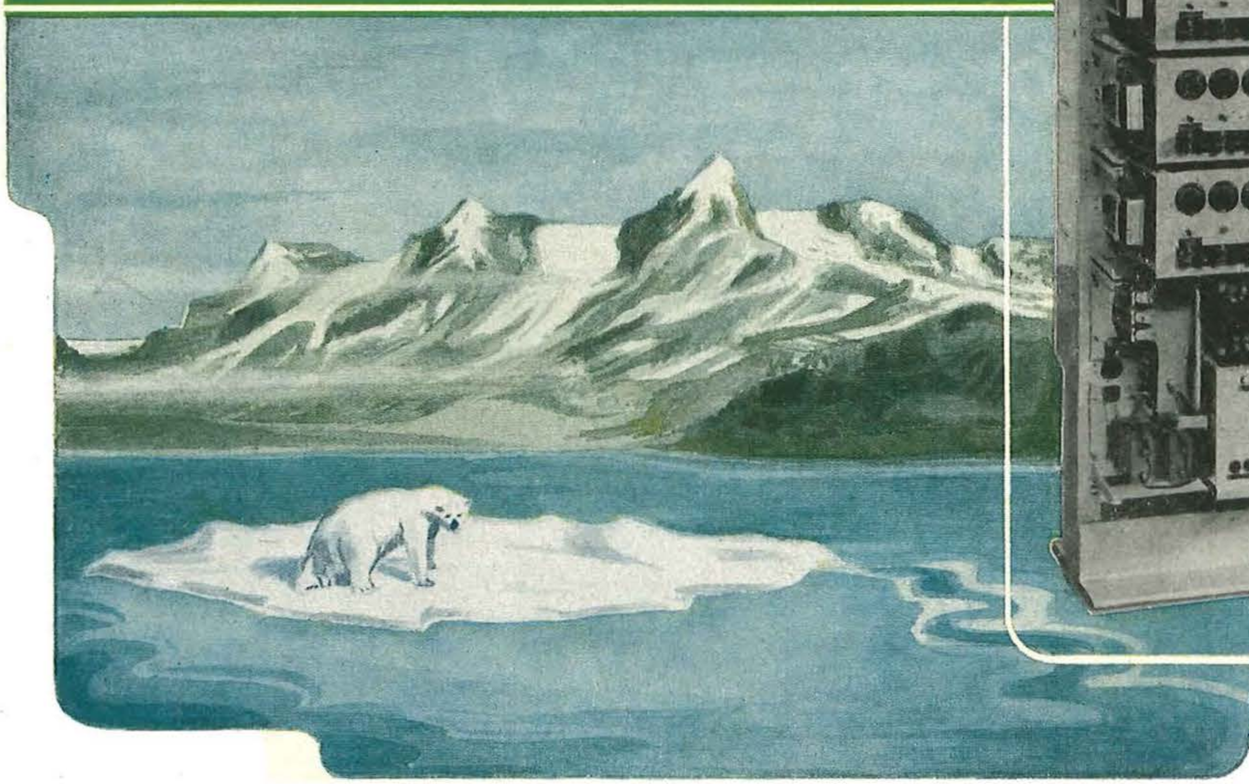
Neither sub-zero temperatures nor the heat and humidity of the tropics have any adverse effect on the high quality materials and finishes used in the manufacture of this apparatus.

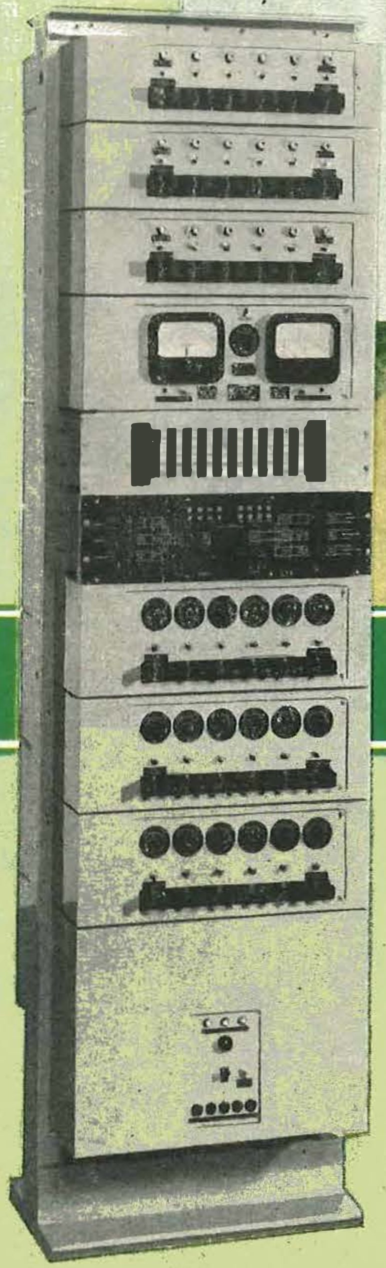
The complete equipment combines all the essential features of telegraph working in a compact design which allows easy extensibility of the number of channels, when not fully equipped initially. Maintenance is reduced to a minimum.

Its installation in any part of the world is a sound and economical proposition.



ERICSSON





V.F. TELEGRAPH EQUIPMENT

The Telegraph Terminal illustrated is equipped with all the intermediate apparatus necessary to connect a teleprinter to a radio, carrier or line circuit, and is basically a conventional single tone duplex equipment providing up to eighteen voice frequency telegraph channels (6′-6″ bay) or twenty-four channels (8′-6″ bay). The equipment is completely A.C. mains operated and also provides the 80 + 80 v. D.C. supply for the teleprinters when receiving.

Group modulation is used, the basic unit consisting of six channels. Automatic gain control is provided to cover a reasonable variation of the level of received signals.

The compact design has been achieved by the use of modern miniature components and unit construction. Modulators, amplifier detectors and oscillators are made up as individual units which can be removed for quick replacement.

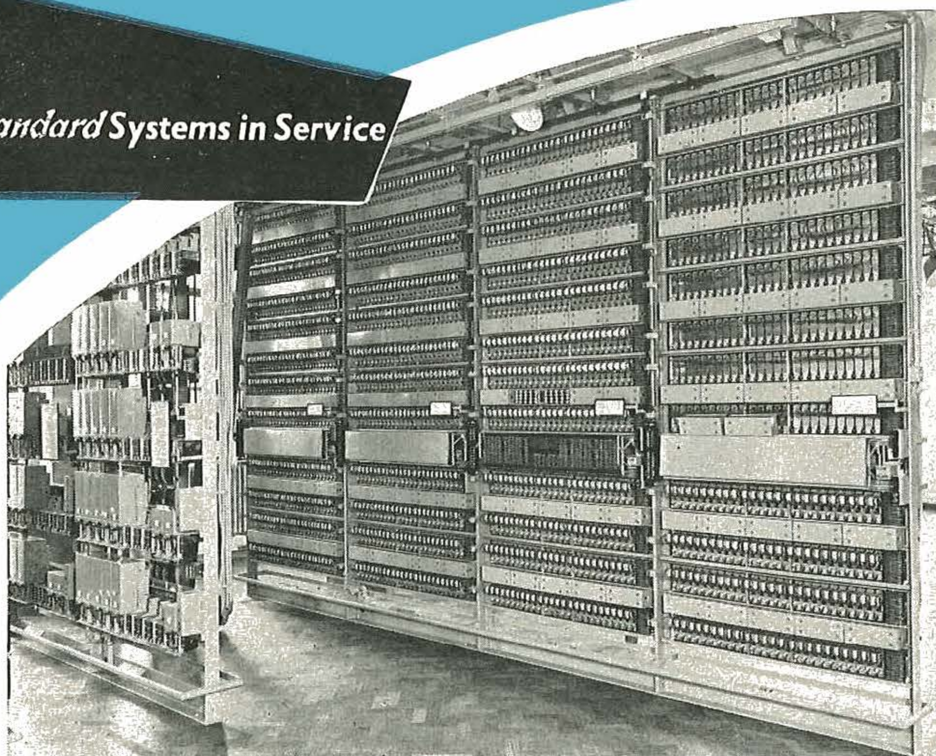
ERICSSON TELEPHONES LIMITED

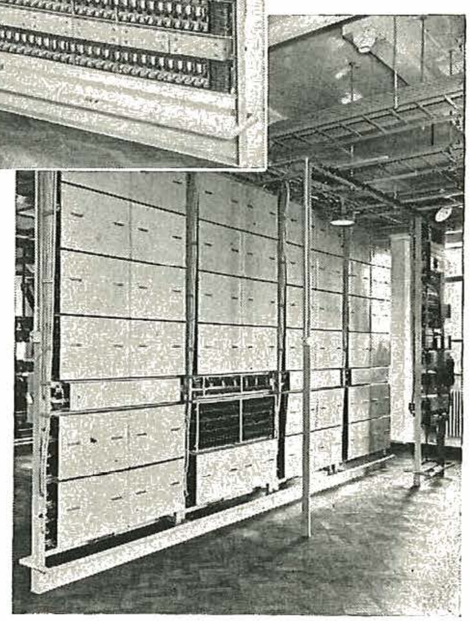
HEAD OFFICE: 22 Lincoln's Inn Fields, London, W.C.2. Telephone: Holborn 6936

WORKS: Beeston, Nottingham. Telephone: 54225 (6 lines) Beeston, Nottingham.

Communication

Standard Systems in Service





Illustrations show, top: front view of the subscribers' line circuit equipment. Below: a rear view of the installation.

THE Great Missenden (Buckinghamshire) Automatic Telephone Exchange, now ready to be put into service, incorporates the new standard subscribers' line circuit equipment (described in the July issue of the Post Office Electrical Engineers' Journal), and is one of the first exchanges to be so equipped by Standard Telephones and Cables Limited.

STC *Standard Telephones*

(TELECOMMUNICATION

Connaught House, Aldwych,

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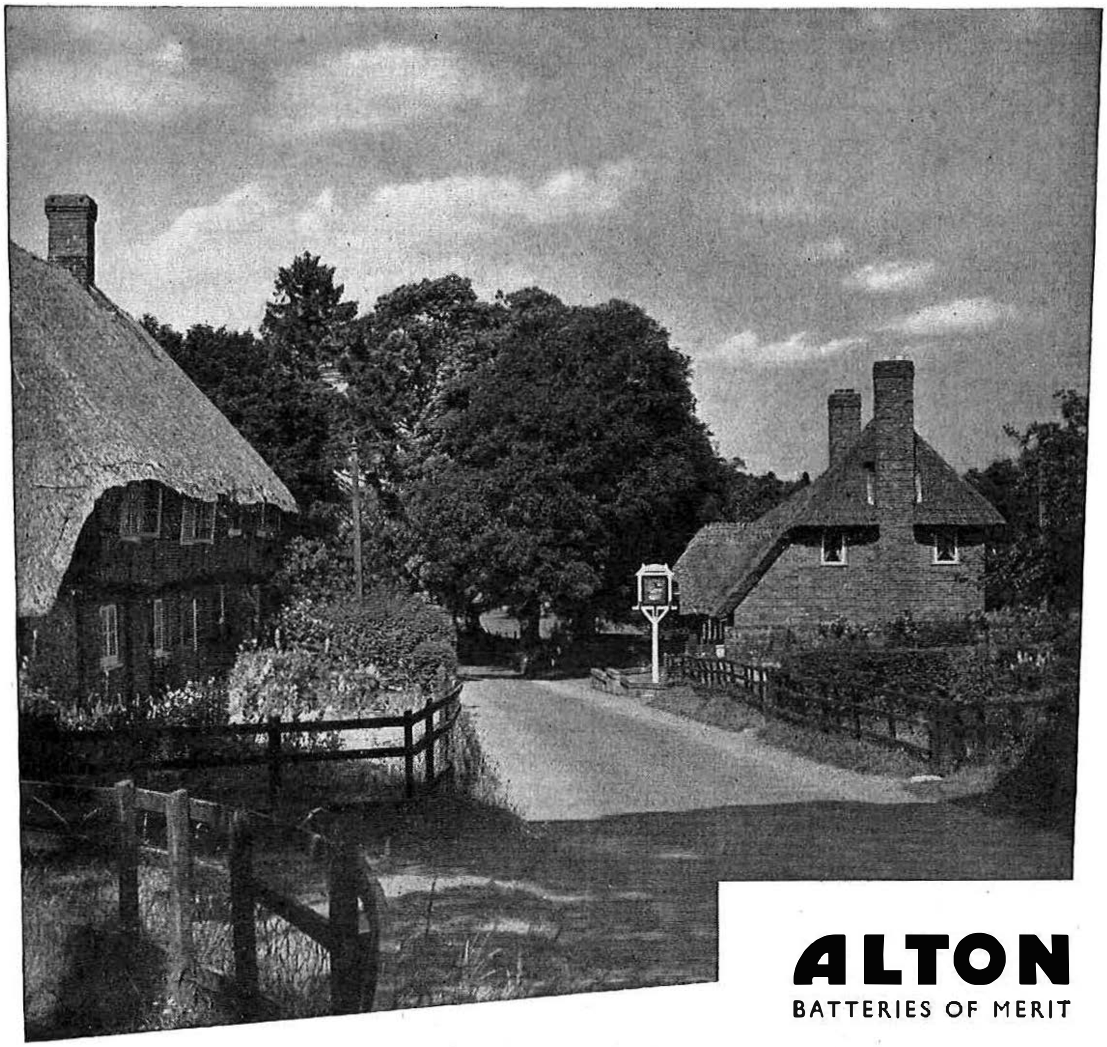
Know this village?

If you worked at the Alton Battery works you'd know it well—and a dozen others like it. You'd know the lanes that lead to each. You'd know the streams—and the fish in them: the pubs and the beer they cool in their cellars, the teas they serve on their lawns . . . . Alton's a country town—and the men it breeds are countrymen at heart. Men with roots in their birthplace. Men with a quiet pride in themselves and the patient skill of their hands. A clipped yew hedge in his garden . . . a battery plate at 'the Works' . . . *making something better than merely well comes very naturally to an Alton man.*



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Alton stationary batteries: 10 to 15,000 Ah. Also in regular production, renewal plates for all makes of battery, British and Continental

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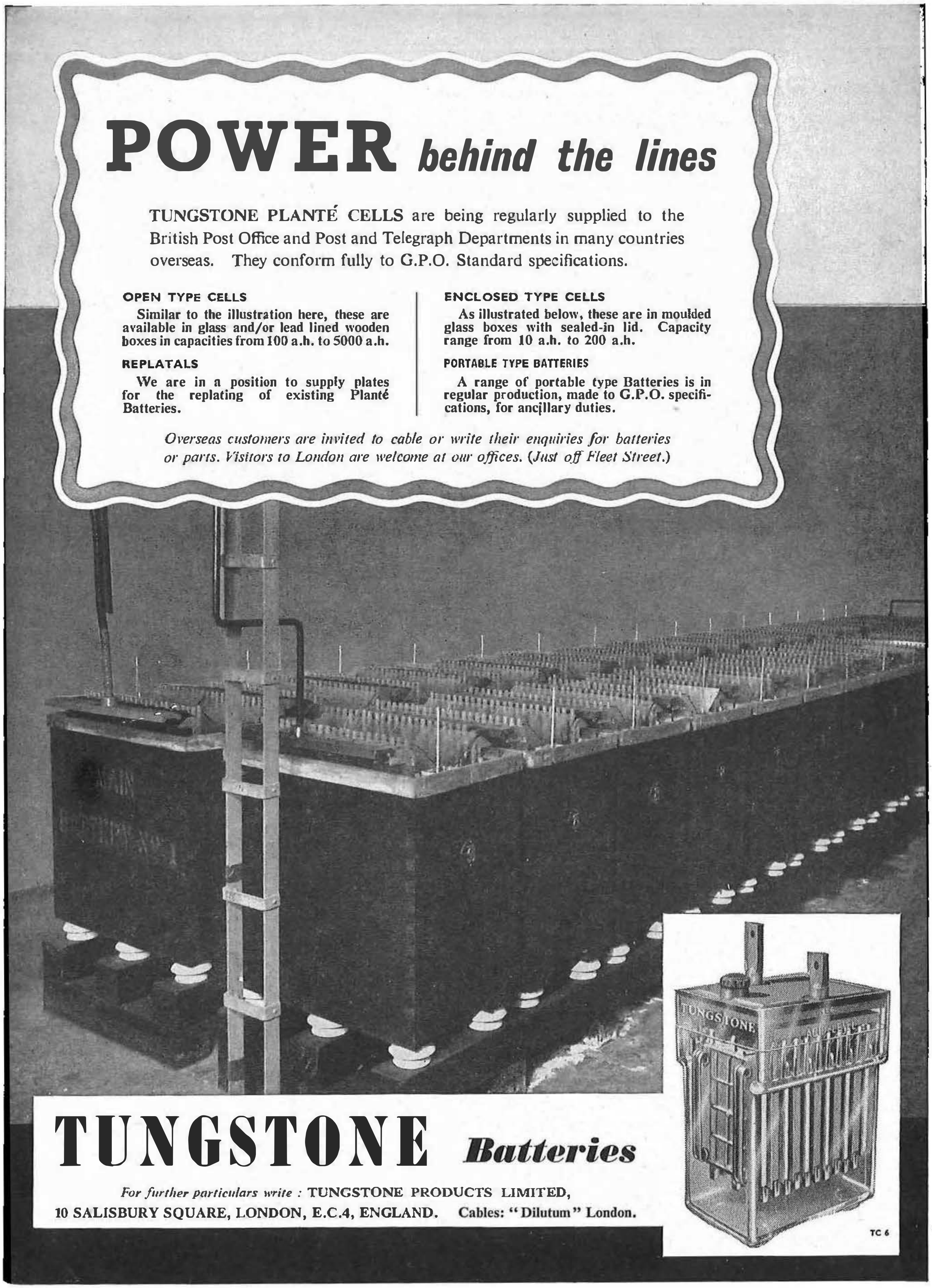
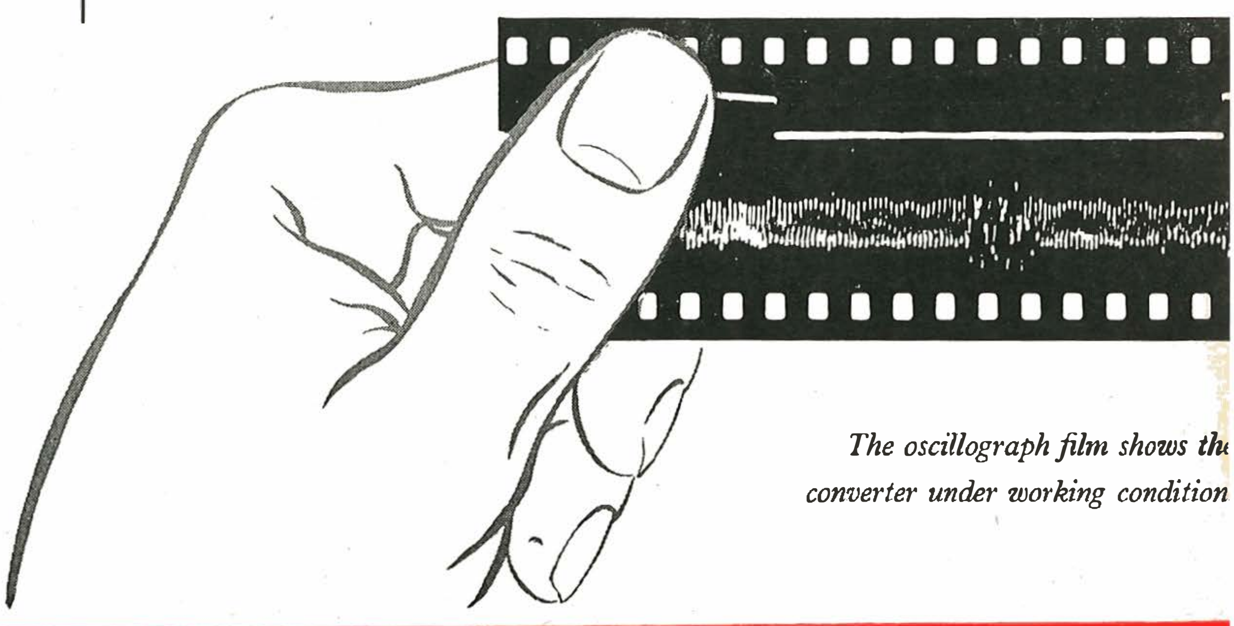

POWER behind the lines
TUNGSTONE PLANTÉ CELLS are being regularly supplied to the British Post Office and Post and Telegraph Departments in many countries overseas. They conform fully to G.P.O. Standard specifications.
OPEN TYPE CELLS
Similar to the illustration here, these are available in glass and/or lead lined wooden boxes in capacities from 100 a.h. to 5000 a.h.
REPLATALS
We are in a position to supply plates for the replating of existing Planté Batteries.
ENCLOSED TYPE CELLS
As illustrated below, these are in moulded glass boxes with sealed-in lid. Capacity range from 10 a.h. to 200 a.h.
PORTABLE TYPE BATTERIES
A range of portable type Batteries is in regular production, made to G.P.O. specifications, for ancillary duties.
Overseas customers are invited to cable or write their enquiries for batteries or parts. Visitors to London are welcome at our offices. (Just off Fleet Street.)
TUNGSTONE Batteries
For further particulars write : TUNGSTONE PRODUCTS LIMITED,
10 SALISBURY SQUARE, LONDON, E.C.4, ENGLAND. Cables: "Dilutum" London.
TUNGSTONE
TC 6

Introducing

Pilot Carrier

The unit illustrated is a single receiver converter: dual or triple-diversity converters can also be supplied. All can be worked on bandwidths from 10 to 200 cps. In addition, plug-in discriminators have been developed, which enable the equipment to be used on orthodox wide shift F.S. circuits.



The oscillograph film shows the converter under working condition

✱ *Reduces errors by a ratio of 4: 1*

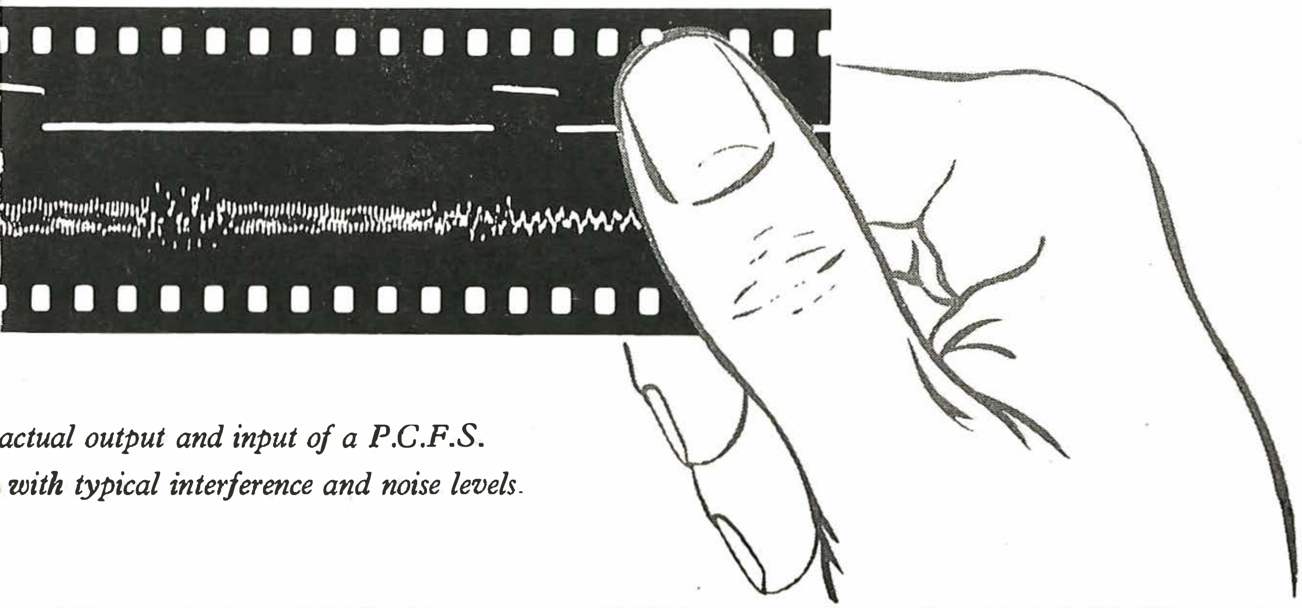
✱ *Is unaffected by fading of as much as 85 db*

✱ *Is unaffected by receiver frequency drift*

Working on an exceptionally narrow bandwidth of only 50 cps, instead of the conventional 850 cps, the new P.C.F.S. equipment operates with unprecedented efficiency despite high noise and interference levels. On live circuit operation, errors are reduced by a ratio of 4 : 1, whilst fading of as much as 85 db has no effect on reception.

NARROW BAND

Frequency Shift Equipment



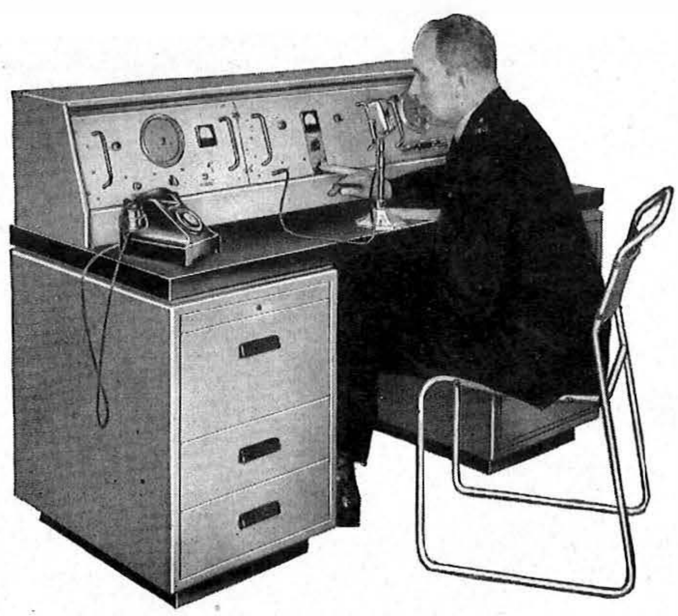
actual output and input of a P.C.F.S. with typical interference and noise levels.

& ELECTRIC CO. LTD.

RADIO AND TRANSMISSION DIVISION, STROWGER HOUSE, ARUNDEL STREET, LONDON, W.C.2.

Flexibility

THE use of mobile V.H.F. radio-telephone equipment in this country was pioneered by Pye. Over two-thirds of the equipment now operating in the United Kingdom has been supplied by this company and exports for government and commercial applications overseas are made to more than fifty countries. With staunch faith in the value of its own products the Pye Group employs V.H.F. to maintain contact with all its delivery and service vehicles.



A police patrolman singled out by Selective Calling stops to receive instructions from H.Q. over the V.H.F. radio-telephone.

TAXICABS

TUGS

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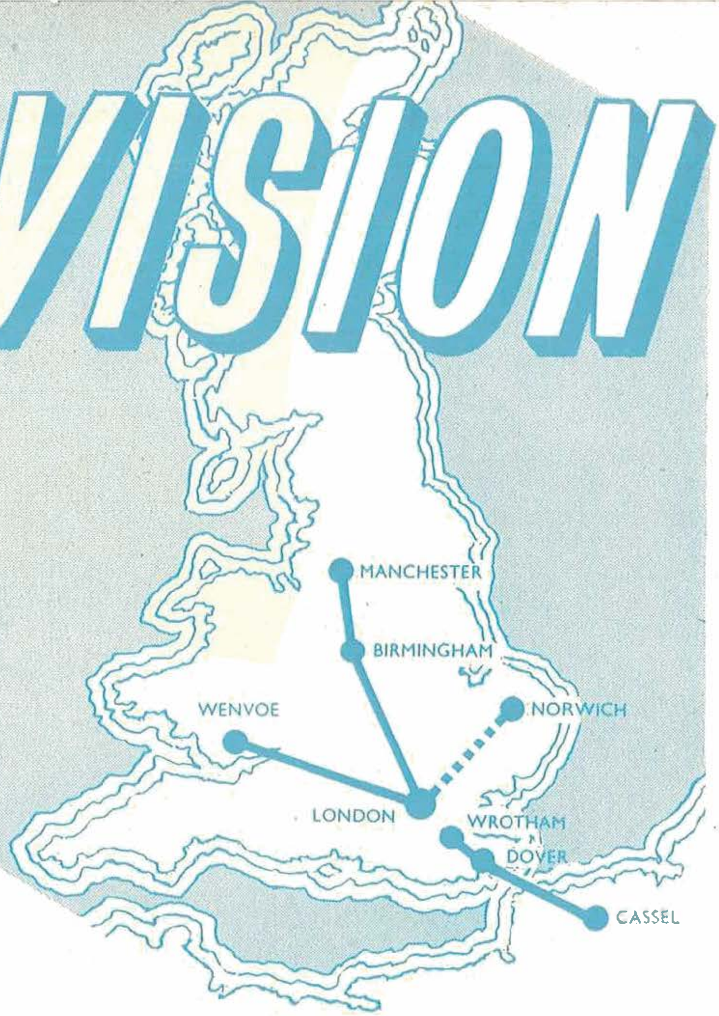
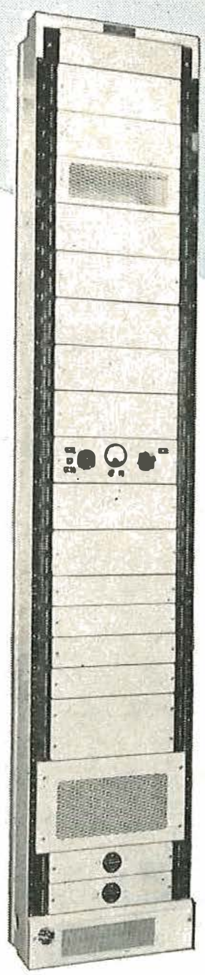
EUROVISION





Swiss link installed by Hasler S.A. (Berne).

Paraboloids by Precision Metal Spinnings (Stratford-upon-Avon) Ltd.

The G.E.C. television relay across Switzerland —the vital link in Eurovision—undoubtedly represents the greatest heights yet reached by television.

The problems of the long hops over the most difficult Alpine country were solved, and the equipment manufactured and supplied at short notice, by the G.E.C.

This link is to form a permanent installation for the Swiss P.T.T. Department's national television network. It uses G.E.C. microwave radio relay equipment, operating in the 1700-2300 Mc/s range and conveying a 625-line picture transmission. This equipment, too, is to be manufactured by Hasler S.A. . . . on behalf of the G.E.C. . . . to extend the Swiss national network between Uetliberg, Chasseral, Romont and La Dole.

In addition, the G.E.C. supplied to the B.B.C. the 2000 Mc/s equipment to form reversible links between Wrotham and Cassel to link the British Isles to the Continental television network.

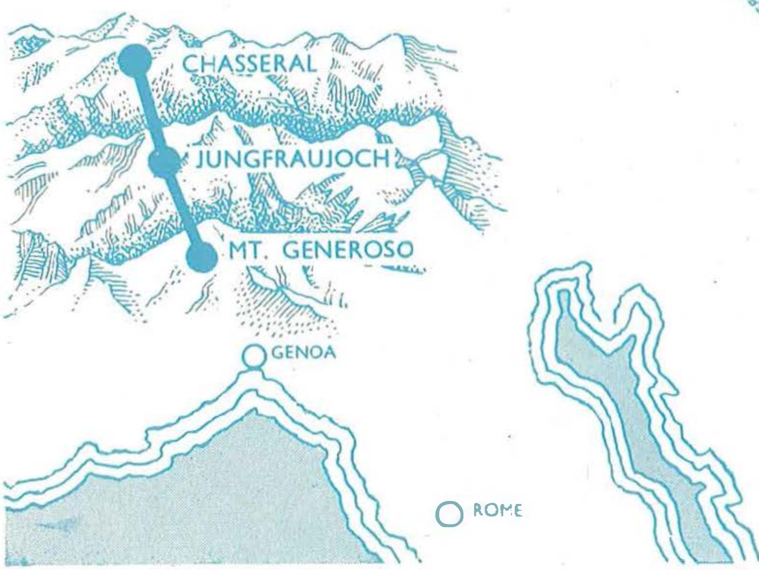
G.E.C. line transmission and radio relay equipment also brings B.B.C. and international television to the south-west, midlands and north-west of Britain.

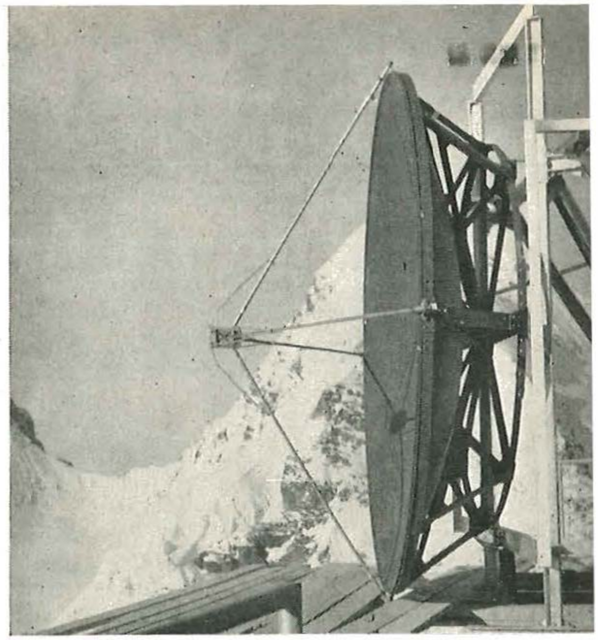
. . . and soon G.E.C. Radio Relay Equipment will bring Television to Norwich

THE GENERAL ELECTRIC COMPANY LIMITED OF ENGLAND

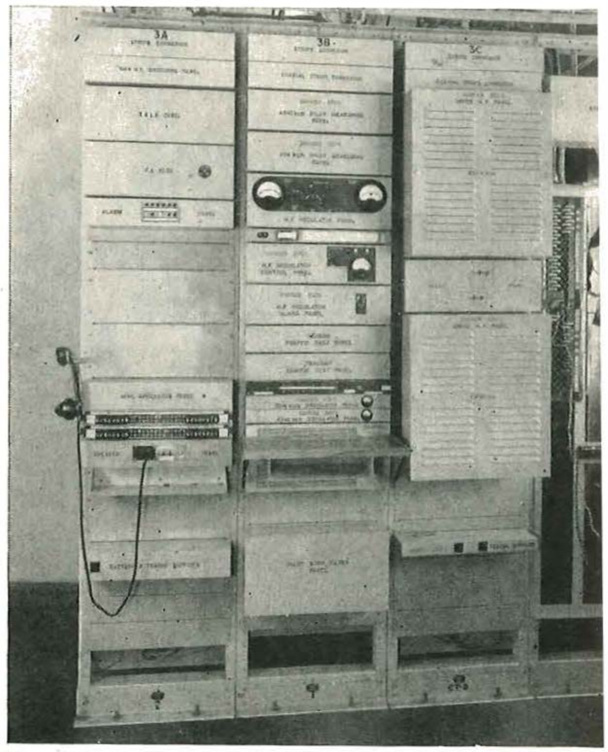
made possible by G.E.C.

The greatest heights yet reached by television

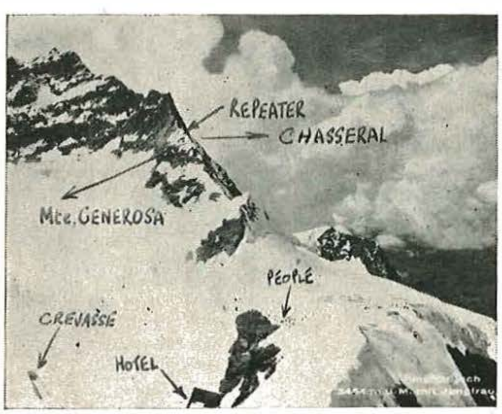




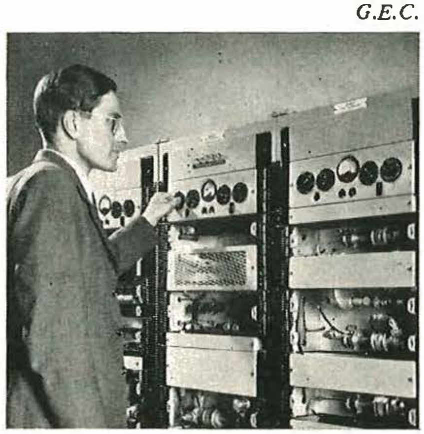
Snow and ice failed to delay the rapid installation of the G.E.C. aerial which faces Chasseral at the Jungfraujoch.



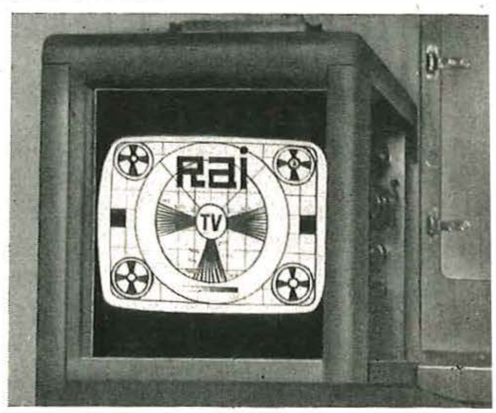
Terminal equipment at the Wenvoe end of the G.E.C. London-Wenvoe link.



This view was sent to G.E.C. by the Company's installer, and illustrates the difficulty of establishing the relay station at 12,000 ft. on the Jungfraujoch.



A rear view of the G.E.C. transmitting equipment at Cassel, relaying programmes to Swingate.



The first picture received over the G.E.C. television link in Switzerland from Rome was sharp and clear.

Telephone, Radio and Television Works, COVENTRY, ENGLAND

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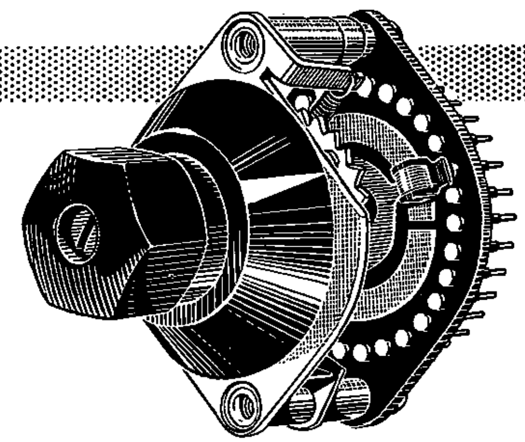
By Appointment to the Professional Engineer

PAINTON WINKLER SWITCH

PAINTON & CO. LTD. have entered into an exclusive arrangement with Eduard Winkler Apparatebau of Nuremberg, Germany, to manufacture and market the well-known Winkler Precision Multi-Way Switches.



Switching up to 30 positions per bank.
Adjustable stop to set number of positions.
Single, Double, Three-Pole or Four-Pole designs.
1 to 6 Banks operated from common shaft.
Distinctive design Knob, with adjustable skirt.

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† The Council have awarded Institution Medals for these papers.

Printed by SANDERS PHILLIPS & CO., LTD., The Baynard Press, Chryssell Road, London, S.W.9, and Published by BIRCH & WHITTINGTON (*Prop. Dorling & Co. Epsom*), *Ltd.*), Epsom, Surrey.